ÖGOR
Österreichische
Gesellschaft für
Operations Research
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GOR-AG
Praxis der
Mathematischen
Optimierung
Dr. Jens Schulz
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Herewith, we invite you to the joint meeting of ÖGOR and GOR working group “Practice of Mathematical Optimization” hosted by ÖBB (Österreichische Bundesbahnen) with the topic

Practice of Optimization in Transportation

The workshop will take place in Wien hosted by ÖBB on **September 28 & 29, Thursday and Friday, 2023**. The working language will be English to be inclusive for a non-German speaking audience. GOR members are warmly invited to attend also the meeting of ÖGOR, while all ÖGOR members are invited to attend the meeting of the GOR working group.

Note that the participation in our workshops for non-members of GOR or ÖGOR is subject to a slightly higher registration fee at the amount of an annual membership. Feel free to join either society.
Given the uncertainty of Covid, travel restrictions, and company policies, we strongly advise you to book your stay and travel accordingly. Cancellation of the on-site event may occur on short notice, and the organizers will waive the registration fee but will not refund any other cost.

Please, register no later than September 10 via https://www.redseat.de/pmo107-oegor

The latest information on the meeting is available on the homepage of GOR and of ÖGOR.

Yours sincerely,

Jens Schulz, Julia Kallrath, Josef Kallrath (GOR AG)

Ulrich Pferschy (ÖGOR)

Bertram Wassermann (ÖBB)

Practice of Optimization in Transportation

Specific aims

In this workshop we want to exchange knowledge about Operations Research methods to deal with practical applications in transportation. We will explore the challenges and opportunities in optimizing transportation networks to improve efficiency, reduce costs, and minimize environmental impact. The speakers will present and discuss cutting-edge research and practical applications of mathematical optimization techniques specifically tailored for transportation systems. The sessions will cover topics such as optimization models for transportation planning, routing and scheduling in logistics, fleet management and vehicle routing algorithms, multi-modal transportation optimization, traffic flow modeling and control as well as hybrid approaches and applications of machine learning and artificial intelligence in transportation optimization.

We want to foster collaboration and knowledge sharing among industry experts, researchers, and academics. We provide a platform for networking and exchanging ideas with fellow professionals and industry practitioners. Practical, computational and theoretical contributions from academia and industry are welcome to be submitted.

About ÖBB

The ÖBB-Personenverkehr sub-group of the Austrian Federal Railways (OBB) achieved EBT of EUR 185 million in 2022 based on a total income of EUR 2,727 million. Every day the ÖBB-Personenverkehr operates

- 40 night connections,
- more than 400 long-distance connections during the day and
- around 4000 local transport services.

In 2022, around 41,8 million travelers were transported in long distance trains (27,1 millions in domestic long distance trains and around 14,7 million internationally in long distance trains). To properly yield-manage ÖBBs savings offers Sparschiene more than 1.3 million control activities are processed systemically and manually every day. A team of 3 Operations Research specialists supports the yield management group to handle these activities by means of reporting, programming, and forecasting. Their main project for 2023 is to automatically forecast utilization rates for day trains in Austria.

The core of this 1.5 day workshop (Thursday and Friday morning) will consist of an attractive schedule of talks covering a broad range of mathematical techniques and real world applications. As usual, we will reserve plenty of time for informal exchange and networking. In talks of 15+5min, 25+5min or 40+5min duration, experts from practice and research will address problems and solutions.

If you would like to contribute a talk, please contact any of the organizers.

Jens Schulz (schulz-gor ‘at’ gmx.net)
Julia Kallrath (julia.kallrath ‘at’ h-da.de)

ÖGOR - Jahrestagung 2023

Agenda

The yearly **Meeting of ÖGOR** will take place in the afternoon of September 29, 2023. Confirmed invited speakers will be:

- Stefan Irnich (University of Mainz)
- Eranda Dragoti-Cela (Graz University of Technology)
- Elisabeth Zehendner (Österreichische Post AG)

Furthermore, there will presentations by the winners of the ÖGOR-Dissertation and Master-thesis prices sponsored by **scc EDV-Beratung AG**.
The detailed Schedule can be found further below.

