DIGITAL TRANSFORMATION AND QUANTITATIVE DECISION-MAKING: NEW PARADIGMS

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PREFACE

The developments that have taken place in world history are associated with industrial revolutions. Today, we have witnessed great inventions that have impacted our lives and changed humanity. These developments, which have transformed production and work processes over time, have entered our lives, particularly during the first three industrial revolutions.

Since 2011, when the latest industrial revolution was announced, the world has entered a rapid digital transformation process. This revolution, announced based on previously developed technologies, continues to shape our present day. This era, in which innovations such as sensors, cloud computing, artificial intelligence, and big data analytics have entered our lives, is now referred to as the digital age.

In this era where we are experiencing the impact of the digital age quite rapidly and to a significant extent, the primary focus for businesses has been the digital transformation of their processes. However, the exact starting points for businesses to transform their business processes through digital transformation are not fully understood. In this process, where all processes, from leadership style to the mission and vision of the business, from data analytics to supply chain management, are digitized, i.e., transferred to virtual environments, businesses need to identify their starting point. In addition, as businesses operate in a highly competitive environment with numerous factors, issues such as flexibility, efficiency, and resilience have gained importance.

In this period where businesses are focusing on digital transformation and making significant investments, it is essential that efforts are grounded in scientific principles. Only policies based on scientific principles will be successful. In this context, the sections forming the basis of this book identify the starting point of the digital transformation process and include analyses using quantitative decision-making methods regarding sectoral applications.

The sections on quantitative decision-making and digital transformation in this book will serve as a useful reference book for industry professionals, readers, and researchers, providing scientific foundations and practical examples. Finally, I would like to thank all the authors who contributed to the preparation of this book. I hope the book will be useful to readers.

Asst. Prof. Serkan DERİCİ

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FUNDAMENTALS OF QUANTITATIVE METHODS AND DECISION THEORY[1]

Gülper Basmacı Aktuna[*]

1. FUNDAMENTALS OF QUANTITATIVE METHODS

Quantitative methods are a branch of science that evaluates the decision-making processes of people and organizations for the purpose of optimizing and developing strategies. In each of the dimensions of the individual, society, and business, decisions that must be made in line with the objectives are faced with multiple alternatives. Consequently, identifying and selecting the most appropriate action among alternatives in decision-making is a crucial task. This task is accomplished through disciplines such as statistics, optimization, simulation, and computer science, which operations research utilizes (Winston, 2004). Establishing the fundamentals of numerical methods is very important in evaluating and understanding the studies in this field.

1.1. Definition Quantitative Methods

Quantitative methods (QM) is defined as a concept aimed at understanding and improving the decision-making processes of people and organizations (Ramamurthy, 2007). When considered as a concept, "QM" refers to the use of mathematical tools and methods to find solutions to complex decision-making problems (Büyüktahtakın and Haight, 2018). In other words, it is defined as the application of scientific methods to complex problems in directing large-scale systems composed of people, machines, materials, and capital in the industrial, business, government, and defense sectors and performing management functions (Ramamurthy, 2007). According to Kirby, QM refers to the application of scientific methodology to decision problems related to large-scale commercial, governmental, and military systems composed of people,

[1] This study is derived from Gülper Basmacı Aktuna's 2024 PhD dissertation titled 'Modeling of business processes with discrete event simulation in assembly line balancing decision problems and multi-objective optimization: A manufacturing enterprise application.'

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machines, capital, and products. OR originated in the military field and has subsequently been addressed by sectoral practitioners and academic researchers (Kirby, 2000). Certain characteristics of QM are utilized when defining it. Some definitions of QM are as follows:

- QM involves quantitative decision-making techniques (Lee et al., 2008).
- QM is the practice of making quantitative managerial decisions using scientific methods (Morse and Kimball, 2003).
- QM is a discipline that utilizes mathematical methods to optimize decisions (Saaty, 2004).
- QM is an interdisciplinary branch of science that utilizes algorithms and applied mathematical methods to find optimal solutions to inherently complex decision problems (Sottinen, 2009).
- QM is a scientific analysis used in productivity issues such as workforce performance and machinery and equipment utilization rates (Gass and Assad, 2005). Within the framework of these definitions and explanations, it can be said that QM incorporates many technical and scientific methods and offers scientific methods for the design and management of systems for the allocation of limited resources (Roy, 1956). In other words, QM aims to provide optimal solutions to decision problems encountered in complex systems by making changes to controllable variables using interdisciplinary scientific methods based on teamwork (Rindengan et al., 2018).
- QM is based on a systems approach and approaches problems encountered in businesses from a general perspective, encompassing the entire system. It is concerned with systematically formulating a decision problem, analyzing it, and making the appropriate decision based on the objective among the decision alternatives obtained from the solution (Cheema, 2005).
- QM aims to provide system administrators with possible solutions to problems encountered in the system (Ramamurthy, 2007). It attempts to offer alternative solutions that consider decision-making processes such as uncertainty and probability inherent in systems (Hitchman, 1953).
- It is an applied science. It utilizes technical methods offered by science. It focuses on the scientific problem-solving process. It deals with identifying decision problems and reaching the optimal solution (Minas et al., 2012).

- The application area of QM concerns the optimal use of scarce resources (Nyor et al., 2014).
- QM is an interdisciplinary approach aimed at optimization (Winston, 2004).

The roots of QM as defined above can be traced back to the first studies investigating decision making and has been increasingly adopted and applied to the present day (Simon and Newell, 1958).

