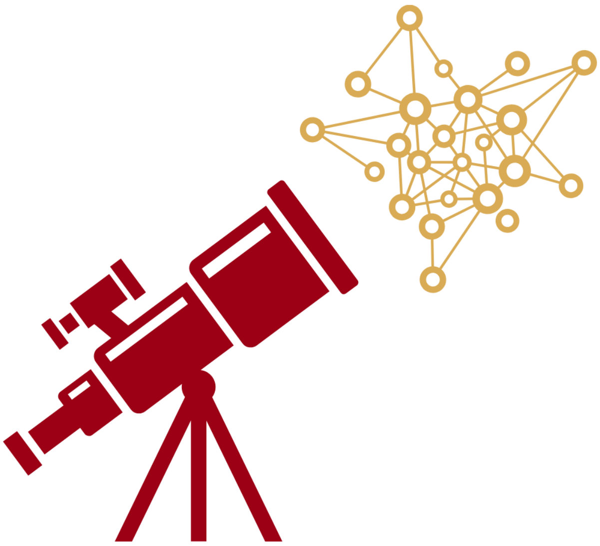
10th AIROYoung Workshop and Ph.D. School

Optimization between determinism and uncertainty

February 9–13, 2026

University of Padova, Italy

Book of Abstracts



Preface

"Measure what is measurable,
and make measurable what is not so."
Galileo Galilei

This volume contains descriptions of all the contributions accepted and presented during the 10th AIROYoung Workshop and Ph.D. School (10AYW), that is, the 10th edition of the annual conference organized by AIROYoung, the Young Chapter of the Italian Operations Research Society (AIRO).

After the workshops held in Rome (2017, 2019, 2022), Cosenza (2018), Bozen (2020), Milan (2023), Rende (2024), Pavia (2025), and the online version organized in 2021, the 10AYW takes place at the University of Padova, Italy, from February 9 to 13, 2026. To celebrate this anniversary, the conference is enhanced with a Ph.D. School, on the first day (Monday, 9th February 2026). The event is supported by AIRO, the University of Padova, the Department of Information Engineering, and the Department of Mathematics.

The primary theme of the 10AYW is "*Optimization between determinism and uncertainty*", offering the opportunity to reflect on the degree of abstraction of the mathematical models we formulate and solve, on their adherence to the original problems under our study, and therefore on the corresponding gaps that remain to be closed, at least ideally. Indeed, reality is stochastic and dynamic by nature, and, as it is continuously evolving and changing, always representing it exactly is impossible. Nonetheless, the discipline of Operations Research has reached such a maturity that it can dedicate itself not only to problems in deterministic-static contexts. This does not imply stopping studying these well-defined and reassuring (yet sometimes NP-hard) problems or putting them aside. On the contrary, in all the most widespread paradigms to address and integrate uncertain information (i.e., from Stochastic Programming to Robust Optimization, passing through Distributionally Robust Optimization, Chance Constrained Programming, and Bilevel Optimization), the "ex-post" versions and single-level reformulations are always used as benchmarks and as a base to build sharper and sharper approximations of the unknown.

By following, in a certain sense, Galileo's suggestion, what is generally done is re-exploiting the knowledge, skills, and competences developed for something known and "measurable" to solve something probable or a worst case under some assumptions, thus making "measurable what is not so". Handling all this in both static and multi-stage settings is not easy. Still, Operations Research is not alone but naturally joins forces with other branches of Mathematics and Computer Science that have established themselves in recent decades, such as Machine Learning and Data Science: prescription meets prediction. Among the main challenges to tackle, we find the following: how to overcome drawbacks of uncertainty paradigms such as the critical number of scenarios in Stochastic Programming or the over conservatism of static Robust Optimization; how to reduce the distance between nice theoretical results and expensive runtimes needed to solve more than just numerical examples; and, in this regard, we cannot ignore data availability and quality. Therefore, there is plenty of research work from both the methodological and computational sides.

Overall, throughout the event, there are four plenaries held by international professors; four Ph.D. School lectures given by professors in Operations Research affiliated with the Department of Information Engineering and the Department of Mathematics of the University of Padova; two sponsor sessions; and, mainly, 59 scientific talks by young researchers and practitioners. These contributions cover a variety of topics, including but not limited to the following ones (in alphabetical order):

- Artificial Intelligence
- Big Data Analytics and Optimization
- Bilevel Optimization
- Chance-constrained Programming
- City Logistics
- Control Theory and System Dynamics
- Covering and Location
- Cutting and Packing
- Data Mining and Classification
- Data-driven Optimization
- Decision-making under Uncertainty
- Decision Support Systems
- Disaster Management
- Discrete and Combinatorial Optimization
- Emergency and Humanitarian Logistics
- Energy, Environment, and Natural Resources
- Exact Methods

- Financial Modeling and Risk Management
- Game Theory
- Global Optimization
- Graph Theory and Network Optimization
- Health Care and Outbreak Management
- Homeland Security and Infrastructure Protection
- Heuristics and Metaheuristics
- ICT and Computer and Mobile Networks
- Industrial Production
- Linear and Nonlinear Programming
- Logistics and Supply Chain Management
- Machine Learning
- Mathematical Programming
- Multi-objective Optimization
- Multiple-Criteria Decision Making
- Network Analytics
- Optimization Software
- OR Teaching
- Planning and Project Management
- Railway and Air Traffic Problems
- Robust and Distributionally Robust Optimization
- Routing and Transportation
- Scheduling and Timetabling
- Simulation and Queuing Theory
- Soft OR
- Stochastic Programming

Padova, February 2026

Acknowledgments

We are deeply grateful to all those who contributed to making the conference possible. In particular, we thank AIRO, AIROYoung, the Department of Information Engineering, and the Department of Mathematics of the University of Padova. A special thanks to all our sponsors:

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Day 1

Monday, February 9th, 2026

Ph.D. School Lectures

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Francesco Rinaldi	Frank-Wolfe and friends: a journey into projection-free optimization methods
Domenico Salvagnin	Computational Research 101

Comparing branch-and-bound, cutting planes, and branch-and-cut

Marco Di Summa

Department of Mathematics, University of Padova, Padova, Italy

Abstract. In this lecture, we will explore what is known about the theoretical complexity of branch-and-bound, cutting-plane, and branch-and-cut algorithms for linear and convex mixed-integer optimization. We will compare the efficiency of these methods and discuss how their worst-case performance depends on the choice of branching strategy and cutting-plane paradigm.

Short bio. Marco Di Summa is a Full Professor of Operations Research at the Department of Mathematics, University of Padova, Italy. He earned his Ph.D. in Computational Mathematics from the same university in 2008 and has held research positions at Center for Operations Research and Econometrics (Université catholique de Louvain), the University of Torino, and École Polytechnique Fédérale de Lausanne. His research focuses on mixed-integer programming, polyhedral theory, and cutting-plane methods in optimization.

Benders and Bilevel Optimization

Matteo Fischetti

Department of Information Engineering, University of Padova, Padova, Italy

Abstract. In this introductory talk, I will address Benders decomposition methods, and I will present some basic solution methods for Mixed-Integer Bilevel optimization. The talk is intended for Ph.D. students who are not working on these problems, but want to know more about them.

Short bio. Matteo Fischetti is full professor of Operations Research at the University of Padova, Italy. He is Associate Editor of the journals "Operations Research" (till 2024) and "Mathematical Programming Computation". He won the "Best PhD Dissertation on Transportation" prize awarded by ORSA (1987) and the INFORMS Edelman award (2008). In 2015, he won the Harold Larnder Prize awarded by the Canadian Operational Research Society. His research interests include Integer Programming, Combinatorial Optimization, Railway Optimization, Vehicle and Crew Scheduling Problems. Matteo Fischetti published more than 130 papers on top-level international journals of the field; his H-index on Google Scholar is 73.

Frank-Wolfe and friends: a journey into projection-free optimization methods

Francesco Rinaldi

Department of Mathematics, University of Padova, Padova, Italy

Abstract. This lecture explores the use of projection-free algorithms, such as the Frank-Wolfe Method and its variants, for constrained optimization problems. We analyse both theoretical and computational properties of those methods. Additionally, we discuss some applications in, e.g., machine learning, and complex network analysis where the methods enable scalable and efficient solutions.

Short bio. Francesco Rinaldi is a Full Professor of Mathematics at the University of Padova's Math Department. He received his Ph.D. in Operations Research from Sapienza University of Rome in 2009. His research focuses on nonlinear and derivative-free optimization, with applications in many scientific fields such as machine learning, medicine and biology.

Computational Research 101

Domenico Salvagnin

Department of Information Engineering, University of Padova, Padova, Italy

Abstract. In this talk, we discuss the joy and pain of computational research. We start from basic principles on experimental design, continue with tips and pitfalls in data analysis, and finally argue why software engineering best practices are relevant even in the context of academic research. We conclude with a few comments on how (not) to present empirical results.

Short bio. Domenico Salvagnin is an Associate Professor of Operations Research at the Department of Information Engineering, University of Padova. He earned his Ph.D. in Computational Mathematics (Operations Research) from the same university in 2009. His research focuses on linear and mixed-integer programming, constraint programming, and hybrid optimization methods. He has received several international awards, including the DIMACS Implementation Challenge (2014) and best paper prizes at CPAIOR 2019 and ICAPS 2019. He has collaborated with IBM ILOG CPLEX and FICO XPRESS and serves as Technical Editor for Mathematical Programming Computation.

Day 2

Tuesday, February 10th, 2026

Session I: Transportation and Logistics I

Time: 9:20-11:00 **Chair:** Francesco Cavaliere

Abdelouahab Moubane	Modeling and Optimization of Truck and Robot Routing without Robot-Depots
Fabio Buffoli	Beating Highway Gridlock: Iterative User Equilibrium with Local Congestion Caps
Antonino Carè	Last-mile Delivery with Autonomous Robots and Public Transport Lines
Pierre Vendé	The Electric Vehicle Fleet Composition Problem with temperature considerations
Khaoula Kharfati	A Two-Stage Decomposition Method for the Electric Traveling Salesman Problem with Time Windows

Modeling and Optimization of Truck and Robot Routing without Robot-Depots

Abdelouahab Moubane[1,*], Edoardo Fadda[2], and Tiziana Delmastro[1]

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Last-mile logistics has become important with the growth of e-commerce and the rising demand for fast deliveries. The Truck and Robot concept, which integrates autonomous delivery robots (ADRs) into truck operations, enables parallel deliveries and reduces completion times. In Truck and Robot systems described in the literature [1], robots can be deployed at drop-off areas or from ADR depots where additional robots are available.

This work proposes a more practical variant, in which robots are owned by the delivery company, and no external depots are required, making the system less dependent on additional infrastructure [2]. The strategy is evaluated using a matheuristic algorithm inspired by column generation, tested on simulated instances and a real case study, analyzing costs and delivery times and comparing them with the traditional delivery approach.

Keywords. Routing and Transportation – City Logistics – Heuristics and Metaheuristics.

References

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[2] C. Chen, E. Demir, Y. Huang, and R. Qiu. The adoption of self-driving delivery robots in last mile logistics. *Transportation Research Part E: Logistics and Transportation Review*, 146:102214, 02 2021.

Beating Highway Gridlock: Iterative User Equilibrium with Local Congestion Caps

F. Buffoli[1], C. Filippi[1], V. Morandi[1], M.G. Speranza[1]

[1]Department of Economics and Management, University of Brescia, Italy

We analyze a route–and–departure assignment problem on a time-expanded highway network. Given a set of OD trip requests, admissible departure slots, and exogenous background traffic over arc–time cells, the planner must assign each request to a path–departure option to minimize Total System Travel Time (TSTT) while enforcing a transparent, local cap on congestion measured by the Travel Time Index (TTI). We encode the TTI cap as a per–arc flow limit that scales with capacity, so links with more lanes can accommodate proportionally higher loads. System costs follow a Beckmann-type potential induced by a BPR latency; we approximate this potential with a tight piecewise-linear (PWL) envelope and align the last breakpoint with the TTI cap so that the feasible domain and the cost approximation coincide. The model employs an iterative User Equilibrium refinement strategy, starting from realistic initial travel times and converging in 2-3 iterations to ensure assigned routes reflect actual congestion patterns, with typical TSTT changes under 3% after the second iteration.

Keywords. Routing and Transportation – Graph Theory and Network Optimization – Linear and Nonlinear Programming.

References

[1] Martin Beckmann, Charles B McGuire, and Christopher B Winsten. Studies in the economics of transportation. Technical report, 1956.

[2] John Glen Wardrop. Some theoretical aspects of road traffic research. *Proceedings of the institution of civil engineers*, 1(3):325–362, 1952.