For further information please contact Ulrich Pferschy (ulrich.pferschy@uni-graz.at)

Venue & accommodation

Venue

The meeting is hosted by ÖBB and takes place at “Skylobby”
Lassallestraße 5
1020 Wien; Austria

How to get there?
The venue is in walking distance from train station Praterstern.

Conference dinner

The conference dinner will take place on Thursday, 28.9, in Salmbräu; Rennweg 8, 1030 Wien, Austria. Participation is included in the registration fee. Still, please, indicate during registration whether you like to participate at the dinner.

Accommodation

Vienna offers a variety of hotels, pensions and b&b’s. Please, arrange your stay yourself. Bear in mind that due to external circumstances, the organizers may decide to cancel the event, or switch to an online format. We cannot refund any cost incurred. Please, arrange your bookings accordingly.
A hotel near Praterstern (workshop location) or main station (excursion and dinner), or else close to public transport line U1 may be beneficial.

Joint meeting of ÖGOR and GOR working group PMO at ÖBB

Practice of Optimization in Transportation

Thursday, September 28, 2023: 09:00 – 18:00

09:00-09:30 *Feel free to join, take a seat and have first chats*

09:30-10:00 **Opening and Welcome** (Ulrich Pferschy & Jens Schulz & Christoph Hinterleitner)

10:00-10:30 **Bertram Wassermann & Johannes Hofrichter (ÖBB)**
Operations Research at ÖBB

10:30-11:00 ---------- Coffee Break ----------

11:00-11:30 **Stefan Voß**
Robust Optimization for Vehicle Routing and Vehicle Scheduling with Uncertainty in the Number of Vehicles

11:30-12:00 **Alexander Bosse & Dirk Mattfeld**
Tactical Planning of a Flexible Transit Service

12:00-13:00 ---------- Lunch Break (Cafeteria) ----------

13:00-13:45 **Niels Lindner**
Recent Advances in Railway Timetable Optimization

13:45-14:30 **Dominik Leib**
A multicriteria approach to a multimodal transportation planning problem

14:30-15:00 ---------- coffee break ----------
---------- Taking a Group Photo for OR News, ÖGOR and Press ----------

15:00-15:30 **Kanchan Joshi & Jan Fabian Ehmke**
A bi-objective locomotive scheduling problem using time-space network formulations

16:00-19:00 ---------- Excursion by ÖBB ----------

19:00-21:00 **Conference Dinner**

Friday, September 29, 2023: 09:00 – 13:00

07:30-09:00	---------- Breakfast at hotels ----------
09:00-09:15	Welcome second day
09:15-10:00	**Martin Knoll & Sander van Aken** Developing an OR-based software product to support network planners at Flixbus
10:00-10:30	**Jakob Rosenberger, Matthias Rößler** Robustness proof for traction unit circulations and shift plans in an agent-based simulation model depicting the railway system in Austria
10:30-11:00	----------coffee break ----------
11:00-11:45	**Fatih Kocatürk** Energy Consumption Prediction Models for Locomotives Used in Railway Freight Transportation
12:00-13:00	---------- Lunch Break ----------
13:00-13:15	Welcome to **ÖGOR - Jahrestagung 2023** Ulrich Pferschy
13:15-14:00	**Stefan Irnich** (University of Mainz) New Models and Methods for Picker Routing and Order Batching
14:00-14:45	**Eranda Dragoti-Cela** (Graz University of Technology) A tour around optimization problems over permutations
14:45-15:15	----------coffee break ----------
15:15-16:00	**Elisabeth Zehendner** (Österreichische Post AG) How to forecast parcel quantities at node level in a distribution network
16:00-16:15	**Presentation of scc EDV-Beratung AG,** Sponsor of the 2023 ÖGOR-Prize
16:15-17:00	**Presentations by the winners of the 2023 ÖGOR Prize**
17:15-	Conclusion with a light buffet

