Technical Program

International Conference on Operations Research 2026

~Converging Streams in Decision Making~

UNIVERSITÄT PASSAU

GOR

Contents

Contact

info@or2026.de

Website

https://or2026.de/

Impressum

V.i.S.d.P. Prof. Dr. Marc Goerigk
Unversität Passau
Wirtschaftswissenschaftliche Fakultät
Lehrstuhl für Business Decisions and Data Science
Dr.-Hans-Kapfinger-Str. 30
94032 Passau

Scientific Program Overview

Tuesday **September 1, 2026**	**Wednesday** **September 2, 2026**
	8:30–9:00 Opening
	9:00–10:00 Plenary Talk *Dick den Hertog*
9:30–11:00 Dokt!OR Workshop *Christina Büsing*	10:00–10:30 Coffee Break
	10:30–12:00 Parallel Sessions, GOR Master Thesis Award Talks
11:15–12:15 Dokt!OR Workshop *Clemens Thielen*	
12:15–13:15 Lunch Break	12:00–13:15 Lunch Break
13:15–14:30 Workshop *Hexaly* - - - - - - - - - - - - - - - 13:30–14:30 Dokt!OR Tutorial *Kevin Tierney*	13:15–14:45 Parallel Sessions, GOR PhD Award Talks
14:45–16:00 Workshop *Gurobi* - - - - - - - - - - - - - - - Dokt!OR Master Class *Dick den Hertog*	15:00–16:00 Semi-Plenary Talks *M. Bichler, M. Bodur, S. Pokutta,* *R. Luce (Gurobi)*
16:00–16:30 Coffee Break	16:00–16:30 Coffee Break
16:30–18:00 Dokt!OR Panel Discussion	16:30–18:00 Parallel Sessions, GOR Young Researchers Award Talks

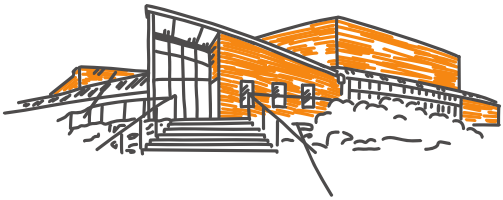
Thursday **September 3, 2026**	**Friday** **September 4, 2026**
8:30–10:00 Parallel Sessions	8:30–10:00 Parallel Sessions
10:00–10:30 Coffee Break	10:00–10:30 Coffee Break
10:30–11:30 Plenary Talk *Phebe Vayanos*	10:30–11:30 Semi-Plenary Talks *G. Kauermann, M.-È. Rancourt, S. Szeider*
11:45–12:45 Parallel Sessions, GOR Company Award Talk, Experiences with DFG Funding	11:45–12:45 Plenary Talk *Ivana Ljubić*
12:45–14:00 Lunch Break	12:45–13:15 Closing
	13:15–14:00 Lunch Break
14:00–15:30 Parallel Sessions	
15:30–16:00 Coffee Break	
16:00–17:00 Semi-Plenary Talks *R. Sioshansi, F. Spieksma, S. Weltge, L. Blaise (Hexaly)*	
17:00–18:30 GOR Meeting	

Opening and Closing Sessions

Opening

Opening Ceremony

Wed 8:30–9:00 in AM, HS 10



Closing

Closing Session

Fri 12:45–13:15 in AM, HS 10

Streams

Overview

Stream	Day(s)	Number(s)	Room(s)
Building PHIL			
Decision Theory and Multi-criteria Decision Making	Wed	12	HS 2
Health Care Management	Thu, Fri	12	HS 2
Mobility, Transportation, and Traffic	Wed, Thu, Fri	02, 03, 13	HS 1, HS 3, HS 4
OR in Developing Countries	Wed	13	HS 4
Project Management and Scheduling	Thu, Fri	13	HS 4
Building WIWI			
Analytics, Data Science, and Forecasting	Wed	16	033
Artificial Intelligence, Machine Learning and Optimization	Wed, Thu, Fri	07, 09	029, HS 7
Continuous and Global Optimization	Wed, Thu	15	034
Discrete and Combinatorial Optimization	Wed, Thu, Fri	06, 07	HS 5, 029
Financial Management and Accounting	Wed	15	034
Optimization Under Uncertainty	Wed, Thu, Fri	10	HS 8
Pricing and Revenue Management	Thu	15	034
Simulation and Quantum Computing	Thu, Fri	16	033
Software for Operations Research	Wed, Thu, Fri	11	HS 6
Building AM			
Supply Chain Management and Production	Wed, Thu, Fri	01, 08	HS 10, HS 9
Building IM			
Energy and Sustainability	Wed, Thu, Fri	04, 05	HS 13, HS 11
Game Theory and Behavioral Management Science	Thu, Fri	14	HS 12
Technical Operations Research	Wed, Thu	14	HS 12

Parallel Sessions on Wednesday, September 2

Room	10:30–12:00	13:15–14:45	16:30–18:00
Analytics, Data Science, and Forecasting Stream Chairs: Thomas Setzer, Sven F. Crone, Ralph Grothmann			
WIWI 033	WB 16: Prescriptive Analytics	WC 16: Feature Representation and Investment Strategies	WE 16: Features and Architectures
Artificial Intelligence, Machine Learning and Optimization Stream Chairs: Marc Goerigk, Frauke Liers			
WIWI HS 7	WB 09: Routing and Scheduling 1	WC 09: Routing and Scheduling 2	WE 09: Where we are and where we go
Continuous and Global Optimization Stream Chairs: Stephan Bütikofer, Andrea Seidl, Tristan Gally, Johannes Thürauf			
WIWI 034			WE 15: Optimal Control Applications
Decision Theory and Multi-criteria Decision Making Stream Chairs: Kerstin Dächert-Pauly, Michael Stiglmayr			
PHIL HS 2	WB 12: Part I	WC 12: Part II	WE 12: Part III
Discrete and Combinatorial Optimization Stream Chairs: Marc Pfetsch, Arie Koster			
WIWI HS 5	WB 06: Bilevel Optimization 1	WC 06: Quadratic Optimization	WE 06: Graphs and Networks 1
WIWI 029	WB 07: Applications 1	WC 07: Applications 2	WE 07: Routing Problems
Energy and Sustainability Stream Chairs: Dominik Möst, Dogan Keles			
IM HS 13	WB 04: Offshore wind & transmission and generation investments	WC 04: CO2 capture, transport, use and storage	WE 04: Bridging the Granulatiry Gap
IM HS 11	WB 05: Energy storage operation and fleet planning	WC 05: OR for industrial symbiosis - the case of Greenlab in DK	WE 05: Energy communities and local flexibilties

Room	10:30–12:00	13:15–14:45	16:30–18:00
Financial Management and Accounting Stream Chairs: Michael Breitner, Elmar Lukas, Matthias Amen			
WIWI 034	WB 15: Accounting	WC 15: Finance	
Mobility, Transportation, and Traffic Stream Chairs: Natalia Kliewer, Maximilian Schiffer, Marie Schmidt, Ralf Borndörfer			
PHIL HS 1	WB 02: Vehicle Routing	WC 02: Transportation in Logistics	WE 02: Vehicle Routing and Inventory Routing
PHIL HS 3	WB 03: Challenges in Mobility, Transport, and Traffic	WC 03: Hub Location and Resource Acquisition	WE 03: Route and Tour Planning under uncertain Conditions
PHIL HS 4	WB 13: Scheduling and Fleet Balancing		
Optimization Under Uncertainty Stream Chairs: Steffen Rebennack, Christina Büsing			
WIWI HS 8	WB 10: (Approximate) Dynamic Programming	WC 10: Vehicle Routing Problem	WE 10: Chance-Constraints and Decision-Dependent Robust Optimization
OR in Developing Countries Stream Chairs: Gerhard Wilhelm Weber, Tristan Becker			
PHIL HS 4		WC 13: Part I	WE 13: Part II
Software for Operations Research Stream Chairs: Jens Schulz, Stefan Vigerske			
WIWI HS 6	WB 11: Latest and Greatest in Solvers	WC 11: Modern Algorithms and Frameworks	WE 11: Fast Feasible Solutions
Supply Chain Management and Production Stream Chairs: Martin Grunow, Justus Arne Schwarz			
AM HS 9	WB 08: Lot Sizing	WC 08: Designing Manufacturing Systems	WE 08: Master Planning
Technical Operations Research Stream Chairs: Ulf Lorenz, Lena Charlotte Altherr, Peter Pelz			
IM HS 12	WB 14: Part I	WC 14: Part II	

Parallel Sessions on Thursday, September 3

Room	8:30–10:00	11:45–12:45	14:00–15:30
Artificial Intelligence, Machine Learning and Optimization Stream Chairs: Marc Goerigk, Frauke Liers			
WIWI 029	TA 07: Explainability and Interpretability		TD 07: Learning Rewards
WIWI HS 7	TA 09: Reinforcement Learning	TC 09: Production and Inventory Planning	TD 09: Robust and Stochastic Optimization
Continuous and Global Optimization Stream Chairs: Stephan Bütikofer, Andrea Seidl, Tristan Gally, Johannes Thürauf			
WIWI 034	TA 15: Theory, Algorithms, and Applications		
Discrete and Combinatorial Optimization Stream Chairs: Marc Pfetsch, Arie Koster			
WIWI HS 5	TA 06: Integer Programming	TC 06: Fairness & Robustness	TD 06: Nonlinearities
WIWI 029		TC 07: Selection Problems	
Energy and Sustainability Stream Chairs: Dominik Möst, Dogan Keles			
IM HS 13	TA 04: Near optimal solutions and system design		TD 04: Energy investments, peak power & storage
IM HS 11	TA 05: Electricity market modelling and price forecasting	TC 05: Green hydrogen production and grids	TD 05: Electricity and heating networks
Game Theory and Behavioral Management Science Stream Chairs: Nicolas Fugger, Florian Sachs			
IM HS 12	TA 14: Decision-making and AI	TC 14: Auctions	TD 14: Behavioral Logistics
Health Care Management Stream Chairs: Jens O. Brunner, Katja Schimmelpfeng			
PHIL HS 2	TA 12: Transportation problems	TC 12: Care Access and Intervention Strategies	TD 12: Scheduling Problems

Room	8:30–10:00	11:45–12:45	14:00–15:30
Mobility, Transportation, and Traffic Stream Chairs: Natalia Kliewer, Maximilian Schiffer, Marie Schmidt, Ralf Borndörfer			
PHIL HS 1	TA 02: Electric Vehicles	TC 02: Network Design and Urban Planning	TD 02: Railway Network Capacity Planning
PHIL HS 3	TA 03: Data Analysis in Mobility and Transport	TC 03: Network Design	TD 03: Drones 2
Optimization Under Uncertainty Stream Chairs: Steffen Rebennack, Christina Büsing			
WIWI HS 8	TA 10: Robust Optimization Applications	TC 10: Approximations for Robust Optimization	TD 10: Learning and Sequential Decision Making
Pricing and Revenue Management Stream Chairs: Claudius Steinhardt, Robert Klein, Christiane Barz			
WIWI 034		TC 15: Competition and Cancellations	TD 15: Applications to Last-Mile Logistics & Mobility
Project Management and Scheduling Stream Chairs: Simon Emde, Florian Jaehn			
PHIL HS 4	TA 13: Models and Optimization	TC 13: Project Management and Performance Control	TD 13: Scheduling in Logistics
Simulation and Quantum Computing Stream Chairs: Maximilian Moll, Max Krüger			
WIWI 033	TA 16: Quantum Computing Applications for Complex Optimization Problems	TC 16: Quantum Algorithms for Complex Optimization Problems	TD 16: Modeling and Learning in Complex Systems
Software for Operations Research Stream Chairs: Jens Schulz, Stefan Vigerske			
WIWI HS 6	TA 11: Beyond Linearity		TD 11: Modern Modeling
Supply Chain Management and Production Stream Chairs: Martin Grunow, Justus Arne Schwarz			
AM HS 10	TA 01: Scheduling in the Service and Paper Industries		TD 01: Sustainable Supply Chains
AM HS 9	TA 08: Supply Chain Management	TC 08: Scheduling in Semiconductor Manufacturing	TD 08: Integrating Production and Transportation

Parallel Sessions on Friday, September 4

Room	8:30–10:00
Artificial Intelligence, Machine Learning and Optimization	
Stream Chairs: Marc Goerigk, Frauke Liers	
WIWI HS 7	FA 09: LLMs for Optimization
Discrete and Combinatorial Optimization	
Stream Chairs: Marc Pfetsch, Arie Koster	
WIWI HS 5	FA 06: Bilevel Optimization 2
WIWI 029	FA 07: Graphs and Networks 2
Energy and Sustainability	
Stream Chairs: Dominik Möst, Dogan Keles	
IM HS 13	FA 04: Hydrological and Hydropower Modelling
IM HS 11	FA 05: Power-to-X and alternative fuels
Game Theory and Behavioral Management Science	
Stream Chairs: Nicolas Fugger, Florian Sachs	
IM HS 12	FA 14: Strategic Resource Allocation
Health Care Management	
Stream Chairs: Jens O. Brunner, Katja Schimmelpfeng	
PHIL HS 2	FA 12: Data-driven Planning and Cyber Risk
Mobility, Transportation, and Traffic	
Stream Chairs: Natalia Kliewer, Maximilian Schiffer, Marie Schmidt, Ralf Borndörfer	
PHIL HS 1	FA 02: Parcel Logistics and Location Routing
PHIL HS 3	FA 03: Route Planning for Public Transport Services
Optimization Under Uncertainty	
Stream Chairs: Steffen Rebennack, Christina Büsing	
WIWI HS 8	FA 10: Regret Optimization and Hurwicz Criterion
Project Management and Scheduling	
Stream Chairs: Simon Emde, Florian Jaehn	
PHIL HS 4	FA 13: Scheduling in Manufacturing and Projects

Room	8:30–10:00
Simulation and Quantum Computing Stream Chairs: Maximilian Moll, Max Krüger	
WIWI 033	FA 16: Optimization Across Complex Hierarchies, Organizations, and Networks
Software for Operations Research Stream Chairs: Jens Schulz, Stefan Vigerske	
WIWI HS 6	FA 11: Modeling Ecosystem
Supply Chain Management and Production Stream Chairs: Martin Grunow, Justus Arne Schwarz	
AM HS 10	FA 01: Scheduling Additive Manufacturing Systems and Lean in the Flower Industry
AM HS 9	FA 08: Risks in Supply Chains

Pre-Conference Program (Tuesday)

PhD Program Dokt!OR

Christina Büsing

Workshop: *Giving Better Presentations*

Tue 9:30–11:00 in AM, HS 10

The workshop Giving Better Presentations introduces key principles of effective scientific communication. Through an Euler presentation, participants first experience a deliberately poor presentation and then a well-designed version of the same content, highlighting common pitfalls and best practices. The workshop covers techniques for creating a strong opening, maintaining audience attention, using slides effectively, and improving delivery through body language, interaction, and clear structure. Practical exercises and discussions provide participants with concrete tools to enhance their own presentation skills and communicate their ideas more effectively.

Clemens Thielen

Workshop: *Making an Impact*

Tue 11:15–12:15 in AM, HS 10

This workshop will explore how Operations Research can create impact in practice. It will focus on how OR models, analytical methods, and decision-support approaches can inform and improve real-world decisions, tools, and processes. Based on examples and experiences from applied research projects, the workshop will address factors that can enable or hinder practical impact, such as problem selection, stakeholder involvement, model realism, usability, trust, and communication. It will also consider the relation between scientific depth and practical relevance, and why technically strong research does not automatically lead to practical adoption. Interactive elements will help participants reflect on the practical impact potential of their own research.

Kevin Tierney

Tutorial: *Automatic Heuristic Discovery: From DRL to LLMs*

Tue 13:30–14:30 in AM, HS 10

In this tutorial, I will discuss the topic of automatic heuristic discovery, which is the task of creating custom heuristics to solve optimization problems. Starting from a deep reinforcement learning (DRL) perspective, I will cover the main mechanisms for directly predicting decisions of routing and scheduling problems. Following a look at DRL, I will turn to large language models (LLMs), which can also automatically design and code solution methods for optimization problems. The methods I will show match or beat state-of-the-art, human-designed heuristics on challenging routing and scheduling problems. The tutorial will end with ideas for integrating these methods into PhD student's work.

Dick den Hertog

Master Class: *Mixed Integer Optimization with Constraint Learning*

Tue 14:45–16:00 in AM, HS 10

Many real-world optimization problems involve objectives and constraints that cannot be explicitly specified by mathematical formulas. For example, the effectiveness of a humanitarian intervention, the feasibility of a logistics plan, or the acceptability of a medical treatment may depend on complex relationships that are only partially understood but for which historical data are available. This raises a fundamental question: how can we optimize decisions when the optimization model itself must be learned from data?

This master class introduces the emerging field of constraint learning, which combines machine learning and optimization to construct prescriptive models directly from data. We will discuss how predictive models, including linear models, decision trees, ensemble methods, and neural networks, can be embedded within mixed-integer optimization formulations, enabling the representation of complex objectives and constraints that are difficult or impossible to model analytically.

A central challenge in this setting is reliability. Optimization algorithms tend to exploit imperfections in learned models, often leading to decisions in regions where little or no data are available. We will examine several approaches to addressing this issue, including trust-region methods that prevent harmful extrapolation and ensemble-based approaches that explicitly account for model uncertainty. The master class will present both the methodological foundations and practical applications of constraint learning, drawing on examples from humanitarian logistics and healthcare. Throughout the course, particular attention will be paid to the many open research questions that arise at the intersection of machine learning and optimization, making this a rich area for future PhD research.

Panel Discussion: *Careers in OR*

with Christina Büsing, Dick den Hertog, Frauke Liers, Sonja Mars, Nikolas Stott, Clemens Thielen

Tue 16:30–18:00 in AM, HS 10

Join us for an interactive session that is about your future! What pathways are there for a career in Operations Research, either in academia or in industry? Will we still need OR experts in the era of AI? Our panel of experts shed light on their individual experiences and take any questions you have.

Gold Sponsor Workshops

Léa Blaise

Pre-Conference Workshop: *Modeling and Solving Routing Problems with Hexaly Studio*

Tue 13:15–14:30 in AM, HS 9

Hexaly Optimizer is a next-generation mathematical optimization solver that extends the traditional Mixed-Integer Programming (MIP) paradigm with a richer modeling framework. Alongside classical algebraic formulations, it supports native combinatorial constructs, nonlinear expressions, and black-box optimization, enabling users to express complex optimization problems in a compact and natural way. By preserving high-level problem structure, Hexaly automatically leverages advanced algorithmic techniques, including decomposition methods, column generation, branch-price-and-cut, and decision diagrams. As a result, it delivers state-of-the-art performance across challenging optimization domains such as routing, scheduling, packing, simulation-based optimization, machine-learning-driven decision problems, and more.

In this hands-on workshop, we will focus on the application of Hexaly to routing problems, showcasing how the solver's set-based modeling capabilities naturally align with the structure of these problems. Participants will be guided through building and solving real-world routing problems using Hexaly Studio, a web-based integrated development environment designed specifically for optimization modeling. Hexaly Studio features intuitive dashboards, interactive widgets, and graphical solution visualizations, making it easy to both formulate models and interpret results. Through guided examples and interactive problem-solving, participants will gain hands-on experience with Hexaly and will be equipped to explore it further in their own research or applied projects.

Robert Luce

Pre-Conference Workshop: *Smarter Modeling with Gurobipy*

Tue 14:45–16:00 in AM, HS 9

This hands-on workshop explores the powerful capabilities of gurobipy, Gurobi's Python interface, with a focus on best practices and comparative analysis of different modeling paradigms. Participants will gain practical insights into different modeling flavors:

- *Traditional Term-Based Modeling:* The foundational approach using object-oriented constructs with variables, constraints, and expressions built iteratively.
- *Matrix-Friendly API:* Introduced in Gurobi 9.0 and enhanced through version 13.0, this paradigm leverages NumPy-style vectorization, broadcasting, and multi-dimensional operations.
- *gurobipy-pandas:* A convenience layer that allows mathematical model building directly out of DataFrames. The workshop is suitable for both optimization practitioners seeking to enhance their gurobipy skills and students who want to get started with modelling in gurobipy.

Prerequisites: Basic familiarity with Python and mathematical optimization concepts.

WA 01: Plenary Dick den Hertog

Time: Wednesday, 02/Sept/2026: 9:00am - 10:00am · *Location:* HS10 (AM)
Session Chair: Marc Goerigk

Optimization for a Better World

Dick den Hertog
University of Amsterdam, Netherlands, The

This keynote explores the transformative role of optimization in helping non-governmental organizations (NGOs) and non-profit organizations (NPOs) accelerate progress toward the United Nations Sustainable Development Goals (SDGs). Through the work of the Analytics for a Better World Institute, cutting-edge optimization methods are developed and applied to address some of society's most pressing humanitarian and environmental challenges.

Drawing on real-world collaborations with NGOs and NPOs, the keynote will demonstrate how optimization can substantially enhance social impact. One featured example is a collaboration with The Ocean Cleanup, where advanced optimization models are used to determine how cleanup vessels should be deployed and routed to maximize the removal of plastic from the world's oceans, thereby increasing the effectiveness of large-scale efforts to combat marine pollution.

The keynote will also present a range of projects that use geospatial optimization to improve access to healthcare and other essential services. These include optimizing the locations of primary healthcare facilities in Timor-Leste, determining the optimal placement of stroke centers in Vietnam, planning COVID-19 testing centers in Nepal, and identifying suitable locations for water wells in Sudan. These initiatives have been conducted in partnership with organizations such as the World Bank, the World Health Organization, Amref Health Africa, and the American Red Cross.

Beyond showcasing the societal impact of these applications, the keynote will discuss the novel methodological and computational challenges they have generated. Many of these challenges remain open research questions, creating exciting opportunities for future advances in optimization and analytics for social good.

WB 01: GOR Master Thesis Award

Time: Wednesday, 02/Sept/2026: 10:30am - 12:00pm · *Location:* HS10 (AM)
Session Chair: Rouven Schur

On Integrality of Queries in Robust Binary Optimization Problems under Controllable Uncertainty

Asra Dia
University of Hamburg, Germany

Many real-world optimization problems involve data that is uncertain or only partially known. Often, that uncertainty can be reduced through costly queries before a decision is made. We study decision-dependent robust optimization problems in which each element of the uncertainty set can be adjusted independently. Uncertain cost coefficients lie in bounded intervals and the decision maker selects a query vector that shrinks each interval toward a hedging point, possibly to a single value.

The problem can be formulated as a four-level problem. The decision-maker first chooses the query vector, an adversary then sets the hedging points within a budgeted uncertainty set, the underlying binary decision follows and finally the remaining uncertainty is realized adversarially within the narrowed intervals. Computationally, optimal query variables appear to take integral values despite being modeled as continuous. We prove that, for problems of this form under budgeted uncertainty sets, optimal queries are indeed integral.

Reformulating the four-level model as a two-level bilinear program allows us to treat the query as a parameter in a parametric optimization problem. Because the query appears on both sides of the constraints, classical concavity results do not apply directly. We overcome this by using McCormick relaxations to linearize the bilinear terms and move the parameter to the right-hand side. Although such relaxations are generally approximate, we show they are exact in our setting. This reformulation allows us to apply standard concavity arguments, which in turn yield integrality of optimal queries.

Stochastic Optimization and Dispatching Rules for Railway Delay Management

Patricia Alexandra Ebert
Technische Universität Berlin, Germany

In railway traffic, source delays occur daily. If the original timetable becomes infeasible, delay management aims to construct a disposition timetable minimizing propagated delays and passenger inconvenience. Two classes of decisions arise: wait-depart decisions determining whether trains should wait for delayed feeder trains to maintain passenger transfers, and precedence decisions defining the order of trains while respecting limited network capacities. The classical Offline Delay Management Problem assumes source delays are fully known and stable. We propose the Stochastic Delay Management Problem (DM), treating source delays as constant within an initial control horizon and as random variables following a delay distribution thereafter. DM is NP-hard for finitely many second-stage scenarios. We introduce a two-stage stochastic mixed-integer linear programming formulation for DM.

To achieve comparability with common practices, we integrate six simple dispatching rules into our optimization framework. Additionally, we present the Doing-Nothing algorithm to study the price of non-dispatching. Computational experiments for the Berlin S-Bahn network show that stochasticity improves disposition timetables by 1.7% on average, at the cost of higher runtimes. The price of non-dispatching of 2.7% indicates a moderate benefit of dispatching, and three dispatching rules perform comparably to DM.

Solving Large Constrained Clustering Problems

Jonathan Scholz
Otto-von-Guericke-Universität Magdeburg, Germany

Through globalization, outsourcing, and increasingly demanding customer requirements, effective supply chains are more important than ever. On the strategical level, this concerns, amongst others, the planning of facility locations and the assignment of customers to locations. Such problems are often solved by means of clustering methods. In practice, however, decisions are accompanied by many operational constraints, e.g., capacity of facilities, or that specific customers must (not) be assigned to the same facility. The constraints make finding effective and feasible location and assignment decisions significantly more complex. This work analyzes the complexity of different constraint types, including capacity constraints, pairwise link constraints and cluster size constraints. It then extends the BLP-Kmeans algorithm to simultaneously incorporate several of these constraint types. It introduces a method for transforming pairwise link constraints into general capacity constraints, which leads to improved runtime performance. Since no standard datasets jointly include both capacity and link constraints, existing data sets from the literature are extended. For a large set of different instances, experimental results show that the transformed model can reduce runtime significantly and therefore allows for solution for instances of realistic sizes.

WB 02: Mobility, Transport, and Traffic: Vehicle Routing

Time: Wednesday, 02/Sept/2026: 10:30am - 12:00pm · *Location:* HS1 (PHIL)
Session Chair: Alexander Bönisch

Node aggregation heuristics for large-scale capacitated vehicle routing problems

Patricia Zech, Christian Almeder
European University Viadrina, Germany

The continuous growth of e-commerce requires last-mile delivery service providers to determine cost-effective route plans for thousands of customers every day. Various distribution or collection applications, such as postal delivery or newspaper distribution, can be modeled as arc routing problems to facilitate problem abstraction. This research is motivated by the distribution of free advertising newspapers in Germany, where publishing companies face increasing logistical pressure due to rising operational costs and the statutory minimum wage for newspaper carriers.

In dense urban areas, taking an aggregated view of arcs rather than nodes reduces problem complexity; however, the situation in rural or suburban areas is different. Aggregating customers along long road segments can significantly reduce route quality. We therefore investigate node aggregation heuristics, where aggregation is performed before solving the routing problem. The proposed approaches transform a capacitated vehicle routing problem (CVRP) into a smaller capacitated general routing problem (CGRP), where demands can be located on nodes, edges, or arcs.

Various aggregation strategies, including a regret-based approach, are applied to benchmark CVRP instances with known optimal solutions. The objective is to identify aggregates that are consistent with optimal route structures while avoiding non-optimal segments that would degrade solution quality. Thus, our study considers the trade-off between reducing computational complexity and maintaining high-quality routing solutions.

Branch-Price-and-Cut for the One-commodity Full-truckload Pickup and Delivery Problem with Time Windows

Eric Fauß
RPTU Kaiserslautern-Landau, Germany

This talk focuses on the one-commodity full-truckload pickup and delivery problem with time windows (1-FTPDPTW). In the 1-FTPDPTW, we are given a set of vehicles and a set of pickup and delivery customers. Vehicles have to serve customers within a given time window where customers demand a single unit of a full-truckload. The goal is to find a cost minimal transportation plan in which the demand of each customer is satisfied and time windows as well as capacity limits are respected. From a practical point of view, the 1-FTPDPTW may arise during the pre- and end-haulage of a transportation chain when focusing on empty container movements. From a theoretical standpoint, the 1-FTPDPTW belongs to the class of many-to-many pickup and delivery problems (PDPs). Looking at the literature regarding many-to-many PDPs, only few papers focus on full-truckload deliveries. This talk presents different model formulations for the 1-FTPDPTW as well as different branch-price-and-cut (BPC) algorithms for its solutions. Computational tests are conducted on derived and established benchmark instances to evaluate the performance of the proposed algorithms.

Validating the benefit of time dependent vehicle routing in simulated urban traffic

Alexander Bönisch, Berde Volkan, Alexander Schiendorfer, Stefanie Schmidtner
Technische Hochschule Ingolstadt, Germany

The Time-Dependent Vehicle Routing Problem (TDVRP) is widely used to model urban traffic dynamics, yet most reported computational benefits remain theoretical and lack validation under realistic conditions. This study proposes a closed-loop, simulation-based evaluation framework to evaluate TDVRP solutions. Using a real-world city network, we extract time-dependent travel times in 15-minute intervals on the street-segment level and optimize routing instances via an Adaptive Large Neighborhood Search (ALNS) under both static and time-dependent costs. The resulting routes are executed in the Simulation of Urban Mobility (SUMO) environment to measure their realized performance. The experimental results show that static routing models underestimate travel time by approximately 14%. The time-dependent models reduce this error to 3.6%. Moreover, a theoretical travel time reduction of 2.4% achieved by the time-dependent optimizer translates reliably to an average saving of about 2%. in the simulation. These findings confirm that the benefits of time-dependent planning persist under realistic traffic dynamics. The proposed framework further quantifies the discrepancy between optimized and realized costs. This enables a systematic assessment of solution quality in dynamic environments.

WB 03: Mobility, Transport, and Traffic: Challenges in Mobility, Transport, and Traffic

Time: Wednesday, 02/Sept/2026: 10:30am - 12:00pm · *Location:* HS3 (PHIL)
Session Chair: Sebastiano Insinga

A Bi-Level Optimization Framework for Equitable Public Bus Fleet Transition Planning under Uncertainty

Ali Mahmoudi[1], Hamid Afshari[1], Hassan Sarhadi[2], Armin Jabbarzadeh[3]
1: Dalhousie University, Canada; 2: Acadia University; 3: École de technologie supérieure (ÉTS), University of Quebec

Decarbonizing public bus fleets requires long-term transition strategies that balance emissions reduction, fiscal sustainability, infrastructure readiness, and equitable service provision across urban areas. This study develops a novel bi-level optimization framework for public bus fleet transition planning under uncertainty, explicitly capturing the hierarchical interaction between a public authority and a transit operator. At the upper level, the public authority minimizes system-wide greenhouse gas emissions while improving the spatial equity of sustainable bus deployment across routes and regions using a Gini-based fairness metric. At the lower level, the transit operator determines fleet procurement, diesel bus conversion, vehicle assignment, retirement timing, and energy infrastructure investment decisions to minimize total life-cycle costs. The framework integrates heterogeneous bus technologies, including diesel, electric, hydrogen, and dual-fuel buses, alongside seasonal operating conditions, midlife and salvage dynamics, budget constraints, and endogenous infrastructure expansion. To better reflect real-world planning conditions, the model incorporates uncertainty in key transition parameters, including fuel and electricity prices, hydrogen availability, technology costs, emissions factors, and service demand. This uncertainty-aware structure enables evaluation of robust fleet transition pathways rather than relying on deterministic forecasts. A Canadian case study demonstrates the applicability of the framework and shows how uncertainty alters investment timing, technology selection, and infrastructure deployment. Incorporating equity promotes balanced allocation of sustainable buses, while uncertainty highlights the value of flexible transition pathways that avoid premature dependence on a single technology. The proposed framework offers a practical decision-support tool for cost-effective, equitable, and resilient zero-emission transit planning.

Allocating Pilgrim Groups to Camps and Routes to Reduce Peak Congestion During the Hajj

Usama Dkaidik, Matthes Koch, Tobias Vlcek, Knut Haase
University of Hamburg, Germany

Hajj, the annual Islamic pilgrimage to Mecca, draws more than two million pilgrims each year and is one of the largest pedestrian-management problems in the world. A central element is the Stoning of the Devil ritual at Jamarat, which pilgrim groups perform at varying times set by transport schedules and religious preferences. The resulting concentrations along the routes between the Mina tent city and Jamarat have caused fatal crowd incidents in the past.

Earlier work optimized the temporal scheduling of groups across timeslots for a fixed spatial allocation. We address the upstream problem: assigning pilgrim groups to camps and paths such that peak utilization of the pedestrian infrastructure is reduced before any scheduling decision is taken. We propose two integer programming models and an iterative solution procedure. The first model lexicographically minimizes the maximum utilization across resources and time periods, fixing each binding peak before reoptimizing the remaining load. The second model extends the first by additionally keeping groups from the same geographical region in neighboring camps, so they can be guided and moved together during the pilgrimage.

A Discrete Optimization Framework to Mitigate Urban Sprawl

Sebastiano Insinga[1], Jochen A. G. Jaeger[2], Roberto Maria Rosati[1,3]
1: WU Vienna University of Economics and Business, Austria; 2: Concordia University, Montreal, Canada; 3: University of Klagenfurt, Austria

Urban sprawl, i.e., the expansion of towns and cities into dispersed low-density, car-dependent settlements, is one of the most critical issues in urban planning. Sprawl increases travelled distances, induces car dependency, and harms transportation efficiency in cities, leading to negative economic, social and environmental impacts. Strategic urban planning decisions are inherently complex: they involve many variables and yield multiple interacting effects. Approaches based on operations research can be especially effective at reducing sprawl while guiding planning decisions.

This research proposes a Mixed-Integer Linear Programming (MILP) approach to optimize urban planning decisions. We model the city as a grid of cells with given land use and intensity. The objective is to make land-use assignment choices that minimize transformation costs, maximize inter-cell suitability while ensuring that demand for housing and jobs is met. The framework incorporates urban sprawl as a constraint or as a minimization objective as qualified by the Weighted Urban Proliferation (WUP) metric.

We validate our approach on instances based on the city of Vienna that we obtained by combining official records on land use with georeferenced time series on population, jobs and built-up surface. We show the potential of an approach based on operational research for making complex decisions in urban planning that mitigate urban sprawl limitation. Our method is scalable to other metropolitan areas facing similar growth pressures.

WB 04: Energy and Sustainability: Offshore wind & transmission and generation investments

Time: Wednesday, 02/Sept/2026: 10:30am - 12:00pm · *Location:* HS13 (IM)
Session Chair: Hannes Hobbie

Generation and Transmission Expansion under Aspects of Cooperation: Insights from Offshore Wind Integration in Baltic Region

Akshay Singh Yadav, Hannes Hobbie
TU Dresden, Germany

The rapid expansion of offshore wind generation and the growing need for cross-border electricity exchange in Europe have intensified interest in integrated offshore grids—shared infrastructures that combine wind power collection with interconnection capacity. This thesis investigates the techno-economic and market coordination challenges of developing such hybrid interconnectors in the Baltic Sea region through optimization and equilibrium modeling. The framework considers Germany (DE), Denmark (DK), and Sweden (SE) connected through both onshore and offshore hybrid interconnectors. Four market frameworks are compared: a centralized planner benchmark, a decentralized equilibrium without compensation, and two market-based mechanisms involving explicit Financial Transmission Right (FTR) allocation and FTR trading. Results show that decentralized decision-making without compensation leads to overinvestment and price divergence, while FTR-based mechanisms improve coordination and maintain near revenue-neutral outcomes. Among them, the market-based FTR trading scenario achieves the most balanced performance across price convergence, welfare, and investment efficiency. Explicit FTR allocation leads to higher investment but slightly lower efficiency, and the centralized planner remains the upper bound for global optimality. The cost and welfare distribution are examined with two (DE-DK) and three (DE-DK-SE) market zones configuration, including Sweden in the latter case enhances welfare and price stability but increases investment asymmetry. Overall, the mechanisms ensuring revenue neutrality through FTR based compensation and trading effectively compress welfare disparities, providing key insights on cooperative offshore grid development.

Coupled Investments in SMRs and Industrial Sites: a Real Options Analysis

Cyrian Hallermeyer[1,2,3]
1: LGI CentraleSupélec, France; 2: IFP School, France; 3: EDF R&D, France

Decarbonising industrial heat has become a pivotal challenge for policymakers and industrial stakeholders alike. However, investment in low-carbon heat technologies is still timid. This paper explores the potential role of Small Modular Reactors (SMRs) in supplying decarbonised heat and electricity to industrial sites. In particular, we explore the possible emergence of bilateral contracts between SMR developers and industrial firms, which may offer a viable pathway to overcome investment hurdles and align supply with demand.

To investigate this, we develop a coupled investment model within a Real Options Analysis framework, capturing the strategic decision-making processes for both an industrial firm and a SMR developer. We combine Dynamic Programming with Game Theory to solve for the strategic behavior of both firms. The model considers five options for the industrial firm and three for the SMR firm, incorporating the irreversibility of capital expenditures, and the potential for bilateral contracting in heat and electricity supply. We solve the ROA model by adapting the Least-Square Monte Carlo method to a two-agent setting with risk aversion.

Our results suggest that both firms delay their investment decisions when given the option to wait before investing: The industrial firm keeps its initial gas boiler for a longer period, while the SMR firm holds off investment and construction of the SMR. Furthermore, risk aversion exacerbates the postponing of investments in non-nuclear investments. Finally, when contracting between firms is allowed, an increased risk aversion motivates both firms' to sign heat supply contracts in order to hedge against energy price risks.

RFNBO Meets §13k: The Hidden Trade-off in Green Hydrogen Policy and its Effect on Offshore Wind Integration

Hannes Hobbie, Lisa Lorenz
TU Dresden, Germany

Hydrogen is widely considered a cornerstone of Germany's decarbonisation strategy. To support investment in hydrogen infrastructure, the European Renewable Fuels of Non-Biological Origin (RFNBO) certification scheme defines criteria for classifying hydrogen as renewable. At the same time, the German regulator has introduced the Use Instead of Curtailment mechanism (§13k EnWG), which enables flexible demand to procure electricity that would otherwise be curtailed through dedicated auctions. This mechanism is intended to facilitate the integration of renewable generation, particularly offshore wind, by alleviating grid congestion.

Despite these aligned objectives, their interaction may create a policy conflict affecting offshore wind integration. In particular, proposed changes to the RFNBO framework directly affect the incentives of electrolyser operators to participate in §13k auctions, potentially limiting their ability to provide system-relevant flexibility during periods of surplus generation and network congestion.

We apply a fundamental power market and congestion management model of the European electricity system to simulate electricity prices and curtailment volumes across scenarios with varying renewable build-out and offshore grid configurations. Building on this,

we develop a detailed electrolyser dispatch model that optimises operation under both RFNBO compliance constraints and §13k procurement opportunities for different RFNBO design options. We then compare resulting hydrogen production costs and system outcomes to assess the implications for offshore wind integration.

The results provide insights for policymakers and regulators on how to better align hydrogen certification rules with electricity market mechanisms, thereby supporting a more efficient integration of offshore wind.

WB 05: Energy and Sustainability: Energy storage operation and fleet planning

Time: Wednesday, 02/Sept/2026: 10:30am - 12:00pm · *Location:* HS11 (IM)
Session Chair: Dogan Keles

Battery Storage Optimization for Multi-Market Participation under Uncertainty: A Case Study Using Real-World Utility Data

Tobias Backmann, Ioanna Gkiata, Marie-Louise Arlt
Universität Bayreuth, Germany

Market actors such as municipal utility companies face an integrated operational challenge as variable renewable energy sources (VRES) infeed places stress on distribution grids while simultaneously increasing local imbalances. Battery energy storage systems (BESS) can provide operational flexibility by enabling load shifting within such energy systems. However, studies that combine grid- and market-facing dispatch remain limited. This study analyzes the optimal dispatch of a municipal battery energy storage system, combining intraday energy arbitrage, local congestion management, and imbalance management. We formalize a mixed-integer linear programming (MILP) based economic model predictive control (EMPC) framework with deterministic approximated chance constraints, with the objective to maximize profit and handle battery and transformer constraints with and without modeled uncertainty. Forecast uncertainty is represented through simple baseline forecasts, uncertain scenarios, and controlled information leakage. We calibrate our model using real-world data of a German municipal utility. The analysis is conducted for two representative weeks with different market conditions, representing a low and a high volatility scenario. The results show that the stacked provision of intraday arbitrage, local congestion management, and imbalance management can lead to higher economic profitability compared to non-stacked operation. While forecast uncertainty strongly influences the results, especially reducing the effectiveness of transformer management, intraday energy arbitrage remains profitable. Future research could build on these findings and improve uncertainty handling through stochastic optimization approaches or investigate additional services such as frequency control embedded in this framework.

Charging Electric Bus Fleets: Deriving Spatially Differentiated Load Profiles from Schedule Data

Arnd Hofmann
Universität Duisburg-Essen, Germany

As electric buses increasingly replace conventional public transport fleets, electricity demand will increase and recharging may impose additional stress on electricity grids. Accurate regional load profiles are essential for grid infrastructure planning at regional level and beyond. Existing approaches typically rely on generic usage assumptions applied uniformly across large territories. This obscures structural differences between urban and rural service patterns.

Here, a parsimonious modelling approach is presented that derives annual hourly depot charging load profiles for all 400 German NUTS3 regions from publicly available GTFS schedule data. Final terminal stop departure times per route and day are extracted at the regional transit authority level and combined with triangular distributions for depot return delay and charging duration. Each distribution is fully described by three parameters, keeping all modelling assumptions explicit and editable while using publicly available operational data of regional origin. Special attention is given to the spatial mismatch between terminal stop location and actual depot location, a systematic bias not addressed in comparable approaches and with direct implications for load curve shape.

For regions without dedicated schedule data available, a distance-weighted spatial interpolation procedure may be applied to fill data gaps. The resulting profiles reflect structural differences in service patterns, suitable for grid planning and scenario analysis. They also allow to identify potentials for smart charging or vehicle-to-grid flexibility provision.

The annual hourly time series may be derived based on a limited, transparent set of assumptions, facilitating the application of the methodology to different regions or scenarios for future years.

The Role of Flexible Storage in a Grid-Constrained High-Renewable System

Jilles De Blauwe, Xiaobing Zhang, Dogan Keles
Technical University of Denmark (DTU), Denmark

Rising shares of variable renewable energy increasingly expose transmission bottlenecks, driving substantial redispatch costs—exceeding €4 billion in Germany in 2023—and challenging the efficiency of existing market designs. This paper evaluates the role of grid-scale battery storage (“GridBoosters”) as a congestion management instrument in a grid-constrained, high-renewable system.

We develop an integrated operations research framework that combines (i) a network-constrained optimization model for GridBooster operational allocation, (ii) a large-scale linear optimal power flow (LOPF) model of the European transmission system implemented in PyPSA-Eur and (iii) an optimized bidding strategy incorporating congestion-operational constraints in spot market bidding. Congestion is estimated through a granular mapping from physical bottlenecks to economically meaningful scarcity signals.

The framework jointly captures system-level welfare effects and asset-level profitability under alternative allocation regimes between transmission system operators (TSOs) and merchant market participation.

Applying the model to the 250 MW Kupferzell GridBooster, we quantify congestion relief in MWh and translate it into monetary value using redispatch cost data.

Results show substantial heterogeneity in value depending on operational allocation, with centralized (TSO-driven) dispatch maximizing system benefits, while hybrid and merchant strategies introduce efficiency losses but may improve private incentives.

A central contribution is to formalize the trade-off between model accuracy and computational feasibility, e.g., spatial resolution and clustering choices in LOPF. These findings provide decision-relevant insights for transmission planning and storage investment, and demonstrate how optimization-based market design can internalize network constraints in high-renewable systems.

WB 06: Discrete and Combinatorial Optimization: Bilevel Optimization 1

Time: Wednesday, 02/Sept/2026: 10:30am - 12:00pm · *Location:* HS5 (WIWI)
Session Chair: Vladimir Stadnichuk

On Big-M reformulations of bilevel linear programs: hardness of a posteriori verification

Sergei Ketkov, Oleg Prokopyev
University of Zurich, Switzerland

A standard approach to solving optimistic bilevel linear programs (BLPs) is to replace the lower-level problem with its Karush-Kuhn-Tucker (KKT) optimality conditions and reformulate the resulting complementarity constraints using auxiliary binary variables. This yields a single-level mixed-integer linear programming (MILP) model involving big-M parameters. While sufficiently large and bilevel-correct big-Ms can be computed in polynomial time, verifying a priori that given big-Ms do not cut off any feasible or optimal lower-level solutions is known to be computationally difficult. In this study, we establish two complementary hardness results. First, we show that, even with a single potentially incorrect big-M parameter, it is coNP-complete to verify a posteriori whether the optimal solution of the resulting MILP model is bilevel optimal. In particular, this negative result persists for min-max problems without coupling constraints and applies to strong-duality-based reformulations of mixed-integer BLPs. Second, we show that verifying global big-M correctness remains computationally intractable a posteriori, even when an optimal solution of the MILP model is available.

A bilevel approach to k-extendability of matchings in bipartite graphs

Maurice Draeger, Arie M.C.A. Koster
RWTH Aachen University, Germany

A graph is called k-extendable for an integer k if every matching of size k is included in a perfect matching. This can be seen as a two player Stackelberg game, where the leader chooses a matching of size k and the follower verifies whether or not it is included in a perfect matching. Based on this we formulate for bipartite graphs different bilevel programs to check whether a graph is k-extendable. These are based on two main concepts. In both the leader first chooses k edges that form a matching. In the first approach the follower constructs a matching of maximum size, which contains all of these edges. In the second they search for a perfect matching, that contains as many edges of the leader as possible. Building on that we derive corresponding single level reformulations via dualization of the lower level. We proceed by analyzing the integrality gaps of the resulting formulations. It is known, that the bipartite case is decidable in polynomial time, in contrast to the general case, which is co-NP-hard. Thus we evaluate whether and how the bilevel formulations can be extended to the non-bipartite case. We conclude by giving preliminary computational results.

On the Potential of Bilevel-Feasible Paths for Discrete Bilevel Network Design with Existing Infrastructure

Vladimir Stadnichuk
Research Group on Algorithmic Algebra and Discrete Mathematics, University of Kassel, Germany

We study multi-follower Discrete Bilevel Network Design Problems (DBNDP), in which a leader decides on the inclusion of candidate arcs while multiple independent followers solve (constrained) shortest path problems on the resulting network. We focus on settings where a base network is given and the leader's task is to select a subset of potential extensions to be constructed. To address this problem class, we transfer the concept of bilevel-feasible paths, originally developed for Network Pricing Problems, to the DBNDP setting. Building on this concept, we propose a compact path-based formulation, and compare this formulation with established arc-based exact approaches, including the strong-duality-based formulation and the Benders-like decomposition method. Furthermore, we show how bilevel-feasible paths can be used to significantly tighten big-M parameters in existing formulations, leading to stronger relaxations. Then, we introduce a novel hybrid formulation that combines the path-based model with arc-based approaches. Preliminary computational experiments demonstrate that tightening big-M parameters substantially improves the performance of classical models. Moreover, the proposed path-based formulation outperforms existing approaches on our test instances, while the hybrid formulation achieves the best overall performance by leveraging the strengths of all considered methods.

WB 07: Discrete and Combinatorial Optimization: Applications 1

Time: Wednesday, 02/Sept/2026: 10:30am - 12:00pm · *Location:* SR029 (WIWI)
Session Chair: Sabrina Ammann

Optimal Loading of Industrial-Scale Autoclaves

Christoph Brauer[1], Tanja Führer[2], Tim Niemann[3], Andreas M. Tillmann[3], Hakan Ucan[1], Lukas Windgätter[4]

1: German Aerospace Center, Institute of Lightweight Systems, Stade; 2: German Aerospace Center, Institute of Lightweight Systems, Braunschweig; 3: Clausthal University of Technology, Institute of Mathematics, Germany; 4: German Aerospace Center, Institute of Software Technology, Hamburg

Autoclaves are gas-tight pressure and heat vessels that facilitate chemical curing reactions and material consolidation. Such materials include, e.g., metal laminates or carbon-fiber reinforced polymers that are widely used in aerospace, automotive, and shipbuilding applications due to their high strength-to-weight ratio. When multiple components of different geometries are processed simultaneously, their arrangement within the autoclave affects local temperature distribution, curing kinetics, and overall process duration as well as energy consumption. In this work, we tackle autoclave loading optimization with integer programming, aiming to minimize total curing time. We formulate both compact models for off-the-shelf solvers and a problem-specific column generation approach, and evaluate computational experiments with our respective implementations as well as results from a quantum annealer.

Optimal Planting and Harvesting Decisions in Agroforestry Systems: A Binary Optimization Problem in Two-Dimensional Time

Nico Tauchnitz

Fraunhofer IKTS, Germany

The transition of the chemical industry toward low-carbon production requires bio-based feedstocks and efficient models for optimizing material flows. In the Leipzig–Halle region, sustainable biomass supply is a key challenge.

We study agroforestry systems as a link between agricultural production and industrial use. The core contribution is a binary optimization model for joint planting and harvesting decisions, based on a two-dimensional time structure capturing both plant age and regrowth time. This enables the integration of dynamic growth and nonlinear yield functions within a discrete decision framework.

The problem can be formulated as a shortest path problem in a time-expanded state graph, allowing efficient solution via Dijkstra's algorithm in a basic setting. However, incorporating additional operational constraints leads to NP-hard extensions. This highlights the trade-off between computational tractability and realistic system modeling.

A speed-up for Helsgaun's TSP heuristic by relaxing the positive gain criterion

Sabrina Ammann, Birte Ostermann, Sebastian Stiller, Timo de Wolff

TU Braunschweig, Germany

The Traveling Salesman Problem (TSP) is one of the most extensively researched and widely applied combinatorial optimization problems. It is NP-hard even in the symmetric and metric case. Building upon elaborate research, state-of-the-art exact solvers such as CONCORDE can solve TSP instances with several ten thousand vertices. A key ingredient for these integer programming approaches are fast heuristics to find a good initial solution, in particular the Lin-Kernighan-Helsgaun (LKH) heuristic. For instances with few hundred vertices heuristics like LKH often find an optimal solution. In this work we develop variations of LKH that perform significantly better on large instances. LKH repeatedly improves an initially random tour by exchanging edges along alternating cycles. Thereby, it respects several criteria designed to quickly find alternating cycles that give a feasible improvement of the tour. Among those criteria, the positive gain criterion stayed mostly untouched in previous research. It requires that, while constructing an alternating cycle, the total gain has to be positive after each pair of edges. We relax this criterion carefully leading to improvement steps hitherto undiscovered by LKH. We confirm this improvement experimentally via extensive simulations on various benchmark libraries for TSP. Our computational study shows that for large instances our method is on average 13% faster than the latest version of LKH.

WB 08: Supply Chain Management and Production: Lot Sizing

Time: Wednesday, 02/Sept/2026: 10:30am - 12:00pm · *Location:* HS9 (AM)
Session Chair: Daryna Dziuba

Decentralized Coordination for Multi-Level Lot Sizing with Minimal Information Sharing

Anton Klymenko, Margaretha Gansterer
University of Klagenfurt, Austria

Centralized lot-sizing planning yields the lowest system cost but assumes full cost disclosure, which competing firms are typically unwilling to provide. We study the decentralized multi-level uncapacitated lot-sizing problem with rivaling agents and full item reassignability, in which independent manufacturers must jointly decide who produces each item of a shared bill-of-materials while keeping their cost structures private.

We develop a single-shot coordination mechanism with two variants. The base variant generates candidate item-to-agent reassignments by random perturbation, while the enhanced variant additionally uses LP-relaxation shadow prices to guide candidate generation. In both variants, agents respond with ordinal vetoes and a binary accept/reject signal. A voting-by-veto procedure followed by an acceptance check delivers individually rational outcomes without monetary transfers or absolute cost disclosure.

We evaluate the mechanism on 272 benchmark instances and document a clear efficiency–fairness tension. With two agents, average gap closure under individual rationality ranges from 14% to 43% across instance groups, and the best individual instance closes 93% of the decentralization gap. With five agents on medium instances, Pareto-improving closure falls below 10%, reflecting the structural difficulty of achieving unanimity as the number of agents grows; system-level improvements of up to 76% nonetheless remain achievable if side payments compensate disadvantaged agents. Shadow-price disclosure improves gap closure by up to 20 percentage points relative to random generation while revealing only the relative ranking of agents' costs, not their absolute levels, and the acceptance step deters naive uniform misreporting on the tested instances.

Integrating Returnable Transport Item Fleet Sizing into Capacitated Lot Sizing for RFQs

Marion Sandra Lemke[1,2], Heinrich Kuhn[2]
1: Landshut University of Applied Sciences; 2: Catholic University of Eichstaett-Ingolstadt

Regulatory and sustainability requirements are driving the adoption of returnable transport items (RTIs), while intensified competition increases cost pressures and encourages firms to introduce an increasing number of product variants to better satisfy market needs. In request-for-quotation (RFQ) processes with OEMs, suppliers must estimate not only manufacturing and material costs but also the total number of RTIs required over the entire series-production phase, commonly referred to as the fleet size. The fleet size depends on the production lot size, the filling quantity per RTI, and the loop time in the circulation system. An additional layer of complexity arises when a single container type is shared across multiple variants of the same product type, as leveraging effects can unlock additional cost-reduction potential by better utilizing shared RTI capacity and reducing redundant investments. Consequently, companies need to determine optimal production lot sizes for each variant while explicitly accounting for RTI-related costs in their decision-making.

