Preface

The Multicriteria Analysis Paradigm

During the past decades, operations research (OR) has come a long way as a field that supports scientific management. Within the OR field, various interconnected areas have been developed on the basis of different decision-making paradigms and problem contexts. OR is mainly involved with model building and algorithmic optimization procedures that facilitate the analysis of complex real-world problems. This complexity can be due to the dimensionality of a given problem (e.g., the number of available options and actions), the uncertainty that prevails in most real-world situations, the nature of the available data which are often imprecise, as well as the multiple stakeholders that are often involved.

An important implication of the above issues involves the multidimensional character of real-world decision-making problems, which requires the consideration of multiple conflicting points of view, even in situations where a single decision maker is involved. Nowadays, economic, social, and environmental criteria are nowadays involved in practically all decision situations, in order to describe the diverse outcomes of the existing options. Within this context, the decision process should naturally explore the conflicting nature of the criteria, the corresponding tradeoffs, the goals set by the decision makers, and of course the way that these can be introduced in an appropriate decision model that takes into account the subjectivity of the decision process and the preferences of the decision makers.

Nevertheless, with the introduction of multiple points of view, criteria, and factors, universally acceptable (objective) solutions are no longer feasible. While this may be cumbersome, it highlights the difficulty of decision-making in a realistic context. The well-known theorem of Arrow [1] is indicative of these difficulties. In a social choice setting, Aror’s axiomatic system defines the necessary conditions for democracy, and the paradox is that it leads to dictatorship. Arrow and Raynaud put this argument in a decision-making context (see [2], p. 21):

You want to make a real, wise, multicriterion decision, and the simplest and most natural axioms drive you toward a monocriterion one!
In explaining this paradox Vincke [9] notes that Arrow’s axioms are incompatible when one tries to select a single (right) solution (preorder of some alternatives) from a set of plausible ones defined by the information that multiple criteria provide. Vincke emphasizes that the final choice requires more information or implicit assumptions about the preferences of the individuals involved in the decision process (i.e., the decision-makers).

With these issues in mind, multicriteria analysis has become an important and active discipline in OR, focusing on providing the theory and methodologies needed for supporting the decision-making process in complex and ill-structured problems, within a realistic context taking into account all the multiple points of view, criteria, and stakeholders involved. Among others multicriteria analysis focuses on issues such as: (1) the resolution of the conflicting nature of the criteria, (2) the modeling of the decision-makers’ preferences, (3) the identification of compromise solutions and the analysis of the consequences of multicriteria solutions, and (4) the development of decision-making models.

The Evolution of Multicriteria Analysis and Current Status

The increasing complexity the economic, technological, and business environment, have contributed to the establishment of multicriteria analysis as an important field of OR and management science. Actually, however, the field has a long history, which can be traced back to the works of Jean-Charles de Borda and Marquis de Condorcet on voting systems in the late 18th century. About a century after these works, Vilfredo Pareto introduced the concept of dominance, which is fundamental in modern theory of multicriteria analysis, which was later on extended by Koopmans [4]. During the 1940s and the 1950s, von Neumann and Morgenstern [10] as well as Savage [8] introduced utility theory for normative decision-making, which set the grounds for multiattribute utility/value theory, one of the major methodological streams of multicriteria analysis. These pioneering works inspired several researchers during the 1960s. Charnes and Cooper [3] extended the traditional mathematical programming theory through the introduction of goal programming. By the end of the 1960s, multicriteria analysis attracted the interest of European OR too. Roy [7], one of the pioneers in this field, introduced the outranking relation approach; he is considered as the founder of the “European” school of multicriteria analysis.

During the recent years, multicriteria analysis has continued its growth through:

- New theoretical developments on new techniques and the characterization of existing decision models.
- The implementation of multicriteria methodologies into integrated decision support systems.
- Innovative applications into new areas, including among other management, economics and finance, environment and energy planning, telecommunications, transportation, etc.
• The exploration of the interactions with other disciplines such as artificial intelligence, evolutionary computation, fuzzy sets theory, and soft computing.

Outline of the Book

Aims and Scope

Research works on multicriteria analysis is often published in premier OR journals, special issues, conference proceedings, and textbooks. Nevertheless, a publication such as this edited volume provides the unique opportunity to present in a unified and comprehensive way the foundations of multicriteria analysis, its core concepts, and the recent advances in the field. To this end, the book covers the theory of multicriteria analysis on discrete problems and multiobjective optimization, the connections of multicriteria analysis with other disciplines, and applications. All chapters are written by leading experts in the field, in an expository yet scientifically vigorous manner. In this way, we think that a broad readership including among others researchers, graduate students, and practitioners who are interested in management science, operations research, and decision analysis, will find in this book a complete coverage of the recent advances in the different aspects of MCDA and the state-of-the-art research in this field.

The book is organized into four main parts, covering all aspects of multicriteria analysis, including issues in decision aiding and support, discrete problems, multiobjective optimization, and applications. Below we provide an outline to the contents of the book.

