XXIV Congresso da Associação Portuguesa de Investigação Operacional (IO2025)

Sunday 7 September 2025 - Tuesday 9 September 2025

Book of Abstracts

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New Integer Programming Models for the Multi-Depot Vehicle Routing Problem with Inter-Depot Routes

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Optimization of berth allocation and tugboat scheduling under uncertainty

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Ver submissão em anexo.

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Otimização Aplicada a uma Empresa de Processamento e Embalamento de Arroz

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A gestão eficiente do processo produtivo numa unidade de descasque, transformação e embalamento de arroz enfrenta diversos desafios operacionais e logísticos, que se traduzem em pontos críticos. Estes problemas podem ser agrupados em três grandes dimensões: a matéria-prima (arroz), a estrutura produtiva e a capacidade de armazenamento. Relativamente ao arroz, surgem várias restrições que condicionam a organização da produção, tais como a disponibilidade e o arroz em si, que se organiza em variedade, estado de entrada e tipo de arroz. Por outro lado a estrutura da fábrica, bem como a organização laboral da mesma apresentam problemas que impedem flexibilidade do mecanismo. Por fim, os limites de capacidade, em questão de armazenamento de matéria-prima e produto já branqueado.
O presente trabalho desenvolvido propõe dois modelos de otimização matemática para as áreas de planeamento de compras e planeamento de produção para uma empresa de transformação, embalamento e expedição de arroz.

Procurou-se explorar, analisar e definir modelos matemáticos que respondessem a duas questões com grande ênfase a nível empresarial e, de seguida, foram delineados vários cenários de interesse empresariais e aplicados aos modelos matemáticos propostos. Para a área de planeamento de compras, queria-se definir qual o melhor planeamento de compras de forma a não haver roturas de \textit{stock}, cumprindo com os requisitos logísticos do sistema produtivo, minimizando os custos globais de aquisição, preservando quantidades mínimas de \textit{stock} e outros requisitos operacionais e financeiros.
Para a área de planeamento de produção, desejava-se obter o melhor planeamento produtivo de forma a minimizar as perdas de negócio, garantindo que não há rotura de \textit{stock}, reduzindo as mudanças de tipo de produto e cumprindo com os requisitos operacionais do sistema produtivo.

Plenary Session / **115**

Startup selection, performance, and impact of business incubators

Business incubators are often seen as essential tools for fostering startup success and driving regional economic development. But how much of that impact is real, and how much is assumed? In this plenary session, I will share a reflection grounded in empirical data and hands-on experience on how incubation programs can —or sometimes cannot —make a meaningful difference for startups. We will explore key issues around startup selection criteria, performance metrics, and the real challenges of evaluating the territorial impact of incubation initiatives. Combining practical insights with quantitative analysis, this talk aims to question some common assumptions about incubation ecosystems and the way we measure their effectiveness. Using real-world examples and comparative data, we will discuss when and how incubation adds value. The goal is to contribute to a more rigorous and realistic understanding of what works, what doesn't, and how to design better support systems for entrepreneurship.

Session 1.1 - Optimization-Simulation / **42**

Optimization-Simulation approach for the vehicle routing problem with time windows and synchronized visits under travel and service time uncertainty

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In this presentation, we address the vehicle routing problem with time windows and synchronized visits under uncertain service and travel times. Specifically, a subset of clients require simultaneous service by two vehicles, which is initiated only after the arrival of both vehicles and, consequently, enforces a waiting period for the vehicle that arrived earlier. To tackle this problem, we propose an optimization-simulation framework. Through an iterative process, a deterministic optimization model generates potential solutions which are then assessed through a simulation model. If the solution is found to lead to a bad average performance, new constraints and penalties are added to the deterministic optimization model. This iterative process continues until the performance criteria are satisfied. We validate our approach through experiments on benchmark instances from the literature.