Last-mile Delivery with Autonomous Robots and Public Transport Lines

Antonino Carè[1,*], Alice Raffaele[2], Roberto Roberti[2], Sara Stoia[3], and Yanlu Zhao[4]

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In the routing literature, several papers investigate the collaboration of autonomous robots with traditional trucks, but only a very few deepen the integration of public transport (e.g.,[1]). In this work, motivated by an industrial case study, we define the *Public Transport-aided Robot Routing Problem*, including multiple trips and a robot load-dependent energy consumption model. First, we describe a MILP model based on a commonly employed node duplication strategy. Then, we present a novel compact model by representing the underlying network as a multi-graph, where vertices are the depot and the customers, and arcs represent alternative paths using public transport lines. We assess the performance of the two formulations over synthetic instances derived from the metro lines of Brescia, Rome, and Tokyo, and provide managerial insights.

Keywords. Routing and Transportation – Graph Theory and Network Optimization – City Logistics – Exact Methods.

References

[1] Annarita De Maio, Gianpaolo Ghiani, Demetrio Laganà, and Emanuele Manni. Sustainable last-mile distribution with autonomous delivery robots and public transportation. *Transportation Research Part C: Emerging Technologies*, 163:104615, 2024.

The Electric Vehicle Fleet Composition Problem with temperature considerations

Pierre Vendé[1,2,*], Ola Jabali[2], and Joe Naoum-Sawaya[1,3]

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[3]IE University, Segovia, Spain
[*]Corresponding author

We optimize the composition of an electric vehicle fleet considering several EV types, while explicitly accounting for the impact of daily temperature on energy consumption. The fleet must be dispatched from a depot to a set of sectors over a multi-day planning horizon that is long enough to cover all seasonal variations (365 days in our experiments). Each sector is characterized by an area, a daily density of demand points, and its demand must be served daily. Each EV type has a load capacity, a battery capacity, a purchase cost, and an operating cost. This operating cost is determined by the energy required to reach a sector, serve part of its demand points, and return to the depot. An EV's energy consumption rate changes on a daily basis due to temperature. Given the strategic nature of fleet composition, we approximate routing costs using continuous approximation. Our goal is to determine the optimal fleet composition and its operation. The fleet is available every day throughout the planning horizon. For each day, EVs must be dispatched to sectors so their combined load capacity can serve the demand. The objective is to minimize total EV purchase and operating costs over the planning horizon. We propose two MILP formulations for the problem, a lower bound based from a Lagrangian relaxation, and heuristic algorithm. We demonstrated that the latter two yield a competitive solution method for the problem.

Keywords. Routing and Transportation – Discrete and Combinatorial Optimization – Heuristics and Metaheuristics.

A Two-Stage Decomposition Method for the Electric Traveling Salesman Problem with Time Windows

Khaoula Kharfati[1,2,*], Francesca Guerriero[1], Giusy Macrina[1], Luigi Di Puglia Pugliese[3], and Ahmed Roubi[2]

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[3]Istituto di Calcolo e Reti ad Alte Prestazioni, Consiglio Nazionale delle Ricerche, Italy
[*]Corresponding author

We study the electric traveling salesman problem with time windows (E-TSPTW), where a single electric vehicle must visit all customers, while minimizing both routing and energy consumption. Energy usage is modelled as a nonlinear function of vehicle speed and carried load, leading to a mixed-integer nonlinear program (MINLP). To avoid linearization of the energy function, we adopt a two-stage framework based on Benders decomposition. The first stage solves a classical TSP to generate a feasible tour, while the second stage optimizes speeds on the selected arcs under time-window constraints. Feasibility and optimality cuts from the speed subproblem iteratively refine the master problem and guide convergence. Computational experiments on synthetic and benchmark instances show that the proposed nonlinear decomposition approach outperforms a standard linearized formulation, producing higher-quality solutions and improved numerical stability within comparable computational times.

Keywords. Routing and Transportation – Linear and Nonlinear Programming – Exact Methods.

Plenary Talk by Wolfram Wiesemann

Time: 11:40-12:40 **Chair:** Anthony Palmieri

Wolfram Wiesemann	Large-Scale and Data-Driven Markov Decision Processes

Large-Scale and Data-Driven Markov Decision Processes

Wolfram Wiesemann

Department of Analytics, Marketing & Operations, Imperial College Business School

Abstract. Markov decision processes (MDPs) constitute one of the predominant modeling and solution paradigms for dynamic decision problems affected by uncertainty. MDPs model the dynamics of a system through a random state evolution that generates rewards over time. The decision maker aims to select actions that influence this state evolution so as to maximize rewards. In this talk, we review recent advances in MDPs along two directions: (i) the construction of data-driven policies that combine the (traditionally separated) tasks of estimating the system's behavior and selecting actions that maximize rewards in the estimated system, and (ii) the exploitation of structure to solve large-scale problems. In view of (i), we will show how the consideration of data-driven policies naturally leads to the study of robust MDPs, where the decision maker combats overfitting by hedging against the worst system dynamics that are plausible under some given training data. We will also discuss how alternative models of robustness offer different trade-offs between the competing goals of out-of-sample performance and complexity of the involved policies and computations. As for (ii), we will review two types of structure that allow us to alleviate the well-known curse of dimensionality: weakly coupled MDPs that combine a potentially large number of MDPs via a small number of linking constraints, and factored MDPs whose states are represented by assignments of values to state variables that evolve and contribute to the system's rewards largely independently.

Short bio. Wolfram Wiesemann is Professor of Analytics & Operations at the Analytics, Marketing & Operations department at Imperial College Business School. His research interests evolve around decision-making under uncertainty, with applications to logistics, supply chain management and healthcare. Wolfram has served as an elected member of the boards of the Mathematical Optimization Society and the Stochastic Programming Society, and he currently serves as editor in-chief of Operations Research Letters as well as a department co-editor for Management Science.

Session II: Optimization under Uncertainty I

Time: 14:00-15:00 **Chair:** Lorenzo Perinello

Federica Donnini	Heuristics for two-stage stochastic K-adaptability
Hubert Villuendas	First-Order Methods for Distributionally Robust Mixed-Integer Optimization
Soroush Fatemi-Anaraki	Network Flexibility Design Under Endogenous Uncertainty

Heuristics for two-stage stochastic K-adaptability

Marianna De Santis[1] and Federica Donnini[1,*]

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[*]Corresponding author

Two-stage stochastic programs are used to model problems with uncertain data, where a decision maker first decides the values of first-stage variables, then observes the values of the uncertain data, and finally decides the values of the second-stage decisions. In many applications, however, it is convenient to only have a small set of precomputed second stage solutions from which to choose. The K-adaptability approach for two-stage problems under uncertainty calculates K second-stage solutions already in the first-stage. In the case where uncertainty can be modeled by a finite number of scenarios, the K-adaptability problem can be formulated as a minimization problem over all the possible partitions of the scenario set [1, 2]. We present new partition-based heuristic methods able to provide upper bounds for the K-adaptability problem for two-stage stochastic optimization. Experimental results on linear and quadratic knapsack and facility location problems are presented.

Keywords. Stochastic Programming – Heuristics and Metaheuristics.

References

[1] Christoph Buchheim and Jonas Pruente. K-adaptability in stochastic combinatorial optimization under objective uncertainty. *European Journal of Operational Research*, 277(3):953–963, 2019.

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First-Order Methods for Distributionally Robust Mixed-Integer Optimization

Hubert Villuendas[1]

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We consider combinatorial optimization problems in which some imput data are only partly observed or subject to estimation errors. When the probability distribution of uncertain parameters is unknown, one typically relies on a finite historical dataset to infer plausible distributions. In this context, Wasserstein Distributionally Robust Optimization (WDRO) has become a powerful framework, by its nice modeling and generalisation properties [1, 3].

In our work, we consider WDRO models involving combinatorial or discrete decision structures, for which we provide a new approach. We propose a tractable approach, based on the entropic regularization of the value function, which enables the computation of stochastic gradient estimators [2]. To tackle the problem, we propose to use a stochastic Frank–Wolfe algorithm to optimise the WDRO objective while preserving the combinatorial nature of the constraints. We illustrate our method on classical optimization problems, such as the minimum quadratic spanning tree and the facility location problem.

Keywords. Data-driven Optimization – Robust and Distributionally Robust Optimization – Decision-making under Uncertainty.

References

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[2] Vincent, Azizian, Iutzeler, and Malick. `skwdro`: a library for wasserstein distributionally robust machine learning. *arXiv preprint*, 2024.

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Network Flexibility Design Under Endogenous Uncertainty

Soroush Fatemi-Anaraki[1,*], Martin Grunow[1,2], Giovanni Pantuso[3], and Stefan Weltge[4]

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[3]Department of Mathematical Sciences, University of Copenhagen, Denmark
[4]Department of Mathematics, Technical University of Munich, Germany
[*]Corresponding author

In real-world supply networks, capacity and demand are uncertain. A hedging mechanism is to enable plants to produce multiple products, making them flexible. While adding flexibility can compensate for uncertainty, it decreases capacity due to changeovers between different products. Conversely, assigning fewer products to a plant allows for the use of specialized equipment and workforce, leading to higher efficiency (specialization effect). Additionally, the flexibility design affects demand as it determines whether a product is sourced from plants that are subject to high tariffs (consumers pay inflated prices) or the country-of-origin effect (influencing the consumer's perception). Motivated by this, we extend the traditional flexibility design literature to study supply networks in which supply and demand uncertainty depend on the flexibility design, i.e., the uncertainty is endogenous. We propose a two-stage stochastic programming model and solve it via a decomposition scheme that derives Benders cuts for individual distributions. We further derive multiple distribution-free inequalities that are valid for all or subsets of distributions to speed up the solution process. Through extensive computational experiments, we demonstrate the performance of our solution approach and provide managerial insights on the impact of endogenous uncertainty on flexibility design.

Keywords. Logistics and Supply Chain Management – Stochastic Programming – Mathematical Programming.

Session III: Scheduling and Timetabling I

Time: 15:00-16:00 **Chair:** Alessandro Druetto

Annalisa Castelletti	Batch Scheduling with Compatible Families and Setups: Enhanced MILP Formulations
Lorenzo Tomasetti	A Comprehensive Hybrid Flow Shop Scheduling Model for Steelmaking and Ingot Casting
Marco Zunino	University Timetabling with Professor Preferences: Exact and Heuristic Methods

Batch Scheduling with Compatible Families and Setups: Enhanced MILP Formulations

Annalisa Castelletti[1,*], Renata Mansini[1], and Lorenzo Moreschini[2]

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[2]Department of Design, Polytechnic of Milan, Milan, Italy
[*]Corresponding author

Motivated by an industrial application in scraps melting, this study addresses a scheduling problem on a single batch-processing machine with limited capacity, where jobs correspond to heterogeneous scraps to be melted. Jobs must be assigned to batches and processed simultaneously minimizing the overall makespan. The duration of each batch is determined by its dominant job (the one with the longest processing time), while sequence-dependent setup times arise from transitions between dominant families of consecutive batches, defined as those with the highest melting-temperature requirement within each batch. We strengthen the MILP formulation introduced in [1] by presenting alternative decision variables that more explicitly capture batch composition and sequencing, together with new classes of valid inequalities that tighten the linear relaxation and reinforce the modeling of dominance and setup interactions. Preliminary computational experiments confirm the effectiveness of the proposed improvements and provide a performance comparison with the original formulation.

Keywords. Discrete and Combinatorial Optimization – Industrial Production – Scheduling and Timetabling.

References

[1] Annalisa Castelletti, Renata Mansini, and Lorenzo Moreschini. A new parallel-batch scheduling problem with non-identical jobs, compatible families, and setup times. *IFAC-PapersOnLine*, 59(10):1023–1028, 2025.

A Comprehensive Hybrid Flow Shop Scheduling Model for Steelmaking and Ingot Casting

Renata Mansini[1] and Lorenzo Tomasetti[1,*]

[1]Department of Information Engineering, Università degli studi di Brescia, Brescia, Italy
[*]Corresponding author

Effective scheduling in steel-making is crucial for optimizing resource utilization and production flow, particularly in the comparatively underexplored ingot casting process. This research investigates an effective application of hybrid flow shop scheduling at the steel manufacturing facility level. The hybrid flow shop configuration manages the process of specified steel type via a series of consecutive processing phases, some of which may use parallel machines. The analyzed process has five consecutive stages: melting, preliminary refining, impurity elimination, ingot casting, and ingot solidification. We develop a mixed-integer linear programming formulation to accurately represent the system. The model incorporates additional constraints, including mandated transit times and no-wait conditions, as well as supplementary resources such as ladles and ingots. Unlike most existing studies, the proposed formulation considers alternative objective functions, addressing not only makespan minimization but also cost optimization related to raw material use. The model's performance is then thoroughly evaluated against the company's current solution

Keywords. Scheduling and Timetabling – Industrial Production – Discrete and Combinatorial Optimization

University Timetabling with Professor Preferences: Exact and Heuristic Methods

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[2]Facultad de Ingeniería, Universidad de la República, Montevideo, Uruguay

Abstract. University Course Timetabling is a combinatorial optimization problem, which scales significantly with the dimensions of the institution (e.g. number of courses and professors). This approach incorporates professors' preferences [1] within predefined time slots and employs a post-enrolment guided formulation in which students are clustered into groups. An exact method with Gurobi has been successfully applied at the Facultad de Ingeniería of the Universidad de Montevideo (FIUM), to handle simultaneous courses spanning five academic years, six study majors, and three time shifts. Performance statistics are presented together with a trade-off analysis addressing course overlaps, non-standard time slots, and the weekly distribution of professors' teaching hours. Building on these results, heuristics such as simulated annealing [2] and genetic algorithms are being tested to enhance solution times, scalability, and multi-objective evaluation.

