Preface

Scheduled transportation networks give rise to very complex and large-scale network optimization problems requiring innovative solution techniques and ideas from mathematical optimization and theoretical computer science. Examples of scheduled transportation include bus, ferry, airline, and railway networks, with the latter being a prime application domain that provides a fair amount of the most complex and largest instances of such optimization problems. Scheduled transport optimization deals with planning and scheduling problems over several time horizons, and quite some progress has been made for strategic planning and scheduling problems in all transportation domains.

In this volume, we focus on two important facets of scheduled transportation planning that pose even harder optimization questions: robust planning and online (real-time) planning. These two, tightly coupled, facets constitute a proactive and a reactive approach, respectively, to deal with disruptions to the normal operation. Robust planning is concerned with the development of an a priori plan that allows the absorption of disruptions to the best possible extent. Online planning is concerned with real-time decision making when, typically unpredictable, disruptions in daily operations occur, and before the entire sequence of disruptions is known. Since railway systems provide the largest, most complex and hence most challenging problems, we have put a special emphasis in this volume on robust and online railway optimization.

The papers appearing in the volume have been selected after an open call for contributions asking for either research papers or state-of-the-art survey articles. We received 24 submissions that underwent two rounds of the standard peer-review process, out of which 18 were finally accepted for publication.

The selected papers cover several aspects of robust and online large-scale optimization. With respect to the former, they cover issues of robust timetabling and route planning, as well as robust planning under scarce resources. With respect to the latter, they cover issues of delay and disruption management. Moreover, a fair amount of papers introduce new concepts of robustness and recoverability (to the normal operation) that turn out to be particularly useful when dealing with problems in railway optimization. The volume is organized in four parts reflecting the above areas.

The first part, Robustness and Recoverability: New Concepts, consists of five papers that introduce new concepts of robustness and recoverability and exemplify their usefulness on various applications. More specifically:

- In The Concept of Recoverable Robustness, Linear Programming Recovery, and Railway Applications, Christian Liebchen, Marco Lübbecke, Rolf Möhring, and Sebastian Stiller introduce a new concept of robustness that does not only help to achieve robust plans but also allows recovery to a feasible solution under certain circumstances. The new concept is exemplified in the
railway optimization problems of delay resistant, periodic and aperiodic timetabling, and train platforming.

- In *Recoverable Robustness in Shunting and Timetabling*, Serafino Cicerone, Gianlorenzo D’Angelo, Gabriele Di Stefano, Daniele Frigioni, Alfredo Navarra, Michael Schachtebeck, and Anita Schöbel apply the concept of recoverable robustness to the shunting problem and also extend the concept to situations where multiple stages of recovery are required.

- In *Light Robustness*, Matteo Fischetti and Michele Monaci introduce the concept of light robustness, which couples robust optimization with a simplified two-stage stochastic programming approach, and constitutes a flexible counterpart of (classical) robust models.

- In *Incentive-Compatible Robust Line Planning*, Apostolos Bessas, Spyros Kontogiannis, and Christos Zaroliagis introduce the concept of incentive-compatible robustness and demonstrate its application on robust line planning when several competing operators demand line frequencies over a transportation network.

- In *A Bicriteria Approach for Robust Timetabling*, Anita Schöbel and Albrecht Kratz introduce a bicriteria approach for studying the trade-off between an optimal and a robust solution, by adding the robustness of the problem’s solution as an additional objective function. They demonstrate their approach on the aperiodic timetabling problem in which a timetable is sought that is robust against delays.

The second part, *Robust Timetabling and Route Planning*, consists of five papers that present new approaches for robust timetabling, route planning, route re-planning, and timetable information updating in case of delays. More specifically:

- In *Meta-Heuristic and Constraint-Based Approaches for Single-Line Railway Timetabling*, Federico Barber, Laura Ingolotti, Antonio Lova, Pilar Tormos, and Miguel A. Salido study the single-line railway timetabling problem (which is NP-hard) under several heuristic approaches, which are based on constraint techniques (distributed constraint satisfaction and topological constraint optimization) and on meta-heuristic techniques (GRASP-based variable ordering and genetic algorithms).

- In *Engineering Time-Expanded Graphs for Faster Timetable Information*, Daniel Delling, Thomas Pajor, and Dorothea Wagner present an extension of the time-expanded model for computing timetable information that results in faster query times using less space than the original one. They also show how known query speed-up techniques can be adapted to the extended model in order to gain further performance speed-up.