We address this problem by extending the classical Capacitated Lot Sizing Problem (CLSP) to account for dependent RTI fleet requirements. The resulting model jointly minimizes setup, inventory holding, and RTI procurement costs over the full lifetime planning horizon. Numerical experiments based on industrial data illustrate the model's behavior and quantify the value of integrating RTI fleet dimensioning into production planning. The results provide methodological and managerial insights for supply chains relying on RTIs.

A scoring-guided fix-and-optimize approach for capacitated lot-sizing problems

Daryna Dziuba, Christian Almeder
Europa-Universität Viadrina Frankfurt (Oder)

The capacitated multi-item lot-sizing problem with setup times is known to be NP-hard. Dziuba and Almeder (2023) proposed the 2-step construction heuristic (2-SCH), which provides competitive solution quality within short computational times and can be adapted to different problem extensions with only minor modifications. The results showed that instances with high capacity utilization and a high average time between orders are especially challenging; in the worst cases, feasible solutions could only be constructed by using overtime capacity. In this work, we use solutions obtained by 2-SCH to predict promising setup patterns for capacitated lot-sizing problems. These patterns are then combined with a Fix-and-Optimize improvement heuristic, in which several scoring-guided strategies for unfixing decision variables are investigated. Numerical results show that the proposed solution approach performs competitively for single-level problems with setup times, as well as for multi-level problems with and without setup times.

WB 09: Artificial Intelligence, Machine Learning and Optimization: Routing and Scheduling 1

Time: Wednesday, 02/Sept/2026: 10:30am - 12:00pm · *Location:* HS7 (WIWI)
Session Chair: Pietro Ansidei

Deep Q-Learning for Adaptive Operator Selection in Multiobjective Evolutionary Algorithms: Application to Time-Dependent Green Vehicle Routing Problems

Fakhita Eddaoudi[1], Halima Lakhbab[1], Mohamed Naimi[2]

1: Laboratory of Mathematical Analysis, Algebra and Applications, Faculty of Science, Aïn Chock, Hassan II University of Casablanca, Morocco.; 2: Laboratory for Analysis and Modeling of Systems for Decision Support (LAMSAD), Hassan First University, National School of Applied Sciences of Berrechid, Morocco.

Multi-objective evolutionary algorithms (MOEAs) have recently been combined with reinforcement learning to choose parameters or control operators. In this regard, Qi et al. has devised a Q-learning based MOEA (QMOEAs) to select local search operators for the time dependent green vehicle routing problem with time windows (TDGVRPTW) which has three objectives; the total travel time, energy consumption and costgumor satisfaction. Although QMOEA performs well, its tabular nature restricts the state space to be a low-dimensional and static representation, which may lack evolutionary information. In this paper, we explore if using a Deep Q-Network (DQN-QMOEA) agent instead of the Q-table can improve solution quality, convergence, and scalability over the tabular Q-learning agent. The same NSGA-II framework, initialization procedure, and four problem-specific crossover operators are used in both QMOEA and DQN-based QMOEA, allowing us to isolate the impact of the reinforcement learning agent. The DQN agent estimates Q-values based on state features - diversity of the Pareto front, success rates of operators, and generation number - using a neural network in a continuous state space. We compare the two approaches on various data instances. Our findings highlight the strengths and potential limitations of each of the two approaches being compared. We believe that the obtained results can also offer insights for practitioners who may want to use reinforcement learning in metaheuristics for combinatorial optimization.

Truck to Door Assignment Problem with Neighbor Constraints

Pia Schreynemackers[1], Christina Braun[2], Joelle Hohnsel[2], Alexander Krooß[2], Nuri Morava[3], Alice Kirchheim[1,2]

1: TU Dortmund University, Germany; 2: Fraunhofer Institute for Material Flow and Logistics IML, Germany; 3: DSV A/S, Germany

The assignment of truck lines to terminal gates is a fundamental operational task in freight terminals but has received limited academic attention. This is remarkable given the volume of road freight transport in Germany, where 3.4 billion tons of goods were transported in 2023, predominantly by truck due to its flexibility and wide accessibility. With freight volumes expected to increase further toward 2026, improving internal terminal efficiency is increasingly important (statista.com). For practitioners, optimized truck to gate assignments and reduced distances are especially relevant, as shorter cross-loading times enable more efficient workforce deployment and higher terminal capacity.

This study adapts the line-to-gate assignment problem – previously analyzed mainly in airport logistics – to the cargo terminal context. A novel contribution is the inclusion of neighborhood relationships between gates, which are crucial for handling cargo flows directed to geographically related destinations, but are not required in passenger terminals.

The problem is formulated as an integer program with binary variables representing each line-to-gate pair. The model incorporates operational constraints such as required adjacency for specific line groups, limit of cargo capacity per gate, and limits on the number of lines per gate. Implemented in Python using the CBC solver, the model was complemented by testing alternative formulations with modified constraints and auxiliary variables.

Validation with real operational data from a DSV Global Transport and Logistics cross-dock terminal showed that the optimized solution reduced daily internal transport distances by 33,206 meters, corresponding to an efficiency gain of about 18%. Experts confirmed the practical relevance of the solution.

Scaling Constraint Programming for Industrial Long-Term TV Content Scheduling

Pietro Ansidei, Leonardo Lovato

ProSiebenSat.1 Media SE, Unterföhring, Germany

We present Boost, a production system deployed at ProSiebenSat.1 that automates five-year television content scheduling across six channels, reducing the process from weeks of manual planning to under two hours of computation. Boost plans approximately 90,000 broadcast runs considering constraints such as licensing windows, yearly budget caps, episode ordering, age-rating restrictions, and editorial placement rules.

Given the number of runs and constraints, it would be intractable to assign runs to days over a five-year horizon when formulated as a single optimization problem, due to combinatorial explosion. Here, we present a way to make it tractable following two key ideas. First, a constraint reformulation via slot indexing, which reduces the complexity of episode-ordering constraints from a product of runs and days to a function of runs alone. Second, a divide-and-conquer decomposition that partitions the content into over four thousand independent subproblems ordered by a directed acyclic graph ensuring high-priority content is scheduled first, and executed in parallel across distributed workers. Last, we present a multi-phase pipeline that combines exact constraint solving with constraint relaxation for filling purposes and cross-channel slot aggregation, with real-time state synchronization through a key-value store.

Each subproblem solves in under 15 seconds on average (median under 3 seconds), while the full pipeline completes in under two hours on eight workers, achieving a five- to eightfold speedup over sequential execution. The system has been in development since 2024 and enters production in 2026, replacing three to four weeks of manual planning effort for a team of 8 people.

WB 10: Optimization under Uncertainty: (Approximate) Dynamic Programming

Time: Wednesday, 02/Sept/2026: 10:30am - 12:00pm · *Location:* HS8 (WIWI)
Session Chair: Simon Caspar Zeller

Which Actions Should a Dynamic Program Keep?

Simon Caspar Zeller, Steffen Rebennack
Karlsruhe Insititute of Technology, Germany

Dynamic programming is usually discussed in terms of the size of the state space. In many sequential decision problems under uncertainty, however, the action space is just as restrictive. Even with an explicit uncertainty model and a manageable state space, evaluating thousands of actions in every Bellman step can make a model computationally intractable.

This talk focuses on action-library design for stochastic dynamic programming. Instead of carrying the full feasible action space through the recursion, we use a smaller library of useful actions and compute the final policy on the restricted stochastic dynamic program. The main question is how to choose this library.

Candidate actions can come from sample-average approximation, historical decisions, simulation, or problem-specific discretizations. They can then be filtered or compressed using clustering, value-based diagnostics, or information from restricted dynamic programming solves. This gives a common view of two related algorithmic questions: how to generate useful candidate actions, and how to reduce a large candidate set to the actions that matter most for policy value.The final policy is still computed by dynamic programming: offline computation is used to focus the action set, not to replace the model.

The talk is motivated by operational planning problems including energy storage, inventory systems with lead times, and dynamic resource allocation. The goal is to understand when action-sparse dynamic programming can make otherwise expensive sequential decision models practical.

Inventory for Impact: Scalable Inventory Routing for Clean Cooking Access in Developing Economies

Simon Thomä[1,2], Dan Iancu[3], Maximilian Schiffer[2]
1: RWTH Aachen, Germany; 2: TU Munich, Germany; 3: Stanford University, California

Access to clean cooking technologies remains an issue in developing economies. Around 2.1 billion people around the globe rely on polluting fuels for cooking, leading to more than 3 million premature deaths annually. In Kenya, where most households rely on polluting fuels, bio-ethanol stove suppliers use carbon credits to subsidize stove prices. Still, affordability remains a challenge due to high distribution costs caused by highly stochastic and heterogeneous demand distributed over several thousand small retailers in Nairobi alone. We address this challenge by formulating a large-scale Inventory Routing Problem with stochastic demand and propose a new two-step approach to solve it. First, we relax the problem by taking long-term averages to compute target policies and valid lower bounds. Building on these target policies, we derive dynamic routing and replenishment policies that scale well to real-world instances with several thousand stores. Our numerical experiments show that the proposed methods significantly improve over the status quo, leading to significant cost savings.

Dynamic scheduling in circular economies

Hendrik Busmann
Otto-von-Guericke Universität Magdeburg, Germany

Valuable materials are contained in most modern technical systems. The growing demand for those systems further emphasizes the importance of recovering these scarce materials. Even if they were recovered, reusing returned materials into a firm's supply chain introduces organizational challenges by increasing problem complexity. Although reuse is a well-known circular economy approach on a strategic level, it has received limited attention in scheduling.

We consider a dynamic permutation flow shop respecting release dates, deadlines, and inventory costs. Returned materials are incorporated in the production process, reducing processing times. Job overtaking is permitted when processing times are zero. Job releases as well as the arrival dates of returned materials are dynamic.

To efficiently schedule these materials under uncertainty, predictive methods are employed to simulate future material returns. This enables the estimation of the value of allocating returned materials to certain jobs in order to reduce tardiness. Our results indicate that the application of an approximate dynamic programming method is effective. Simulating and estimating the expected value of integrating returned materials into the schedule leads to reductions in both job tardiness and overall system costs.

WB 11: Software for Operations Research: Latest and Greatest in Solvers

Time: Wednesday, 02/Sept/2026: 10:30am - 12:00pm · *Location:* HS6 (WIWI)
Session Chair: Leona Gottwald

What's new in MOSEK 12

Jens Schulz
MOSEK

We present the key advances in MOSEK 12, focusing on algorithmic improvements and their impact on real-world optimization problems from diverse industries. Key performance improvements stem from re-implementation of the simplex optimizers, basis identification (a.k.a. crossover), enhanced presolving for continuous problems, and the default enabling of LP folding. For the mixed-integer optimizer, we discuss the impact on space and time efficiency coming from improvements to conflict analysis, symmetry reduction, and symmetry handling, as well as new heuristics that are independent of a root LP.

Benchmark results show significant runtime reductions across a diverse set of large-scale instances from domains such as energy, finance, and forestry.

Further, we illustrate MOSEK's modeling concepts for handling uncertainty and risk awareness using new marimo notebooks in the energy domain, and how the solver enhancements carry over to these types of problems.

What's New in FICO Xpress Solver

Timo Berthold
FICO Xpress Optimization, Germany

We will give an overview of the latest enhancements, the newest features, and the most recent performance improvements in the FICO Xpress Solver for mixed-integer linear and nonlinear optimization problems.

What's new in the Hexaly Optimizer

Leona Gottwald
Hexaly, France

We will look at recent advancements in the Hexaly Optimizer with a particular focus on the solvers behavior on the class of mixed integer programming (MIP) problems.

This includes algorithmic advancements, such as in presolve and cutting plane separation, as well as technical improvements that affect the solver performance.

Where available computational results are presented that highlight the impact of the changes.

WB 12: Decision Theory and Multi-criteria Decision Making I

Time: Wednesday, 02/Sept/2026: 10:30am - 12:00pm · *Location:* HS2 (PHIL)
Session Chair: Kathrin Klamroth

The bi-objective single-row facility layout problem

Christof Brandstetter[1], Elisabeth Gaar[2], Markus Sinnl[1]
1: Johannes Kepler University Linz; 2: University of Augsburg

In this work, we present a bi-objective extension of the well-known single-row facility layout problem (SRFLP). In the SRFLP, a set of one-dimensional facilities must be arranged in a single row, such that the weighted sum of the center-to-center distances of each distinct pair of facilities is minimized. For our bi-objective extension, we introduce an additional such weighted sum objective and want to obtain the set of Pareto optimal points using the epsilon-constraint method. As it is known that using semi-definite programming (SDP) relaxation is more effective in solving the SRFLP than integer programming (IP), we present a custom SDP-based branch-and-bound algorithm to solve each iteration of the epsilon-constraint method. This is in contrast to many works on the epsilon-constraint method, which use a black-box IP solver to solve each iteration of the epsilon-constraint method. This allows us to propose several enhancement procedures for our epsilon-constraint approach, such as i) multiple branching strategies, including non-binary branching, ii) variable fixing, iii) problem reduction, iv) re-using of branch-and-bound trees, and v) solution pooling.

GPU Parallel Pareto Local Search for Multi-objective QUBO

Stephanie Riedmüller[1], Thorsten Koch[1,2]
1: Zuse Institute Berlin, Germany; 2: Technische Universität Berlin, Germany

We revisit Pareto Local Search (PLS) for multi-objective quadratic unconstrained binary optimization (QUBO) problems. Multi-objective QUBO formulations have gained increasing attention as a universal modeling method and natural input for quantum optimization. While exact methods exist, their unconstrained binary structure makes them well-suited for heuristics such as PLS. At the same time, GPUs offer a powerful classical alternative to quantum-inspired optimization. We develop an efficient GPU-based parallel implementation of PLS for multi-objective QUBO problems. Our approach combines coarse-grained and fine-grained parallelization. On the coarse-grained level, an initial set of supported solutions is generated using weighted-sum optimization, from which multiple PLS processes are started in parallel. At the fine-grained level, neighborhood exploration is parallelized on the GPU by simultaneously evaluating binary-flip candidate solutions across all objectives. Non-dominated solutions are maintained using an ND-tree data structure to support efficient Pareto updates. The implementation combines several known PLS techniques within a unified CPU/GPU hybrid architecture. We describe the algorithmic components, the GPU-specific design decisions, and report results from a computational study evaluating the effectiveness of the proposed approach.

Safe routing options based on ordinal optimization

Kathrin Klamroth, Julia Sudhoff Santos, Michael Stiglmayr
University of Wuppertal, Germany

We use ordinal categories to reflect the safety of street segments, aiming at the identification of safe paths for children on their way to elementary school. In this context, we discuss the interrelation between ordinal shortest path problems and associated multi-objective shortest path problems. Modeling aspects with regard to consistency of preference choices and wrt. the avoidance of safe, yet overly long paths, are discussed. Associated solution concepts are suggested, and the problem is illustrated at a small example instance.

WB 13: Mobility, Transport, and Traffic: Scheduling and Fleet Balancing

Time: Wednesday, 02/Sept/2026: 10:30am - 12:00pm · *Location:* HS4 (PHIL)
Session Chair: Michael Kahr

A state-expanded network formulation for Multiple-Depot Integrated Vehicle and Crew Scheduling

Jonas Brenker[1], Michael Römer[2], Guido Schryen[1]
1: Department of Management Information Systems, Paderborn University, Germany;
2: Department of Management Science and Business Analytics, Bielefeld University, Germany

In public transport systems, both vehicle deployment and crew assignment constitute major planning challenges for urban, metropolitan, and intercity services. The integrated vehicle and crew scheduling problem (VCSP) addresses both challenges simultaneously. Given a set of timetabled trips, it seeks to determine minimum-cost schedules for vehicles and crews that are feasible and compatible with each other. As both vehicle scheduling in the multiple-depot case and crew scheduling are NP-hard, existing research mainly relies on heuristic solution methods, while exact approaches have thus far been limited to smaller instances. To address this gap, we propose a novel exact reformulation of the multiple-depot VCSP in which crew duties are constructed as paths in a state-expanded network, with the goal of reducing overall run time, in particular for large-scale instances. We solve the resulting mixed-integer programming model using a standard solver and conduct experiments on well-known benchmark instances from the literature to compare solution quality and run time against state-of-the-art exact and heuristic methods.

Strategic deployment planning for inspection trains

Maximilian Selch[1], Karl Nachtigall[2]
1: German Centre for Rail Traffic Research, Germany; 2: TU Dresden

The German rail network operates at or near capacity in many areas and is already classified as overloaded on some corridors. Close monitoring of rail infrastructure condition is essential to ensure safe operations. As the national infrastructure manager, DB InfraGO is responsible for inspecting and maintaining approximately 33,480 km of track.

Various inspection trains are used for the regular inspection of most of the track network to check the condition of the infrastructure efficiently and reliably. These trains are deployed in the areas of rail inspection, track geometry, and overhead wire measurement. Today, the scheduling of these inspection trains still relies heavily on manual planning in many areas. In operational practice, however, short notice disruptions frequently require rapid rescheduling, affecting both the current operating day and subsequent days of the affected train. This creates a need for robust, efficient, and scalable planning methods.

Using rail inspection as a representative case, we model the strategic scheduling as a Vehicle Routing Problem, and present solution methods for the instance size of the entire DB InfraGO rail network. This determines inspection train schedules for a one-year planning horizon that serve all sections of track to be inspected while utilizing the trains as efficiently as possible. In addition, the approach quantifies reserve capacity that can be strategically allocated throughout the year to mitigate operational disruptions. The methodology is transferable to the other inspection domains of track geometry and overhead wire measurement.

Balancing the Fleet: An ILP Approach to Homogeneous Tram Dispatching

Michael Kahr[1], Markus Leitner[2], Rosario Paradiso[2]
1: University of Graz, Austria; 2: Vrije Universiteit Amsterdam, The Netherlands

We address the homogeneous usage dispatch problem in public transit operations. The goal is assigning trams to trips to balance fleet mileage, which is critical for maintenance and investment planning. We propose a graph representation and a compact integer linear programming (ILP) formulation. To improve tractability, we introduce a relaxed model where optimality is enforced via cuts based on the compact formulation. Computational experiments on (pseudo-)real-world instances demonstrate the framework's efficacy in significantly reducing the Gini coefficient of fleet usage.

WB 14: Technical Operations Research I

Time: Wednesday, 02/Sept/2026: 10:30am - 12:00pm · *Location:* HS12 (IM)
Session Chair: Apostolos Aslanidis

Extended Ground Structure Modells for Mechanical Construction

Ulf Lorenz
University Siegen, Germany

Optimization approaches for the design of truss structures with the aim of systematically generating structurally stable and material-efficient and flexible load-bearing systems, is in the focus of this talk. Here, flexible means that the structures constist of telescoping rods and joints such that the artefact can change its geometric form. Mathematical optimization models are presented which not only consider various load scenarios, but also consider a simple route from one scenario to another.

Segment-Wise Pressure Control in Paper Deep Drawing: An Optimisation Approach

Cédric Brunk[1], Julian Mrochen[2], Peter Groche[1], Ulf Lorenz[2]
1: Institute for Production Engineering and Forming Machines, Technical University Darmstadt, Germany; 2: Chair of Technology Management, University of Siegen, Germany

Deep-drawing of paper is becoming increasingly important as a sustainable alternative to plastic-based packaging; however, its industrial applicability is limited by quality variations. In particular, the formation of wrinkles in the flange area and anisotropic springback resulting from direction-dependent material behaviour present key challenges. One approach to specifically influencing these effects is to use a segmented blank holder, which allows surface pressure to vary locally throughout the forming process. This, in turn, provides a wide range of control parameters for material flow management. Building on initial experimental investigations, this approach is formulated as an optimisation problem and thus placed within the context of technical operations research. The surface pressure, which can be adjusted segment-by-segment and depending on the draw depth, can be treated as a decision variable, whilst the resulting component quality is described by appropriate target variables. The resulting problem has a complex structure characterised by non-linear relationships, stochastic influences and interactions between the decision variables. The aim is to conceptualise this structure and to establish a basis for applying model- and data-based optimisation methods. This demonstrates how a forming process for fibre-based materials can be systematically translated into an OR framework and what potential this offers for process design.

Truss Topology Optimization for Additively Manufacturable Tool Structures

Apostolos Aslanidis, Julian Mrochen, Peter Frohn-Sörensen, Bernd Engel, Ulf Lorenz
Universität Siegen, Germany

The transition from mass production to mass customization poses a major challenge for forming technology, requiring resource-efficient, highly flexible, and additively manufacturable tool concepts. Conventional tools produced by subtractive manufacturing are typically designed as solid structures and lack both systematic mass optimization and process-specific functionalization. In contrast, additive manufacturing combined with topology optimization offers significant potential to address these limitations while enabling the reintegration of recycled scrap material into manufacturing processes. However, this requires the early and systematic consideration of manufacturing constraints. Against this background, this study presents an approach for developing additively manufacturable lightweight tools based on mixed-integer linear programming (MIP). The method employs truss topology optimization for targeted mass minimization and is embedded in an integrated design-to-manufacturing workflow linking finite element simulations, MIP, and CAD modeling. Additive manufacturing constraints are explicitly incorporated into the optimization procedure to ensure the direct manufacturability of the generated structures. The load cases for structural optimization are derived from validated finite element simulations of a bending process. The approach is demonstrated using a segmented, truss-based bending die for compression bending and evaluated in terms of structural performance and additive manufacturability. The proposed MIP-based truss optimization framework, combined with manufacturing-oriented modeling, enables the generation of robust, mass-efficient, and additively manufacturable tool structures. The early integration of manufacturing constraints is shown to be essential for industrial applicability. Furthermore, the approach provides a basis for the integrated design of load-path-optimized and adjustable tool structures with segmented functional surfaces within a unified optimization framework.

WB 15: Financial Management and Accounting: Accounting

Time: Wednesday, 02/Sept/2026: 10:30am - 12:00pm · *Location:* SR034 (WIWI)
Session Chair: Matthias Amen

Short-term allocation of orders to existing production sites with different German trade tax rates

Matthias Amen
Bielefeld University, Germany

Under the German Trade Tax Act, a company's total gross profit is allocated to the various production sites in proportion to labor costs. The allocated gross profit is then subject to local trade tax rates, which can vary significantly from municipality to municipality.

Profit is thus not taxed based on its origin. These circumstances must be taken into account when assigning orders to different production sites. Short-term production planning is no longer a simple LP model, as its objective function becomes nonlinear.

We present a model formulation and use AMPL as a tool for implementation. An instance of the problem is solved using a standard solver. The solution shows that it is necessary to explicitly account for business tax, as the allocation to production sites differs from that resulting from the solution to the standard LP maximization problem and leads to a higher net profit after business tax.

The Accounting Treatment of Cryptocurrencies in Consolidated Financial Statements for a Share Deal with Control under IFRS

Wladislav Gawenko
Lancaster University Leipzig, Germany

The accounting treatment of cryptocurrencies under IFRS is one of the most urgent and current topics for stakeholders of IFRS statements. According to the IASB's meeting agendas, an increasing number of stakeholders are demanding an IASB project on the accounting treatment of cryptocurrencies. The reason for this is that an increasing number of companies are holding cryptocurrencies and/or building their business models around them. However, there are currently no set rules on how to account for cryptocurrencies in the financial statements. Currently, only one statement from the IFRS IC, from June 2019, covers some cryptocurrencies. Also, there are some papers discussing the treatment of cryptocurrencies under IFRS. However, these only cover treatment in individual statements. There are no papers in the literature which discuss the treatment of cryptocurrencies in consolidated financial statements under IFRS. However, this is of great importance, as companies within a group may hold cryptocurrencies, thus creating many challenges. For example, measurement at the acquisition date in respect of a share deal with control. Furthermore, there is the issue of intragroup transactions, whereby companies may use cryptocurrencies to pay for products or services within a group, or have receivables or liabilities in the form of cryptocurrencies. In my presentation and paper, I will cover the main cryptocurrency transactions and present solutions for how to treat them in the consolidated financial statements for a share deal with control according to IFRS. These results are useful for companies and will also be presented to the IASB.

Do Investors Care About Biodiversity Greenwashing?

Charlotte Neuss, Matthias Horn, Andreas Oehler
Bamberg University, Germany

We investigate the relation between firms' biodiversity-related disclosures and stock returns and idiosyncratic risk. We use 10-K filings of US listed firms from 2018 to 2024 and text-based measures of biodiversity greenwashing risk. The evaluation is conducted through a customized large language model, with rule-based instructions for assessing the biodiversity disclosures. When considering biodiversity footprints provided by Iceberg Data Lab, we find that companies with high biodiversity impact show lower returns when their disclosure is subject to biodiversity greenwashing risk. We find a similar pattern for the idiosyncratic stock risk. The latter increases when firms with high biodiversity footprint provide disclosure with high biodiversity greenwashing risk. Notably, these results are based on biodiversity footprints adjusted by capital expenditure. The results do not hold when the biodiversity footprint is adjusted by sales. Our interpretation is that investors consider biodiversity risk as a future long-term risk related to long-term investments and not to recent sales. The findings highlight the importance of biodiversity disclosure practices for financial markets, emphasizing the need for standardized reporting frameworks and highlighting potential greenwashing risk faced by investors.

WB 16: Analytics, Data Science, and Forecasting: Prescriptive Analytics

Time: Wednesday, 02/Sept/2026: 10:30am - 12:00pm · *Location:* SR033 (WIWI)
Session Chair: Sven F. Crone

Data-Driven Order Fulfilment for Electronic Grocery Retailing

David Winkelmann[1], Charlotte Köhler[2], Hermann Jahnke[3]
1: University Of Vienna, Austria; 2: Europa-Universität, Viadrina; 3: Universität Bielefeld

Online grocery retailing poses complex operational challenges for providers in order fulfilment. We investigate the key decision problems arising in the three core phases of fulfilment: replenishment, picking, and delivery. Specifically, we analyse both their specific characteristics and their interaction with order acceptance decisions. Particular attention is paid to the role of data-driven approaches in improving process performance and retail profitability. Adopting a managerial and analytical perspective, we combine theoretical insights with practical implications. It highlights how integrated decision-making and advanced analytics can enhance operational efficiency, service levels, and economic outcomes in online grocery fulfilment.

Online Misinformation: A Generation and Propagation Model

Xuan Vinh Doan[1], Tri-Dung Nguyen[2]
1: University of Warwick, United Kingdom; 2: University of Kent, United Kingdom

We propose a model of how messages that may contain misinformation are generated and how they impact people's beliefs. The framework captures the sequential arrival of messages and the resulting dynamics of belief updating over time. The results show the asymptotic convergence of beliefs when individuals receive multiple messages, highlighting how beliefs can evolve given the generation framework.

The decision of whether to verify messages is explicitly incorporated into the model, accounting for the costs and incentives associated with verification. This allows us to analyze the verification decision under different settings, especially the setting of current belief and the properties of incentives.

Finally, the role of online platforms in message propagation is examined, together with user sharing behavior based on different incentives including social engagement, belief alignment, and reputation. It demonstrates how platform mechanisms and network effects influence the propagation of misinformation when the focus of the platform is to maximize user interaction.

Transhipment policies for a multi-echelon retailer with partial lost-sales

Anna-Lena Sachs, Ben Lowery
Lancaster University, United Kingdom

Inventory management of slow moving and expensive items, especially during the end of a product's life cycle, comes with a number of important operational challenges in retailing. Motivated by the collaboration with a large retailer selling mobile handsets, we consider an inventory system with integrated online and offline storefronts. Demand is stochastic and exhibits non-stationary, declining behaviour over a finite time horizon. Through transhipments, on-hand inventory levels at individual stores can be adjusted to better balance the overall distribution of stock. To accommodate for geographical distance and intractability of transhipments across large networks, we use clustering to create transhipment regions for stores to send stock. The overall aim is to reduce the stock across the system by the end of the horizon, as well as balancing system costs, and maintaining key KPIs. We model the problem as a Stochastic Dynamic Program minimising costs within the transhipment region, as well as at the warehouse. We formulate a solution framework integrating forecasting, clustering, and inventory and transhipment policies. Across real data for six handsets, we note a number of interesting observations on how each part of the framework affects different aspects of the cost and company KPIs. As a result, we find that the forecasting method selection has an important effect on inventory levels, whereas the service level is influenced most by the selection of inventory and transhipment decisions.

WC 01: GOR PhD Award

Time: Wednesday, 02/Sept/2026: 1:15pm - 2:45pm · *Location:* HS10 (AM)
Session Chair: Dominik Möst

Integrated Demand Management and Vehicle Routing – Theory and Applications in Sustainable Planning for Rural Shared Mobility-on-Demand

David Fleckenstein
University of Augsburg, Germany

In a variety of business models, logistical service providers face two intertwined decisions: which offers to make to requesting customers, and how to fulfill confirmed orders with a feasible route plan. The objective is often to maximize revenue net of routing cost. Due to structural similarities, application-specific problems belong to a common family of optimization problems, termed integrated demand management and vehicle routing problems (i-DMVRPs). The first part of this cumulative dissertation investigates i-DMVRPs from a theoretical, cross-application perspective. Building on a comprehensive literature review of models and solution concepts, it analyzes the properties of opportunity cost, which can be exploited in the development of approximation algorithms – a key component of many i-DMVRP solution approaches. The second part focuses on rural shared mobility-on-demand (SMOD) services, a flexible form of local public transport, as an i-DMVRP application of particularly high societal relevance. Using a real-world data set from the German SMOD provider FLEXIBUS, the dissertation identifies structural patterns in demand and analyzes the potential of various demand management approaches. Finally, it proposes a sustainable dynamic pricing approach that balances multiple social, environmental, and economic objectives and yields benefits for both providers and customers.

Computational Complexity of Robust Bilevel Optimization Problems

Dorothee Henke
University of Passau, Germany

Bilevel optimization problems involve two decision makers, a leader and a follower. Each player's decision influences the other player's optimization problem. The leader has to anticipate the follower's reaction, which can make the bilevel problem hard to solve. In terms of computational complexity, combinatorial bilevel problems are typically on the second level of the polynomial hierarchy.

In this work, we study three relatively easy and natural combinatorial bilevel problems. The Bilevel Selection Problem and the Bilevel Continuous Knapsack Problem can be solved in polynomial time and the Bilevel Minimum Spanning Tree Problem is NP-equivalent. All three belong to the class of partitioned-items bilevel problems.

We also study the additional complexity that uncertainty introduces in bilevel problems. In our setting of robust bilevel optimization, we assume that the leader does not have full information about the follower's objective and optimizes for the worst case. We consider several types of uncertainty sets and study their effect on the underlying bilevel problem. We present complexity results for a class of robust linear bilevel problems and thoroughly study robust versions of the Bilevel Selection Problem and Bilevel Continuous Knapsack Problem. The results reveal differences between robust bilevel and robust single-level optimization.

Machine Learning for Stochastic Dynamic Vehicle Routing Problems

Florentin Hildebrandt
Otto-von-Guericke Universität Magdeburg, Germany

Spontaneous transportation of passengers and goods is popular but challenging for logistics service providers. New requests, fleet outages, and traffic jams continuously necessitate route plan updates. Reacting to these uncertain events is not sufficient to ensure smooth operations. Instead, it is a strategic necessity to anticipate future developments to stay competitive. This constitutes a new problem class: stochastic dynamic vehicle routing problems (SDVRPs) with three main challenges: The planner must repeatedly search for new route plans, evaluate each route plans' long-term cost by anticipating future developments, and do so fast to provide a smooth customer experience. We show how machine learning may be embedded in established SDVRP solution methods to surmount the challenges. One particularly promising idea is based on the observation that many established solution methods are parameterized globally such that they perform well in uncertain environments. However, as we show, these methods can often be significantly improved by reparameterizing them dynamically based on the current decision state. We show for a wide range of problems how this reparameterization may look like, and how it is learned with reinforcement learning.

Equilibrium Learning in Auction Games

Matthias Oberlechner
Technical University of Munich, Germany

Markets increasingly consist of automated agents that adapt their behavior through independent learning. This raises fundamental questions about whether these systems achieve the equilibrium outcomes predicted by economic theory. In this dissertation, we demonstrate that automated agents using online learning algorithms can reliably converge to equilibrium in auction games with

incomplete information. We introduce an algorithmic framework that discretizes type and action spaces to learn distributional strategies via online optimization. We prove that discretized game equilibria approximate continuous equilibria in single-item auctions, and demonstrate empirically that the method closely approximates equilibria across diverse auction formats. To understand why learning algorithms converge, we analyze equilibrium problems through infinite-dimensional variational inequalities. We show that equilibria in first- and second-price auctions correspond to variational inequality solutions, yet standard sufficient conditions for convergence fail. This opens important questions about why algorithms converge in practice. Despite the lack of convergence guarantees, our framework can analyze settings where analytical solutions are unknown. We demonstrate this by addressing a practical question from display ad exchanges, where we show that second-price auctions achieve higher revenue under return-on-investment maximization, and that bandit algorithms show no systematic deviation from equilibrium. Overall, this work demonstrates that market automation need not undermine equilibrium predictions of economic theory.

WC 02: Mobility, Transport, and Traffic: Transportation in Logistics

Time: Wednesday, 02/Sept/2026: 1:15pm - 2:45pm · *Location:* HS1 (PHIL)
Session Chair: Benedikt Schulz

An Exact Solution Approach for a Direct Delivery Scheduling Problem in Intralogistics

Oleg Horshkov, Julia Lange, Timo Gschwind
Rhineland-Palatinate Technical University Kaiserslautern-Landau, Germany

In make-to-order manufacturing systems intralogistics transport is crucial for timely order fulfillment. Customer orders must be shipped at certain time points, which often do not align with production completion times. Since storage capacities in production, shipping and intermediate storage areas are limited, the coordination of transport and storage activities constitutes a challenging planning problem.

To deliver orders to the shipping area and pickup orders from the production area, three types of direct transports with predefined origins and destinations can be used. Existing work considers only the case of unique orders, where these so-called trips must be selected, scheduled, and assigned to vehicles from a homogeneous fleet. We extend the planning problem by considering product groups so that several production orders and initial inventories may be available to fulfill a customer order. In addition, limited capacity in the intermediate storage area requires scheduling decisions for stored orders.

We propose the first mixed-integer programming (MIP) formulation for the direct delivery scheduling problem with intermediate storage and order matching. The problem is modeled as determining sequences of trips for each vehicle in a trip-based graph, ensuring all orders are fulfilled while simultaneously minimizing both the total travel time and the number of vehicles deployed.

Computational results obtained by a general MIP Solver allow for initial managerial and methodological insights. To improve scalability, we derive an exact decomposition approach separating order matching and trip selection from routing and scheduling decisions, and evaluate its performance against the MIP solver approach.

Optimizing DSV's land transport linehaul network

Katrin Heßler, Tilo Wiedera
DSV, Germany

We investigate a real-life network optimization problem, where shipments must be routed from origin to destination terminals. The underlying network is given as a directed multi-graph, with terminals represented by nodes and connections between terminals by arcs. The routing of each shipment through the network is uniquely determined by a global transit function, which specifies the next terminal based on the current departure terminal, the day of the week, and the destination terminal.

The goal is to find a transit function such that all shipments arrive within their respective lead times while minimizing total costs, which are composed of handling costs at terminals as well as tariff and vehicle costs on connections. Additional constraints, such as limiting the number of vehicles per connection, can be set. Generally, the transit function can only be modified in a limited way because subsets of decisions are interdependent and routes are strongly coupled.

Typical real-world instances are large and highly constrained, making the development of an efficient solution approach challenging. To tackle the problem at hand, we present a path-based formulation solved by a MIP solver. Moreover, we propose a heuristic that first determines a feasible solution by alternating between a repair operator and Iterated Local Search (ILS) with a complex penalty function. Feasible solutions are then improved using ILS with several neighborhoods that locally modify the transit function and a comprehensive perturbation routine. Computational results on real-life instances show the effectiveness of both methods and help to significantly reduce the linehaul transport costs.

Modeling and Performance Analysis of Multi-Load Automated Guided Vehicles

Benedikt Schulz
KIT, Germany

Since many years, automated guided vehicles (AGVs) are used in industry to perform transportation tasks. In literature, many methods for planning and control of AGVs have been proposed. While most AGVs are designed to transport a single load at a time, multi-load AGVs gained increasing interest in research and practice in recent years. In contrast to single-load AGVs, multi-load AGVs are able to transport multiple loads at a time. On the one hand, this brings about a higher degree of freedom when it comes to operations. On the other hand, this degree of freedom complicates performance evaluation and analysis of multi-load AGVs, which is an important issue when it comes to designing an AGV system.

To evaluate and analyze the performance of multi-load AGVs, we first model an AGV system using a Markov Chain. Thereby, we accommodate the degree of freedom regarding operations by integrating possible decisions within the logic of the Markov Chain. Based on the steady state distribution, different performance measures can be determined. Building on that, we conduct numerical

experiments and analyze the performance of multi-load AGVs depending on different system parameters. Based on the results, we finally formulate recommendations regarding planning and control of multi-load AGV systems.

WC 03: Mobility, Transport, and Traffic: Hub Location and Resource Acquisition

Time: Wednesday, 02/Sept/2026: 1:15pm - 2:45pm · *Location:* HS3 (PHIL)
Session Chair: Yannick Scherr

A Bilevel Hub Location Problem with weight categories

Nele Pommerening, Christoph Buchheim
TU Dortmund University, Germany

We study a bilevel variant of the well-known hub location problem. Here, a logistic service provider (the leader) wants to build up a complete new network. So she can decide the hub locations and the allocations. Moreover, she has to set prices for each route and for each weight category. So instead of letting the customer pay per volume, as an input there are given some weight categories and for every category the leader can set a price. Following that, the customer decides about booking the transport or not. This decision is based on his budget, which the leader knows in advance, so the customer will book the transport if the price is lower than his budget.

The leaders goal is it to maximize her profit, so on the one hand she prefers higher prices but she also has to take the customers' reaction into account, who can reject the transport if the price is too high.

Due to the classical hub location, our bilevel problem is NP-hard. We present a Langrangian decomposition approach that yields the customers' decision problem which lies in P and an NP-hard prize-collecting Hub Location Problem. We specify Lagrangian multipliers and prove their optimality, showing that they leave no duality gap. As a by-product, we obtain a polynomial-time reduction of our bilevel problem to the more compact (single-level) prize-collecting problem which may offer a significant advantage with respect to the required computational effort compared to standard single-level reformulations.

A Hub Location Model for Rail Freight Network Design under Modal Share Constraints

Henning Preis, Daniel Haalboom, Uwe Höppner, Nikola Besinovic
TU Dresden, "Friedrich List" Faculty of Transport and Traffic Sciences, Chair of Railway Operations

Single wagonload transport is a key component of rail freight transportation, enabling flexible and sustainable logistics for medium-sized shipments. Public loading locations provide essential access to the rail network and play a critical role in increasing the modal share of rail freight. In Germany, 579 public loading locations are connected to the rail infrastructure, but they differ significantly in their operational relevance.

This paper investigates a hub location problem with modal share constraints, aiming to determine the minimum set of public loading locations required to achieve a prescribed share of rail transport. The selected locations serve as consolidation hubs for single wagonload operations. The model is based on real-world demand data derived from transport forecasts for 2040 and is solved using CPLEX. Results show that the required share of rail transport can be maintained with a reduced number of actively used public loading locations for single wagonload operations. This highlights the potential to reallocate existing locations towards other rail freight functions, such as block train operations or additional logistics services, while preserving overall network performance. The findings provide a quantitative basis for identifying network-relevant locations for cross-docking activities and demonstrate the value of integrating modal share constraints into strategic rail freight network design.

The Scheduled Service Network Design Problem with Terminal Resource Acquisition

Yannick Oskar Scherr[1], Simon Belieres[2], Mike Hewitt[3]
1: University of Vienna, Austria; 2: TBS Business School, France; 3: Loyola University Chicago, USA

Freight transportation requires careful tactical planning for efficiently moving commodities between terminals of a middle-mile network. Commonly, decisions about the acquisition of terminal resources, such as dock doors available for loading and unloading vehicles, and decisions on designing and scheduling the service network, i.e., regular vehicle movements between terminals, are made sequentially. Motivated by the rise of fourth-party logistics providers, we propose the Scheduled Service Network Design Problem with Terminal Resource Acquisition integrating this decision making. We present two mathematical models, one classical formulation based on time-expanded networks and one consolidation-based formulation that relies on enumerating potential consolidations. Given the computational difficulties of solving large instances, we propose an Integer Programming-Based Local Search (IPBLS) method that repeatedly solves well-chosen restrictions of the consolidation-based formulation. To assess the value of integration, we consider a sequential process as a benchmark approach that comprises two subsequently solved subproblems. The first one allocates terminal resources on a static network, and the second one determines scheduled vehicle movements and commodity consolidations. We conduct computational studies to analyze the performance of the solution approach, to assess the value of integration, and to gain insights into the structure of solutions from integrated decision making. The observed value of

integration can be significant, sometimes exceeding 50 %, and is particularly sensitive to the duration of (un)loading operations. Integrated decision making leads to solutions that notably reduce the need for terminal resources and the associated costs.

WC 04: Energy and Sustainability: CO2 capture, transport, use and storage

Time: Wednesday, 02/Sept/2026: 1:15pm - 2:45pm · *Location:* HS13 (IM)
Session Chair: Frank Meisel

Contract Driven CO2-Transport Network Design

Stephan Bogs[1], Ali Abdelshafy[2], Grit Walther[1]
1: RWTH Aachen University, Germany; 2: TU Delft, Netherlands

As industries face increasing pressure to reduce emissions, Carbon Capture and Storage (CCS) is widely considered a key mitigation option. Its deployment requires transport infrastructure linking CO2 sources with geological storage sites. Pipelines are central to this infrastructure due to their economies of scale, yet they offer limited flexibility once constructed.

The development of CO2 transport networks therefore involves sequential investment decisions under uncertain participation by industrial emitters. Pipeline operators expand networks incrementally as capture projects materialise and connection requests arise. This paper models the pipeline operator's expansion problem as a Markov Decision Process, capturing how connection opportunities emerge over time and how operators decide whether and when to extend the network.

The model represents the arrival of potential emitter connections and the operator's decision to expand the pipeline network to serve them. At each decision stage, the operator weighs expected revenues from new contracts against infrastructure investment costs while accounting for uncertainty about future participation. This framework enables the analysis of how different institutional settings shape infrastructure development.

The paper compares operator behaviour and resulting network outcomes across three stylised third party access regimes: (1) mandatory acceptance; (2) constrained rejection, where operators retain limited discretion to refuse connections; and (3) free acceptance of contracts. The model is applied to a case study of the German cement and lime industry, a sector in which CCS is widely considered necessary to address process emissions.

A CO2-Price-Driven Model for Optimal Infrastructure Planning in Germany's Industrial Heartland

Roman Landwehr, Valentin Bertsch
Ruhr University Bochum, Germany

The European Green Deal sets an emission target of net zero for 2050, leading to major changes across sectors like energy conversion, heating, and transportation. The resulting infrastructure projects to achieve these goals need years to complete and require a robust basis for decision-making.

While emissions in some sectors can be mitigated relatively easily, in others, additional challenges arise. Especially in the chemical industry, process-inherent emissions make their reduction more challenging and net-zero targets, in some cases, even impossible to achieve.

To ensure decarbonization in such sectors, Carbon Capture and Storage (CCS) could be a solution. Nevertheless, how to utilize and transport the captured carbon in a cost-efficient manner remains an open question.

We present a CO_2-price-driven model to determine a least-cost infrastructure in Germany, with a focus on North Rhine-Westphalia as a highly industrialized region, and to identify a pathway to achieve net-zero emissions by 2050. The model optimizes whether CO2 is transported and stored via a dedicated infrastructure or released to the atmosphere subject to a CO2-price. Sinks, usage of carbon in the chemical industry itself, and the cost of different types of transport are incorporated.

Driven by different emission scenarios and CO2 prices, the results allow for comparing the impact on infrastructure costs and carbon released into the atmosphere. Furthermore, insights into what a future infrastructure could look like are presented, highlighting the amount of carbon that needs to be transported and stored, thereby adding further information for decision-makers.

Optimization of the Ramp-up of Carbon-Capture-and-Storage Supply Chains

Frank Meisel, Lisa Herlicka
Kiel University, Germany

Carbon capture and storage (CCS) requires coordinated capture, transport, and storage infrastructure. In this talk, we present a mixed integer linear program (MILP) to analyze the ramp-up of corresponding CCS supply chains under increasing capture targets. The model integrates several relevant problem features such as transportation mode selection, pipeline and vehicle deployment, capture decisions, condition changes, intermediate storage, and permanent storage within a multi-period framework. To enable a regional case study for Germany, emission sources are spatially clustered and connected through a backbone pipeline structure that allows the evaluation of regional transport configurations during the ramp-up phase. For this methodological approach, the MILP is decomposed into subproblems that individually address subsets of the entirety of decisions. The solutions to the subproblems are then composed into an overall solution of the problem. Our case study for Germany evaluates the resulting cost, infrastructure requirements, and ramp-up processes for various capture targets.

WC 05: Energy and Sustainability: OR for industrial symbiosis - the case of Greenlab in DK

Time: Wednesday, 02/Sept/2026: 1:15pm - 2:45pm · *Location:* HS11 (IM)
Session Chair: Leon Aahave Uhd

Cost-Environmental Trade-offs and Internal CO_2 Pricing in Eco-Industrial Clusters

Nicolas Campion[1], Dhruv Sharma[2], Giulia Montanari[4], Christos Koumparakis[3], Zoé Wieser[2], Rasmus Bramstoft[2], Dogan Keles[2]

1: Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping, Denmark; 2: Technical University of Denmark (DTU); 3: E3-Modelling (E3M); 4: Politecnico di Torino

Using the GreenLab Skive eco-industrial cluster as a case study, this analysis applies a greenfield, multi-objective optimization approach to identify trade-offs between costs and environmental impacts across both the construction and operation of the cluster. The assessment incorporates a full life-cycle analysis of the cluster's components, with particular attention to grid-related impacts. Building on this sustainable design, we then examine how internal CO_2 prices emerge as a function of system design and market structure, focusing on the interaction between a biogas plant (CO_2 source) and a methanol plant (CO_2 demand). Two market configurations are considered: a central planner setting, in which prices arise from the joint optimization of all actors, and a firm-level setting, in which actors optimize individually and prices emerge from their strategic interaction.

The cost-environmental trade-off analysis shows that electricity consumption from the Danish grid is the dominant driver of environmental impacts, followed by the biogas supply chain. On-site renewable generation, particularly wind, combined with storage and smarter grid use can substantially reduce these impacts. Optimizing solely on electricity price signals does not guarantee low environmental impact, highlighting the need to monitor embedded grid emissions and adjust operations accordingly. The internal CO_2 pricing analysis reveals that prices are primarily driven by resource scarcity and system flexibility. Under coordinated operation, the average price is 78 EUR/t, with notable variability across scenarios. Under strategic behaviour, it rises to 137 EUR/t highlighting challenges from misaligned incentives.

How Energy Storage Deployment Shapes the Phased Evolution of Industrial Energy Symbiosis Networks — A What-if Analysis of GreenLab Skive

Shi You, Alberto Alamia, Marta Victoria, Parisa Rahdan, Rossella Frugis

Technical University of Denmark, Denmark

Industrial energy symbiosis networks enable resource efficiency by facilitating cross-facility exchanges of heat, gases, electricity, and other energy carriers. Integrating energy storage can further enhance flexibility, resilience, and sustainability. However, existing literature often overlooks a critical reality: within such symbiotic networks, facilities—and their respective owners—operate under different development stages, business strategies, and risk profiles. This temporal and strategic heterogeneity drives a phased evolution of the park operator, progressing from L1 (Foundation: Basic Utilities) to L2 (Value-Add: Service Advantage), L3 (Asset Operator: Asset-Based Optimization), and ultimately L4 (Orchestration: Systemic Synergy).

Using GreenLab Skive, a Danish industrial symbiosis network, as a case study and evaluating a set of 2030 target scenarios, this paper shows that the value of energy storage—across multiple storage types—changes substantially as the operator transitions from L1 to L4. Moreover, the magnitude and nature of this value depend strongly on the collaboration model and the maturity level of the industrial symbiosis network.

The GreenLab Research Platform - a case for OR in praxis

Leon Aahave Uhd[1,2]

1: Technical University of Denmark, Denmark; 2: GreenLab A/S, Denmark

Green industrial clusters promise deep decarbonisation by coupling renewable power with flexible industrial processes, storage, and circular resource exchange—yet their operation requires coordinated decisions across timescales, energy carriers, and stakeholders. This session introduces The GreenLab Research platform: a mission-driven research and demonstration environment that turns “wicked problems” of the green transition into solvable challenges by connecting researchers, companies, and other stakeholders. The platform’s core approach combines applied research, testing results in real-life settings, and upscaling solutions that have previously only been demonstrated at small scale, with a strong focus on higher TRL activities, commercialisation, and new market creation.

We present GreenLab as a living laboratory for Operations Research: a place to study multi-energy system optimisation, industrial symbiosis network design, and market-compatible control of an integrated site-level energy system under uncertainty. We outline a unifying OR agenda spanning: (i) planning—capacity sizing, infrastructure layout, and investment under policy, technology, and price uncertainty; (ii) operations—stochastic dispatch and scheduling across electricity, heat, and molecules, including flexibility and storage; and (iii) coordination—mechanism design and incentive alignment for sharing surplus energy and resources among independent firms.

This abstract frames the specialised GreenLab session: the following 3–4 talks will dive into focused methods and pilots, while linking back to the shared platform narrative and cross-cutting decision problems that determine scalability and impact.

WC 06: Discrete and Combinatorial Optimization: Quadratic Optimization

Time: Wednesday, 02/Sept/2026: 1:15pm - 2:45pm · *Location:* HS5 (WIWI)
Session Chair: Sven Mallach

Preprocessing for Maximum Cut and Quadratic Unconstrained Binary Optimization: A Unified View and New Rules

Chris Cohadari[1], **Sven Mallach**[2]
1: University of Bonn, Germany; 2: University of Siegen, Germany

We study preprocessing techniques for the Maximum Cut (MaxCut) problem, which play an important role in solving real-world instances to optimality. MaxCut and the Quadratic Unconstrained Binary Optimization (QUBO) problem are well-known to be equivalent, and both communities have independently developed a variety of preprocessing rules. We systematically investigate the relationship between these rules and present a unified view. Inspired by existing QUBO rules, we derive novel preprocessing rules and establish their correctness using techniques from the MaxCut perspective.

A Parallel Heuristic for the Fixed Cardinality Binary Quadratic Program

Thi Thanh Tu Le[1], **Thorsten Koch**[2]
1: Software and Algorithms for Discrete Optimization, Technische Universität Berlin, Germany; and Applied Optimization Department, Zuse Institute Berlin, Germany; 2: Chair of Software and Algorithms for Discrete Optimization, Technische Universität Berlin, Germany; and Applied Optimization Department, Zuse Institute Berlin, Germany

The fixed cardinality binary quadratic optimization problem (FCBQP) requires each feasible solution to contain a prescribed number of one-valued variables. In this study, we propose a new parallel heuristic for the FCBQP. High-quality initial feasible solutions are generated by an impact-based variable selection. A combination of tabu search with guided restarts and path-relinking is then used to balance intensification and diversification throughout the search. We conduct extensive experiments with the proposed heuristic on benchmark instances from various applications, including the maximum dispersion problem, the maximum clique problem, and the minimum bisection problem. The experimental results show that the new heuristic is competitive and often attains the best-known solutions on many instances in the benchmark set.

Strengthening a linearized non-convex program for the Hospital Facility Layout Problem

Sven Mallach
University of Siegen, Germany

We consider the Hospital Facility Layout Problem (HFLP) which asks for a two-dimensional rectangular arrangement of facilities with a given area restriction such as to minimize the costs of material and personnel flow between them. Since both the positions and the precise shape of the facilities are variable, the HFLP proves very difficult, i.e., it can be solved only for very small instances with current techniques. In this talk, we revisit the classical model by Montreuil et al., which approximates the area of a facility via its perimeter, in lieu of solving a straightforward non-convex mixed-integer quadratic program. We then focus on strengthening the linearized model with McCormick inequalities which has an effect on both the quality of the area approximation and the bounds obtained in a branch-and-bound scheme, and we compare its performance with the one obtained when solving the non-convex program. Effectively, we obtain several variants each of which differs in the quality of the area approximation. Moreover, we introduce further valid inequalities to strengthen the continuous relaxation of any of the models at hand.