1.2. Historical Development of Quantitative Methods

The first applications of QM came from the military field. The QM's origins date back to 1939-1945. QM was used by the UK in World War II to develop an effective anti-aircraft weapon. Scientists specializing in various disciplines were brought together to address the efficient use of scarce resources, the importance of which was once again proven during World War II. The name of this group was "Blackett Circus" and its leader was P.M.S. Blackett. The group's goal was to increase resource efficiency and utilize scientific methods to address ongoing military operations. The first decision-making problem addressed by the working group is known historically as the "radar problem." The task force was asked to measure the effectiveness of radar devices. While the study envisioned some technical changes to radar devices, the most significant outcome of the study concerned the optimization of information flow between radar devices, control units, and combat aircraft. The radar problem, for the first time, demonstrated the importance of organizational and optimization issues, in addition to technical ones (McArthur, 1990; Saaty, 2004; Gass and Assad, 2005; Gupta and Hira, 2022).

The British Army's success in some air combats with the radar problem optimized by the working group increased interest in QM among both the military and scientists. As a result, QM became a method used in many military decision-making problems in the British Army, and following the British Army, it was also used by the American Army. After World War II, QM has also been a part of production management since 1951. The QM working group first published a journal in 1950 to publish their work, and the association was established in 1953. The first QM book was published in the United States in 1951, and the first QM master's and doctoral programs were opened in the United States in 1953 (Saaty, 2004). QM investigates how people and organizations behave and what kinds of options they can utilize during the decision-making process, helping to develop effective strategies (Corbett and Wassenhove, 1993). The systematic and interdisciplinary nature of QM has also

played a significant role in its academic development. Some important events in the historical development of QM are as follows (Saaty, 2004; Gass and Assad, 2005; Gupta and Hira, 2022; Ramamurthy, 2007):

- The scientific basis of QM comes from Frideriek Winslow Taylor. In 1910, Taylor published his work "Principles of Scientific Management" to eliminate the productivity problem experienced in manufacturing enterprises. This work introduces methods such as motion study and work study, which are used in business today. Taylor's systemic approach is called "Taylorism" and was one of the first examples of QM.
- In the 1900s, Henry L. Gantt developed a graphical method for use in planning and control. This method, called the Gantt chart, sheds light on OR techniques.
- Vilfredo Pareto introduced the principle of "Pareto Optimality" in 1906. This principle examines how production factors are distributed among individuals in society. Josep Juran, who studied Pareto Optimality, based this principle on the 80/20 principle and introduced it to the literature. According to the 80/20 rule, when 20% of the work is completed, 80% of the problems are solved. This rule is also called the 80/20 rule and appears in academic literature as the "Pareto Principle."
- A. Markov introduced "Markov Decision Chains," which can be considered one of the first examples of QM, to the literature with his 1907 work.F. W. Harris studied the economic order quantity model, which is still frequently used in production management in 1915.
- Agner Kraup Erlag developed the theory of waiting lines and queues in 1917, based on experiences of waiting on telephone lines.
- W. Leontief, Von Neumann, and Stigler introduced game theory in their work in the 1930s.

The historical developments mentioned above laid the foundations for QM as discipline. This development continues today, with increasing impact.

1.3. Characteristics of Quantitative Methods

QM is a concept widely used in fields such as mathematics, statistics, and engineering. This concept has some generalizable properties. These properties can be expressed as follows (Shah et al., 2007; Gupta and Hira, 2022; McCloskey, 1955; Brooks, 1972):

- QM is a discipline that utilizes a systems approach.

- QM is a discipline suitable for interdisciplinary work.
- QM is a discipline that adheres to the principles of scientific research.

QM and decision theory are interrelated. The next section outlines the place of decision theory within OR and transitions to the conceptual framework of decision theory.

2. FUNDEMANTALS OF DECISION THEORY

The importance of decision-making, decisions, and the decision-making process in decision theory stems from the fact that it determines how a decision will be made, and the steps involved in analyzing alternatives and selecting the most appropriate one are crucial for the accuracy and effectiveness of the decision. Managing the decision-making process effectively ensures that decisions are made accurately and effectively (Drucker, 1967).

For the academic purpose of examining decision theory, the concepts of decision and decision-making are discussed under subheadings. Then, starting with the characteristics of decision-making, the concept of the decision-making problem and the decision-making process are examined. Furthermore, subheadings are provided on decision-making approaches and how decision problems are classified.

2.1. Definitions of Decision and Decision Making

Decision-making is an action frequently performed by both individuals and businesses, which are also defined as living organisms. Decision-making is one of the actions that people and businesses must take throughout their lives (Rue and Byars, 2003). To discuss the meaning of this concept in terms of operations, it is first necessary to examine the literal meanings of the concepts of decision and decision-making. While the Turkish Language Association (TDK) defines the concept of "decision" as "a definitive judgment made after careful consideration about a task or problem," an examination of the literal meaning of "decision-making" reveals that the TDK defines it as "to decide on, to resolve, a problem" (TDK, 2022). As can be seen, the concepts of decision and decision-making refer to different situations. A decision is a purposeful response to any situation (Jack, 1978). Based on the literal meanings of the concepts of decision and decision-making, it can be seen that the concept of decision refers to the choices made, while the act of choosing and preferring is defined as "decision making" (Koçel, 2007). A decision is the act of selecting one of the available options for an individual or institution in a given situation and implementing

this choice. Decision-making, on the other hand, is the thinking and evaluation stages involved in this selection process. Unlike decisions, the concept of decision-making is a planning process. Planning, on the other hand, is a process. The planning process carried out during the decision-making process involves what will be done, when, for what purpose, and in what order (Rue and Byars, 2003). In other words, decision-making is the process of determining how a decision will be made, and the decision itself constitutes the outcome of this process (Lunenburg, 2010). Decision-making is a central element of managerial activities. When definitions of decision-making are examined, they appear to have three fundamental elements. According to decision theory, when one of these elements is absent, the decision process ends (Kolbin, 2003):