Keywords. Scheduling and Timetabling – Discrete and Combinatorial Optimization – Multi-objective Optimization.

References

[1] F. Werner M. Chen and M. Shokouhifar. Mathematical modeling and exact optimizing of university course scheduling considering preferences of professors. *Axioms*, 12:498, 2023.

[2] L. Di Gaspero S. Ceschia and A. Schaerf. Design, engineering, and experimental analysis of a simulated annealing approach to the post-enrolment course timetabling problem. *Computers & Operations Research*, 39:1615–1624, 2012.

Session IV: Advances in Mathematical Programming I

Time: 16:30-17:30 **Chair:** Matteo Pernini

Diego Scuppa	A gradient method with momentum for Riemannian manifolds
Elisa Trasatti	Manifold optimization methods for the XY random field
Riccardo Tomassini	Combining discretization and exact penalty techniques in semi-infinite programming

A gradient method with momentum for Riemannian manifolds

Diego Scuppa[1,*]

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In this work, we consider smooth optimization problems on Riemannian manifolds and propose Riemannian Gradient Methods with Momentum [1], adapting a recent algorithm originally developed for unconstrained optimization [3]. We establish convergence results together with worst-case complexity bounds under milder assumptions than those required in existing works [4]. Numerical experiments on standard test problems are conducted, comparing the proposed method with state-of-the-art solvers available in the Manopt package [2]. The computational results demonstrate the effectiveness and robustness of the proposed approach.

Keywords. Mathematical Programming – Linear and Nonlinear Programming.

References

[1] N. Boumal. *An introduction to optimization on smooth manifolds*. Cambridge University Press, 2023.

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[4] T. Tang et al. A riemannian dimension-reduced second-order method with application in sensor network localization. *SISC*, 2024.

Manifold optimization methods for the *XY random field*

Ramgopal Agrawal[1], Lorenzo Ciarpaglini[2], Enzo Marinari[1], Marco Sciandrone[2], Diego Scuppa[2], and Elisa Trasatti[2,*]

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Complex systems, characterized by the presence of multiple equilibrium states, have attracted growing interest due to their ability to effectively describe numerous natural phenomena. This work analyzes a specific example of a complex system: the XY random field model [1]. The goal is to explore its energy landscape, identifying as many local minima as possible as the model parameters vary, while also aiming to determine the global minimum whenever feasible. To address this problem, an alternative approach to traditional statistical-mechanics methods, such as Monte Carlo techniques, is proposed by instead adopting a manifold optimization methodology [2]. This type of approach has proven to be more effective than classical optimization algorithms, offering advantages both in computational efficiency and in the ability to identify multiple solutions.

Keywords. Global Optimization – Mathematical Programming – Multi-objective Optimization.

References

[1] R. Agrawal and et al. Domain growth and aging in the random field xy model: A monte carlo study. *Phys. Rev. E*, 104:044123, 2021.

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Combining discretization and exact penalty techniques in semi-inifite programming

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Semi-infinite programming provides a natural mathematical framework for robust optimization, as the uncertainty on the feasible region may lead to infinitely many constraints. A classical approach to tackling such problems relies on discretization techniques, in which only a finite subset of constraints is considered and additional constraints are iteratively introduced to ensure convergence to a feasible solution. In this talk, we analyze how, under suitable regularity assumptions, exact penalty methods can be effectively combined with discretization techniques. In fact, we show that there exists a uniform exact penalty parameter for all discretized subproblems, enabling the design of algorithms that converge to stationary points of the original semi-infinite problem. Numerical experiments are reported on problems arising from production planning under uncertainty to demonstrate the effectiveness of the proposed approach.

Keywords. Mathematical Programming – Robust and Distributionally Robust Optimization–Linear and Nonlinear Programming.

Session V: Energy and Environmental Applications I

Time: 17:30-18:30 **Chair:** Martina Galeazzo

Andrea Spinelli	A Stochastic Electric Vehicle Routing Problem under Uncertain Energy Consumption
Pietro Girardis	A Three-Stage Lexicographic Constraint Programming Approach for an Energy-Efficient Scheduling Problem
Leena Aizdi	Energy-Aware Sequencing and Routing in GreenWarehouses by Integrating Energy Management Systems and Renewable Energy

A Stochastic Electric Vehicle Routing Problem under Uncertain Energy Consumption

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In this work [1], we address the Stochastic Electric Vehicle Routing Problem with a Threshold recourse policy (SEVRP-T). We account for uncertainty in electric vehicle energy consumption and employ a recourse policy to ensure that vehicles recharge at charging stations when their state of charge falls below a predefined threshold. We formulate the SEVRP-T as a two-stage stochastic mixed-integer model and solve it with a heuristic combining an Iterated Local Search procedure with a Set Partitioning formulation. The approach is validated through extensive computational experiments.

Keywords. Stochastic Programming – Routing and Transportation – Decision-making under Uncertainty.

References

[1] A. Spinelli, D. Bezzi, O. Jabali, and F. Maggioni. A stochastic electric vehicle routing problem under uncertain energy consumption. *Transp. Res. Part C Emerg. Technol*, 2026. doi: doi.org/10.1016/j.trc.2025.105480.

A Three-Stage Lexicographic Constraint Programming Approach for an Energy-Efficient Scheduling Problem

Pietro Girardis[1,*], Mirko Cavecchia[1], and Manuel Iori[1]

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The growing complexity of energy market regulations and the increasing demand for energy require modern industries to adopt advanced techniques and technologies for scheduling. The presented study contributes to this effort by addressing an energy-efficient scheduling problem arising in a real-world consortium responsible for the storage, distribution, and sale of apples. The task consists in coordinating the daily refrigeration cycles of a set of cells whose availability varies stochastically. Each cell must alternate between cooling and non-cooling phases while satisfying specific constraints. The problem is modeled as an energy-efficient identical parallel machine scheduling problem with sequence constraints, pursuing three different objectives: (i) minimizing the peak of cells in the cooling phase simultaneously, (ii) ensuring a balanced temporal distribution of cooling cycles, and (iii) guaranteeing robustness across all scenarios of cell availability. The problem has been solved with a three-stage lexicographic constraint programming approach, where each stage aims to solve one of the three objectives while maintaining the solution found in the previous phase. Computational experiments based on real data demonstrate the effectiveness of the proposed method.

Keywords. Scheduling and Timetabling – Decision-making under Uncertainty – Discrete and Combinatorial Optimization.

Energy-Aware Sequencing and Routing in Green Warehouses by Integrating Energy Management Systems and Renewable Energy

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Driven by the growing need for sustainability, we introduce a novel Energy-Aware Green Sequencing and Routing Problem (EGSRP) [1], formulated through Mixed-Integer Linear Programming, jointly optimizing an Energy Management System (EMS) and operations in a grid-connected warehouse with photovoltaic (PV) generation, battery storage (BS), fuel-based and electric vehicles (EVs). The EMS optimizes energy flows between the grid, PV, BS, and warehouse. Operations include storage/retrieval task sequencing and assignment to vehicles, vehicle routing, and EVs charging. A matheuristic algorithm is developed to solve real-case instances efficiently, with results confirming cost-savings and energy self-sufficiency. Aligned with the conference theme, this approach frames future research to address inherent uncertainties, e.g., in PV generation and energy pricing.

Keywords. Logistics and Supply Chain Management – Energy, Environment, and Natural Resources – Mathematical Programming.

References

[1] Leena Aizdi, Giacomo Lanza, Mauro Passacantando, Maria Grazia Scutellà, Silvia Siri, and Stefano Bracco. Integrating energy management systems and renewable energy sources in green warehouses: the energy-aware green sequencing and routing problem. *International Journal of Production Research*, 0(0):1–27, 2025. doi: 10.1080/00207543.2025.2561776.

Day 3

Wednesday, February 11th, 2026

Session I: Network Optimization I

Time: 9:00-10:00 **Chair:** Gabriele Sanguin

Eleonora Bellesso	Analysis of a general regularized continuous formulation for the maximum s-plex problem
Roberto Ronco	On the Spectrum of Path-Length Density Matrices of Unrooted Binary Trees
Stefano Ardizzoni	Shortest Path Problem with Functional Edge Costs

Analysis of a general regularized continuous formulation for the maximum s-plex problem

Eleonora Bellesso[1*], Francesco Rinaldi[1], and Immanuel M. Bomze[2]

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Community detection is an important task in social network analysis. In this study, we focus on the s-plex clique relaxation model which allows each member to have at most $s - 1$ non-neighbours inside the relaxed structure. In particular, we provide a continuous regularized optimization framework for the maximum s-plex problem, where we consider a broad class of regularization terms that can be included in the Motzkin-Straus continuous formulation [2]. Inspired by previous results and techniques used to provide a regularization framework for the maximum clique problem [1], we then develop conditions that guarantee the local (and global) equivalence between the continuous regularized problem and the original one. We further analyze some regularized functions that meet the detected conditions.

Keywords. Graph Theory and Network Optimization – Mathematical Programming – Network Analytics.

References

[1] J. T. Hungerford and F. Rinaldi. A general regularized continuous formulation for the maximum clique problem. *Math. Oper. Res.*, 44: 1161–1173, 2019.

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On the Spectrum of Path-Length Density Matrices of Unrooted Binary Trees

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An *Unrooted Binary Tree* (UBT) is a tree with $n \geq 3$ leaves, $n-2$ internal nodes of degree three, and $2n-3$ edges. In several contexts arising from information theory and the life sciences, a UBT T can be conveniently encoded by means of a *Path-Length Density Matrix* (PLDM), i.e., a symmetric matrix of order n having null diagonal entries and off-diagonal entries equal to $2^{-\tau_{ij}}$, where τ_{ij} denotes the number of edges along the unique path in T between leaves i and j [1]. In this work, we investigate the extent to which the spectrum of a PLDM reflects the topology of the underlying UBT. We prove that all eigenvalues of a PLDM of a UBT T lie in the interval $\left[-\frac{1}{4}, \frac{1}{2}\right]$ and that specific families of rational eigenvalues can be associated with well-identified subtrees of T obtained through a recursive merging of characteristic subtopologies. For extremal tree structures, we further derive closed-form expressions for the whole spectrum that highlight an explicit link between the tree topology and its spectral properties.

Keywords. Graph Theory and Network Optimization – Discrete and Combinatorial Optimization.

References

[1] D. Catanzaro, R. Pesenti, and R. Ronco. On the spectrum of path-length density matrices of unrooted binary trees, 2025. CORE, UCLouvain.

Shortest Path Problem with Functional Edge Costs

Stefano Ardizzoni[1,*], Luca Consolini[1], Mattia Laurini[1], and Marco Locatelli[1]

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We introduce a generalization of the Shortest Path Problem (SPP) on graphs called the Shortest Path Problem with Functional Edge Costs (FSPP), where each arc cost is expressed as a function of two real variables. We consider a graph $G = (V, A)$. For each arc $(a, b) \in A$ we define a function arc cost $c_{ab} : \mathbb{R}^2 \to \mathbb{R}$. Given two nodes $o, d \in V$ we define $\mathcal{P}_{od}$ the set of path from o to d. Given a path $P \in \mathcal{P}_{od}$, let $\mathbf{w} \in \mathbb{R}^{|P|+1}$ be the vector of variables associated with the nodes in P, each bounded between its corresponding lower and upper limits. For every arc $(P(k), P(k+1)) \in P$, with $k = 1, \dots, |P|$, the cost incurred on that arc is $c_{P(k)\,P(k+1)}\big(w_k, w_{k+1}\big)$. We aim to determine both a path $P \in \mathcal{P}_{od}$ and a vector of node variables $\mathbf{w} \in \mathbb{R}^{|P|+1}$ that minimize the total cost of travelling from o to d. Finding the optimal solution P^* of this problem is NP-hard. Therefore, we present an approximation algorithm for FSPP with a complexity that is polynomial with respect to the size of the data of the original problem and the inverse of the approximation factor. The idea is to discretize the variable $\mathbf{w}$ in order to obtain a finite set of possible values of it. In this way, we can define an extended graph that enables us to solve this discretized version of the problem by means of some shortest path algorithm. Let h be the discretization step, we denote with P^h the optimal solution of the discretized problem and with $F^h(P^h)$ the corresponding optimal value. Assuming that for each $(a, b) \in A$, c_{ab} is locally Lipschitz continuous at each point of the domain, and that the length of the optimal solution P^* is bounded, we prove that for h small enough the absolute error $F^h(P^h) - F(P^*)$ is bounded by a fixed constant $\epsilon \in (0, 1)$.