WC 07: Discrete and Combinatorial Optimization: Applications 2

Time: Wednesday, 02/Sept/2026: 1:15pm - 2:45pm · *Location:* SR029 (WIWI)
Session Chair: Nathan Sudermann-Merx

A Matheuristic Method for the CpMP with Territorial Coverage Constraints

Felipe Albuquerque[1], Rosa Figueiredo[1], Cyrille Genre-Grandpierre[2]
1: Laboratoire Informatique d'Avignon, Avignon Université, France; 2: UMR 7300 ESPACE, Avignon Université, France

Location Science addresses the challenge of optimally placing facilities to serve populations efficiently and equitably. In this work, we consider the Capacitated p-Median Problem (CpMP) with territorial coverage constraints, ensuring that solutions respect the geographical divisions critical for public service planning. Given a set of customers and a set of candidate locations for facility installation, the problem seeks to select exactly p facilities and assign each customer to an open facility, minimizing the total distance between customers and their assigned facilities, while respecting capacity limits. The territorial coverage constraints require that a minimum number of facilities be installed within each predefined territorial division, guaranteeing service presence across the region. We first study exact solution techniques and extend them to a Random Sampling and Spatial Voting (RSSV) matheuristic, which integrates heuristic reduction techniques with exact optimization methods to efficiently handle large scale instances. The approach is evaluated through a real world case study focused on public services in France, examining different scenarios and territorial divisions. Experiments compare the performance of the pure exact method against the proposed matheuristic in terms of solution quality under a fixed execution time limit. Furthermore, an accessibility analysis examines the trade-off between equity and objective cost by contrasting solutions obtained with and without the territorial coverage constraints.

A Benders-Inspired Exact Solution Method for the Stackelberg Competitive Facility Location Problem

Warley Almeida Silva[1], Margarida Carvalho[1], Sanjay Dominik Jena[2]
1: Université de Montréal, Canada; 2: Université du Québec à Montréal, Canada

In competitive markets, companies must decide where to open facilities while anticipating how competitors will react to their location decisions and, furthermore, how customers will patronize available facilities. The resulting Stackelberg Competitive Facility Location Problem is notoriously difficult to solve, as the search space grows rapidly with the number of candidate locations, targeted customers, and installed facilities. We propose a Benders-inspired exact solution method that reformulates how customer choice behavior is represented in the underlying mathematical formulation. Instead of the traditional primal representation — which tracks assignments of customers to locations through a large number of variables and constraints — we leverage a dual representation that describes revenues extracted from customers more compactly. We prove that this dual representation requires only a polynomial number of constraints and provide an analytical procedure to compute them. We then develop a branch-and-cut algorithm that (I) incorporates tightened value-function cuts to address the bilevel nature of the problem and (II) generates dual-representation constraints on-the-fly. Computational experiments show that our branch-and-cut algorithm requires, on average, 24 times fewer value-function cuts than the state-of-the-art to certify optimality. Our branch-and-cut algorithm equipped with the dual representation of customers choice' behaviour is also approximately 10 times faster than when equipped with the primal one, with performance gains that grow with the number of targeted customers. These results indicate that reformulating how customer behavior is represented can yield performance improvements for competitive location problems.

Heilbronn's Triangle Problem on the Unit Square Using Mixed-Integer Optimization

Nathan Sudermann-Merx
DHBW Mannheim, Germany

The Heilbronn triangle problem is a classical problem in discrete geometry: how should n points be placed in the unit square so that the smallest triangle formed by any three of them has maximal area?

We develop an optimize-then-refine framework that integrates global mixed-integer nonlinear programming with exact symbolic computation. A novel symmetry-breaking strategy based on the boundary structure of optimal configurations yields a substantially stronger optimization model: for nine points, the problem can be solved to certified global optimality in 15 minutes on a standard desktop computer, improving upon the previously reported effort of about one day by more than an order of magnitude.

Combining the numerical certificate with exact symbolic computation, we provide the first proof that the nine-point configuration discovered by Comellas and Yebra in 2002 is globally optimal, and derive exact coordinates for all optimal configurations with nine or less points. An analysis of these configurations reveals structural patterns - notably the clustering of noncritical triangle areas around a small number of distinct values - which give rise to new research questions. All configurations and code are publicly available.

WC 08: Supply Chain Management and Production: Designing Manufacturing Systems

Time: Wednesday, 02/Sept/2026: 1:15pm - 2:45pm · *Location:* HS9 (AM)
Session Chair: Justus Arne Schwarz

The Dynamic Facility Layout Problem with Modular Production Capacities

Bajram Mavraj[1], Tristan Becker[2], Stefan Lier[1]
1: Department of Engineering and Economics, South Westphalia University of Applied Sciences, Meschede, Germany; 2: Faculty of Business and Economics, Technische Universität Dresden, Dresden, Germany

Standardisation and physical relocatability are core principles of modular production concepts: factories are assembled from modules that can be placed, relocated, activated, and deactivated as demand and product mix evolve. This kind of layout flexibility opens a new factory planning problem in which module type, count, placement, and reconfiguration timing must be decided jointly.

The literature on facility layout offers the Dynamic Facility Layout Problem (DFLP), which optimises the spatial arrangement of a fixed, often homogeneous set of units across multiple periods. A neighbouring stream, Reconfigurable Manufacturing Systems (RMS), focuses on selecting and configuring variable module sets while treating location largely as an abstraction. Recent work has begun to bridge these streams, yet typically retains two simplifying assumptions: (i) a variable number of modules is not combined with heterogeneous modules on a geometric multi-period layout, and (ii) reconfiguration time is not modelled as a capacity-effective loss with type-dependent ramp-up dynamics. Both assumptions trace back to treating modules as fixed, identical units. Once this abstraction is lifted, module type, count, placement, and inter-period transitions become tightly coupled, rendering sequential approaches inadequate.

To close this gap, we formalise the Dynamic Modular Facility Layout Problem (DMFLP) as a mixed-integer programming model that jointly optimises the selection, placement, and relocation of heterogeneous modules, while explicitly accounting for reconfiguration downtime through capacity constraints. We study the scalability of exact approaches, identify the key drivers of computational difficulty, and propose a heuristic that scales the model to practical-sized instances, motivated by the bio-based process industry.

A Convolutional Neural Network Surrogate Approach for Integrated Performance Evaluation & Optimization of Flow Lines via Mixed-Integer Programming

Justus Arne Schwarz, Andreas Kloos
University of Regensburg, Germany

Simulation is widely used for evaluating stochastic manufacturing systems, due to its adaptable modeling capabilities and the absence of exact or even approximate analytical solutions. However, solving optimization problems with performance evaluation via simulation can be time-consuming, due to the need for many replications and the combinatorial complexity of the problems. To increase the speed of performance evaluation, the existing literature suggests replacing simulation with Artificial Neural Networks pretrained with simulation results. We train a Convolutional Neural Network (CNN) with flow line feature data to predict flowline throughputs for different system configurations. The proposed CNN architecture enforces domain-specific structural properties of the underlying system. We then solve the Buffer Allocation Problem (BAP) by linearizing the trained CNN, thereby transforming the non-linear problem into a mixed-integer linear problem (MILP), which is tractable by standard solvers. We introduce a structured sampling strategy for training data generation and investigate the effects of regularization methods on the MILP. Furthermore, we demonstrate the flexibility of our approach by applying it to different production networks and optimization problems.

Enhancing Operational Reliability in Aviation MRO: A Systematic Literature Review on Dynamic Bowtie Analysis for Optimization of Critical Industrial Asset Management

Prudente Jose Tavares Aguiar, Carmo Credíney Melo, Jose Cristiano Pereira, Luciano Moreira da Silva Varricchio, Felipe Machado Lopes, Bruno Malhano de Oliveira Jordao
Universidade Católica de Petrópolis, Brazil

Background and Objectives: In the high-stakes component repair segment of jet engine MRO, operational quality and on-time delivery depend on the reliability of highly specialized assets such as vacuum furnaces and laser cladding cells. Performance drift or failure directly leads to quality escapes, turnaround delays, and regulatory non-conformances. This study conducts a systematic literature review to examine how Dynamic Bowtie Analysis can be deployed to optimize operations, safeguard process quality, and enhance asset reliability in this context.

Methodology: The review follows the PRISMA framework, querying Scopus and Web of Science (2010–2025). Search terms combined “bowtie analysis” and “risk-based maintenance” with domain-specific keywords such as “critical equipment,” “aviation

MRO," and "component repair." The focus was on applications where dynamic bowtie, integrated with operational systems (e.g., ERP, maintenance and training systems), enables proactive, real-time risk control of critical assets in precision repair environments.

Findings: Two main contributions emerge. First, Bowtie Analysis provides a clear visual link between asset failure modes (e.g., calibration drift) and potential quality defects, supporting targeted barrier design. Second, semi-dynamic implementations incorporating real-time condition data transform bowtie into a tool for prioritizing maintenance actions and validating barrier effectiveness, reducing defects and unplanned downtime.

Originality/Value: This review offers an operation-centric synthesis of Dynamic Bowtie Analysis for industrial asset management in aviation MRO, outlining pathways for implementation through digital dashboards and quantitative barrier metrics to improve asset uptime and first-pass yield.

Keywords: Bowtie Analysis; Operational Reliability; Industrial Asset Management; Risk-Based Maintenance; Aviation MRO; Quality; Critical Equipment.

WC 09: Artificial Intelligence, Machine Learning and Optimization: Routing and Scheduling 2

Time: Wednesday, 02/Sept/2026: 1:15pm - 2:45pm · *Location:* HS7 (WIWI)
Session Chair: Rossana Cavagnini

Convergence of Regularized Fictitious Play in Dynamic Traffic Assignment

Tobias Harks, Andreas Wever, Fabian Wirth
University of Passau, Germany

This article investigates the dynamics of regularized fictitious play in dynamic flow networks to eventually learn a (regularized) dynamic equilibrium. The resulting dynamical system lives in an infinite dimensional Hilbert space and as a first result we show that, in general dynamic flow networks, solutions to initial value problems for this dynamical system exist for all positive times. We then specialize to the case of monotone path delay operators and show uniqueness of regularized equilibria. Furthermore, for the monotone case and under the assumption that the path delay is locally Lipschitz continuous, it is shown that regularized fictitious play globally converges to the unique regularized equilibrium. The proof is based on Lyapunov stability theory and uses several structural results on the regularized best-response correspondence. We finally test regularized fictitious play empirically for instances (including a real-world network) that do not satisfy the monotonicity condition. It turns out that despite the lack of monotonicity, the dynamics seem to exhibit converging trajectories.

Agent-enabled Optimization of Airport Gate Assignment

Shaham Jafarpisheh, Heba Elkilany, Georg Reuber, Joseph Doetsch
Lufthansa Industry Solutions, Germany

This contribution investigates how agentic AI can complement established methods in operations research by enabling natural language interaction with optimization models for airport operations. Focusing on the airport gate assignment problem at Hamburg Airport, we present a demonstrator in which users specify ad hoc rules and operational preferences in plain language, for example adding constraints for particular gates or flight types. The system translates these requests into consistent modifications of a preexisting optimization model, which is then solved by a standard mathematical programming backend.

This setup allows operative personnel to implement and test new gate assignment rules without writing code or involving specialized modeling experts, thereby reducing iteration time and communication overhead. In the conference presentation, the overall architecture and interaction design will be outlined, followed by a live demonstration of natural language driven gate assignment at Hamburg Airport and a discussion of benefits, current limitations, and future research directions for agentic AI supported decision making in operations research.

Data-Driven Activation Strategies for the Edge Set Vehicle Routing Problem with Time Windows

Rossana Cavagnini
University of Duisburg-Essen, Mercator School of Management, Chair of BWL, insb. Data Analytics, Germany

Urban restrictions and toll regulations introduce an additional decision layer to vehicle routing, particularly when sets of roads require a fixed activation cost before they can be used. The edge set vehicle routing problem with time windows addresses this challenge by jointly deciding which fee-based road sets to activate and how to route vehicles to serve customers within given time windows. Our solution approach combines machine learning with a metaheuristic to make these activation decisions more efficient. We extract descriptive features of each instance—such as road-set costs, customers' spatial distribution metrics, and time window characteristics—and use them to train a predictive model that identifies promising road sets for activation. The metaheuristic then constructs high-quality routes on the resulting reduced graph. The approach is designed to reduce computational effort while maintaining solution quality. We outline an experimental framework to evaluate performance against state-of-the-art methods on benchmark instances, and we investigate which instance features most strongly influence activation decisions.

WC 10: Optimization under Uncertainty: Vehicle Routing Problem

Time: Wednesday, 02/Sept/2026: 1:15pm - 2:45pm · *Location:* HS8 (WIWI)
Session Chair: Lelisa Kebena Bijiga

A Hybrid Tabu Search and Machine Learning Framework for the Stochastic Vehicle Routing Problem with Flexible Deliveries

Basak Çarhacıoğlu, Duygu Taş
Sabancı University, Turkey (Türkiye)

In this study, we address a vehicle routing problem with flexible delivery locations and stochastic travel times. This setting is motivated by real-life last-mile delivery systems in which customers may specify multiple potential delivery locations, each associated with its own time window. These time bounds are modeled as soft constraints, allowing deviations that are computed based on arrival time distributions. Such deviations are penalized through expected earliness and delay, reflecting customer dissatisfaction. The model incorporates both operational and service-related costs. Operational costs include the total distance traveled, the number of vehicles used, and the expected driver overtime, while service-related costs arise from the expected earliness and the expected delay.

Given the problem's computational complexity, we propose a tabu search based solution approach enhanced with a machine learning model, specifically logistic regression. During the search, features extracted from neighborhood moves are used to train predictive models that identify promising candidate moves. The trained model then guides the search toward more effective neighborhoods, reducing unnecessary evaluations and improving computational efficiency.

The performance of the proposed approach is thoroughly analyzed. To validate its effectiveness, the method is also tested on a deterministic version of the problem, for which optimal or best-known solutions are available in the literature. Results show that the proposed approach achieves optimal solutions for most instances, with an average optimality gap of 1.02%.

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On The Apparent Robustness of Variable Neighbourhood Search Operators in Vehicle Routing Problems

Berry Gerrits, Leendert Kok
University of Twente, Netherlands, The

Does the structure of a solution to a vehicle routing problem determine how it responds to operational perturbations such as congestion? Two routes may be similar in terms of objective value, yet one might absorb delays more gracefully while the other cascades into chaos. If solution structure matters for this so-called \textit{apparent robustness}, then the operators used to construct solutions also matter --- not because of their efficiency, but because of the geometric signatures they leave behind.

We explore this question through the lens of Variable Neighbourhood Search and its operators. A preliminary answer to this question --- through experiments on the Solomon instances --- reveals a fascinating duality. Our results suggest that inter-route operators like Single-Relocate tend to leave more slack in routes that can more easily absorb travel time fluctuations resulting in higher feasibility rates and fewer violated customers. Intra-route operators like 2-opt tend to produce more violations under uncertainty, affecting more customers with larger individual delays. Interestingly, combining intra- and inter-route operators produces superior routes in terms of the objective function with nearly identical slack levels, but a noticeably lower feasibility rate. On the other hand, the magnitude of the violation tends to be lower than with inter-operators. This duality suggests there is no universally robust operator, yet different operators . Understanding why certain solution structures absorb uncertainty better than others may ultimately matter more than which operator found them — pointing toward a geometry of robustness yet to be fully explored.

Resilient optimization for VRP subject to stochastic vehicle breakdown

Tjitze Karel Scheepstra, Bilge Atasoy
Delft Technical University, Netherlands, The

The problem studied in this work is a generic vehicle routing problem (VRP) that is subject to a stochastic vehicle breakdown. A set of initial routing decisions is implemented in the first stage and set of (centralized) recourse decisions is implemented after the vehicle breakdown has occurred in the second stage. The problem of interest reflects a number of challenges present in general logistics practices. For instance, this problem contains a (naturally imposed) hierarchical decision-making structure, where the initial decisions must be made under uncertainty, an inherent characteristic of logistics operations, which generally transpire in stochastic environments.

The problem formulation considers an uncapacitated VRP for which a routing plan is decided initially. During the execution of the initial plan, a random vehicle is guaranteed to break down at a random time point along its route. The remaining vehicles

instantaneously devise an optimal set of (centralized) recourse decisions to serve all remaining nodes in minimal time. The objective function of the resulting two-stage optimization problem is the VRP makespan of the worst-case vehicle breakdown realization. The optimal solution is a worst-case two-stage-optimal initial routing plan.

In our methodology we propose an exact algorithm to evaluate the worst-case stochastic VRP makespan with respect to the complete continuous uncertainty set. Together with a sample-based two-stage stochastic program, the optimal solution is obtained in an iterative manner.

WC 11: Software for Operations Research: Modern Algorithms and Frameworks

Time: Wednesday, 02/Sept/2026: 1:15pm - 2:45pm · *Location:* HS6 (WIWI)
Session Chair: Olivier Huber

Using VRPSolver's Price-and-Cut Engine within GCG

Marco Lübbecke[1], Erik Mühmer[1], Eduardo Uchoa[2]
1: RWTH Aachen University, Germany; 2: Universidade Federal Fluminense, Brazil

GCG and VRPSolver are branch-price-and-cut solvers that serve complementary needs. GCG is a general-purpose mixed-integer linear programming solver built on the SCIP framework. It automatically applies a Dantzig-Wolfe reformulation. VRPSolver directly works with the reformulated model for a wide range of vehicle routing and related problems. It deeply integrates a labeling algorithm for resource constrained shortest path subproblems with cutting plane separation. We experiment with joining these solvers, discuss challenges, early results, and a potential roadmap towards a unified framework.

Advances in parallelization of adaptive discretization-based algorithms for (generalized) semi-infinite programming

Adrian W. Lipow[2], Alexander Mitsos[1,2,3]
1: JARA-CSD, 52056 Aachen, Germany; 2: Process Systems Engineering (AVT.SVT), RWTH Aachen University, 52074 Aachen, Germany; 3: Institute of Climate and Energy Systems: Energy Systems Engineering (ICE-1), Forschungszentrum Jülich GmbH, 52425 Jülich, Germany

(Generalized) semi-infinite programs are hierarchical optimization problems with a finite number of variables and an infinite number of constraints. Adaptive discretization-based methods for global optimization of these problems are an active research area and multiple related algorithms have been published. In these methods, the original problem is decomposed into finite subproblems, which are solved with a standard optimization solver and then refined iteratively. While implementations of previously published algorithms allowed for parallelization at the subsolver level (assuming the use of an appropriate subsolver), they did not consider parallelization of the algorithmic steps.

In this contribution, we consider several adaptive discretization-based algorithms implemented in our C++ framework libDIPS [Jungen et al., Optimization Online (preprint, 2023), Math Prog Comp, In Press]. We extend the implementations to allow parallelization at the algorithmic level: The algorithms of [Mitsos, Optimization 60:1291-1308 (2011)] as well as [Mitsos and Tsoukalas, J Glob Optim 61:1-17 (2015)] allow for parallel upper- and lower-bounding, while the algorithm of [Tsoukalas and Rustem, Optim Lett 5:705-716 (2011)] allows several objective function values to be probed for feasibility in parallel. Using the library of test problems implemented

in libDIPS, we demonstrate that parallelization at the algorithmic level is a superior use of computational resources compared to parallelism within the subsolver.

ReSHOP: a modeling and algorithmic framework for complex optimization problems and equilibrium problems

Olivier Huber
GAMS Software GmbH, Germany

Algebraic modeling languages (AML) have shaped the problem structure considered in numerical optimization, and indirectly have an impact on the instances coming from applications and the ones considered by solvers. However, problems not fitting the classical AML format are abundantly found in applications. For instance, nonsmoothness commonly arises in (multistage) stochastic programming problems with coherent risk measures. Bilevel or multilevel models feature multiple optimization problems, and so do Nash equilibrium problems.

A given application can feature a combination of the above challenge. Consider the decentralized electricity market, where the weather affect the production level of some producers. This leads to a Nash equilibrium problem with multistage risk-averse agents. To capture these challenging but structured models, we propose a modeling framework based on a directed acyclic graph (DAG). The nodes are of two type: the first one subsumes classical optimization problems and variational inequalities, while the second one indicates a Nash behavior among its children nodes. The directed arcs capture the interactions between optimization problems. This modeling approach is implemented via annotation and extends an AML modeling power. Model transformations are defined over the DAG structure to convert part or all of the model into a form amenable to computations by existing solvers.

Many instances captured by this modeling paradigm fall outside of the scope for robust solvers, an algorithmic framework to solve these instances, for instance by decomposition or approximation, is presented. An implementation of these ideas is present in ReSHOP, a reformulation solver for hierarchical optimization problems.

WC 12: Decision Theory and Multi-criteria Decision Making II

Time: Wednesday, 02/Sept/2026: 1:15pm - 2:45pm · *Location:* HS2 (PHIL)
Session Chair: Daniel Hauer

ESG-Focused Supplier Selection Strategies Considering Risk and Digital Readiness: A Multi-Criteria Decision-Making Approach

Suzan Oguz[1], Adel Aazami[2], Zahradokht Rahmati[3]
1: Çağ University, Department of Foreign Trade, Yenice, 3800 Mersin, Turkiye; 2: Vienna University of Economics and Business, Austria; 3: Department of Industrial Engineering, Sharif University of Technology, Tehran, Iran

The study develops an integrated multi-criteria framework to prioritize ESG-focused supplier selection strategies by incorporating environmental, social, governance, risk, and digital readiness dimensions into a single decision problem. While existing research typically examines these dimensions in isolation, focusing on sustainability, circularity, risk, or digitalization separately, this study positions supplier selection as a strategic orientation choice rather than a purely criteria-based evaluation. A set of strategic approaches, ranging from low-carbon and circular procurement to ethical sourcing, governance-driven compliance, risk-sensitive assessment, and digitally enabled supplier integration, is evaluated using the Best-Worst Method to derive criteria weights and Fuzzy TOPSIS to rank strategic priorities under uncertainty. By integrating ESG concerns with risk exposure and digital capability requirements, the framework clarifies how firms can balance sustainability ambitions with operational resilience and technological maturity. The findings are expected to guide managers in identifying which supplier selection strategies will become more dominant under varying organizational conditions, offering a transparent and justifiable basis for strategic decision-making. The study contributes to the literature by bridging fragmented research streams and demonstrating the value of a unified, ESG risk digital perspective in shaping future supplier selection practices.

Optimal Reduction of Extreme Input-Output Substitution in Frontier-Based Incentive Regulation

Sara Kamali[1], Mohsen Afsharian[2], Heinz Ahn[1]
1: TU Braunschweig, Germany; 2: Leibniz FH, University of Applied Sciences, Germany

Frontier benchmarking is central to incentive regulation and is widely used by regulators to set efficiency targets and shape firms' cost-reduction incentives. However, its flexibility in assigning weights can lead to extreme input–output trade-offs and to evaluations that rely on frontier segments arising from free disposability. Using the Brazilian water and sewage sector as motivation, we study one regulatory response to these challenges: exogenous weight restrictions to limit such trade-offs. We show that these restrictions may alter the frontier more broadly and affect firms beyond those associated with the underlying issue, thereby giving rise to further issues, including acceptance, transparency, and interpretability. To address this challenge, we propose an alternative approach that operates directly on the frontier structure. The approach identifies the minimum number of efficient supporting hyperplanes required for evaluation and assesses firms relative to the retained hyperplanes. In this way, it replaces exogenously imposed trade-off restrictions with trade-offs derived endogenously from the frontier itself. The empirical illustration shows how the proposed approach can replace the regulator's current response and address the underlying issues in a more transparent and less controversial way. The proposed approach also provides a useful alternative in other regulatory contexts where similar trade-off problems arise in frontier benchmarking.

Fairness Objectives for the Multiway Number Partitioning Problem with an Application to Physician Duty Rostering

Daniel Hauer, Heiner Ackermann, Sandy Heydrich
Fraunhofer ITWM, Germany

The multi-way number partition problem assigns a multiset of positive integers to a fixed number of subsets so as to optimize a fairness objective. This NP-complete problem arises when loads must be shared equitably, for example when distributing unattractive duties among physicians in hospital rosters.

Common objectives—MinMax, MaxMin, and MinMaxDeviation—are easy to implement but focus on extreme recipients only and can permit arbitrarily large overall inequality. Minimizing global inequality, as measured by the Gini coefficient (or, equivalently, the total deviation), leads to substantially fairer allocations but is computationally demanding.

We propose the FLOP-k family of surrogate objectives, which minimizes the total load of the k worst-off recipients. We analyze how classical objectives relate to FLOP-k and how different FLOP-k variants approximate each other, deriving approximation bounds for different representatives of the FLOP-k family. We further study how the choice of k shapes the trade-off between fairness and computational effort.

Our analysis starts with a stylized setting with unit weights and then extends to general positive integer weights. Finally, we integrate FLOP-k objectives into a duty-rostering tool for a German hospital and evaluate the resulting schedules, showing that suitable FLOP-k choices closely mimic Gini-optimal solutions at much lower computational cost.

WC 13: OR in Developing Countries I

Time: Wednesday, 02/Sept/2026: 1:15pm - 2:45pm · *Location:* HS4 (PHIL)
Session Chair: Robin Schuchmann

Ethics and OR in different Cultures – Global-Indian collaboration

Gerhard-Wilhelm Weber[1], Jinal Parikh[2], Ismail Ozcan[3], Jacek Dominik Śledziński[1]
1: Poznan University of Technology, Poland; 2: Ahmedabad University, India; 3: University of Parma, Italy

In this talk the authors will express how their collaboration which initiated in 2018 from the EURO and IFORS conferences has evolved and turned in global collaborations. Specifically, we will discuss how we align our research across countries and topics which are of common interest to everyone in the teams that we work in. Examples of OR cooperation from India with Germany, Poland, Spain and Turkey, EURO and IFORS.

Scaling Climate Policy Impact Assessment: The UNFCCC CPIA-GEM Interface and the "Last Mile" of OR in the Maldives

Robin Schuchmann[1], Lindsay Shutes[2]
1: GAMS Software GmbH, Germany; 2: Elevate Economics, UK

Under the Paris Agreement, nations must implement ambitious climate policies while navigating complex socio-economic trade-offs. In developing economies, assessing the “response measures” of such policies is often constrained by limited access to specialized analytical tools. While Computable General Equilibrium (CGE) models provide the rigor needed to capture cross-sectoral effects, such as the impact of global decarbonization on a net oil importer like Maldives, their complexity creates a “black box” barrier for policy-makers.

This presentation explores the UNFCCC CPIA-GEM (Climate Policy Impact Assessment - General Equilibrium Model) interface as a solution to this deployment gap. Developed to make high-level economic modeling more accessible, the interface leverages GAMS MIRO to transform a sophisticated GAMS-based CGE model into an user-friendly, cloud-deployed SaaS application.

Focusing on recent capacity-building initiatives in Maldives, we demonstrate how this interface enables local analysts to stress-test domestic and international climate policies. By moving from static reports to interactive scenario analysis, the UNFCCC helps close the “last mile” of Operations Research: ensuring that rigorous mathematical insights directly support national decision-making. We further show how user-centric design supports climate action while safeguarding economic stability and social equity.

We conclude that the future of OR in development lies in making complexity operationally invisible, aligning advanced modeling with the practical needs of decision-makers on the path to Net Zero.

WC 14: Technical Operations Research II

Time: Wednesday, 02/Sept/2026: 1:15pm - 2:45pm · *Location:* HS12 (IM)
Session Chair: Lennard Hansmann

Kinematic Stability in Truss Topology Optimization: A Singular Disturbance Scenario Approach

Julian Mrochen[1], Michael Hartisch[2]
1: University of Siegen, Germany; 2: University of Passau, Germany

Kinematic instability poses a fundamental challenge in truss topology optimization, as unstable nodes can compromise both structural performance and numerical reliability. In current engineering practice, stability is typically enforced only after optimizing the force distribution — either by adding unstrained members or by iteratively modifying the layout until stability conditions are met. From an optimization perspective, however, such post-hoc corrections are problematic: designs optimized without stability considerations may result in suboptimal or practically inefficient structures. This motivates the development of optimization approaches that inherently guarantee kinematic stability from the outset.

We present the Singular Disturbance Scenario (SDS), an approach that distinguishes itself from established methods such as the Nominal Lateral Force (NLF) and Nominal Disturbing Force (NDF) approaches. While NLF and NDF rely on multiple disturbance scenarios computed implicitly during optimization, SDS precomputes a single disturbance scenario directly from the ground structure. The resulting nodal forces are incorporated into the optimization model and become active exclusively at nodes selected in the final design. The scenario is determined by solving a dedicated optimization problem that constrains every degree of freedom, leveraging the member directions and spanned planes of the predefined ground structure.

SDS is benchmarked against a conventional two-stage workflow in which load cases are optimized first and kinematic stability is subsequently restored through heuristic post-processing. The results demonstrate that SDS successfully integrates stability considerations directly into the optimization process, yielding truss designs that are kinematically stable across all evaluated instances.

A mathematical programming-based approach to examination timetabling using integer primary decision variables

Sina Nunes, Guido Sand
Pforzheim University of Applied Science, Germany

Examination timetabling is the problem to optimally assign exams to time slots and rooms under certain constraints; review and original research papers of the last 20+ years cover a spectrum of models and solutions algorithms. In mathematical programming-based approaches the degrees of freedom are typically modelled by two types of binary primary decision variables: 1) Each exam is assigned to a particular time slot or not. 2) Each exam is assigned to a particular room or not. In contrast, this paper introduces a new model using integer primary decision variables; their integrality relaxations are typically tighter than those of binary variables.

Firstly, the assignment of exams to time slots is modelled by an integer variable for each exam reflecting the assigned time slot. In addition, binary secondary decision variables reflect the relative sequence of exams. Secondly, the assignment of exams to rooms is modelled by an integer variable for each combination of exams and rooms reflecting the number of students taking this exam at this room.

The constraints model the real-world situation at Pforzheim University covering multiple study programs, synchronization of exams, exams requiring more than one time slot and exam splitting among rooms. The model is heuristically decomposed into sufficiently small mixed-integer programs and solved by a standard solver in four major steps. The decomposition carefully handles the binary secondary decision variables and the symmetry of solutions. In the full paper, the new model and solution approach will be described in detail along with numerical experiments demonstrating its performance.

A MINLP Approach to Flexible Template-Based Newspaper Layout Optimization

Lennard Hansmann
Universität Siegen, Germany

Newspaper layout design requires numerous decisions, from structuring pages to strategically placing content. Due to the vast number of possible arrangements and the multitude of editorial constraints, this task is inherently complex and time-consuming.

In this work, we present a mixed-integer nonlinear program (MINLP) for optimizing template-based newspaper layouts. In contrast to strictly fixed templates, our model introduces additional flexibility by allowing certain layout properties, to vary within predefined bounds. This enables the layout to adapt more naturally to content while still respecting structural constraints. Our aim is to facilitate the selection of feasible layout designs that minimize the need for post-editing, thereby enabling a more efficient and automated layout generation workflows.

WC 15: Financial Management and Accounting: Finance

Time: Wednesday, 02/Sept/2026: 1:15pm - 2:45pm · *Location:* SR034 (WIWI)
Session Chair: Michael Breitner

Investment and financing with a project life cycle

Michi Nishihara[1], Takashi Shibata[2], Artur Rodrigues[3], Paulo Pereira[3]
1: The University of Osaka, Japan; 2: Hosei University, Japan; 3: University of Porto, Portugal

This paper examines a dynamic investment and financing problem in a market incorporating a product life cycle, where market demand grows rapidly (i.e., the growth phase) until reaching a peak threshold (i.e., a turning point), after which the growth rate slows (i.e., the maturity phase). Debt financing decreases the investment threshold and increases the possibility of investment in the growth phase. A firm utilizes higher leverage taking account of lower bankruptcy risk in the growth phase than in the maturity phase. Then, firms that enter the growth-phase market earlier can have higher default risk when the market shifts to the maturity phase. This mechanism leads to a First In, First Out (FIFO) scenario especially with a bell-shaped pattern of PLC, while a First In, Last Out (FILO) scenario tends to occur with a plateau-type pattern of PLC. Higher volatility can decrease the option value of investment in the growth phase and lead the firm to invest in the maturity phase. The growth-phase investment threshold with debt financing can be nonmonotonic with levels of the peak threshold, while that of the unlevered firm is independent of the peak threshold.

Zero shots, on target: Transformer-based financial sentiment for earnings call Q&A sessions

Jan König, Ralf Kellner
Uni Passau, Germany

Measuring financial sentiment has traditionally relied on domain- and task-specific models, such as dictionaries, machine-learning models, or fine-tuned transformers. We study how zero-shot sentiment measures from a transformer-based model perform in explaining short-term market reactions around earnings calls. We employ a BART model fine-tuned for natural language inference to measure positive and negative sentiment in the Q&A sessions of earnings call transcripts, comparing its performance to domain-specific dictionaries and to FinBERT, a transformer model fine-tuned for financial sentiment classification. Exploiting the fact that zero-shot learning requires no further training on labeled data, we examine additional sentiment dimensions identified and defined through dictionaries in prior studies, and we compare the dictionary-based measures to their zero-shot counterparts. Our results show that the zero-shot measures outperform both benchmarks by a substantial margin, even though the model was not trained or fine-tuned on the financial domain. We further observe that several sentiment dimensions are economically relevant, but are captured only by the zero-shot measures, while the defining dictionaries fail to do so. Overall, we demonstrate that transformer-based models in a zero-shot setting can effectively capture financial sentiment without domain-specific training, and that established sentiment dimensions exhibit explanatory power for short-term market reactions when translated into zero-shot prompts.

An AI Agent for Automated Document Verification in Capital Construction Investment Decision Making

Adela Shkurtaj[1,2], Darya Yudahina[3], Peter Panfilov[1]
1: HSE University, Myasnitskaya St. 20, 101000 Moscow, Russia; 2: University of Passau, Innstr. 41, 94032 Passau, Germany; 3: Technologies of Trust, Krzhizhanovsky street 14/3, 117218 Moscow, Russia

Investment activities in capital construction projects depend on large packages of interrelated documents, including technical specifications, draft contracts, cost estimates, and work schedules, that must remain complete and internally consistent throughout the project lifecycle. Key parameters such as contract price, completion deadlines, and payment conditions appear across multiple documents prepared by different stakeholders, creating systematic risks of omission, contradiction, and late error detection. Manual cross-document review is labor-intensive and error prone, particularly under time pressure at stage-gate decision points where documentary evidence determines whether a project may proceed.

This work develops a bounded AI agent for automated verification of procurement documentation packages in capital construction projects. The system addresses a decision-support problem: given a heterogeneous document package and a set of verification targets, determine whether required parameters are present and whether their values are mutually consistent across the package. The agent combines format-sensitive document parsing, quality-gated OCR recovery, hybrid retrieval over a chunk-level semantic and lexical index, iterative evidence gathering coordinated by a large language model, and parameter-specific extraction logic for both scalar values and clause-like contractual formulations. Consistency is assessed through normalized value comparison and structured semantic comparison of extracted clause representations, with all outputs linked to their source for human review.

The approach targets a recurring bottleneck in investment decision-making where fragmented documentation delays approvals and reduces governance transparency. Initial evaluation on annotated procurement packages demonstrates feasibility across heterogeneous document collections, suggesting that bounded agentic architectures offer a viable path toward traceable, human-supervised document verification in capital construction.

WC 16: Analytics, Data Science, and Forecasting: Feature Representation and Investment Strategies

Time: Wednesday, 02/Sept/2026: 1:15pm - 2:45pm · *Location:* SR033 (WIWI)
Session Chair: Hans Georg Zimmermann

Low-Dimensional Representations in High-Dimensional Time Series Forecasting

Joshua Arnold, Maximilian Moll, Stefan Pickl
Universität der Bundeswehr München, Germany

High-dimensional time series forecasting in sparse regimes is challenging due to limited sample sizes and complex cross-series dependencies. A common approach is to first reduce dimensionality, perform forecasting in a low-dimensional latent space, and subsequently reconstruct predictions in the original space. While such pipelines are widely used, their impact on the relative effectiveness of simple versus complex forecasting models remains underexplored. In this paper, we study a reduction–forecast–reconstruction pipeline using structured dimensionality reduction methods combined with neural sequence models. We systematically compare univariate and multivariate forecasting models in both the original and latent spaces. We find that low-dimensional representations can substantially improve forecasting performance under data scarcity. In particular, simple univariate models applied in the latent space consistently outperform both their original-space counterparts and full multivariate LSTM models. Moreover, multivariate models do not exhibit a consistent advantage even after dimensionality reduction.

SMART: Smoothed Momentum-Aware Reallocation Tool To Beat Your Bank's Best Interest Offer At Zero Risk

Deniz Aksen
Koç University, Turkey (Türkiye)

Our objective is to reap improved returns on low-risk investment funds traded in TEFAS, Türkiye's electronic fund trading platform. We work exclusively on money market funds and short-term debt instrument funds for two reasons. First, they can be traded within the same value date. Second, they are all low-risk investment instruments with a risk factor of either 1 or 2 on a scale of 1 to 7. An elite subset of 50+ such funds is identified based on historical return-on-investment (ROI) performance. Fund-specific trading-time constraints are incorporated into the analytics as well. SMART, the Smoothed Momentum-Aware Reallocation Tool is developed as a data-driven decision support framework. It is a reallocation strategy that periodically reviews and shifts the entire portfolio to the fund with the highest smoothed ROI over a rolling lookback window while preserving same-day liquidity. We also explore an escape rule for restricted funds, i.e. funds which can be bought or sold only before 13:30 on a workday. Six alternative smoothing formulas are evaluated to reduce noise in short-term returns. We use the highest bank deposit interest rate as the risk-free benchmark, which varied between 33% and 50% per annum in the past 18 months. Simulation results over multiple investment horizons show that SMART can outperform the benchmark by up to 10%. We highlight the benefit of ROI smoothing over the lookback window in choosing the more profitable fund. SMART is transparent, easy to implement in Microsoft Excel, and directly applicable for individual and institutional risk averse investors.

WD 01: Semi-Plenary Martin Bichler

Time: Wednesday, 02/Sept/2026: 3:00pm - 4:00pm · *Location:* HS10 (AM)
Session Chair: Tobias Harks

Learning, Games, and Algorithmic Markets

Martin Bichler
Technical University of Munich, Germany

While OR has made significant progress in solving optimization problems, we still know comparatively little about solving equilibrium problems. Recent algorithmic developments have shown that learning algorithms often find equilibrium in important classes of games. This is not only relevant to equilibrium computation, but also provides a model for learning agents in automated markets such as display advertising auctions or price competition on online retail platforms. Such markets are still not well understood theoretically. This talk provides a brief overview of mathematical concepts that help us understand when and why learning algorithms converge to a Nash equilibrium in games, and when this is not the case.

WD 04: Semi-Plenary Merve Bodur

Time: Wednesday, 02/Sept/2026: 3:00pm - 4:00pm · *Location:* HS13 (IM)
Session Chair: Marc Goerigk

Decision Diagrams for Discrete Decision-Making Under Uncertainty and Beyond

Merve Bodur
University of Edinburgh, United Kingdom

Sequential decision-making under uncertainty arises in many operations research applications. These problems become particularly challenging when recourse actions are binary or integer, and scalable solution methods remain limited in scope. This motivates approaches that leverage the combinatorial structure of discrete recourse.

In this talk, we will present how decision diagrams (DDs) can represent relevant combinatorial substructures in two-stage stochastic programming and adaptive robust optimization. For stochastic programs, we will show how DDs can convexify discrete recourse representations and make the problem amenable to Benders decomposition, including risk-averse extensions. For adaptive robust binary optimization, we will present DD-based network-flow formulations that provide exact models, size-controlled approximations, and high-quality primal and dual bounds. We will further touch on learning-guided DD construction for stronger relaxations.

We will also briefly discuss extensions beyond uncertainty, including multiobjective discrete optimization for efficient Pareto frontier enumeration and column generation settings where DDs support pricing.

WD 06: Semi-Plenary Sebastian Pokutta

Time: Wednesday, 02/Sept/2026: 3:00pm - 4:00pm · *Location:* HS5 (WIWI)
Session Chair: Frauke Liers

Frank-Wolfe Beyond Polytopes: Convergence on Non-Polyhedral Sets

Sebastian Pokutta
Zuse Institute Berlin and TU Berlin, Germany

Frank-Wolfe methods are a classical projection-free approach to constrained optimization and are particularly attractive when linear minimization oracles are significantly cheaper than projections. Much of the classical theory and intuition has been developed for polyhedral domains, where active-set structure and sparsity play a central role. In many applications, however, the feasible region is not polyhedral but curved, for example a Euclidean ball, a spectrahedron, or a strongly convex set. This raises a natural question: how does the geometry of a non-polyhedral domain change the convergence behavior of Frank-Wolfe?

In this talk, I will discuss recent progress on Frank-Wolfe convergence beyond polytopes, with a particular focus on uniformly convex sets. After briefly reviewing the geometric picture and what is known about improved rates under additional assumptions, I will focus on a recent constructive lower bound, obtained through an approach that is rather unusual for lower-bound arguments, showing that even when both the objective and the constraint set are smooth and strongly convex, the classical O(1/sqrt(ε)) guarantee is tight in general. In particular, this settles, roughly a decade after the 2015 Garber-Hazan upper bound, the question of whether strong convexity of the feasible set alone can guarantee a uniformly faster rate. I will conclude by complementing this picture with a surprising new result.

WD 08: Gurobi Lecture

Time: Wednesday, 02/Sept/2026: 3:00pm - 4:00pm · *Location:* HS9 (AM)
Session Chair: Robert Luce

Gurobi's Primal-Dual Hybrid Gradient (PDHG) algorithm: practice and performance

Robert Luce
Gurobi, Germany

Gurobi's Primal-Dual Hybrid Gradient (PDHG) algorithm has evolved rapidly since its introduction, with both the CPU and GPU backends having grown into production grade Gurobi features. In this session, we will share key insights from this exciting period of algorithmic innovation, including benchmarking results, customer success stories, and an overview of the technical capabilities of Gurobi's PDHG implementation. We will also discuss where PDHG fits within the broader optimization landscape and the types of problems where it can deliver the greatest value.

WE 01: GOR Young Researchers Award

Time: Wednesday, 02/Sept/2026: 4:30pm - 6:00pm · *Location:* HS10 (AM)
Session Chair: Stefan Ruzika

Design of Multi-Optional Pickup Time Offers in Ride-Sharing Systems

Jarmo Haferkamp
Universität Bremen, Germany

On-demand ride-sharing systems provide travelers with a set of transportation alternatives that differ, among other aspects, in their pickup times. Designing such multi-optional offers requires balancing traveler acceptance with operational efficiency, as individual preferences vary while vehicle resources are limited. In our work on designing pickup time offers, we propose a cost function approximation that balances estimated acceptance probabilities with approximated routing effort to identify promising transportation offers. Building on this work, we discuss how transportation offer design can be extended beyond short-term acceptance maximization. We outline future research directions on how transportation offers shape user expectations over time and how strategic offer design can support long-term user retention.

Inverse Demand Tracking in Transportation Networks

Simone Göttlich[1], Patrick Mehlitz[2], Thomas Schillinger[1]
1: University of Mannheim, Germany; 2: University of Marburg, Germany

This work deals with the reconstruction of the desired demand in an optimal control problem, stated over a tree-shaped transportation network which is governed by a linear hyperbolic conservation law. As desired demands typically undergo fluctuations due to seasonality or unexpected events making short-term adjustments necessary, such an approach can exemplary be used for forecasting from past data.We suggest to model this problem as a so-called inverse optimal control problem, i.e., a hierarchical optimization problem whose inner problem is the optimal control problem and whose outer problem is the reconstruction problem. In order to guarantee the existence of solutions in the function space framework, the hyperbolic conservation law is interpreted in weak sense allowing for control functions in Lebesgue spaces. For the computational treatment of the model, we transfer the hierarchical problem into a nonsmooth single-level one by plugging the uniquely determined solution of the inner optimal control problem into the outer reconstruction problem before applying techniques from nonsmooth optimization. Some numerical experiments are presented to visualize various features of the model including different types of noise in the demand and strategies of how to observe the network in order to obtain good reconstructions of the desired demand.

WE 02: Mobility, Transport, and Traffic: Vehicle Routing and Inventory Routing

Time: Wednesday, 02/Sept/2026: 4:30pm - 6:00pm · *Location:* HS1 (PHIL)
Session Chair: Margaretha Gansterer

Inventory routing of perishable products using multi-compartment vehicles

Manuel Ostermeier, Selina Sartor
University of Augsburg, Germany

The efficient distribution of perishable products poses major challenges for grocery supply chains, driven by strict freshness requirements, heterogeneous temperatures, and rising cost pressures. In practice, food waste caused by inadequate coordination between inventory decisions and transportation planning remains a critical issue, both economically and environmentally. In this regard, multi-compartment vehicles (MCVs) provide promising opportunities to consolidate deliveries of products with different temperature requirements. Yet, their potential remains largely unexplored in integrated planning models for perishable product supply chains.

Our work addresses this issue and introduces the Inventory Routing Problem for Perishable Products with MCVs (IR-PP-MCV). Perishability is explicitly modeled via maximum shelf-life constraints limiting the usable lifetime of inventory before disposal. The problem integrates inventory management, delivery scheduling, routing decisions, and vehicle compartment configuration decisions in a deterministic multi-period setting. We propose a decomposition-based solution framework to tackle the problem. A Genetic Algorithm forms the core of the approach and jointly optimizes delivery schedules and vehicle routes. Building on these solutions, a dedicated heuristic determines vehicle compartment configurations and computes feasible delivery quantities while accounting for perishability constraints and inventory dynamics. Detailed numerical experiments demonstrate the benefits of integrating perishability and multi-compartment transportation into inventory routing decisions. The coordinated planning can significantly reduce total distribution costs while improving product freshness and reducing food waste compared to conventional inventory-routing models with homogeneous fleets.

Routing and Replenishment of Mobile Grocery Stores

Doriana Vizzini[1], Margaretha Gansterer[1], Simona Mancini[2]
1: University of Klagenfurt, Austria; 2: University of Palermo, Italy

We consider the case of buses used as mobile grocey stores mainly in order to satisfy basic needs of elderly people in urban areas. With these buses traveling in residential areas on a regular basis, customers have the possibility to perform shopping activities individually in their close neighborhood. While the main objective is to serve as many elderlies as possible, we assume that also regular (non-elderly) customers can use these mobile stores for small shopping activities. These customers do not only generate additional profits for store providers, but their usage of the grocery buses might also reduce CO2 emissions, as they are not required to drive to larger grocery stores for small shopping amounts. We formulate the underlying decision problem with two hierarchical objectives from the perspective of store providers, where both routing and replenishment costs are taken into account. Overall, we present a multi-stage stochastic model, where different customer types are mainly distinguished based on their preferred time windows. Small instances are solved to optimality, while we propose a metaheuristic approach for larger problems. Managerial findings for store providers as well as for city municipalities, who have incentives to financially support this novel distribution concept, are derived.

Optimizing Ambulift Routing at Airports for Passengers with Reduced Mobility

Deepthi Cherullil Padinjaroot, Rainer Kolisch
Technical University of Munich, Germany

Ambulifts or medical high-loaders are vehicles used for (de-)boarding of passengers with reduced mobility. For a given day of operation, demand is known in terms of a set of flights, their service time windows, and locations. However, throughout the day, changes may occur. We address the problem of routing ambulifts to serve all requests throughout the day using a rolling-horizon approach. At each planning stage, we solve a deterministic heterogeneous vehicle routing problem with time windows, considering two objectives: minimizing the total travel time and minimizing the total delays. In a computational study based on real-world data of a major European airport, we evaluate our proposed approach, including a comparison with the dispatching approach currently used.

WE 03: Mobility, Transport, and Traffic: Route and Tour Planning under uncertain Conditions

Time: Wednesday, 02/Sept/2026: 4:30pm - 6:00pm · *Location:* HS3 (PHIL)
Session Chair: Marie Schmidt

Fuel-Efficient Vessel Routing for Ghost Net Recovery: An Orienteering Problem with Moving Targets

Paulina Heine, Kevin Tierney, Daniel Wetzel
University of Vienna, Austria

Abandoned fishing gear (ghost nets) drifting with ocean currents poses a severe threat to marine ecosystems, entangling wildlife for decades and breaking down into microplastics. Targeted recovery by collection vessels is an effective remediation, but operationally costly. This is because nets drift continuously across a vast, dynamic environment, and fuel consumption dominates mission cost.

We formulate maritime ghost net collection as an Orienteering Problem with Moving Targets, where a fleet of vessels must intercept drifting nets within a time horizon. The objective is to minimize fuel cost per kilogram of collected nets. We model the fuel consumption of the vessel considering ocean currents, wind and waves to ensure routes avoid adverse weather conditions.

We compare three methods along a spectrum of information availability. In the perfect information setting, we introduce an offline benchmark that plans with full hindsight: full GPS trajectories and environmental data are known in advance, and the fuel cost per kilogram of collected nets is solved to optimality. Moving toward operational realism, the rolling-horizon variant still uses full environmental data but receives GPS updates only incrementally, re-planning with dynamic planning windows after each collection. In the most realistic setting, the reactive method mirrors real operations: future GPS positions and environmental conditions are unknown, and decisions rely on drift and weather forecasts, with dynamic weather routing along the way, extending the classical problem to support energy-efficient ocean cleanup.

Inferring Aircraft Intent and Model Parameters from Observed Storm-Avoidance Aircraft Trajectories using Inverse Optimal Control

Almudena Buelta, Alberto Olivares, Ernesto Staffetti
Universidad Rey Juan Carlos, Spain

In this article, an approach for inferring aircraft intent from observed storm-avoidance maneuvers using inverse optimal control is presented. Inverse optimal control is a methodology that seeks to deduce the underlying cost functional from observations of the behavior of a dynamical system, under the assumption that the observed behavior results from the solution of an optimal control problem. Assuming the availability of a map with storm forecasts, containing spatial and temporal predictions of storm-cell locations and intensity levels of convective activity, the methodology presented in this article is capable of inferring the weighting factors associated with each component of the objective functional that characterizes the underlying goals of the flight in the storm-avoidance maneuver. These weighting factors are assumed in this article to represent the aircraft intent, such as clearance from the storm cells, smoothness of the trajectory, and time/fuel costs. However, in general, aircraft intent also depends on some parameters of the model, such as wind velocity. The method presented in this article is capable of estimating these parameters as well. Once the latent objective functional underlying an observed storm-avoidance trajectory has been inferred, it can be used to inform the planning strategies of other aircraft operating in the same or similar adverse weather scenarios. The ultimate goal of this article is to enable knowledge transfer from observed storm-avoidance maneuvers to future trajectory planning.

The best-traversable edge-disjoint paths problem

Aaron Neugebauer[1,2], Marie Schmidt[1]
1: Universität Würzburg, Würzburg, Germany; 2: Fraunhofer ITWM-Institute for Industrial Mathematics, Kaiserslautern, Germany

Motivated by challenges occurring in disaster relief operations, we study the problem to find two edge-disjoint paths in a graph whose arcs are labeled with traversability probabilities that maximize the probability that (at least) one of the paths is traversable.

We show that this problem is NP-hard in directed graphs. To solve the problem, we propose to model it as a bi-objective problem, taking traversability probabilities of the the two individual paths as objective functions. We show that an optimal solution to our problem is a supported solution of the so-defined bi-objective problem and exploit this property to find optimal solutions. Furthermore, we present some approximation approaches, and show some computational results to illustrate the outcomes of our approaches.

WE 04: Energy and Sustainability: Bridging the Granulatiry Gap

Time: Wednesday, 02/Sept/2026: 4:30pm - 6:00pm · *Location:* HS13 (IM)
Session Chair: Armin Ardone

Bridging the Granularity Gap in Cross-Sectoral Energy Resilience Analysis (X-SAFE)

Eric MSP Veith, Torben Logemann, Lasse Hammer
OFFIS - Institute for Information Technology, Germany

Highly coupled energy infrastructures are prone to cascading failures that originate from seemingly local disturbances and then propagate across sectors such as electricity, gas, heat and communication. Bridging the granularity gap between high-level system views and detailed asset behaviour is crucial to understand and mitigate these cascades. We propose a hybrid modelling and simulation framework that combines scenario-based exploration on a knowledge graph with targeted detail simulations of selected critical chains of events.