Session 1.1 - Optimization-Simulation / 90

An Optimisation and Simulation Approach for the Design of Demand Responsive Transport Services

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Demand-responsive transport (DRT) systems are quite flexible, adapting quickly to changes in demand through dynamic routing, scheduling, and fleet sizing. Unlike conventional public transport, DRT operations are often planned daily, especially in low-demand contexts. However, as demand grows, planning becomes computationally intensive. While effective methods exist in the literature, many are complex and not easily implemented.
This work proposes a two-phase heuristic embedded in a simulation-based framework to support the design and operation of DRT services. In the first phase, a constructive algorithm generates feasible routes by sequencing trips to avoid overlaps. The second phase enhances these routes by adjusting pick-up and drop-off times to facilitate ride-sharing and improve vehicle utilization. This optimization component is integrated into a simulation environment that evaluates system performance under varying demand conditions.
Preliminary experiments on small-sized instances showed that the heuristic provides high-quality solutions with very low computational effort. The approach offers a balance between simplicity, efficiency, and practical applicability, making it suitable for iterative simulation optimization schemes. This study is part of a broader framework aimed at designing more adaptive and efficient DRT systems.

Session 1.1 - Optimization-Simulation / 97

A hybrid optimization-simulation framework for sustainable closed-loop supply chains design and planning

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Sustainability challenges have become a central concern in supply chain design and planning, requiring effective decision-support methods that address economic, environmental, and social objectives. This work proposes a hybrid optimization–simulation framework that combines a mixed-integer linear programming model, used to optimize sustainability goals through a novel practically oriented objective function, with a discrete-event simulation model to assess the solution under uncertain conditions. A closed-loop supply chain design, inspired by the case of a chemical manufacturer, is optimized and subsequently simulated under realistic variability scenarios to yield more feasible sustainable solutions. Results demonstrate how operational decisions, such as workforce expansion, enhance demand fulfillment, while strategies like order consolidation contribute to environmental improvements. The proposed framework provides a structured methodology for evaluating strategic trade-offs across the triple bottom line, offering actionable insights for supply chain managers aiming to align operations with long-term sustainability objectives.

Session 1.2 - OR in Energy 1 / 56

Optimizing Hybrid Renewable Energy with Tidal and Offshore Wind in the Mersey Estuary

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The River Mersey in Liverpool has long been recognized for its considerable tidal range, offering significant potential for energy generation. However, none of the studies explored integrating tidal and offshore wind energy systems within a hybrid configuration. This study addresses this gap by investigating the integration of these two sources by leveraging the proximity of the existing Burbo Bank Offshore Wind Farm (OWF) to a proposed tidal barrage site. An optimization model is developed to determine the most cost-effective configuration of the tidal barrage by maximizing its net present value. The design variables include the barrage location, the number and type of turbines, and the number of sluice gates. The model accounts for the combined energy contributions from the tidal barrage and the OWF, which share a common export cable that constrains the total energy exported to the grid. The study demonstrates the benefits of hybridizing tidal and wind energy sources in the region, highlighting synergies that can enhance energy reliability and efficiently use existing transmission infrastructure.

Session 1.2 - OR in Energy 1 / 59

An effective hybrid decomposition approach to solve the network-constrained stochastic unit commitment problem in large-scale power systems

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We propose an effective hybrid decomposition method to solve network-constrained stochastic unit commitment (SNCUC) problems. We address large-scale SNUC cases involving renewable generation units, hundreds of thermal generation units, thousands of transmission lines and nodes, and uncertain renewable generation and demand. The problem is formulated as a two-stage stochastic program with continuous and binary variables in the first stage and only continuous variables in the second stage. We developed a hybrid Benders decomposition that recasts the original SNCUC problem into a novel master problem and subproblems. The proposed master problem encompasses unit commitment decisions and dispatch decisions across all scenarios, resulting in an extended master problem with first- and second-stage variables and constraints. At each iteration, a new column-and-constraint generation step adds selected transmission variables and constraints per scenario to the master problem. Detailed computational results compare the proposed hybrid decomposition performance with the extensive formulation via branch-and-cut and multiple Benders decomposition implementations. The results show that the hybrid decomposition achieves bounds of superior quality and finds solutions for instances where other Benders decompositions fail.