- The decision problem to be solved
- The person or group in the decision-making position
- Several decision alternatives to choose from

The concept of decision-making can be addressed at the individual level as well as at the organizational level, and organizational decisions can be made. Accordingly, decision-making in its organizational sense is the selection process that involves making a decision in a way that creates value for the organization's internal and external stakeholders (Jones, 2006). Decision-making is a difficult task because it involves simultaneously considering the benefits of many stakeholders. The most significant challenge encountered in decision-making is the existence of conflicting objectives and choosing among alternatives that have relative advantages and disadvantages (Saaty and Vargas, 2001). Deep consideration of the possible outcomes of decision alternatives is necessary. Despite this difficulty, decision-makers must consider decision alternatives and develop the most appropriate solution after a series of elimination processes. As a result of this selection process, the decision is made by selecting the best solution based on the objective of the decision problem. A sufficient amount of information must be collected to make accurate decisions (Saaty, 2008). Different types of knowledge, information, and technical data are needed for decision-making. These are as follows (Saaty, 1994):

- Details about the problem to be decided,
- The individuals or actors involved,
- Their goals and policies,
- Factors affecting the results, and
- Temporal information, scenarios, and constraints.

Decision-making uses past data to predict future outcomes. Therefore, decision-making is a process involving uncertainty (Dinçer and Fidan, 1996). Decisions are also defined as solutions offered to conflicting objectives (Terry, 1977). In other words, decisions are proposed solutions to encountered decision-making problems. However, because decision problems arise from a mismatch between the current and ideal situations, decisions cannot always fully solve the problem. Experience is necessary for a successful decision (Gilboa, 2010). The characteristics of decision-making are examined in the next section.

2.2. Characteristics of Decision Making

The existence of many different definitions of the concept of decision-making allows us to identify its fundamental characteristics based on these definitions. Accordingly, some of the fundamental characteristics of decision-making are as follows (Torunlar, 2010; Güngör and Özcan, 2022; O'Fallon and Butterfield: 2013; Sucu et al., 2012:; Bengül, 2018):

- Decision making is a task that concerns the future.
- Decision making is a process that involves making choices.
- Decision making is a process that requires problem solving.
- Decision making is a task that requires the collection and processing of information.
- Decision making has both material and moral costs due to opportunity loss.
- Decision making is a process that extends over time.
- Decision making is a process that places responsibility on the decision maker.
- Decision-making is a process that requires rational behavior.

Understanding the characteristics of decision-making is crucial for decision-making theory. The concept is examined in terms of the "decision problem" dimension in the next section.

2.3. Definition of Decision-Making Problem

For the decision-making process to constitute a decision-making problem, the encountered situation or problem must address a specific goal, and various decision alternatives must be available to achieve this goal. In situations where there is only one decision-making alternative, it is not possible to speak of a

decision-making problem. If there is only one decision-making alternative, there is no other option but to implement the existing solution, demonstrating that the decision-making process cannot be defined as a problem (Miettinen, 2014).

A decision problem is defined as the situation that creates the difference between the current and the ideal (Can et al., 2015). In situations where multiple decision alternatives exist, in other words, a decision problem, the decision-making process is accomplished by selecting the best among these alternatives. A decision problem arises from the uncertainty and choices that arise when a decision must be made (Jahanshahloo, 2006: 1544). In other words, the source of the decision problem is the dissatisfaction felt by the decision-maker (Pomerol and Adam, 2003).

Decision making, on the other hand, is the process of solving a decision problem. In other words, a decision problem is a situation, while decision making is a process involving the resolution of that situation. Decision making as a process is discussed in the next section.