At the system level, open infrastructure and geospatial data are integrated into a machine-readable graph that encodes cross-sectoral dependencies between assets, sectors and actors. On this basis, scenario simulations trace “storylines” of triggers, intermediate events and impacts, making qualitatively visible which paths of escalation are most critical for a given question or region. For those storylines where quantitative insight is required, the framework automatically launches detailed simulations using reinforcement-learning-based operator and attacker agents that iteratively probe infrastructure models to uncover and quantify vulnerabilities.

By feeding the resulting probabilities, thresholds and impact metrics back into the knowledge graph, the overall situation picture is continuously refined while preserving a transparent link between abstract scenarios and asset-level dynamics. A natural-language interface exposes this capability to practitioners, allowing them to formulate everyday questions and receive geo-localised situation views, dependency graphs and narrative scenario descriptions that are grounded in both systemic and detailed simulations.

The Benefits of an Integrated Approach for Dynamic-Stability-Constrained Power System Planning

Gereon Recht[1,2], Benedikt Jahn[2], Oussama Alaya[1,2], Karl-Kiên Cao[1], Hendrik Lens[2]
1: German Aerospace Center (DLR), Institute of Networked Energy Systems, Curiestr. 4, 70563 Stuttgart, Germany; 2: Institute for Energy Process Engineering and Dynamics in Energy Systems (IED), University of Stuttgart, Germany

Due to reduced generation from synchronous machines, considering dynamic stability for planning highly renewable power systems becomes increasingly important.

Yet, dynamic stability so far is mostly considered ex-post.

We investigate whether integrating simplified stability constraints into power system planning can potentially lead to lower system costs, as e.g. synergies of stabilising options with steady-state system operation could be exploited.

We consider how system costs change between an integrated approach, which considers constraints on frequency and voltage stability, and the established sequential approach, where stability and possible additional stabilising measures are analysed ex post.

To that end, we formulate two corresponding capacity expansion problems as convex optimisation problems.

Both consider simultaneous expansion of generation, transmission, storage, and stabilising options and furthermore include linearised power flow constraints with transmission losses.

The stability-constrained problem includes two known constraints related to frequency and voltage stability, of which the voltage stability constraint has not been considered in an expansion problem before.

For a problem instance representing the European power system, we determine a reduction in system costs with the integrated approach, while the increase in computational demand remains acceptable.

A Reproducible Workflow for Regionalisation of European Network Expansion Scenarios

Eric Jahnke, Armin Ardone, Wolf Fichtner
Chair of Energy Economics, Institute for Industrial Production, Karlsruhe Institute of Technology, Germany

European power system planning and operation studies require spatially consistent input data that connect national scenario assumptions, weather-dependent renewable profiles, hydro inflows, and detailed grid representations. This paper presents a reproducible preprocessing workflow for deriving nodal input data for large-scale European unit commitment and optimal power flow analyses based on capacity and transmission expansion scenarios from the ten-year network development plan (TYNDP) by ENTSO-E and ENTSO-G. The workflow combines TYNDP 2024 National Trends data with a PyPSA-based grid model, extended by selected grid expansion assumptions and maps all relevant demand, generation, storage, and flexibility data to the nodes of a reduced grid with user-specific size. The methodology covers two complementary spatial transformations. First, raster-based renewable energy potentials, capacity factors, and hydro inflow profiles are generated using an extended approach based on Atlite functionalities and aggregated to grid nodes using technology-specific availability masks. Second, national scenario quantities, including load, thermal generation, hydro capacities, other renewable and non-renewable technologies, and battery storage, are disaggregated to nodes using transparent allocation rules based on existing assets, population, GDP, distance, renewable potentials, load shares, and hydro shares. The resulting data pipeline produces consistent nodal timeseries, installed capacities, and technology attributes for subsequent optimisation. By separating grid reduction, geo-spatial profile generation, and technology-specific disaggregation, the workflow supports reproducible scenario construction, sensitivity analysis, and transparent validation of European power system optimisation studies.

WE 05: Energy and Sustainability: Energy communities and local flexibilties

Time: Wednesday, 02/Sept/2026: 4:30pm - 6:00pm · *Location:* HS11 (IM)
Session Chair: Tizian Schug

Fairness in Optimized Energy Communities

Kai Hoth, Kathrin Fischer
TUHH, Germany

In this talk, the aspect of fairness among prosumer households within an energy community that is centrally managed by an aggregator is analyzed. The basis for this analysis is a MILP model that optimizes the energy management of an aggregator. The optimization focuses on the deployment of the households' various flexible energy resources while considering multiple energy trading options, including a local market and internal trading (i.e. energy sharing). Since internal trading creates interdependences between the households and the aggregator's decisions are made such that the community as a whole benefits, but individual households not necessarily achieve an advantage, fairness becomes a relevant factor. The model results show that some households profit from internal trading, while others are exploited. Consequently, a post-optimization redistribution of the community surplus achieved through internal trading must be carried out such that households are rewarded in accordance with their contribution.

In a case study with a community of 111 households, an established fairness index from existing literature is applied to determine the fair monetary redistribution for 31 days. While the optimization results without a subsequent redistribution are not fair, the determination of the ideal redistribution requires large computational effort and might hence be prohibitive. Therefore, the objective of this work is to identify generalizable measures that can be used as a basis for appropriate redistribution decisions. Different measures considering the households' participation in internal trading and characteristics of the shared flexible energy resources lead to promising results and to substantial improvements of the achieved fairness.

When Optimization Meets Reality: Challenges in Operationalizing Optimization for Renewable Energy Communities

Elias Gumpinger, Nathalie Frieß, Ulrich Pferschy
Department of Operations and Information Systems, University of Graz

The Renewable Energy Directive (2018/2001) enables citizens to jointly produce, store, and consume renewable electricity through collective self-consumption in Renewable Energy Communities (REC), creating new opportunities — and challenges — for coordinated operational decision-making.

In such communities, distributed energy resources such as batteries, electric vehicles, and heat pumps must be coordinated across multiple households under technical, regulatory, and informational constraints. In the literature, this coordination is typically addressed using model predictive control and mixed-integer linear programming, assuming a high degree of observability and well-defined asset behavior.

However, when moving toward practical implementation, these assumptions are frequently not met. While high-resolution consumption data becomes available with a 24-hour delay, data availability is limited with respect to asset-level metadata behind the meter, which complicates forecasting. Moreover, system states may be incomplete, and real-world assets expose heterogeneous interfaces and constraints that are typically not captured in idealized models.

This paper reports on challenges arising in the ongoing operationalization of an MPC-based optimization framework in a large-scale REC setting in Austria with several hundred members, a subset of which participates in active central optimization.

Building on our earlier ECOS framework for scheduling distributed energy resources, we characterize practical implementation challenges, including data collection and state inference as well as the reformulation of asset models to reflect actual hardware interfaces and constraints.

Rather than proposing a new methodology, we provide a structured account of the modeling decisions and technical challenges encountered in bridging the gap between optimization theory and operational REC management.

Multi-Market Optimization for an Energy Aggregator Pooling Residential Flexibility

Tizian Schug, Kathrin Fischer
Institute for Operations Research and Information Systems, Hamburg University of Technology, Germany

The increasing deployment of battery electric storage systems and flexible sector-coupling technologies in prosumer households create opportunities for new business models. One promising concept is the energy aggregator, which pools multiple prosumer households to aggregate small-scale distributed energy resources (DERs) and to enable participation in markets that have traditionally been accessible only to larger actors. While previous studies have demonstrated the benefits of spot market trading for

such aggregators, the potential of additionally providing ancillary services in corresponding balancing markets has received comparatively little attention.

To quantify the potential of such multi-market strategies, this study investigates a key operational decision-making process of an aggregator. A mixed-integer optimization model is proposed to determine bids on day-ahead balancing markets with the overarching objective of maximizing profit. Since successful bids reduce the flexibility available for exploiting price fluctuations on the spot market, the aggregator must identify an optimal trade-off between maximizing revenues from the provision of ancillary services to the grid operator and minimizing energy procurement costs for customers. The model incorporates technical constraints of residential DERs, user preferences, and relevant market specifications.

The proposed model captures the first decision stage of the multi-market optimization process, while subsequent stages, including participation in the day-ahead spot market and intraday trading, are left for future work. A preliminary quantitative assessment of the economic potential of multi-market participation is presented.

WE 06: Discrete and Combinatorial Optimization: Graphs and Networks 1

Time: Wednesday, 02/Sept/2026: 4:30pm - 6:00pm · *Location:* HS5 (WIWI)
Session Chair: Anja Fischer

An expanded approach for the constrained Single-Row Facility Layout Problem

Anja Fischer, Frank Fischer, Louisa Semrau
TU Dortmund University, Germany

In the Single-Row Facility Layout Problem (SRFLP) one has given a set of departments, their lengths and pairwise weights between the departments. The aim is to arrange the departments along one side of a path without overlapping such that the sum of the weighted center-to-center distances is minimized. In the SRFLP any permutation of the departments is feasible but in real-life applications the placement of the departments may underlie specific requirements. Therefore, we consider the constrained SRFLP (cSRFLP). The cSRFLP expands the SRFLP by integrating positioning, ordering and relation constraints. Positioning constraints fix departments to positions in the permutation. A fixed order of two departments in the permutation is expressed with ordering constraints. Relation constraints express that two departments are placed directly next to each other in the permutation. To solve the problem, we first reduce the size of the instances by merging particular departments. Afterwards, we expand a cutting plane approach for the SRFLP from the literature, based on betweenness variables, by adding strengthened constraints for the cSRFLP to derive good lower bounds. To build integral solutions a construction heuristic is used. We present preliminary results.

The exact subgraph hierarchy for stable set in Paley graphs

Elisabeth Gaar[1], Dunja Pucher[2]
1: University of Augsburg, Germany; 2: University of Klagenfurt, Austria

To determine the stability number of a graph, defined as the cardinality of the largest set of pairwise non-adjacent vertices, is a fundamental NP-hard discrete optimization problem. The exact subgraph hierarchy (ESH) provides a sequence of increasingly tighter upper bounds on the stability number based on non-smooth optimization, starting with the Lovász theta function at the first level and including all exact subgraph constraints of subgraphs of order k into the semidefinite program to compute the Lovász theta function at level k.

In this talk, we investigate the ESH for Paley graphs, a class of strongly regular, vertex-transitive graphs. We show that for Paley graphs, the bounds obtained from the ESH remain the Lovász theta function up to a certain level, i.e., the bounds of the ESH do not improve up to a certain level.

To overcome this limitation, we introduce the vertex-transitive ESH for the stable set problem for vertex-transitive graphs such as Paley graphs. We prove that this new hierarchy provides upper bounds on the stability number of vertex-transitive graphs that are at least as tight as those obtained from the ESH. Additionally, our computational experiments reveal that the local ESH produces superior bounds compared to the ESH for Paley graphs.

Solution approaches for the adjacent-only and the general quadratic minimum arborescence problem

Anja Fischer[1], Frank Fischer[1], Angelika Wiegele[2]
1: TU Dortmund University; 2: University of Klagenfurt

In this talk we present solution approaches for two variants of the NP-hard quadratic minimum arborescence problem (QARBP) which is the directed version of the well-studied quadratic minimum spanning tree problem. First, we study the adjacent-only QARBP which is already an NP-hard problem. We linearize the quadratic monomials by introducing a new variable for each of them and study the associated polytope. Several classes of valid inequalities are presented and we consider the complexity of the associated separation problems. Using our cutting plane classes in a branch-and-cut scheme we are able to solve hard instances with changeover costs from the literature for the first time. Additionally, we test our approach on randomly generated instances. Second, we study the general case of the QARBP with arbitrary quadratic monomials of the arc variables. For this, we present two mixed-integer semi-definite programming formulations and derive associated relaxations. Some preliminary computational results are discussed at the end of the talk.

WE 07: Discrete and Combinatorial Optimization: Routing Problems

Time: Wednesday, 02/Sept/2026: 4:30pm - 6:00pm · *Location:* SR029 (WIWI)
Session Chair: Bin Wu

A Simulated Annealing Approach for Routing of Industrial Inspection Robots in Bus Manufacturing

Mehmet Erol Kara, Aydin Sipahioglu, Ahmet Yazici
Eskisehir Osmangazi University, Turkey (Türkiye)

This study addresses the routing problem of industrial inspection robots used in bus manufacturing. In the production process, the body in white of a bus consists of approximately three thousand subparts, and all of them must be inspected to ensure quality standards. Since minimizing inspection time is crucial for production efficiency, determining an effective route for the robot arm is essential. This study specifically focuses on the inspection of body in white structures, where a robot arm starts from an initial point, traverses to designated checkpoints, performs inspections, and continues until all subparts are adequately controlled.

The routing of inspection robots is inherently similar to the Traveling Salesman Problem. Both problems involve one or more vehicles navigating through a network with a limited number of nodes and arcs to obtain a minimum cost tour. However, the inspection robot routing problem introduces additional complexity, as the robot does not necessarily visit all nodes in the network, and movements are restricted due to obstacles within the body in white.

In this study, shortest path distances between all pairs of nodes are computed using the Floyd-Warshall algorithm, and an integer linear programming model is formulated to minimize total traversal distance. Given the computational complexity of real-world instances involving over a thousand subparts, a simulated annealing algorithm is also applied to obtain high-quality solutions within reasonable computation times. Preliminary experiments on real-world instances demonstrate that the proposed metaheuristic approach yields promising results in terms of both solution quality and computation time.

A Utility-Based Heuristic with Triggered Local Search for the Combined Maintenance Routing Problem

Bin Wu, Laurence Dieulle, Nacima Labadie
Université de Technologie de Troyes (UTT), France

This work studies a combined maintenance routing problem in which geographically distributed machines are subject to stochastic degradation and must be serviced by a limited set of technicians with different skill capacities. The decision maker jointly determines which machines to maintain, in which periods, by which technicians, to which restoration target states, and along which routes. The problem is challenging because maintenance decisions and routing decisions are tightly coupled: a maintenance operation may reduce expected maintenance and penalty costs, but it also consumes technician working time and increases routing cost.

We propose a utility-based heuristic framework for constructing and improving maintenance-routing solutions. Candidate maintenance operations are evaluated by their marginal utility, defined as the expected reduction in machine-side maintenance and penalty cost minus the routing insertion cost. The constructive procedure is combined with several local-search mechanisms, including route reordering, local assignment improvement, slot-opening moves, cross-period intensification, target-depth tuning, and one-for-one replacement. We further investigate triggered variants of selected local searches and final intensification cycles based on refill and all-route improvement strategies.

Computational experiments on 50 benchmark instances with 150 machines compare 53 algorithmic configurations. The results show that combining construction-stage triggered target-depth tuning and replacement moves with final refill intensification improves the strengthened baseline while keeping the computational time moderate. The study demonstrates that utility-guided construction and carefully coordinated local-search neighborhoods can effectively address large-scale combined maintenance and routing decisions.

WE 08: Supply Chain Management and Production: Master Planning

Time: Wednesday, 02/Sept/2026: 4:30pm - 6:00pm · *Location:* HS9 (AM)
Session Chair: Stefan Nickel

Perishable Inventory Management under Inventory Record Inaccuracy

Aleksandra Petrenko, Marjolein Buisman
Technical University of Munich, Germany

Discrepancies between recorded inventory and available inventory, often referred to as inventory record inaccuracy (IRI), are known to distort replenishment and planning decisions. Most of the literature on IRI focuses on non-perishable items and overlooks the fact that IRI is particularly critical in the context of perishable food and grocery retail. Perishable products possess several characteristics that add complexity to inventory management under IRI, including limited shelf life, quality deterioration, frequent material handling, and often low margins. Thus, inventory discrepancies are especially consequential not only for product availability but also for waste generation, profitability, and sustainability. Using grocery retail data, this work proposes an analytical model for perishable inventory management under IRI and analyzes how inventory inaccuracies and perishability jointly distort common inventory control policies. The research provides insights into enhancing product availability, planning inspection decisions, and reducing waste without investing in tracking technologies.

Tactical Supply Network Planning for a Consumer Goods Manufacturer with Limited Reallocations

Philipp Melchiors[1], Miriam kiessling Kiessling-Dürrschmidt[2]
1: COSMO CONSULT Data & Analytics GmbH, Germany; 2: Technische Hochschule Nürnberg Georg Simon Ohm, FACULTY OF APPLIED MATHEMATICS, PHYSICS AND HUMANITIES, Germany

We study a tactical supply network planning problem for a leading German consumer goods manufacturer. The company operates a Europe wide production network with multiple plants producing a broad product portfolio. The proposed mixed integer linear programming (MILP) model extends classical supply network planning by incorporating constraints specific to consumer goods manufacturers. Specifically, the model includes basket constraints restricting feasible product combinations per customer, as well as raw material transportation costs. This refined cost modeling supports realistic decision making and more sustainable production and distribution planning.

To enhance practical applicability, the model does not compute a fully optimal plan from scratch. Instead, starting from a company provided baseline plan, only a limited and parametrizable number of reallocations is optimized. This approach significantly improves solution implementability and acceptance in practice. Using advanced decomposition techniques, the model can be extended to longer planning horizons, such as a full year. Consequently, the approach supports both tactical and strategic supply network planning.

Integrated Master Planning and Demand Fulfillment in Multi-Echelon Supply Chains: A Graph-Based Approach

Felix P. Broesamle, Hannah Bakker, Stefan Nickel
Karlsruhe Institute of Technology, Germany

Many modern supply chains are characterized by geographically dispersed manufacturing processes, long lead times, and capital-intensive bottlenecks. We consider semiconductor manufacturing as a primary example, which is additionally characterized by re-entrant process flows and highly volatile demand. Within Advanced Planning Systems (APS), the management of these dynamics demands for the synchronization of Master Planning (MP) and Demand Fulfillment (DF) to align finite resource capacities with volatile and complex customer orders. Conventionally, these functions are decoupled via hierarchical decomposition; while this reduces the computational effort, it inherently neglects the critical interdependencies between material availability, capacity utilization, and the commitment logic of delivery promises. This work proposes an integrated model that internalizes these interactions by jointly capturing MP and DF decisions. By mapping the integrated model to a graph-based representation, we expose a combinatorial structure suitable for the exploitation of specialized algorithms and decomposition techniques, significantly extending the tractable range for large-scale industrial instances. We present a rolling-horizon framework that leverages this formulation to seamlessly integrate the physical state and demand evolution into a dynamic execution environment. Finally, we utilize this framework to evaluate the performance of the proposed integrated model.

WE 09: Artificial Intelligence, Machine Learning and Optimization: Where we are and where we go

Time: Wednesday, 02/Sept/2026: 4:30pm - 6:00pm · *Location:* HS7 (WIWI)
Session Chair: Recep Günes

Operations Research in the Age of Large Language Models

Kevin Tierney
University of Vienna, Austria

The operations research (OR) community has long sought to make writing heuristics to solve optimization problems faster and easier through established paradigms, freely available frameworks, and automated parameter tuning. OR specialists play a decisive role in this process: they experiment with different heuristics and metaheuristics, implement them, and examine their efficacy. This process is time-consuming, requiring weeks or even months to develop methods for large-scale optimization problems. Automated heuristic-discovery techniques based on large language models (LLMs) are fundamentally changing how OR specialists develop heuristics. These techniques can create heuristics for optimization problems that rival state-of-the-art OR methods in solution quality within just a few days, requiring only limited human input. This talk will show how these techniques work and examine how the field of OR may evolve in the near future with the rise of LLMs.

Recommender Systems in Healthcare

Sanjog Ray
Indian Institute of Management Indore, India

Recommender systems are intelligent systems for mitigating information overload by providing personalized item recommendations based on user explicit and implicit preferences. While these systems have achieved widespread maturity and commercial success in ubiquitous domains such as e-commerce, digital media, and tourism, their application within the healthcare sector remains disproportionately limited and complex. This research first provides a systematic analysis of the extant literature to explain the current landscape of Health Recommender Systems. We analyse the challenges faced in applying recommender systems in healthcare and then focus on the critical requirement for clinical explainability and data privacy.

The study further narrows its focus to the specialized domain of medicine recommendations within e-pharmacy environments. We investigate proposed strategies for enhancing the adoption of these systems. Using an experiment-based methodology, we test our strategies. Our experiment shows that recommender systems adoption is difficult to achieve without the involvement of all the stakeholders in the healthcare domain

Predictive Maintenance as a Causal Problem: A Systematic Review and Future Research Directions

Recep Günes, Kathrin Fischer
Technical University of Hamburg, Germany

Unplanned machine failures are a major cost factor in practice, which is why good decisions on a consistent basis for maintenance treatments are essential for companies. Predictive Maintenance (PdM) has emerged as a crucial enabler, offering the data-driven prediction of machine failures before they occur by using conventional machine learning (ML) models. However, predictive models are not able to differentiate causality from correlation and just optimize statistical accuracy metrics. Consequently, ML models do not provide any information about causal relationships or counterfactual scenarios, which could provide better insights about the system response to specific maintenance treatments. PdM is typically viewed as a prediction problem, although the determination of the effect of maintenance treatments for machine failures should also take a causal perspective.

In this study, we conduct a systematic literature review of PdM studies and demonstrate the importance of a conceptual shift to Prescriptive Maintenance (PsM), which focuses on optimizing maintenance decisions rather than merely predicting failures. We also highlight that causal inferences are shown as a key driver for PsM in the literature, where existing approaches largely focus on identifying causal relationships between influencing factors (e.g., temperature, vibration) and failure events. Tools such as Directed Acyclic Graphs (DAGs) are commonly employed to structure these relationships, rather than to model maintenance interventions as treatments. Consequently, current causal approaches with a particular focus on heterogeneous treatment effects for maintenance interventions are presented as a promising, underexplored direction. Moreover, perspectives for further developments and future research in the field are developed.

WE 10: Optimization under Uncertainty: Chance-Constraints and Decision-Dependent Robust Optimization

Time: Wednesday, 02/Sept/2026: 4:30pm - 6:00pm · *Location:* HS8 (WIWI)
Session Chair: Frauke Liers

Branch-and-Cut for Mixed-Integer Linear Decision-Dependent Robust Optimization Problems

Henri Lefebvre[1], Martin Schmidt[2], Simon Stevens[2], Johannes Thürauf[3]
1: LIRMM, University of Montpellier, CNRS, France; 2: Universität Trier, Germany; 3: University of Technology Nuremberg, Germany

In contrast to classical robust optimization, decision-dependent robust optimization (DDRO) considers uncertainties that depend on the decision variables, which enables some control over these uncertainties within the model. DDRO problems are usually tackled by reformulating them using a strong-duality theorem for the uncertainty set model. If the uncertainty set is, however, described by a mixed-integer linear model, dualization techniques cannot be applied and the literature on solution methods remains scarce. We exploit the equivalence of DDRO and optimistic bilevel optimization to derive the first tailored branch-and-cut method for mixed-integer linear DDRO problems. To this end, we consider both general-purpose intersection cuts for the case of decision-dependent uncertainty sets given by general mixed-integer linear models as well as more tailored interdiction cuts for the case of downward monotone uncertainty set models. Using the special structure of robust optimization problems, we also derive a novel version of intersection cuts that are only stated in the space of the upper-level variables of the respective bilevel reformulation. We present an extensive numerical study that demonstrates the applicability of our method.

Robust Unit Commitment in District Heating Networks: Chance-Constrained and CVaR Optimization Under Demand Uncertainty

Annika Buchholz, Janina Zittel, Thorsten Koch
Zuse Insitute Berlin, Germany

District heating networks are a key component of the energy transition. Yet their operational planning is challenging due to substantial uncertainty in heat demand. We address this volatility without compromising system reliability. By adapting chance-constrained programming and conditional value-at-risk (CVaR) optimization to the mixed-integer unit-commitment problem for district-heating networks, we are able to compute optimal unit commitment schedules under demand uncertainty. We generate heat demand time series using a Bayesian model, which explicitly quantifies forecasting uncertainty and yields predictive distributions as input to the network optimization. To handle the inherent uncertainty in heat demand, we apply both robust optimization approaches: chance-constrained programming limits the probability of unmet demand, while CVaR optimization penalizes severe shortfalls in the tail of the distribution. We evaluate the approaches both on real-world data from the Berlin district heating network and on a benchmark set of synthetic, realistically parameterized instances of varying sizes. The results compare the two uncertainty-handling methods with respect to solution quality, risk exposure, and computational effort.

Branch-and-cut for mixed-integer robust chance-constrained optimization with discrete distributions

Daniela Bernhard, Frauke Liers, Michael Stingl
Friedrich-Alexander Universität Erlangen-Nürnberg, Germany

We study robust chance-constrained problems with mixed-integer design variables and ambiguity sets consisting of discrete probability distributions. Allowing general non-convex constraint functions, we develop a branch-and-cut framework using scenario-based cutting planes to generate lower bounds. The cutting planes are obtained by exploiting the classical big-M reformulation of the chance-constrained problem in the case of discrete distributions. Furthermore, we include the calculation of initial feasible solutions based on a bundle method applied to an approximation of the original problem into the branch-and-cut procedure. We conclude with a detailed discussion about the practical performance of the branch-and-cut framework with and without initial feasible solutions. In our experiments we focus on gas transport problems under uncertainty and provide a comparison of our method with solving the classical reformulation directly for various real-world sized instances.

WE 11: Software for Operations Research: Fast Feasible Solutions

Time: Wednesday, 02/Sept/2026: 4:30pm - 6:00pm · *Location:* HS6 (WIWI)
Session Chair: Michael Feldmeier

Stop waiting for the relaxation: New MIP Heuristics in FICO Xpress

Gregor Hendel
FICO Xpress Optimization

Research on general-purpose primal heuristics for mixed-integer linear programming (MIP) has been trending in recent years.

It is no secret that modern MIP solvers such as FICO Xpress typically orchestrate many primal heuristics to boost primal convergence by discovering high-quality solutions early during the search.

In this talk, we present new primal heuristic concepts from recent releases of the FICO Xpress Optimizer, namely pre-root parallel and LP background heuristics, that do not require a solution to the LP relaxation as input. They leverage parallelism and a diverse portfolio of heuristic strategies, which improve the primal convergence by 24% on our internal test bed. We will discuss the impact of these recent additions and conclude with guidance on the best use of heuristic control parameters in typical application scenarios.

SCIP-Racer: A Lightweight Parallel Racing Framework for MIP

Gioni Mexi, Daniel Rehfeldt
Zuse Institute Berlin, Germany

Finding good feasible solutions fast is often more valuable than proving optimality in practice, yet most parallelization efforts in MIP focus on the latter. We present a lightweight multi-threaded racing approach built on top of SCIP that runs independent solver configurations concurrently, using low-overhead communication to exchange primal solutions and selected auxiliary information. The framework achieves strong primal integral on the MIPLIB 2017 benchmark set, closing the gap to commercial solvers on feasibility performance. We report detailed computational results and discuss which design choices matter, and which don't.

Model representation and primal heuristics in Hexaly

Michael Feldmeier
Hexaly, France

Hexaly is a mathematical optimization solver based on various operations research techniques, combining both exact and approximate methods such as linear programming, non-linear programming, constrained programming and primal heuristics. Depending on the implementation of the solution technique, a different technical representation of the users model may be required. Among other variants, the model could be stored as an expression tree, or in the form of a collection of e.g. uni- bi- and multivariate functions. In the same manner, one algorithm can be implemented to work on several technical model variants. In this talk, we will highlight some of the features of the latest release of Hexaly, as well as present some model representations within Hexaly, and compare how some primal heuristics (such as Undercover) perform when implemented and run on those different models.

WE 12: Decision Theory and Multi-criteria Decision Making 3

Time: Wednesday, 02/Sept/2026: 4:30pm - 6:00pm · *Location:* HS2 (PHIL)
Session Chair: Anjan Kumar Swain

A Multi-Objective Framework for R&D Portfolio Selection Using NSGA-II and Monte Carlo Simulation

Rafael Albea, Hadi Harb
Engineering Institute of Technology, Australia

R&D portfolio optimization in industrial enterprises requires balancing value creation, risk exposure, and complex operational constraints, including multi-period budgets, workforce capacity, project dependencies, and minimum innovation investment policies. These challenges are further compounded by execution and market uncertainties that deterministic approaches often fail to capture. This paper presents an uncertainty-aware, multi-objective optimization framework integrating the Non-dominated Sorting Genetic Algorithm II (NSGA-II) with Monte Carlo (MC) simulation. Portfolio value is modeled via Net Present Value (NPV), while risk is represented using category-dependent lognormal distributions, with volatility further amplified through a project size-dependent scaling mechanism. The framework is implemented in Python using the DEAP library and evaluated on a synthetic dataset designed to represent industrial R&D portfolios of 30 R&D projects over a five-year planning horizon. Results demonstrate that combining evolutionary optimization with stochastic evaluation produces well-differentiated Pareto fronts, with additional insight gained through pessimistic and optimistic efficiency metrics that reveal sensitivities to innovation allocation and project scale. The proposed approach bridges theoretical optimization and industrial decision-making by providing transparent, decision-ready outputs. Future work will extend the framework through agentic AI to incorporate qualitative reasoning on market dynamics, competitive context, and technology maturity.

Achieving Excellence in E-Healthcare: A Robust Fuzzy Group Decision-Making Framework for Telemedicine Provider Optimization

Palanivel Kaliyaperumal
Vellore Institute of Technology, Vellore, India

Abstract: A leading telemedicine platform looking to digital healthcare services, expand its virtual consultation capabilities, and patient engagement through innovative e-medical solutions. This study aims to identify and select suppliers that can provide secure, scalable, compatible medical equipment and user-friendly software solutions while adhering to regulatory standards set by the Ministry of Health and Family Welfare and ensuring cost-effectiveness to the health care providers. Although, the study introduces a fuzzy based Superiority and Inferiority Ranking method tailored for selecting telemedicine suppliers for the health care providers within the Indian E-Medical sector using Group Multi-Criteria Decision Making (GMCDM). Leveraging fuzzy set theory, the proposed model adeptly handles the inherent uncertainties and complexities associated with supplier performance evaluation in the current dynamic and rapidly evolving domain. Further, it requires the rigorous assessment of the efficacy and performance of the proposed Interval Valued Triangular fuzzy based ranking method, a comprehensive comparative analysis is undertaken, which has benchmarking it against established Multi-Criteria Decision Making (MCDM) techniques such as TOPSIS, GRA, and PROMETHEE. To notice the cost effectiveness, adaptability, and transparency of the supplier selection process, this study integrates the BWM for dynamic adjustment and optimization of criterion weights are employed in the fuzzy based Ranking Method. Lastly, the integration enables a more nuanced and comprehensive evaluation of telemedicine suppliers, allowing healthcare organizations and stakeholders to prioritize and weigh criteria based on their relative importance and impact on overall services of and patient care and Telemedicine software solutions.

Multiple Attribute Decision Making under Hesitant Fuzzy Linguistic Environment: An Ascending Price Multi-Unit Auction Platform

Anjan Kumar Swain, Bhaba Krishna Mohanty
INDIAN INSTITUTE OF TECHNOLOGY MANDI, Himachal Pradesh, India

The proposed work introduces a methodology that solves Multi-Attribute Decision Making (MADM) problem under Hesitant Fuzzy Linguistic Environment. The MADM problem is modelled as a multi-unit auction with an ascending price option platform. In the MADM, the alternatives are treated as multiple non-identical units, and the attributes as the agents to whom units are to be allocated at a price. The worth of attribute values that are in hesitant fuzzy linguistic values corresponding to alternatives is calculated in numerical numbers using geometric mean. Depending on an alternative's worth and its rank position amongst the alternatives in each attribute, a set of lower-ranked alternatives are taken as non-identical items (S1) for auctions. The auctioneer starts the auction with a lower price for each item (alternative), and the agents (attributes) quote their demands according to their utility in the price. The auctioneer gradually raises the price of the items until the demand of all the agents exceeds the items in S1. This is repeated for all the alternatives, and the alternative that maximizes the utility of all the stakeholders (agents and auctioneer) is taken as the best alternative in MADM.

As the attributes are in different dimensions, the price and utility in each attribute cannot be identical. The proposed work takes the ideal point and numerical worth of each attribute to find the prices and utility of the agents for single items. For multiple items, this study uses Extreme Value Reduction OWA operators to find the price and utility.

WE 13: OR in Developing Countries 2

Time: Wednesday, 02/Sept/2026: 4:30pm - 6:00pm · *Location:* HS4 (PHIL)
Session Chair: Bayu Purnomo

Logistical Network Design for Enhanced Rock Weathering in Developing Countries

Ghazal Ziadlou, Arne Heinold, Maria Besiou
Kuehne Logistics University, Germany

Enhanced rock weathering (ERW) is a potential new carbon dioxide removal strategy that accelerates the rate of natural weathering reactions by spreading finely ground minerals onto land or aquatic environments. Through these reactions, carbon dioxide is captured and stored in stable forms over long periods. While the potential of ERW is increasingly recognized, its large-scale deployment depends heavily on the design of effective logistics systems, especially in developing countries where transportation infrastructure constraints and uncertainty are more pronounced.

This work addresses the design of a logistics network for ERW, which specifies the number, location, and capacity of warehouses and the flow of minerals from ports to deployment sites over time. This problem is influenced by different uncertainty factors such as demand variation, transport networks, unreliability, and carbon removal effectiveness uncertainty. Meanwhile, logistics-related emissions must be carefully managed to ensure that they do not offset the environmental benefits of ERW.

We develop an optimization-based framework, formulated as a mixed-integer linear programming model, integrating long-term infrastructure decisions with day-to-day distribution planning. The model is a multi-objective problem balancing economic efficiency, carbon removal performance, and socio-economic development. To keep it tractable, we propose an iterative solution approach and evaluate uncertainty scenarios. Using Nigeria as a case study, we show how infrastructure limitations and demand variability influence network design.

Our results suggest that explicitly accounting for these uncertainties leads to more resilient logistics configurations. They also highlight the importance of considering broader socio-economic objectives, such as regional development, alongside cost and environmental performance.

Optimizing the UAV-MPA Force Mix for Cost-Efficient Maritime Surveillance in Indonesia's North Natuna Sea

Bayu Purnomo, Chad Seagren
Naval Postgraduate School, United States of America

The North Natuna Sea is part of Indonesia's Exclusive Economic Zone (EEZ) and faces persistent threats including illegal, unreported, and unregulated (IUU) fishing, foreign vessel incursions, gray-zone pressure, and overlapping maritime claims by China. The area's vast extent strains limited surveillance assets, making domain awareness difficult to sustain. While existing literature examines Unmanned Aerial Vehicle (UAV) employment and Manned Maritime Patrol Aircraft (MPA) operations independently, no published study develops a quantitative model identifying the optimal force mix between these two assets for Indonesia's North Natuna Sea. This study applies a Linear Programming (LP) model to optimize MPA and UAV patrol hour allocation subject to budget and asset availability constraints. The study area is represented as an analytical grid of six equal sectors. Three threat scenarios representing Low, Medium, and High conditions are modeled with distinct risk weights derived from empirical vessel density and incident data. The model was implemented in Python. Preliminary results show the model correctly follows empirically derived risk weights, concentrating patrol hours in Sector B under Low and Medium scenarios and shifting to Sector C under High threat. Asset availability is the binding constraint, as Medium and High scenarios exhaust available flight hours while leaving budget unspent. Under Medium and High scenarios, total expenditure reaches $5.78 million against budgets of $10 million and $15 million, confirming that fleet size rather than funding limits surveillance capacity. This study provides the first quantitative force-mix optimization framework, offering defense planners a basis for resource allocation and procurement decisions.

WE 15: Continuous and Global Optimization: Optimal Control Applications

Time: Wednesday, 02/Sept/2026: 4:30pm - 6:00pm · *Location:* SR034 (WIWI)
Session Chair: Andrea Seidl

Comparative Analysis of Sales Models in a Dynamic Dual-Channel Supply Chain

Gromova Ekaterina[1], Gromov Dmitry[2], Sigué Simon[3]

1: Transport and Telecommunication Institute (TSI), Riga, Latvia; 2: University of Latvia, Riga, Latvia; 3: Athabasca University, Canada

This paper extends the static framework developed in Sigué and Gromova (2023) to a dynamic continuous-time setting by formulating the problem as a differential game. We analyze the choice between reselling and agency selling in a dual-channel supply chain with service spillover effects.

Three alternative models are examined under Stackelberg competition. For each model, equilibrium strategies are derived and the corresponding equilibrium payoffs of the supply chain members are compared. The results show how service spillovers and channel structure influence the relative attractiveness of different sales formats over time.

We also derive and compare the vertical Nash equilibria for all three models and further extend the analysis to the case of multiple retailers.

The dynamic analysis provides new insights compared with the static benchmark and helps identify the conditions under which one sales model dominates the others.

Reference

Sigué, S., and Gromova, E. (2023). The role of advertising in the choice between reselling and agency selling. International Transactions in Operational Research. https://doi.org/10.1111/itor.13351

From Skiba Thresholds to Narrow Corridors

Gustav Feichtinger[1], Dieter Grass[1], Aart de Zeeuw[2], Peter M. Kort[2], Andrea Seidl[3], Stefan Wrzaczek[4], Reinhard Neck[5]

1: TU Vienna, Austria; 2: Tilburg University, The Netherlands; 3: WU Vienna, Austria; 4: IIASA, Austria; 5: University of Klagenfurt, Austria

In the present talk, we illiustrate a procedure to generate corridors in the usual shallow lake framework by assuming a special form of the damage function for pollution. The case of one Skiba point separating two saddle-point equilibria is extended to two Skiba thresholds and three optimal equilibria, the middle one of them in a corridor.

Secondly, following Acemoglu & Robinson (2019) a 2-state optimal control model is presented analyzing the dynamic interaction between 'the state' and 'the society'. There exists a 'narrow corridor' in which the two powers are balanced and each side finds it optimal to make sufficient investment to grow and eventually to converge to a steady state of maximum powers for both.

Another example would be two competing firms being initially similar in size, for whom it is optimal in the long run that the market remains in the corridor of a duopoly. However, if one of the two firms is stronger, it can follow entry deterrence, i.e. remain monopolist.

Applying the Epsilon-Control Method in an Optimal Control Framework

Andrea Seidl[1], Richard F. Hartl[2], Peter M. Kort[3]

1: WU Vienna, Austria; 2: University of Vienna, Austria; 3: Tilburg University, The Netherlands

While the epsilon-constraint method is well known e.g. in discrete optimization, it has not yet found much attention in applied optimal control. In the present talk we aim to determine the Pareto front by means of the epsilon-constraint method for a problem where a firm aims to maximize profits, but also wants to keep emissions caused by production as small as possible. We consider a linear-quadratic version of the problem, for which we are able to derive parts of the Pareto front analytically. Furthermore, we mostly numerically study a version of the problem with a convex-concave revenue function, for which we discuss the implications of multiple long run steady states for the calculation of the Pareto front. We find that the shape of the Pareto front substantially depends on the initial state value and are able to detect indifference points on the Pareto front, i.e. points where the decision maker is indifferent between different long run solution taking into account both objectives.

WE 16: Analytics, Data Science, and Forecasting: Features and Architectures

Time: Wednesday, 02/Sept/2026: 4:30pm - 6:00pm · *Location:* SR033 (WIWI)
Session Chair: Ralph Grothmann

Fooled by Spurious Correlation – an investigation into the "intelligence" of Deep Neural Network and Foundation Models in Forecasting with non-stationary covariates

Sven F. Crone
Lancaster University // iqast, Germany

Deep Neural Networks (DNN) and Foundation models have increasingly been portrayed as "intelligent" and, by implication, robust to the pitfalls that have long challenged econometric forecasting. This perception has led to the widespread and often careless application of DNN to non-stationary time series, where explanatory variables are frequently integrated, highly persistent, or cointegrated. In such settings, practitioners routinely include large sets of covariates—many of which are spuriously correlated—and subsequently rely on explainable AI (xAI) tools such as SHAP values, partial dependence plots (PDPs), or permutation importance (PI) to justify their inclusion. These explanations convey a compelling narrative of variable importance yet fail to acknowledge that the underlying statistical relationships may not exist.

This paper argues that DNNs are inherently as vulnerable as classical regression models to select spuriously correlated predictors and assign significant feature weights in forecasting contexts, when non-stationarity is present. In addition, they remain highly susceptible to explainability failure, as post hoc xAI methods indicate misleading attributions that conflate spurious co-movement with genuine predictive content. As a result, time series xAI can generate economically invalid explanations, even when predictive performance appears satisfactory. We identify a critical gap in the literature of existing xAI approaches for time series forecasting which assume stable, independent feature distributions and do not account for the econometric properties of non-stationary data, such as unit roots, stochastic trends, cointegration or spurious correlation.

From Time Series Analysis to Modeling of Dynamical Systems: The Art and Beauty of Architectural Thinking

Hans Georg Zimmermann
Fraunhofer Gesellschaft IIS, Germany

In economic forecasting, typically we have to work with small data sets and complex causalities! How can we use pre-designed neural network structures to overcome the lack of information in the data? Concerning dynamical systems, can we formulate general classes of problem questions, independent of specific applications? How to balance pre-designed architecture with learning algorithms?

Fuzzy Local Attribution with Relative-Share Evaluation (FLARE): A novel filter method for supervised feature selection

Christoph Lohrmann
Reykjavik University, Department of Computer Science, Iceland

Feature selection aims to retain relevant variables while discarding irrelevant and redundant ones to support a classifier in finding generalizable patterns in the data and to promote the interpretability of results. This research proposes a new filter method for feature selection termed Fuzzy Local Attribution with Relative-Share Evaluation (FLARE) that is inspired by the fuzzy k-nearest neighbor classifier and the well-known ReliefF filter method. The novelty in the filter method lies in the fact that it combines an estimate of the local classification difficulty of an observation with the difference in the relative share each feature contributes to the observation-neighbor distance between hit (same class) and miss (other classes) instances in the neighbourhood. The proposed filter method is tested on 20 real-world datasets and benchmarked against six popular filter methods, MRMR, ReliefF, Chi-squared test, Fisher score, (absolute) Pearson correlation, and Strife. The results demonstrate the new approach's ability to provide feature importance scores that frequently lead to feature sets with lower error rates than most or all benchmark methods. Moreover, a comparison of feature weighting using the scores that FLARE provides, indicates that its scores often lead to lower classification errors than most of the popular filter methods in this study.

TA 01: Supply Chain Management and Production: Scheduling in the Service and Paper Industries

Time: Thursday, 03/Sept/2026: 8:30am - 10:00am · *Location:* HS10 (AM)
Session Chair: Raik Stolletz

Heuristic Approaches for Defect-Aware Cutting Stock Problems in the Decor Paper Industry

Nick Kloster, Sigrid Knust
Universität Osnabrück

In coated paper production, large paper rolls frequently contain localized defects caused by technical limitations of the manufacturing process. When customer orders are cut from these rolls, items containing too many defects cannot be sold or reused, making defect-aware cutting plans essential to minimize material loss, reduce waste and increase the overall economic value of production.

Motivated by a real-world application from a paper manufacturer, we study defect-aware cutting optimization problems on paper rolls. We introduce several problem variants that differ in operational constraints and planning objectives, capturing key challenges faced in practice, aiming to minimize waste and maximize total profit. Since exact approaches quickly become computationally intractable for realistic instance sizes, we develop heuristic solution methods. These heuristics are designed to balance solution quality and runtime while remaining flexible enough to handle the different problem variants. We present computational experiments and results based on realistic instance settings inspired by industrial practice.

Déjà-Vu on The Line: Should We Care About Retrials?

Ömer Schmiel[1], Benjamin Legros[2], Raik Stolletz[1]
1: University of Mannheim, Germany; 2: SKEMA Business School, France

In call centers, customers leave the queue before being served due to a lack of patience, if they face longer waiting times. However, these impatient customers may re-enter the system after some time as retrials. In this work, we present an empirical analysis of customer retrials in a technical call center. We distinguish between same-day and next-day retrials, as they stem from different behavioral mechanisms; same-day retrials typically represent reattempts driven by unresolved urgency, whereas next-day retrials arise after a temporal break and may result due to scheduling constraints. Although existing literature on the analysis of retrial queueing systems assume exponentially distributed retrial times, we show through a descriptive analysis that general distributions provide a better fit.

Furthermore, utilizing the Stationary Coupled-Flow (SCF) approximation, we present analytical and numerical insights on how the retrial time distribution impacts time-dependent performance measures and staffing decisions. Specifically, we prove that increasing the retrial probability or faster retrials, under certain assumptions, result in a larger abandonment probability and throughput. However, less customers are served on their initial try. This phenomenon is explained by overlapping retrial attempts akin to a snowball effect. We further quantify the implications of these insights for time-dependent staffing decisions under consideration of a service level which prioritizes the service of fresh arrivals.

Simultaneous Optimization of Time-dependent Staffing Levels

Tim Maximilian Weber, Raik Stolletz
University of Mannheim, Germany

Staffing determines the number of employees per period that should be present given stochastic and time-dependent demand. The less servers (employees) are working in a given hour, the lower personal costs, but the longer customers have to wait until service and the higher customer dissatisfaction. Thus, the goal is to minimize the number of servers, while still adhering to some service level constraint (SLC). These SLCs can be defined locally or globally, i.e., constraining a single period or the entire planning horizon.

Prominent staffing methods, such as the Stationary Independent Period by Period (SIPP) approach determine staffing requirements for each period in isolation. However, a high demand in a certain period may affect the performance measures in succeeding periods. We propose a staffing method for an M(t)/M/c(t) queueing system that optimizes staffing levels simultaneously over all periods of the planning horizon subject to local and global SLCs. In particular, we integrate the Stationary Backlog Carryover (SBC) approach for performance evaluation into a nonlinear optimization model. An efficient linearization of this model is introduced.

The numerical study analyzes the effectiveness of this approach. We discuss the changes in the structure of the staffing levels for different demand patterns and assumptions on local and global SLCs.

TA 02: Mobility, Transport, and Traffic: Electric Vehicles

Time: Thursday, 03/Sept/2026: 8:30am - 10:00am · *Location:* HS1 (PHIL)
Session Chair: Ayoub Laamim

A Computational Study on Battery Capacity Sizing in Heterogeneous Electric Bus Fleets

Robert Janus, Nils Katzke, Natalia Kliewer
Freie Universität Berlin, Germany

The electrification of public transport poses substantial investment and planning challenges for bus operators. The growing variety of electric bus models with different battery capacities enables more demand-oriented and potentially cost-efficient fleet procurement. From an operational perspective, heterogeneous fleets increase scheduling and coordination complexity, creating a trade-off between investment efficiency and operational simplicity. Computational experiments are conducted on real-world public transport networks from major German cities. We analyze the impact of battery-capacity heterogeneity on investment and operational efficiency and assess the statistical significance and transferability of the observed effects across different timetable structures. The results provide practical guidance for public transport operators in fleet procurement and operations planning, while also supporting policymakers in the design of economically viable public transport electrification strategies.

Electric vehicle routing problem with time-window and capacitated charging station constraints

Hinata Moriyama[1], Ken Kobayashi[1], Kazuma Kawai[2], Yutaro Ito[2], Noriaki Ikemoto[2], Kazuhide Nakata[1]
1: Department of Industrial Engineering and Economics, School of Engineering, Institute of Science Tokyo; 2: Research & Development Center, Corporate R\&D Division, DENSO CORPORATION

In recent years, electric vehicles have been increasingly introduced into logistics due to environmental considerations and the growing demand for sustainable transportation. Since electric vehicles have a short driving range and require long charging times, deciding when, where, and how much to recharge is an important issue for electric vehicle delivery operations. The Electric Vehicle Routing Problem (E-VRP) consists of designing optimal delivery routes, including visits to customers and charging stations, while minimizing the objective value, such as total cost or time. The Electric Vehicle Routing Problem with Time Windows (E-VRP-TW) further extends the E-VRP by incorporating customer time-window constraints.

However, the number of vehicles that can be charged simultaneously at a charging station has not been considered much in existing E-VRP-TW models, although multiple vehicles may charge at the same station when charging infrastructure is scarce, or the number of vehicles is large. Moreover, the nonlinear nature of charging functions and partial charging policies have not been adequately addressed with these capacity limitations under hard time-window constraints.

In this study, we propose an E-VRP-TW model with capacitated charging stations by introducing charging reservation slots to represent limited simultaneous charging capacity. We also consider nonlinear charging functions and allow partial charging decisions to better reflect realistic electric vehicle operations. Since the proposed problem with hard time-window constraints and charging capacity limitations has a limited number of feasible solutions and becomes computationally difficult for large-scale instances, we further develop a heuristic algorithm based on column generation to efficiently solve such instances.

Enhancing EVRP Metaheuristics with an Efficient Global Charging Operator

Ayoub Laamim, ElHassania Messaoud, Hanane Assellaou
Hassania School of Public works, Morocco

In recent years Electric vehicles (EVs) have gained significant attention as an alternative to combustion engine vehicles due to concerns about pollution and energy independence. As a result incorporating electric vehicle specific constraints and particularities is necessary for optimization models used for managing logistics operations. One of these constraints is the charging model for electric vehicles. In combustion engine vehicles the refueling time for the vehicle can be considered negligible. This simplification does not hold for electric vehicles. That is because the charging time is consequential. And Charging stations are still sparse and far in-between. This has led researchers to introduce the Electric vehicle routing problem with time windows and Non linear charging function (EVRPTW-NL), a variant of the Electric vehicle routing problem. In this variant the charging function of EVs is considered non-linear. In this paper we propose and study an improvement to the charging operator that can be used, within a metaheuristic framework, to handle the charging decisions of the routing problem. The charging operator consists of solving a sub-problem: the Fixed route vehicle charging problem (FRVCP). This sub-problem aims to find the optimal charging schedule to produce an energy-feasible route. We propose the usage of a bi-directional labeling algorithm to solve this sub-problem. We study the proposed operator within an Iterated local search metaheuristic. And we show that replacing a standard embedded solver by the proposed method, greatly improve the computation time and the solution quality across tested instances.

TA 03: Mobility, Transport, and Traffic: Data Analysis in Mobility and Transport

Time: Thursday, 03/Sept/2026: 8:30am - 10:00am · *Location:* HS3 (PHIL)
Session Chair: Mohammad Ghuloum

A Data-Driven Analysis of Cycling Preferences in Route Planning

Felix Möller, Noah Gollnick, Dirk Mattfeld
TU Braunschweig, Germany

Courier services have a long tradition in urban logistics, primarily in the delivery of valuable documents, medicines, or food. Furthermore, there is a trend forward using cargo bikes for last-mile deliveries. For short distances, bicycle couriers have major advantages: they are less affected by traffic volume and congestion, they do not block small streets while serving, and they can more easily serve customers in car-free zones. In recent years, bicycle logistics, and particularly the planning process, have become increasingly diverse. This is due to the variety of bicycle types and routing preferences of the riders.

In this research, we focus on preferences for routing in the road network. Since cities are structured differently and therefore are differently bike-friendly, the preferences may be reflected in different route choices. From an economic perspective, the cost of integrating preference into route planning can vary depending on the specific city. To investigate these effects, we analyze routes based on different preferences in several European cities. We consider several cycling profiles resulting from the combination of three distinct preference types with varying levels. These types are physical comfort, mental comfort, and environment. Based on these profiles, we generate routes as weighted shortest paths between a large variety of locations in each city. We perform a data-driven analysis on cities, preference profiles, and routes. Preliminary results confirm that the routes differ both in terms of profiles and cities. For example, the lengths of the routes and the proportion of certain road types within the routes change.

Regression Analysis of Economic Factors Influencing Cross-Border Commuting from Czech Republic to Bavaria

Dominic Scholze, Maren Martens
Hochschule Landshut, Germany

This talk presents a quantitative analysis of commuter mobility demand using regression models based on commuter data from 2021 to 2024, which detail the number of Czech commuters working in Bavaria. We hypothesize that commuting patterns are influenced by regional economic factors such as employment rates and the number of registered employers. The study uses multiple datasets from sources like the Federal Statistical Office of Germany to validate these hypotheses, revealing key drivers behind different levels of mobility demand.

Our analysis aims to identify how regional economic indicators impact commuter behaviour, providing valuable insights for transportation planning and policymaking. This research offers a better understanding of commuter needs and potential areas for improvement in mobility services, such as targeted investments in public transport infrastructure to make cross-border commuting future-oriented.

Conflict-driven airspace closures: a multi-ring empirical analysis

Mohammad Ghuloum
Kuwait University, Kuwait

Conflict-driven airspace closures disrupt the global air transport network at multiple geographic scales. What originates as a local disruption propagates through adjacent reroute corridors and secondary hub airports to affect the global non-adjacent network. Networks require time to absorb the shockwave created by closures and for the resulting operational impact to resolve. Existing empirical work treats these scales and phases in isolation, leaving the joint propagation of conflict-driven closures through the network underexamined.