Session 1.2 - OR in Energy 1 / 85

Towards energy transition in the mining supply chain

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The mining industry plays a crucial role in the global energy transition, which is essential for achieving net-zero carbon emissions. As the main source of critical minerals essential to renewable energy technologies, mining supplies the foundational materials needed for the development and deployment of clean energy solutions. Consequently, the demand for these minerals is projected to grow significantly in the coming years.
However, supporting the energy transition poses substantial challenges for the mining sector, including high energy consumption, dependence on fossil fuels, complex supply chains, large-scale technological investments, and significant environmental and social impacts. This research addresses these challenges by proposing an optimization approach to mining supply chain planning that enhances both operational efficiency and sustainability.
The study integrates clean-efficient technologies and renewable energy to reduce carbon emissions and improve energy efficiency within mining operations. Recognizing the capital-intensive nature of these initiatives, it emphasizes the importance of long-term strategic planning to ensure economic feasibility and sustainable outcomes.
An optimization model is developed for long-term mining supply chain planning, encompassing multiple echelons, periods, and mineral products. A case study of the Chilean mining industry illustrates the practical application of this model, analysing the sector's specific challenges in transitioning to a cleaner energy paradigm. By providing a decision-support tool, this work aims to contribute to the transformation of the mining industry toward sustainability and support the global clean energy transition.

Session 1.3 - Scheduling and transportation / 74

Rolling stock rotation planning in a regular operation context

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The rolling stock rotation planning problem with maintenance constraints can be stated in the following way: given a set of train trips each one with its own passenger demand find, from scratch, for a standard week, the most cost-effective rotations that assign a vehicle composition (hereafter composition) to each trip that covers all or part of the demand and that satisfy all operational constraints, namely maintenance constraints and many others. The overall rotation cost includes aspects like track occupation, fleet depreciation, maintenance and energy consumption, crew utilization and uncovered demand.
Since the problem cannot be solved exactly, due to the size of problem instances and the complexity of maintenance constraints, we propose approximate solution methods. Our approaches take advantage of splitting the standard week into several subproblems involving one or more days. Furthermore, we consider the trips'regularity, meaning that there are exactly the same set of trips repeated on different days (e.g. weekdays usually have the same timetable every day).
Our solution methods were evaluated with problem instances from a European passenger railway operator that provides a regular service with multiple-unit trains. Results highlight the potential of the proposed approaches.

Session 1.3 - Scheduling and transportation / 76

Improving efficiency in Container Terminals through Coordinated Truck Scheduling: a Heuristic-based Approach

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Maritime trade has been continuously growing in the last decades, increasing the pressure on container terminals and intensifying needs for more effective management systems. Inefficiency arises on the land-side operations with the increasing number of truck arrivals for the collection and delivery of containers. The highly stochastic nature of truck arrivals leads to an unbalanced workload distribution and inconsistent resource utilization, heavily impacting congestion and overall operational efficiency.
Conventional appointment systems still prioritize carrier requests without considering terminal constraints, resulting in a suboptimal truck scheduling performance.
To tackle these challenges, a heuristic-based optimization model was developed in this work, to improve the scheduling of container pickups. The model integrates the truck appointment preferences with terminal-related data such as container yard locations, terminal layout, and resources availability. To minimize operating time, the model addresses two core decisions –the assignment of containers to time-windows and the truck pickups sequencing within each time-window.
By dynamically reallocating containers within the yard, aiming to minimize relocations and handling times, the heuristic seeks to balance resource utilization and carrier preferences. Preliminary results show the proposed approach reduces operational time, decreases truck waiting times, and enhances terminal throughput, thus contributing to more sustainable and efficient port operations.

Session 1.3 - Scheduling and transportation / 75

Enhancing Port Efficiency and Sustainability through Just-in-Time Arrivals and Tugboat Resource Management

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Maritime transport and port operations are vital to global trade but face growing pressure to improve efficiency and lower greenhouse gas (GHG) emissions. Just-in-Time (JIT) arrival offers a promising management solution, involving speed adjustments so that vessels reach the pilot boarding point only when port services are confirmed. This approach aims to cut fuel and emissions by reducing idle time at anchor. However, JIT success depends on efficient tugboat operations, which are essential for berthing and departure. Their effective scheduling is crucial to avoid congestion, especially in high-traffic ports.

In this work a discrete event simulation-based decision-support tool was developed to assess JIT arrival strategies in container terminals, focusing on tugboat resource allocation and scheduling. By modelling port processes and analysing scenarios involving vessel speed optimisation and tugboat availability, the tool evaluates impacts on a set of key performance indicators: waiting times, emissions, and resource utilisation.