Location: Skylobby
Lassallestraße 5
1020 Wien; Austria

Abstracts

Tactical Planning of a Flexible Transit Service
Alexander Bosse (a), Dirk Mattfeld (a), Mike Hewitt (b), Maximilian Merkert (a)
(a) TU Braunschweig, (b) Loyola University Chicago

Public transportation often suffers from a lack of flexibility. A possible solution for this is the use of flexible transit services, which are a combination of fixed-route and demand-responsive transit systems. While the individual systems focus on either mid- to long-term (tactical) planning or short-term (operational) planning for routing, a combined system must address both of these planning levels. In this work, we address the tactical planning of such system in the context of public transport. For this purpose, we propose a two-stage stochastic programming model to determine a cost-efficient fleet size and service patterns for the synchronization of both systems that can later be used as a base for operational planning.

A bi-objective locomotive scheduling problem using time-space network formulations
Kanchan Joshi & Jan Fabian Ehmke (Wien)

In this work, a crucial rolling stock planning problem, the locomotive scheduling problem is addressed. The locomotive scheduling problem aims to determine a sequence of trips and empty runs to be followed by each locomotive starting from and returning to the depot over the given planning horizon. A time-space network formulation provides information about the trip connections and the locomotive's availability status that allows to determine assignment and sequencing of a locomotive. Using the cyclic circulation plan restriction, we model a mixed integer linear program for two objective functions, namely, minimize the number of locomotives and minimize empty-run kilometres. We investigate the results for both single objective functions and weighted bi-objective function. We also consider variants including buffers to hedge against delays. The results provide insights to decision makers and planners managing the capital-intensive rolling stock. Finally, the model is tested on real-world Austrian railway use cases to evaluate its performance for different objective functions.

Energy Consumption Prediction Models for Locomotives Used in Railway Freight Transportation
Fatih Kocatürk, Gislind Stefan, Ninja Soeffker, Jan Fabian Ehmke

In railway transportation, there is a high potential of energy saving by means of optimizing train schedules, circulation plans or locomotive assignments with the objective of minimizing energy consumption. There are several approaches regarding the modelling of train energy consumption, but the deterministic approach based on Davis equation is the most common method. In its basic form, the Davis equation calculates the total resistance force required to keep the train moving at a constant speed by considering the mass and velocity of the train, and journal, flange, air resistances acting on the train. In this study, data-driven energy consumption models are proposed for each locomotive type by utilising multiple linear/polynomial regressions and predicting the resistance coefficients of Davis equation. The input data is generated using two different sources: i) The real distance and gradient data for each single track in railway infrastructure is extracted from the RINF database (European Union Agency for Railways), ii) Time schedules of trains and energy consumption of locomotives are provided by the Austrian Federal Railways (¨OBB). The performance of each model is compared to the actual energy consumption of each locomotive type in terms of the coefficient of determination and mean squared error accuracy metrics. The Davis

equations proposed in the literature with different resistance coefficient estimators are also compared to the proposed models. Finally, the provided energy consumption models are integrated into a real-world locomotive assignment optimization model.

A multicriteria approach to a multimodal transportation planning problem
Dominik Leib (Fraunhofer ITWM)

In the collaborative research project SynphOnie, founded by the Ministry of Education and Research, the aim is to balance passenger comfort, CO2 emissions and costs of a public multimodal transport system in a decision support framework for strategic and tactical infrastructure planning. These aspects to be balanced vary for the different modes of transport considered, e. g. metro, bus, ridesharing and private transport. Furthermore, they are typically in conflict with each other, which favors a multi-criteria approach. For this we have developed a multicriteria network design model that will be used to compute system-optimal solutions to the problem with pre-adjusted median parameters. The proposed design will then be worked out into a detailed transportation plan.