This paper introduces a multi-ring empirical framework for analyzing conflict-driven airspace closures. The framework analyzes the impact of closures on the network during active closure and recovery, relative to a pre-closure baseline. It examines this impact across four geographic rings: closed flight information regions, adjacent reroute corridors, secondary hub airports receiving cascade effects, and the global non-adjacent network. This structured decomposition supports a comparative assessment of how closures propagate through the global air transport network.

TA 04: Energy and Sustainability: Near optimal solutions and system design

Time: Thursday, 03/Sept/2026: 8:30am - 10:00am · *Location:* HS13 (IM)
Session Chair: Dogan Keles

Think Inside the Box: Exploring Continuous Near-Optimal Solution Spaces in MILP Energy System Models

Alwin Haese, Malte Strewick, Lennart Scheer, Hendrik Schricker, Niklas von der Assen
Institute of Technical Thermodynamics, RWTH Aachen University

Planning energy system transformation is a complex decision problem. Mathematical optimization identifies cost-optimal configurations. However, near-optimal alternatives often better reflect real-world constraints, implementation risks, and stakeholder preferences. Modeling to generate alternatives (MGA) is commonly used to provide alternatives for linear programs (LPs) and mixed-integer linear programs (MILPs). Site-scale energy system models rely on MILP formulations to capture operational complexities. In MILPs, MGA yields isolated solutions rather than continuous solution spaces, limiting decision flexibility and insight into plausible system configurations.

We present an algorithm to systematically explore continuous near-optimal solution spaces in MILP-based energy system models. The algorithm first computes the global optimum and then introduces a persistent near-optimality constraint with predefined slack. The potential near-optimal space is explored and decomposed into convex segments. Additional constraints restrict the exploration variables in each segment. If a feasible solution is obtained in a section, all discrete variables are fixed, which reduces the problem to a convex LP. MGA then generates the corresponding continuous near-optimal space. The algorithm terminates once all segments are classified as either infeasible or near-optimal.

We demonstrate the algorithm using a small industrial case study with part-load-dependent efficiencies and minimum part-load constraints. We compare the resulting continuous near-optimal space with that of a corresponding LP model without complexities and with isolated solutions from conventional MILP MGA. The LP near-optimal space deviates substantially from our results. Convex hulls of isolated MILP solutions falsely classify 5.4% of the hull interior as near-optimal with part-load-dependent efficiencies and 26.6% with minimum part-load constraints.

Exploring Near-Optimal Multi-Energy System Designs via Surrogate-Assisted Modeling to Generate Alternatives

Boyung Jürgens, Sebastian Pieper, Hendrik Schricker, Niklas von der Assen
Institute of Technical Thermodynamics, RWTH Aachen University

Energy system planning often relies on optimization models that yield a single optimum. A single optimum can mislead design decisions because optimization models simplify real systems. Modeling to Generate Alternatives (MGA) addresses this limitation by identifying near-optimal solutions, giving decision makers flexibility in system design. However, MGA requires repeated model evaluations, limiting its use for expensive models and preventing interactive exploration of user-defined scenarios.

Researchers increasingly use surrogate models to reduce the computational burden of optimization models. In design optimization, surrogate-assisted design optimization (SADO) proposes designs, evaluates them with surrogate models, and updates the search iteratively. Direct-surrogate design optimization predicts optimal solutions directly. One direct-surrogate approach has accelerated MGA for multi-national power systems, but does not test whether predicted near-optimal systems can meet energy demand.

We embed surrogate models into MGA and call this approach surrogate-assisted MGA (SA-MGA). SA-MGA uses two neural networks that take a design and a scenario as inputs. Each scenario specifies energy demands, energy-carrier prices, and renewable availability. The networks predict operational cost and feasibility. After training, SA-MGA generates near-optimal designs with customizable feasibility margins: it predicts a feasible cost-optimal design, then explores the near-optimal space by enforcing a predefined cost slack relative to this predicted optimum.

We demonstrate SA-MGA on an industrial multi-energy system. SA-MGA identifies diverse near-optimal designs, and for most predicted designs, the realized cost slack exceeds the predefined cost slack by at most 5 percentage points. SA-MGA reduces the average identification time per near-optimal design from 40 to 0.2 seconds.

Optimizing the transformation of industrial energy systems

Dominik Bierer
Technische Universität Darmstadt, Germany

The transformation of existing energy systems towards a carbon neutral operation is an important task for industrial companies. Such energy systems connect components such as processes, machines, storage units, and suppliers via energy networks.

The goal is to find an optimal restructuring of these networks over time, with limited investment budgets and given emission targets. The transformation of such energy systems is modeled as a mixed-integer-program, based on energy flows in a directed graph. We investigate the structure of this problem, it's solutions and the sensitivity of solutions to uncertainty in the parameters. We

demonstrate our approach by a realistic case study of an industrial plant containing a heat supplier, cooling tower and multiple consumers.

TA 05: Energy and Sustainability: Electricity market modelling and price forecasting

Time: Thursday, 03/Sept/2026: 8:30am - 10:00am · *Location:* HS11 (IM)
Session Chair: Philipp Castro

The Right Model for the Right Time: Applying Mixture of Experts for Electricity Price Forecasting

Julian Sauerbier, Nick Frowerk, Alexander Szimayer
University of Hamburg, Germany

Forecasting day-ahead electricity prices in the German market is complicated by the simultaneous trading of 24 hourly contracts with distinct demand profiles, and by shifting market states driven by renewables, regulatory change, and European market integration. We propose a SARIMA-augmented Mixture of Experts (MoE) framework that assigns machine learning models to rule-based clusters.

The framework operates in three stages. A global SARIMA model, refitted daily on a rolling 12-month window, generates baseline forecasts that serve as engineered features rather than standalone predictions. A rule-based clusterer then assigns each hour to overlapping clusters spanning day type, time of day, season, and market state. For each cluster the best-performing expert is selected from a candidate pool (OLS, Lasso, XGBoost, RF, SVR, ANN) via Optuna-tuned validation. An exhaustive subset search retains the cluster combination that minimizes MAE on the evaluation set. At inference, predictions from all active experts are averaged.

We evaluate the framework on the German day-ahead market from January 2024 to September 2025, using both Mean Absolute Error and a Forecasting Efficiency Ratio (FER) derived from a simulated Battery Energy Storage System. The MoE achieves an MAE of 13.36 EUR/MWh and an FER of 96.44\%, outperforming all benchmark models on both metrics.

Ex Post Statistical Analysis of the Residuals of a Parsimonious Fundamental Electricity Price Model

Haman Nabi, Philipp Castro, Christoph Weber
House of Energy, Climate and Finance, University of Duisburg-Essen

Fundamental electricity price forecasting models offer the structural interpretability and counterfactual capability that long-horizon applications such as Power Purchase Agreement (PPA) valuation require. However, fundamental models have limitations in capturing price volatility and extreme prices. The literature on combining fundamental and statistical approaches has predominantly focused on hybrid power price forecasting models that combine fundamental model output with statistical processing (Beran et al., 2021; de Marcos et al., 2019; Ghelasi & Ziel, 2026). This presentation takes a different stance: rather than improving forecast accuracy through statistical (post-)processing, we analyze the residuals of a fundamental electricity price model to identify when and why it fails.

We perform a systematic statistical analysis of the residuals of a Parsimonious Fundamental Model (based on Beran et al., 2019) using German day-ahead market results of the period 2019–2025. The analysis period spans structurally distinct market regimes: a pre-crisis period of lower fuel prices and substantial nuclear and coal generation, and a post-crisis regime characterized by higher fuel prices, the German nuclear phase-out, coal reduction, and rapid renewable expansion. Treating each residual as a realization of a random variable, its distribution is characterized through its first four moments and its conditional dependence on key model parameters, motivated by the non-normality of electricity price distributions (Marcjasz et al., 2023). Particular attention is paid to systematic patterns fundamental models fail to capture, identifying which drivers of error warrant correction and which reflect irreducible uncertainty.

The results provide an empirical foundation for improved fundamental models for long-horizon applications such as PPA valuation.

Dynamic Quantile Bidding for Renewable Power Producers under Multivariate Market Dependence

Philipp Castro, Haman Nabi, Christoph Weber
University of Duiusburg-Essen, Germany

The increasing share of generation from variable renewable energy sources has made electricity markets – particularly day-ahead, intraday and balancing markets – more volatile. As a result, the revenues of wind power producers have become increasingly uncertain, creating potential for improved bidding strategies. Existing studies have shown that bidding the expected value of the generation forecast may not be optimal. Instead, profit-maximizing and/or risk-minimizing offers may correspond to more conservative or more aggressive forecast quantiles, depending on prevailing market conditions. However, to our knowledge existing approaches focus on univariate forecast uncertainty, simplified market environments and largely neglect explicit risk preferences.

We develop a multi-stage stochastic optimization framework for wind power bidding in sequential electricity markets. Bidding quantities are parameterized through dynamic conditional production quantiles, allowing the optimal bid decision to vary over time

with current market and system states. This includes forecast uncertainty for both an individual asset and the aggregated national wind portfolio.

A key contribution is the explicit incorporation of the multivariate dependence structure among relevant forecast, production, and market variables. In particular, we analyze how optimal bidding behavior depends on the correlation between the asset's generation profile and the aggregated portfolio. To capture nonlinear and tail-dependent relationships, the stochastic environment is modeled using flexible multivariate dependence structures, with copula-based approaches as the main methodology. Using historical quarter-hourly data, we evaluate the economic value of dependence-aware dynamic quantile bidding relative to standard benchmarks. The results aim to provide guidance for renewable producers.

TA 06: Discrete and Combinatorial Optimization: Integer Programming

Time: Thursday, 03/Sept/2026: 8:30am - 10:00am · *Location:* HS5 (WIWI)
Session Chair: Ulrich Pferschy

Integer Programming Strategies for the Snake-in-the-Box Problem

Tim Kunt, Thorsten Koch
Zuse Institute Berlin, Germany

We present a selection of Integer Programming (IP) strategies for the Snake-in-the-Box problem, which asks for the longest induced path in the n-dimensional hypercube.

Current records are based on sophisticated, exhaustive searches, with optimality proven only for instances up to dimension 8, motivating our study of IP formulations. We discuss several base formulations, analyze formulation symmetries and symmetry-breaking constraints, potential strengthenings, and the resulting speedups on solver performance. With the smallest open instance having as few as 512 binary decision variables, the proposed IPs offer a challenging and intriguing combinatorial problem. In addition, we extend the problem to higher-dimensional grid graphs and provide initial solutions and computational results for unexplored and unsolved instances.

Accelerating column generation procedures for the GAP

Basile Blayac, Andrew J Mason, Andrea Raith
University of Auckland, New Zealand

The Generalized Assignment Problem (GAP) is a classic combinatorial optimisation problem. The best heuristic on the most challenging literature instances applies a diving procedure on an extended formulation (EF) solved with column generation, which often converges slowly. We propose two methods to accelerate column generation that we combine with existing ones: Neighbourhood Pricing which consists in restricting new columns to those close to columns from the current primal solution, and estimating EF optimal dual values using relaxations of EF. These relaxations also reveal GAP structural insights, leading to new challenging instance classes and helping explain the strong performance of diving methods on the formulation EF.

Selection and scheduling of advertisements in a TV break

Michele Monaci[1], Ulrich Pferschy[2]
1: University of Bologna, Italy; 2: University of Graz, Austria

We consider the selection and scheduling of TV advertisements within a commercial break. The profit generated by an advertisement depends not only on its revenue rate and duration but also on its placement within the break, captured by a time-dependent impact function. This position-dependent valuation yields a non-standard generalization of the classical 0-1 Knapsack Problem, namely the Advertisement Knapsack Problem (AKP). Continuing previous work from the literature, we investigate AKP under arbitrary impact functions, establish strong NP-hardness and describe an assignment-based integer linear programming formulation of pseudo-polynomial size.

Focusing on the practically relevant case of negative unimodal impact functions, which reflects higher audience attention at the beginning and end of a break, we discuss structural properties of optimal schedules. We introduce two relaxations based on splitting advertisements into unit-length slices. For the split relaxation (S-Rel), we provide a combinatorial algorithm and prove a tight worst-case bound of three on the optimality gap. For the stronger, but NP-hard complete split relaxation (CS-Rel), we develop a dynamic programming algorithm and establish a tight optimality bound of two.

Besides giving an exact dynamic programming algorithm, we examine several greedy-type approximation algorithms. While natural sorting-based heuristics admit only a tight worst-case ratio of h (=length of the commercial break), we design a composite greedy algorithm with a tight approximation guarantee of three.

TA 07: Artificial Intelligence, Machine Learning and Optimization: Explainability and Interpretability

Time: Thursday, 03/Sept/2026: 8:30am - 10:00am · *Location:* SR029 (WIWI)
Session Chair: Sebastian Merten

Conformal Counterfactual Explanations in Regression

Matthias Soppert[1], Alexandre Forel[2], Thibaut Vidal[2], Maxime Cohen[3]
1: University of the Bundeswehr Munich; 2: Polytechnique Montreal; 3: McGill University

We propose a method to generate counterfactual explanations in regression with formal validity guarantees. Given a trained regressor and an initial feature vector, the goal is to find the closest actionable counterfactual whose true response exceeds a target threshold with high confidence. The central challenge is that standard conformal prediction calibrates uncertainty using residuals from observed data points in the original prediction task, which does not yield valid guarantees for counterfactuals obtained via optimization. To overcome this, we shift the calibration from the prediction setting to the counterfactual generation pipeline itself. Specifically, we generate counterfactuals using the same optimization procedure as in deployment, obtain their corresponding outcomes through an oracle or a suitable proxy, and compute residuals on these counterfactuals. The residuals are then used to calibrate a quantile-based lower confidence bound that is enforced directly in the optimization model. As a result, the method returns regression counterfactuals that are not only close to the original instance, but are also designed such that their true response exceeds the target threshold with a guarantee valid under the distribution of counterfactuals induced in deployment.

Explainable AI-Guided NSGA-II for Energy-Efficient Job Shop Scheduling

Mahdi Homayouni
Constructor University, Germany

The Energy-Efficient Job Shop Scheduling Problem (EEJSP) involves jointly determining operation sequences and machine processing speeds to minimize both makespan and energy consumption. This interplay creates a high-dimensional multi-objective optimization (MOO) challenge. While the Non-dominated Sorting Genetic Algorithm II (NSGA-II) generates diverse Pareto-optimal solutions, it struggles to scale efficiently for large instances. Its uniform treatment of the search space and lack of intelligent feedback often lead to excessive computation and suboptimal Pareto front coverage.

To address this, we propose a novel framework that integrates Explainable AI (XAI) directly into the NSGA-II process. Every T generations, surrogate models are trained using XGBoost to approximate the relationships between decision variables and the two objectives. We then apply TreeSHAP to interpret feature influence, specifically isolating the impact of job sequencing and speed assignments. Based on these SHAP value patterns, the population is clustered into interpretable subspaces exhibiting similar decision–objective behaviors. Localized neighborhood searches are subsequently applied within these clusters to intensify exploration in high-potential regions.

Preliminary experiments demonstrate that periodic XAI-guidance significantly improves optimization efficiency and solution quality without introducing major computational overhead. By leveraging SHAP-driven clustering, NSGA-II dynamically focuses on the most impactful decisions, drastically reducing ineffective evaluations. Early results indicate promising scalability, transforming interpretability into an active computational accelerator. We will present these findings and ongoing runtime analyses at the conference.

Finding Interpretable Surrogates for Optimization through Dynamic and Integer Programming

Marc Goerigk[1], Michael Hartisch[1], Sebastian Merten[1], Daniel Vos[2]
1: University of Passau, Germany; 2: Delft University of Technology, Netherlands

In recent years, interpretability and explainability have become increasingly important in mathematical optimization. Both of these aspects can be addressed by the use of so-called (feature-based) interpretable surrogates. These approximate the conventional black box solution process by a set of interpretable decision rules (represented e.g. as a decision tree) mapping instances to (sets of) solutions.

Computing them is challenging and finding optimal surrogates is currently not possible for large underlying problems. While existing heuristics for decision trees can be applied in a modified form, their performance is usually not satisfactory.

We present algorithms to compute decision trees for interpretable optimization that utilize existing dynamic programming frameworks to generate tree structures. These are combined with integer programming techniques to generate candidates for the leaves of the tree in an iterative way, and can be used both as an exact or heuristic approach. Computational results for instances based on underlying Knapsack and Scheduling problems are discussed and compared to the performance of state-of-the-art methods.

TA 08: Supply Chain Management and Production: Supply Chain Management

Time: Thursday, 03/Sept/2026: 8:30am - 10:00am · *Location:* HS9 (AM)
Session Chair: Eugene Khmelnitsky

Revenue-sharing contract in a digital-content supply chain

Eugene Khmelnitsky
Tel Aviv University, Israel

We study the design of a revenue-sharing contract between a platform and an app developer (or other digital content provider) when the parties hold heterogeneous beliefs with regard to the future income. We design a contract in which the commission is a continuous function of the revenue generated by the app within the current period. This implies that the division of the total revenue between the partners is not necessarily linearly proportional to the revenue realization, but may have a more complicated non-linear structure. In contrast to the majority of prior studies, which analyze the homogeneous beliefs scenario, we introduce heterogeneous beliefs, which turn out to be a crucial consideration in designing the contract structure. We use game theory and optimal control methods to derive the properties of the proposed contract. The analysis of necessary optimality conditions allows developing an efficient numerical procedure for determining the terms of an optimal contract. The best linear contract serves as a performance benchmark. We show that the proposed contract has the potential to enhance the relationship between platforms and digital content providers. In particular, using extensive numerical analysis, we demonstrate that the proposed contract may yield a significant improvement in expected profits compared with the best linear contract. We investigate two case studies illustrating the relationship between platforms, developers, and third-party investors. Based on real data, we demonstrate the applicability and advantages of the proposed contract for the considered cases.

LLM-Based Feature Extraction for Multi-Criteria Inventory Classification

Humza Akhtar, Rami Pinto
MongoDB, Inc.

The global automotive industry faces significant supply chain disruptions requiring improved approaches to inventory classification and control. Traditional inventory classification techniques such as ABC analysis rely primarily on annual dollar usage and therefore fail to capture additional operational signals relevant for inventory prioritization. Multi-criteria inventory classification (MCIC) methods extend ABC analysis by incorporating multiple attributes, but they typically rely on structured quantitative data and do not utilize the growing volume of unstructured information available in modern supply chains.

This paper proposes an AI-based feature extraction approach using large language models (LLMs) to transform unstructured data sources such as customer reviews, supplier reports, and operational messages into quantitative features. Using vector embeddings of textual data and LLM-generated evaluation criteria, qualitative signals are extracted and integrated alongside traditional metrics such as annual dollar usage, average unit cost, and lead time.

The enriched feature set is incorporated into an MCIC decision framework based on the A. Hadi-Vencheh model, enabling inventory classification that combines structured operational metrics with qualitative indicators derived from unstructured data. Experimental results comparing traditional ABC analysis, conventional MCIC, and the proposed AI-augmented MCIC approach show measurable improvements in classification outcomes when customer-centric signals derived from review sentiment are included.

The results demonstrate that integrating unstructured data into MCIC models can enhance inventory prioritization and support more adaptive inventory control strategies in complex supply chain environments.

A lifecycle laptop supply chain model with reinforcement learning-based energy management and circular innovations

Umakanta Mishra
Vellore Institute of Technology, Vellore, India

The rapid growth of the electronics industry, driven by frequent product upgrades and technological advances, has increased reliance on critical materials while progress in recycling and end-of-life management remains limited. Despite efforts toward eco-design and cleaner production, electronic industries continue to face inefficiencies in energy use, product recovery, and waste management, highlighting the need for more effective circular and sustainable strategies. In this study, a two-layer sustainable reverse logistics (RL) supply chain (SC) model for the laptop industry is proposed, incorporating both manufacturing and remanufacturing activities. Reinforcement learning-based energy management (RLEM) and modular design technology (MDT) are implemented to support sustainable production. A return-on-delivery collection mechanism, computer vision and robotic-based dismantling technology (CVRDT), and electronics waste minimization technology (EWMT) are innovatively integrated into the model to improve product recovery efficiency and reduce environmental impacts. A classical optimization method is employed to maximize the laptop SC profit with respect to the decision variables. Numerical analysis is conducted to evaluate the proposed model, showing that RLEM reduces remanufacturing and manufacturing energy costs by 13.9% and 16.9%, respectively, and increases overall system profit by 7.3%. The results further show that excluding any individual technology reduces integrated profit, indicating that each contributes to overall system performance and sustainability. Sensitivity analysis and managerial insights support the

robustness and practical relevance of the proposed model. Overall, this study presents a structured modelling framework for the laptop industry that enables profitable and energy-efficient production while advancing circular economy and sustainability practices.

TA 09: Artificial Intelligence, Machine Learning and Optimization: Reinforcement Learning

Time: Thursday, 03/Sept/2026: 8:30am - 10:00am · *Location:* HS7 (WIWI)
Session Chair: Bernhard Lutz

Configuring LLM-Generated Heuristics via Instance-Specific Deep Reinforcement Learning

Xiaowei Liu, Kevin Tierney
University of Vienna, Austria

Designing effective optimization algorithms requires both discovering high-quality heuristic functions and fine-tuned parameter configurations. Large language models (LLMs) have recently demonstrated promising performance in automated heuristic discovery, but configuring the parameters of these generated heuristics remains a challenge. Existing work relies on prompt tuning rather than integrating automated algorithm configuration with LLM-generated heuristics. This paper proposes a method that employs deep reinforcement learning to configure generated heuristic operators in an instance-specific manner. The method combines LLM-based heuristic refinement with local search to minimise the modification in the parameter space. We evaluate the proposed approach on vehicle routing problems.

From Learning Dynamics to Dynamic Programming Structure in Deep Reinforcement Learning

Ivo Nowak
HAW-Hamburg, Germany

Reinforcement learning has become a central paradigm for solving sequential decision problems. However, it often suffers from slow convergence compared to classical dynamic programming, which exploits structured information propagation.

Recent advances in distributional reinforcement learning, particularly actor–critic methods such as Cramér Distance Soft Actor-Critic (C-DSAC), have demonstrated strong empirical performance. A key reason is that distributional updates implicitly introduce a form of weighted learning, where variance-related signals influence how information propagates through the state space.

In this work, we make this effect explicit and propose to use learning dynamics as a source of structure. We analyze the temporal evolution of the return variance under recursive Bellman updates and introduce a temporal learning indicator based on its rate of change. Because updates propagate from terminal states, the learning speed of the variance reflects the proximity of states to terminal events.

Empirically, this induces an ordering over states that is consistent with dynamic programming–style propagation. Based on this insight, we construct a structure-aware mechanism that derives a global distance function from early-activated states and uses it to guide exploration and sampling.

We present results in a gridworld setting, demonstrating that the proposed approach achieves significantly faster and more stable convergence than a standard baseline, indicating its potential for more sample- and energy-efficient reinforcement learning (Green AI).

Solving the Knapsack Hiring Problem using Reinforcement Learning

Mirko Stappert[1], Bernhard Lutz[2], Dirk Neumann[1]
1: University of Freiburg, Germany; 2: University of Vienna, Austria

The knapsack hiring problem is a sequential decision problem, in which a firm wants to fill a number of open positions from a pool of candidates within the time horizon subject to a budget constraint. Each candidate has a value to the firm, a probability of accepting offers, and a salary expectation. The firm wants to maximize the expected total value of all hired candidates while respecting the budget. Simple heuristics like greedily making offers to the candidates with the greatest (expected) value are not optimal due to the time and budget constraints. In this study, we propose a reinforcement learning approach to maximize the desired expected value. We employ action masking to eliminate dominated actions and partially enforce optimal actions according to the expected order policy to improve the learning process. Our RL approach outperforms existing heuristics and approximation algorithms, as well as a newly designed simulated annealing approach on a variety of simulated instances. We also analyze the position constraint variant of the problem, where instead of a total budget, a given number of positions needs to be filled. Here, we find that our approach is comparable to the top-performing method and outperforms several heuristics, confirming its effectiveness for this variant as well. We aim to extend this study towards more realistic hiring environments by incorporating dynamic acceptance probabilities, richer organizational constraints, and risk-sensitive decision criteria.

TA 10: Optimization under Uncertainty: Robust Optimization Applications

Time: Thursday, 03/Sept/2026: 8:30am - 10:00am · *Location:* HS8 (WIWI)
Session Chair: Andrea Gilch

A decomposition-based approach to robust mixed-integer optimal control with applications to separation processes

Dominik Cebulla[2], Andrea Gilch[1], Jan Rolfes[3], Christian Kirches[2], Frauke Liers[1]
1: Friedrich-Alexander Universität Erlangen-Nürnberg, Germany; 2: Technische Universität Braunschweig, Germany; 3: Linköping University, Sweden

Engineering applications frequently give rise to optimization problems governed by partial differential equations (PDEs) that combine discrete decision variables with uncertain parameters. Incorporating robustness into such models naturally leads to distributionally robust mixed-integer optimal control problems (MIOCPs) constrained by PDEs. However, solving these problems directly remains extremely challenging, as efficient and scalable algorithms for this class are still largely lacking. In this work, we consider a representative application from material design in separation processes.

To address these challenges, we propose a decomposition-based solution strategy. Rather than treating the full robust MIOCP in a single, unified formulation, the approach alternates between solving PDE-constrained optimal control subproblems and distributionally robust optimization problems. This separation enables a tractable treatment of uncertainty while avoiding the significant computational effort associated with solving the full problem simultaneously.

The effectiveness of the proposed framework is illustrated through a case study on a particle separation process, which is commonly employed in the purification of high-value products such as pharmaceuticals. These processes are highly sensitive to variations in operating conditions, where even minor perturbations can significantly degrade performance or result in complete batch failure. The system dynamics are modeled by nonlinear transport–dispersion PDEs, while discrete operational decisions and uncertain parameters are incorporated into the optimization framework.

Overall, the presented methodology provides a promising avenue for efficiently solving complex robust MIOCPs arising in engineering practice.

Demand Management for Attended Home Delivery with Concurrent Customer Interactions

Le Hoang Phuc Nguyen, Jonas Stein, Florentin Hildebrandt, Marlin Ulmer
Otto-von-Guericke-University Magdeburg, Germany

Attended home delivery (AHD) is a type of delivery in which a service provider and customers agree on when and where the services happen. Demand management in AHD is the coordination between the order capture phase when customers place their orders on an online platform and the order delivery phase when delivery routes are planned and executed. When a customer arrives at an online platform while another customer has not checked out, concurrency happens. Few studies in AHD consider this concurrent customer interactions in literature, although they have an effect on the routing outcomes. Our research models the problem of demand management for AHD with concurrent customer interactions as a Markov Decision Process (MDP), which focuses on time windows offering decisions in order capture phase with consideration of concurrency of customers. At the end of the planning horizon, a Team Orienteering Problem with Time Windows is solved to serve as the reward to the MDP. We develop a Value Function Approximation (VFA) policy to make the time window offering decisions. VFA policy trains an artificial neural network to learn the value of each time window through a vector of features, which include temporal, spatial, and concurrency information from the post-decision state. The training process is conducted via offline simulation episodes following off-policy Monte Carlo mechanism. The VFA policy outperforms two other benchmarks.

Equity-Aware Green Last-Mile Routing with Robust and Adaptive Optimization

Mesut Sayin
Ozyegin University, Istanbul, Turkey

We study last-mile delivery planning in the presence of carbon regulation, low-emission-zone policies, and increasing pressure to ensure equitable service across urban areas. We formulate the Multi-Depot Sustainable Prize-Collecting Routing Problem with Equity Constraints (MD-SPRPEC), which selects a subset of customers to serve while accounting for load-dependent emissions, global and zone-specific carbon limits, sustainability-adjusted rewards, minimum service quotas across customer groups, and both open and closed routes from multiple depots. To address uncertainty in rewards, demands, service times, travel times, and emissions, we develop a Robust Sustainable Routing Model (RSRM) and a Rolling-Horizon Adaptive Sustainable Routing Model (RH-ASRM), which updates decisions dynamically as information is revealed. We propose scalable solution methods: a Hybrid Large-Neighborhood Decomposition Search (HLNDS) for the deterministic model, its robust variant (R-HLNDS), and a Dynamic Robust Matheuristic Search (DRMS) for the adaptive case. Experiments on real-world instances from three retail companies in Türkiye show that the deterministic heuristic matches optimal solutions on all tractable instances and outperforms exact methods

on larger cases with significantly lower computation times. Robust planning increases feasibility from 66.3% to 90.7%, substantially reducing violations of capacity, time, and carbon constraints, with an average robustness cost of 3.3%. The adaptive approach yields further improvements, especially in worst-case performance. Sensitivity analysis indicates that time and emission uncertainties drive most of the adaptive value.

TA 11: Software for Operations Research: Beyond Linearity

Time: Thursday, 03/Sept/2026: 8:30am - 10:00am · *Location:* HS6 (WIWI)
Session Chair: Stefan Vigerske

Multi-Period Portfolio Optimization with Discrete Decisions

Silke Horn
Gurobi

Portfolio optimization is often formulated as a single-period mean-variance problem, leading to a continuous quadratic program. In practice, however, portfolio construction involves discrete decisions such as asset selection, minimum trade sizes, and turnover limits. We briefly introduce how these features can be incorporated into the classical model using mixed-integer optimization.

We then extend this formulation to a multi-period setting. By introducing time-indexed decision variables and linking constraints, portfolio decisions are propagated across periods, allowing for the modeling of trading dynamics and transaction costs, including time-varying market impact.

We focus on the computational implications of this extension. Multi-period formulations significantly increase problem size and require solving many related instances in backtesting or rolling-horizon settings. We discuss practical strategies to balance solution quality and runtime.

Solving continuous nonlinear problems with Hexaly

Nikolas Stott
Hexaly, France

Hexaly is a hybrid optimization solver combining many exact and heuristic operations research techniques. It offers a "model-and-run" approach to combinatorial, continuous, or mixed optimization problems.

We present the techniques employed by the solver on continuous nonlinear problems. The problem can be provided as an expression graph, as pairs of opaque functions provided by the user to obtain the value and gradient of objectives and constraints, or a mix of both. When the model is provided as an expression graph, the solver can perform an analysis pass to identify the model's structure such as linearity, quadratic convexity, or general convexity. When the model contains opaque user functions, some structures become undetectable and the most general case is identified instead.

Hexaly leverages this information to choose the most efficient algorithms for a given model without any user input. When possible, Hexaly favors running an interior point method using explicit hessians. It falls back to a first order method (augmented lagrangian or quasi-newton interior point method) when hessian matrices are unavailable, e.g. due to memory constraints. All these algorithms are modular, and their configurations can target a wide spectrum of problems: linear or nonlinear, convex, or nonconvex, few or many constraints, dense or sparse, etc.

We compare the performance and robustness of Hexaly with Ipopt and SCIP. Three instance sets are used: portfolio optimization (convex QPs), pooling (nonconvex QCQPs) and general nonlinear instances exported from the CUTEst library.

A brief overview of CONOPT

Stephen Maher, Stefan Vigerske
GAMS Software GmbH, Germany

CONOPT is a robust nonlinear optimization solver that it is based on the Generalized Reduced Gradient (GRG) algorithm, setting it apart from other nonlinear solvers such as IPOPT and KNITRO. While the GRG algorithm has been shown to be effective for solving nonlinear programming problems, the ability to solve large-scale problems requires careful algorithmic engineering and enhancement techniques. This talk will look at some of the techniques that are key to the success of CONOPT.

TA 12: Health Care Management: Transportation problems

Time: Thursday, 03/Sept/2026: 8:30am - 10:00am · *Location:* HS2 (PHIL)
Session Chair: Johannes Uhrmann

A Multiobjective Optimization Perspective On Resilience in Healthcare

Stephan Helfrich[1], Gabriela Ciolacu[1], Jan Boeckmann[2], Emilia Grass[1]
1: Karlsruhe Institute of Technology, Germany; 2: Katholische Universität Eichstätt-Ingolstadt, Germany

The resilience of a healthcare system is its capacity to prepare for, resist, absorb, and recover from adverse events without an irreversible decline. Hence, to enhance a healthcare system's resilience, all enumerated capabilities should be considered jointly, balancing the speed of return to routine operations with performance during adverse events (e.g., earthquakes, mass-casualty incidents). In addition, the healthcare system must also not compromise its effectiveness during routine operations (e.g., by posing a risk to patients) or over-prepare to achieve resilience (e.g., by exhausting public and limited resources). However, little to no literature has considered all capabilities jointly in an optimization setting; instead, it treats them separately.

Therefore, we approach resilience as a multiobjective problem, treating each capability as an individual decision objective. To tackle this, we propose a novel flow-over-time formulation that explicitly models resistance, rebound, impact, and performance loss within a single optimization model. Using a case study on blood collection and transportation following earthquake scenarios in Iran, we also demonstrate how introducing each resilience objective influences both preparation before an earthquake (e.g., investments in additional blood facilities) and the response to an earthquake (e.g., blood distribution). Our results also reveal trade-offs among resilience objectives, underscoring the risks of policies that prioritize a single capability and the resulting unmet demand for critical resources, such as blood.

Transportation of Patients between Hospitals and Homes: A Dial-a-Ride Problem solved by Particle Swarm Optimization

Johannes Uhrmann[1], Jens O. Brunner[1,2,3]
1: University of Augsburg, Germany; 2: Technical University of Denmark; 3: University of Siegen, Germany

Patient transportation to and from hospitals is essential for ensuring timely access to care and stable clinical operations. Daily transports such as admissions, discharges, and inter-hospital transfers must be coordinated under time constraints, heterogeneous patient requirements, and limited vehicle capacities. We model this setting as a heterogeneous dial-a-ride problem with pickup and delivery time windows and distinct patient types. To solve it, we develop a tailored particle swarm optimization heuristic that constructs feasible routing plans while respecting operational constraints. Experiments based on real-world data from a partner hospital show that the heuristic produces high-quality solutions within short computation times and reduces travel distance and transportation cost compared to current practice. We further quantify the impact of shared ride planning and demonstrate efficiency gains over individual transport policies.

TA 13: Project Management and Scheduling: Models and Optimization

Time: Thursday, 03/Sept/2026: 8:30am - 10:00am · *Location:* HS4 (PHIL)
Session Chair: Anke Stieber

An Integer Programming Formulation for Scheduling Double Round Robin Tournaments with Coupled Team Pairs

Johannes Weiland
Brandenburg University of Technology Cottbus - Senftenberg, Germany

In common double round robin (2RR) tournaments, each team has one match per round and must meet each other team twice. Especially for larger numbers of participating teams, this requires numerous rounds, resulting in long travel distances for the teams. One possibility to relax this problem is to assign more than two teams to the same venue and increase the number of matches played at each round of the tournament. In this work, we consider a 2RR tournament, where pairs of teams are determined before the season. Then, in each round, either two of these pairs meet at the venue of one of the related teams and each team plays the two matches against the teams of the other pair, or the teams of a pair play against each other. This format requires assigning the team pairs in parallel to the scheduling process. We derive a linear integer programming model to minimize the total travel distance of all teams, tackling both problems simultaneously, and incorporate restrictions regarding the distribution of the home-field advantages. Finally, we examine the model's performance in an extensive computational study.

Heuristic approaches and lower bounds for the multi-interval resource investment problem

Laura Henke, Jürgen Zimmermann
Clausthal University of Technology, Germany

The classic resource investment problem (RIP) is a project scheduling problem which minimizes the highest resource peak of each type of resource caused by overlapping activities within the project duration. However, in practice, there are certain resources that must be paid for at regular intervals, not just once during the project. For instance, energy-intensive companies in Germany not only pay for the electrical energy they draw from the grid, but also for the highest power peak they cause within a monthly or yearly billing period. Assuming a monthly billing of power peaks, a project duration of several months, and activities consuming electrical power to be processed, more than one resource peak per type of resource must be considered to accurately calculate the total cost. We term this kind of scheduling problem multi-interval RIP because the objective function accounts for one resource peak per billing interval and resource type.

In this work, we analyze the structural properties of the multi-interval RIP. It can be shown, that there is always an optimal solution in which an activity starts at one of three distinct types of start times. Based on these insights, a multi-start serial generation scheme is proposed to generate feasible solutions exploiting the structural properties. Furthermore, we extend this solution approach by an iterated greedy method to improve initial solutions. Experiments are conducted on different benchmark instances known from literature. The experimental results and the performance of the algorithms presented are compared using relaxation-based and workload-based lower bounds.

Modeling and Solving Workflow Scheduling Problems on Shared Computing Units

Anke Stieber, Andreas Fink
Helmut-Schmidt-Universität/Universität der Bundeswehr Hamburg, Germany

The workflow scheduling problem on shared computing units is a combination of the workflow scheduling problem and the vector bin packing problem. We consider a set of interdependent and non-preemptive tasks, originating from a project. The tasks require processing by computing units such as virtual machines, while respecting precedence constraints and capacity restrictions, for example, in terms of virtual central processing units. The computing units may be heterogeneous or homogeneous in their processing characteristics. This problem arises in cloud environments that allow multiple tasks to share resources to improve utilization and reduce energy consumption in accordance with a race-to-idle strategy. We present different mathematical model formulations: a mixed-integer program based on the pulse disaggregated discrete time formulation, a mixed-integer quadratically constrained program, and a constraint programming satisfiability model, which can be further extended to related scheduling settings. The formulations are evaluated under a makespan objective and a weighted-sum objective combining makespan and active-unit energy cost with regard to different instance characteristics. Computational experiments with the Gurobi Optimizer and the CP-SAT solver show that the pulse-based formulation provides the strongest bounds and proves optimality most often, whereas the constraint programming formulation quickly finds high-quality incumbent solutions for the combined objective.

TA 14: Game Theory and Behavioral Management Science: Decision-making and AI

Time: Thursday, 03/Sept/2026: 8:30am - 10:00am · *Location:* HS12 (IM)
Session Chair: Lijia Tan

Beyond the Signal: How Explanation Fit, Complexity, and Source Shape Belief Updating

Anika Bittner
University of Technology Hamburg, Germany

In decision-making, individuals often observe not only a signal but also an explanation of the signal. This is especially relevant in decision-making in which people interact with algorithmic systems. While Bayesian belief updating suggests that beliefs should respond to the informational content of the explanation alone, actual belief updating may also depend on the characteristics of the explanation itself. This paper studies three such characteristics: the fit of an explanation to an individual's own prior explanation, the complexity of the explanation and whether the explanation is generated by a human or by AI.

The experimental design is based on Graeber et al. (2024), with an application to AI-assisted decision-making. The experiment consists of two stages. In the first stage, participants solve binary prediction problems and provide short incentivized explanations for their answers. This stage generates a pool of human explanations. In parallel, AI-generated explanations are created for the same problems.

In the second stage, a new sample of participants faces the same prediction problems. For each problem, participants first report their prior belief and provide their own short explanation. They then observe an AI prediction, for example "AI predicts A", and receive either no explanation or one external explanation. Depending on the treatment, the explanation is human-generated, AI-generated or mixed. Participants then report their posterior belief.

The key identification strategy is to hold the AI prediction constant while varying characteristics of the explanation. The main outcome is belief updating, measured as the change from prior to posterior beliefs.

Designing the Moment: Performance Effects and Revealed Preferences for Recommendation Timing

Florian Sachs[1], Dmitri Bershadskyy[2], Kai Heinrich[3]
1: University of Cologne, Germany; 2: Vienna University of Economics and Business, Austria; 3: University of Magdeburg, Germany

Effective decision support depends not only on the quality of a recommendation but also on the moment it enters the decision process. This study investigates how the timing of numerical advice influences decision quality, learning, and user preference in a repeated newsvendor task. We employ a multi-phase experimental design that modifies the canonical behavioral newsvendor problem by introducing round-specific overage and underage costs, ensuring that the optimal order quantity varies and advice remains informative throughout the task. Participants are randomly assigned to one of four advice-timing conditions: pre-decision, corrective during-decision, just-in-time (JIT) during-decision, or post-feedback. By tracking ordering behavior across baseline, assigned-timing, and withdrawal phases, we isolate the causal effects of timing on immediate performance and long-term learning. Finally, we use a revealed-preference phase, where participants choose their preferred timing for the final block of rounds, to examine the alignment between objective performance and subjective preference. Our results provide insights into the design of digital decision environments, demonstrating how the "moment" of intervention shapes both the accuracy of operational decisions and the long-term adoption of decision support.

Can a Deep Reinforcement Learning-Based Decision Support Tool Bridge the Experience Gap? Experimental Evidence from a Supply Chain Planning Task

Lijia Tan[1], Eirini Spiliotopoulou[2], Willem van Jaarsveld[1]
1: Eindhoven University of Technology, the Netherlands; 2: Tilburg University, the Netherlands

Artificial intelligence (AI) technologies can enhance human decision-making in supply chain planning. We experimentally investigate the impact of AI support on human planning decisions in supply chains that require sequential and multi-faceted decision-making. The AI tool, based on deep reinforcement learning, provides human planners with decision suggestions. We design two sets of experiments to examine how planner experience and time pressure influence the effectiveness of the AI tool. In the first experiment set, the AI tool significantly improves the performance of inexperienced planners but has minimal impact on experienced planners. Moreover, it enables inexperienced planners to perform at a level comparable to experienced planners, indicating that AI can, in certain contexts, substitute for human experience. The second experiment set explores the effect of AI support under time pressure. The results show that inexperienced planners learn more slowly and take longer to develop expertise in time-pressured environments. However, AI support substantially enhances their performance even under these challenging conditions. This study contributes to research on AI–human collaboration in decision-making by highlighting the role of AI in boosting the performance of

planners with varying experience levels and in high-pressure contexts. The findings offer practical implications for the design and deployment of AI systems in supply chain management.

TA 15: Continuous and Global Optimization: Theory, Algorithms, and Applications

Time: Thursday, 03/Sept/2026: 8:30am - 10:00am · *Location:* SR034 (WIWI)
Session Chair: Thi Huong Vu

Characterizing the mathematical viability of system archetypes

Sigifredo Laengle[1], **Tomás Laengle-Aliaga**[2]
1: University of Chile, Faculty of Economics and Business, Diagonal Paraguay 257, 8320000 Santiago, Chile; 2: Humboldt-Universität zu Berlin, Unter den Linden 6, 10099 Berlin, Germany

System archetypes provide a robust framework for explaining the behavior of complex systems. Conventionally, these patterns are modeled using System Dynamics to induce controlled differential equations focused on equilibrium states. Nevertheless, such models often fail to address critical questions regarding system viability and resilience. This paper explores the mathematical characteristics of the set-valued mappings induced when addressing viability problems within these archetypal structures, grounded in Jean-Pierre Aubin's Viability Theory. We conduct a formal analysis of three fundamental archetypes: "Limits to Growth", "Shifting the Burden", and "Eroding Goals". By characterizing the resulting set-valued mappings, we identify and prove key properties of monotonicity, continuity, and convexity. Our findings suggest that equilibrium behavior is not a primary determinant of viability; instead, viability is governed by the structural geometry of the system's constraints. Consequently, we introduce the concept of archetypal (or canonical) viability. This approach enables a novel characterization of complex systems, shifting the focus from equilibrium stability toward a rigorous assessment of resilience and functional viability.

Mixtures of Gases on Networks - a MINLP Approach

Pascal Börner, **Marc Pfetsch**, **Stefan Ulbrich**
TU Darmstadt, Germany

With the change towards renewable energies, the re-usage or re-purposing of natural gas networks to hydrogen-natural gas mixtures has become a topic of interest. In this talk, we provide a global optimization approach for this topic: For the modeling of the gas mixture, we present a model which is consistent with thermodynamics. The model is based on the isothermal Euler equations for single gas flow and an equation of state for the mixture. To extend the single pipe model to networks, the gas composition needs to be tracked as follows. At each node the ratio of the two gases is calculated as a weighted average of the inflowing gases. This ratio is then propagated onto the arcs with outflow of the given node.

For the stationary setting we obtained a MINLP which we implemented in the SCIP framework.

From a computational perspective, solving the mixing MINLP is significantly harder than the single gas case, even for smaller networks. As an improvement, we present an iterative solution algorithm. The algorithm reduces the problem to a single gas problem and exploits a contraction property.

The algorithm is implemented as primal heuristic, and enables the solution of large networks with, e.g., 582 nodes in reasonable time. Lastly we sketch an extension to the instationary case.

NesPDHG and KM-PDHG: Nesterov- and Krasnosel'skii--Mann-type accelerations of the primal--dual hybrid gradient method for linear programs

Vu Thi Huong[1,2], **Le Duc Hiep**[3], **Thorsten Koch**[1,4]
1: Zuse Institute Berlin, Germany; 2: Institute of Mathematics - Vietnam Academy of Science and Technology, Vietnam; 3: FPT University, Vietnam; 4: Technische Universität Berlin

We propose NesPDHG and KM-PDHG, two accelerated variants of the primal--dual hybrid gradient (PDHG) method for linear programs, based on Nesterov- and Krasnosel'skii--Mann-type iterations. Using the firm nonexpansiveness of the PDHG operator together with recent advances in operator theory, we derive a family of accelerated schemes with improved residual convergence guaranties. Numerical experiments on root relaxations of the MIPLIB2017 benchmark instances demonstrate the effectiveness of the proposed methods.

TA 16: Simulation and Quantum Computing: Quantum Computing Applications for Complex Optimization Problems

Time: Thursday, 03/Sept/2026: 8:30am - 10:00am · *Location:* SR033 (WIWI)
Session Chair: Maximilian Moll

Hybrid Quantum Algorithms for Optimizing Intermodal Freight Transport Networks

Richard Lopp[1], Daniel Ohl de Mello[2], Felix Westerkamp[2], Solveig Plomer[2], Anisa Rizvanolli[3], Oliver Szal[3], Ayse Kotil[4], Adam Prystupiuk[4], Marcel Schindler[5], Alessandro Tarantola[5], Ibraheem O. Adeniran[6], Carina Kehrt[6]

1: d-fine Austria GmbH; 2: d-fine GmbH; 3: Fraunhofer Center for Maritime Logistics and Services; 4: PlanQC GmbH; 5: German Aerospace Center, Institute of Quantum Technologies; 6: German Aerospace Center, Institute of Transport Research

Combined transport, a subcategory of intermodal freight transport, leverages the advantages of road, rail, and maritime transport, reducing congestion and emissions while improving efficiency through integrated logistics processes that can lower operating costs and optimize transport capacity utilization. However, the resulting models contain a complicated set of constraints and a large number of variables. Quantum Computing (QC) is seen as an enabler to solve complex optimization problems in logistics more efficiently. By reducing computation time, QC could realize real-time calculations for combinatorial problems and thus enhance resilience and efficiency in logistics.

We study quantum optimization algorithms for realistic booking assignment problems in intermodal road-rail transport networks, based on real-world operational data. The booking assignment is modeled as a time-expanded Multi-Commodity Network Flow problem then encoded as a Quadratic Unconstrained Binary Optimization (QUBO) problem.

Building on a detailed complexity analysis, we identify bookings, trains, and planning horizons as the main drivers of problem size and QUBO connectivity. We use this hierarchy to construct toy instances that retain the essential structure of the original models while significantly reducing variable counts, couplings, and resulting qubit requirements. In parallel to the classical integer linear program-based pipeline, we develop a QUBO-based quantum optimization pipeline and systematically explore different encodings, penalty constructions, and graph reductions to obtain compact formulations suitable for current QC simulators and devices.

Within this pipeline, we compare different quantum imaginary time evolution and annealing-based algorithms, as well as classical solvers. Here we present preliminary results of this analysis

Quantum Computing for Airline Optimization

Joseph Doetsch, Robert Glöckner, Georg Reuber, Yannick Schäfer, Eike Mentzendorff, Julian Moeller

Lufthansa Industry Solutions, Germany

This contribution reports on investigations into the potential of quantum computing for aviation specific optimization problems. Targeted use cases include cancellation candidate selection, route planning, crew assignment, and tail assignment, which are characterized by large combinatorial decision spaces, tight operational constraints, and strong coupling between planning dimensions. The work is structured into tactical and strategic projects, distinguished by the underlying time horizon and decision frequency, in order to capture both day of operations decisions and long term planning questions.

For each use case, we present a classical baseline based on established optimization methods and discuss why these problems are particularly challenging with respect to size, constraint structure, and robustness requirements. On this foundation, we introduce and implement several quantum algorithms, including the quantum approximate optimization algorithm, Grover adaptive search, and approaches based on Rydberg annealing, tailored to the aviation scenarios. We report concrete benchmark results comparing classical and quantum methods, highlighting current limitations of quantum hardware, but also problem structures where quantum inspired or hybrid approaches show promising behavior. The presentation concludes with a discussion of lessons learned on modeling, algorithm design, and benchmarking methodology, and outlines a roadmap for evaluating quantum computing in real world airline and airport decision processes.

A Decision Support Model for Cost-Utility Optimisation in Hierarchical Systems

Philipp Triebold, Rudy Milani, Stefan Pickl, Maximilian Moll

Universität der Bundeswehr München, Germany

Hierarchical systems occur in many decision-making contexts, including product architectures, organisational structures and infrastructure systems. In such systems, cost-reduction decisions are interdependent: removing one element may affect the feasibility, value, or relevance of other elements in the hierarchy. This paper presents a mixed-integer linear programming model

for optimising hierarchical tree structures with an arbitrary number of levels and nodes per level. Each node is assigned a cost and a utility value, representing its resource requirement and contribution to the overall system objective. Given a required reduction in total system cost, the model determines which nodes should be retained or removed in order to maximise the utility preserved in the resulting hierarchy. The MILP formulation captures structural dependencies and functional requirements. Globally necessary nodes are constrained to remain in the tree. Locally necessary nodes are linked to their parent nodes, such that a child node may be removed only if its parent node is also removed. Nodes with intrinsic purpose may remain as standalone elements even if all children are removed, with their utility reduced to a predefined intrinsic value. Non-leaf nodes without intrinsic purpose are removed when all children are eliminated. The model enables systematic cost reduction in complex N-level hierarchies while preserving essential components and maximising retained functional value.

TB 01: Plenary Phebe Vayanos

Time: Thursday, 03/Sept/2026: 10:30am - 11:30am · *Location:* HS10 (AM)
Session Chair: Stefan Ruzika

Learning to Allocate Scarce Resources: Balancing Efficiency, Fairness, and Transparency from Real-World Data

Phebe Vayanos
University of Southern California, United States of America

Motivated by collaborations with homelessness service providers, we study how causal inference, machine learning, and optimization can support high-stakes decisions involving scarce resources. In the first part of this talk, I focus on the allocation of scarce interventions such as housing to individuals experiencing homelessness. Using observational data collected in deployment, we develop a framework that learns simple, interpretable waitlist-based policies that maximize long-run outcomes while accounting for resource constraints and fairness considerations. Empirical results from a collaboration with the Los Angeles Homeless Services Authority show that our policies increase rates of exit from homelessness by 5.16% relative to current practice, while fairness constraints can often be incorporated at little cost to efficiency.

In the second part of the talk, I discuss the design of risk assessment tools used to prioritize individuals for scarce interventions. In collaboration with the Missouri Balance of State Continuum of Care, we are developing risk scores that balance predictive accuracy, fairness, and transparency while remaining aligned with community values and operational needs. Our work combines machine learning, optimization, and extensive stakeholder engagement to evaluate alternative models and their associated trade-offs. Interestingly, community stakeholders ultimately preferred a substantially more interpretable risk score despite a non-negligible reduction in predictive performance. Determining when such trade-offs are worthwhile requires direct engagement with the communities affected by these systems.

Together, these projects illustrate a broader vision for designing human-centered decision-support systems that combine prediction and optimization to allocate scarce resources efficiently, fairly, and transparently in high-stakes social service settings.

TC 01: GOR Company Award

Time: Thursday, 03/Sept/2026: 11:45am - 12:45pm · *Location:* HS10 (AM)
Session Chair: Hanno Schülldorf

Every two years the GOR honors a company that has demonstrated exceptional commitment to the application and dissemination of operations research in practice. The award is intended to recognize successfully completed, innovative projects with a proven, significant OR component in planning, implementation, or practical application.

The winning company will be announced during the opening session of the conference.