2.4. Decision-Making Process

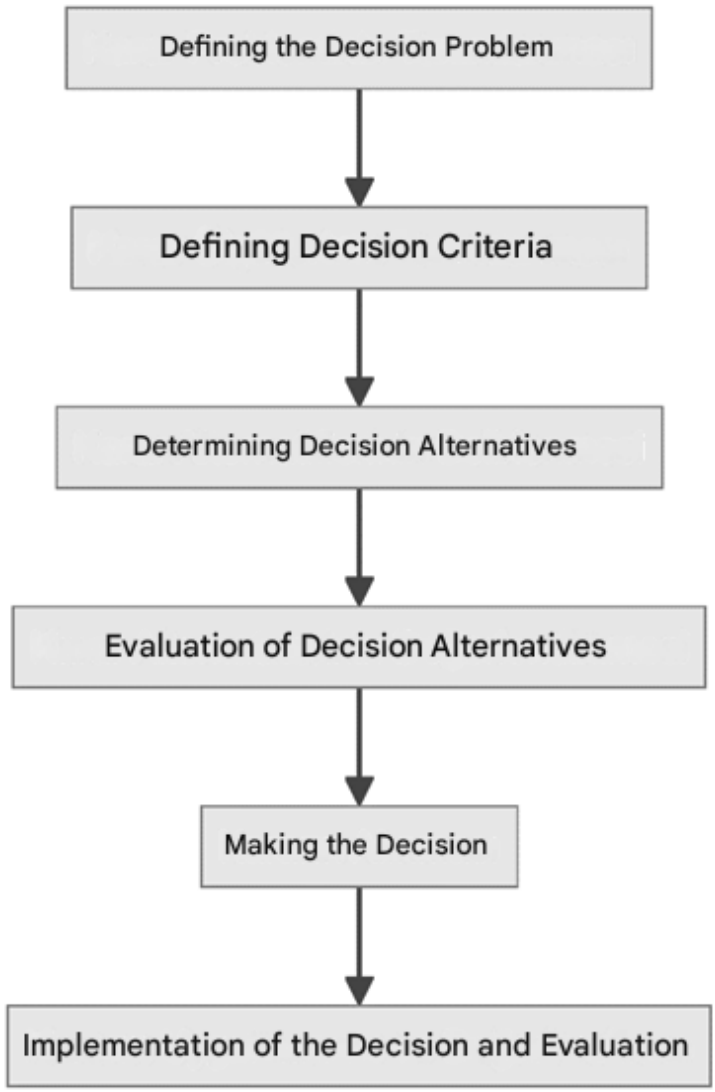
A decision should not be an instantaneous outcome. It should involve the systematic and sequential selection of the most appropriate decision alternative from among various decision alternatives, as a result of the decision maker's mental reasoning (Tekin, 2008). Homo economic system assumptions also define decision making as a process (Edwards, 1954).

Decision making is the process of evaluating, investigating, and selecting the most appropriate alternative in a situation requiring a decision. This process begins with individuals or groups entering into a decision-making process and ends with the implementation of the decision (Fülöp: 2005). The outcome of the decision-making process is the "decision" (Özdemir and Gümüşoğlu, 2007).

Decision-making is a process that can be examined at both individual and organizational levels. Individual and organizational decision-making are similar in that decision-makers in organizations are also individuals (Shapira, 2010). In this process, alternatives to the decision-making problem to be addressed are evaluated, and the process is completed by making the necessary comparisons, resulting in a decision-making choice (Emhan, 2007). The efficiency and effectiveness of the decision-making process are crucial for a decision to be made accurately and effectively, as this allows the best option to be selected, taking into account the consequences of the decision.

The decision maker must follow a series of sequential steps throughout the decision-making process. (De Almeida and Bohoris, 1995). The decision-making process is frequently described in the literature as six steps (Özdemir, 2010).

Figure 1: Decision Making Process (1)



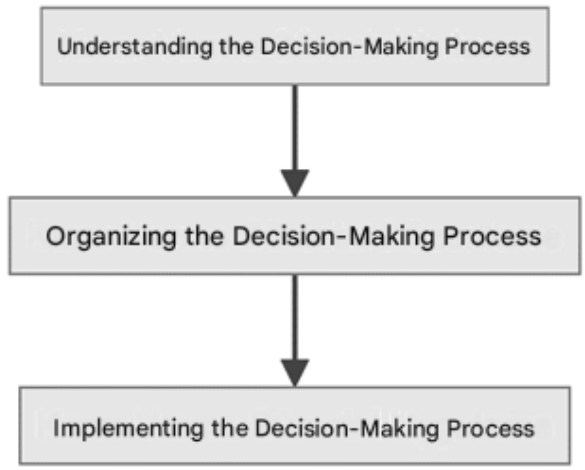
Source: Dash et al., 2017

- The decision problem must be defined and stated.
- The decision criteria to be used in the decision problem must be established.
- The decision alternatives from which a choice will be made must be determined.
- The decision must be evaluated using the appropriate method.

- The most appropriate decision must be made.
- The decision must be implemented, and the implemented decision must be evaluated.

Another decision-making process described in the literature as a series of sequential stages is that of Bell, Raiffa, and Tversky. This process examines the decision-maker's thinking and decision-making style, and then moves on to the stages of the decision-making process. This approach uses psychological and mathematical methods to understand people's thinking and decision-making processes, helping to understand people's behavior during the decision-making process. This process is examined in three stages. These stages are as follows (Bell et al., 1988; Bell et al., 1989; Malakooti, 2012):

Figure 2: Decision Making Process (2)



Source: Bell et al., 1988

- The decision-making process must be understood by the decision-maker(s).
- The factors that will regulate the decision-making process must be identified.
- The decision-making process must be carried out in accordance with its methodology.

Decision-making is not as simple as it appears, and the stages of the decision-making process are not standardized (Schwarber, 2005). The process may vary depending on the decision problem and the environment faced by the decision-

maker; accordingly, one or more of these stages may be omitted, or additional stages may be added.

2.5. Elements of Decision Problems

Decision problems consist of a combination of elements. Each of these elements has a function within the decision-making problem. These concepts are defined as follows:

- Decision Maker: This is the element that plays a leading role in the decision-making process. Responsibility for the decision process rests with the decision maker. The decision maker directs and concludes the decision process towards a specific goal. During the decision process, they gather information about the decision problem and conclude the process by making a decision (Sağır, 2006). The decision maker must make rational decisions and must also have the ability to update their decision in response to potential changes (Hartmann and Patrickson, 1998).

- Objective: The desired outcome of the decision process, determined by the decision maker or group of decision makers (Brunsson, 2007). One of the crucial steps in the decision-making process is establishing the objective. For the decision process to be successful, the objective must be well defined (Lezki et al., 2019).

- Goal: Unlike the objective, it refers to the measurable point to be achieved (Lezki et al., 2019).