Recent Advances in Railway Timetable Optimization
Niels Lindner (ZIB / FU Berlin)

The timetable is the heart of a public transportation system. It does not only communicate the service to customers, but also has a large impact on the outcome of subsequent cost-sensitive planning steps, e.g., vehicle and crew scheduling. Moreover, it is often necessary to modify timetables to different extents due to planned construction sites, so that timetabling is a frequent and fundamental planning task. We will present several recent successes in railway timetabling:
* Many public transportation networks are operated in a periodic manner. It is therefore of interest to design and to optimize periodic timetables. The main mathematical model for this purpose is the Periodic Event Scheduling Problem (PESP). Although the problem is notoriously hard, there is a variety of primal heuristics available. We will outline tropical neighborhood search, a local heuristic based on the geometric properties of the space of the feasible timetables, which proved to be valuable for PESP benchmark instances.
* Although PESP is quite versatile, it has a limited capability of modeling safety distances, so that conflict-free timetables cannot be guaranteed. This can be resolved easily when dwelling times are rather short, but fails when trains occupy parts of the infrastructure for comparably long times, e.g., when turning. We show how to integrate conflict-freeness into PESP, and showcase this by means of a real-world application for construction sites on the S-Bahn Berlin network.
* Finally, we will discuss non-periodic microscopic railway timetabling in the context of moving block. To exploit the capacity increase by giving up traditional block sections, we present a mixed-integer programming model based on a velocity-expanded graph for railway track allocation and timetabling. On the Hanover-Minden corridor, together with a tailored branch-and-cut method, this approach demonstrated to be viable for up to 100 trains.

Robustness proof for traction unit circulations and shift plans in an agent-based simulation model depicting the railway system in Austria
Jakob Rosenberger, Matthias Rößler

The potential in train systems to achieve savings in terms of energy, material, working hours and much more through optimized traction unit circulation plans and driver shifts is giant. There are various optimization approaches capable of delivering good plans for this purpose. A decisive aspect as to whether a circulation plan or a shift plan can also be reasonably used in the real world is the effect on the overall system in the train network, i.e., if specific traction unit assignments to train services are very likely to cause a consequence of massive delays,

the corresponding circulation plan cannot be considered as robust. For this purpose, we developed an agent-based model to depict the railway system in Austria as well as a delay prediction model that was trained on historical delay data to stochastically introduce primary delays into the system. One of the goals of this work is to develop and calculate specific KPIs for the different aspects that are in the focus of the optimization objective for the generation of plans. Furthermore, circulation plans can be continuously improved in a feedback loop together with existing optimization models to achieve not only improvements in energy consumption and/or costs, but also in robustness.

Developing an OR-based software product to support network planners at Flixbus
Sander van Aken, Martin Knoll (Flix SE)

Flix is Europe's largest player in the long-distance bus transportation market, transporting tens of millions passengers in 41 different countries. Thorough network planning enables unlocking Flix's vision of providing smart, sustainable, and affordable travel for everyone. Our network planners create timetables, bus and driver schedules for lines in the European network running between 1 and 51 hours. They have to handle a high degree of complexity such as region- and bus partner-specific constraints and requests, different cost models etc. Although they can rely on a wide range of high-quality data sources and supporting tools, it remains a very manual and experience-based process.

Our team's mission is to provide data-driven solutions based on operations research algorithms enabling network planners to build customer-oriented and profitable networks. A first significant step towards that focuses on bus and driver scheduling. The product's core consists of a hybrid algorithm capable of generating solutions for cases of different levels of complexity. As such, network planners can unlock cost savings, and spend more of their time focusing on the timetable design. We will share our insights on what it took us to put OR in practice, and how we balance the iterative improvement of the product results and the extension of its scope.