Keywords. Graph Theory and Network Optimization – Discrete and Combinatorial Optimization.

Plenary Talk by Stefan Røpke

Time: 10:30-11:30 **Chair:** Francesco Cavaliere

Stefan Røpke	Vehicle Routing Problems

Vehicle Routing Problems

Stefan Røpke

Department of Management Engineering, Technical University of Denmark

Abstract. Vehicle routing problems (VRPs) form a central class of optimization problems in operations research, with many practical applications. This talk provides a tutorial-style overview of key VRP variants and reviews state-of-the-art exact and heuristic solution techniques. We then highlight several problem extensions that have attracted significant research interest in recent years, driven by new application domains. The talk concludes with a forward-looking discussion of emerging research directions in vehicle routing, with particular emphasis on the integration of machine learning into routing algorithms.

Short bio. Stefan Røpke has been Professor of Operations Research at the Technical University of Denmark since 2012. His research has provided numerous contributions on exact and heuristic methods to solve routing and logistics problems, including the well-known Adaptive Large Neighborhood Search meta-heuristic, co-authored with David Pisinger.

Session II:
Scheduling and Timetabling II

Time: 11:30-12:30 **Chair:** Martina Doneda

Alice Daldossi	Building a fair and efficient surgical unit: insights from academic vascular surgery
Sara Cambiaghi	A Column-Generation Approach to Joint Master Surgical Scheduling and Case Assignment under Bed Capacity Constraints
Martina Doneda	An ILP approach to urgent patient management in an orthopedic department

Building a fair and efficient surgical unit: insights from academic vascular surgery

Alice Daldossi[1,*], Roberto Aringhieri[1], Alessandro Druetto[1], and Davide Duma[2]

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Surgical departments must coordinate patient priorities, operating room (OR) capacity, and staff availability [1]. In academic hospitals, this complexity grows due to the need to offer equitable resident training while ensuring timely care [2]. Residents follow a structured, multi-year learning path, making balanced exposure to procedures essential. Balancing these goals is key to efficient OR management.

We address a scheduling problem that integrates trainee assignment into surgical timetabling, aiming to balance fair training opportunities with efficient OR use. Validation uses data from the Vascular Surgery Unit of the Città della Salute e della Scienza Hospital (Molinette), Turin, collected between 2018 and 2025.

Keywords. Scheduling and Timetabling – Health Care and Outbreak Management – Multi-objective Optimization.

References

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[2] A. Testi, , E. Tanfani, R. Valente, G.L̃. Ansaldo, and G.C̃. Torre. Prioritizing surgical waiting lists. *Journal of Evaluation in Clinical Practice*, 1: 59–64, 2008.

A Column-Generation Approach to Joint Master Surgical Scheduling and Case Assignment under Bed Capacity Constraints

Sara Cambiaghi[1,*], Saverio Basso[2], Davide Duma[1], and Matteo Salani[2]

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[*]Corresponding author

In hospital management, operating room scheduling involves strategic, tactical, and operational decisions, ranging from long-term resource allocation to patient assignment and sequencing [1]. We address a joint Master Surgical Scheduling and Surgical Case Assignment problem in a week-surgery context, incorporating the management of hospital beds to minimize patient hospitalization over weekends, as well as maximizing patient priority. The problem is solved using a column-generation approach, in which each subproblem is formulated as a shortest-path problem and solved with the PathWyse library [2].

Keywords. Health Care and Outbreak Management – Scheduling and Timetabling – Exact Methods.

References

[1] R. Aringhieri, D. Duma, P. Landa, and S. Mancini. Combining workload balance and patient priority maximisation in operating room planning through hierarchical multi-objective optimisation. *European Journal of Operational Research*, 2022.

[2] M. Salani, S. Basso, and V Giuffrida. Pathwyse: a flexible, open-source library for the resource constrained shortest path problem. *Optimization Methods and Software*, 2024.

An ILP approach to urgent patient management in an orthopedic department

Martina Doneda[1*], Alberto Brigatti[1,2], Silvia Goglio[2], Silvia Scetti[2], Federico Chiodini[2], Luca Grion[2], Giuliana Carello[3], and Ettore Lanzarone[1]

[1]DIGIP, University of Bergamo
[2]ASST Papa Giovanni XXIII Bergamo
[3]DEIB, Politecnico di Milano

We present an ILP-based tool for surgical scheduling in an orthopedic department, addressing the challenge of managing a patient mix of elective and urgent cases– who require prioritized intervention do not qualify for emergency surgery. Given the growing importance of balancing efficiency and fairness, exacerbated by the backlogs in elective waiting lists induced by the COVID-19 pandemic [2], our model pursues ward efficiency while ensuring equitable patient treatment [1]. The approach is validated using real data from the orthopedic department of ASST Papa Giovanni XXIII in Bergamo, Italy. Its performance is evaluated under different levels of uncertainty regarding urgent arrivals and surgery durations, and benchmarked against schedules used in practice. Results indicate the potential of our methodology in improving operational performance.

Keywords. Decision Support Systems – Health Care and Outbreak Management – Scheduling and Timetabling.

References

[1] B Addis, G Carello, A Grosso, and E Tànfani. Operating room scheduling and rescheduling: a rolling horizon approach. *Flexible Services and Manufacturing Journal*, 28(1):206–232, 2016.

[2] E van Ginneken, L Siciliani, S Reed, A Eriksen, F Tille, T Zapata, et al. Addressing backlogs and managing waiting lists during and beyond the COVID-19 pandemic. 2022.

Session III: Transportation and Logistics II

Time: 14:00-15:00 **Chair:** Matteo Cosmi

Cevat Enes Karaahmetoglu	Multiobjective Route Planning for Multi-Truck Multi-UAV Operations: Multi-Visit Sorties and Flexible Rendezvous Points
Paolo Beatrici	A Benders decomposition approach for a green bi-objective stochastic fleet size and mix vehicle routing problem
Veronica Mosca	Multi-Quality Multi-Objective Green VRP with Air-Conditioning Systems

Multiobjective Route Planning for Multi-Truck Multi-UAV Operations: Multi-Visit Sorties and Flexible Rendezvous Points

Cevat Enes Karaahmetoğlu[1,*] and Diclehan Tezcaner Öztürk[1]

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Hybrid ground–air operations have emerged as an important area in logistics, combining the speed of unmanned aerial vehicles (UAVs) with the endurance of trucks. This study addresses a multi-truck, multi-UAV routing and scheduling problem that jointly considers multi-visit sorties, flexible rendezvous points, battery limits and restricted zones. Two objectives, minimization of makespan and energy related operational costs, are considered. To find the non-dominated frontier of this problem, we propose a decomposition strategy in which truck routing and UAV sortie planning are decoupled via a graph-based resource-constrained shortest path (RCSP) kernel to generate feasible efficient sorties. On top of this core, we plan to design a multiobjective genetic algorithm . Additionally, we are aiming to incorporate learning-enhanced mechanisms in the genetic algorithm inspired by [1]. The expected contribution is a scalable framework that can effectively balance trade-offs in complex hybrid ground–air fleets.

Keywords. Routing and Transportation – Multi-objective Optimization – Heuristics and Metaheuristics.

References

[1] A. Bogyrbayeva, T. Yoon, H. Ko, S. Lim, H. Yun, and C. Kwon. A deep reinforcement learning approach for solving the traveling salesman problem with drone. *Transportation Research Part C: Emerging Technologies*, 148:103981, 2023. doi: 10.1016/j.trc.2022.103981.

A Benders decomposition approach for a green bi-objective stochastic fleet size and mix vehicle routing problem

Paolo Beatrici[1,*], Francesca Maggioni[1], Mike Hewitt[2], Sebastian Birolini[1], and Paolo Malighetti[1]

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Last Mile logistics increasingly requires balancing cost efficiency with environmental performance, especially when customer demand is uncertain. This work introduces a two-stage bi-objective stochastic mixed-integer programming model that jointly optimizes fleet size, fleet composition, and vehicle routing while explicitly accounting for vehicle emissions. The first stage defines tactical decisions on fleet dimensioning, vehicle types, and routing plans; the second stage manages parcel allocation and the possible outsourcing of selected deliveries to external providers. The bi-objective structure is handled through the ε-constraint method. To address the computational complexity of realistic problem sizes, an adapted L-shaped algorithm is developed and integrated within the ε-constraint framework. Numerical results show that the proposed approach yields cost-effective solutions within short computational times. The performance of deterministic solutions is also evaluated in the stochastic multi-objective setting, and managerial insights are discussed.

Keywords. Routing and Transportation – Multi-objective Optimization – Stochastic Programming.

Multi-Quality Multi-Objective Green VRP with Air-Conditioning Systems

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Perishable products are goods whose quality is susceptible to degradation, especially depending on storage temperatures and travel times. To prevent excessive spoilage, it is important to monitor shipping conditions. Furthermore, products may come from different suppliers and therefore have different initial qualities. To mitigate the risk of deterioration and ensure products reach customers at an acceptable quality level, it is imperative to check product quality along the supply chain [1]. The objective of the proposed model is to maximize the quality level of the product delivered to the customer while minimizing the environmental impact of the route execution and the cost of routing activities. The problem is formulated as a multi-quality multi-objective vehicle routing problem with heating/cooling systems, and tested on both Solomon benchmark and realistic instances.

Keywords. Routing and Transportation – Multi-objective Optimization – Logistics.

Acknowledgement. This work was supported by grants awarded by the project Tech4You - Technologies for Climate Change Adaptation and Quality of Life Improvement, identification code ECS 00000009, CUP H23C22000370006.

References

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Session IV: Heuristics and Meta-heuristics

Time: 15:00-16:00 **Chair:** Marta Leonina Tessitore

Elisa Savio	A Tabu Search for the Three-Dimensional Block Relocation Problem with Item Families
Seyyedeh Reihaneh Naghib Hosseini	Minimizing the Energy Consumption of Terminal Vehicles for Stowage Planning
Enrico Brambilla	Relax-and-Explore Kernel Search for Multidimensional Multiple-Choice Knapsack Problems

A Tabu Search for the Three-Dimensional Block Relocation Problem with Item Families

Elisa Savio[1,*], Alice Raffaele[2], Pasquale Claudio Africa[1], Loris Busolini[3], Laura Meneghetti[1], Gianluigi Rozza[1], and Matteo Sandri[3]

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Motivated by a real-world application from Danieli Automation S.p.A. in industrial warehouse management, the *Three-Dimensional Block Relocation Problem with Item Families* (3D-BRPIF) is an $\mathcal{NP}$-hard problem in which a set of items, divided into families based on their features, are stored in a yard comprising multiple bays. Given a single crane and a family retrieval sequence, the goal is to find an optimal movement sequence for the crane to retrieve a subset of items that satisfies the output sequence, minimizing the total crane time or the number of relocations. We tackle the 3D-BRPIF by presenting a MILP model and a tailored Tabu Search metaheuristic. We test our approaches on two benchmark sets from the literature [1, 2], as well as a third set from Danieli's case study, and show preliminary results.

Keywords. Heuristics and Metaheuristics – Industrial Production – Logistics and Supply Chain Management.

References

[1] Sven Boge and Sigrid Knust. The blocks relocation problem with item families minimizing the number of reshuffles. *OR Spectrum*, 45(2):395 – 435, 2023.

[2] Yusin Lee and Yen-Ju Lee. A heuristic for retrieving containers from a yard. *Computers & Operations Research*, 37(6):1139–1147, 2010.

Minimizing the Energy Consumption of Terminal Vehicles for Stowage Planning

Seyyedeh Reihaneh Naghib Hosseini[1,*], Massimo Paolucci[2], and Anna Franca Sciomachen[1]

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Efficient stowage planning is increasingly important as terminals seek to reduce energy use and maintain smooth operations. Several studies propose heuristics for the master bay plan problem [1], and recent works focus on improving energy consumption and operational efficiency [2]. We present a three phase fast heuristic that converts an aggregate stowage plan into a detailed bay–row–tier allocations for export containers. The yard-to-ship vehicle travel distance is minimized, while lowering energy consumption and emissions, also accounting for container weight, size and type, and yard distance. The heuristic proceeds through of tier-by-tier assignments. A mixed-integer programming model is developed to validate the heuristic behavior using data from a real container terminal.

Keywords. Logistics and Supply Chain Management – Heuristics and Metaheuristics

References

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Relax-and-Explore Kernel Search for Multidimensional Multiple-Choice Knapsack Problems

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We introduce the Relax-and-Explore Kernel Search (REKS), a novel matheuristic framework for the Multidimensional Multiple-choice Knapsack Problem (MMKP), addressing key limitations of classical Kernel Search (KS) methods. REKS overcomes the strong dependence on Linear Programming (LP) relaxation and sensitivity to bucket size by employing a controlled-relaxation mechanism: it identifies highly promising variables by solving a sequence of restricted Mixed-Integer Linear Programs (MILPs) with incrementally relaxed resource constraints.

