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Ravindra K. Ahuja   Rolf H. Möhring
Christos D. Zaroliagis (Eds.)

Robust and Online Large-Scale Optimization

Models and Techniques for Transportation Systems

Springer

Volume Editors

Ravindra K. Ahuja
University of Florida, Department of Industrial & Systems Engineering
303 Weil Hall, Gainesville, FL 32611-6595, USA
E-mail: ahuja@ufl.edu

Rolf H. Möhring
Technische Universität Berlin, Institut für Mathematik
Straße des 17. Juni 136, 10623 Berlin, Germany
E-mail: Rolf.Moehring@TU-Berlin.de

Christos D. Zaroliagis
University of Patras, Department of Computer Engineering & Informatics
26500 Patras, Greece
E-mail: zaro@ceid.upatras.gr

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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 Schöebel 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 Singe-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.

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July 2009

Ravindra K. Ahuja
Rolf H. Möhring
Christos D. Zaroliagis

List of Contributors

Luzi Anderegg
Institute of Theoretical
Computer Science
ETH Zürich
Switzerland
`anderegg@inf.ethz.ch`

Federico Barber
Instituto de Automática
e Informática Industrial
Universidad Politécnica de Valencia
Spain
`fbarber@dsic.upv.es`

Apostolos Bessas
Department of Computer Engineering
and Informatics
University of Patras
26500 Patras
Greece
and
R.A. Computer Technology Institute
N. Kazantzaki Str.
Patras University Campus
26504 Patras
Greece
`mpessas@ceid.upatras.gr`

Christina Büsing
Institut für Mathematik
Technische Univeristät Berlin
Strasse des 17 Juni 136
10623 Berlin
Germany
`cbuesing@math.tu-berlin.de`

Serafino Cicerone
Department of Electrical
and Information Engineering
University of L'Aquila
Italy
`serafino.cicerone@univaq.it`

Jens Clausen
DSB S-tog, Denmark
and
Department of Informatics
and Mathematical Modelling
Technical University of Denmark
2800 Kongens Lyngby
Denmark
`jencl@man.dtu.dk`

Francesco Corman
Transport & Planning Department
Delft University of Technology
Stevinweg 1
2628 CN Delft
The Netherlands
`f.corman@tudelft.nl`

Gianlorenzo D'Angelo
Department of Electrical
and Information Engineering
University of L'Aquila
Italy
`gianlorenzo.dangelo@univaq.it`

Andrea D'Ariano
Dipartimento di Informatica
e Automazione
Università degli Studi Roma Tre
via della Vasca Navale 79
00146 Rome
Italy
and
Transport & Planning Department
Delft University of Technology
Stevinweg 1, 2628 CN Delft
The Netherlands
`a.dariano@dia.uniroma3.it`

Daniel Delling
Department of Computer Science
University of Karlsruhe
P.O. Box 6980
76128 Karlsruhe
Germany
delling@ira.uka.de

Guido Diepen
Paragon Decision Technology
Schipholweg 1
2034 LS Haarlem
The Netherlands
Guido.Diepen@aimms.com

Gabriele Di Stefano
Department of Electrical
and Information Engineering
University of L'Aquila
Italy
gabriele.distefano@univaq.it

Matteo Fischetti
DEI, University of Padova,
Via Gradenigo 6/A
35131 Padova
Italy
matteo.fischetti@unipd.it

Holger Flier
Institute of Theoretical
Computer Science
ETH Zürich
Switzerland
holger.flier@inf.ethz.ch

Daniele Frigioni
Department of Electrical
and Information Engineering
University of L'Aquila
Italy
daniele.frigioni@univaq.it

Michael Gatto
Institute of Theoretical
Computer Science
ETH Zürich
Switzerland
michael.gatto@inf.ethz.ch

Rati Gelashvili
Tbilisi State University
Georgia
gelash@gmail.com

Rob M.P. Goverde
Transport & Planning Department
Delft University of Technology
Stevinweg 1
2628 CN Delft
The Netherlands
r.m.p.goverde@tudelft.nl

