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EDITORIAL

Multi-criteria optimization in industry

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Many real-world optimization and decision-making problems comprise several, partly conflicting objective functions. The English saying "Quality has its price" is just as true on a large scale as it is in private sphere and, therefore, quality and price are a typical pair of conflicting objective functions that are very common in applications. Yet, in industrial applications, both quality and cost may be understood in the specific context and differ whether a transportation, a production, or a planning problem is considered. Other objective functions that are receiving increasing attention in real-world decision-making situations are, for example, robustness, time, sustainability, adaptability, or longevity.

Thus, in light of mathematically supported decision making, the question is how to deal with such objective functions that are conflicting and incommensurable. The quick and easy answer to this is a weighted additive aggregation of all the objective functions into a single, artificial objective function. Then, the resulting single objective problem may be solved and a finally preferred solution obtained. This one-step approach is simple, produces a quick result, but raises quite a few questions starting with the specific choice of auxiliary parameters in the aggregation and ending with the interpretation of the resulting solution.

In contrast, multi-criteria modeling and optimization assume that every objective function should be optimized individually. The contradictory nature of the given

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objective functions inevitably leads to tradeoff situations. This may be dealt with in several ways depending on whether and when preferences of the decision maker are available. The common underlying idea of all multi-criteria approaches is that they do not aggregate lightly, but address this trade-off more or less explicitly and in detail. Often, ordering relations are determined and corresponding minimizers are searched, multiple and in a sense equally good solutions are computed, and the more complex decision making step, i.e., the choice of a finally preferred solutions among a set of alternatives, has to be supported. In total, multi-criteria modeling and optimization is more demanding but it offers insights into the structure of the problem at hand, it quantifies tradeoffs, it informs the decision maker about options and their consequences, and, as a result, it has the big potential to lead to better solutions.

Multi-criteria modeling and optimization is a well-established subfield of mathematical optimization and operations research. In short, it encompasses the set of all concepts, theoretical results, and methods necessary to mathematically represent and deal with such conflicting decision processes in the context of optimization problems. Besides being an inspiring theoretical research area, multi-criteria optimization has proved to facilitate decision-making situations allowing reliable and provably good decisions. Since substantial advances in terms of theory have been made and since computational capabilities developed significantly in the last decades, more and more models indeed reflect the multi-criteria nature of real-world applications.

This special issue aims at presenting original and innovative pieces of research in multi-criteria optimization which combine both, a sound theoretical work and a practical impact in some real-world applications. All articles were carefully peer-reviewed and the acceptance rate was 9%. In the review process, it was important to us, that each article contains a significant contribution in terms of theory *and* application. In each article of this special issue, the problem under consideration is inherently multicriteria and triggered a theoretical development which then caused a boost in terms of the application. In particular, this special issue addresses the following topics.

In the article "The Bi-objective Multimodal Car-Sharing Problem", Miriam Enzi, Sophie N. Parragh and Jakob Puchinger introduce different formulations of a car sharing problem, where the task is to assign modes of transport to trips, cars and user routes. A group of users uses a pool of cars and the two objectives considered are minimizing cost and maximizing user satisfaction. The authors have a user-centered point of view including user preferences. They propose a branch-and-cut algorithm, conduct numerical experiments and analyze findings paying attention, for example, to computational efficiency.

In the article "Multi-criteria Asset Allocation in Practice," authors Kerstin Dächert, Ria Grindel, Elisabeth Leoff, Jonas Mahnkopp, Florian Schirra and Jörg Wenzel study strategic asset allocation in an insurance company. The model includes the traditional Markowitz objectives associated with return and risk. The third objective function captures the solvency of the portfolio. The fourth objective function measures how different the portfolio is from the current one. Finding all non-dominated solutions of a multiobjective optimization model with four objective functions is a challenge and the authors resort to finding a diverse set of representative solutions that can be depicted visually so that a most preferred allocation scenario can be identified. The authors report that the decision support tool that is built is in use in the client insurance company.

In the article “Bin Packing with Lexicographic Objectives for Loading Weight- and Volume-Constrained Trucks in a Direct-Shipping System,” authors Katrin Heßler, Stefan Irnich, Tobias Kreiter and Ulrich Pferschy focus on the problem of packing trucks in the food and beverage industry where trucks are constrained by weight and volume. Five objective functions are defined and handled lexicographically. In addition to an exact branch-and-price approach that is reported to be quite successful, several heuristic approaches are proposed. These are examined in a detailed experimental setting and valuable insights are drawn. The authors report that the heuristic framework has been coded into the ERP system of the industrial partner and is in use for daily planning of shipments.

The article “A Branch-and Benders-cut Algorithm for a Bi-objective Stochastic Facility Location Problem” by Sophie N. Parragh, Fabien Tricoire and Walter Gutjahr, addresses a public facility location problem in context of disaster relief. Cost and uncovered demand are the objectives under discussion. For the demand only a probability distribution is known, which serves as a basis for scenario analysis. The underlying optimization problem is solved by use of Benders’ type decomposition. Different cutting schemes are used to compute lower bound sets for comparison with branch-and-bound implementations.

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