A case study at a Portuguese seaport shows the effectiveness of the model, revealing notable reductions in emissions and operational inefficiencies. These findings highlight the potential of JIT operations and effective tugboat scheduling to enhance sustainability and efficiency in the maritime sector. Future work will extend the current approach by the adoption of a mixed-integer linear programming model for tugboat scheduling with time constraints.

Session 1.4 - SPE Session on Statistics / **101**

An Hybrid Neural Network-Optimal Control Approach for Irrigation Scheduling Based on Satellite Data

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Plantations face significant challenges due to water scarcity and prolonged periods of drought. Currently, irrigation management is mostly performed manually and relies heavily on the experience of farmers, who make adjustments based on the time of year. However, several factors influence irrigation needs, including air and soil humidity, temperature, and the amount of rainfall. Incorporating these variables into irrigation planning is crucial for optimising water use and ensuring efficient resource management, thereby supporting sustainability. Moreover, climate change has led to an increase in extreme weather events and atmospheric instability, making optimal water management even more difficult. In this work, we formulate an optimal control problem that recommends the amount of water to use for irrigation in a given time horizon. To support long-term decision making, we use variables given by a neural network to the optimal control problem. The neural network identifies and models new and complex causal relationships between atmospheric and soil variables from satellite data. Our approach allows for intelligent irrigation management that can anticipate periods of drought or extreme precipitation events.

Session 1.4 - SPE Session on Statistics / **102**

Interval-Censored Survival Analysis with Continuous Covariates

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This work addresses the problem of estimating the conditional survival function when event times are subject to interval censoring and continuous covariates are present. Such data structures arise frequently in real-world operational contexts, including maintenance planning, healthcare monitoring, and quality control systems, where events are only observed within time intervals due to periodic inspections. We propose two nonparametric methodologies based on kernel smoothing and iterative Expectation-Maximization (EM) algorithms. These approaches generalize Turnbull's estimator to the conditional setting and enable flexible estimation without relying on strong parametric assumptions. From an operational research perspective, the ability to accurately model survival probabilities as a function of continuous covariates supports more informed decision-making under uncertainty.

Session 1.4 - SPE Session on Statistics / 103

Data-Driven Insights into Trust for Decision-Making in Social Robot Interaction

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Trust is a key determinant of successful human-robot interaction across diverse application domains. This study investigates the formation of trust in robots through an online experiment where participants viewed curated videos showcasing varied robotic behaviors. Conducted within the I-CATER project, which focuses on social robots in workplace environments, the research explores how communication strategies and social behaviors influence trust perceptions. The video scenarios included differences in error communication, task initiation approaches, and facial expressions. Participants completed a questionnaire integrating the Godspeed Questionnaire Series (GQS) and the Big Five Inventory-10 (BFI-10), supporting a multifaceted assessment of trust-related dimensions. Statistical analyses using Friedman and Wilcoxon tests revealed that verbal justifications and apologies significantly improved perceived likeability and intelligence, while dynamic facial expressions increased perceptions of anthropomorphism, likeability, and animacy. Although demographic factors such as age, technological background, and robot ownership showed no significant correlation with trust, a weak gender trend indicated lower trust ratings among male participants. Clustering analysis further identified distinct participant profiles based on trust responses. The study provides valuable insights to support decision-making in robot design and interaction strategies.

Session 1.5 –Education / 67

O Ensino da Investigação Operacional na Voz dos Alunos: Dificuldades, Motivações e Propostas de Melhoria

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Esta comunicação explora o ensino da Investigação Operacional (IO) a partir da perspetiva dos estudantes, procurando fomentar uma reflexão crítica e informada sobre as práticas pedagógicas nesta área. A metodologia integra o testemunho de uma antiga aluna —que partilha os principais desafios e fatores de motivação vivenciados —e a análise preliminar de um questionário atualmente em curso junto de estudantes do mesmo curso. O inquérito incide sobre as perceções dos alunos quanto aos conteúdos lecionados, estratégias de ensino utilizadas, dificuldades sentidas e relevância da IO para a sua formação académica e futura vida profissional. Esta abordagem visa valorizar a experiência discente como eixo central para a melhoria contínua do ensino da IO, promovendo um diálogo construtivo entre docentes e alunos. A comunicação culminará com um conjunto de propostas para tornar o ensino da IO mais dinâmico, envolvente e alinhado com os interesses e necessidades dos estudantes.