- Decision Variables: These are the elements that can affect the decision problem by taking different values (Ünal and Atılgan, 2007).

- Decision Alternatives: These are the possible alternatives that can be selected at the end of the decision process. The decision maker should evaluate them and select the most appropriate one depending on the purpose of the decision problem (Arslankaya and Göraltay, 2019).

- Evaluation Criteria/ Characteristics: These are the characteristics used in the evaluation of decision alternatives. The weighting given to these criteria affects the decision problem (Öztürk and Batuk, 2007). Characteristics constitute a sub-branch of evaluation criteria (Arslankaya and Göraltay, 2019).

- Constraints: These are limited elements, such as economic, physical, and human resources, that limit the possible solution to a decision problem (Yürekli, 2008).

- Natural States/Events: These are events that occur during the decision process, without the decision maker's intervention, but that influence the decision process. They occur in the future, but when and which one will occur is uncertain (Ünal and Atılgan, 2007).

- Probability: This refers to the probability of any natural state affecting the decision process occurring. When calculating probabilities, the probability of a future event occurring is calculated based on past data (Lezki et al., 2019).

- Payoffs/Consequences: These represent the numerical values expected to be achieved as a result of the decision (Lezki et al., 2019). In cases where gains and costs cannot be expressed in numerical values, the outcome values are shown as utility units.

Elements of decision problems are used to understand the decision-making process. The next section discusses decision-making approaches and examines the changes in decision-making processes depending on the approaches.

2.6. Decision Making Approaches

Decision makers may approach decision problems differently. Accordingly, decision-making approach can be defined as the attitude an individual exhibits towards a decision-making problem (Taşdelen, 2001). While some decision makers acquire more information and conduct detailed analyses, others rely more on intuitive methods (Galotti et al., 2006).

Saaty, a decision-making approach should have the following features (Saaty, 1985):

- It must have a simple structure.
- It must be adaptable to both groups and individuals.
- It must be in line with our intuition and general thinking.
- It should encourage compromise and consensus building.
- It should not require excessive expertise.

Decision-making approaches frequently used in the literature are classified as scientific, intuitive and experiential decision-making approaches (Güngör and Özcan, 2022).

- Scientific Decision-Making Approach: In this approach, people make decisions by combining and evaluating all relevant information using rational

thinking methods. In other words, people do not consider their emotions and personal expectations during the decision-making process. The rational decision-making approach is a decision-making method in which people try to find the best option by using their thought processes and logic when making decisions. In other words, rational decision-making is the effort of decision-makers to express their thoughts logically and consistently by investigating the causes and consequences of their decisions (Güngör and Özcan, 2022). Rational decision-making requires decision-makers to think objectively and try to control their emotions when making decisions. Thus, the best outcome is achieved by using a rational decision-making style (Doyle, 1999).

- Intuitive Decision-Making Approach: This is a decision-making approach in which decision-makers base their decisions on intuition rather than analytical methods. Emotions and personal expectations play a significant role in decisions, and decisions are subjective. It is an easy and quick decision-making approach (Karamustafa and Arsan, 2019). The biggest risk of this approach is the disregard for objectivity (Sauter, 1999).

- Experiential Decision-Making Approach: This is a decision-making approach in which the decision-maker draws on their own personal experiences when making decisions. A disadvantage of the experiential decision-making approach is the risk that current conditions may not be similar to the external environmental conditions from which past experiences were derived (Lezki et al., 2019). In this decision-making approach, the decision problem is solved based on the solution methods the decision-maker has used in similar situations in the past. This approach lacks rationality and scientific principles (Güngör and Özcan, 2022). This decision-making approach is not rationalistic; it is adaptable (Etzioni, 2001).

Another classification of decision-making approaches in the literature is the classification divided into two as normative and descriptive decision-making approaches (Sousa and Kaymak, 2002):

- Normative Decision-Making Approach: It considers the decision as an act of rational selection among valid alternatives (Sousa and Kaymak, 2002). It considers how a decision would be made in an ideal world and explores how these ideas can be applied in the real world. These models follow a rational approach to the decision-making process and strive to ensure that the organization best achieves its objectives. It considers the selection of a decision among valid alternatives as a rational action. This decision-making approach

suggests a number of steps in the decision-making process. The focus is on how the decision can be made better. In other words, it focuses on improving the decision-making process (Pitz and Harren, 1980). The normative decision-making approach examines mathematical methods for modeling the decision-making process. Classical decision-making theory and most of its technical applications follow this approach. Normative decision-making theory aims to make the optimal decision using available information. Therefore, it is an approach closely related to optimization theory. The concept of decision making in engineering and business fields is mostly addressed within the framework of the normative approach (Sousa and Kaymak, 2002).

- Descriptive Decision-Making Approach: This approach describes real-world situations and investigates how these situations affect the decision-making process. It attempts to identify mental pathways leading to a decision in order to influence and guide decision-making processes (Sousa and Kaymak, 2002).

One of the key elements of success in the decision-making process depends on correctly identifying the decision problem. The next section covers the classification of decision-making problems.

2.7. Classification of Decision Problems

Successful decision-solving is significantly impacted by correctly identifying the decision problem. Therefore, classifying decision problems is crucial. Decision problems can be categorized based on their characteristics. There are different classifications defined in the literature. This section includes the most frequently used ones.