- In *Time-Dependent Route Planning*, Daniel Delling and Dorothea Wagner survey query speed-up techniques for route planning under the time-dependent model, and identify the most important ingredients along with their augmentations that make some techniques superior to others.

- In *The Exact Subgraph Recoverable Robust Shortest Path Problem*, Christina Büsing presents approximate approaches for route re-planning on a small
subnetwork when delays occur, and demonstrates that the achieved approximation ratio is the best possible.

– In Efficient Timetable Information in the Presence of Delays, Matthias Müller-Hannemann and Mathias Schnee present an efficient method for updating timetable information when a stream of delay information and schedule changes arise, and demonstrate its applicability on a real-world scenario.

The third part, Robust Planning Under Scarce Resources, consists of four papers that deal with several problems that demand scarce resources. More specifically:

– In Integrating Robust Network Design and Line Planning Under Failures, Angel Marin, Juan A. Mesa, and Federico Perea present a heuristic approach for robust network design and line planning that integrates these two phases, and consider two new notions for measuring robustness.

– In Effective Allocation of Fleet Frequencies by Reducing Intermediate Stops and Short Turning in Transit Systems, Juan A. Mesa, Francisco A. Ortega, and Miguel A. Pozo develop an effective model for allocating rolling-stock frequencies at stops along a line, and develop a heuristic approach for its solution.

– In Shunting for Dummies: An Introductory Survey with an Algorithmic Focus, Michael Gatto, Jens Maue, Matus Mihalak, and Peter Widmayer survey several commonly used as well as new train classification (or shunting) methods from an algorithmic perspective.

– In Integrated Gate and Bus Assignment at Amsterdam Airport Schiphol, Guido Diepen, Marjan van den Akker, and Han Hoogeveen present a column generation approach for achieving a robust model that integrates the phases of gate and bus assignment at an airport, and show that it is acceptable in practice.

The fourth part, Online Planning: Delay and Disruption Management, consists of four papers that deal with several aspects of delay and disruption management including detection of delay dependencies and conflict resolution among complex train routes. More specifically:

– In Mining Railway Delay Dependencies in Large-Scale Real-World Delay Data, Holger Flier, Rati Gelashvili, Thomas Graffagnino, and Marc Nunkesser present efficient algorithms to detect important types of systematic delay dependencies (that are one of the main sources of delay propagation), and demonstrate their practical applicability on real-world data.

– In Rescheduling Dense Train Traffic over Complex Station Interlocking Areas, Francesco Corman, Rob M.P. Goverde, and Andrea D’Ariano present two graph-theoretic approaches for modeling multiple conflicting train routes in busy stations along with their solution methods and their experimental comparison.

– In Online Train Disposition: To Wait or not to Wait?, Luzi Anderegg, Paolo Penna, and Peter Widmayer present deterministic polynomial-time optimal
algorithms and matching lower bounds for several variants of an online delay management problem, where the delay is unknown and the vehicle can only wait in a station so as to minimize the passengers waiting time.

– In Disruption Management in Passenger Railway Transportation, J. Jespersen-Groth, D. Potthoff, J. Clausen, D. Huisman, L. Kroon, G. Maroti, and M.N. Nielsen give a comprehensive description of the problems arising in railway disruption management (timetable adjustment, rolling stock and crew rescheduling) along with the actors involved, and also describe the challenges confronted by railway companies in order to improve their operational performance.

Overall, the volume comprises a blend of state-of-the-art surveys and original research contributions. It is addressed to students, researchers, and practitioners who are interested in robust and online optimization of large-scale systems. We hope that they will find it useful.

We would like to thank all those who submitted papers for consideration, as well as the referees for their invaluable contribution. We also thank Apostolos Bessas for helping with several technical issues during the whole process of this volume production.

We gracefully acknowledge the support of the Future and Emerging Technologies Unit of the European Commission, under contract no. FP6-021235-2 (FP6 IST/FET Open/Project ARRIVAL). The ARRIVAL project not only supported part of the work presented in this volume, but most importantly it provided the means to stimulate a new line of research on robust and online railway optimization and also to create a critical mass of researchers, who are now able to deal with challenging problems in this area.

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