Organization

Issues in Decision Aiding

The first part of the book is devoted to some important issues that analysts and decision-makers should bear in mind during the decision process. Irrespective of the methods used, it is always important to have in mind issues related to problem modeling and structuring, as well as the robustness and sensitivity of the obtained solutions and recommendations. The careful consideration of such points ensures that the decision aiding process is well designed and implemented, which is fundamental for the quality of the results, their acceptability by the decision-maker, and their actual applicability.

In the first chapter of this introductory part, Roy discusses the important concept of robustness. All decision aiding models are naturally based on a set of assumptions of the real world, which by itself implies that such models provide (by definition)
an approximation of reality. This raises the question on whether the results and recommendations obtained by decision models are actually as good as analysts and decision-makers assumed during the analysis process. Robustness analysis enables the consideration of this issue which is crucial for decision aiding. Roy analyzes the concept of robustness in decision aiding and discusses four proposals that clarify the broad and subjective nature of robustness, its importance for decision aiding, and its implementation in multicriteria methodologies.

The second chapter by Montibeller and Franco, involves the use of multicriteria analysis for strategic decision-making. Strategic decisions are taken at the top level of an organization, require a vast amount of resources, and the magnitude of their results is decisive for the future of the organization. Multicriteria methods are particularly well-suited to this type of problems, but there is a number of issues involved for their successful application. Montibeller and Franco discuss the complexity of the strategic decision-making process as far as its technical and social aspects are concerned and outline the multicriteria modeling framework for strategic decisions including the role of multiple objectives, the uncertainties involved, the identification of robust options and their evaluation, as well as the analysis of their long term consequences. The authors provide suggestions on how to implement a multicriteria modeling approach, focusing on the design of decision support processes to tackle the complexity of strategic decisions.

Multicriteria Decision Aid Methodologies

The second part of the book covers issues related to discrete multicriteria problems. By “discrete problems”, we refer to decision situations involving the evaluation of a finite set of alternatives and actions over a predefined set of evaluation criteria. Such problems are encountered in numerous cases, including among others finance and economics, strategic planning, human resources management, marketing, engineering, etc. The chapters in this part cover the main multicriteria paradigms and methods to address such problems.

The first chapter in this part involves the family of ELECTRE methods. Founded on the theory of outranking relations, the ELECTRE methods have played a prominent role in the development of multicriteria analysis during the past 40 years. During this period several extensions and variants of the original ELECTRE method have been developed for decision aiding in different kinds of problem contexts. In this chapter Figueira, Greco, Roy, and Słowiński provide a comprehensive discussion of the main features of the ELECTRE methods, their weak and strong points, and present an overview of all the recent advances of this modeling approach.

In the next chapter, Saaty provides a comprehensive discussion of the analytic hierarchy process (AHP) and its generalization to dependence and feedback, the analytic network process (ANP). AHP/ANP implement a completely different approach to multicriteria analysis compared to the outranking relations approach of the ELECTRE methods. Both methods have become very popular techniques with numerous applications in various fields, since the introduction of AHP by Saaty in
1980. In this chapter Saaty describes the foundations of AHP/ANP and their assumptions, using several detailed examples and real-world applications. Extensions to group decision-making are also discussed together with the well-known issue of rank preservation and reversal.

The third chapter, by Salo and Häämäläinen, introduces preference programming methods, which include techniques that model incomplete preference information through set inclusion, provide decision recommendations based on dominance concepts and decision rules, and support the iterative exploration of the decision-maker’s preferences. The chapter presents the key concepts of this approach, the preference elicitation techniques employed, the existing methods, as well as their implementation into decision support systems, and their applications.

The next chapter is devoted to the aggregation-disaggregation approach. Similarly to preference programming, disaggregation techniques facilitate the preference elicitation process during model building. This approach is particularly helpful when the decision-maker has difficulties in specifying the detailed preferential information that is needed for the decision aiding process. Disaggregation analysis uses regression-like techniques to infer this information from a set of decision examples. In this chapter Siskos and Grigoroudis present the new research developments on aggregation-disaggregation models, including among others issues such as post-optimality analysis, robustness analysis, group and collective decision-making.

In last chapter in the second part of the book, Doumpos and Zopounidis explore the connections between the disaggregation paradigm of multicriteria analysis with statistical learning and data mining. Similarly to disaggregation analysis, statistical learning/data mining is also involved with the problem of inference from data. However, the scope and context of the two fields is substantially different. This chapter discusses the similarities and differences between the two fields, and explores the ways that they can be combined to provided integrated decision support. To this end, a comprehensive literature review is presented.

**Multiobjective Optimization**

The third part of the book is devoted to multiobjective optimization, which extends the traditional single objective toward the consideration of multiple (conflicting) objectives and goals. Multiobjective optimization has been a very active research field in multicriteria analysis. Its development has been motivated by the diversity and complexity of business and engineering problems, which led to important developments such as interactive and iterative algorithms, goal programming formulations, and (more recently) multiobjective evolutionary optimization techniques.

