

Preface

The increasing complexity of modern-day society has brought new problems having multiple objectives including economic, environmental, social and technical ones. Hence, it seems that the consideration of many objectives in the actual decision making process requires multiobjective approaches rather than that of a single objective. One of the major systems-analytic multiobjective approaches to decision making under constraints is multiobjective programming as a generalization of traditional single objective programming. For such multiobjective programming problems, it is significant to realize that multiple objectives are often noncommensurable and conflict with each other. With this observation, in multiobjective programming problems, the notion of Pareto optimality or efficiency has been introduced instead of the optimality concept for single-objective problems. However, decisions with Pareto optimality or efficiency are not uniquely determined; the final decision must be selected by a decision maker (DM), which well represents the subjective judgments, from the set of Pareto optimal or efficient solutions. For deriving a compromise or satisficing solution through interactions with a decision maker, interactive methods for multiobjective programming have been developed.

When formulating a multiobjective programming problem which closely describes and represents the actual decision making situations, the uncertainty inherent in real-world complex systems or human being, such as the randomness of events related to the systems or the fuzziness of human judgments, should be reflected in the description of the objective functions and constraints as well as in the representation of parameters involved in the formulated problems. For dealing with not only the multiobjectiveness but also the uncertainty in decision making, multiobjective stochastic programming and multiobjective fuzzy programming have been individually developed together with the introduction of various optimization models and corresponding solution techniques.

However, recalling the vagueness or fuzziness inherent in human judgments for the objective functions and/or constraints involving randomness, it is significant to realize that the uncertainty in real-world decision making problems is often expressed by a fusion of fuzziness and randomness rather than either fuzziness or randomness. For such decision making situations, there are two types of inaccura-

cies to be incorporated into multiobjective stochastic programming problems. One is the fuzzy goal of a DM for each of the stochastic objective functions, and the other is the experts' ambiguous understanding of random parameters in the problem-formulation process. When we model actual decision making situations under uncertainty as multiobjective programming problems involving random variables, following a major conventional stochastic programming approach together with the introduction of probabilistic constraints, the original problems can be transformed into deterministic multiobjective programming problems by replacing the original stochastic objective functions with some deterministic ones such as their expectations or variances. However, considering the imprecise nature of DMs' judgments in multiobjective problems, it is natural to assume that the DM has a fuzzy goal for each of the resulting deterministic objective functions which originally involve randomness. Furthermore, in multiobjective stochastic programming, it is implicitly assumed that the realized values of random parameters can be definitely expressed by real values. However, considering that the realized values may be only ambiguously known to or observed by the experts, it may be more appropriate to express these values as fuzzy numerical data which can be represented by means of fuzzy subsets of the real line known as fuzzy numbers. For handling and tackling such a fusion of fuzziness and randomness in multiobjective decision making, it is not hard to imagine that conventional fuzzy multiobjective programming or multiobjective stochastic programming cannot be applied. Naturally, simultaneous considerations of multiobjectiveness, fuzziness and randomness involved in the real-world decision making problems lead us to the new field of multiobjective mathematical programming under fuzzy stochastic environments.

So far, we have restricted ourselves to mathematical programming problems where decisions are made by a single DM. However, decision making problems in hierarchical managerial or public organizations are often formulated as two-level programming problems, where there exist two DMs. When we deal with decision making problems in decentralized organizations such as a firm's organizing administrative office and its autonomous divisions, it is quite natural to suppose that there exists communication and some cooperative relationship among the DMs. For handling such cooperative hierarchical decision making situations, two-level programming with random variables or fuzzy random variables are introduced to derive a satisfactory solution taking a balance between the DMs' satisfactory degrees. Furthermore, in order to resolving conflict in hierarchical noncooperative decision making situations, computational methods for Stackelberg solutions for two-level programming problems involving random variables or fuzzy random variables are presented.

Concerning computational aspects of multiobjective programming under fuzzy stochastic environments, because real-world decision problems under uncertainty can be often formulated as difficult classes of optimization problems such as combinatorial problems and nonconvex nonlinear problems, it is difficult to obtain exact optimal solutions, and thus it is quite natural for DMs to require approximate optimal solutions instead. To meet this demand, genetic algorithms initially introduced by Holland in early the 1970's and tabu search methods proposed by Glover *et al.*

in the mid-1980's, which have attracted considerable attention as efficient meta-heuristics, should be incorporated into interactive multiobjective programming with random variables or fuzzy random variables.

In this book, after presenting basic concepts in conventional multiobjective programming, the authors intend to introduce the latest advances in the new field of multiobjective programming involving fuzziness and randomness. Special stress is placed on interactive decision making aspects of fuzzy stochastic multiobjective optimization in order to derive a satisficing solution for a DM. Extensions to two-level programming are also given to resolving conflict in hierarchical decision making problems under fuzzy stochastic environments.

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