TC 02: Mobility, Transport, and Traffic: Network Design and Urban Planning

Time: Thursday, 03/Sept/2026: 11:45am - 12:45pm · *Location:* HS1 (PHIL)
Session Chair: Alexander Bode

Dimensioning and quality assessment for track groups in railway nodes based on the optimisation of waiting times and waiting probabilities

Jan Eisold, Henning Preis, Nikola Bešinović
Technische Universität Dresden, Germany

Railway nodes play a crucial role in ensuring the efficient operation of a railway system. They are where trains are formed, handled and decomposed, play an important role for train dispatching, and also serve to directly fulfil transport service requirements. Within the nodes, track groups are of particular importance and they must be efficiently dimensioned to accommodate the future demand, i. e. an adequate number of trains in a timely manner. Otherwise, operational quality will be compromised and/or performance requirements cannot be fully met. Today, analytical models based on queueing theory and simulations are used in particular for dimensioning and quality assessment of track groups. The expected waiting probabilities or waiting times for a (future) operating programme usually serve as the quality criteria. In this paper, we present a mathematical optimisation model that determines the track occupation in a defined track group for given timetables. The objective is a weighted function of the waiting probability and the waiting times of trains. As input data, we use randomly generated timetables based on given distribution functions, which anticipate the expected characteristics of the planned railway operations and cover the uncertainty within it. Practical scenarios are used to illustrate how the approach works. In addition, a quantitative comparison is made with the methods used to date for the estimation of waiting times and waiting probabilities for track groups in railway nodes.

Dynamically adjusting planned transportation capacity to accommodate variations in demand

Alexander Bode[1], Michael Hewitt[2], Dirk C. Mattfeld[1]
1: TU Braunschweig, Germany; 2: Loyola University Chicago, Illinois, USA

We consider a less than-truck-load (LTL) logistics service provider that faces ad hoc demand to be routed through a network of transshipment facilities such that deadline for the individual shipments is met. Since this ad hoc demand, e.g. the distribution of machinery spare parts, is unforeseen, trucks are hired on the spot market in order to fulfill the demand. The overall goal of the LSP is to transport all given shipments to their destination at the lowest possible cost.

However, long announced contractual shipments have already been assigned to trucks of the own fleet constituting a so-called baseline transportation plan. Within this plan, truck capacity may be available that can be utilized for ad hoc shipments. On the other hand side, contractual shipments may be shifted to trucks hired for ad hoc demand on the spot market. At the extreme, trucks already assigned in the baseline plan may be omitted in favor to trucks hired externally on short notice.

Due to the changing conditions with respect to the arrival of ad hoc shipments, new plans have to be setup on a day-to-day basis. We model the problem as a sequential decision process and present a cost function approximation that solves the problem in a cost-saving way. The cost function approximation is based on two components, a slack-based component and a predictive component that incorporates the knowledge of the underlying baseline plan. Preliminary results suggest significant cost savings when compared to rivaling heuristic approaches.

TC 03: Mobility, Transport, and Traffic: Network Design

Time: Thursday, 03/Sept/2026: 11:45am - 12:45pm · *Location:* HS3 (PHIL)
Session Chair: Asrat Mekonnen Gobachew

A Decentralized Approach for Collaborative Service Network Design

Roberto Maria Rosati[1], Yannick Oskar Scherr[2], Mike Hewitt[3], Margaretha Gansterer[1]
1: University of Klagenfurt, Austria; 2: University of Vienna, Austria; 3: Loyola University Chicago, USA

Consolidation-based carriers address middle-mile trucking via the tactical Service Network Design problem to schedule services and route freight. Middle-mile trucking, however, is a major driver of costs, congestion, and CO2 emissions, while planning in isolation leaves capacity unused: 21.6% of total road freight vehicle-kilometers in Europe were run by empty vehicles in 2024. Yet, a centralized planning approach is incompatible with carriers' unwillingness to share information and delegate their decision autonomy.

In this work, we investigate how decentralized horizontal collaboration between carriers can improve consolidation and reduce costs, while preserving planning autonomy. Relying on a five-phase auction mechanism, carriers can trade selected commodities. The commodities are then composed into multiple bundles, for which each carrier bids according to their attractiveness. A winner determination phase performs the bundle-carrier assignment to ensure all commodities are traded and that the total cost is minimized. Finally, commodities are exchanged, and profit is shared to ensure no carrier loses from the auction.

We validate our framework on 390 instances generated from real-world road networks across multiple European countries, with up to 100 commodities. Our results indicate that our decentralized collaboration approach, enabled by a combinatorial auction framework, can better employ unused capacity, reducing total and individual cost, while preserving carrier decision autonomy.

Designing Multi-Role Drone Networks: A Role-Switching Metaheuristic and Asymmetric LP-Guided Matheuristic

Asrat Mekonnen Gobachew, Stefan Lier
South Westphalia University of Applied Sciences, Germany

This paper introduces the Integrated Micro-Hub and Relay-Hub Network Design Problem (IMRNDP), a two-echelon location-routing problem for multi-modal drone logistics. We address a novel role-exclusivity constraint where candidate sites are jointly selected as either full-service micro-hubs or lightweight relay hubs for battery charging.

To solve this combinatorial problem, we develop three scalable approaches. First, an exact MILP integrates facility location, multi-stop truck routing with MTZ sub-tour elimination, and multi-modal drone assignment, utilizing pre-filtered relay path enumeration. Second, we propose a GRASP-VND-PR metaheuristic featuring novel role-switching neighborhood operators; specifically, facility upgrade and downgrade moves and an interleaved path relinking procedure that preserves hub-count stability. Third, we introduce LGSF-AST, a hybrid matheuristic based on the Asymmetric Signal Trust principle. We formally demonstrate that in multi-role location problems, LP relaxation signals become structurally unreliable for low-fixed-cost facilities due to cost dilution. Consequently, LGSF-AST asymmetrically utilizes LP signals to guide micro-hub selection while substituting a conditional marginal savings score for relay-hub selection.

Computational experiments show that the MILP solves medium instances to optimality, while LGSF-AST matches these bounds and outperforms the metaheuristic on large-scale networks. A case study in North Rhine-Westphalia reveals that a dual-hub architecture acts as a vital CAPEX-hedging mechanism, as the network optimally substitutes relay hubs for micro-hubs under rising infrastructure costs. Finally, we demonstrate that targeting a high but relaxed service level yields a significantly more efficient cost-frontier than enforcing absolute coverage.

TC 04: Experiences with DFG Funding

Time: Thursday, 03/Sept/2026: 11:45am - 12:45pm · *Location:* HS13 (IM)
Session Chair: Katja Schimmelpfeng

Experiences with DFG Funding

This session provides an overview of current developments and funding opportunities at the German Research Foundation (DFG). Members of the DFG Review Board will share recent news and practical information, followed by brief presentations of successful proposal examples. We will conclude with an open Q&A, giving participants the opportunity to discuss their questions about DFG funding and the proposal process. This session is particularly intended for early-career researchers who are interested in learning more about third-party grant applications at the DFG. It is organized by Martin Bichler, Frauke Liers, and Katja Schimmelpfeng.

TC 05: Energy and Sustainability: Green hydrogen production and grids

Time: Thursday, 03/Sept/2026: 11:45am - 12:45pm · *Location:* HS11 (IM)
Session Chair: Sarah Hasslacher

Using mathematical optimization to optimize the combined operation of green hydrogen production and hydrogen networks

Sleman Saliba[1], Simone Göttlich[2], Riccardo Martini[3]
1: Hochschule Karlsruhe University of Applied Science, Germany; 2: University of Mannheim, Germany; 3: ABB S.p.A., Italy

The goal of this work is to investigate and identify cost reduction potential of producing green hydrogen and green ammonia, especially in the context of different energy carriers and the integration of production facilities with grid requirements.

The decarbonization of industry is one of the most pressing challenges of the 21st century. Green hydrogen and green ammonia are considered key technologies for making "hard-to-abate" sectors such as steel, chemicals, and cement climate-neutral. However, their breakthrough has so far been hampered by factors including high production costs and a lack of economic integration into existing energy systems as well as hydrogen and natural gas grids.

The specific goal of this research work is to combine first the development of mathematical optimization solutions, which optimally plan the complex energy flows of the various energy carriers, with second the integration of the gird models and requirements, to reduce manufacturing costs and deepen integration with the energy industry in a way that increases profits and stabilizes the grid.

Optimal production planning is based on forecasts (prices, demand, availability), production costs, the costs of individual energy carriers, and the technical restrictions and efficiency curves of the so-called Technical Units (TUs) of a hydrogen-producing or -consuming plant. This approach is showcased at an industrial 1 MW hydrogen station saving 2,200 tons of CO2 and 16% of production cost.

Model-based analysis of logistics and recycling networks for electrolyzer systems

Sarah Haßlacher, Magnus Fröhling
Chair of Circular Economy and Sustainability Assessment, TUM Campus Straubing for Biotechnology and Sustainability, Technical University of Munich, Straubing, Germany

The large-scale development of electrolyzer in green hydrogen systems will require efficient logistics and recycling structures. This transformation towards a Circular Economy (CE) highlights the importance of handling future end-of-life materials flows. In particular, the design of material flow networks between producers, users and recycling facilities plays a key role in developing sustainable and future-oriented network structures. In this study, a model-based analysis of logistics and recovery structures for the electrolyzer supply chain is conducted. A linear optimization model is developed to determine optimal configurations of material flows between producers, operators and recyclers. The objective is to minimize transport-related greenhouse gas emissions while ensuring material balance and demand satisfaction within the network. The model is applied to both proton exchange membrane electrolyzer (PEMEL) and high temperature electrolyzer (HTEL) systems using real-world locations of manufactures, users and recycling facilities in Germany. The results provide insights into an emission-efficient material flow network and allow for the identification of relevant transport patterns. The proposed approach provides a quantitative framework for designing efficient recycling networks and supports decision-making in emerging green hydrogen value chains.

TC 06: Discrete and Combinatorial Optimization: Fairness & Robustness

Time: Thursday, 03/Sept/2026: 11:45am - 12:45pm · *Location:* HS5 (WIWI)
Session Chair: Johannes Thürauf

Fairness over time in repeated constrained optimization problems: an application to aircraft conflict resolution

Sonia Cafieri[1], David Rey[2]
1: Ecole Nationale de l'Aviation Civile (ENAC), Toulouse, France; 2: SKEMA Business School, Université Côte d'Azur, Sophia Antipolis, France

We consider constrained mixed-integer nonlinear optimization problems that occur repeatedly over time. We refer to this as a repeated setting and we explore the concept of fairness over time in this context. Existing studies on repeated settings and fairness over time largely focus either on unconstrained optimization problems or on per-round goals. In contrast, we focus on settings where long-term goals cannot be decomposed in per-round goals and where the repeated optimization problems are constrained mixed-integer nonlinear programs. This complex repeated settings is motivated by a real-world decision-making problem encountered in air traffic control: the aircraft conflict resolution problem (ACRP). Given a set of aircraft trajectories, the ACRP is the problem of finding least-cost aircraft trajectories that satisfy separation constraints, i.e., conflict-free trajectories. The ACRP can be modeled as a nonconvex mixed-integer nonlinear optimization problem. Aircraft travel patterns are recurrent, e.g., daily flows over Europe, but aircraft specific space-time trajectories may vary from day to day, due, e.g.,to departure time changes and/or weather conditions. Thus, potential conflicts (loss of separation) among aircraft may occur repeatedly but problem data is expected to vary over time, which implies potentially different conflicts over time. Air traffic control services must repeatedly solve ACRPs to ensure safety. Ignoring the role of fairness over time may lead to undesirable outcomes where certain aircraft incur significantly larger conflict resolution costs than others. We demonstrate this behavior and we propose new approaches to incorporate fairness over time as a long-term goal in such repeated settings.

Adjustable robust network design with controllable elements

Kristina Rolsing, Johannes Thürauf
University of Technology Nuremberg, Germany

We study an adjustable robust network design problem for energy and utility networks subject to uncertain loads. To this end, we consider (nonlinear) potential-based flow networks with controllable elements such as compressors or pumps, and control valves. This setting leads to an adjustable robust mixed-integer nonlinear optimization problem that combines here-and-now expansion decisions with wait-and-see operational decisions. In particular, the latter contains adjustable integer decisions arising from the operation of the controllable elements. We characterize robust feasibility of a given network by verifying worst-case load scenarios, which are obtained via nonlinear bilevel problems. We further extend this framework by incorporating worst-case operating costs, which are also computed using nonlinear bilevel problems. Under the structural assumption that no controllable element lies on a cycle of the network, we then present equivalent single-level reformulations of the occurring nonlinear bilevel problems. Based on these results, we present an exact iterative solution approach that computes adjustable robust network designs accounting for controllable elements and providing protection against load uncertainties. Finally, we present computational results for gas networks.

TC 07: Discrete and Combinatorial Optimization: Selection Problems

Time: Thursday, 03/Sept/2026: 11:45am - 12:45pm · *Location:* SR029 (WIWI)
Session Chair: Liliana Grigoriu

A Two-Phase Framework for Efficiently Solving the Three-Dimensional Bin Set Selection Problem

Leon Binder, Michael Scholz
Deggendorf Institute of Technology, Germany

One of the most important factors in reducing packaging and shipping costs of e-commerce companies is the unused space within packages. Typically, companies use a small number of bin types to pack their orders. Determining which and how many bin types should be used while minimizing cost requires the Three-Dimensional Bin Set Selection Problem (3D-BSSP) to be solved.

We propose the S1B2 framework, which stands for single-bin feasibility (SBF) first and bin set selection second. In the first phase it determines a SBF matrix, describing for all order-bin-type combinations if the order can be packed into a single instance of the bin type. S1B2 uses various SBF, inference and bin type sequence heuristics to reduce the number of SBFs that need to be determined by solving the NP-hard Three-Dimensional Bin Packing Problem. In the second phase, an unused-space matrix is calculated and condensed to reduce the number of variables and constraints in a mixed integer programming model used for optimal bin set selection.

A comparison of S1B2 against state-of-the-art solvers shows that S1B2 has a better run time performance for B2C companies, where orders typically consist of at most ten items. While previous solvers react sensitively to an increase in the number of available bin types and orders, S1B2 can quickly solve even large instances by reducing both run time and memory usage by up to 80%.

Linear-time approximation for minimum subset sum

Liliana Grigoriu
Universitatea Nationala de Stiinta si Tehnologie Politehnica Bucuresti, Romania

Given a multiset of positive integers J and a positive number S, the minimum subset sum problem asks for a subset of J such that the sum of its elements is at least S and as close to S as possible. Thus, it applies to problems where we seek the smallest collection of discrete resources that sufficiently covers a required demand, such as buying stock batches to cover a certain necessary quantity, while minimizing excess stock. It can also appear as a subproblem in other problems, for example from the area of Scheduling.

We present a family of approximation algorithms for minimum subset sum with a worst-case approximation ratio of 1+1/k and which run in linear time assuming that k is constant. We also present computationally determined values of the maximum number n(k) of times a linear-time procedure with a low constant factor may be called by the algorithms for various values of k, in order to achieve approximation factors such as 1.0244, where k=40 and n(k) = 215306, and 1.0197, where k=50 and n(k)=1295969. The presented family of algorithms is a generalization of a linear-time approximation algorithm for minimum subset sum with a worst-case approximation factor of 5/4 by Grigoriu and Briskorn, which was included in a work addressing a scheduling problem. The algorithms are not very complex and thus relatively easy to implement.

TC 08: Supply Chain Management and Production: Scheduling in Semiconductor Manufacturing

Time: Thursday, 03/Sept/2026: 11:45am - 12:45pm · *Location:* HS9 (AM)
Session Chair: Gian Tuor

Model Predictive Control of Cluster Tools Using Constraint Programming

Gian Tuor, Harold Tiemessen, Christoph Strauss, Neva Nann, Fabian Leuthold
OST Ostschweizer Fachhochschule, Switzerland

Thin-film coating for high-precision applications in the semiconductor industry is typically performed by multi-chamber automated systems that deposit, etch, or process wafers without exposing them to air. These so-called cluster tools contain robot arms that transfer wafers between chambers. Each wafer follows a recipe that defines the sequence in which the chambers must be visited. Processing times in the chambers may be subject to variability.

The main challenge in the intelligent control of cluster tools is the sequencing of processing steps, since these decisions have a substantial impact on system throughput, idle times, robustness, and deadlock-free operation. Robust control is particularly important because wafers represent high-value products and process failures can lead to considerable losses. We propose an approach that combines model predictive control with a wafer selection heuristic for defining the rolling horizon and constraint programming for solving the resulting sequencing problem. This enables the control logic to respond dynamically to process deviations, disturbances, and changing operating conditions.

We compare the proposed model predictive controller with alternative approaches, including integer linear programming, rule-based systems, and heuristics, using real-life test instances.

Optimization-Based Rescheduling of Photolithography Operations under Drought and Geopolitical Disruptions

Nadia Aghamohammadtajer[1], Alejandro Vital-Soto[1,2], Hamid Afshari[1]
1: Department of Industrial Engineering, Dalhousie University, Halifax, NS B3H 4R2, Canada;
2: Shannon School of Business, Cape Breton University, Sydney, NS B1M 1A2, Canada

Photolithography is a capacity-constrained and disruption-sensitive stage in semiconductor wafer fabrication, where re-entrant flows, machine eligibility, auxiliary resource dependencies, and high resource intensity make schedules vulnerable to external shocks. This study develops an optimization-based resilient rescheduling framework for the photolithography flexible job shop scheduling problem under drought and geopolitical disruptions. These disruptions are considered because drought can constrain water-intensive fabrication operations, while geopolitical shocks can affect the availability and cost of critical materials and auxiliary resources, both of which may reduce effective production capacity.

The proposed framework first generates a baseline schedule under normal operating conditions and evaluates it using discrete-event simulation. After a disruption is detected, the affected machines, lots, operations, and resources are identified, and a mixed-integer rescheduling model is solved to update only the disrupted portion of the schedule. The model includes assignment, sequencing, timing, machine eligibility, re-entrant routing, auxiliary-resource, and capacity constraints. Its objective function balances operational recovery and schedule stability by minimizing weighted service loss, including tardiness and critical-lot delays, together with deviations from the original schedule.

The contribution of this paper is to link disruption-specific capacity loss, optimization-based rescheduling, and simulation-based performance evaluation in a unified preliminary framework for photolithography operations. The framework provides a basis for comparing baseline and recovered schedules using resilience-oriented measures such as tardiness, work-in-process accumulation, recovery time, and schedule instability. The results can support semiconductor manufacturers in assessing recovery strategies under water- and supply-related shocks.

keywords: Photolithography rescheduling, flexible job shop scheduling, semiconductor wafer fabrication, drought disruption, geopolitical disruption

TC 09: Artificial Intelligence, Machine Learning and Optimization: Production and Inventory Planning

Time: Thursday, 03/Sept/2026: 11:45am - 12:45pm · *Location:* HS7 (WIWI)
Session Chair: Bo-Cheng Yang

Production Allocation under Procurement-Driven Cost Uncertainty in Make-to-Order Systems

Yingying Huang[1], Shu-Jung Sunny Yang[2]
1: Harbin Institute of Technology, China; 2: University of York, United Kingdom

Manufacturing firms using make-to-order systems often plan production over a long horizon after customer demand is confirmed. A central challenge is that procurement conditions, such as raw material prices and supply availability, affect marginal production costs before production decisions are made. We study how firms should allocate known demand across time when these procurement-driven costs are uncertain. Traditionally, the "Predict-then-Optimize" (PO) approach has attempted to mitigate these issues by separating tasks of prediction and optimization. However, this methodology tends to falter, especially with scarce or volatile historical data, leading to fragile production schedules that overreact to predicted cost fluctuations. This study employs the emerging "Smart Predict-then-Optimize" (SPO) framework, which harnesses limited data to derive optimal decisions, to develop a data-driven optimization model of integrating machine learning and mathematical programming. A proximal SPO loss function is proposed to improve convergence and performance. We perform numerical experiments on both real-world and synthetic data to empirically verify the success of our data-driven optimization model in comparison to the standard PO and SPO approaches. We show that the SPO-based solutions tend to diversify production schedule to mitigate the inherent risks of cost fluctuations but the PO-based solutions tend to produce more in the periods with predicted low operational costs. These results suggest that integrating prediction with decision-making in sales and operations planning can serve as an implicit hedging mechanism against cost uncertainty.

Enhancing Agility and Resilience in Production Planning: A Neural Network-Based Approach to Master Production Scheduling

Bo-Cheng Yang[1], Frank Herrmann[2], Thorsten Claus[3]
1: OTH Regensburg, Germany; 2: OTH Regensburg, Germany; 3: TU Dresden, Germany

Solving complex operational production planning problems through mathematical optimization presents two fundamental structural challenges. First, the computational demand for realistic problem instances often far exceeds the timeframes available in industrial practice, even when using state-of-the-art hardware. Second, these mathematical models imply a level of precision regarding input parameters that is rarely achievable under real-world conditions. Even marginal data differences can lead to structurally different solutions, meaning that plans which are optimal (based on incorrect parameters) lose their validity and effectiveness in a real-world industrial context due to a lack of operational robustness.

For several applications, machine learning provides robust solutions within timeframes that meet the tight constraints and operational demands of industrial practice. In this paper, the implementation of this approach for Master Production Scheduling (HPPLAN) using a deep neural network is presented. Within the framework of operational production planning and control, Master Production Scheduling determines the precise quantities and timing for the production of end products across specific periods, such as days, weeks, or months. The goal is the most effective use of resources and inventories as well as the maintenance of high delivery reliability.

The numerical results of this study demonstrate that production plans are provided within a few minutes. Furthermore, a systematic comparison with optimal solutions confirms the high solution quality and performance of this neural network-based approach, highlighting its potential to enhance agility and resilience in dynamic manufacturing environments.

TC 10: Optimization under Uncertainty: Approximations for Robust Optimization

Time: Thursday, 03/Sept/2026: 11:45am - 12:45pm · *Location:* HS8 (WIWI)
Session Chair: Lelisa Kebena Bijiga

Approximation Algorithms for the Robust Multi-Representative Selection Problem

Trajana Erlenberg, Marc Goerigk, Dorothee Henke
University of Passau, Germany

This work studies the robust multi-representative selection problem under discrete uncertainty. In this problem, the set of items is partitioned into multiple subsets, and the task is to select a prescribed number of items from each subset. The objective is to minimize the worst-case total cost over a finite set of scenarios. This setting generalizes both the classical selection problem and the representative selection problem, and captures applications in which decisions must be balanced across several categories or groups. Although the nominal problem is polynomially solvable, the robust counterpart becomes computationally challenging. We therefore investigate approximation algorithms for this problem setting. In particular, we adapt primal rounding and dual rounding approaches to the multi-representative structure and compare them with a randomized rounding method and classical representative-scenario methods such as midpoint and worst-case-per-item. We derive new approximation guarantees for primal and dual rounding as well as for the worst-case-per-item method, while also extending known bounds for robust selection to the multi-representative setting. The primal rounding procedure improves upon previous bounds in specific parameter regimes. Overall, the results highlight the effectiveness of simple rounding-based methods for robust multi-representative selection problems.

Approximation for Robust Optimization Problems by Uncertainty Set Transformation

Qiongyan Zeng[1], André Chassein[2], Jamie Fairbrother[3], Marc Goerigk[1]
1: Business Decisions and Data Science, University of Passau, Germany; 2: Deutsche Post, Germany; 3: Department of Management Science, Lancaster University, United Kingdom

Robust optimization relies heavily on the choice of uncertainty sets, which needs to balance modeling flexibility and computational tractability. Two important challenges remain insufficiently addressed: constructing tractable uncertainty sets directly from discrete observed data, and systematically transforming one type of uncertainty set into another while preserving guarantees on solution quality. This presentation combines two complementary works addressing these issues. The first develops a principled geometric framework for constructing budgeted uncertainty sets from discrete data. The proposed approach is independent of the underlying nominal optimization problem and guarantees that solutions obtained under the constructed budgeted uncertainty set admit provable approximation bounds with respect to the original discrete robust problem. Both exact and heuristic construction methods are investigated, together with efficient evaluation procedures. The second work introduces a general framework for uncertainty set transformation, enabling the replacement of one uncertainty representation by another while quantifying the induced approximation error in the corresponding robust optimization problem. Several representative transformations are studied in detail, including replacing axis-parallel ellipsoids with budgeted uncertainty sets through an optimal closed-form solution, as well as transformations between discrete, ellipsoidal, and axis-parallel ellipsoidal uncertainty sets. These transformations can be chained to obtain tractable uncertainty representations directly from data. Computational experiments across both studies demonstrate that the proposed methods achieve guarantees that are close to optimality, providing practical tools for both data-driven and classical robust optimization.

TC 12: Health Care Management: Care Access and Intervention Strategies

Time: Thursday, 03/Sept/2026: 11:45am - 12:45pm · *Location:* HS2 (PHIL)
Session Chair: Jens Otto Brunner

Expanding Naloxone Accessibility: A Lifesaver or a Risky Setback?

Junyang Cai, Noa Zychlinski
Technion, Israel

The opioid epidemic has prompted governments to expand access to naloxone, a potent opioid antagonist that can reverse overdoses. While naloxone is highly effective, greater availability may entail trade-offs when moral hazard is present: easier access can encourage riskier opioid use.

We develop a dynamic compartmental model that tracks transitions between susceptible individuals and those with opioid use disorder (OUD) to assess how naloxone accessibility affects overdose mortality and to derive the optimal access policy. Full accessibility is optimal when moral hazard is absent or small. However, when moral hazard is substantial—so that increased access induces riskier behavior—expanding accessibility can paradoxically raise overdose deaths.

We extend the model to incorporate peer-driven contagion in opioid misuse. The structure of the optimal policy remains robust, retaining a bang-bang (all-or-nothing) form and the moral-hazard-driven policy reversal. Two additional insights emerge. First, in epidemics driven mainly by prescription-induced initiation, full accessibility remains optimal. In contrast, when opioid use spreads socially—especially as naloxone effectiveness declines due to potent synthetic opioids such as carfentanil—limited accessibility may become preferable. Second, the relationship between accessibility and overdose mortality can become non-monotonic, exhibiting an inverted U-shape in which moderate increases in access initially worsen outcomes.

A calibrated case study using U.S. data indicates that under current epidemic conditions, full accessibility remains optimal, consistent with existing regulatory approaches. Nonetheless, our results suggest that shifts in epidemic dynamics, including rising opioid potency, could overturn this conclusion, underscoring the need to continually reassess naloxone distribution policies as the crisis evolves.

Structural Properties of Optimal Intervention Strategies in an Extended SEIR Model

Laura Flinkert
Universität Hamburg, Germany

During a pandemic, a rapid increase in infections can lead to a simultaneous rise in severe cases and demand for intensive care. If the number of patients requiring treatment exceeds the available healthcare capacity, the healthcare system may become overwhelmed. In order to prevent this situation and to ensure adequate medical care for all patients, intervention measures are necessary. At the same time, such measures interfere with individual freedoms and therefore should only be imposed to the extent that is strictly required for public health protection.

The central question is how interventions can be chosen so that healthcare capacity is respected while restrictions on personal freedom remain as limited as possible. This problem is studied using an extended SEIR model that captures the epidemiological dynamics and the effects of contact restrictions. Their timing, duration, and intensity are examined in detail. The model also includes the maximum capacity of available intensive-care beds, ensuring that the number of hospitalized individuals in a critical condition does not exceed this limit at any time.

The present work focuses on the structural properties of the resulting optimal solutions. The aim is to understand how these solutions depend on the epidemic situation and on the timing, duration, and intensity of contact restrictions. Preliminary results reveal characteristic patterns that provide insight into the balance between healthcare protection and restrictions on personal freedom.

TC 13: Project Management and Scheduling: Project Management and Performance Control

Time: Thursday, 03/Sept/2026: 11:45am - 12:45pm · *Location:* HS4 (PHIL)
Session Chair: Lena Sophie Wohlert

A comparison of different tolerance limits for project control using earned value management systems

Yuxuan Song, Mario Vanhoucke
Ghent university, Belgium

Monitoring the project performance in progress to detect problems is key to supporting corrective actions to bring the project back on track. Tolerance limits are tools for generating warning signals that tell the project manager whether the project progress is acceptable and when corrective actions are required. Although different types of tolerance limits have been proposed in the literature, a comprehensive comparison of all of them has never been made. This makes it difficult to know which tolerance limits perform better and under what circumstances.

This paper develops a unified framework to compare different types of tolerance limits in a systematic way. Not only the detection ability but also the control effectiveness and efficiency combined with corrective actions under budget constraints are investigated. While the majority of the studies assume a critical path schedule, this paper further extends the analysis to resource-constrained projects. Extensive computational experiments are conducted on a large set of projects with different characteristics. The results show that the choice of tolerance limits for project control depends on the action setting, the project network structure, and the level of resource scarcity.

Maximizing the project's net present value with cash flows and inventory holding cost

Lena Sophie Wohlert, Jürgen Zimmermann
TU Clausthal, Germany

The net present value is an important performance measure for capital-intensive projects with a long duration. Examples of such projects include construction projects, like the development of offshore wind farms. In project scheduling, the net present value is typically computed based on cash flows associated with project activities. However, when a large component is produced and then remains idle for an extended time interval before work on it resumes, additional storage and capital tie-up cost arise. We refer to this cost as inventory holding cost. Unlike the cash flows considered, this inventory holding cost cannot be attributed to a single activity. Instead, they depend on the time interval between two activities, and can accumulate in long-term and capital-intensive projects. Therefore, we investigate the maximization of the project's net present value including cash flows and inventory holding cost under general temporal constraints. In the presentation, we discuss the structural properties we derived for discounted inventory holding cost. Building on these structural properties, we adapt an existing steepest ascent solution approach to solve the problem. Additionally, we present three mathematical models: a pulse-based formulation, a step-based model, and a formulation with continuous start time variables and a nonlinear objective as well as non-linear constraints. To evaluate and compare these solution approaches, we present computational results for large-scale instances with 100 or more activities.

TC 14: Game Theory and Behavioral Management Science: Auctions

Time: Thursday, 03/Sept/2026: 11:45am - 12:45pm · *Location:* HS12 (IM)
Session Chair: Nicolas Fugger

Simultaneous Gradient Learning in First-Price Auctions

Janik Bürgermeister[1], Julius Durmann[1], Martin Bichler[1], Marco Scarsini[2], Bary Pradelski[3], Mete Ahunbay[3]

1: Technical University of Munich; 2: Luiss University; 3: National Centre for Scientific Research (CNRS)

We study equilibrium learning in discretized Bayesian games, with a focus on first-price auctions as a testbed for gradient-based learning dynamics under private information. While the symmetric independent private values model admits a unique Bayesian correlated equilibrium (BCE) in the continuous limit, standard convergence guarantees for gradient-based learners do not apply: classical no-regret theory predicts convergence only to Bayesian coarse correlated equilibria (BCCE), which can remain large and far from the competitive equilibrium even under fine discretizations.

To bridge this gap, we introduce the notion of a Bayesian semicoarse correlated equilibrium (BSCCE), an equilibrium concept that refines BCCE by restricting deviations to tangential, probability-preserving transformations consistent with projected gradient dynamics. We provide a linear programming characterization of BSCCE and establish that BCEs are a subset of BSCCEs which in turn are a subset of BCCEs.

Our main finding is that the BSCCE set contracts in many cases as the discretization of the Bayesian game is refined. Even with priors for which BCCE fails to concentrate, the diameter of the BSCCE polytope shrinks toward zero, indicating convergence to the unique continuous-game Bayes-Nash equilibrium.

These results provide a principled explanation for the observed robustness of gradient-based learning in discretized Bayesian games, showing that these dynamics select a smaller equilibrium set than predicted by standard no-regret theory.

Auctions and Negotiations in Procurement

Nicolas Fugger

University of Cologne, Germany

In many procurement settings, managers can choose between auctions and negotiations to award contracts. In this project, we investigate the mechanism choice theoretically and experimentally.

TC 15: Pricing and Revenue Management: Competition and Cancellations

Time: Thursday, 03/Sept/2026: 11:45am - 12:45pm · *Location:* SR034 (WIWI)
Session Chair: Christina Johanna Liepold-Viehweger

Dynamic price competition with informed and loyal consumers

Yang Wang[1], Benny Mantin[2]
1: Southwest Jiaotong University, China, People's Republic of; 2: University of Luxembourg

This paper studies dynamic price competition between two firms over two periods in a market with two types of consumers: informed, who compare prices before purchasing, and loyal, who buy only from one firm. Although no pure-strategy equilibrium exists in the second period, we characterize the firms' mixed pricing strategies, which guide their respective first-period's decisions. We consider and characterize both symmetric and asymmetric first-period pricing policies where, in the latter case, the relative price ranking (i.e., which firm sets the higher price) is predetermined. Our solutions shed light on the nature of price competition and price dispersion in dynamic settings.

Mechanism Design for Deterring Post-Match Cancellations

Christina Johanna Liepold, Grit Walther
RWTH Aachen University, Germany

Post-match cancellations (PMC), i.e., when either side of a two-sided platform withdraws after a match has been confirmed, generate disruption costs that often exceed the cost of a single missed transaction. Buyers may experience expensive downstream delays if a supplier cancels, whereas suppliers facing last-minute cancellations may be unable to reallocate reserved capacity. Therefore, PMCs threaten platform stability and reduce gains from trade.

Our study introduces a mechanism design framework that explicitly accounts for users' PMC incentives and the impact of cancellation fees. A central feature are precautionary cancellations, which arise when agents perceive high counterparty cancellation risk and thus may exit proactively despite current profitability, as the match's continuation value is significantly reduced by its instability.

To mitigate the negative impact of PMCs on platform operators, we formulate their fee-setting and pricing problem as a Markov Decision Process. We explicitly distinguish between two platform regimes for which we derive closed-form optimal fee-setting policies: (I) a price-accepting platform that controls only the cancellation fee, and (II) a price-setting platform that also determines transfer prices. Our analysis demonstrates that the optimal policy is state-dependent across a heterogeneous match population and that a uniform fee necessarily results in a value loss relative to the match-specific optimum. Security deposits are also evaluated as an alternative to cancellation fees. We show that while both fees and deposits expand the set of feasible contracts, they function through fundamentally different mechanisms and diverge when belief heterogeneity is present.

TC 16: Simulation and Quantum Computing: Quantum Algorithms for Complex Optimization Problems

Time: Thursday, 03/Sept/2026: 11:45am - 12:45pm · *Location:* SR033 (WIWI)
Session Chair: Maximilian Moll

Analysis of Selected Quantum Circuits for Graph Optimization Problems.

Ali Abbassi[1], Caroline Prodhon[1], Philippe Lacomme[2], Alexey Bochkarev[3]
1: Université de technologie de Troyes; 2: Université Clermont-Auvergne; 3: RPTU Kaiserslautern-Landau

This work focuses on hybrid quantum-classical (gate-based) optimization approaches in the space of valid paths between two selected nodes in a graph. We take finding a shortest path in a graph as our model problem, but aim to discuss results that can be broadly generalized, with interdiction variants constituting notable possible further applications. We present several hands-on numerical illustrations, where we create and vary a superposition state encoding a probability distribution over valid paths. From the methodological standpoint, we take a quantum walks inspired perspective to analyze a few possible mixing Hamiltonians, including ones stemming from the research on the feasibility preserving mixers. This allows us to analyze the role played by the interference and entanglement throughout the circuit. We differentiate between the "classical" search in the space of quantum circuit parameters (driven by the classical assessment of the solutions sample) and "quantum" (interference-driven) search throughout the single circuit application and highlight it how different quantum circuits can entail emphasis on either of the two. We illustrate this theoretical point by implementing a few hybrid quantum-classical optimization procedures for the Shortest Path problem. We use the Quantum Alternating Operator Ansatz Framework and improve previously known circuits stemming from the quantum computing research on the Traveling Salesman problem to accommodate for variable-length paths.

Gradient-free Optimization in Hybrid-Quantum Supervised Learning

Stefan Klug, Maximilian Moll
Universität der Bundeswehr München, Germany

Despite the common idea that quantum computing is fast, the same typically does not hold for Quantum Machine Learning: Each data point has to be processed individually and the number of circuit evaluation for derivatives by the parameter shift rule scales linearly with the number of parameters. This leads to long computation time during training, but also allows for direct comparison with gradient-free optimization algorithms. In this talk, we present a comprehensive comparison of 14 algorithmic choices on 4 real world benchmark datasets. The results show that the asexual reproduction optimization algorithm - the simplest of the investigated algorithms - is preferable among gradient-free algorithms and provides a good alternative to traditional gradient-based approaches.

TD 01: Supply Chain Management and Production: Sustainable Supply Chains

Time: Thursday, 03/Sept/2026: 2:00pm - 3:30pm · *Location:* HS10 (AM)
Session Chair: Teresa Melo

From Product Information to Strategic Disclosure: Green Quality Claims under Downstream Finance

Yun Liu
University of York, United Kingdom

We study product-level green quality disclosure in supply chains. Unlike traditional quality disclosure, green quality claims leave greater room for selective or misleading presentation, making disclosure a question of both whether and how it is implemented. This paper develops a supply-chain disclosure model where a manufacturer discloses green quality while extending trade credit to a capital-constrained retailer. Embedded in the same transactional exchange, product claims become intertwined with downstream finance. The analysis shows that greater retailer internal capital lowers the manufacturer's disclosure-entry threshold, making disclosure more attractive. With misleading claims, this entry threshold no longer coincides for the retailer and the manufacturer: the retailer's perceived threshold rises relative to truthful disclosure, whereas the effect on the manufacturer's disclosure-entry decision may go in either direction depending on financial conditions. At the truthful-greenwashing margin, downstream finance acts not as a continuous shifter but as a gatekeeper: beyond the gate, truthful and misleading implementation become directly comparable, and the choice is then governed by the gain from claim inflation and the expected regulatory cost; below it, truthful disclosure weakly dominates. These findings show that downstream finance is not merely a background condition for green quality disclosure in supply chains. It shapes disclosure entry and, more importantly, qualifies the usual governance view of greenwashing as a standing problem once disclosure takes place: in this supply-chain financing setting, downstream finance determines whether the truthful-greenwashing margin exists at all.

Green Supply Chain Management (GSCM) and financial resilience in crisis: the role of ownership type constraints in decision-making

Alexander Platsch, Roel Gevaers
University of Antwerp, Belgium

Europe faces the highest number of firm insolvencies in the last decade. From past crises academic literature has identified operational mechanisms as driving forces for firm financial resilience. GSCM is seen as beneficial to mitigate effects if crises hit, but the role of corporate ownership types is linked to heterogenous outcomes. We argue the two concepts are interdependent while shareholder specific constraints drive the strength of the effect, although their link is underexplored. We compare relevant stakes of private shareholders, states, institutional investors and diverse ownership and their decision-making constraints reflected in risk tolerance and investment horizon around the Covid-19 pandemic as an external shock. Responding to calls for further research at this intersection, we build on firm-level data from LSEG Workspace covering the years 2018 to 2025 to execute our empirical study. The study is framed in the system relevant yet recently volatile European chemicals and life science industries. Linear mixed models and moderation analysis are employed to answer the central research question: How do ownership type decision-making constraints shape the strength of GSCM effects on financial resilience in crisis?

Settled in two critical, crisis hit European industries to our knowledge this research delivers a first contribution to integrate the heterogenic effect of both concepts in a single study. Through a rigorous, longitudinal approach it will advance our knowledge in the field by refining the understanding under which shareholder decision-making constraints GSCM supports financial resilience in crises.

Resilient supply chain network design: A bi-objective two-stage stochastic model with flexible strategies

Teresa Melo[1], Angelo Aliano Filho[2], Isabel Correia[3]
1: Saarland University of Applied Sciences, Germany; 2: Federal Technological University of Paraná, Brazil; 3: NOVA University Lisbon, Portugal

We address the design of a resilient and responsive three-echelon supply chain network under uncertainty in disruption events, demand, and distribution costs. Uncertainty is modeled through a finite set of scenarios representing joint realizations of these factors over a multi-period planning horizon. To enhance preparedness and recovery, several flexibility mechanisms are incorporated across the network. At the supplier level, backup sourcing is activated when primary suppliers experience capacity losses. In the intermediate echelon, facility location decisions are combined with fortification investments at disruption-prone sites, where the extent and duration of capacity loss depend on the protection level. At the customer level, responsiveness is ensured through minimum service requirements and bounded delivery delays. We formulate the problem as a bi-objective two-stage stochastic program that minimizes total expected cost and expected unmet demand. First-stage decisions determine facility deployment, fortification levels, and the selection of primary and backup suppliers. After uncertainty is realized, second-stage decisions govern the activation of backup suppliers and the material flows across the network. To generate Pareto-optimal solutions,

we apply the epsilon-constraint method and solve the resulting subproblems with a tailored MIP-based heuristic. The latter constructs a feasible solution and improves it by selectively revising earlier decisions. Computational experiments on randomly generated instances demonstrate the effectiveness of this approach, particularly for large-scale problems, and provide insights into the trade-offs between cost efficiency and supply chain responsiveness.

TD 02: Mobility, Transport, and Traffic: Railway Network Capacity Planning

Time: Thursday, 03/Sept/2026: 2:00pm - 3:30pm · *Location:* HS1 (PHIL)
Session Chair: Sara Comelli

A Gomory-Hu Approach to Railway Network Capacity Planning

Paula Franke[1], Ralf Borndörfer[2], Niels Lindner[2], Christian Puchert[3], Tuomo Takkula[3]
1: Freie Universität Berlin, Germany; 2: Zuse-Institut Berlin, Germany; 3: Ab Ovo Germany GmbH

Railway networks face growing pressure from rising demand for both freight and passenger traffic, as well as increasing requirements for robustness and efficiency. Identifying critical bottlenecks to devise strategic infrastructure upgrade policies therefore becomes a central task in long-term capacity planning of railway networks. This talk explores the potential of Gomory-Hu trees as a graph-based approach to railway capacity analysis and makes the case for its incorporation into long-term strategic planning.

Gomory-Hu trees provide an efficient representation of all minimum cuts between all

pairs of vertices in a network, permitting a global perspective on structural bottlenecks. Unlike conventional local analyses, this perspective highlights critical corridors within the network whose expansion yields the highest system-wide benefits, or conversely, the restriction of which have the gravest consequences. To accommodate demand data and to integrate flexible train routing, we combine Gomory-Hu trees with origin-destination flow information from a multi-commodity flow problem instance. This allows for a more adequate and yet network-scale investigation. The resulting approach further provides an intuitive basis for evaluating network robustness and supporting data-driven approaches to the long-term planning of railway infrastructure.

Cleared for Delay: Robustifying Fleet Assignments using Kumaraswamy DRO

Dennis Adelhütte[2], Julius Bauss[2], Martin Betz[1], Frauke Liers[1], Antonio Mester[2]
1: Friedrich-Alexander-Universität Erlangen-Nürnberg; 2: M2P Consulting GmbH

Creating an airline schedule is a multi-step planning process. Before flights are assigned to individual aircraft, they are assigned to one of the airline's fleets. This decision is driven by expected revenue and cost, as fleets are heterogeneous: they differ in physical characteristics, route feasibility, fuel consumption, and economic implications. This planning step is known as the fleet assignment problem and is particularly relevant for multiple-fleet airlines.

State-of-the-art models typically account for fuel, airport, and operational costs. However, they often neglect disruption-related costs, especially those arising from passenger recovery when passengers miss connecting flights.

In this talk, we present a fleet assignment model that incorporates passenger recovery costs and, additionally, enforces a high likelihood of avoiding missed connections by allowing small shifts in departure and arrival times. Since fleet assignment models do not usually consider passenger connections explicitly, we first estimate the number of passengers on potential connecting flights. To this end, we propose a modeling approach based on distributionally robust optimization (DRO).

While DRO provides strong statistical guarantees, standard ambiguity sets may render discrete assignment problems computationally intractable. To address this, we use a novel parametric DRO framework in which delays, modeled as random variables, are restricted to finite mixtures of Kumaraswamy distributions. This enables a tractable reformulation while preserving the order of magnitude of the original problem.

The resulting framework offers a scalable, data-driven methodology for mitigating passenger connection disruptions in large-scale airline networks, ultimately reducing airline costs and improving customer satisfaction.

Path-Based Evaluation of Delay-Critical Points in Railway Timetables

Sara Comelli[1], Jonas Aumeier[1], Norman Weik[1], Franziska Theurich[2], Cédric Kekes[2], Karl Nachtigall[2]
1: Professorship for Design and Operation of Public Rail Transport Systems, TU Munich, Germany; 2: Professorship of Traffic Flow Science, TU Dresden, Germany

When railway systems operate close to their maximum capacity, even small delays can propagate through the network, generating widespread knock-on effects. In the timetable planning phase, it is challenging to identify and target these local weaknesses to improve timetable robustness, as existing approaches mainly rely on aggregate delay statistics or buffer-based metrics.

In our approach, we model a timetable as a stochastic event-activity network, where each train activity is associated with a random duration, and we aim to quantify the delay risk arising from cross-train interactions. For this purpose, we present a novel methodology to explicitly reconstruct local delay propagation chains by backtracking all the critical paths in the graph-representation of the timetable. The proposed methodology goes beyond purely statistical indicators by capturing the causal structure of delay propagation chains through a network-based formulation.

To test our methodology, we analyse a set of timetables spanning up to 300 km in a region of northern Germany. By applying our metric, we illustrate how variations in one train's duration impact the operations of other trains, thereby identifying the most critical interdependencies within the schedule. This can improve service efficiency and stability, for instance, by assisting timetable planners in allocating timetable reserves or assessing residual freight capacity, as it provides structural insight into delay amplification beyond traditional global robustness metrics.

TD 03: Mobility, Transport, and Traffic: Drones 2

Time: Thursday, 03/Sept/2026: 2:00pm - 3:30pm · *Location:* HS3 (PHIL)
Session Chair: Mahdi Moeini

Drone Routing with Multiple Time Windows for Laboratory Logistics

Niklas Wolfrum
TU Berlin, Germany / FU Berlin, Germany

The use of drones for time-critical laboratory logistics opens new possibilities but also introduces complex planning challenges. This work investigates a drone-based routing problem motivated by the transportation of laboratory samples between collection points and processing facilities. In many real-world settings, sample collection and processing follow predefined schedules, resulting in multiple feasible time windows for each location. This leads to a complex decision problem that integrates routing, scheduling, and time window selection.

We consider a drone system operating over a given planning horizon, where drones may perform multiple consecutive trips. Each sample must be assigned to exactly one of several available time windows, while respecting operational constraints such as battery-based range limits, payload capacity, and synchronization with laboratory schedules. This leads to a tightly coupled decision problem that extends classical vehicle routing formulations.

A mathematical optimization model is developed to jointly determine routing decisions, trip sequences, and time window assignments. The objective is to minimize total transportation effort and maximize the share of demand served by drones, while ensuring feasibility with respect to all temporal and operational constraints.

The proposed framework provides a basis for evaluating the potential of drone-supported logistics in time-critical laboratory environments, where flexible scheduling and fast transportation are essential.

Chance-Constrained Optimization Models for Drone-Based Logistics Networks

Rashed Khanjani Shiraz
Technical University of Munich, Germany

The deployment of drones in logistics networks offers significant potential for improving delivery efficiency, but inherent uncertainties such as in demand, service times, and operational conditions complicate planning. To address these challenges, this paper develops chance-constrained optimization models for drone-based networks, allowing planners to ensure that operational constraints are satisfied with a specified probability. Recognizing the challenge of incomplete or ambiguous knowledge of uncertain parameters, we extend the framework to distributionally robust optimization (DRO), which captures uncertainty through ambiguity sets. This formulation hedges against the worst-case distribution consistent with available statistical information, thereby strengthening solution reliability. We provide tractable reformulations of both the chance-constrained and DRO models, enabling efficient solution with standard solvers.

Surveillance through Deploying Autonomous Unmanned Vehicles

Mahdi Moeini
National School of Computer Science for Industry and Business, France

In this study, we study a routing problem that is considered as a variant of the Vehicle Routing Problem (VRP), the Covering Tour Problem (CTP), and the Covering Salesman Problem (CSP). More precisely, we investigate the multi-visit multi-drone Vehicle Routing Problem (m2VRP). In the m2VRP, given a depot, a set of main vehicles, each of them equipped with a set of unmanned autonomous vehicles (AUVs), the objective consists in routing the whole fleet to visit or cover a given set of locations in minimal time. Each location can be visited or covered exactly once by either of the vehicles, and by the end of the mission, all vehicles return to the depot. The m2VRP can be formulated as a Mixed-Integer Linear Programming (MILP) model. Beside using a standard solver for addressing small instances, we introduce a heuristic algorithm, which is used for solving larges instances. Through computational experiments, the model is validated and the efficiency of the heuristic algorithm is tested.

TD 04: Energy and Sustainability: Energy investments, peak power & storage

Time: Thursday, 03/Sept/2026: 2:00pm - 3:30pm · *Location:* HS13 (IM)
Session Chair: Dominik Möst

Energy investments with incomplete markets for risk: Market equilibria based on second-order cone programs

Christoph Weber
University Duisburg-Essen, Germany

In electricity markets, generation companies face substantial risks regarding future market prices when making investment decisions. In economic theory, perfect hedging contracts are often assumed (so-called Arrow-Debreu securities). Yet real-world risk markets are incomplete. This may lead to substantial distortions in the optimal generation mix compared to the welfare optimum with complete markets (cf. Mays et al. 2019, Dimanchev et al. 2024…). Yet the algorithms available so far to identify these kinds of market equilibria are iterative and hardly scale to larger problem instances. We therefore explore the use of second-order cones to obtain an integrated convex problem formulation. The investment decisions of the individual agents are thereby taken as starting point, and the corresponding dual problem formulations are derived. Thereby, the share of debt financing is treated as endogenous and dependent on the riskiness of the investments. The novel method is demonstrated on a case study for Germany, including renewable, back-up power plant and storage investments.

A new exact approach for a Line Balancing Problem with Peak Power Minimization

Xavier Delorme, Paolo Gianessi
Mines Saint-Étienne, Univ Clermont Auvergne, INP Clermont Auvergne, CNRS, UMR 6158 LIMOS, F-42023 Saint-Étienne, France

Motivated by Sustainable Development Goals, mostly 9 and 12, to consider sustainable development as the main driver of economic and societal decisions, Manufacturing Systems (MS) have in the last decades put energy efficiency at the forefront of their agendas. Many research works have emerged that consider energy consumption, energy cost and/or power as constraints and/or criteria to be optimized, especially in tactical or operational problems, e.g. production planning or scheduling.

Much fewer problems, as far as we know, have been studied that consider energy in the design of an MS. One is the Simple Assembly Line Balancing Problem with Power Peak Minimization (SALB3PM). In it, the tasks of a production process are considered, with known precedence relations and constant processing time and electric power consumption. Tasks must be assigned to the workstations of a paced assembly line with given number of workstations in precedence-compliant manner, and scheduled along the line cycle so as to minimize the power peak.

We study a three-index Integer Linear Programming formulation allowing to model both the SALB3PM and the SALB3PM-ESD, a version of SALB3PM imposing earliest possible task starting dates, more suitable to the case of manual or semi-automated MSs. We run the model on benchmark instances from the literature and on new instances with non-constant and/or noisy task power consumption profiles. In order to improve computational performance when dealing with the hardest SALB3PM instances, we obtain warmstart solutions from both a metaheuristic algorithm and the optimal SALB3PM-ESD solution. Numerical results are presented and discussed.

On the complexity of Single-Target Retrieval in Side-Access Compact Storage Systems

Yagmur Gül
Universität Hamburg, Germany

The Side-Access Compact Retrieval Problem (SACRP) is a recently introduced energy minimization problem arising in compact storage systems where target bins are retrieved through tunnels created by lifting blocking bins. In this talk, we study the single-target variant of the SACRP restricted to two stacks. Although SACRP is strongly NP-complete, we show that the single-target variant reduces exactly to a one-dimensional scheduling problem and derive structural properties of optimal solutions, including a characterization of the decomposition at the topmost element. Our main technical contribution is a novel exchange argument which establishes that every optimal decomposition uses an index-prefix structure. Building on these insights, we propose a dynamic programming algorithm that solves the problem in $O(n^6)$ time, where n is the number of targets. All theoretical results are corroborated by exhaustive computational verification. Our findings show that, despite the intractability of the general SACRP, its two-stack restriction admits rich combinatorial structure that can be fully exploited algorithmically.

TD 05: Energy and Sustainability: Electricity and heating networks

Time: Thursday, 03/Sept/2026: 2:00pm - 3:30pm · *Location:* HS11 (IM)
Session Chair: Tizian Schug

A Temperature-Aware MINLP Model for Optimizing the Operation of Domesting Heating Networks

Baraa Mohammad[1], Andreas Bley[1], Juan Rodriguez Santiago[2], Pedro Jose Giron Cruz[2]
1: University of Kassel, Germany; 2: Fraunhofer Institute for Energy Economics and Energy System Technology, Kassel, Germany

We consider the problem of optimizing the operation of decentralized heat pump systems in existing buildings. Given an in-house thermal network consisting of a heat pump, storage(s) for space-heating and domestic hot water, radiator-based heating circuits, and bypass systems for controlled mixing and splitting of thermal flows, the task is to operate these components over a given time-horizon in such a way that all thermal demands are fulfilled and operational costs are minimized.