Furthermore, REKS incorporates a robust incremental bucket-exploration strategy that dynamically enlarges subproblems during the search, mitigating the traditional reliance on a fixed bucket size and enhancing robustness. These core components are integrated into a multi-policy parallel search scheme for strong diversification and intensification.

REKS constitutes a general matheuristic framework adaptable to a broad class of MILP problems. Extensive computational evidence on standard MMKP benchmarks demonstrates the effectiveness of REKS, matching or improving upon the best-known solutions for many long-standing open instances, confirming its status as a uniquely powerful performer in this domain.

Keywords. Mathematical Programming – Discrete and Combinatorial Optimization – Heuristics and Metaheuristics.

Session V: Optimization under Uncertainty II

Time: 16:00-17:00 **Chair:** Martina Galeazzo

Arianna Freda	Cost-Aware Scheduling under Uncertainty: An Optimization Model for Heart Donor Management
Giovanni Spisso	The Maximum Clique Problem under Adversarial Uncertainty: a min-max approach
Yasmany Fernández Fernández	Hybrid Strategy in the Robust Evacuation Problem Considering Network Complexities

Cost-Aware Scheduling under Uncertainty: An Optimization Model for Heart Donor Management

Alessandro Agnetis[1], Arianna Freda[2,*], Piero Ghersi[1], Gaia Nicosia[2], Andrea Pacifici[3], and Marco Pranzo[1]

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In this work, we introduce a general cost-aware project scheduling model that incorporates probabilistic activity outcomes into the optimization of time-critical processes. The framework addresses settings in which each activity is characterized by a duration, a cost, and a success probability, and where delays may have severe consequences. To capture these features, we model the problem of determining the optimal ordering and timing of tasks, so as to minimize expected total cost while ensuring completion within strict deadlines, as a Mixed Integer Linear Programming model. Moreover, to assess the practical relevance of this approach, we apply the model to the pre-transplant assessment phase of the heart donation process, a context where multiple diagnostic tasks must be scheduled under strict time constraints and uncertain donor suitability outcomes. This case study highlights how explicitly modeling uncertainty can prevent inefficient task ordering and costly delays, thereby supporting more informed decision-making in high-stakes clinical settings. Beyond this application, the proposed framework is broadly applicable to project scheduling problems with uncertainty, cost considerations, and strict time requirements.

Keywords. Decision-making under Uncertainty – Planning and Project Management – Mathematical Programming.

The Maximum Clique Problem under Adversarial Uncertainty: a min-max approach

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We study the problem of identifying large cliques in graphs subject to adversarial uncertainty. The adversarial maximum clique problem extends the classical formulation by allowing an adversary to strategically perturb edges, modeled as a two-player zero-sum game. Using regularized continuous reformulations [1, 2], we derive a penalized model that yields a nonconvex and nonsmooth optimization problem. We introduce stable global solutions—points that remain optimal under small perturbations—and show that they correspond to largest cliques common to all adversarially perturbed graphs. To solve the model, we develop a projection-free first-order method based on Clarke–Goldstein generalized subgradients with a global $O(1/\sqrt{k})$ rate. Numerical experiments demonstrate that the approach efficiently identifies large common cliques.

Keywords. Decision-making under Uncertainty – Graph Theory and Network Optimization – Linear and Nonlinear Programming.

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[2] Immanuel M. Bomze, Francesco Rinaldi, and Damiano Zeffiro. Fast cluster detection in networks by first-order optimization. *SIAM Journal on Mathematics of Data Science*, 4:285–305, 2022.

Hybrid Strategy in the Robust Evacuation Problem Considering Network Complexities for Humanitarian Logistic Tasks

Yasmany Fernández-Fernández[1,2,*], Sira M. Allende Alonso[1], Ridelio Miranda Pérez[3], and Gemayqzel Bouza Allende[1]

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[3]Universidad de Cienfuegos, Cienfuegos, Cuba
[*]Corresponding author

Evacuation planning in hazard-prone areas requires coupling network design with vehicle scheduling under uncertainty. We propose a hierarchical metamodel integrating two-stage stochastic programming and robust optimization. At the first level, a family-based multi-source–multi-sink network flow formulation assigns indivisible family units to discrete paths, accounting for heterogeneous family sizes, transit nodes, and capacity-constrained shelters. At the second level, a robust fleet-scheduling model allocates a heterogeneous vehicle fleet over a discretized time horizon, enforcing capacity and temporal constraints while protecting against uncertainty via box-type uncertainty sets. The hybrid strategy pre-identifies and packs candidate routes from the deterministic network, reducing combinatorial complexity before the robust scheduling layer. This yields a tractable framework preserving network connectivity while capturing scenario-dependent demand and worst-case delays. Computational experiments show improved coverage and temporal robustness with limited additional cost compared to deterministic baselines. The methodology is implemented in a Python prototype with visualizations for civil protection agencies.

Keywords. Decision-making under uncertainty – Stochastic Programming – Robust and Distributionally Robust Optimization

Day 4

Thursday, February 12th, 2026

Session I:
Network Optimization II

Time: 9:00-10:00 **Chair:** Anthony Palmieri

Luca Pirolo	Optimal location of e-bike chargers on touristic cycleway networks
Fabio Ciccarelli	Branch-and-price strikes back for the k-vertex cut problem
Nikola Kovačević	Network design and material flow simulation for wood value chains

Optimal location of e-bike chargers on touristic cycleway networks

Luca Pirolo*[1], Pietro Belotti[1], Federico Malucelli[1], Rossella Moscarelli[2], and Paolo Pileri[2]

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[2]Dipartimento di Architettura e Studi Urbani, Politecnico di Milano, Milano, Italy
*Corresponding author

In recent years, with the rise of electrically assisted bicycles within the field of cycling mobility, the planning of charging infrastructure for e-bikes has become a strategic element in supporting the development of cycling tourism. At the same time, considering the socio-demographic conditions of the Italian territory, cycling tourism can act as a driving force for fostering territorial regeneration processes in marginal areas.

In this work, we propose a Set Covering Problem model to identify the optimal location of e-bike charging stations along cycle tourism routes and within cycling networks characterized by small towns, villages, and hamlets, as well as major tourist attractions, so that charging points can serve as catalysts for new micro-economies and help reduce the risk of depopulation. The objective is to ensure adequate territorial coverage while minimizing the number of stations to be installed, taking into account vehicle-related requirements such as battery capacity and riding range, planning constraints such as budget, and local socio-economic potential.

The developed solution algorithm reduces the computational complexity of the problem and achieves improved computational performance. Preliminary results show that appropriate optimization of the infrastructure can support sustainable development policies, enhance less central territories, and promote a more responsible use of resources.

Keywords. Covering and Location – Discrete and Combinatorial Optimization – Graph Theory and Network Optimization.

Branch-and-price strikes back for the k-vertex cut problem

Fabio Ciccarelli[1,*], Fabio Furini[1], Christopher Hojny[2], and Marco Lübbecke[3]

[1]Department of Computers, Control and Management Engineering, Sapienza University of Rome, Rome, Italy
[2]Department of Mathematics and Computer Science, Eindhoven University of Technology, Eindhoven, The Netherlands
[3]Chair of Operation Research, RWTH Aachen, Aachen, Germany
[*]Corresponding author

We study the k-vertex cut problem (k-VCP), which seeks a minimum-cost set of vertices whose removal partitions a graph into at least k connected components. We propose a new exact algorithm based on a strengthened branch-and-price framework, integrating refined pricing schemes, problem-specific branching rules, valid inequalities, symmetry-handling techniques and a new primal heuristic. The method relies on a novel extended ILP formulation that unifies and strengthens existing models, supported by theoretical results on its structure and relaxation quality. The algorithm is implemented in SCIP, and it significantly outperforms existing exact methods. Extensive computational experiments against state-of-the-art methods demonstrate substantially improved performance, both in terms of instances solved to proven optimality and running times. On the full benchmark of 608 instances, our algorithm consistently outperforms all competitors and is able to solve 73 previously unsolved instances within the time limit of one hour.

Keywords. Exact Methods — Discrete and Combinatorial Optimization -– Graph Theory and Network Optimization.

Network design and material flow simulation for wood value chains

Nikola Kovačević[1,*] and Balázs Dávid[1,2]

[1]UP FAMNIT, University of Primorska, Koper, Slovenia
[2]InnoRenew CoE, UP IAM, University of Primorska, Koper, Slovenia
[*]Corresponding author

This work studies how redirecting lower-quality wood from its traditional use as energy [2] towards higher-value alternative applications could reshape material flows in wood value chains [1]. We propose a two-stage hybrid approach: a mixed-integer linear programming model to design network layout based on product demands, combined with a discrete event simulation layer that evaluates network performance under uncertainties in supply, production yield, and reuse rates.

Keywords. Logistics and Supply Chain Management – Network Analytics – Energy, Environment, and Natural Resources

Acknowledgements: The authors gratefully acknowledge the Slovenian Research and Innovation Agency (ARIS) and the Ministry of the Economy, Tourism and Sport (MGTŠ) for the grant V4-2512.

References

[1] Jue Mo, Eva Haviarova, and Manja Kitek Kuzman. Wood-products value-chain mapping. *Wood Material Science & Engineering*, 19(4):955–965, 2024. doi: 10.1080/17480272.2024.2328787. URL `https://doi.org/10.1080/17480272.2024.2328787`.

[2] Špela Ščap and Matevž Triplat. Utilisation, market volumes and projections of the potential of hardwood roundwood in slovenia. *Les/Wood*, 72(1):5–20, Jul. 2023. doi: 10.26614/les-wood.2023.v72n01a02. URL `https://journals.uni-lj.si/les-wood/article/view/13197`.

Plenary Talk by Martine Labbé

Time: 10:30-11:30 **Chair:** Matteo Pernini

Martine Labbé

Solving Chance-Constrained (mixed integer) Linear Optimization Problems with Branch-and Cut

Solving Chance-Constrained (mixed integer) Linear Optimization Problems with Branch-and Cut [a]

Martine Labbé

Department of Computer Science, Université Libre de Bruxelles

Abstract. We consider chance-constrained optimization problems (CCOPs), where constraints with random coefficients must hold with probability above a given threshold. Such problems arise frequently in energy applications and are NP-hard. In the linear case with random data of finite support, CCOPs can be reformulated as mixed-integer linear programs using big-M constants. We propose a Branch-and-Cut algorithm for linear CCOPs, introducing new valid inequalities and analyzing their closures. Theoretical and computational results demonstrate the strength of these inequalities compared to existing ones, confirming the effectiveness of the proposed approach.

Short bio. Martine Labbé is an honorary professor at the Université Libre de Bruxelles. She was a full professor from 2000 to 2019 and was president of EURO between 2007 and 2008. She has contributed substantially to various topics, including bilevel optimization, network optimization, location problems, routing, and machine learning. In 2019, she was the first female researcher to receive the EURO Gold Medal, the highest distinction in our field in Europe.

[a] This is a joint work with Diego Cattaruzza, Matteo Petris, Marius Roland and Martin Schmidt.

Session II: Transportation and Logistics III

Time: 11:30-12:30 **Chair:** Sara Stoia

Alessia Ciacco	Steiner Traveling Salesman Problem with Time Windows and Pickup–Delivery: integrating classical and quantum optimization
Carlo Maria Aloe	Bi-Objective Programming for Time–Energy AS/RS Cycle Planning in Single-Deep Racking
Sara Stoia	Crowdshipping and Locker Solutions for Dynamic Last-Mile Delivery

Steiner Traveling Salesman Problem with Time Windows and Pickup–Delivery: integrating classical and quantum optimization

Alessia Ciacco[1,*], Francesca Guerriero[1], and Eneko Osaba[2]

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[*]Corresponding author: alessia.ciacco@unical.it

We propose the *Steiner Traveling Salesman Problem with Time Windows and Pickup & Delivery* (STSP-TWPD). This variant integrates three key aspects: partial network coverage, time-window constraints and pickup–delivery precedence relations. We propose two mixed-integer formulations (an Arc-Based Formulation and a Node-Based Formulation) and a preprocessing reduction method that removes redundant arcs using temporal, spatial and precedence dominance rules. Beyond classical optimization with Gurobi, we also explore a hybrid quantum approach by implementing both models using D-Wave's `LeapCQMHybrid` solver [1], based on the Constrained Quadratic Model framework, which allows explicit constraint handling, reduces penalty tuning and preserves the structure of the original formulations.

Keywords. Routing and Transportation – Logistics and Supply Chain Management – Discrete and Combinatorial Optimization

References

[1] Alessia Ciacco, Francesca Guerriero, and Giusy Macrina. Review of quantum algorithms for medicine, finance and logistics. *Soft Computing*, 29(4):2129–2170, 2025.

