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Editorial

Methodological foundations of multi-criteria decision making

This feature cluster of the European Journal of Operational Research is one of three special issues devoted to results from the Sixteenth International Conference on Multi-Criteria Decision Making held at Semmering, Austria, on February 18–22, 2002. The special issue of the Journal of Multi-Criteria Decision Making edited by Matthias Ehrgott and Mikulas Luptacik will focus on application-oriented papers, another one in the Central European Journal of Operations Research, edited by Gregory Kersten and Rudolf Vetschera, on the intersection between multi-criteria decision making and group decision making.

The focus of this issue is on methodological foundations of multi-criteria decision making. It is intended to provide an overview of developments which are likely to shape the field of Multi-Criteria Decision Making (MCDM) during the coming years. The issue contains papers that indicate a new direction in MCDM research, either by developing new methods or applying MCDM to a new class of problems in an innovative way or by showing new possibilities to solve existing problems. To reach this goal, new research contributions to the methodology of MCDM have also been openly sought beyond the Semmering Conference. Out of the 12 papers included in this issue, eight are based on work presented at the conference, the remaining four papers have been received in response to the open call for papers. All papers have been reviewed according to the standards of the European Journal of Operational Research. The guest-editors gratefully acknowledge the cooperation of all authors and thank more than 70 anonymous reviewers for their contribution to the refereeing process.

The feature issue begins with the invited review paper "Axiomatic characterization of a general utility function and its particular cases in terms of conjoint measurement and rough-set decision rules" by Salvatore Greco, Benedetto Matarazzo and Roman Słowiński. Aggregation functions, also called utility or value functions, play an important role as preference models in multi-criteria decision making. The paper investigates the relationships between these models and the decision-rule preference model obtained from the dominance-based rough set approach. The relationships are established by means of special "cancellation properties" used in conjoint measurement as axioms for the representation of aggregation procedures. From a general utility function, three important special cases are derived: the associative operator, the Sugeno integral and the ordered weighted maximum. For each of these aggregation functions, a representation theorem is given establishing an equivalence between a very weak cancellation property, the specific utility function and a set of rough-set decision rules. In comparison to other studies on the characterization of these aggregation functions, the axioms given in this paper do not require assumptions about the scales of criteria. Moreover, these characterizations include, for the first time, an equivalent set of decision rules with a special syntax involving partial evaluation profiles and a dominance relation on these profiles. The clarity of the rule representation permits to see the limits of the considered aggregation functions.

There is a wide-spread agreement in the MCDM community that the decision maker

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should play a central role in solving a multi-criteria decision problem. This strong conviction, which has characterized the field since the development of the first interactive methods in the early 1970s, is also clearly visible in many of the papers collected in this issue.

The paper "Out of the mist: Towards decision-maker-friendly multiple criteria decision making support" by Ignacy Kaliszewski concentrates on the interface between the algorithmic part of MCDM tools and the external world of their users and decision makers. For this purpose, the author considers two separate levels: the methodological level and the technical level. A decision maker is usually interested only in the rules and the methodology defining the choice process, and not in the technical details of underlying mathematical methods. To improve the user interface, it is suggested to develop the two levels independently, which requires a common standard of communication between them. The paper shows that the majority of MCDM methods fall into one of two prototype classes and it establishes a common communication standard covering both classes.

The interface between decision maker and methods is also considered in the paper "Phased multicriteria preference finding" by Cathal M. Brugha. Based on empirical results about the behavior of decision makers, it structures the process of solving multi-criteria decision problems into screening, ordering and choosing phases. These phases are characterized by increasing levels of effort and willingness to use sophisticated cognitive processes. Therefore, different methods of multi-criteria decision making are considered most appropriate for the different phases. The theory also leads to suggestions on how criteria trees should be structured and scores synthesized across the criteria tree. Empirical tests show the viability of the proposed approach.

While these two papers have an explicit focus on the interface between decision makers and methods, the role of the decision maker is more implicit, but still of considerable importance, in the next group of four papers. All these papers deal with issues in multi-criteria decision methods arising from the fact that decision makers are not perfectly rational superhuman beings, but possess limited information and bounded abilities for processing information, and their preference structures deviate from those of normative theories.

Limited information about decision alternatives, or the inability to measure all aspects of decision alternatives quantitatively, leads to the problem of integrating data of different measurement levels into a decision model. The paper "Integration of ordinal and cardinal information in multi-criteria ranking with imperfect compensation" by Edwin Hinloopen, Peter Nijkamp and Piet Rietveld deals with this problem. The method proposed in this paper is based on pairwise comparisons of alternatives evaluated on a mixture of ordinal and cardinal judgment criteria. Moreover, a preference structure that allows for less than perfect compensation between criteria is used. The final ranking of alternatives is generated by an overall value function, which is a weighted aggregation of the marginal value functions.

The paper "Preference and veto thresholds in multi-criteria analysis based on stochastic dominance" by Maciej Nowak considers a different type of incomplete information. Here it is assumed that the decision maker does not know the outcomes of alternatives in the various attributes with certainty, but that only the performance probability distribution for each alternative is known. Pairwise comparisons of alternatives with respect to several attributes are made by referring to the stochastic dominance relation. The concept of pseudo-criteria is then employed and a threshold is used to build the outranking relations. Finally, the ELECTRE-III procedure allows to construct a multiattribute ranking of alternatives.