Thomas Graffagnino
SBB AG Bern
Infrastruktur/Trassenmanagement
Switzerland
thomas.graffagnino@sbb.ch

J.A. Hoogeveen
Department for Information
and Computing Sciences
Utrecht University
P.O. Box 80089
3508 TB Utrecht
The Netherlands
slam@cs.uu.nl

Dennis Huisman
Econometric Institute
Erasmus University Rotterdam
P.O. Box 1738,
3000 DR Rotterdam
The Netherlands
and
Erasmus Center for Optimization
in Public Transport (ECOPT)
and

Department of Logistics
Netherlands Railways
P.O. Box 2025,
3500 HA Utrecht
The Netherlands
huisman@ese.eur.nl

Laura Ingolotti
Instituto de Automática
e Informática Industrial
Universidad Politécnica de Valencia
Spain
lingolotti@dsic.upv.es

Julie Jespersen-Groth
DSB S-tog, Denmark
and
Department of Informatics
and Mathematical Modelling
Technical University of Denmark
2800 Kongens Lyngby
Denmark
jjespersen@s-tog.dsb.dk

Spyros Kontogiannis
Computer Science Department
University of Ioannina
45110 Ioannina
Greece
and
R.A. Computer Technology Institute
N. Kazantzaki Str.
Patras University Campus
26504 Patras
Greece
kontog@cs.uoi.gr

Albrecht Kratz
Institut für Numerische
und Angewandte Mathematik
Georg-August Universität Göttingen
Germany
Albrecht.Kratz@gmx.de

Leo Kroon
Rotterdam School of Management
Erasmus University Rotterdam
P.O. Box 1738,
3000 DR Rotterdam
The Netherlands
and
Erasmus Center for Optimization
in Public Transport (ECOPT)
and
Department of Logistics
Netherlands Railways
P.O. Box 2025,
3500 HA Utrecht
The Netherlands
LKroon@rsm.nl

Christian Liebchen
Institut für Mathematik
Technische Univeristät Berlin
Strasse des 17 Juni 136
10623 Berlin
Germany
liebchen@math.tu-berlin.de

Antonio Lova
Instituto de Automática
e Informática Industrial
Universidad Politécnica de Valencia
Spain
allova@eio.upv.es

Marco Lübbecke
Institut für Mathematik
Technische Univeristät Berlin
Strasse des 17 Juni 136
10623 Berlin
Germany
m.luebbecke@math.tu-berlin.de

Angel Marín
Department of Applied Mathematics
and Statistics
Madrid Polytechnic University
Spain
angel.marin@upm.es

Gábor Maróti
Rotterdam School of Management
Erasmus University Rotterdam
P.O. Box 1738
3000 DR Rotterdam
The Netherlands
and
Erasmus Center for Optimization
in Public Transport (ECOPT)
marotig@gmail.com

Jens Maue
Institute of Theoretical
Computer Science
ETH Zürich
Switzerland
jens.maue@inf.ethz.ch

Juan A. Mesa
Department of Applied Mathematics II
University of Seville
Spain
jmesa@us.es

Matúš Mihalák
Institute of Theoretical
Computer Science
ETH Zürich
Switzerland
matus.mihalak@inf.ethz.ch

Rolf Möhring
Institut für Mathematik
Technische Univeristät Berlin
Strasse des 17 Juni 136
10623 Berlin
Germany
Rolf.Moehring@TU-Berlin.DE

Michele Monaci
DEI, University of Padova,
Via Gradenigo 6/A
35131 Padova
Italy
michele.monaci@unipd.it

Matthias Müller–Hannemann
Martin-Luther-University Halle
Department of Computer Science
Von-Seckendorff-Platz 1
06120 Halle
Germany
muellerh@informatik.uni-halle.de