This part of the book begins with the chapter of Zeleny, who explains in the simplest possible terms what multiobjective optimization is and discusses the role of tradeoffs, distinguishing between a tradeoffs-based approach and tradeoffs-free thinking. This distinction leads to two different optimization paradigms: the optimization of a given system versus the design of the optimal system. On the basis of the latter approach, Zeleny discusses the foundations of De novo programming and
provides examples optimal design and multiobjective optimization can be used in areas such as risk management, conflict dissolution, and product pricing.

In the next chapter, Korhonen and Wallenius focus on interactive multiobjective optimization methods. Interactive methods are widely used in multiobjective optimization to facilitate the search for an appropriate solution in accordance with the decision-maker’s preferences. Korhonen and Wallenius present the main ideas and principles of interactive methods, their implementation in different methodological approaches, together with a discussion of the context within which such methods can be used efficiently for decision-making and support. Examples of two software implementations are also given.

The third chapter of this part is devoted to evolutionary multiobjective optimization, which has emerged during the past decade as an important development in the theory and practice of multicriteria analysis in computationally complex problems that are hard to solve to optimality with traditional optimization techniques. In this chapter Fontes and Gaspar-Cunha introduce the concepts on which evolutionary multiobjective optimization algorithms are based, together with a summary of the main algorithmic implementations and their applications in engineering, industry, economics, and management, among others.

Goal programming is the subject of the next chapter. Since the 1950s, goal programming formulations have constituted an important modeling approach in multicriteria analysis and OR. Instead of considering multiple objectives as in a multiobjective optimization context, goal programming is based on the definition of goals, which represent targets that the decision-maker’s would like the obtained solution to reach on a number of measures (criteria). González-Pachón and Romero, begin with the discussion of the connections between goal programming and Simon’s bounded rationality theories, and present several types of goal programming formulations. Important issues for the successful use of this approach are also discussed along with several extensions.

In the last chapter of this part, Engau discusses the use of decomposition-coordination methods in multiobjective problems. Such methods are very useful in complex decision problems involving a large number of decision variables and/or objectives. Decomposing such problems into smaller ones not only improves the computational aspects of the solution process, but it may also facilitate the active participation of the decision-maker. The overview in this chapter collects and reports on some of the most important methods and results, including but not limited to multidisciplinary design optimization, multiobjective hierarchical analysis, tradeoff-based decision-making, and multiscenario multiobjective optimization.

Applications

The fourth part of the book is dedicated to applications of multicriteria analysis. We consider applications as being of equal importance to the advances in theory. Applications enable the testing of new multicriteria methodologies in real-world situations, thus highlighting the practical contributions of this field, the existing lim-
itations of the methods, and pinpointing new issues that require new methodologies or further validation [5, 6, 11].

In the first chapter of this last part, André and Roy present a multicriteria approach, based on the ELECTRE TRI method, designed to evaluate non-financial performance in companies. The methodology implements a hierarchical evaluation scheme, in accordance with a hierarchy of responsibilities in an organization. The chapter discusses in detail the modeling framework and discusses the application of the proposed methodology in several companies for the evaluation of sponsorship projects.

The next chapter, by Schauten and Spronk, deals with the optimal capital structure problem, which is of major importance in corporate finance, which emphasizes the objective of shareholder wealth maximization. However, as Schauten and Spronk show the management of the firm’s capital structure is much more involved, as the capital structure decision process involves multiple considerations of diverse nature. Within this context, the authors propose to translate some of these considerations as separate criteria, which can be traded off against the hard and quantifiable criterion of market value, and present an overview of the different objectives and considerations that have been proposed in the literature.

The book ends with the chapter of Tsafarakis, Lakiotaki, and Matsatsinis on the applications of multicriteria analysis in marketing and e-commerce. In the marketing domain, the chapter illustrates the uses of multicriteria analysis in issues such as consumer preference measurement, market segmentation, targeting, and simulation. In the e-commerce domain business-to-consumer tools and recommender systems are discussed among others. Examples of multicriteria applications and decision support methodologies are also discussed.

**Acknowledgements**

Sincere thanks must be expressed to all the authors, who have shown increased interest in contributing to this edited volume. They have devoted considerable time and effort to prepare excellent comprehensive works of high scientific quality and value. Without their help it would be impossible to prepare this book in line with the high standards that we have set from the very beginning of this project. We are also grateful to Michael Doumpos, Aggeliki Liadaki, and Dimitrios Niklis for their valuable help with the editorial process and the preparation of the final manuscript.

*Constantin Zopounidis*
*Panos M. Pardalos*
February 2010
References

Handbook of Multicriteria Analysis
Zopounidis, C.; Pardalos, P.M. (Eds.)
2010, XXV, 455 p. 92 illus., Hardcover
ISBN: 978-3-540-92827-0