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## Article

# Introduction to the special issue on combining optimization and machine learning: Application in vehicle routing, network design and crew scheduling

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## Introduction to the special issue on combining optimization and machine learning: Application in vehicle routing, network design and crew scheduling



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Several families of core problems in transportation and logistics such as vehicle routing, facility location, and crew scheduling remain formidably challenging to solve for the operations research community and, for most of them, efficient algorithms are still sought after by the industry. One recent research trend explores the possibility of combining optimization and machine learning in innovative ways to provide more accurate models and design improved algorithms. Machine learning and optimization can be applied sequentially or in an integrated fashion. In the former case, machine learning can be used, for example, to estimate some problem input for the optimization model, to preprocess data with the goal of reducing the size of the model to solve, or to describe customer behavior and preferences. In the latter case, machine learning can be applied, for example, to adjust the values of some of the parameters controlling the optimization algorithm or to make heuristic decisions within the algorithm to increase its efficiency.

This special issue focuses on the development of data-driven optimization models and innovative solution methods that combine machine learning and optimization to efficiently solve transportation and logistics problems. It consists of four papers that have been submitted following an open call for papers, and accepted after a rigorous peer review process. These original contributions highlight different ways of integrating machine learning techniques and optimization for different applications.

Gimra, Gendreau, Lodi and Potvin study the problem of travel time prediction in a urban context where travel speed variations result from recurrent patterns, like traffic congestion, and non-recurrent patterns like accidents, construction, emergencies, special events and bad weather. Accurate travel time predictions are of foremost importance for efficient planning of delivery routes in freight transportation as well as for optimizing mobility services. The paper focuses on the prediction of travel speeds using as input GPS traces of commercial vehicles collected over a significant period of time. The authors propose an algorithmic

framework which makes use of different machine learning and data mining methods.

Yaakoubi, Soumis, and Lacoste-Julien tackle the airline crew pairing problem that consists of determining least-cost crew pairings (sequences of flights starting and ending at the same crew base) which will later be assigned to individual crew members in the rostering phase. This problem is solved by a column-generation-based dynamic constraint aggregation algorithm which requires good initial clusters of flights that have a high probability to be flown consecutively in the same crew pairing. To build initial clusters, the authors develop different heuristics that exploit flight connection probabilities which are computed using a machine learning algorithm.

Beulen, Scherp, and Santos address the problem of accepting or rejecting flight requests from crew members before solving the crew rostering problem that will determine the schedules of the individual crew members. These requests arrive dynamically and must be answered in a relatively short time span. To evaluate these requests, the authors use a neural network algorithm that is embedded, together with a column generation algorithm, in a dynamic rostering framework.

Lodi, Mossina and Rachelson explore how combinatorial optimization and machine learning can be integrated in the context of a decision problem where some of the input data are subject to variations. Assuming that many problem instances and their corresponding optimal solutions are known, they introduce a classifier to determine whether the solution to a reference instance is applicable or not to a perturbed instance, as well as a regressor to estimate the magnitude of the required changes to make the solution applicable. This information is then embedded in the optimization problem in the form of an additional constraint. The methodology is applied to a core problem in network design: the classical facility location problem.

This special issue is an initiative of two regular members and one

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regular collaborator of the GERAD to highlight the 40th anniversary of this renowned research center. The GERAD gathers more than 90 professors and 450 graduate students/post-doctoral fellows who pursue research in mathematics for decision-making, operations research and data science, to be applied in various fields such as transportation, energy, finance, and engineering to name just a few. This special issue in an international journal on transportation and logistics illustrates the interest of some GERAD researchers (who co-wrote three of the four papers). It is part of a series of other special issues co-edited by GERAD members that will appear, more or less at the same time, in journals

dedicated to other research areas.

We would like to thank the former Editor-in-Chief Michel Bierlaire for accepting our special issue proposal and the current Editor-in-Chief Dominique Feillet for supervising its completion. We are also very grateful to the contributing authors and the anonymous reviewers who ensured that the standards of the Journal were maintained.

#### **Declaration of competing interest**

We have no conflict of interest.