2.7.1. Decision Problems According to Decision Environment

Businesses operate in a complex environment where numerous variables interact with each other (Şahin, 2006). The starting point of decision theory is the distinction between different natural states or decision environments. This distinction varies depending on the degree of knowledge possessed by the decision maker. According to decision theory, decision environments are examined under four headings (Doğan, 1985).

- Decision Making in an Environment of Certainty: This refers to a situation in which the decision maker can make certain inferences about the future based on past events and data collected in the past during the decision process. In this environment, for each alternative, the decision maker is certain of the loss or

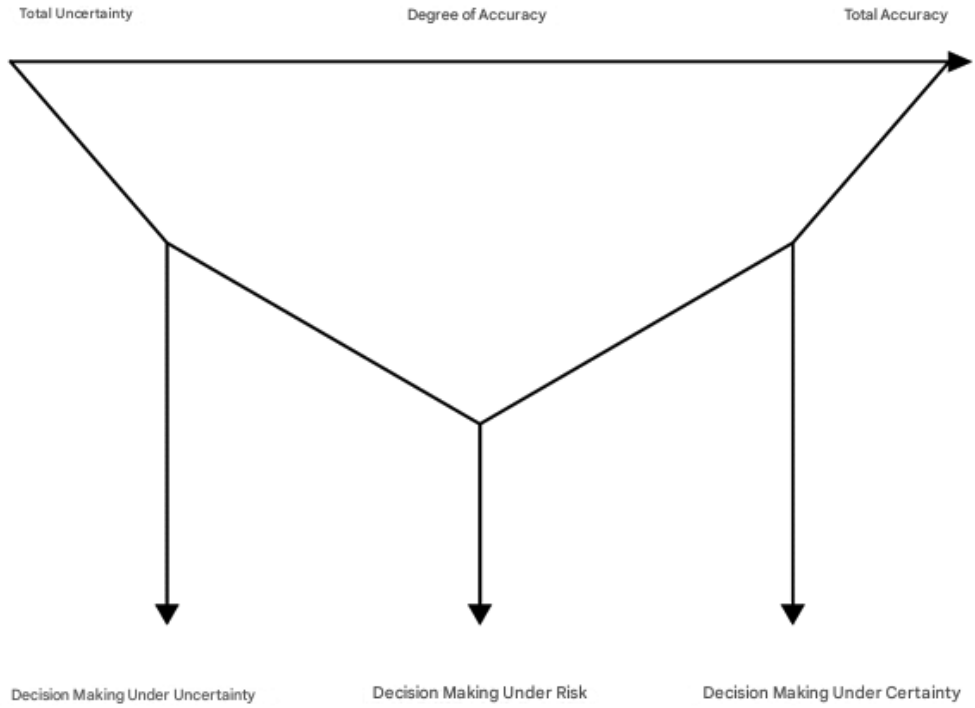
gain they will incur if they choose that alternative (Hansson, 2005). In a state of certainty, the decision maker has complete information about the outcome of each alternative, and each alternative has only one outcome (Doğan, 1985). This situation provides the most comfortable decision environment for the decision maker because all elements of the decision problem are independent of probability, risk, and chance (Tütek et al., 2016). The success of decisions made in an environment of certainty is evaluated solely by the quality of the outcome (Taghawifard and Damghani, 2009). Certainty is a theoretical environment. Certainty rarely occurs in practice (Bejleri et al., 2022).

- Decision Making Under Uncertainty: Uncertainty is a fact of life and business, and most business decisions are made under uncertainty (Taghawifard and Damghani, 2009). Uncertainty means that it is impossible to assess the probability of various possible future events (Bejleri et al., 2022: 2). A decision maker who lacks information about the events that will occur cannot know the consequences of each alternative (Doğan, 1985). In decision making under uncertainty, the decision maker has no knowledge of the consequences of natural states and/or obtaining the necessary information is costly. In such cases, decision making depends solely on the decision maker's personality type (Taghawifard and Damghani, 2009).

- Decision Making in a Risk Environment: When the decision maker has some knowledge about the states of nature and can assign subjective probability estimates for each event to occur, the decision problem is classified as decision making under risk (Taghawifard and Damghani, 2009). Decision making under risk refers to the situation where the number of events is greater than one and the probabilities of the events are known to the decision maker (Doğan, 1985). When the decision maker can assign probabilities to states of nature, it can be said that the decision maker is making a decision under risk (Tütek et al., 2016). Decisions made in a risky environment involve more than one state of nature (Bejleri et al., 2022).

- Decision Making in a Competitive Environment: A competitive environment arises when the interests of two or more decision-makers conflict and they compete with each other. In a competitive environment, decision-makers are concerned not only with their own actions but also with the actions of others when making decisions in conflict situations. (Bejleri et al., 2022).

