PREFACE

Probably the most perpetual intellectual challenge in science and engineering is how to make the optimal decision in a given situation. This is a problem as old as mankind. In some ancient civilizations people attempted to solve complex and risky decision problems by seeking advice from priests or the few knowledgeable individuals. In ancient Egypt it was believed that only the kings and the upper clergy could find what is the best solution to a given problem. In classical Greece oracles served a similar purpose.

Many centuries passed since then. Today mankind has replaced the old methods with modern science and technology. The development of scientific disciplines such as operations research, management science, computer science, and statistics, in combination with the use of modern computers, are nothing but aids in assisting people in making the best decision for a given situation. Theories such as linear programming, dynamic programming, hypothesis testing, inventory control, optimization of queuing systems, and multi-criteria decision making have as a common element the search for an optimal decision (solution).

Among the previous methods, there is one class of methods which probably has captured the attention of most of the people for most of the time. This is multi-criteria decision making (MCDM). That is, given a set of alternatives and a set of decision criteria, then what is the best alternative? This problem may come in many different forms. For instance, the alternatives or the criteria may not be well defined, or even more commonly, the related data may not be well defined. In many real life cases it may even be impossible to accurately and objectively quantify the pertinent data. Often a decision problem can be structured as a multi-level hierarchy. Also, it is not unusual to have a case in which all or part of the data are stochastic or even fuzzy.

The central decision problem examined in this book is how to evaluate and rank the performance of a finite set of alternatives in terms of a number of decision criteria. It is assumed that the decision maker is capable of expressing his/her opinion of the performance of each individual alternative in terms of each one of the decision criteria. The problem then is how to rank the alternatives when all the decision criteria are considered simultaneously.

In the main treatment the data are assumed to be deterministic. In the latter part of this book we also consider the case in which the data are fuzzy. That is, this book does not consider stochastic or probabilistic data. Although this may sound restricted, nevertheless it captures many real life situations, for stochastic data are difficult to be obtained or individual decision makers feel uncomfortable dealing with them.

The author of this book became actively involved with research in this

area of decision making when he was a graduate student at Penn State University, more than seventeen years ago. What has captured his attention since the early days was the **plethora** of alternative methods for solving the same MCDM problem. In most cases the authors and supporters of these methods have identified some weaknesses of the previous methods and then they propose a new method claiming to be the best method. As a result, today a decision maker has an array of methods which all claim that they can correctly solve a given MCDM problem. The subjectivity and the tremendous conceptual complexity involved in many MCDM problems make the problem of comparing MCDM methods a challenging and urgent one.

This book presents the research experiences of the author gathered during a long search in finding which is the best MCDM method. Although the final goal of determining the best method seems to be unattainable and utopian, some useful lessons have been learned in the process and are presented here in a comprehensive and systematic manner.

A methodology has been developed for evaluating MCDM methods. This methodology examines methods for estimating the pertinent data and methods for processing these data. A number of evaluative criteria and testing procedures have been developed for this purpose. What became clear very soon is that there is no single method which outperforms all the other methods in all aspects. Therefore, the need which rises is how one can conclude which one is the best method. However, for one to answer the problem of which is the best MCDM method, he/she will first need to use the best MCDM method! Thus, a decision paradox is reached.

This is the main reason why a comparative approach is needed in dealing with MCDM methods. By simply stating various MCDM theories and methods one fails to capture the very real and practical essence of MCDM. The present book attempts to bridge exactly this gap. Although not every MCDM method has been considered in this book, the procedures followed here can be easily expanded to deal with any MCDM method which examines the problem of evaluating a discrete set of alternatives in terms of a set of decision criteria.

This book provides a unique perspective into the core of MCDM methods and practice. It provides many theoretical foundations for the behavior and capabilities of various MCDM methods. This is done by describing a number of lemmas, theorems, corollaries, and by using a rigorous and consistent notation and terminology. It also presents a rich collection of examples, some of which are extensive. A truly unique characteristic of this book is that almost all theoretical developments are accompanied by an extensive empirical analysis which often involved the solution of hundreds of thousands or millions of simulated test MCDM problems. The results of these empirical analyses are tabulated, graphically depicted, and analyzed in depth.

In this way, the theoretical and empirical analyses presented in this book are complementary to each other, so the reader can gain both a deep theoretical and practical insight of the covered subjects. Another unique characteristic of this monograph is that at the end of almost each chapter there is description of some possible research problems for future research. It also presents an extensive and updated bibliography and references of all the subjects covered. These are very valuable characteristics for people who wish to get involved with new research in MCDM theory and applications. Some of the findings of these comparative analyses are so startling and counter intuitive, that are presented as decision making paradoxes.

Therefore, this book can provide a useful insight for people who are interested in obtaining a deep understanding of some of the most frequently used MCDM methods. It can be used as a textbook for senior undergraduate or graduate courses in decision making in engineering and business schools. It can also provide a panoramic and systematic exposure to the related methods and problems to researchers in the MCDM area. Finally, it can become a valuable guidance for practitioners who wish to take a more effective and critical approach to problem solving of real life multi-criteria decision making problems.

The arrangement of the chapters follows a natural exposition of the main subjects in MCDM theory and practice. Thus, the first two chapters provide an outline and background information of the most popular MCDM methods used today. These are the weighted sum model (WSM), the weighted product model (WPM), the analytic hierarchy process (AHP) with some of its variants, and the ELECTRE and TOPSIS methods.

The third chapter provides an exposition of some ways for quantifying qualitative data in MCDM problems. This includes discussions on the elicitation of pairwise comparisons and the use of different scales for quantifying them. Chapters four to seven describe some different approaches for extracting relative priorities from pairwise comparisons and also of ways for reducing the number of the required judgments.

Chapter eight is the longest one and it deals with a unified sensitivity analysis approach for MCDM methods. Since no real life decision problem can be considered completely analyzed without a sensitivity analysis, this is a critical subject. As with most of the chapters, this chapter provides an in depth theoretical and empirical analysis of some key sensitivity analysis problems.

Chapters nine to eleven deal with the comparison of different MCDM methods and procedures. Chapter nine presents a comparison of different ways for processing a decision matrix. Chapter ten presents a computational study of the AHP and the Revised AHP. Chapter eleven presents some new cases of ranking irregularities when the AHP and some of its additive variants are used. One can claim that these new cases of ranking irregularities are

strongly counter intuitive. They have been analyzed both theoretically and empirically.

Chapters twelve and thirteen present some fundamental concepts of fuzzy decision making. As always, the treatments here are accompanied with extensive comparative empirical analyses. Finally, some conclusions and possible directions for future research are discussed in the last chapter.