Robust Optimization for Vehicle Routing and Vehicle Scheduling with Uncertainty in the Number of Vehicles
Stefan Voß, University of Hamburg; Liping Ge, Abtin Nourmohammadzadeh, Lin Xie

When emphasizing the Stochastic Vehicle Routing Problem (SVRP), among the issues receiving general attention in recent scientific literature on logistics and transportation are the topics of robustness and uncertainty. This becomes especially important in the context of disaster relief problems. In this context, we consider some open ties in public transport and vehicle routing for using robust optimization in an integrated way. The focus is on integrated vehicle and crew scheduling as well as the SVRP. Motivated by disaster relief issues or the use of electric buses, the number of available vehicles (e.g., depending on the battery, driving skills, temperature etc.) is uncertain and may be predicted using appropriate tools.
Robustness is included into given optimization models allowing to consider two types of uncertainty (i.e., uncertain input data being reflected in a given objective as well as uncertainty in the number of available vehicles reflected as parameter on the right-hand side of the model).
Problem issues, models and numerical results will be presented.

ÖGOR - Jahrestagung 2023:

New Models and Methods for Picker Routing and Order Batching
Stefan Irnich, University of Mainz

Warehouse activities include receiving, storing, picking, packing, and shipping operations. We address order picking, which is the process of retrieving inventory items from their storage locations in response to specific customer requests. More than 80 percent of all order-picking systems in Western Europe are manual (non-automated) low-level picker-to-parts picking systems, where pickers move through the warehouse in order to retrieve articles from the storage locations (picker-to-parts). In this context, the single picker routing problem (SPRP) is the basic routing problem and seeks for a minimum-length picker tour given the warehouse layout and the pick locations from where items must be collected. We show that the well-known dynamic-programming approach of Ratliff and Rosenthal can be extended and modified to model and solve NP-hard problems that have the SPRP as a subproblem. In particular, we consider warehouses with scattered storage and order batching problems as such hard optimization problems.

A tour around optimization problems over permutations
Eranda Dragoti-Çela, Graz University of Technology

Optimizing over permutations is a generic problem in combinatorial optimization. Some fundamental and prominent representatives are the linear or the quadratic assignment problem and the travelling salesman problem. From the point of view of the theoretical complexity most of these problems are challenging. In a tour along the borderline between hard and easy problems, we will point out to features of problems on both sides of the border and sketch some ideas on border-crossing heuristic solution approaches.

How to forecast parcel quantities at node level in a distribution network?
Elisabeth Zehendner, Österreichische Post AG

Logistics and postal service providers all around the world need to deliver never-seen-before amounts of parcels. Reliability comes from thorough network planning on all time horizons. For these planning activities, accurate forecasts and network planning tools are needed. We propose a three-stage forecasting framework for parcel distribution networks. It combines forecasting, routing rules, and simulation. Its output is the forecast of daily parcel quantities for all nodes in the distribution network. Another topic we address is how to measure and evaluate forecast quality at different aggregation levels. We demonstrate the applicability of our framework in a real-world environment.

CVs

Alexander Bosse studied Business Information Systems (Wirtschaftsinformatik) at the Technische Universität Braunschweig and graduated with a Master's degree in 2021. Since the end of 2021, he is a doctoral student and works as research assistant at the Decision Support Group of TU Braunschweig. His research is concerned with decision support using methods of operations research.

Kanchan Joshi received the Ph.D. degree from Indian Institute of Technology (IIT) Bombay, India, in 2014, with a focus on pre-emption and learning effects in resource constrained project scheduling. From 2014 to 2015, she was with Uhuru Corporation, Japan as a data scientist. She was a faculty member with National Institute of Industrial Engineering, India from 2015 to 2021, where she was involved in conducting consultancy as well as research assignments related to OR and teaching masters' students. From 2021 to 2022, she was a postdoctoral research fellow with University of Exeter, UK, where she was involved in developing model for offshore wind farm installation and operations & maintenance logistics planning. She is currently a postdoctoral researcher with Business Analytics research group of University of Vienna. Her current research interests include reliable and integrated planning and scheduling of circulations and shifts.

Martin Knoll and Sander van Aken are both Senior Operations Research Engineers at Flix SE, the umbrella brand of (a.o.) FlixBus and FlixTrain. The network planning optimization team develops and implements OR algorithms as part of software products for network planners. Martin had been working a couple of years on optimization-related topics in a different department before joining the team. Sander worked as an advanced analytics consultant in the public transportation industry on projects including simulation-, data science- and optimization-based analyses.