Alfredo Navarra
Department of Mathematics
and Computer Science
University of Perugia, Italy
navarra@dmi.unipg.it

Morten Nyhave Nielsen
DSB S-tog, Denmark
and
Department of Informatics
and Mathematical Modelling
Technical University of Denmark
2800 Kongens Lyngby
Denmark

Marc Nunkesser
Institute of Theoretical
Computer Science
ETH Zürich
Switzerland
marc.nunkesser@inf.ethz.ch

Francisco A. Ortega
Department of Applied Mathematics I
University of Seville
Spain
riejos@us.es

Thomas Pajor
Department of Computer Science
University of Karlsruhe
P.O. Box 6980
76128 Karlsruhe
Germany
pajor@ira.uka.de

Paolo Penna
Dipartimento di Informatica
ed Applicazioni
"R.M. Capocelli", Università di Salerno
via S. Allende 2
84081 Baronissi (SA)
Italy
penna@dia.unisa.it

Federico Perea
Department of Applied Mathematics II
University of Seville
Spain
perea@us.es

Daniel Potthoff
Econometric Institute
Erasmus University Rotterdam
P.O. Box 1738
3000 DR Rotterdam
The Netherlands
and
Erasmus Center for Optimization
in Public Transport (ECOPT)
potthoff@ese.eur.nl

Miguel A. Pozo
Department of Applied Mathematics I
University of Seville
Spain
miguelpozo@us.es

Miguel A. Salido
Instituto de Automática
e Informática Industrial
Universidad Politécnica de Valencia
Spain
msalido@dsic.upv.es

Michael Schachtebeck
Institut für Numerische
und Angewandte Mathematik
Georg-August Universität Göttingen
37083 Göttingen
Germany
schachte@math.uni-goettingen.de

Mathias Schnee
Darmstadt University of Technology
Department of Computer Science
Hochschulstraße 10
64289 Darmstadt
Germany
schnee@algo.informatik.
tu-darmstadt.de

Anita Schöbel
Institut für Numerische
und Angewandte Mathematik
Georg-August Universität Göttingen
37083 Göttingen
Germany
schoebel@math.uni-goettingen.de

Sebastian Stiller
Institut für Mathematik
Technische Univeristät Berlin
Strasse des 17 Juni 136
10623 Berlin
Germany
stiller@math.tu-berlin.de

Pilar Tormos
Instituto de Automática
e Informática Industrial
Universidad Politécnica de Valencia
Spain
ptormos@eio.upv.es

J.M. van den Akker
Department for Information
and Computing Sciences
Utrecht University
P.O. Box 80089
3508 TB Utrecht
The Netherlands
marjan@cs.uu.nl

Dorothea Wagner
Department of Computer Science
University of Karlsruhe
P.O. Box 6980
76128 Karlsruhe
Germany
wagner@ira.uka.de

Peter Widmayer
Institute of Theoretical
Computer Science
ETH Zürich
Switzerland
widmayer@inf.ethz.ch

Christos Zaroliagis
Department of Computer Engineering
and Informatics
University of Patras
26500 Patras
Greece
and
R.A. Computer Technology Institute
N. Kazantzaki Str.
Patras University Campus
26504 Patras
Greece
zaro@ceid.upatras.gr

Referees

Reinhard Bauer
Apostolos Bessas
Suat Bog
Amy Cohn
Gianlorenzo D'Angelo
Daniel Delling
Camil Demetrescu
Maged Dessouky
Gabriele Di Stefano
Matteo Fischetti
Holger Flier
Dimitris Fotakis
Daniele Frigioni
Michael Gatto
Kalliopi Giannakopoulou
Tobias Harks
Dennis Huisman
Spyros Kontogiannis
Leo Kroon
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Christian Liebchen
Marco Lübbecke
Matthias Müller-Hahnemann
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Ashish Nemani
Marco Pranzo
Evangelia Pyrga
Christina Puhl
Anita Schöbel
Sebastian Stiller
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