The paper "A method for dealing with inconsistencies in pairwise comparisons" by Jacinto González-Pachón and Carlos Romero deals with a situation in which a decision maker is not able to provide consistent information about his or her preferences towards different attributes. The starting point of this paper is a matrix of pairwise comparisons between alternatives, as it is used in several multi-criteria decision methods, and it develops a new approach to the problem of inconsistencies in such a comparison matrix. The authors distinguish between a normative

approach, which sacrifices part of the original information from the decision maker in order to fulfill theoretical requirements, and a descriptive approach, which is focused on the decision maker's information and rather accepts some violations of those rules. A distance-based framework is proposed for analyzing the gap between the descriptive and normative perspectives in the pairwise comparison method. A goal programming formulation is developed, which provides a flexible and powerful tool for managing this gap.

Non-standard forms of preference are analyzed in the paper "Equitable aggregations and multiple criteria analysis" by Michael M. Kostreva, Włodzimierz Ogryczak and Adam Wierzbicki. In the past decade, increasing interest in equity issues resulted in new methodologies in the area of Operations Research. The concept of equitably efficient solutions is a specific refinement of the Pareto-optimality and it requires special types of aggregations, which are analyzed in this paper. In order to generate equitably efficient solutions, the aggregation functions must be symmetric and maintain some convexity properties (be Schur-convex). In the case when outcomes are restricted to positive values, norms can be used as aggregation functions. In this paper, the authors demonstrate that much better results can be achieved with the Ordered Weighted Averaging (OWA) aggregations. The OWA aggregations provide a family of piecewise linear functions allowing to model various equitable preferences. They can be easily implemented as extensions of the original problem by simple linear constraints.

The acceptance of multi-criteria decision methods depends not only on their interface to the decision maker and their adjustment to the limited information and the cognitive processes of decision makers. Another important issue is their ability to solve precisely the type of problem which decision makers face. A decision problem is not always solved by determining the one best alternative. The classification of alternatives into different sets based on multiple criteria is also an important type of problems, which is addressed by the next two papers.

In classification problems, a given set of alternatives is to be assigned into predefined homogeneous classes. The paper "A multicriteria classification approach based on pairwise comparisons" by Michael Doumpos and Constantin Zopounidis employs the concepts of multi-criteria decision analysis to this type of problems. It proposes a new approach that involves pairwise comparisons based on the outranking relation. The criteria weights used to construct the outranking relation are determined from a reference set of alternatives in the sample by linear programming techniques.

In other situations, the decision makers must group alternatives into homogeneous, but initially unknown classes, which leads to clustering problems. Multi-criteria clustering is considered in the paper "Towards multi-criteria clustering: an extension of the k-means algorithm" by Yves De-Smet and Linett Montano Guzman. They present an extension of the k-means algorithm of data mining with a multi-criteria methodology. It is based on the concept that the alternatives within the cluster are similar in terms of the decision maker's preferences. This is quantified using a multi-criteria distance based on the preference structure.

The following two papers mark another important development in multi-criteria decision making: the growing interaction of MCDM with other fields of research like game theory and global optimization.

The paper "Multi-criteria minimum cost spanning tree games" by Francisco R. Fernández, Miguel A. Hinojosa and Justo Puerto considers the multi-criteria version of the classical minimum cost spanning tree game. The game considered is a set-valued TU-game and the extension of Bird's cost allocation rule generates dominant core solutions. Other core solutions are identified as based on proportional allocations generated by supported scalar solutions of the multi-criteria spanning tree problem. The authors prove necessary and sufficient conditions guaranteeing that the preference core of the game is not empty.

In the paper "Unified approaches for solvable and unsolvable linear complementarity problems" by Michael M. Kostreva and Xiao Q. Yang, general linear complementarity problems (LCP) are studied. A characterization of unsolvable LCP is obtained via the existence of a nonzero efficient

point of a multiobjective optimization problem. The corresponding minimax and quadratic problems are then introduced, zero (global) optimal values of these problems are equivalent to the LCP solvability. This allows to derive first-order and second-order global optimality conditions of LCP.

The last paper of this special issue deals with computational aspects of discrete multiobjective optimization problems. Recent research on the use of metaheuristic methods has opened a promising way to attack this class of problems. In his paper "On the computational efficiency of multiple objective metaheuristics: the knapsack problem case study", Andrzej Jaszkiewicz evaluates the computational efficiency of three multiobjective evolutionary metaheuristics for the multiple constraints knapsack problem. The relative efficiency of multiobjective algorithms is compared to single objective algorithms employed to generate the Pareto-optimal set. The paper identifies considerable differences in the computational efficiency of the algorithms studied and thus provides valuable guidelines for potential users of such methods.

In our opinion, the papers collected in this volume provide a good overview of the directions in which the field of multi-criteria decision making is moving. The early stages of this field were characterized by the rapid development of new algorithms, which sometimes were rather similar to each other or had only a weak theoretical basis. The papers in this volume focus on methodologies which are theoretically founded, can be applied by real-world decision makers and provide valuable inputs to other fields of research. We hope that this volume will contribute to the future development of MCDM.

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