Session 1.5 –Education / 77

Aprender Otimização a Jogar: Relato de uma Experiência com o Burrito Optimization Game

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Este trabalho apresenta, do ponto de vista de um grupo de estudantes da Licenciatura em Gestão Industrial e Logística da ESTG, P.PORTO, uma experiência de integração da gamificação no ensino da modelação matemática, através de um Trabalho Prático que tem como ponto de partida o Burrito Optimization Game, desenvolvido pela Gurobi (https://www.gurobi.com/burrito-optimization-game/). O trabalho foi desenvolvido em três etapas de complexidade crescente. A primeira consistiu na implementação e análise dos resultados do modelo binário apresentado no site da Gurobi. Nas fases seguintes, os grupos foram desafiados a modificar o modelo, introduzindo variáveis contínuas ou inteiras e restrições adicionais realistas, como limites de capacidade, locais obrigatórios ou proibidos e dependências condicionais entre decisões. Cada fase exigiu a implementação em software de otimização, reflexão crítica e comunicação clara dos resultados, culminando com uma apresentação e defesa oral. O enunciado aberto do trabalho permitiu aos estudantes explorar diferentes abordagens, propor variantes criativas e adaptar o modelo às suas próprias ideias, promovendo a autonomia, o pensamento crítico e o desenvolvimento de competências práticas em Investigação Operacional.

Acknowledgement:
This work has been supported by national funds through FCT - Fundação para a Ciência e Tecnologia, under the projects UIDP/04728/2020 and UIDB/04728/2020.

Session 1.5 –Education / 94

Hierarchical Analysis of Educational Strategies for Youth Financial Literacy Using the Analytic Hierarchy Process

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Financial literacy is essential for the well-being and social inclusion of individuals of all ages, but its absence is particularly detrimental to young people. Portuguese students exhibit significant shortcomings in this area, largely due to the lack of structured instruction during compulsory education. This study applies the Analytic Hierarchy Process (AHP) to rank pedagogical strategies aimed at improving financial literacy among Portuguese youth.
Four evaluation criteria were established - knowledge acquisition, motivation and engagement, accessibility and flexibility, and behavioral impact - alongside five pedagogical alternatives: in-person courses, online courses, digital content, books, and educational games/apps.
Criterion weights were obtained via pairwise comparisons carried out with students using a survey, whereas the alternatives were assessed by a subject-matter expert.
Findings indicate that behavioral impact is the most highly valued criterion, followed by knowledge acquisition. Among the alternatives, in-person courses were identified as the most effective, with online courses ranked second. Although digital tools scored highly on flexibility, their perceived effectiveness was lower. The study concludes that innovation in financial education should emphasize

not only delivery format, but more critically, pedagogical quality and the capacity to drive behavioral change.

Session 2.1 –Transportation / 36

Enhancing carsharing pricing and operations through integrated choice models

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Balancing supply and demand in free-floating one-way carsharing systems is a critical operational challenge. We propose a novel approach integrating a logit model into a mixed integer linear programming framework to optimize short-term pricing and fleet relocation. Based on a binary logit model, demand modelling aggregates different trips under a unified utility model and improves estimation by incorporating information from similar trips. A categorizing approach is used to speed up the estimation process, where variables such as location and time are classified into a few categories based on shared attributes. The modelling framework adopts a dynamic structure where the binary logit model estimates demand using accumulated observations from past iterations at each decision point. This continuous learning environment allows for dynamic improvement in estimation and decision-making. At the core of the framework is a mathematical program that prescribes optimal levels of promotion and relocation. The framework then includes simulated market responses to the decisions, allowing real-time adjustments to balance supply and demand effectively. Computational experiments demonstrate the effectiveness of the proposed approach and highlight its potential for real-world applications. The continuous learning environment, combining demand modelling and operational decisions, opens avenues for future research in transportation systems.