In this work, we develop a time-discrete MINLP model for this problem, where discrete variables describe the operating modes of the components and continuous variables model the power flows and temperatures per time step in the system. The mixing of thermal flows and the thermodynamic behavior of several components, some described by AI-based surrogate models, lead to nonlinear constraints in the model. We also present first computational results obtained with of this model for some test instances.

The key contribution of the proposed formulation is its temperature awareness. In contrast to previous models, not only the net power flows, but also the supply and return temperatures of thermal flows are explicitly modeled. This allows for a more realistic representation of temperature dependent efficiencies and losses.

This work is funded by the German Federal Ministry for Economic Affairs and Energy via the project EnOb BuildHPFlex.

Building reconfigurable communication networks for resilient electrical distribution grids: From tri-level to single-level MILP

Andrew Eliseev, Florian Steinke
Technical University of Darmstadt, Germany

Natural disasters are increasingly threatening power system reliability. At the same time, decarbonisation is driving the adoption of distributed energy resources (DERs), such as rooftop solar panels and local battery storage systems. Unlike large power plants connected to high-voltage transmission grids, DERs operate within municipal distribution grids (DGs). This local setup can improve resilience and reliability, enabling DGs to keep operating (at least partially) during widespread outages. Automated distributed control systems can be deployed to facilitate this process, requiring DG substations to coordinate their control actions via a communication network (CN). For stable and cost-efficient operation, a condition called 'congruence' must hold: two substations should be connected by a path in the CN if and only if they are connected by a path in the DG. After failures in the DG, restoring congruence requires rapid CN reconfiguration by the means of adding or removing links.

We study the problem of designing a CN that minimises its 'α-incongruity' from the DG, defined as the total cost of reconfigurations required in the worst-case failure scenario. Here, link addition and link removal have respective costs 1 and α ($0 \le \alpha \le 1$), reflecting potentially lower removal effort. This problem can be straightforwardly formulated as a tri-level mixed-integer linear program (MILP). In our work, we: (1) simplify the computation of α-incongruity for any CN-DG pair; (2) show that real DGs are likely to have low treewidth (mostly up to 6); (3) use these insights to reformulate the problem as an equivalent single-level MILP.

Learning-Based Consensus for Distributed Optimization of Active Distribution Networks

Miguel Huerta, Alejandro Angulo, Pablo Escalona
Universidad Técnica Federico Santa María, Chile

We propose a physics-based neural controller for real-time operation of active distribution networks with high penetration of distributed photovoltaic generation. In this context, distributed optimization is attractive because it decomposes the operation problem into local subproblems solved in parallel, reducing computation time and improving scalability under variable demand and generation. However, distributed operations still face challenges related to iterative coordination, communication overhead, and uncertainty. To address these issues, the proposed approach embeds power-system physics in agent training, combining optimized local subproblems with learned inter-area consensus for real-time coordination.

Inspired by proximal Jacobian ADMM formulation, the proposal preserves optimization-based local subproblem solving while replacing iterative boundary exchanges with a learning-based consensus agent that approximates the coordinated optimum in one step. The agent internalizes neighboring responses through dual and uncertain information, without sharing primal solutions, preserving data confidentiality. The distribution network is represented as a static, directed graph whose nodes and arcs represent busbars and power lines. Since the topology is fixed and nodal variables change over time, a temporal graph neural network

captures the network's spatial coupling and temporal evolution of operating conditions. Thus, the agent integrates linearized power-flow models, operational constraints, stability conditions, and optimality criteria within a rolling-horizon architecture.

The framework is evaluated on IEEE test feeders of different sizes. Results show that the proposed controller outperforms state-of-the-art methods in computational speed while adding a privacy-preserving layer by design. Overall, the study highlights physics-informed learning and optimization as a promising path toward robust, scalable, and efficient control.

TD 06: Discrete and Combinatorial Optimization: Nonlinearities

Time: Thursday, 03/Sept/2026: 2:00pm - 3:30pm · *Location:* HS5 (WIWI)
Session Chair: Julia Grübel

A Continuous Reformulation for MINLPs Satisfying Constraint Qualifications

Andreas Horländer[1], Martin Schmidt[1], Johannes Thürauf[2]
1: Trier University, Germany; 2: University of Technology Nuremberg, Germany

We study general mixed-integer nonlinear problems (MINLPs) with continuously differentiable objective and constraint functions. We derive a continuous reformulation of this class of problems that (under mild assumptions) satisfies standard constraint qualifications such as the Abadie constraint qualification, the Mangasarian–Fromovitz constraint qualification, and the linear independence constraint qualification. To the best of our knowledge, a continuous reformulation with these properties has not yet been reported in the literature. Based on this reformulation, we establish Karush–Kuhn–Tucker conditions for the original MINLP. Finally, we perform a preliminary numerical study on benchmark instances from the MINLPLib to evaluate the practical applicability of the proposed approach. In particular, we compare solution times and solution quality obtained by solving the continuous reformulation with a nonlinear programming (NLP) solver against those obtained by solving the original MINLP with a state-of-the-art MINLP solver.

Matheuristic for the Electric Vehicle Routing Problem with Time Windows and Nonlinear Recharging Functions

Lelisa Kebena Bijiga[1], Steffen Rebennack[1], John Alasdair Warwicker[2]
1: Karlsruhe Institute of Technology, Germany; 2: Lancaster University Leipzig

The increasing interest in sustainable transportation has promoted electric vehicles (EVs) as an alternative to internal combustion engine vehicles. The EV routing problem (EVRP) accounts for the unique constraints of EVs, such as limited battery capacity and the need for recharging stops, which can be time-consuming. These challenges have motivated extensive research on EVRPs, particularly the electric vehicle routing problem with time windows (EVRPTW), where customers are serviced within predefined time windows. A key aspect of EVRPTW is the modeling of the charging process. Most studies in the literature assume linear charging functions, which simplify the relationship between charging time and battery level and improve computational tractability. However, they fail to accurately capture the nonlinear behaviour of real-world battery charging, where charging rates decrease as the battery approaches full capacity. To address this limitation, more recent works consider nonlinear charging functions, leading to the EVRPTW with nonlinear charging function (EVRPTW-NL). In this work, we propose two path-based formulations for EVRPTW-NL and study variants under different recharging policies, allowing either at most one recharge or multiple recharges per route. For the single-recharge case, we propose valid inequalities that limit each route to at most one charging operation, which is enforced via lazy constraints. We solve these formulations through a POPMUSIC matheuristic algorithm that relies on branch-and-cut, which can be implemented using Hexaly and commercial optimisation software. In computational studies, we demonstrate the effectiveness of the proposed algorithm on known benchmark instances of EVRPTW-NL and compare it with state-of-the-art solutions.

Capacity and network expansion in the multilevel European entry-exit gas market system with nonlinear flow models on trees

Veronika Grimm[1], Julia Grübel[1], Martin Loy[1], Lars Schewe[2], Martin Schmidt[3], Johannes Thürauf[1], Gregor Zöttl[4]
1: University of Technology Nuremberg (UTN), Germany; 2: University of Edinburgh, UK; 3: Trier University, Germany; 4: Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany

In order to decouple gas transport from trading, European gas markets are primarily organized as so-called entry-exit systems. This market design was first modeled as a multilevel optimization problem by Grimm et al. (2019). In this work, we extend the four-level entry-exit framework of Schewe et al. (2022) by incorporating endogenous capacity and network expansion decisions. The resulting model poses major challenges due to the discrete expansion variables, the nonlinear gas flow physics on the lowest level, and the computation of the so-called technical capacities on the first level. Due to their conservative nature, the computation of the latter leads to infinitely many nonlinear adjustable-robust constraints. To address these challenges, we develop techniques for deriving an exact nonconvex mixed-integer single-level reformulation for tree-shaped passive networks. Our approach exploits structural properties that ensure equivalence to the original multilevel model, now including capacity and network expansion. Numerical experiments on real-world-sized tree-shaped gas networks are conducted to investigate the practical limits of the model with respect to the number of expansion candidates.

TD 07: Artificial Intelligence, Machine Learning and Optimization: Learning Rewards

Time: Thursday, 03/Sept/2026: 2:00pm - 3:30pm · *Location:* SR029 (WIWI)
Session Chair: Julius Durmann

In-Context Learning for Data-Driven Censored Inventory Control

Sohom Mukherjee
Julius-Maximilians-Universität Würzburg, Germany

Inventory systems with stockouts create a fundamental learning problem: the order quantity affects both operational cost and the information revealed about demand. In the repeated newsvendor problem, unmet demand is censored, so conservative ordering may reduce short-term cost while limiting future learning. We propose in-context generative posterior sampling, a sequential decision method that combines offline learning from censored historical episodes with online exploration through generative demand completion. Offline, the method trains a censoring-aware completion model. Online, the model remains frozen and adapts only by conditioning on the growing history of orders, sales, and stockout indicators; it samples demand trajectories consistent with observed censoring and then applies the newsvendor critical-fractile decision rule. The main contribution is to connect modern in-context generative modeling with performance guarantees for operational learning under decision-dependent censoring.

Theoretically, we decompose Bayesian regret into an ideal posterior-sampling component and a deployment penalty that captures the error from using a learned completion model. For the repeated newsvendor setting, we show that the ideal component admits sublinear regret through a reduction to one-dimensional bandit convex optimization, while the deployment penalty can be controlled by an observable censoring-aware predictive mismatch under coverage and stability assumptions.

Practically, we instantiate the approach with ChronosFlow, combining a time-series transformer backbone with a conditional normalizing-flow head for fast censoring-consistent sampling. Synthetic and real-data experiments show that ChronosFlow matches correctly specified Thompson sampling, is more robust to prior misspecification and distribution shift, and performs especially well under heavy censoring.

A Lower Bound for Mean-Based Algorithms

Julius Durmann, Amelie Kleber
Technical University of Munich, Germany

Mean-based algorithms are online learning algorithms that play actions with low average reward with low probability. Recent work suggests that these algorithms ensure favorable convergence guarantees to serially undominated actions, which are close to the Nash equilibria in economic games. However, empirical evidence also indicates slower convergence than established algorithms in the bandit-feedback setting.

We focus on mean-based algorithms in environments where the time horizon is unknown and only bandit feedback is available. In this setting, we provide the first lower bound on the algorithm-defining sequence γ_t that formally establishes a limit on how fast these algorithms can learn. Additionally, we propose two mean-based algorithms: one that generalizes the ϵ-greedy algorithm and another that extends the mean-based Exp3 algorithm to the infinite-horizon setting.

Using numerical experiments, we support the claim that bandit-feedback mean-based algorithms exhibit slowly decaying exploration rates, resulting in inferior rewards.

Our results suggest that, while theoretical convergence guarantees exist for mean-based algorithms in the limit, this convergence is slow under bandit feedback.

We also elaborate on their relation to no-regret algorithms, providing a more nuanced understanding of the class of mean-based algorithms.

Sentiment in Financial Disclosures and Stock Returns: Scoring based on a fine-tuned FinBERT model

Niklas Kestler[1], Hendrik Scholz[1], Nicolas Webersinke[2]
1: Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany; 2: MUNICH ERGO Kapitalanlagegesellschaft mbH

In this study, we analyze the sentiment of the MD&A sections of 10-K filings for companies listed on the S&P 500 from 2010 to 2023. We employ three sentiment analysis approaches: the Loughran-McDonald dictionary, the FinBERT large language model and a fine-tuned version of FinBERT. The fine-tuning is conducted using FinSentSet, a human-annotated dataset consisting of approximately 3000 sentences from MSCI-listed firms between 2010 and 2020, allowing for sentiment scoring instead of classification to enhance measurement precision.

Our contribution is threefold. First, we provide a novel application of large language models in financial sentiment analysis by examining the relationship between management sentiment in 10-K filings and stock returns using FinBERT. Second, we try to

enhance FinBERT by fine-tuning it with FinSentSet. Third, we publicly release FinSentSet, thereby contributing a valuable dataset for future research in financial sentiment analysis.

We measure the sentiment of these MD&A sections using the three mentioned approaches. Then we assess the significance of these sentiment measures using cumulative abnormal returns (CARs) around the filing dates. Thereby we use panel regression analysis with several controls, which reveals mixed results: our sentiment measures show significant effects for the FinBERT and fine-tuned FinBERT models, particularly for CAR(0, 10) up to CAR(0, 80) days post-filing. In contrast, the Loughran-McDonald dictionary method shows less significance.

Lastly, we implement a basic trading strategy based on portfolio sorting and annual rebalancing. The strategy does not yield statistically significant outperformance.

TD 08: Supply Chain Management and Production: Integrating Production and Transportation

Time: Thursday, 03/Sept/2026: 2:00pm - 3:30pm · *Location:* HS9 (AM)
Session Chair: Kevin Tierney

A Memetic Algorithm for the Two-Echelon Cyclic Inventory Routing Problem

Sahar Anvariazar, Birger Raa
Ghent University, Belgium

We study two-echelon cyclic inventory routing, where customers with constant demand rates are jointly and periodically replenished using capacitated vehicles from a single depot with limited storage. The depot is itself replenished by a vehicle with limited capacity. Over an infinite planning horizon, we apply a fixed-partition policy in which customers are divided into subsets that are always served together in the same cyclic route. Thus, three planning problems are integrated: designing outbound milk runs for periodic customer replenishment with optimized cycle times; scheduling these routes across the least possible number of vehicles; and synchronizing inbound deliveries to the depot with the cyclically repeated outbound routes.

We formally describe this integrated problem in a non-linear mathematical model that can be linearised when route cycle times are limited to a given set of values. We then propose a heuristic solution method based on a two-phase procedure for fleet scheduling, comprising an insertion-based construction phase and a variable-depth local-search improvement phase. This fleet scheduling heuristic is embedded in a local-search heuristic for route design. Customer-to-route assignments are thus determined jointly with vehicle scheduling, while customer holding costs and depot replenishment costs are evaluated dynamically for each newly generated route. These heuristic building blocks are in turn embedded in a memetic metaheuristic.

Computational experiments (i) show that, for the single-echelon problem, the proposed solution framework outperforms existing approaches in which route and fleet design are solved sequentially, and (ii) illustrate how the trade-off between first and second echelon costs is optimized.

Clustering-guided hybrid Genetic Algorithm with adaptive local search for integrated production-distribution planning

Mohammad Kaviyani-Charati, Fantahun Defersha, Sheng Yang
University of Guelph, Canada

Ultra-fresh food products, such as ready-to-eat salads, must be produced and delivered within a very short horizon, creating a tight coupling between production scheduling and distribution that is conventionally optimized in isolation. This paper studies an integrated production scheduling and vehicle routing problem for ultra-fresh food supply chains, in which a multi-stage flexible flow shop is coordinated with multi-trip capacitated vehicle routing under soft time windows and a one-day freshness constraint. The problem is formulated as a mixed-integer linear optimization model that jointly minimizes production, inventory, time-window violation, routing, overtime, waste, and lost-sales costs, with production and distribution integrated by linking vehicle departures to the completion times of assigned production batches. As the integrated problem becomes computationally intractable at realistic scale, we propose a hybrid genetic algorithm that combines a spatio-temporal clustering-based initialization with an adaptive local search that selects among multiple neighborhood structures online based on recent search performance. The clustering procedure groups

customer orders by spatial proximity and time-window urgency to generate high-quality, structured initial solutions and to guide cluster-aware crossover and mutation operators. The algorithm is validated against an exact solver on small instances, achieving near-optimal solutions and, in several cases, outperforming the solver's best-found solutions under the imposed time limit. On larger instances generated from a real distribution network in Southern Ontario, Canada, computational experiments show that the proposed algorithm consistently outperforms established benchmark metaheuristics in solution quality. The results highlight the value of clustering-informed initialization and adaptive neighborhood search for time-sensitive food supply chains.

Industrial-scale load carrier to truck assignment with implicit truck loading constraints

Daniel Wetzel[1], Jakob Schulte[2], Mohamed Amine Khatouf[3], Michael Römer[2], Kevin Tierney[1]
1: University of Vienna, Austria; 2: Bielefeld University, Germany; 3: Renault, France

Efficient transportation is critical to modern supply chains, where timely deliveries and cost control are key. This work presents a novel approach for optimizing load carrier–truck assignments by explicitly integrating truck loading constraints into an assignment formulation. Our method determines the daily number of trucks required to meet demand while ensuring on-time delivery. We propose a mixed-integer linear programming model that provides reliable lower and upper bounds on required truck capacity, complemented by a fast heuristic to minimize total supply chain costs. These costs include both transportation expenses and penalties from late shipments. The approach is evaluated through a large-scale case study with Renault, involving up to 15,000 trucks and 210,000 items. Computational results demonstrate significant improvements in decision-making and truck utilization. Moreover, the method delivers high-quality cost bounds within minutes, enabling practical use in real-world planning. Benchmarking

against a state-of-the-art algorithm highlights the benefits of incorporating truck loading anticipation into assignment models. Overall, our approach reduces costs, improves operational efficiency, and supports more sustainable supply chain planning.

TD 09: Artificial Intelligence, Machine Learning and Optimization: Robust and Stochastic Optimization

Time: Thursday, 03/Sept/2026: 2:00pm - 3:30pm · *Location:* HS7 (WIWI)
Session Chair: Jonathan Hornewall

Safe Mixed-Integer Approximation for Non-Convex Distributional Robustness with Univariate Indicator Functions

Jana Dienstbier[1], Frauke Liers[1], Florian Rösel[1], Jan Rolfes[2]
1: FAU, Germany; 2: Linköping University, Sweden

In this work, we present an algorithmically tractable safe approximation of distributionally robust optimization (DRO) problems that contain univariate indicator functions. The latter appear in different applications, but render the model nonlinear and nonconvex. The considered ambiguity sets can exploit moment information. Typically, reformulation approaches using duality theory need to make strong assumptions on the structure of the underlying constraints, such as convexity in the decisions or concavity in the uncertainty which cannot be assumed in our setting. We nevertheless present an equivalent semi-infinite reformulation that is subsequently approximated by a discretized counterpart. Under mild assumptions, the latter provides a safe approximation that is formulated as a tractable mixed-integer linear problem, which can be solved by available standard software. Obtained solutions are guaranteed to be feasible for the original distributionally robust problem. Although we show that in general convergence to the true DRO problem cannot be expected, we furthermore prove that the approximation of the adversarial problem indeed converges to its true value for increasingly fine discretization. On the practical side, the approach is made concrete for a challenging, fundamental task in material design, namely in particle separation. Computational results for a realistic setting show that the safe approximation yields robust solutions of high-quality and can be computed within short time.

Grey-Box Attacks to ReLU Deep Neural Networks with Sample-Robust Optimization

Jörg Rambau, Ronan Richter
University of Bayreuth, Germany

Adversarial Examples (AEs) for classifiers based on Deep Neural Networks (DNNs) are inputs that are misclassified although they are "close" to a "correctly classified" input. AEs for ReLU-DNNs can be constructed using the Fischetti-Jo MILP (FJ-Model) from 2018 if all internal weights and biases of the DNN are known ("White-Box Attack"). However, such AEs often fail on DNN classifiers with perturbed weights and biases (obtained, e.g., by mild retraining) or on similar DNN claissfiers with completely unrelated weights and biases (obtained, e.g., by training from scratch on identical training data).

In this talk, it is shown how a sample-robust counterpart to the FJ-Model can help to generate AEs that remain AEs even if applied to DNNs for which only the training data is known. To this end, two metric spaces on DNNs are constructed and compared that govern the similarity of DNNs. One is based on the distance of weights and biases, and one is based on the distance as classifying functions. Some computational results on small images of apparel show that, even with a small number of samples, this indeed opens the door to "Grey-Box Attacks" for DNN classifiers, i.e., with unknown internal weigths and biases but known training data.

Decision Focused Learning for Contextual Stochastic Programming

Jonathan Hornewall[1], Tito Homem-de-Mello[2], Vincent Leclère[1]
1: École Des Ponts, France; 2: Universidad Adolfo Ibáñez, Chile

Contextual stochasic programming is a young subfield of stochastic programming which has gained increased attention in the last few years. It is of interest, both because of its numerous natural applications to real-world decision problems, and because of the rich expressiveness of its models. It exists in the intersection of decision focused learning, mathematical programming, and optimization under uncertainty.

Decision-focused scenario learning is a specific strategy for addressing the problem, which has recently emerged as a promising research direction. It exists in the intersection of typical contextual stochastic programming, and smart-predict-and-optimize adjacent work in decision focused learning. It has several obvious benefits and strengths compard with alternative approaches, but open questions remain.

A general theory for when the strategy can yield optimal decision policies is currently lacking. Many existing applications require strict assumptions on which second-stage data are allowed to be random. Generally, the non-differentiability of the decision-focused objective is a source of difficulty, and most approaches rely either on black-box or handcrafted decision surrogates.

Our work focuses on addressing these issues. We present foundational theoretical results that address open questions, and present novel methods that remedy existing limitations.

TD 10: Optimization under Uncertainty: Learning and Sequential Decision Making

Time: Thursday, 03/Sept/2026: 2:00pm - 3:30pm · *Location:* HS8 (WIWI)
Session Chair: Simon Caspar Zeller

Choosing Among Multiple Job Shop Schedules Representing the Same Pareto-Front Point: A Weighted Robustness-Rank Ensemble Approach

Žiga Letonja, Nikolaus Furian, Siegfried Vössner
Graz University of Technology, Austria

In cases where multiple job shop schedules represent the same Pareto-front point, a decision must be made: “Which specific schedule should be chosen?” This selection is crucial, because these schedules can be structurally different and may thus degrade differently when disruptions occur, making the choice non-trivial. This paper studies such a case for a bi-objective job shop scheduling problem with makespan and total tardiness, facing random machine breakdowns and repair times that are unknown at planning time. The examined selector combines two complementary robustness measures, one based on operation-level total slack and one based on due-date slack, using their dense-rank normalised values for each non-dominated point individually. This approach is evaluated in a simulation study on an established benchmark instance. For each non-dominated point on the approximated Pareto front, a set of representative schedules is evaluated under common perturbation scenarios. The ensemble-selected schedules, using different weight pairs, are compared with the best observed schedule from the same representative set in terms of mean realised makespan and total tardiness over all replications. The results suggest that there is no one globally best weight pair. Rather, the approach is useful for distinguishing between decision-sensitive and decision-insensitive points as well as indicating which weighting emphasis may reduce degradation for specific schedule performance metrics. Overall, the findings support weighted robustness-rank ensembles as a decision-support technique for selecting among objective-equivalent schedules when the degradation of specific schedule performance metrics is of concern.

Quantile-Based Sequential Learning and Optimization

Nele Bertling[1], Kevin Tierney[1], Michael Römer[2]
1: University of Vienna, Austria; 2: Bielefeld University

Predict-then-optimize problems arise in resource allocation, production planning, and scheduling, where uncertain parameters must be predicted from contextual information before a decision is made. Unlike uncertainty in objective coefficients, uncertainty in the constraints poses the distinct challenge that prediction errors can render solutions infeasible, and the cost of correcting such decisions must be accounted for. Integrated learning and optimization (ILO) methods address this by integrating the optimization problem into the training process, but they require repeated optimization during training, and rely on problem-specific (surrogate) losses. We propose a Quantile-based Sequential Learning and Optimization (QSLO) approach that predicts a conditional quantile of the uncertain parameters, with the quantile level serving as an interpretable control parameter for the feasibility vs. (post-hoc) regret trade-off. We compare QSLO against ODECE, a state-of-the-art feasibility-aware ILO method, on three benchmark problems: the multi-dimensional knapsack problem with uncertain weights and with uncertain capacities, and a brass alloy production problem with uncertain ore quantities. We find that QSLO matches or dominates ODECE on the feasibility vs. (post-hoc) regret Pareto frontier while requiring up to 99\% less training time. These results suggest that in the constraint-uncertain setting, fitting the predictive distribution of the uncertain parameters matters more than aligning the training loss with decision quality, which challenges a common assumption in the integrated learning and optimization literature.

Robust Bayesian Optimization

Sebastian Denzler, Kevin-Martin Aigner, Frauke Liers, Larry Lüer, Christoph Brabec
Friedrich-Alexander Universität Erlangen-Nürnberg, Germany

We propose a novel active learning framework for robust Bayesian optimization of uncertain black-box functions.

While Bayesian optimization is well-suited for data-efficient optimization of expensive objectives, its standard form can be sensitive to hidden or varying parameters.

To address this issue, we consider a min–max robust counterpart of the optimization problem and develop a practically efficient solution algorithm, BROVER (Bayesian Robust Optimization via Exploration with Regret minimization).

Our method combines Gaussian process regression with a decomposition approach: the minimax structure is split into a non-convex online learner based on the Follow-the-Perturbed-Leader algorithm together with a subsequent minimization step in the decision variables.

We prove that the theoretical regret bound converges under assumption of convexity in the decision variable, ensuring asymptotic convergence to robust solutions.

Numerical experiments on synthetic data validate the regret guarantees and demonstrate fast convergence to the robust optimum.

TD 11: Software for Operations Research: Modern Modeling

Time: Thursday, 03/Sept/2026: 2:00pm - 3:30pm · *Location:* HS6 (WIWI)
Session Chair: Matthias Miltenberger

Modelling APIs and new API features for FICO Xpress

Susanne Heipcke
FICO, Xpress Optimization, United Kingdom

After developing an algebraic model of a business problem on paper, OR practitioners are faced with deciding how to implement the model by having to choose between direct APIs to specific solvers and (largely solver agnostic) modelling APIs. Modelling APIs aim at faster implementation and speed to market by making easier tasks such as verifying model correctness, model maintenance and modification, and they typically also provide support for data access and manipulation. Algorithmic considerations (problem types, support for more advanced tasks such as infeasibility handling or callbacks) also are of importance. Model execution speed might equally be considered among the evaluation criteria.

This talk discusses a non-comprehensive list of open-source third party modelling APIs for Xpress giving a comparative feature overview, including Pyomo, PuLP, Google OR-Tools, Linopy, CVXPY, MiniZinc, PyOptInterface, Jump, AMPL, as well as Xpress' Python API on top of which some of these APIs are built and Xpress Mosel. We also give an overview of Xpress Solver APIs with some recently added new features. Lastly, this talk introduces the new Python package moselpy for embedding Mosel models into Python host applications.

Symbolic mathematical programming language expressions

Christoph Hofer-Temmel
illwerke vkw, Austria

How do I keep track of families of related models: extensions, variants, refinements and experiments? I present a personal toolkit working on symbolic representations of a purely declarative algebraic modelling language. With it I can build models incrementally while avoiding a super-model with lots of configuration options. I can also run various static analysis to shift left from solution to model design time.

Raising well-behaved models: Numerics and Scaling

Matthias Miltenberger
Gurobi, Germany

Better performance, both regarding run time and solution quality, may be obtained by considering the best scaling choices during the model formulation process. After discussing suitable background information, this presentation will consider scaling strategies for model creation, including the proper choice of units of measurement and alternate formulations to preempt numerical problems. Furthermore, a new open-source scaling package will be presented.

TD 12: Health Care Management: Scheduling Problems

Time: Thursday, 03/Sept/2026: 2:00pm - 3:30pm · *Location:* HS2 (PHIL)
Session Chair: Sebastian Schiffels

Structure-Aware Optimization of Decision Diagrams for Health Guidance via Integer Programming

Nanako Shimaoka[1], Naoyuki Kamiyama[2], Shinji Hotta[1], Sayuri Kohmura[1], Yuta Kurume[1], Hiroko Suzuki[1], Eigo Segawa[1], Akihiro Inomata[1]

1: Fujitsu Limited; 2: Institute of Mathematics for Industry, Kyushu University

Decision diagrams are frequently used in determining public health guidance due to their high interpretability and transparency; however, their construction is often based on expert heuristics and lacks systematic optimization. This paper studies a structure-aware optimization problem for decision diagrams used in health guidance programs, focusing on decisions regarding which individuals should be encouraged to consult medical workers and which notification methods should be applied.

We propose an integer programming formulation that optimizes decision diagrams under explicit cost constraints while balancing multiple key performance indicators. These indicators include the degree of similarity to the existing decision diagram, expected positive reactions to notifications, and expected improvements in health outcomes. In contrast to standard decision tree optimization and learning approaches, our framework does not assume predefined classification labels, allows structural modification of the diagram, and explicitly incorporates practical constraints, such as limiting deviations from current policies to preserve operational feasibility.

The proposed model accommodates heterogeneous examinee types, multiple health checkup items, and various notification methods, enabling a realistic representation of real-world health guidance systems. We evaluate the effectiveness of our approach through numerical experiments on several realistically sized instances motivated by Japanese public health applications. The results demonstrate that the optimized decision diagrams improve key performance indicators compared with the original rules, while remaining computationally tractable using a commercial integer programming solver.

These findings indicate that integer programming provides a practical and rigorous framework for improving interpretable, cost-aware decision diagrams, bridging the gap between optimization theory and real-world public health policy design.

An Anticipatory Multi-Stage MIP Approach for the Integrated Healthcare Timetabling Problem

Michael Römer[1], Henning Witteborg[1], Daniel Wetzel Wetzel[2]

1: Universität Bielefeld, Germany; 2: Universität Wien, Austria

Scheduling both patients and resources in healthcare is a highly complex problem that requires balancing limited resources, legal regulations, and quality-of-care considerations, as institutions like hospitals must allocate surgeons, nurses, and rooms while ensuring continuity of patient care and compliance with institutional and contractual requirements. The Integrated Healthcare Timetabling Problem (IHTP) introduced in the context of the Integrated Healthcare Timetabling Competition 2024 (IHTC 2024) provides a standardized framework to evaluate algorithms for this integrated timetabling challenge under diverse and realistic hospital settings. In this work, we propose an anticipatory multi-stage decomposition approach that integrates patient admission, room assignment, and nurse-to-patient assignment into an optimization framework. The method combines a sequential decomposition strategy, which separates the problem into interdependent subproblems modeled as Mixed-Integer Programs, with anticipatory model components that capture the future effects of decisions in earlier stages on later stages. In a set of experiments with the instances used in the IHTC 20254 competition, we demonstrate the beneficial effect of increasing anticipation levels within our multi-stage approach. In particular, out approach identifies new best-known solutions for 18 of the 60 competition instances .

Humans Are Not Machines - Scheduling of Healthcare Workers Accounting for Consistent Work Schedules

Lorenz Wagner[1], Sebastian Schiffels[1], Jens Brunner[1,2]

1: University of Ausgburg, Germany; 2: University of Siegen, Germany

An efficient use of medical staff, i.e., efficient scheduling, is vital for hospitals due to increasing economic pressure. However, the shortage of skilled workers in hospitals is a serious problem that partly results from unattractive working hours, often leading to decreased worker performance. The current state of the literature addressing quantitative healthcare scheduling approaches largely neglects behavioral findings regarding worker behavior. In contrast, behavioral studies reveal that the insights gained should be implemented in workforce schedules. A Mixed-Integer Linear Programming model is developed that complements common hospital regulations with constraints designed to model performance degradation and recovery due to scheduling inconsistencies. The model captures how inconsistent shift patterns impair worker performance over time, while consistent schedules allow adaptation and performance recovery. Due to the computational complexity, we decompose the compact model via the Dantzig-Wolfe reformulation and solve it with a column-generation framework that uses an exact dynamic-programming labeling algorithm for the pricing subproblem, yielding high-quality solutions with small final restricted-master integrality gaps. Our findings demonstrate that accommodating human factors within optimization models can reduce average schedule disruption while improving operational

performance in healthcare staff scheduling, although relative burden concentration can increase in some settings. Consequently, this work provides a foundation for rethinking workforce scheduling practices to create schedules that are operationally feasible and less disruptive on average for employees while remaining effective from a management perspective.

TD 13: Project Management and Scheduling: Scheduling in Logistics

Time: Thursday, 03/Sept/2026: 2:00pm - 3:30pm · *Location:* HS4 (PHIL)
Session Chair: Lara Nehrke

Comparing Robotic, Automated, and Manual Order Picking Systems: A Simulation-Based Analysis of Performance and Cost Trade-Offs

Julia Wenzel[1], Simon Emde[2], Ralf Elbert[1], Felix Weidinger[3]

1: Technische Universität Darmstadt, Fachgebiet Unternehmensführung und Logistik; 2: Friedrich-Schiller-Universität Jena, Lehrstuhl für Wirtschaftsinformatik, insbes. Business Intelligence; 3: Technische Universität Darmstadt, Fachgebiet Management Science/Operations Research

Order picking is among the most expensive warehouse activities, making the choice of an order picking system (OPS) a critical managerial decision. With the growth of e-commerce and demand volatility, Robotic Mobile Fulfillment Systems (RMFS) have emerged as flexible alternatives to established automated and manual systems. However, existing studies mainly evaluate individual systems or pairwise comparisons, while systematic quantitative comparisons of RMFS, autonomous vehicle storage and retrieval systems (AVS/R), and manual order picking systems (MOPS) under comparable operational conditions remain limited. This study addresses this gap through an agent-based simulation comparing RMFS, AVS/R, and MOPS using identical demand profiles, storage capacities, and performance indicators. We evaluate throughput, cycle time, resource utilization, and cost efficiency while integrating optimization-based planning procedures to ensure efficient system operation. The results show that AVS/R achieves the highest throughput and shortest cycle times in high-volume settings, but requires the highest investment and sufficient demand to utilize its installed capacity. RMFS reaches lower absolute throughput than AVS/R but clearly outperforms MOPS, achieving approximately 800--2,700 orders per hour compared with 50--300 orders per hour for MOPS. Cost results indicate that RMFS has lower cost per order than MOPS and lower initial investment than AVS/R. Overall, AVS/R is most suitable for large, stable, high-throughput operations, whereas RMFS represents a competitive and flexible alternative for medium-scale e-commerce warehouses where MOPS reaches throughput limits and AVS/R investment is difficult to justify.

A Tight Double-Exponentially Lower Bound for High-Multiplicity Bin Packing

Klaus Jansen, Felix Ohnesorge, Lis Pirotton

Univ Kiel, Germany

Consider a high-multiplicity Bin Packing instance I with d distinct item types. In 2014, Goemans and Rothvoss gave an algorithm with runtime ||I|^{2^{O(d)}} for this problem (SODA'14), where ||I| denotes the encoding length of the instance I. Although, Jansen and Klein (SODA'17) later developed an algorithm that improves upon this runtime in a special case, it has remained a major open problem by Goemans and Rothvoss~(J.ACM'20) whether the doubly exponential dependency on d is necessary.

We solve this open problem by showing that unless the ETH fails, there is no algorithm solving the high-multiplicity Bin Packing problem in time ||I|^{2^{o(d)}}. To prove this, we introduce a novel reduction from 3-SAT. The core of our construction is efficiently encoding the entire information from a 3-SAT instance with n variables into an ILP with O(\log(n)) variables and constraints.

This result confirms that the Goemans and Rothvoss algorithm is essentially best-possible for Bin Packing parameterized by the number d of item sizes.

Conflict-Free Collaborative Routing

Julian Golak[1], Niklas Jost[2], Dominik Kress[3], Lara Nehrke[3]

1: University of Hamburg Business School, Hamburg, Germany; 2: TU Dortmund University, Dortmund, Germany; 3: Helmut Schmidt University/ University of the Federal Armed Forces Hamburg, Hamburg, Germany

We study collaborative routing problems in which multiple mobile agents must coordinate their routes in a shared, spatially constrained environment to meet and perform joint operations. We consider a problem in which agents move through an environment with static obstacles, must meet pairwise to complete tasks, and cannot occupy the same space simultaneously. The planner seeks collision-free routes and schedules that complete all meetings while minimizing the makespan. The coupling between meeting locations and collision-free routes poses additional challenges than in classical multi-agent routing. This setting arises, for example, in warehouses where picking and transport agents hand over items at flexible meeting points.

We introduce a general framework for conflict-free collaborative routing that incorporates agents of physical size and static obstacles, together with a classification scheme for collaborative routing problems and a survey of previous work. We show that the problem is NP-hard even for a basic case. For two agents with predetermined trajectory prefixes, we provide a polynomial-time algorithm that computes optimal solutions in the presence of obstacles when agents are dimensionless, and nearly optimal solutions when agents occupy physical space.

TD 14: Game Theory and Behavioral Management Science: Behavioral Logistics

Time: Thursday, 03/Sept/2026: 2:00pm - 3:30pm · *Location:* HS12 (IM)
Session Chair: Christian Jost

Competition for used apparel acquisition between charities and for-profit organizations

Sabrina Rinder[1], Marc Reimann[2], Gilvan Souza[3], Guido Voigt[4]
1: University of Graz; 2: University of Graz; 3: University of Tennessee; 4: Universität Hamburg

Rising competition from for-profit organizations (FPOs) in the used apparel market challenges charities that have traditionally dominated this sector. This study examines how consumers' decisions to return used apparel are influenced by (1) competition, (2) drop-off point density, (3) collection channel, (4) information, and (5) financial reward. We conduct incentivized, non-hypothetical discrete-choice experiments in a lab where participants bring a used apparel item they have not worn for about two years and decide whether to donate it to a charity, give it to an FPO, or keep it. The alternatives vary across drop-off point density, collection channel, information, and financial reward. Additional online experiments yield a total of 1,056 participants and 21,120 decisions. Using multinomial logit models and market simulations, we find that competition broadens the total market for collected used apparel. Financial rewards significantly favor FPOs, while charities remain competitive through higher drop-off point density or by emphasizing donation purposes. Increasing drop-off point density strongly affects consumer return decisions for both organization types. Consumers prefer physical collection to postal delivery, and the most valued message indicates that clothing is collected for communities in need. We conclude that FPOs can gain market share by offering financial incentives, higher drop-off point density, or communicating a donation purpose. In response, charities should maintain at least medium density or stress their charitable mission to preserve competitiveness.

Improving Human Packing Through Standardization: Insights from a Lab-in-the-Field Experiment

Sebastian Schiffels[1], Christian Jost[1], Franziska Heinlein[1], Pirmin Fontaine[2]
1: University of Augsburg, Germany; 2: Catholic University of Eichstätt-Ingolstadt, Germany

Packing goods is a central logistics activity, including tasks such as palletizing and loading transport vehicles. Key objectives are packing speed (to reduce labor costs) and packing efficiency (to increase space utilization), as inefficient packing leads to unnecessary transport costs and environmental pollution. Despite increasing digitalization, packing processes often rely on human workers, making human packing efficiency economically and ecologically relevant.

Against this background, we conduct an experimental study to investigate the influence of standardized packaging on human packing efficiency. We analyze the interplay between two opposing effects: On the one hand, standardization may increase efficiency, as similarly sized packages are easier to arrange and enable workers to quickly identify space-efficient solutions. On the other hand, standardized packaging of differently sized items creates unused interior space within parcels, reducing utilization.

While there is a rich body of literature on algorithmic solutions to packing problems, studies on human packing behavior remain scarce. We design and run a lab-in-the-field experiment using actual packages and a delivery van which allows us to compare treatments with and without parcel standardization. Our results suggest an increased packing speed while we observe mixed effects regarding efficiency.

Workstation Design in Parts-to-Picker Systems: Evidence from a Laboratory Experiment

Christian Jost[1], Sebastian Schiffels[1], Nils Boysen[2]
1: University of Augsburg; 2: Friedrich-Schiller-University Jena

With the expansion of e-commerce, efficient order fulfillment has driven the adoption of parts-to-picker systems that autonomously deliver stock-keeping units (SKUs) to picker workstations. Despite this automation, human workers remain integral, extracting items from inbound SKU bins and placing them into outbound customer bins.

A primary objective in parts-to-picker systems is to maximize efficiency by minimizing setup times, for example, by reducing the number of SKU bins delivered to a workstation. However, existing models typically assume constant human performance, regardless of the workstation configuration. Our research challenges this assumption through an experimental study of picker performance across different workstation setups.

In a laboratory experiment, we analyze how the number of parallel SKU bins and customer bins affects picking performance. Each participant operates a single-worker workstation with predefined inbound and outbound configurations. We focus on the interplay between two opposing effects: on the one hand, increasing the number of bins raises autonomy and may reduce worker fatigue; on the other hand, higher task complexity increases cognitive load, potentially leading to more picking errors and lower picking speed. Preliminary results indicate that a setup with one SKU bin and multiple customer bins may represent a "sweet spot" that

maximizes picking speed while reducing errors. Our findings aim to bridge the gap between theoretical optimization models and real-world human behavior in parts-to-picker systems.

This research is funded by the project AuLoKomp within the framework of dtec.bw.

TD 15: Pricing and Revenue Management: Applications to Last-Mile Logistics & Mobility

Time: Thursday, 03/Sept/2026: 2:00pm - 3:30pm · *Location:* SR034 (WIWI)
Session Chair: David Fleckenstein

Delivery Profiles in Attended Home Delivery: Integrating Demand Management and Vehicle Routing Problems with Delivery Options

Kilian Hein, Matthias Soppert, Claudius Steinhardt
University of the Bundeswehr Munich, Germany

In attended home delivery, customers have to be present to receive their delivery in person. For that purpose, in the classical setting, customers are presented with multiple delivery time slots selected by the service provider, from which the customers get to choose one when placing their order. In this work, in contrast, we analyze a setting where the provider offers delivery profiles, consisting of sets of delivery options, which each are defined by one time slot and one delivery location. The intention behind offering delivery profiles instead of individual delivery options is that the provider obtains more flexibility in forming the final routing decision, while the customers still get to communicate their preferences for delivery options to the provider. To incentivize the customers to choose more flexible delivery profiles, we propose a setting where the provider optimizes different prices for these delivery profiles. Methodologically, we formulate a mixed-integer programming model for this problem. It is designed as a static problem and we use scenarios to incorporate customers' choices. In our computational study, we show that our approach can reduce delivery costs for the service provider compared to the classical setting, namely attended home delivery without delivery options.

Integrated Dynamic Pricing and Compensation Setting in Crowdshipping

Kai Winheller[1], Rouven Schur[1], Simone Neumann[2], Leonie Nothelfer[3]
1: Universität Duisburg-Essen, Germany; 2: Universität Hamburg; 3: Universität Augsburg

E-commerce growth puts pressure on last-mile logistics, where conventional fleets struggle to balance cost and service. Crowdshipping addresses this by letting ordinary citizens deliver orders on their regular routes, but confronts decision makers with a two-sided market problem: customer demand and driver supply are both stochastic and price-sensitive, and decisions on either side affect future fulfillment capacity through zone-level backlogs.

We develop an integrated dynamic pricing and compensation framework for crowdshipping. The problem is formulated as a finite-horizon Markov Decision Process that captures customer heterogeneity in delivery preferences, stochastic occasional driver arrivals, and zone-specific delivery costs. Behavioral parameters are calibrated from a large empirical dataset with more than 500 participants each from the United States and Europe.

We make three contributions. First, structural analysis of the single-period subproblems yields a three-regime characterization of customer pricing and a separable structure of the joint zone-and-compensation decision for drivers, reducing the original optimization to tractable one-dimensional problems. Second, we develop a scalable separable value function approximation that decomposes the state space into zone-level components. Third, an extensive computational study across 16 scenarios (Germany vs. United States, urban vs. rural, four market phases) shows that naive crowdshipping can destroy value by up to 25 percent, while our integrated dynamic policy dominates all benchmarks and improves profit by 9 to 60 percent in a hybrid fulfillment setting.

Sustainable Dynamic Pricing for Urban Shared Mobility-on-Demand Services

David Fleckenstein
University of Augsburg, Germany

Urban shared mobility-on-demand (SMOD) services increasingly serve as a complement to scheduled public transport, enabling cities to guarantee area-wide, continuous basic mobility provision as a public service. While dynamic pricing is a well-established tool for improving the operational performance of urban SMOD systems, existing approaches predominantly optimize for profit maximization, which sits in tension with the public service nature of municipally operated SMOD. Instead, pricing decisions for such services must reflect a broader set of sustainability objectives, spanning social, economic, and environmental dimensions.

This talk presents a sustainable dynamic pricing approach that also explicitly accounts for the availability and quality of scheduled public transport alternatives when optimizing prices. Further, it incorporates a discrete choice model estimated on real-world data. First results from simulations based on a large dataset from a German municipal SMOD provider are presented, from which implications for the practical application can be derived.

TD 16: Simulation and Quantum Computing: Modeling and Learning in Complex Systems

Time: Thursday, 03/Sept/2026: 2:00pm - 3:30pm · *Location:* SR033 (WIWI)
Session Chair: Max Krueger

Multi-Agent Reinforcement Learning for Controlling and Optimising the Intermodal Transport Chain in Real-Time in Germany: A Proof of Concept

Carina Kehrt
German Aerospace Center, Germany

The increasing complexity and dynamism of intermodal freight transport systems – combining road-based pre- and post-haulage with rail-based main-haul – require decision-making mechanisms capable of operating in real time under uncertainty. Traditional optimisation approaches, such as mixed-integer programming and heuristics, are computationally limited and inflexible when handling large-scale, stochastic logistics environments. This paper introduces a Multi-Agent Reinforcement Learning (MARL) framework for the real-time operational optimisation of intermodal transport chains across a nationwide network. Each transport entity – trucks, trains, and terminals – is modelled as an autonomous learning agent trained under a centralised coordination structure but executing decisions independently through Centralised Training with Decentralised Execution (CTDE). The framework minimises total transport time, costs, and emissions while ensuring punctual coordination between modes and efficient use of terminal resources. A digital twin of the German intermodal network serves as the testbed for policy training and evaluation. Results demonstrate reductions of up to 12% in total transport time, 19% in total costs, and 17% in CO_2 emissions, alongside improved resource utilisation and network reliability. The agents exhibit emergent cooperative behaviour, achieving synchronised intermodal operations without centralised control. The findings highlight the potential of MARL to transform intermodal freight systems into adaptive, self-optimising networks, advancing both operational performance and sustainability. The research contributes to the theoretical integration of MARL and network flow optimisation, and provides a practical blueprint for deploying intelligent, data-driven control systems in large-scale logistics operations.

Comparison of Soft-Classifications of Bayesian Networks using the Averaged Jensen-Shannon Metric

Max Krueger
Technische Hochschule Ingolstadt (THI), Germany

Bayesian Networks are an established approach for building classifiers, for example, for decision support. After creating a Directed Acyclic Graph (DAG) that defines the dependencies among the random variables (i.e., nodes of the DAG), the Conditional Probability Table (CPT) of each node must be filled with conditional probabilities, resulting in a complete parameterization of the network. To compare the multiclass soft-classification of Bayesian Classification Networks with the same output classes and possible evidence combinations, the Averaged Jensen-Shannon Metric is introduced as a measure based on the Kullback-Leibler Divergence that captures the similarity of the overall classification results of two Bayesian Classification Networks. In addition to examining the properties of this measure and proposing an interpretation of its values, it is exemplarily applied to scenarios with different-sized sets of classes.

MOSAIC: Modeling Outcomes via Statistical Analysis of Individual athlete Contributions

Matthias Schilling, Samuel Wirth, Stefan Pickl, Maximilian Moll
Universität der Bundeswehr München, Germany

Descriptive statistics are the standard for player evaluation in team sports, however they consider only observable events and do not distinguish between stable baseline production and variation that is relevant to the outcome. A player can contribute consistently strong counting statistics both in wins and losses, while other aspects may look insignificant but are highly informative of the match outcome. This raises the question of which components of an individual athlete are actually predictive of winning.

This work proposes a framework for identifying player-specific performance signatures from game-level data. For each player, predictive models are trained on historical data to connect the observed statistics to the outcome of interest. Through the interpretation of the model predictions, we identify archetypes based on shared patterns and compare player profiles.

This study focuses on cooperative-competitive team sports. It enables a characterization of how different aspects of player performance relate to winning and loosing in a flexible workflow that enables a better understanding of athlete performance and contribution profiles for player comparison. Investigating the player contributions by interpreting predictive models identifies hidden aspects in descriptive statistic measurements

TE 01: Semi-Plenary Ramteen Sioshansi

Time: Thursday, 03/Sept/2026: 4:00pm - 5:00pm · *Location:* HS10 (AM)
Session Chair: Dominik Möst

OR and Its Vital Role in Addressing Technology and Policy Challenges to Decarbonize Electricity Systems

Ramteen Sioshansi
Carnegie Mellon University, United States of America

The electricity industry and policymakers are grappling with the challenge of decarbonizing electricity systems. Decarbonization will require major changes in how electricity systems are planned and operated. Moreover, policy and market reforms will be needed to ease the transition. This talk surveys these changes and challenges and dispels some common misconceptions about decarbonization. Moreover, the important role of operations research in facilitating this transition is discussed.

TE 04: Semi-Plenary Stefan Weltge

Time: Thursday, 03/Sept/2026: 4:00pm - 5:00pm · *Location:* HS13 (IM)
Session Chair: Tobias Harks

Integer programming and bounded subdeterminants

Stefan Weltge
Technical University of Munich, Germany

Identifying parameters that capture the difficulty of integer programs is a central theme in the study of integer programming. One such parameter is the largest absolute value of any subdeterminant of the constraint matrix. In this talk, we explore how bounding this parameter influences the complexity of integer programs. We survey several recent results and discuss intriguing open questions in this area.

TE 06: Semi-Plenary Frits Spieksma

Time: Thursday, 03/Sept/2026: 4:00pm - 5:00pm · *Location:* HS5 (WIWI)
Session Chair: Matthias Amen

Diversity of Solutions within Combinatorial Optimization

Frits Spieksma
Eindhoven University of Technology, Netherlands, The

We describe a framework for quantifying the trade-off between diversity of solutions on the one hand, and their quality on the other hand. For this context, we develop a measure that we call the Price of Diversity (PoD).

We apply this concept to a number of problems. In particular, we investigate the Traveling Salesperson Problem with the triangle inequality, and show how the requirement to generate multiple diverse solutions influences tour quality. Specifically, we consider the problem of finding two edge-disjoint tours while minimizing the length of the longer tour. For this setting, we derive tight results establishing the PoD for this problem.

(Joint work with Andres Lopez Martinez and Mark de Berg)

TE 08: Hexaly Lecture

Time: Thursday, 03/Sept/2026: 4:00pm - 5:00pm · *Location:* HS9 (AM)
Session Chair: Léa Blaise

Hexaly: the Next-Generation MIP Solver

Léa Blaise
Hexaly, France

Mixed-Integer Linear Programming (MIP) has been the dominant optimization framework for decades. While highly successful, many real-world problems remain difficult to express naturally within a purely linear paradigm. Large-scale routing, scheduling, packing, simulation-based optimization, and machine-learning-driven decision problems often require extensive reformulations that can obscure problem structure and limit performance.

Hexaly extends the traditional MIP approach with a richer modeling framework designed to capture optimization problems closer to their original form. In addition to classical algebraic modeling, it introduces native combinatorial constructs such as sets, lists, and intervals, together with nonlinear and black-box optimization capabilities. This allows practitioners to model complex systems, simulations, and predictive models directly, without relying on large reformulations. At the algorithmic level, Hexaly automatically exploits advanced optimization techniques, including decomposition methods, column generation, branch-price-and-cut, and decision diagrams, making sophisticated solution approaches available out of the box.

In this talk, I will present the principles behind this next-generation MIP approach, illustrate its modeling capabilities on routing, scheduling, and packing applications, and provide an overview of the solver's current performance on selected benchmarks.

FA 01: Supply Chain Management and Production: Scheduling Additive Manufacturing Systems and Lean in the Flower Industry

Time: Friday, 04/Sept/2026: 8:30am - 10:00am · *Location:* HS10 (AM)
Session Chair: Benedikt Zipfel

Production Planning and Scheduling in Additive Manufacturing to Minimize Weighted Tardiness

F. Tevhide Altekin[1], Yossi Bukchin[2]
1: Sabanci Business School, Sabanci University, Türkiye; 2: Department of Industrial Engineering, Tel Aviv University, Israel

Additive manufacturing (AM) is increasingly used for the production of high-variety, low-volume metal parts in biomedical, aerospace, automotive, and defense industries. We study the static production planning and scheduling problem for AM environments using direct metal laser sintering, where customer orders differ in terms of priority weights, due dates, and part specifications (including volume, base area, height, and a desired layer thickness). Multiple parts sharing the same desired layer thickness can be grouped into a single job, provided they fit within the machine's chamber constraints in terms of maximum part height and build chamber base area. Producing each job requires a machine-dependent setup time. Each machine supports one or more layer thickness settings depending on its configuration and the chosen setting for a job determines the per-unit-volume production rate and the recoating rate associated with producing the parts in layers. A customer order is completed once all its constituent parts are produced.

The problem involves simultaneously assigning parts to jobs, jobs to machines, and selecting the layer thickness for each job, with the objective of minimizing total weighted tardiness. We propose a mixed-integer programming (MIP) formulation and solve instances involving single, identical, and non-identical machine environments. For the single-machine case, we derive lower and upper bounds on the number of jobs and a lower bound on weighted tardiness, and develop valid inequalities to strengthen the formulation. Computational experiments on instances with up to 8 customers and 34 parts demonstrate the effectiveness of the strengthened model.