Bi-Objective Programming for Time–Energy AS/RS Cycle Planning in Single-Deep Racking

Carlo Maria Aloe[1,*] and Maria Truvolo[1]

[1]Department of Mechanical, Energy and Management Engineering, University of Calabria, Italy
[*]Corresponding author

This paper investigates multi-objective optimization for Automated Storage and Retrieval Systems (AS/RS), key innovation in internal logistics, focusing on the optimization of stacker crane storage and retrieval operations through single-command and dual-command cycles. The problem is modeled as a bi-objective non-balanced assignment problem that minimizes both total cycle time and energy consumption, capturing the trade-off between productivity and sustainability. The lexicographic and the augmented ϵ-constraint methods are analyzed and compared with a mono-objective time-based approach. Computational results show that the augmented ϵ-constraint method offers greater flexibility in exploring the Pareto frontier and better supports decision-making in AS/RS operations.

Keywords. Discrete and Combinatorial Optimization – Logistics and Supply Chain Management – Multi-objective Optimization.

References

[1] Annarita De Maio et al. Configuration of an automated storage and retrieval system via simulation. In *International Conference on Harbour, Maritime and Multimodal Logistics Modelling and Simulation*. I3M Conference, 2024.

Crowdshipping and Locker Solutions for Dynamic Last-Mile Delivery

Sara Stoia[1,*], Demetrio Laganà[1], Jeffrey W. Ohlmann[2], and Francesca Vocaturo[3]

[1]Department of Mechanical, Energy and Management Engineering University of Calabria, Rende, Italy
[2]Department of Business Analytics, University of Iowa, Iowa City, USA
[3]Department of Economics, Statistics and Finance "Giovanni Anania", University of Calabria, Rende, Italy
[*]Corresponding author

The work examines a logistics system that combines in-store shoppers and smart lockers to enhance last-mile delivery efficiency. Physical stores act as hubs for preparing and fulfilling uncertain online orders, and using in-store shoppers can speed up order processing and reduce delivery costs. Smart lockers offer customers a secure and convenient pickup option, lowering transportation costs and improving delivery speed.

The problem is modeled as a same-day pickup and delivery system with online orders and in-store shoppers arriving dynamically. A Markov Decision Process framework is used to determine request–vehicle assignments and routing decisions, aiming to minimize total service cost, including transportation, in-store shopper remuneration, and penalties for late fulfillment. Since finding the optimal MDP policy is intractable, we assign requests at each dispatching epoch by solving a tailored team-orienteering problem. In this formulation, each request's reward reflects the value of serving it with a dedicated vehicle instead of an in-store crowdshipper. These reward values are learned from deterministic instances with perfect information, allowing the resulting team-orienteering solution to approximate an anticipatory policy. Real data instances are used to test the approach and derive managerial insights.

Keywords. Decision-making under Uncertainty – Logistics and Supply Chain Management – City Logistics.

Sponsor Session

Time: 14:00-14:30 **Chair:** Lorenzo Perinello

Hexaly, Julien Darlay	Hexaly, Hybrid Optimization Solver
Mosek ApS, Gustaf Ehn	Conic Optimization for System Building

Hexaly, Hybrid Optimization Solver

Julien Darlay, Co-Founder & Head of Science

Hexaly

Abstract. Hexaly is an innovative hybrid optimization solver based on a nonlinear, set-based modeling formalism. This formalism unifies and extends modeling paradigms from mixed-integer linear programming, nonlinear programming, constraint programming, and black-box optimization. Internally, Hexaly integrates a broad range of exact and heuristic optimization techniques, including branch-and-bound, column and cut generation, constraint propagation, and local search, among others. From a computational standpoint, Hexaly demonstrates competitive performance with state-of-the-art solvers such as Gurobi, CPLEX, and OR-Tools, delivering efficient and scalable solutions to routing, scheduling, packing, clustering, and location problems. This presentation introduces the set-based modeling formalism and demonstrates its scalability for solving large-scale problems. It further examines how the solver exploits this formalism to automatically orchestrate advanced exact and heuristic solution methods drawn from the current state of the art.

Conic optimization for system building

Gustaf Ehn, Head of Sales

Mosek ApS

Abstract. In applications, optimization is embedded in a system performing a higher-level task, for example, workforce scheduling, trajectory optimization in robotics, etc. In this talk, we are going to highlight the strengths and usability of conic optimization in building applied optimization systems.

Session III: Scheduling and Timetabling III

Time: 14:30-15:30 **Chair:** Serena Fugaro

Martina Luzzi	Human resources management in SMEs: an optimized and innovative framework
Alex Fabián Barrales Araneda	Heuristic Approaches for Timetabling and Vehicle Scheduling with Electric Buses
Serena Fugaro	A Soft-Constrained Multi-Objective Facility Location approach to design a Household Waste Recycling Centres network in UK

Human resources management in SMEs: an optimized and innovative framework

Martina Luzzi[1*], Pietro Pallone[2], Loris Filice[1,2], and Francesca Guerriero[1]

[1]Department of Mechanical, Energy and Management engineering, University of Calabria, Rende, Italy
[2]New Program Service S.r.l., Rende, Italy
[*]Corresponding author

This research introduces SIGMA, an innovative, integrated and scalable framework for optimized human resource management in small and medium-sized enterprises (SMEs). The framework combines operations research–based workforce scheduling models with domain reduction techniques to efficiently generate feasible and regulation -compliant plans, building on consolidated personnel scheduling research [1]. SIGMA supports multiple levels of planning granularity, ranging from classical shift rostering and set-covering formulations to activity-based scheduling. By exploiting an ERP-driven data environment, the framework improves computational performance through domain reduction strategies. Implemented as part of an industrial decision-support application, SIGMA enables data-driven and automated workforce management. Computational experiments and a real-world case study demonstrate its effectiveness across heterogeneous SMEs operational contexts.

Keywords. Decision Support Systems – Scheduling and Timetabling.

References

[1] E. H. Özder, E. Özcan, and T. Eren. A systematic literature review for personnel scheduling problems. *International Journal of Information Technology & Decision Making*, 19(6):1695–1735, 2020. doi: 10.1142/S0219622020500417.

Heuristic Approaches for Timetabling and Vehicle Scheduling with Electric Buses

Alex Barrales-Araneda[1,*], Valentina Cacchiani[1], and Emanuele Tresoldi[2]

[1]DEI, University of Bologna, Viale Risorgimento 2, 40136, Bologna, Italy
[2]Computer Science "Giovanni degli Antoni", University of Milan, Via Celoria 18, 20135, Milan, Italy
[*]Corresponding author

This work addresses the problem of determining an optimized timetable and vehicle schedule for a public transport system with mixed fleet, including both electric and conventional buses, while respecting operational and electric-specific constraints ([1]). The goal is to minimize costs which combine service quality and operational costs.

Two heuristic approaches are proposed: an integrated one, which optimizes timetabling and vehicle scheduling simultaneously, and a sequential one, which first determines an optimal timetable and then assigns vehicles to the selected trips. Both approaches are based on an Integer Linear Programming model and employ column generation for vehicle scheduling. We present a comparison between the two approaches to evaluate solution quality, computation times and sensitivity to heuristic parameters.

Keywords. Routing and Transportation – Scheduling and Timetabling – Heuristics and Metaheuristics.

References

[1] Shyam S.G. Perumal, Richard M. Lusby, and Jesper Larsen. Electric bus planning & scheduling: A review of related problems and methodologies. *European Journal of Operational Research*, 301:395–413, 2022.

A Soft-Constrained Multi-Objective Facility Location approach to design a Household Waste Recycling Centres network in UK

Antonino Sgalambro[1], Serena Fugaro[2,*], and Filippo Santarelli[2]

[1]Analytics, Technology and Operations Department, Leeds University Business School, University of Leeds, Leeds, UK
[2]Institute for the Applications of Calculus, National Research Council, Rome, Italy
[*]Corresponding author

In the UK Government's 25 Year Environment Plan, the placement of municipal waste collection and recycling facilities is key to meeting national recycling targets. Economic pressures are prompting UK local authorities to reorganise Household Waste Recycling Centre (HWRC) networks to reduce operating costs, improve user satisfaction, and comply with legislation. Supporting the optimal design of these networks is therefore essential. In [1], we address this need by introducing a Multi-Objective Facility Location problem tailored to the waste management system of Sheffield, South Yorkshire, and by developing a soft-constrained variant to better reflect real decision-making dynamics. We explore the resulting Pareto Sets using a robust variant of the AUGMECON method and provide a computational analysis based on real-world benchmark instances. Scenario and sensitivity analyses then offer insights to guide strategic planning and policy decisions.

Keywords. Decision Support Systems – Multi-objective Optimization.

References

[1] Antonino Sgalambro, Serena Fugaro, and Filippo Santarelli. A soft-constrained multi-objective facility location approach for designing a network of household waste recycling centres in south yorkshire. *Journal of the Operational Research Society*, pages 1–30, 2025.

Session IV: Learning-based Optimization

Time: 15:30-16:50 **Chair:** Martina Doneda

Alessandro Minoli	A Data-Driven State Exploration Policy in Dynamic Programming for RCESPP
Angjelo Zojzi	An optimal dispatching method for incoming alarms in security operations centers
Chiara Faccio	Fast and Simple Multiclass Data Segmentation: An Eigendecomposition and Projection-Free Approach
Virginia Marcelli	Tailored Heuristics for Margin Optimal Regression Tree

A Data-Driven State Exploration Policy in Dynamic Programming for RCESPP

Alessandro Minoli[1,*], Saverio Basso[1], and Matteo Salani[1]

[1]SUPSI, Dalle Molle Institute for Artificial Intelligence (IDSIA), Via la Santa 1, Lugano-Viganello, CH-6962, Switzerland
[*]Corresponding author

An iterative relaxation strategy for solving Resource-Constrained Elementary Shortest Path Problems (RCESPP) has long been established in the literature [1]. Following our exploratory work, which confirmed that machine learning can be leveraged to identify promising states in dynamic programming, we propose an algorithm that prioritizes the extension of states predicted to be dominant and handles the remaining ones at a later stage. The approach is both data-driven and exact. For each instance, we train a classifier to identify dominant states in a given iteration of the algorithm, and we then use it to estimate the quality of the states generated in the subsequent iteration. The algorithm has been integrated into the PathWyse library [2] and tested on instances with multiple resources. Preliminary results show a significant reduction in the number of explored states.

Keywords. Data-driven Optimization – Machine Learning – Exact Methods.

References

[1] Giovanni Righini and Matteo Salani. New dynamic programming algorithms for the resource constrained elementary shortest path problem. *Networks: An International Journal*, 51(3):155–170, 2008.

[2] Matteo Salani, Saverio Basso, and Vincenzo Giuffrida. Pathwyse: a flexible, open-source library for the resource constrained shortest path problem. *Optimization Methods and Software*, 39(2):298–320, 2024.

An optimal dispatching method for incoming alarms in security operations centers.

Giacomo Arcidiaco[2], Valentina Morandi[1], Maria Grazia Speranza[1], and Angelo Zojzi[1,2]

[1]University of Brescia
[2]Multiprotexion s.r.l.
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We present FADE, an optimal dispatching framework for incoming alarms in the Security Operations Centers at Multiprotexion s.r.l., which follows a 'Predict-then-Optimize' paradigm (see [1] for a comprehensive survey). Accurate predictions of event duration are crucial for the efficiency of such operations centers. To this aim, we employed several ML models as a *duration oracle*, using more than 100 problem-dependent features, including stress and fatigue dynamics, geospatial and structural factors. We achieved a mean absolute error (MAE) that meets the company's requirements. In each time slot, the optimal dispatching framework gathers information on incoming events and operators' actual workload. Then, the duration oracle estimates both the duration of incoming events and the residual duration of already assigned events to determine the workload of operators in the next time slots. Lastly, an optimization model assigns all incoming events to the operators, aiming to minimize workload imbalances. The framework includes an exception mechanism based on a temporary buffer (Pool) allowing re-insertion of events.

Keywords. Data-driven Optimization – Machine Learning.

References

[1] J. Mandi, J. Kotary, S. Berden, M. Mulamba, V. Bucarey, T. Guns, and F. Fioretto. Decision-focused learning: Foundations, state of the art, benchmark and future opportunities. *Journal of Artificial Intelligence Research*, 80:1623–1701, 2024.

Fast and Simple Multiclass Data Segmentation: An Eigendecomposition and Projection-Free Approach

Chiara Faccio[1,*], Margherita Porcelli[2], Francesco Rinaldi[1], and Martin Stoll[3]

[1]Department of Mathematics Tullio Levi-Civita, University of Padua, Padua, Italy
[2]Department of Industrial Engineering, University of Florence, Florence, Italy
[3]Department of Mathematics, Chemnitz University of Technology, Chemnitz, Germany
[*]Corresponding author

In this talk, based on [1], we address graph-based multiclass data segmentation. Traditional methods, like convex splitting or the Merriman-Bence-Osher (MBO) scheme, require expensive graph Laplacian eigendecomposition and repeated simplex projections, which slow down computations for large datasets. In order to overcome these limitations, we propose a new framework combining a novel penalty-based reformulation of the segmentation problem, which ensures valid partitions (i.e., binary solutions) for appropriate parameter choices, with an eigendecomposition and projection-free optimization scheme, which guarantees good convergence properties. Experiments on synthetic and real-world datasets, including real networks and images, demonstrate that the proposed framework achieves comparable or better accuracy than the CS and MBO methods while being significantly faster, particularly for large-scale problems.