Figure 3: Deciding on Precision Levels



Source: Ramamurthy, 2007

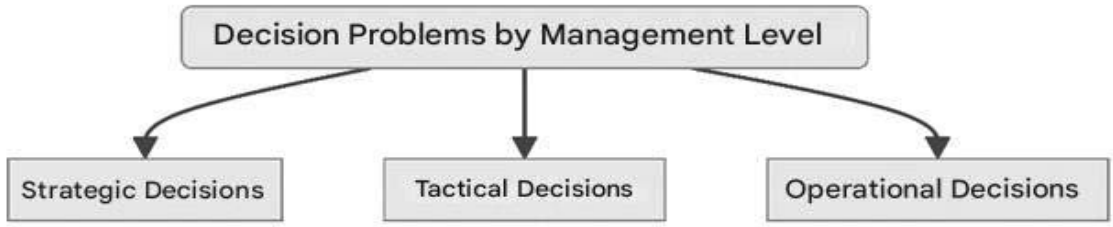
Figure 3 illustrates how the decision-making process changes depending on the decision maker's level of certainty in the decision environment. The left side of the figure represents an uncertain decision environment. In this situation, the decision maker is making a decision under uncertainty. When making a decision under uncertainty, the decision maker lacks knowledge of what will happen in the future. It is difficult to predict the consequences of possible natural events. The center of the figure represents a risk environment. Decision makers make decisions under risk. In risky environments, the probabilities of possible natural events occurring are known. The decision maker bases their decisions on this probabilistic knowledge. The right side represents an environment of certainty. When making decisions under certainty, decision makers know all outcomes with certainty. The curve in the figure represents the transition from uncertainty to certainty. Accordingly, as uncertainty decreases, the environment's certainty increases.

Businesses make decisions based on the different natures and decision environments of decision theory. Furthermore, management levels also play a role in classifying decision problems.

2.7.2. Decision Problems by Management Level

The classification of decision problems according to management level is examined under three headings (Lezki et al., 2019):

Figure 4: Decision Problems by Management Level



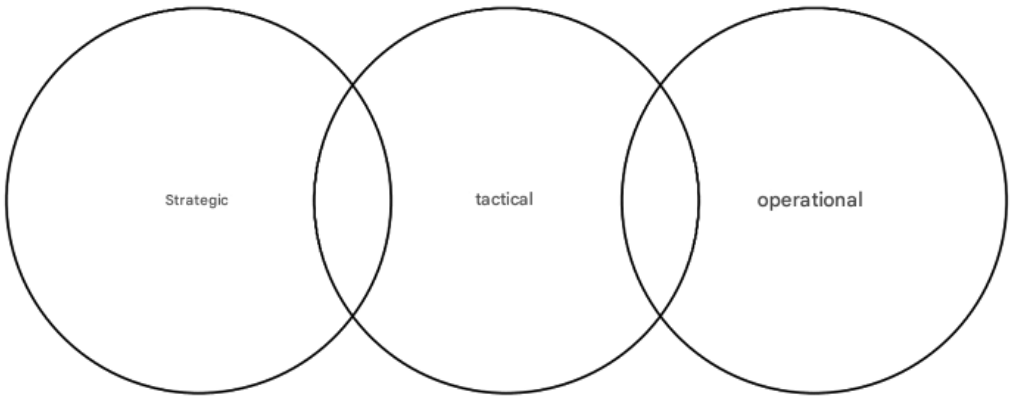
Source: Ramamurthy, 2007

- Strategic Decisions: Strategy is a word with many meanings (Nickols, 2016). The word "strategy" comes from the Greek word " strategos," meaning "general " in the military. Conceptually, strategy is used to explain how to achieve a set of goals, whether short-term or long-term (Freedman, 2015). In other words, strategic decisions arise from organizations' efforts to create a consistent and planned approach (SteadieSeifi, 2011). Strategic decisions are decisions made by senior managers at a management level, and conflicts are likely to occur in strategic decisions (Nutt and Wilson, 2010). Strategic decisions are becoming increasingly important because they are generally large, risky, and difficult to reverse, have long-term effects, bridge the gap between planned and sudden developments, are an important source of corporate learning, play a significant role in the development of individual managers, and facilitate transitions between business functions and academic disciplines (Papadakis and Barwise, 1997).

- Tactical Decisions: These are decisions made by middle-level managers. Tactical decisions are made on a medium- to long-term basis, such as monthly, quarterly, or even annually. Production planning, transportation planning, and resource planning are examples of tactical decision types (SteadieSeifi, 2011).

- Operational Decisions: These refer to decisions made by lower-level managers. Operational decisions are made in real time on a daily or weekly basis and are therefore limited in scope. Decisions such as vehicle loading or shipping, shipping, and warehouse routines are examples of operational decisions. These types of decisions are based on a wealth of detailed data (SteadieSeifi, 2011).

Figure 5: Relationship of Decision Problems According to Management Level



Source: SteadieSeifi, 2011

Because each level makes decisions of different nature and in different timeframes, decision problems must be classified according to management level. Furthermore, decision problems are also classified according to their structural status.

2.7.3. Decision Problems According to Structure Status

Businesses operate in a complex environment where numerous variables interact with each other. These are examined under three headings, depending on the structure of the situation in which decisions are made, as follows (Lezki et al., 2019):

- Structured (Programmable) Decisions: These types of decisions refer to routine and repetitive decisions made by practitioners in various units of the business. These decisions are characterized by practitioners knowing how to react to a specific situation and consistently responding to it. As a result of the repetition of these responses, behaviors become routinized. When structured decisions are first made, they are programmed, specifying what to do. When a similar decision-making situation arises later, the previously established decision is applied to that situation as well. Operational decisions generally fall into this decision category.

- Unstructured (Non-Programmable) Decisions: These are complex decision problems that involve a high level of uncertainty. It is impossible to fit these decision problems into a specific pattern or solve them with a specific procedure.

- Semi-Structured (Semi-Programmable) Decisions: These represent a blend of the previous decision structures. In this type of decision, the decision maker has previously encountered a portion of the decision problem and can utilize a

specific procedure for solving it. However, there is no such procedure for the entire decision, and the remaining decision must be treated as an unstructured decision. Semi-structured decisions are frequently made in businesses. These decisions are generally tactical and are made by middle management.