Fatih Kocatürk completed his PhD in Applied Mathematics and Statistics at Izmir University of Economics in 2022. Between 2012-2014, he participated as a fellow in the research project titled "Pharmacy duty scheduling problems" supported by the Scientific and Technological Research Council of Turkey (TÜBİTAK). Then, he worked for 2.5 years in another research project related to his PhD topic titled "Heuristic Approaches for Multi-depot Vehicle Routing Problems with Heterogeneous Fleet" funded by TÜBİTAK. Afterwards, he worked as a Software Development Specialist in an e-commerce company between 2016-2018. Then he worked as an R&D Specialist at Norm Fasteners, Türkiye for 4 years. Since November 2022, he has been working as a PostDoc Researcher at the University of Vienna for the project about environmental artificial intelligence-based planning of train operations.

Dominik Leib is mathematician at Fraunhofer ITWM, Department of Optimization, for almost 2 years. His research focuses on quantum computing projects and the BMBF transport planning project "SynphOnie". He is doing a PhD within the framework of SynphOnie with the aim of creating a theoretical basis for the problem under consideration.

Niels Lindner is a researcher at FU Berlin and leader of the MobilityLab at Zuse Institute Berlin since 2020. Before he was a researcher at Leibniz university Hannover from 2014 onwards. Then, he joined ZIB working group on Mathematics in Transportation and Logistics in 2017 in the department of network optimization.

Jakob Rosenberger is a researcher at dwh Gmbh and specialises in modelling & simulation of logistical systems, data science and the integration of simulation and optimization methods.

He finished his master thesis in technical mathematics at TU Vienna in 2021 about "Stochastische mikroskopische Simulationsmodelle zur Optimierung von Zielgrößen". He is part of the team that developed the simulation model currently used in different ÖBB projects.

Matthias Rößler is a researcher at dwh GmbH. His main focus is the development of simulation models in health care and logistics using different modellig methods. He studied technical mathematics at TU Vienna and finished his master thesis in 2012 where he wrote about "Modellkopplung thermodynamischer Systeme". He is currently working on his PhD thesis, where he researches model order reduction and meta-modeling techniques for microscopic models. He is part of the team that developed the simulation model currently used in different ÖBB projects.

Stefan Voß is professor and director of the Institute of Information Systems at the University of Hamburg. Moreover, he served as dean of the Hamburg Business School until the end of 2022. His current research interests are in quantitative / information systems approaches to supply chain management and logistics including public mass transit and telecommunications. The most recent Wirtschaftswoche rankings list him among the top 10 professors in business administration. Stefan Voß serves on the editorial board of some journals including being Editor of Public Transport.

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Stefan Irnich is a full professor in logistics management at the Gutenberg School of Management and Economics, Johannes Gutenberg University Mainz, Germany. His research interests include the development and application of optimization methods to solve problems in logistics and transportation, network design, and algorithmic graph theory. In particular, his research focuses on mathematical programming decomposition methods and also on modeling and solving rich vehicle-routing problems.

Eranda Dragoti-Çela is an associated professor at the Department of Discrete Mathematics at the TU Graz. She holds a Master's Degree from the University of Tirana and a PhD from the Graz University of Technology. Her main research interests lie in the area of combinatorial optimization and optimization problems in graphs. In particular, she works on the identification and characterization of combinatorial properties which give rise to tractable special cases of NP-hard problems. Other research topics include mathematical models in portfiolio optimization and models of optimization uncer uncertainty.

Elisabeth Zehendner works at the Österreichische Post AG where she currently tackles questions about forecasting and network optimization at the tactical and strategic level. The objective of her team is to provide tools and data to support operational units with their planning activities and to evaluate scenarios for network design. During her prior job-experience in academia and consulting in Germany, France, and Austria, she acquired knowledge in logistics, computer science, combinatorial optimization, and project management.