Keywords. Graph Theory and Network Optimization – Machine Learning

References

[1] Chiara Faccio, Margherita Porcelli, Francesco Rinaldi, and Martin Stoll. Fast and simple multiclass data segmentation: An eigendecomposition and projection-free approach. *arXiv preprint arXiv:2508.09738*, 2025.

Tailored Heuristics for Margin Optimal Regression Tree

Ilaria Ciocci[1], Virginia Marcelli[1,*], Marta Monaci[1,2], and Laura Palagi[1]

[1]Department of Computer, Control and Management Engineering, Sapienza University of Rome, Rome, Italy
[2]Universitas Mercatorum, Università telematica delle Camere di Commercio Italiane, Rome, Italy
[*]Corresponding author

In this work, we introduce three heuristic approaches designed to generate high-quality feasible solutions for the Margin Optimal Regression Tree (MARGOT^{REG}) problem, formulated as a Mixed Integer Quadratic Program (MIQP). MARGOT^{REG} aims to combine the interpretability of decision trees with the generalization capabilities of Support Vector Regression (SVR), extending the ideas originally proposed for classification [1]. The first proposed heuristic, the *Local SVR*, follows a greedy top-down approach, whereas the *Proximity* and its extended version, the *Antiproximity*, are MIP-based strategies that leverage sample similarities and dissimilarities extracted from a Random Forest model. Empirical results on benchmark datasets show that the *Proximity* heuristic provides higher-quality warm start solutions, highlighting the effectiveness of leveraging data-driven sample relationships to guide mixed-integer optimization in regression tasks.

Keywords. Heuristics and Metaheuristics – Machine Learning – Mathematical Programming.

References

[1] Federico D'Onofrio, Giorgio Grani, Marta Monaci, and Laura Palagi. Margin optimal classification trees. *Computers & Operations Research*, 161:106441, 2024.

AIROYoung Roundtable

Time: 17:20-18:30 **Chair:** Alice Raffaele, AY board

At this special gathering with the founders and members of previous boards, we will talk about AIROYoung's origins, its growth over the years, and its vision for the future. We will also discuss what it means to be an early-career researcher and the importance of building one's own network.

Lavinia Amorosi
Sapienza University of Rome

Michele Barbato
University of Milan

Veronica Dal Sasso
Siemens Mobility, former University of Padova

Martina Fischetti
University of Sevilla

Serena Fugaro
Italian National Research Council

Giusy Macrina
University of Calabria

Valentina Morandi
University of Brescia

Lorenzo Peirano
University of Brescia

Alberto Santini
Universitat Pompeu Fabra

Day 5

Friday, February 13th, 2026

Session I:
Energy and Environmental Applications II

Time: 9:00-10:00 **Chair:** Francesco Cavaliere

Gianluca Sabbatini	A Rolling Horizon Multi-Stage Optimization Framework for Local Flexibility Procurement
Giovanni Micheli	Multi-horizon optimization for domestic renewable energy system design under uncertainty
Silvia Cordieri	An Energy-Efficient Optimization Strategy for Multi-Carrier Energy Systems

A Rolling Horizon Multi-Stage Optimization Framework for Local Flexibility Procurement

Gianluca Sabbatini[1*], Maria Teresa Vespucci[1], Dario Siface[2], and Alessandro Zani[2]

[1]Department of Management, Information and Production Engineering, Università degli Studi di Bergamo, Dalmine, Italy
[2]Ricerca sul Sistema Energetico - RSE, Milan, Italy
[*]Corresponding author

The increased deployment of Distributed Energy Resources[1] (DERs) at the distribution level has resulted in a growing need for advanced coordination mechanisms that can leverage local flexibility to support secure and efficient grid operation. Local Flexibility Markets (LFMs) represent a promising paradigm through which Distribution System Operators (DSOs) may procure flexibility from heterogeneous assets to alleviate network congestion, enhance voltage regulation, and defer grid reinforcements. Within this framework, Flexibility Service Providers (FSPs) play a pivotal role in aggregating and delivering flexibility from DERs. However, the translation of market-awarded flexibility into reliable real-time operation is challenging due to the stochastic and heterogeneous behaviour of DERs. To address these challenges, this work proposes a Rolling Horizon (RH) framework which integrates LFM clearing — formulated as network-constrained AC Optimal Power Flow solved via Second-Order Cone Programming (OPF-SOCP) — with an Economic Model Predictive Control (EMPC) strategy for optimal dispatching at the FSP level. The EMPC has been demonstrated to efficiently allocate flexibility among DERs by minimizing activation costs, degradation effects and comfort penalties. Thanks to these capabilities, the integrated framework has proved effective in procurement flexibility.

Keywords. Energy, Environment, and Natural Resources – Network Analytics – Control Theory and System Dynamics

[1]DERs include photovoltaic power plants, combined heat and power plants, wind turbines, small hydropower plants, energy storage systems, electric vehicles and heat pumps.

Multi-Horizon Optimization for Domestic Renewable Energy System Design Under Uncertainty

Giovanni Micheli[1,*], Laureano F. Escudero[2], Francesca Maggioni[1], and Güzin Bayraksan[3]

[1]Department of Management, Information and Production Engineering, University of Bergamo, Italy
[2]Area of Statistics and Operations Research, Universidad Rey Juan Carlos, Mostoles (Madrid), Spain
[3]Department of Integrated Systems Engineering, The Ohio State University, USA
[*]Corresponding author

In this talk we address the design of optimal domestic renewable energy systems under multiple sources of uncertainty appearing at different time scales. Long-term uncertainties related to investment and maintenance costs are combined with short-term uncertainties such as solar radiation, electricity prices, and load. We formulate the problem as a multi-stage multi-horizon stochastic Mixed Integer Linear Programming (MILP) model, integrating long-term investment decisions with short-term operational decisions. To ensure robust operation under extreme scenarios, first- and second-order stochastic dominance risk-averse measures are considered preserving the time consistency of the solution. Given the computational complexity of solving the stochastic MILP for large instances, a rolling horizon-based matheuristic algorithm is developed. Additionally, various lower-bound strategies are explored. Extensive computational experiments validate the effectiveness of the proposed methods.

Keywords. Stochastic Programming – Heuristics and Metaheuristics – Energy, Environment, and Natural Resources.

An Energy-Efficient Optimization Strategy for Multi-Carrier Energy Systems

Silvia Anna Cordieri[1,*] and Francesco Simmini[1]

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The electricity sector assumes a central and strategic role in the energy transition. This evolution is accompanied by a progressive electrification of final energy uses, which represents one of the main levers for decarbonizing the economy. However, this shift toward electrification brings significant challenges, such as real-time balancing between electricity demand and supply, and managing non-dispatchable renewable sources. In this context, multi-carrier energy systems emerge as solutions, providing additional flexibility. In this work, a predictive optimization algorithm is proposed to manage a multi-carrier energy system. The system consists of Energy Hubs (EHs) linked through different energy carriers. The algorithm is structured into two distinct stages, each based on a MILP model. In the first stage, each EH is independently optimized, while in the second stage, the algorithm coordinates the energy exchanges among the different EHs, to reduce network transmission costs. Moreover, a real-time MPC procedure has been developed with the aim of tracking the optimal trajectories defined during long-term planning. The results highlight the crucial role of hydrogen storage as a flexible energy buffer that complements the battery storage system, ensuring continuous and efficient utilization of renewable energy throughout both day and night. In the second phase, the optimization focuses on minimizing energy transmission costs, thereby promoting efficient and coordinated energy exchange among the interconnected EHs.

Keywords. Energy, Environment, and Natural Resources – Mathematical Programming – Data-driven Optimization – Planning and Project Management.

Plenary Talk by Hande Yaman Paternotte

Time: 10:30-11:30 **Chair:** Lorenzo Perinello

Hande Yaman Paternotte	Partitioning a Graph into Connected Components

Partitioning a Graph into Connected Components [a]

Hande Yaman Paternotte

Faculty of Economics and Business, KU Leuven

Abstract. In this talk, we study problems that involve partitioning the vertices of an undirected graph into a given number of pairwise disjoint sets such that each set induces a connected subgraph. We first propose valid inequalities, which extend and generalize the ones in the literature, and report on computational experiments demonstrating their use (joint work with P. Moura and R. Leus). Then, we extend this problem to also compute a spanning tree for each set of the partition such that the weight of the heaviest tree is minimized. We investigate the complexity of this problem and present formulations and solution methods, which we compare with an experimental study (joint work with M. Davari and P. Moura). Finally, we consider a practical problem encountered in power system restoration, which involves partitioning a power network into connected subnetworks, one for each black start generator, such that the restoration time is minimized. We propose a solution method that uses a new formulation and properties of optimal solutions and report computational results

Short bio. Hande Yaman Paternotte is Professor of Operations Research at the Faculty of Economics and Business at KU Leuven. Research contributions and interests of her include polyhedral approaches for mixed integer programming with applications in production planning, logistics, and network design.

[a] This is a joint work with Hatice Çalik and Dirk Van Hertem

Session II: Scheduling and Timetabling IV

Time: 11:30-12:50 **Chair:** Gabriele Sanguin

Silvia Iuliano	A Global Optimization-based Methodology for Providing Grid Ancillary Services by Electric Vehicles Scheduling
Lingyuan Shi	Integrated optimization of train rescheduling and speed management during partial blockages: A decomposition approach
Xinyi Ye	On Makespan Scheduling with Stability
Marco Dottor	Efficient methods for large-scale cricket farming

A Global Optimization-based Methodology for Providing Grid Ancillary Services by Electric Vehicles Scheduling

Silvia Iuliano[1,*] and Alfredo Vaccaro[1]

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The integration of Electric Vehicles equipped with Vehicle-to-Grid technology has been recognized as a promising solution to enhance the flexibility of modern power systems. However, realizing this approach requires flexible, reliable, and highly scalable computing architectures that can coordinate the charging and discharging processes of EV fleets while identifying the best trade-offs between vehicle charging expectations and grid requirements. This challenging dynamic scheduling problem can be formalized as a welfare maximization problem by introducing marginal utility functions, which have been recast in a Multi-Temporal Mixed-Integer Nonlinear Programming problem. To solve this complex optimization problem, we proposed deploying decomposition methods, which allow the modeling of discrete control variables and computing the optimality gap, enabling the computation of global optimal solutions. [1], [2].

Keywords. Scheduling and Timetabling – Decision Support Systems – Global Optimization

References

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Integrated optimization of train rescheduling and speed management during partial blockages: A decomposition approach

Lingyuan Shi[1], Xin Yang[1,*], Wei Zhang[2,*] , Huijun Sun[1], and Gilbert Laporte[3]

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Disruptions to high-speed train operations result in deviations from the official timetable. As traffic density increases, such delays may rapidly propagate to other trains, triggering scheduling conflicts. Thus, conflict-free rescheduled timetables and adjusted speed profiles are essential to restore disrupted train operations. In this paper, we introduce an integrated framework for the train rescheduling and speed management problem (TRSMP) during disruptions caused by partial segment blockages. Considering a flexible rescheduling strategy, the disruption-affected train is allowed to switch to the opposite track to mitigate train delays. A mixed-integer linear programming model is formulated to simultaneously optimize the train timings, orders, routes and speed profiles. To reduce the complexity of the model, we decompose the model into a reformulated integer programming model, focusing on train interactions, and a series of train-specific operation plans. This decomposition approach transforms the TRSMP into a train plan selection problem, effectively decoupling interactions among trains and interdependencies between rescheduling and speed management. Moreover, we develop an adaptive acceleration algorithm to speed up the solution of the reformulated model. Case studies on the Chinese high-speed railway show that our decomposition approach provides near-optimal solutions within short computation times, validating the effectiveness under disruptions.

Keywords. Scheduling and Timetabling – Multi-objective Optimization – Railway and Air Traffic Problems.

On Makespan Scheduling with Stability

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In this work, we investigate the stability radius of algorithms for the fundamental makespan scheduling problem, a.k.a. P ||Cmax. While prior work primarily examines the stability radius of optimal solutions, we focus on two widely used approximation algorithms that come with optimality guarantees: Longest Processing Time First (LPT) and Greedy Local Search (GLS). To our knowledge, this is the first characterization of the stability radius for LPT and GLS. Our contributions include identifying perturbation factors, such as processing and completion time variations, predecessor counts, and critical job subsets affecting stability; analyzing irrevocable decision properties of constructive algorithms; and establishing conditions for local search algorithms that enable demonstrating and quantifying stability. We show that LPT and GLS exhibit low stability radii under arbitrary perturbations but significantly higher stability under structured perturbations, specifically uniform and box-constrained. These results expand the known stability regions for LPT and GLS, i.e.\ sets of instances where schedules remain unchanged. Finally, we validate our findings using state-of-the-art benchmark instances for P ||Cmax.