To manage the complexity and uncertainty of the decision-making process, decision problems are classified according to their structure. Another characteristic used in classifying decision problems is their connectedness.

2.7.4. Decision Problems Based on Connectedness

The decisions taken are examined under two headings according to their interconnectedness as follows (Lezki et al., 2019):

- Single-Stage Decisions: These are decisions whose outcome affects only the individual. In some cases, a single decision is sufficient. It's not possible to talk about a series of interconnected decisions. In this case, the outcome of a decision doesn't affect any other decision. In other words, the decision isn't related to other decisions.

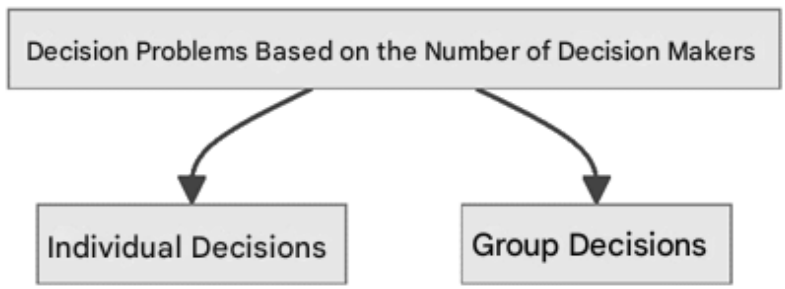
- Multi-Stage Decisions: This refers to a type of decision in which the outcome of one decision process serves as an input to another. In this type of decision, the first decision influences the next decision.

Decision problems can be classified based on their interconnectedness to understand the impact and relationships between decisions. Furthermore, the number of decision makers is also used in classifying a decision problem.

2.7.5. Decision Problems Based on the Number of Decision Makers

Some decisions are made individually, while others are made as a group. Accordingly, decision-making is divided according to the number of people involved as follows (Aşan et al., 2019):

Figure 6: Decision Problems According to the Number of Decision Makers



Source: Ramamurthy, 2007

- Individual Decisions: These are decisions made by the individual, not by any organization. In individual decision-making, the decision-maker makes an individual choice among decision alternatives (Zimmermann, 2012). The most significant advantage of individual decisions is that they can be made quickly because the individual is solely responsible for the decision-making process. If the decision-maker detects any errors or inconsistencies during the decision-making process, they can make revisions. Another advantage of such decisions is that they allow for the production of creative results (İmrek, 2003).

- Group Decisions: This type of decision problem involves expert decision-makers, as a group, reflecting their subjective judgments on the decision-making process. In group decisions, group members may have difficulty reaching consensus despite possessing sufficient information needed for the decision-making process. In this non-individual type of decision, some group members may choose not to make a joint decision (Harrison, 1995).

In group decision-making, decision-makers seek support and input from other group members to make their decisions more objectively and consistently. Furthermore, by sharing and discussing their ideas, decision-makers create the opportunity to explore more options and achieve better results. This makes the decision-making process more objective and fairer (Hwang and Lin, 2012).

Two aspects of group decision-making must be considered. The first is the discussion and exchange of ideas within the group to reach some kind of consensus on a given problem; this presents a relatively minor challenge. The second presents a much greater challenge. The holistic nature of a given problem requires that it be broken down into smaller subject areas, and that groups of experts in these areas determine how each impacts the overall problem. A large and complex problem can rarely be simply broken down into smaller problems, whose solutions can be combined into a general answer. If this process is successful, the initial question can be restructured and the proposed solutions revised (Saaty, 1994).

Group decisions vary depending on whether they are criteria-oriented or alternative-oriented. If the decision is criteria-oriented, decision makers evaluate alternatives based on the criteria. If the decision problem is alternative-oriented, alternatives are evaluated without considering the impact of the decision criteria. In group decisions, the knowledge and experience of the decision makers who make up the group influence the decision (Aşan et al., 2019).

According to this classification, which is necessary due to the nature of decision problems, individual decisions provide the advantage of generating quick and creative solutions, while group decisions aim to achieve more objective and fair results by accumulating more information and perspectives. Another criterion for classifying decision problems is the number of criteria.

2.7.6. Decision Problems Based on the Number of Criteria

Businesses operate in a complex environment where many variables interact with each other (Lezki et al., 2019).

- Single-Criteria Decisions: These are decision problems in which there is no more than one evaluation criterion in the decision process. In single-criteria decision problems, decision alternatives are evaluated based on only a single criterion.

- Multi-Criteria Decisions: These are decision problems where multiple evaluation criteria are used in the decision process. Multi-criteria decision problems arise by evaluating decision alternatives based on multiple criteria. In the real world, it is often possible to solve decision-making problems by adhering to a single objective or criterion. Events are multidimensional, and considering decision problems in one dimension prevents events from being evaluated in a way that reflects reality. In decision problems, not all decision criteria serve the same purpose and can conflict with each other. Consequently, the one that best meets these conflicting criteria must be selected from among decision alternatives (Ishizaka and Nemery, 2013).

There are basically two types of situations that cause the decision problems encountered to enter the solution area of multi-criteria decision-making methods. (Ekel and Palhares, 2008):

- Inability to determine outcomes using a single criterion, and inability to compare decision alternatives against a single criterion.
- In cases where a single criterion cannot provide unique solutions due to information uncertainty, multiple criteria are needed to reduce uncertainty.

Businesses operating in complex environments face both single-criteria and multi-criteria decisions. While single-criteria decisions are simple and based on a single criterion, multi-criteria decisions require more comprehensive and realistic assessments using multiple criteria.

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