Build on Track: Combining Routing and Scheduling Decisions for Additive Manufacturing

Benedikt Zipfel, Florian Linß
Technische Universität Dresden, Germany

This paper presents an integrated optimization problem addressing the simultaneous planning of production and distribution of goods in the field of additive manufacturing (AM). In this problem setting, a fleet of vehicles, each equipped with an AM machine, must deliver customized parts to a set of customers within predefined time windows. Parts are produced in sequential batches en route, where multiple parts may be processed simultaneously subject to the available build space. The objective is to minimize total costs comprising vehicle usage and travel distances. We formulate this problem as a mixed-integer linear program (MIP) that jointly optimizes the assignment of parts to batches, the sequencing of batches on each vehicle, and the routing of vehicles across customers. In contrast to previous studies on similar topics, the presented formulation explicitly allows cross-customer batching and split delivery, whose benefits are evaluated in the computational experiments. The results further reveal the trade-offs between production and delivery performance inherent to this integrated problem, and demonstrate the limitations of the MIP for increasing problem instances. Consequently, the proposed formulation provides a foundation for future solution approaches, including heuristic and metaheuristic methods, to address larger problem instances arising in practice.

Integrating Lean Practices into Perishable Product Supply Chain Modeling

Virna Ortiz-Araya[1], Adela Pagès-Bernaus[2]
1: Universidad del Bío-Bío, Chillán, Chile; 2: Universitat de Lleida, Igualada, España

The production of cut flowers in Chile is highly diversified in terms of species, characterized by strong seasonality, and is primarily carried out by small and medium-sized farmers. In recent years, government programs have been implemented to support the growth of this sector. One of the country's advantages is its geographic location, which facilitates access to additional export markets.

The complex process of cutting flowers involves multiple stages, where product care is one of the most critical factors. The goal of the selection process is primarily to maintain the freshness and quality of the product. This study addresses operational inefficiencies in the cut flower supply chain by integrating lean practices with optimization-based planning. We develop a mixed-integer programming model to coordinate harvesting decisions and downstream logistics, aiming to reduce waste of highly perishable products. The model supports synchronized harvest and distribution planning, improving resource utilization while minimizing product losses throughout the supply chain.

FA 02: Mobility, Transport, and Traffic: Parcel Logistics and Location Routing

Time: Friday, 04/Sept/2026: 8:30am - 10:00am · *Location:* HS1 (PHIL)
Session Chair: Stephan Bütikofer

Multi-perspective analysis of parcel to service point assignment policies

Raffaele Dragone, Margaretha Gansterer
University of Klagenfurt, Austria

Parcel volumes have grown rapidly over the past two decades and are expected to keep rising. Handling these deliveries efficiently is exceptionally challenging. Many parcels nowadays are delivered to automated service points, which are used as a primary alternative to home-deliveries. While prior research mainly focuses on optimizing parcel assignment from the perspective of the logistics companies, we acknowledge the fact that these decisions impact a triad of actors, which also includes recipients and municipalities. Each of these actors follow different and conflicting objectives, namely cost minimization, emission minimization, and utility maximization. In an ongoing computational study based on real-world data, we investigate the trade-offs among these objectives under several parcel assignment policies. Furthermore, we aim to derive decision rules, which policy to use under which level of system load and at which point to switch from service points to home deliveries.

The latency location-or-routing problem

Alan Osorio-Mora[1], Eduardo Álvarez-Miranda[2], Francisco Saldanha-da-Gama[3]
1: RPTU Kaiserslautern-Landau, Germany; 2: Universidad de Talca, Chile; 3: University of Sheffield, UK

The latency location-or-routing problem is introduced. It consists of selecting a subset of depots to serve a set of customers, which can be visited as part of routes also to be decided or using direct services. Direct service is an option only for customers lying within a certain coverage range from an open depot. A homogeneous fleet is assumed. The goal is to minimize the latency, i.e., the sum of the waiting times of the customers. Several MILP formulations are developed, as well as two lower bounds. The tradeoff between cost and latency is also within a bi-objective framework. Extensive computational results are discussed and insights are presented.

Solving the capacitated location routing problem with a genetic algorithm using regression-based routing approximation

Stephan Bütikofer, Maria Zumkehr, Nima Rihai, Steiner Albert
University of Applied Sciences Zurich, Institute for Data Science, Switzerland

The Location Routing Problem (LRP) combines facility location with capacitated vehicle routing, making it a computationally challenging optimization problem of considerable practical relevance. This paper proposes a Genetic Algorithm (GA) for the capacitated LRP in which the fitness function is based on a regression surrogate model that approximates routing costs without exact route evaluation. The surrogate predicts total tour distances from structural solution features, enabling fast fitness computation across large populations throughout the evolutionary search, thereby substantially reducing per-generation evaluation overhead.

The approach was benchmarked with instances of Prodhon, covering problem sizes from 20 to 200 customers with 5 or 10 candidate depots. Solutions were subsequently validated with the routing solver VROOM and compared against the Best-Known Solutions (BKS) reported. The GA reliably produces near-optimal solutions with respect to the published BKS. Correct depot configurations are identified in nearly every case, and vehicle counts deviate by at most one from the respective benchmark optimum.

Runtime scaling behaviour proves highly favourable: while the fixed hyperparameters cause relative slowdowns on smaller instances, the GA ultimately runs 2–4 times faster than both GRASP and MAPM on the largest instances. These results demonstrate that regression-based routing approximation is a viable, effective, and computationally scalable fitness strategy for solving large-scale capacitated location routing problems.

FA 03: Mobility, Transport, and Traffic: Route Planning for Public Transport Services

Time: Friday, 04/Sept/2026: 8:30am - 10:00am · *Location:* HS3 (PHIL)
Session Chair: Markus Dietl

Scaling Network Optimization: Automated Initialization for Global Transport Networks

Sander Van Aken
Flix SE, Germany

Flix is a global leader in long-distance passenger transportation, operating across 46 countries with brands like FlixBus and Greyhound. For Flix and its 1,000+ partners, tailoring supply to seasonal demand is essential for sustainable and profitable growth. This requires accounting for complex network effects, where parallel lines may cannibalize and/or reinforce each other through transfer possibilities. While ML and OR-based tools are used to maximize profitability, the early-stage network planning process - beginning over a year in advance - historically suffered from limited network maturity, hindering effective tool application at scale.

To address this, we developed the Automated Network Initialization, a solution combining ML-based holiday and demand seasonality forecasting, OR-based supply optimization, and domain expertise. By optimizing supply based on anticipated year-on-year demand changes, we generate a complete seasonalized network at the planning cycle's onset. This non-textbook task required navigating the "chicken-and-egg" problem of demand-supply interaction while managing diverse data sources without existing benchmarks.

The results are transformative, as we successfully initialized 1,400 lines for the 2027 network automatically, covering approximately 93% of mature markets. This automation allows planners to focus on high-return strategic improvements, enabling network-wide profitability steering from day one. In this talk, we share our journey of developing this multidisciplinary solution and overcoming the challenges of large-scale automated network design.

Operational route planning under uncertainty for Demand Adaptive Systems with Multiple Lines

Markus Dietl[1], Mike Hewitt[2], Axel Parmentier[3], Maximilian Schiffer[1,4]
1: TUM School of Management, Technical University Munich, Germany; 2: Quinlan School of Business, Loyola University Chicago, USA; 3: CERMICS, École des Ponts, France; 4: MDSI, Technichal University Munich, Germany

Public transportation in low-density and rural areas often suffers from poor alignment between fixed-route networks and actual passenger demand. This reduces willingness to use public transportation, resulting in low utilization and high costs for the provider. Demand Adaptive Systems (DAS) address this misalignment by allowing buses to deviate from fixed routes to serve optional stops corresponding to incoming requests, while still maintaining compulsory stops at scheduled times. Prior work has demonstrated ridership and profit improvements of up to 45% and 37%, respectively, when replacing a fixed-line route by a DAS on a real-world dataset from Munich. This paper provides an extension to a multi-line DAS, which enables coordinated flexible routing of several overlapping lines simultaneously.

We model the operational planning problem as a Markov Decision Process, where an operator accepts or rejects arriving passenger requests in real time. Each request contains sets of possible pick-up and drop-off locations, and, if accepted, is allocated to an applicable line subject to capacity and time constraints. To approximate the optimal policy of this dynamic offline routing problem, we employ a rolling horizon two-stage stochastic program, which we decompose by line and scenario to enable fast solution times.

Building on these foundations, our ongoing work pursues three directions: First, we extend the experimental evaluation using real-world data from Munich. Second, to develop a Combinatorial Optimization Augmented Machine Learning approach to further improve both solution quality and computational efficiency. Third, we aim to transition to dynamic online routing, enabling route adjustments while the vehicle drives.

Crowdkeeping for last-mile delivery with stochastic demand

Iman Dayarian
The University of Alabama, United States of America

This study proposes a crowdsourced last-mile delivery system where individuals act as crowdkeepers (CKs), temporarily holding parcels for customer pickup. The retailer selects CKs and assigns service regions under uncertain demand, balancing fixed hiring costs, routing costs, and potential revenue. The problem is formulated as a stochastic program that integrates CK selection, region assignment, and vehicle routing, and is solved using a branch-and-price algorithm.

FA 04: Energy and Sustainability: Hydrological and Hydropower Modelling

Time: Friday, 04/Sept/2026: 8:30am - 10:00am · *Location:* HS13 (IM)
Session Chair: Jan Boeckmann

A mixed-integer linear programming model for optimal hydrogen and oxygen co-production in run-of-river hydropower plants

Selin Ataç, Matthieu de Lapparent, Massimiliano Capezzali
School of Engineering and Management Vaud, HES-SO, Switzerland

Hydrogen produced from renewable and low-carbon energy sources is considered to contribute to the decarbonization not only of the energy sector but also of other activities such as industrial processes. Among the possible options, hydrogen generation via hydropower plants (HPPs) represents an attractive and sustainable solution. We develop a mixed-integer linear programming (MILP) model for the optimal operation of run-of-river (RoR) HPPs coupled with electrolysis for joint hydrogen and oxygen production. The problem is formulated as a multi-period profit maximization model that co-optimizes electricity generation, power-to-hydrogen conversion, storage, and product sales under given market and technical constraints. The formulation integrates detailed operational features, including electrolyzer operation constraints (such as minimum up-times once switched on), capacity limits, storage dynamics, and contractual delivery obligations (for both electricity and hydrogen) with associated penalty terms. Electrolyzer performance is modeled through degradation-dependent efficiency and lifetime constraints, linking operational decisions to long-term cost impacts. Investment and operational expenditures (CAPEX/OPEX), as well as compression and storage costs, are explicitly represented. The MILP is solved using historical ENTSO-E electricity and HYDRIX hydrogen prices data. A case study based on a mid-sized Alpine RoR HPP shows that oxygen valorization, often overlooked in the literature, significantly alters the structure of optimal solutions and emerges as a dominant economic driver, surpassing hydrogen revenues across scenarios. The proposed framework provides a rigorous decision-support tool for the optimal scheduling and economic assessment of hybrid HPP-electrolysis systems.

Boundary Constraint Handling in Particle Swarm Optimization for Hydropower Equivalent Estimation

Uli Max Rahmlow, Mikael Amelin
KTH Royal Institute of Technology, Sweden

Modeling detailed hydropower systems can be computationally challenging due to nonlinear relationships between discharge and power production and complex cascade river structures, which lead to a large number of time-dependent variables. For large-scale energy system analysis, these systems are therefore often represented using simplified hydropower equivalents. The parameters of such equivalents are commonly estimated using heuristic optimization methods, such as Particle Swarm Optimization (PSO), which is valued for its simplicity and strong global search capabilities. However, PSO performance can be sensitive to how boundary constraints are handled, as early convergence to constraint boundaries can significantly limit exploration.

In estimating hydropower parameters, a number of boundaries. are present, such as maximum reservoir and maximum power production. This paper presents a systematic evaluation of boundary-constraint-handling strategies in PSO. Five different approaches – absorbing, reflection, random, reflective velocity, and intermediate - are implemented and compared within a unmodified PSO framework using real hydropower data. Performance is assessed based on estimation accuracy, exploration factor, and convergence behavior. In addition, the interaction between boundary-handling strategies and different PSO inertia-weight formulations and velocity-update schemes is analyzed to assess their robustness and sensitivity.

The results indicate that proper boundary handling is crucial for accurate parameter estimation and highlight the need to select appropriate PSO parameter configurations.

A Physics-Informed Neural Network to Model Runoff Behaviour in Heavy Rain Events

Jan Boeckmann
Katholische Universität Eichstätt-Ingolstadt, Germany

With the increasing frequency and intensity of extreme rainfall events, accurate modelling of runoff dynamics is becoming ever more pressing for flood risk assessment. Traditional hydrological models often require extensive calibration and are computationally expensive, particularly when based on finite element methods, while purely data-driven approaches may lack physical consistency.

This talk presents a Physics-Informed Neural Network (PINN) that integrates physical principles directly into the learning process. By embedding these constraints into the loss function, the model produces physically consistent runoff patterns while capturing complex nonlinear dynamics.

Applied to high-resolution spatial data, the approach predicts water levels based on rainfall and elevation, while enforcing local flow consistency between adjacent cells. Compared to classical simulation approaches, the model achieves significantly faster runtimes and can serve as an efficient surrogate model for optimization algorithms and real-time applications.

The results highlight the potential of combining physical modelling and machine learning for scalable and reliable flood prediction and hazard mapping.

FA 05: Energy and Sustainability: Power-to-X and alternative fuels

Time: Friday, 04/Sept/2026: 8:30am - 10:00am · *Location:* HS11 (IM)
Session Chair: Dominik Möst

A Model Predictive Control–State Task Network Framework for Energy-Aware Scheduling of Power-to-Methanol Systems under Renewable Energy Uncertainty

Yohanes Kristianto Nugroho, Niels Grom Maly Rytter, Rui Goncalves
University of Southern Denmark, Denmark

Power-to-Methanol (PtM) systems require adaptive operational strategies to manage fluctuations in renewable electricity availability and feedstock conditions. This study proposes a Model Predictive Control–State Task Network (MPC–STN) framework for energy-aware scheduling of PtM systems under uncertainty. The State Task Network (STN) formulation captures process states, material flows, and task dependencies across key stages including hydrogen production, storage, and methanol synthesis. Model Predictive Control (MPC) is integrated with the STN representation to generate rolling-horizon scheduling decisions that dynamically respond to variations in electricity prices, CO_2 availability, and demand conditions. A simulation–optimization environment is developed to evaluate scheduling performance under uncertain operating scenarios. Results indicate that the proposed framework improves scheduling adaptability and resource utilization while reducing operational inefficiencies caused by renewable energy variability. Sensitivity analysis further identifies electricity price fluctuations as a dominant factor influencing scheduling and economic performance. The proposed framework provides a practical approach for dynamic scheduling and control of renewable-driven Power-to-X systems.

Optimising a Hydrogen Refuelling Infrastructure on Airports: Heuristic Solutions to the Liquid-Hydrogen-Aircraft-Refuelling-Problem

Jörn Serrer
Leibniz University Hannover, Germany

In order to meet the European Union's climate neutrality goal by 2050, liquid hydrogen has emerged as the leading candidate for decarbonising air travel. However, loading bowsers with liquid hydrogen takes substantially longer time than loading with conventional jet fuel. There is also limited space at airports for constructing loading stations at a depot, where bowsers can be loaded with hydrogen.

A Liquid-Hydrogen-Aircraft-Refuelling-Problem was formulated to determine the optimal number of bowsers and loading stations needed to satisfy future scenarios with various departure schedules and hydrogen demands at real-life airports. To solve this optimisation problem, a heuristic based on an Iterated Local Search was employed, and key parameters were examined.

FA 06: Discrete and Combinatorial Optimization: Bilevel Optimization 2

Time: Friday, 04/Sept/2026: 8:30am - 10:00am · *Location:* HS5 (WIWI)
Session Chair: Arie Koster

Generalized Inverse Linear Problems

Lowig T. Duer, Christoph Buchheim
Technische Universität Dortmund, Germany

Within inverse linear optimization, we study a generalized inverse problem: can the objective function and right-hand side of a given linear program be modified so that the resulting optimal solution satisfies specified properties? This problem can also be interpreted as a response problem in the context of bilevel linear optimization. We discuss the complexity of this Generalized Inverse Linear Problem under different structural assumptions, showing that the complexity depends on various aspects such as the form of the LP, the desired target properties, and whether we consider the optimistic or the pessimistic scenario. Optimistic and pessimistic refer to whether at least one or all optimal solutions are required to satisfy the target property. Some observations regarding both positive and negative complexity results provide deeper insight into the properties of optimal bases for LPs.

Combinatorial response problems

Christoph Buchheim[1], Lowig Duer[1], Eva Ley[2], Maximilian Merkert[2], Komal Muluk[1]
1: TU Dortmund, Germany; 2: TU Braunschweig, Germany

The response problem over a combinatorial optimization problem P on item set I consists of a bipartition of I into two sets controlled by a leader and a follower. Both decision makers have their own objective functions. Additionally, we are given a target set Y defining the mandatory and the forbidden items from the follower's set of items. The task, in the response problem, is to verify whether there exists a partial solution S over the leader's set of items such that the follower's optimal reaction to S (subject to forming a solution of P) contains all mandatory items and excludes all forbidden items of the target set. We study the computational complexity of the response problem over the bipartite matching problem, in particular, we study the problem in the realm of parameterized complexity.

This is a joint work with Christoph Buchheim, Lowig Duer, Eva Ley, and Maximilian Merkert.

k-Truss Minimization: Complexity and Bilevel Optimization

Arie Koster[1], Jonas Kreyer[1], Ivana Ljubić[2], Matthis Penz[1]
1: RWTH Aachen University, Germany; 2: ESSEC Business School

A k-truss is an induced subgraph, where every edge is contained in k −2 triangles, hence a generalization of cliques. In contrast to cliques, finding the maximum k-truss in a graph is polynomial time solvable (Wang and Cheng, 2012). Given a budget b, the problem of k-Truss Minimization asks for which b edges to remove such that the maximum k-truss in the remaining graph is minimized (regarding the number of edges). We show that this problem is NP-complete, by correcting an earlier attempt to prove hardness.

To solve k-Truss Minimization, we present a bilevel optimization model, inspired by the same approach for the collapsed k-core problem (Cerulli et al., 2023). At the leader level, we decide which b edges are removed from the graph. At the follower level, the maximum k-truss in the remaining graph is determined. The objective of the leader is to select the edges in such a way that the maximum k-truss in the end is as small as possible.

We discuss three ways to solve the problem: exploiting a general-purpose bilevel solver (Fischetti et al., 2017), replacing the lower level problem by its dual yielding a quadratic problem, and replacing the lower level by exponentially many Benders-like cuts. Computational results show that the latter two methods outperform the general-purpose solver with a clear advantage for the quadratic problem solved by Gurobi.

FA 07: Discrete and Combinatorial Optimization: Graphs and Networks 2

Time: Friday, 04/Sept/2026: 8:30am - 10:00am · *Location:* SR029 (WIWI)
Session Chair: Markus Sinnl

The data arrangement problem on regular binary trees

Eranda Çela[1], Joachim Schauer[2], Rostislav Staněk[3]
1: Graz University of Technology, Austria; 2: FH JOANNEUM, Austria; 3: Technical University of Leoben, Austria

The data arrangement problem on regular trees (DAPT) consists in assigning the vertices of a given graph G, called the guest graph, to the leaves of a d-regular tree T, called the host graph, such that the sum of the pairwise distances of all pairs of leaves in T which correspond to the edges of G is minimised. Luczak and Noble (2002) have shown that this problem is NP-hard for every fixed d greater than or equal to 2. We show that this remains true even if the guest graph is a tree.

In this talk we focus on a special case of the DAPT where both guest and host graphs are regular binary trees and present a 1.015-approximation algorithm. We analyse the algorithm by providing the closed-form objective value of its solution. Furthermore, we derive a lower bound by solving a special case of the k-balanced partitioning problem (k-BPP) to optimality, specifically, for regular binary trees and k being a power of 2. Finally, we offer some remarks on the complexity of this special case while leaving the question of the exact complexity class open for future research.

On the p-alpha-closest center problem

Markus Sinnl[1], Elisabeth Gaar[2], Sara Joosten[2]
1: Johannes Kepler University Linz, Austria; 2: University of Augsburg, Germany

In this talk, we introduce the p-alpha-closest-center problem, which is a generalization of the p-second-center problem, a recently emerged variant of the classical p-center problem. In the problem, we are given a discrete set of customers, a discrete set of potential facility locations, distances between each customer and potential facility location as well as two integers p and alpha. The goal is to open facilities at p of the potential facility locations, such that the maximum alpha-distance between each customer and the open facilities is minimized. For a customer, the alpha-distance is defined as the sum of distances from the customer to its alpha closest open facilities.

We present several mixed-integer programming formulations for the problem, as well as valid inequalities for each of the formulations. Moreover, we conduct a polyhedral study comparing the strength of the LP-relaxations of the basic formulations and the enhanced versions. Based on our findings, we develop a branch-and-cut solution algorithm, which is evaluated in a computational study on standard benchmark instances from literature.

Large-Scale Maximum Covering Network Design

Felix Rauh[1], Dick den Hertog[2], Jannik Matuschke[1], Hande Yaman[1]
1: KU Leuven, Belgium; 2: University of Amsterdam, Netherlands

Planning accessible public health services and resilient infrastructure depends on high-quality solutions to network design and facility location problems. We study a problem motivated by improving health care access in regions prone to disruptions such as recurring floods. In this Maximum Covering Network Design Problem, a given budget is split between opening new facilities and reinforcing weak links in the road network. The goal is to maximize the number of households that can reach a facility via a resilient route of, for instance, at most five kilometers. We aim at solving real-world instances with road networks of more than 100,000 nodes.

Our approach starts from a path-based greedy heuristic that builds a solution incrementally by adding road segments connecting facilities to households. For each candidate facility, the steps of the heuristic form an expansion tree in which every node represents one road investment that extends coverage further. On top of this, we formulate a MILP that decides which facilities to open and, for each opened facility, selects a subtree of greedy steps to execute within the shared budget, while ensuring that no household is counted as covered more than once. We further derive dual bounds by drawing on ideas from cost-sharing mechanisms and Shapley values in network design.

In a computational study, we evaluate the resulting solution quality and optimality gaps on a range of instances, including a Timor-Leste case with roughly 158,000 road nodes and 350 candidate facilities.

FA 08: Supply Chain Management and Production: Risks in Supply Chains

Time: Friday, 04/Sept/2026: 8:30am - 10:00am · *Location:* HS9 (AM)
Session Chair: Clemens Löffler

From Weak Signals to Risk Propagation Scenarios in Supply Chains

Mohamed Saad El Harrab
Data Science for Complex Systems - CIL, Industrial Engineering Department, École nationale des ponts et chaussées, France

Supply chain disruptions are often preceded by weak, scattered signals that are difficult to interpret in isolation. These signals may originate from raw material markets, geopolitical tensions, freight conditions, port and airport congestion, regulatory shifts, supplier performance degradation, or macroeconomic stress. Existing risk assessment approaches largely rely on static indicators or local risk scores, which limits their capacity to capture how early tensions propagate across interconnected networks.

We propose a framework that integrates heterogeneous weak signals into a graph representation of supply chains to model how early tensions accumulate and propagate across interconnected entities. The graph captures suppliers, production sites, material references, sourcing dependencies, logistics flows, and geographic exposure. External signals and internal performance indicators are combined to identify critical nodes, vulnerable sub-systems, and plausible disruption pathways.

The framework supports exposure scoring, stress testing, and systemic risk analysis under uncertainty. The approach is evaluated on industrial supply chain data, demonstrating its ability to surface non-obvious propagation patterns ahead of realized disruptions.

Demand Allocation under Facility Disruptions

Abdulrahman Alenezi
Kuwait University, Kuwait

This study investigates the impact of facility disruptions on demand allocation decisions in the Reliable Facility Location Problem (RFLP). Specifically, we analyze how different facility disruption assumptions influence the assignment of demand points to primary and backup facilities. Two failure scenarios are considered: one in which primary and backup facilities cannot fail simultaneously, and another in which simultaneous failures are possible. Although the underlying RFLP formulation remains unchanged across these scenarios, differences arise in the modeling of transportation costs, leading to distinct allocation behaviors. The problem is solved using a Lagrange relaxation approach, which efficiently produces high-quality solutions with an average optimality gap of 0.1% and an average CPU time of 12.2 seconds. The results show that primary facilities are generally located closer to demand points than backup facilities. When simultaneous failures are not allowed, demand points are typically assigned to the nearest available facility, and transportation cost is the dominant factor in allocation decisions. In contrast, when simultaneous failures are possible, facility reliability plays a more significant role, and demand points may be assigned to more reliable facilities rather than the closest ones. These findings highlight the critical influence of facility failure assumptions on demand allocation decisions and provide valuable insights for designing resilient facility location strategies.

Who should collect? Reverse Channel Design for Remanufacturing under Supplier Competition

Clemens Löffler
FHWien der WKW, Austria

This paper investigates the strategic organization of reverse logistics in closed-loop supply chains with remanufacturing. While remanufacturing offers significant economic and environmental benefits, its success critically depends on efficient reverse logistics structures. We develop a game-theoretic model to compare two alternative modes: downstream-driven and upstream-driven collection of used products. The analysis examines how varying levels of upstream competition affect the manufacturer's choice of reverse channel, the equilibrium collection rate, and overall supply chain profitability. Our results show that when suppliers possess substantial market power, delegating reverse logistics to them is optimal, as they directly capture cost savings from remanufacturing and thus have stronger investment incentives. In contrast, under intense supplier competition, manufacturers benefit from coordinating reverse logistics themselves under a downstream-driven system. Extensions considering spillover effects and pooling strategies highlight further strategic trade-offs. The study contributes to theory, managerial practice, and policy by demonstrating that reverse logistics mode must be tailored to market structure to enhance profitability and sustainability.

FA 09: Artificial Intelligence, Machine Learning and Optimization: LLMs for Optimization

Time: Friday, 04/Sept/2026: 8:30am - 10:00am · *Location:* HS7 (WIWI)
Session Chair: Florian Roland Breda

LLM-driven Automated Heuristic Design for Combinatorial Optimization Problems

Jing Chen, Lin Xie
Brandenburgische Technische Universität, Germany

Heuristics are indispensable in practical combinatorial optimization. However, designing high-performance heuristic algorithms for complex optimization problems remains a challenging task, relying on extensive human expertise, iterative trial-and-error, and domain-specific knowledge. Recently, Large Language Model (LLM)-driven Automated Heuristic Design (AHD) has emerged as a promising paradigm for automating heuristic discovery. Inspired by this trend, we explore the direction of LLM-based heuristic discovery for combinatorial optimization. Our goal is to investigate whether LLMs can autonomously discover effective heuristics across diverse combinatorial optimization problems. We believe this direction has the potential to reduce human effort in heuristic engineering and provide new insights into automated heuristic design for combinatorial optimization.

Discovering Heuristics For Highly Constrained Routing Problems with LLMs

Nayeli Gast Zepeda[1], André Hottung[2], Kevin Tierney[1]
1: University of Vienna, Austria; 2: Bielefeld University, Germany

Large Language Model (LLM)-driven heuristic discovery has shown recent promise for solving vehicle routing problems. However, prior work has focused on settings where feasibility is easily guaranteed, such as assuming unlimited fleets. We extend the VRPAgent framework to the heterogeneous capacitated vehicle routing problem with time windows and limited vehicles (HCVRPTW), a setting in which maintaining feasibility becomes a central challenge. We study six penalization strategies in VRPAgent's large neighborhood search, relaxing selected constraints to improve exploration while steering search back toward feasibility. Experiments on 2,000 challenging, guaranteed-feasible instances show that LLM-generated operators match SISRs in feasibility rate and can surpass it on medium-difficulty instances, but performance on the hardest instances remains mixed. Compared with PyVRP, which employs a more complex dynamic penalization mechanism, both approaches still exhibit non-negligible gaps. Our results suggest that LLM-generated heuristics can transfer to highly constrained routing problems, but that designing effective penalization mechanisms remains the key bottleneck for reliably obtaining feasible solutions.

QLPBench: A Benchmark for Evaluating Large Language Models on Quantified Linear Programming

Florian Roland Breda, Ulf Lorenz
University of Siegen, Germany

Large Language Models (LLMs) are becoming an increasingly important tool in everyday life, finding application across a wide range of professional and academic domains. However, since LLMs are not able to reliably assess the quality of their own outputs, standardized benchmarks are essential for understanding where they perform well and where they fall short. While benchmarks exist for many areas, no benchmark has so far been developed to evaluate LLM performance specifically on Quantified Linear Programming (QLP). We address this gap by introducing a dedicated QLP benchmark, designed to measure LLM capabilities across multiple categories, including the construction of QLPs from textual descriptions and single-choice knowledge questions covering conceptual understanding. To cover a broader range of problem-solving strategies, the construction category also includes an indirect approach using a modeling language as an intermediate step. All instances and questions are human-validated to ensure quality and reliability. We evaluate open-source and commercial LLMs under zero-shot and few-shot conditions. The results demonstrate the benchmark's ability to differentiate between models and task types, providing a first view of how well current LLMs handle QLP-related tasks. The complete benchmark will be publicly available to support reproducibility and to encourage further research in this area.

FA 10: Optimization under Uncertainty: Regret Optimization and Hurwicz Criterion

Time: Friday, 04/Sept/2026: 8:30am - 10:00am · *Location:* HS8 (WIWI)
Session Chair: Yannick Becker

Exact Reduction of the Uncertainty Set in Minmax Regret Optimization

Yannick Becker[1,2], Pascal Halffmann[1], Anita Schöbel[1,2]
1: Financial Mathematics, Fraunhofer ITWM; 2: RPTU University of Kaiserslautern-Landau, Germany

Minmax regret robust optimization is a powerful framework for decision-making under uncertainty, as it minimizes the worst-case loss relative to the optimal decision in hindsight. While conceptually appealing, this approach frequently results in computationally intensive mathematical programs, such as nested minmax or semi-infinite problems, which often limit its practical application.

In this talk, we present an exact reduction property for a broad class of minmax regret problems. We show that under standard assumptions – specifically assuming affine uncertainty – an uncertainty set can be simplified to a specific subset, sometimes even to a finite set of scenarios. By exploiting the geometric properties of the uncertainty set and the structure of the optimal value function, we prove that the reduction of this uncertainty set is exact, preserving both the optimal objective value and the optimal decision vector without any loss of information. This theoretical advancement restores the computational tractability of the regret-robust approach, enabling its application to large-scale optimization problems in fields such as logistics, energy, and finance.

Globalized Adversarial Regret Optimization (GARO)

Jannis Kurtz, Bart van Parys
University of Amsterdam, Netherlands, The

Robust optimization models are widely used to solve optimization problems under uncertainty. Often the uncertainty arises from erroneous predictions of the model parameters based on historical data. However, practical data is often more challenging than what curated statistical models may account for, leading to practically meaningless uncertainty sets which make classical robust models impractical. We argue in this talk that not only classical robust models but robust regret and globalized robust models suffer in these situations. To tackle the different drawbacks of the latter models we propose a new model which minimizes the regret to the true robust min-max value if we would have known the size of the adversaries uncertainty set. We show that our model can be solved by a simple discretization approach or a standard cutting plane method. Our experiments show that compared to the previously mentioned robust models the solutions of our model show often an improved out-of-sample performance leading to a better trade-off between worst-case and average performance. This is joint work with Bart van Parys (CWI).

Optimizing the Hurwicz Criterion in Lot-sizing Problem with Uncertain Lead Times

Romain Guillaume[1], Adam Kasperski[2], Szymon Wróbel[2], Paweł Zieliński[2]
1: Université de Toulouse-IRIT, Toulouse, France; 2: Wrocław University of Science and Technology, Poland

Accounting for uncertainty in supply chain management is crucial for robust decision-making. While international manufacturing and shipping reduce production costs, they introduce longer and more uncertain lead times. In our paper, we consider the Capacitated Lot Sizing Problem under lead time uncertainty, with backordering and setup costs. The planning horizon is divided into production periods and subsequent arrival periods. A common nominal lead time for all production periods is given, but the actual times of arrival are uncertain at the time of planning and may deviate from the nominal case.

Robust optimization is an approach that hedges against the worst possible outcome. Budgeted uncertainty models allow decision-makers to reduce the conservativeness of the solutions but remain focused on the pessimistic (min-max) scenario. As an alternative we consider the Hurwicz criterion, which may yield less conservative solutions by optimizing a weighted combination of pessimistic (min-max) and optimistic (min-min) scenario costs. We apply Hurwicz criterion to the Lot Sizing Problem and compare it with models previously discussed in literature.

FA 11: Software for Operations Research: Modeling Ecosystem

Time: Friday, 04/Sept/2026: 8:30am - 10:00am · *Location:* HS6 (WIWI)
Session Chair: Martin Bromberger

Collaborative Data Management with Automatic Alignment to Mathematical Models

Jie Xu, Dennis Schneider, Christoph Weber
University of Duisburg-Essen

Mathematical programming for large-scale applications like energy system planning requires not only lots of data but also modelling experts to collaboratively investigate many hypotheses about different real-world abstractions and extrapolations to future years. Despite advances in modeling tools and databases, an out-of-the-box alignment between a mathematical modeling process and its data management is still missing.

This contribution proposes a conceptual framework to bridge this gap and presents a Python package as proof of concept. The framework provides a fixed database structure for each set and parameter, in which multiple input variants are organized as separate blocks, each corresponding to a hypothesis. It further captures inter-symbol relationships and provides mechanisms for defining shared hypotheses across groups of symbols. On this basis, the Python package merges or partitions initially mapped tables while managing metadata for resulting tables and views. This approach allows the final tables to mirror data sources as closely as possible, while the views remain automatically aligned with the mathematical symbols. For example, a multivariate time series can be stored in separate tables corresponding to original sources, while the interconnection is ensured via a shared hypothesis. As a result, model developers can focus on mathematical formulations, while model users can collaboratively manage data for different hypotheses, try out hypothesis combinations, and compare results. Additionally, some tools in Python ecosystem enables the database to evolve with the model and accommodate formulation variants.

Further development of the Python package will support more database management systems and additional modeling tools besides GAMS.

Bridging the Gap: Seamlessly Integrating Machine Learning and Mathematical Optimization with GAMSPy

Justine Broihan
GAMS Software GmbH, Germany

While Machine Learning (ML) excels at extracting patterns and predicting trends, translating those insights into optimal, constraint-bound decisions requires mathematical optimization. Historically, combining these two disciplines has introduced significant architectural friction between data science environments and traditional modeling tools.

This presentation introduces a unified approach using GAMSPy, a library that embeds the General Algebraic Modeling System (GAMS) directly into the Python ecosystem. We will explore how GAMSPy enables researchers to build seamless "predict-then-optimize" pipelines, natively coupling popular ML frameworks with state-of-the-art mathematical solvers without the need for complex data serialization.

We will demonstrate how integrating prescriptive analytics directly into Python workflows empowers researchers to design more robust, actionable, and mathematically verifiable AI systems.

Gurobi's Hidden Gems: Useful features you may not know

Martin Bromberger
Gurobi Optimization, Germany

Gurobi can do more than just solve LPs, MIPs, and QPs—it also provides many useful features that can enhance your optimization work. In this talk, we will review several of these features, including general constraints, solution pools, callbacks, and infeasibility analysis. Additionally, we will discuss some tools that can help users analyze their results and tune their parameters.

FA 12: Health Care Management: Data-driven Planning and Cyber Risk

Time: Friday, 04/Sept/2026: 8:30am - 10:00am · *Location:* HS2 (PHIL)
Session Chair: Emilia Grass

Data-Driven Planning Groups for Simulation-Based Hospital Bed Capacity Planning

Harold Tiemessen, Fabian Leuthold, Katrin Hügel, Adrian Stämpfli
Ostschweizer Fachhochschule, Switzerland

Swiss hospitals face increasing financial pressure, persistent shortages of nursing and medical staff, and growing demand for hospital treatments. Under these conditions, hospital management must determine the appropriate size and organization of bed capacity while maintaining high quality-of-care and robustness against variability in patient flows.

A central concept of the proposed approach is that of planning groups, defined as a set of patient groups sharing a common pool of resources, such as an entire nursing unit. Pooling patients typically reduces required capacity through risk pooling and may further decrease variability when groups exhibit different daily/seasonal admission patterns. However, not all group-combinations are feasible or desirable in practice. Constraints related to hospital layout, nurse skills, telemetry requirements, clinical compatibility, and organizational preferences limit admissible pooling options and are difficult to model.

To address this, we propose a structured, simulation-based workflow for bed capacity planning that combines data-driven analysis with expert judgment. The workflow comprises four steps: (i) preprocessing of historical patient pathway data; (ii) identification of promising candidate planning groups using data analysis and expert knowledge; (iii) allocation of capacities to the identified planning groups, subject to expert-defined rule-based policies, using a MILP model; and (iv) detailed evaluation of the resulting configurations using discrete event simulation. The simulation framework supports parametrized admission and scheduling policies and captures variability and operational constraints beyond classical queueing models. The workflow is currently being prototyped with four Swiss hospitals for selected use cases, with first capacity-related decisions expected by the end of the year.

Inventory Flexibility and Drug Shortage Mitigation: On the Value of Multi-Market Packs

Niklas Currenti[1], Sebastian Schiffels[2], David Francas[1]
1: Hochschule Worms, Germany; 2: Universität Augsburg, Germany

Drug shortages have emerged as a critical concern for healthcare systems worldwide. Within the European Union, such shortages rarely affect more than a few member states simultaneously; however, national labelling requirements restrict timely redistribution in a shortage case. The predominant industry model relies on dedicated market packs, whereby each stock-keeping unit (SKU) is authorized exclusively in a single market. Recognizing this structural barrier, the EU Pharmaceutical Strategy has identified multi-market labelling as a key lever for strengthening drug supply chain resilience. Building on this regulatory direction, we evaluate the benefits of adopting multi-country packs, authorized for use across multiple markets, in mitigating drug shortages and their health-economic impact.

We consider two types of inventory flexibility: market and redeployment flexibility. Market flexibility is generated by the presence of multi-country packs. Redeployment flexibility is an exogenous parameter that captures the system's ability to sell SKUs in a country where they were not originally authorized through mechanisms such as parallel imports, repacking, or regulatory interventions. We formulate the inventory flexibility problem as a two-stage stochastic program with a mean-CVaR objective based on either Time-to-Survive (TTS) or shortage quantities.

The model is evaluated through a numerical study that combines an industry dataset on European drug distribution, capturing demand quantities and SKU configurations, with disruption scenarios fitted to historical shortage distributions via a Bernoulli mixture model. We report the resulting resilience and health-economic effects in terms of TTS and quality-adjusted life years (QALYs).

FA 13: Project Management and Scheduling: Scheduling in Manufacturing and Projects

Time: Friday, 04/Sept/2026: 8:30am - 10:00am · *Location:* HS4 (PHIL)
Session Chair: Dariusz Ślawski

Modified Giffler-Thompson algorithm for time-dependent job shop problems

Maciej Rymarz[1], Stanisław Gawiejnowicz[2]
1: University of Kalisz, Kalisz, Poland; 2: Adam Mickiewicz University, Poznań, Poland

In the talk, we present the modified Giffler-Thompson algorithm for the construction of all active schedules for a non-classical job shop, where the processing times of operations are functions of the starting times of these operations. Similarly as in the classical case, the problem is NP-hard already for two machines. The aim of the talk is to discuss some results related to two Java implementations of this algorithm: a tabular, based on tables, and a list one, based on lists.

The talk consists of three parts. In the first part, we define the problem and summarize the main relevant results. Next, we describe the proposed implementations and their properties. Finally, we overview the results of numerical experiments with these implementations and give some remarks on possible further research.

Project scheduling with Multi-Skilled Resources and Hierarchical Skill Levels

Guillaume Vermeire, Mario Vanhoucke
Ghent University, Belgium

In the project scheduling literature the resource-constrained project scheduling problem (RCPSP) has been studied extensively in the past decades. The goal of this problem is to find the minimum project duration given a set of resource constraints. This classical problem is often extended to make it more applicable to real life scenarios. One of these extensions considers multi-skilled renewable resources to be human workers who have the possibility to master one or more skills with specified levels of experience. The skills and experience mastered by a resource determine the activities to which the resource can be assigned, and as a result, the achievable solution quality depends on the characteristics of the workforce. Since the scheduling problem and its multi-skilled extension are NP-hard, the use of an integer programming solver is not suitable, especially for large project instances. For that reason, a specialised solution procedure is developed and fine-tuned. An artificially generated, benchmarked dataset with project instances containing multi-skilled characteristics is used to perform computational experiments. The obtained solutions are compared with solutions generated by an integer programming solver to indicate the achieved solution quality. Several indicators are evaluated in order to find trends and insights about the impact of the workforce size, skills and experience on the project performance. Finally, it is discussed how these insights provide guidance for improved decision making in scheduling problems with multi-skilled resources.

Solving a time-dependent scheduling problem by machine learning techniques

Dariusz Ślawski[1], Stanisław Gawiejnowicz[2]
1: Uniwersytet Kaliski, Poland; 2: Adam Mickiewicz University, Poznań, Poland

We present preliminary results of solving an open single-machine time-dependent scheduling problem by machine learning techniques. First, we formulate the considered problem and give a summary of the relevant research. Next, we describe the applied neural network, the used Python-based tools with CUDA acceleration, and the processes of instance generation and the network learning and testing. Finally, we present results of experiments with the proposed neural network and fifty thousand instances: forty thousand in the learning phase and ten thousand in the testing phase. We complete the talk with remarks on the future research.

FA 14: Game Theory and Behavioral Management Science: Strategic Resource Allocation

Time: Friday, 04/Sept/2026: 8:30am - 10:00am · *Location:* HS12 (IM)
Session Chair: Rainer Kleber

Defender-Attacker-Game on Attack-Trees – A Game-Theoretic Approach to Strategic Cyber Defense

Darja Stepanova[1], **Marcus Wiens**[2]
1: Karlsruhe Institute of Technology (KIT), Germany; 2: Technische Universität Bergakademie Freiberg (TUBAF), Germany

Administration, companies and infrastructure providers are increasingly exposed to cyber threats while operating under strict budget and operational constraints. Despite the growing importance of cyber risk management regulation and procedures, the allocation of defense resources remains largely qualitative and lacks formalized, quantitative decision support. This gap makes it difficult to justify investments and to systematically balance cost against security effectiveness.

This paper proposes a network-based Stackelberg game to capture defender-attacker-interactions along an attack tree. The defender, e.g., the manufacturing unit of an industrial company, acts as leader and allocates a limited budget on different stages of an attack. The attacker responds by distributing effort along potential attack vectors to achieve a given goal (e.g., data theft or disruption) in the most efficient way. Although the insights of this study are relevant to a multitude of domains, we mainly focus on the application of industrial manufacturing systems.

The game enables a systematic analysis of the strategic interaction and the resulting Nash Equilibrium between defender and attacker along a given attack tree, taking into account the effectiveness and economic efficiency of the chosen strategies. Finally, the paper also discusses extensions to the game, such as the inclusion of multiple types of attackers and defenders, a more complex attack tree (scalability), and variations in the uncertainty assumptions.

Does Right-to-Repair Legislation Preempt Remanufacturing?

Rainer Kleber[1], **Marc Reimann**[2]
1: University Magdeburg, Germany; 2: University of Graz

Extending the lifespan of products is central to the circular economy, offering environmental and economic benefits by reducing waste and resource consumption. Right-to-repair (RTR) legislation, such as the EU's 2024 directive, mandates manufacturers to facilitate repairs, aiming to encourage consumers to repair rather than replace their products. However, the intended first-life extension can also impact remanufacturing, another circular strategy that adds a second life to a product, by reducing the availability of used cores and affecting residual life, thereby affecting the value of remanufactured products. This study investigates how an RTR-induced product life extension affects the (internal) competition between a new and a remanufactured product, as well as overall circular system outcomes, focusing on the average total usage time per newly sold unit and the remanufacturing quantity per unit time. To this end, we extend standard strategic modeling approaches in the CLSC literature to account for RTR-induced product life extensions and to analyze their effects on firm strategies and system-level outcomes. We find that the RTR-induced product-life extension can preempt remanufacturing. System-level outcomes are non-monotonic: Average total usage time may increase, decrease, or remain unchanged depending on the remanufacturing regime and cost environment. As a main result, RTR legislation, while promoting product longevity, can unintentionally undermine it by reducing core availability and value, and preempting remanufacturing. Policy design should consider these trade-offs to optimize circular system performance and coordinate value-retention strategies.

FA 16: Simulation and Quantum Computing: Optimization Across Complex Hierarchies, Organizations, and Networks

Time: Friday, 04/Sept/2026: 8:30am - 10:00am · *Location:* SR033 (WIWI)
Session Chair: Max Krueger

Optimization of organizational performance: system dynamics meets bureaucracy and innovation

Joachim Block
Public service, Germany

Today's world is dominated by massive social and technical disruptions. The dynamics resulting from a steadily changing environment have big impacts on both private and public organizations. As drivers of wealth and stability, our organizations are forced to react adequately. The challenge for management is how to optimize an organizational system under uncertainty and changing conditions.

For performance optimization, management must balance two forces. On the one hand, there is the bureaucratic system. It stands for efficiency, stability, predictability, approved product and service delivery. In contrast, there is the innovation system focused on new work processes, products, and services. Hence, innovation does not directly contribute to current success but rather addresses an organization's future success.

In both the management and the scientific communities, we encounter a long-standing dispute over the relationship between bureaucracy and innovation. Our research contributes to these discussions by using a simulation-based approach. It is intended to support management actions toward system optimization.

For our model, we draw on the strengths of the system dynamics (SD) methodology. This enables us to integrate variables and their relations identified by research in the fields of bureaucracy and innovation. In addition to the organization's external environment, we examine the effects of innovative culture on organizational performance.

The simulations we conducted reveal that allocating resources to operational or innovative tasks is not enough. For long-term success, management must also focus on culture. Omitting cultural factors may result in good intentions turning into the opposite.

A Heuristic for Graph Coloring Based on the Ising Model

Janez Žerovnik[1,2]
1: University of Ljubljana, Slovenia; 2: Rudolfovo—Science and Technology Centre Novo mesto, Slovenia

We consider a dynamic extension of the Petford–Welsh coloring algorithm that estimates the chromatic number of a graph without requiring k as an input. The basic algorithm is based on the model that is closely related to the Boltzmann machines that minimize the Ising model Hamiltonian. The method begins with a minimal coloring and adaptively adjusts the number of colors based on solution quality. We evaluate our approach on a variety of graphs from the DIMACS benchmark suite using different initialization strategies. On random k-colorable graphs, proper colorings were found for all combinations of initial strategies and parameter values, while for DIMACS graphs, optimal or near optimal solutions were found frequently, without tuning the parameters. The results show that the algorithm designed is not only capable of providing near optimal solutions but is also very robust. We demonstrate that our approach can be surprisingly effective on real-world instances, although more adaptive or problem-specific strategies may be needed for harder cases. The main advantage of the proposed randomized algorithm is its inherent parallelism that may be explored in future studies.

The approach may in principle be easily applied to some related problems, for example to the max stable set problem. However, preliminary experiments have indicated that some nontrivial adaptations are needed.

(The talk is based on joint work with Omkar Bihani.)

FB 01: Semi-Plenary Stefan Szeider

Time: Friday, 04/Sept/2026: 10:30am - 11:30am · *Location:* HS10 (AM)
Session Chair: Ralf Kellner

Large Language Models in the Optimization Loop

Stefan Szeider
Technische Universität Wien

Large Language Models (LLMs) have reshaped natural language processing, but their role in combinatorial optimization and constraint solving is only beginning to take shape. In this talk, I argue that LLMs are most useful not as solvers in their own right, since they cannot guarantee optimality or even feasibility, but as collaborators for the exact solvers we already trust. I illustrate three roles an LLM can play across the optimization workflow.

First, as a modeler: the MCP Solver lets an LLM translate problems stated in plain English into encodings for constraint programming, SAT, MaxSAT, and SMT, editing the model incrementally as an agent. Second, as a search guide: LLM-generated streamlining constraints steer solvers toward promising regions of the search space. They cut runtimes sharply and set new record values for spatially balanced Latin rectangles. Third, as an algorithm selector: pretrained text embeddings replace hand-crafted instance features, beating classical feature-based selection on 10 of 11 benchmark scenarios with no domain-specific engineering.

The thread connecting all three is neurosymbolic: language models supply breadth and creativity, exact solvers supply rigor and guarantees, and the combination outperforms either alone.

FB 06: Semi-Plenary Göran Kauermann

Time: Friday, 04/Sept/2026: 10:30am - 11:30am · *Location:* HS5 (WIWI)
Session Chair: Joachim Schnurbus

Applied Statistics and Operations Research – Two Sides of the same Coin?!

Göran Kauermann
Ludwig-Maximilians-Universität München, Germany

If one consults modern search engines for a brief definition of Operations Research, the answer is typically something along the lines of: “Operations Research is the use of mathematical models, statistical analysis, and optimization techniques to support better decision-making and improve the efficient use of resources”. Statistical analysis is mentioned as one of its tools, alongside mathematics and optimization. However, “Statistical Analysis”, or better “Applied Statistics” today goes much deeper into the subject matter, also with the aim of making “better decision-making.” In this respect, Operations Research and Applied Statistics pursue similar, if not partly identical, objectives. Yet the approaches of the two disciplines have different roots and histories.

This talk highlights the statistical perspective and illustrates how questions can be addressed using a statistical approach. Several practical examples are presented. Specifically, we consider the estimation of price elasticities and the optimization of renewable energy systems, the latter using South Africa as a case study. The central message is that, for concrete and complex problems, an interdisciplinary approach appears to be the most successful. In this sense, the coin has more than two sides, and each side both can and should be examined.

FB 08: Semi-Plenary Marie-Eve Rancourt

Time: Friday, 04/Sept/2026: 10:30am - 11:30am · *Location:* HS9 (AM)
Session Chair: Alena Otto

Data-Driven Optimization in Humanitarian Supply Chains: An Application to Madagascar

Marie-Eve Rancourt
HEC Montréal, Canada

This presentation explores how data-driven optimization can support decision-making in humanitarian supply chains, with a focus on the specific challenges that arise in this context. Decision problems are often ill-defined and must be formulated in data-scarce, uncertain, and resource-constrained environments. In applied research, data collection and processing play a central role, not only in parametrizing mathematical models, but also in shaping relevant and practically meaningful problems and research questions. The presentation will discuss the main features that need to be positioned and clarified when modeling and solving optimization problems related to humanitarian operations.

The proposed approach to problem formulation follows a bottom-up research design, starting from operational challenges encountered by humanitarian organizations in the field and moving toward optimization-based solution approaches. A detailed case study in Madagascar illustrates this approach in the context of anticipatory stock repositioning for cyclone response. We develop a dynamic framework that combines a regression model to predict demand from cyclone forecasts and vulnerability indicators with a two-stage stochastic optimization model to guide repositioning decisions. The results show that anticipatory repositioning can reduce response time by up to 50% compared to a wait-and-see strategy, which remains a common practice.

FC 01: Plenary Ivana Ljubic

Time: Friday, 04/Sept/2026: 11:45am - 12:45pm · *Location:* HS10 (AM)
Session Chair: Sophie N. Parragh

Modeling Fairness Through the Lenses of Ordered and Bilevel Optimization

Ivana Ljubic
WU Wien, Austria

Fairness has become an increasingly important consideration in contemporary societies, which are marked by growing economic and social inequalities. Consequently, policymakers and decision-makers are placing greater emphasis on incorporating fairness considerations into their decision-making processes. In this talk, we establish a connection between fairness modeling in optimization problems and bilevel optimization.

We present a unifying and flexible modeling framework based on the principles of ordered optimization that captures a broad class of fairness measures proposed in the literature. These include both linear and nonlinear notions of fairness, such as the range, the Gini index, least absolute deviations, least squares deviations, and several others. Many of these practically relevant fairness measures are inherently non-monotone, which necessitates the imposition of appropriate optimality conditions. This observation naturally leads to a bilevel optimization perspective.

To illustrate the practical implications of the proposed framework, we consider its application to vehicle routing problems, highlighting how bilevel optimization can be leveraged to model and solve fairness-aware optimization problems in real-world settings. This presentation is based on joint work with Justo Puerto and Alberto Torrejon.

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Session Chairs