Keywords. Scheduling and Timetabling

Efficient methods for large-scale cricket farming

Marco Dottor[1], Pietro Belotti[1,*], and Federico Malucelli[1]

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As global demand for sustainable protein rises, crickets (Acheta domesticus) are gaining attention, with recent work examining how diet, temperature [1], and rearing density [2] can be handled to boost production.
We propose a space-efficient farming strategy based on a two-habitat lifecycle: crickets are initially raised in small condos and are transferred to larger ones when they reach a certain age, preventing overcrowding (and thus loss of productivity) while optimizing space.
We use integer linear programming to schedule transfers to bigger habitats and harvests, in order to maximize flour production. This new approach allows to almost double production of a farm whose limiting factor is space, making it a very promising innovation.

Keywords. Discrete optimization – Linear programming – Scheduling.

References

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Sponsor Session

Time: 14:00-14:40 **Chair:** Matteo Pernini

FICO, Francesco Cavaliere	What's new in FICO Xpress
Institute for System Analysis and Computer Science "Antonio Ruberti", Marco Boresta	Operations Research at IASI–CNR: Methods, Challenges, and Real-World Applications
National Research Council of Italy, Institute for Applied Computing, Serena Fugaro	Mathematical and Computational Methods for Interdisciplinary Science

What’s new in FICO Xpress

Francesco Cavaliere, Software developer

FICO

Abstract. FICO Xpress Optimization[a] is a software suite for developing and deploying optimization models. Xpress solvers and modelling tools have been commercialised for more than 40 years. In 2012 the software suite has been extended with deployment capabilities via FICO Xpress Insight. We shall present highlights of the latest enhancements to Xpress Solver, including the GPU port of the primal-dual hybrid gradient method (PDHG) and performance improvements to the MIP engine and Xpress Global. Furthermore, we shall discuss recent updates to the Xpress Solver APIs, the Xpress Mosel language, and publicly accessible online resources[b], such as Docker files, various Mosel components, and a new collection of Python notebooks that can be run online without any local installation.

[a] `https://www.fico.com/xpress`
[b] `https://github.com/fico-xpress`

Operations Research at IASI–CNR: Methods, Challenges, and Real-World Applications

Marco Boresta, Postdoctoral Researcher

National Research Council of Italy, Institute for System Analysis and Computer Science "Antonio Ruberti"

Abstract. The National Research Council of Italy (CNR) is the largest public research organization in the country. With more than 80 research institutes and approximately 6,000 researchers, CNR aims at producing new scientific knowledge, fostering technology transfer, and promoting research dissemination. This presentation focuses on the research activities carried out at the Institute for Systems Analysis and Computer Science (IASI–CNR), with particular emphasis on the Optima research group, whose work spans multiple Operations Research topics and integrates Artificial Intelligence methods for both research and technology transfer. After outlining the main research areas and methodological challenges addressed at IASI—ranging from optimization under uncertainty to sustainability and fairness-driven decision models—the talk illustrates some examples on how these approaches are applied to real-world problems.

Mathematical and Computational Methods for Interdisciplinary Science

Serena Fugaro, Senior Post-doc and Technology Transfer Officer

National Research Council of Italy, Institute for Applied Computing

Abstract. The increasing complexity of modern scientific and technological challenges demands an integrated approach combining mathematical modelling, advanced algorithms and high-performance computing. Mathematics plays a central role in the design of efficient, scalable, and robust solution strategies, far from being merely a descriptive language. The Institute for Applied Computing (IAC) “Mauro Picone” of the National Research Council (CNR) conducts interdisciplinary research to develop mathematical, statistical and computational methods for significant scientific, social and industrial problems. Its activities span a wide range of application domains, including engineering, medicine, biology, environmental sciences, economics and finance, information and communication technologies, and cultural heritage.

As a concrete example, the presentation will focus on the “Sportello Matematico per l’Innovazione e le Imprese” (Mathematical Desk for Innovation and Industries) project, which is aimed at fostering collaboration between research and industry through technology transfer and networking activities.

Session III: Transportation and Logistics IV

Time: 14:40-16:00 **Chair:** Anthony Palmieri

Luca Dalla Costa	A Constrained Shortest Path Algorithm for Dynamic Airspace Configuration
Filippo Magi	Tactical Deconfliction with Speed and Path Modifications for Urban Air Mobility
Yingzhi Wang	Airport subsidy for air–HSR intermodal service in a multi-airport system: Direct amount vs. discount
Federico Michelotto	A Novel Decomposition Scheme for the CVRP

A Constrained Shortest Path Algorithm for Dynamic Airspace Configuration

Luca Dalla Costa[1], Luigi De Giovanni[1], and Martina Galeazzo[1]

[1]Department of Mathematics, Università degli Studi di Padova

The Dynamic Airspace Configuration (DAC) problem consists in the determination of a sequence of airspace partitions that optimally fits traffic dynamics, subject to side restrictions, aiming at smooth and operationally feasible transitions.

Starting from a formulation of the problem on a weighted graph, as presented in [2, 3], we discuss DAC's computational complexity and propose an exact algorithm for its resolution. The method solves a constrained shortest path problem, using labels inspired by [1] and tailored to express the side constraints.

The method has been implemented in Python on realistic instances created on purpose and compared with *Cplex*.

Keywords. Railway and Air Traffic Problems – Discrete and Combinatorial Optimization – Graph Theory and Network Optimization

References

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Tactical Deconfliction with Speed and Path Modifications for Urban Air Mobility

Claudia D'Ambrosio[1,*], Filippo Magi[2], and Tom Portoleau[3]

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Urban Air Mobility (UAM) is an emerging field that aims to revolutionize transportation in urban areas by utilizing airspace for passenger and cargo transport. This paper presents a novel approach to tactical deconfliction in UAM, leveraging mathematical optimization and math-heuristic methods to improve efficiency while maintaining safety.

In [1], the authors propose a mixed-integer linear programming (MILP) model for tactical deconfliction in UAM, focusing on speed adjustments to ensure safe separation between aircraft.

To enhance performance and feasibility in challenging instances, we propose a mathematical programming model that incorporates both speed and path modifications for deconfliction. The model minimizes deviations from the original flight plans while maintaining safe separation, and a math-heuristic is developed to allow path changes for non-priority flights, improving feasibility without compromising performance.

Keywords. Mathematical Programming – Heuristics and Metaheuristics

References

[1] Mercedes Pelegrín, Claudia D'Ambrosio, Delmas Rémi, and Youssef Hamadi. Urban air mobility: from complex tactical conflict resolution to network design and fairness insights. *Optimization Methods and Software*, 38(6):1311–1343, 2023. ISSN 1055-6788. doi: 10.1080/10556788.2023.2241148.

Airport subsidy for air-HSR intermodal service in a multi-airport system: Direct amount vs. discount

Yingzhi Wang[1], Xiushan Jiang[1,*], and Chuanzhong Yin[2]

[1]School of Traffic and Transportation, Beijing Jiaotong University, Beijing, China
[2]College of Transport & Communications, Shanghai Maritime University, Shanghai, China

Integrating air transport and high-speed rail (HSR) to provide air-HSR intermodal services (AHIS) can coordinate transport resources, enhance airport connectivity, and improve the environment. This paper develops a game model to investigate the optimal rates and market outcomes of airport subsidy schemes for AHIS passengers within a multi-airport system (MAS), considering monopoly and duopoly structures in the airline market as well as typical MAS governance structures (private individual, private group, and public group). We analyze a direct amount subsidy with a fixed amount of money and a discount subsidy dependent on AHIS prices. Our analytical findings show that, compared with no subsidy, the direct amount subsidy increases the AHIS price and traffic and total traffic, and consistently enhances consumer surplus in monopoly markets and social welfare in duopoly markets. Its positive impacts on secondary airport profit and total airport system profit are conditional on private ownership and higher secondary airport charges. In duopoly markets, when a public airport group implements subsidies, the discount subsidy yields a higher AHIS price and operator profit but declines secondary airport profit compared to the direct amount subsidy, with identical effects on other outcomes. Numerical simulations and a case study of the Chengdu-Nanchong-Shanghai market suggest that the direct amount subsidy has a robust advantage in traffic growth, while the welfare implications of subsidies require careful consideration of the subsidy implementer and market circumstances. These findings provide strategic guidance for designing context-specific airport subsidy schemes to promote the development of AHIS and effective management of MAS.

Keywords. Railway and Air Traffic Problems – Game Theory – Routing and Transportation

A Novel Decomposition Scheme for the CVRP

Federico Michelotto[1,*], Luca Accorsi[2], Demetrio Laganà[3], Roberto Musmanno[3], and Daniele Vigo[1]

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[2]Google, Bavaria, Germany
[3]DIMEG, University of Calabria, Rende, Italy
[*]Corresponding author

Is it possible to concurrently optimize different parts of a solution of a Capacitated Vehicle Routing Problem, such that the recombination of the optimized partial solutions is still a feasible solution? The answer is clearly affirmative if the partial solutions to be optimized consist of a disjoint subset of routes, as it happens in the route-based decomposition scheme. In all other cases, the answer is unknown. This work addresses this question and unveils a counterintuitive property of the Capacitated Vehicle Routing Problem. We show that if the solutions' routes have no residual capacity – a condition that can be assumed without loss of generality – a more general decomposition scheme, named sequence-based decomposition, always yields a feasible solution.

Keywords. Discrete and Combinatorial Optimization – Routing and Transportation.

Session IV: Advances in Mathematical Programming II

Time: 16:30-17:30 **Chair:** Martina Galeazzo

Edoardo Cesaroni	Derivative-Free Bilevel Optimization with Inexact Lower-Level Solutions
Matteo Zanella	MIP Formulations for Delete-Free AI Planning
Mariagrazia Cairo	On the Lagrangian Relaxation in a Bi-Objective Branch and Bound Algorithm

Derivative-Free Bilevel Optimization with Inexact Lower-Level Solutions

Edoardo Cesaroni[1,*], Giampaolo Liuzzi[1], and Stefano Lucidi[1]

[1]Department of Computer, Control and Management Engineering "A. Ruberti", "Sapienza" University of Rome, Rome, Italy
[*]Corresponding author

In this work, we propose derivative-free frameworks for bilevel optimization. We consider both the upper and lower-level problems with bound constraints on the variables, as well as general nonlinear constraints, assuming that first-order information is not available or it is impractical to obtain. The lower-level problem is solved with an accuracy that is progressively refined throughout the optimization process. We first analyze the case in which the upper-level problem is subject only to bound constraints, establishing convergence to Clarke-Jahn stationary points when the refinement process is allowed to reach its maximum precision. When a stricter limit is imposed on accuracy, we prove convergence to approximate stationary points using an extended notion of Goldstein stationarity. Finally, we extend the proposed framework to handle more complex constraints via an exact penalty function approach, proving convergence to stationary points under suitable assumptions.

Keywords. Bilevel Optimization – Linear and Nonlinear Programming.

MIP Formulations for Delete-Free AI Planning

Domenico Salvagnin[1] and Matteo Zanella[1,*]

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We investigate existing Mixed Integer Programming (MIP) formulations for cost-optimal delete-free STRIPS planning: these models are built by enforcing acyclicity in the underlying causal relation graph using time labeling and vertex elimination methods. We then propose two new approaches to modeling acyclicity, one based on subtour elimination constraints and the other based on disjunctive landmark constraints [1]. In addition, we propose to warm-start the models with the landmarks computed by the LM-cut [2] heuristic, and describe a simple greedy primal heuristic to provide a starting feasible solution to the MIP solver. Our results demonstrate that the proposed techniques outperform the current state of the art

Keywords. Discrete and Combinatorial Optimization – Exact Methods.

References

[1] Blai Bonet and Julio Castillo. A complete algorithm for generating landmarks. In *Proceedings of the International Conference on Automated Planning and Scheduling*. AAAI Press, 2011. doi: 10.1609/icaps.v21i1.13482.

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On the Lagrangian Relaxation in a Bi-Objective Branch and Bound algorithm

Lavinia Amorosi[1], Mariagrazia Cairo[1], Paolo Dell'Olmo[1], and Serpil Sayin[2]

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Branch-and-bound algorithms are among the most effective methods for single-objective discrete optimization, while their extension to multi-objective settings has been investigated only recently. In Multi-Objective Branch and Bound (MOBB) methods, the definition of effective bounding strategies remains a key challenge, as the notion of a scalar bound is replaced by that of a bound set [2]. Lagrangian relaxation, known for providing tight bounds in single-objective optimization, has recently shown the potential to generate tight bound sets also for multi-objective problems, due to its ability to approximate the interior of the feasible region [1]. This talk investigates the integration of Lagrangian relaxation within a MOBB framework, highlighting the difficulties of exploring these theoretical insights.

Keywords. Discrete and Combinatorial Optimization – Multi-objective Optimization – Exact Methods.

References

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