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Algorithmic Methods for Railway Optimization

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Preface

Algorithmic methods have reached a state of maturity as a consequence of decades of research. Despite its success, the current state of algorithmic research still faces severe difficulties, or cannot cope at all, with highly complex and data intensive real-world applications in large-scale networks. A prominent example is given by *railway networks*, which are used to model the complex systems of railway transportation. The complexity and size of optimization problems arising in railway transportation still pose challenges for algorithmic research.

This volume deals with problems arising in *railway optimization*, i.e., with planning and scheduling problems over several time horizons. Different challenging problems from the railway world are discussed from the point of view of computer science, algorithms, operations research, and discrete mathematics.

The first part of the volume consists of state-of-the-art papers that were selected after an open call that followed a Dagstuhl Seminar on *Algorithmic Methods for Railway Optimization* in June 2004. We had 12 submissions that underwent the standard peer review process, out of which 8 were selected for publication in this volume.

The second part consists of the nine accepted papers in the 4th Workshop on Algorithmic Methods and Models for Optimization of Railways (ATMOS 2004) that took place in Bergen, Norway, September 2004. The series of ATMOS workshops constitute a forum to present and discuss models, algorithms, and results related to railway optimization problems. ATMOS addresses researchers and practitioners working in computer science, discrete optimization, algorithms, or operations research. The ATMOS contributions come from all these fields and reflect the interdisciplinary character of railway optimization.

Within both parts we ordered the papers according to the hierarchical planning process in railway companies, which is roughly divided into the following four groups:

Network and Line Planning. This concerns the construction of the physical network (tracks and stations), the planning of the train lines along with their frequencies, and the design of the tariff system with the prices for the passengers.

Timetabling and Timetable Information. This concerns the construction of timetables, including scheduling and re-scheduling aspects, as well as timetable information systems.

Rolling Stock and Crew Scheduling. This concerns the scheduling of rolling stock and personnel to trains in order to carry out the train schedules in the timetable.

Real-Time Operations. This concerns the online reaction in the case of unexpected disruptions or delays. The delay management problem and its online version is a central issue, along with the improvement of dispatching systems.

Part I starts with three papers concerning the second group (Timetabling and Timetable Information). More specifically:

- In *"The Modeling Power of the PESP: Railway Timetables and Beyond,"* Christian Liebchen and Rolf H. Möhring show how various phases of the railway planning process can be integrated with periodic timetabling in order to achieve an additional optimization potential.
- In *"Cyclic Railway Timetabling: A Stochastic Optimization Approach,"* Leo Kroon, Rommert Dekker, and Michiel Vromans present a stochastic optimization model that can be used to find an optimal allocation of the running time supplements of a number of trains on a common infrastructure in order to minimize the average delays of these trains.
- In *"Timetable Information: Models and Algorithms,"* Matthias Müller-Hannemann, Frank Schulz, Dorothea Wagner, and Christos Zaroliagis give an overview of models and efficient algorithms for optimally solving timetable information problems under single or multiple criteria.

The next three papers concern the third group (Rolling Stock and Crew Scheduling). More specifically:

- In *"Estimates on Rolling Stock and Crew in DSB S-tog Based on Timetables,"* Michael Folkmann, Julie Jespersen, and Morten N. Nielsen describe two models for estimating the requested amount of rolling stock and crew required for operating a given timetable.
- In *"A Capacity Test for Shunting Movements,"* John van den Broek and Leo Kroon describe a capacity test for checking at an early stage of the planning process, whether the capacity of the infrastructure between the platform tracks and the shunting areas is sufficient for facilitating all the shunting movements that have to be planned in between the already timetabled train movements.
- In *"Railway Crew Pairing Optimization,"* Lennart Bengtsson, Rastislav Galia, Tomas Gustafsson, Curt Hjorring, and Niklas Kohl investigate the crew pairing problem that arises at major railways. Even though it is similar to the well-studied airline crew pairing problem, the size and complexity of the railway operation necessitate tailored optimization techniques.

The final two papers concern the fourth group (Real-Time Operations). More specifically:

- In *"Integer Programming Approaches for Solving the Delay Management Problem,"* Anita Schöbel presents path-based and activity-based integer programming models for the delay management problem and shows the equivalence of these formulations, and how to solve them in special cases.
- In *"Decision Support Tools for Customer-Oriented Dispatching,"* Claus Biederbick and Leena Suhl present decision support tools to be used by dispatchers in order to achieve customer orientation.

Part II starts with two papers in the first group (Network and Line Planning). More specifically:

- In *"An Integrated Methodology for the Rapid Transit Network Design,"* Gilbert Laporte, Ángel Marín, Juan A. Mesa, and Francisco A. Ortego present a new model for designing a line concept which is able to compete with private transportation systems.
- In *"A Simulation Approach for Fare Integration,"* Domenico Gattuso and Giuseppe Musolino deal with the problem of tariff planning and show their results within a case study in the region of Calabria.

The next four papers concern the second group (Timetabling and Timetable Information). More specifically:

- In *"Intelligent Train Scheduling on a High-Loaded Railway Network,"* Antonio Lova, Pilar Tormos, Federico Barber, Laura Ingolotti, Miguel A. Salido, and Montserrat Abril present an interactive application to assist planners when adding new trains on a complex railway network.
- In *"Platform Assignment,"* Sabine Cornelsen and Gabriele Di Stefano suggest an approach which is able to assign platforms to trains in such a way that a conflict-free realization of the timetable is possible, assuming a fixed timetable.
- In *"Finding All Attractive Train Connections by Multi-Criteria Pareto Search,"* Matthias Müller-Hannemann and Mathias Schnee discuss algorithms for timetable information systems that are able to find reasonable routes under various objectives.
- In *"The Railway Traveling Salesman Problem,"* Georgia Hadjicharalambous, Petrica Pop, Evangelia Pyrga, George Tsaggouris, and Christos Zaroliagis present a direct integer programming approach, based on timetable information, in order to find a tour through a railway system minimizing the overall time of the journey.

The next paper concerns the third group (Rolling Stock and Crew Scheduling). More specifically:

- In *"Rotation Planning of Locomotive and Carriage Groups with Shared Capacities,"* Taïeb Mellouli and Leena Suhl present a multi-layer multi-commodity network flow model which is able to handle various complex restrictions with respect to the planning of the circulation of locomotive and carriage groups.

The final two papers concern the fourth group (Real-Time Operations). More specifically:

- In *"An Estimate of the Punctuality Benefits of Automatic Operational Scheduling,"* Rien Gouweloos and Maarten Bartholomeus investigate the stability of railway systems and show the effects that suboptimal re-sequencing decisions have on the punctuality of the system.

– In *"Online Delay Management on a Single Train Line,"* Michael Gatto, Riko Jacob, Leon Peeters, and Peter Widmayer present a first theoretical investigation of online delay management problems and show that the special case of online delay management on a line is an extension of the ski-rental problem.

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