Session 2.1 –Transportation / 45

Transit Network Design and Frequency Setting with elastic demand: a mixed-integer linear programming approach

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The main goal of this work is to develop a single-level mixed-integer linear programming framework for the Transit Network Design and Frequency Setting Problem that aims to capture demand by taking into consideration the travellers' preferences and activates or deactivates routes at a certain frequency accordingly, from a given pool of possible routes. This work was applied both to an illustrative example and to a case study of the existing bus and Bus Rapid Transit network in an area of the Barcelona Metropolitan Area, comprising 9 lines and 319 origin-destination pairs. For each origin-destination pair, each possible itinerary within the network is pre-computed and is compared against the best itinerary of each of the competing modes of transport, which are obtained using Google Maps. For each itinerary in the network its probability of being chosen based on its utility is computed, using a multinomial logit model, taking into consideration its access, waiting

and travel time, cost and number of transfers. Its coefficients were calibrated using a Stated Preferences Survey. The goal is to maximize the total network demand by tuning the active routes and frequencies, activating the itineraries with the highest probability of being chosen, allocating most or a pre-determined percentage of the demand to them, constrained by number and capacities of buses. The formulation allows for different assumptions on traveller assignment, by tunning the percentage of travellers on the highest utility itinerary, and coverage, either forcing full coverage or not. The models are solved with the commercial software FICO Xpress within reasonable computational time and low optimality gaps.

Session 2.2 - OR with Social Impact / **106**

Epidemiological Modelling of Misinformation with Optimal Intervention Strategies

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Fake news poses an increasingly critical threat to societal stability by shaping opinions, eroding institutional trust and deepening social polarisation. Every day, misleading content circulates across digital platforms with real consequences such as political manipulation.

Due to the resemblance of the spread of fake news with the transmission of infectious diseases, epidemiological frameworks, specifically the Susceptible-Infected-Recovered (SIR) model, are considered well suited to analyse its dynamics. In this work optimal control theory is applied in order to curb the propagation of false information. The cost functional is defined by two weights: one that penalises the overall number of users who have been mislead - to capture the social cost of the fake news - and another to quantify the economic and/or operational cost associated with the control action itself (e.g. content moderation).

SIR parameters (infection and recovery rates) are estimated by fitting the model to real-world fake-news data. By combining least-squares technique and a derivative-free optimisation algorithm in MATLAB, the optimal parameters that best describe the specific false information spread are obtained. The Forward-Backward-Sweep Method (FBSM) is then applied to compute the optimal control strategy, or intervention, aimed at minimising the number of misinformed individuals while balancing social harm against intervention cost.

Session 2.2 - OR with Social Impact / **110**

Centro de Troca de Alimentos: um enfoque social

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Apesar do compromisso do Brasil em atingir a Fome Zero (2o. Objetivo de Desenvolvimento Sustentável da ONU), o país retornou ao mapa da fome em 2022. Nas cidades brasileiras, é muito comum termos várias instituições civis e religiosas que distribuem cestas de alimentos para famílias em situação de vulnerabilidade. Uma cesta de alimentos, chamada de cesta básica, contém um conjunto de alimentos destinados a ajudar uma família por um mês. Estas instituições dependem de doações, logo podem receber grandes quantidades de certos alimentos e pouca de outros. Portanto, muitas

vezes não conseguem obter todos os ingredientes em quantidade suficiente para montar o número de cestas necessárias para as famílias atendidas. Nesse caso, a instituição precisa buscar outros doadores. Um desses doadores é o Fundo Social de Solidariedade (FSS) do município, que devido ao orçamento limitado, nem sempre consegue comprar todos os alimentos requisitados por todas as instituições. Neste trabalho, estudamos a proposta de um centro de troca social onde as instituições deixam os alimentos que têm em excesso e retiram os precisam. Propusemos um modelo matemático para representar o problema. Experimentos computacionais baseados em instâncias artificiais foram realizados. Apoio financeiro FAPESP 2024/04929-9 e CNPq 309161/2022-3.

Session 2.2 - OR with Social Impact / 96

Social welfare in a design and distribution problem

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While sustainability is a central concern in supply chain management, its social dimension remains widely underexplored. In the pharmaceutical industry, among various social sustainability standards, ensuring product availability and broad access to medicines is largely recognized as a key responsibility.
To integrate social objectives while preserving economic efficiency, this study proposes a decision-support tool for the strategic and tactical planning of pharmaceutical supply chains. A bi-objective mixed-integer linear programming model is developed to simultaneously maximize net present value and ensure equitable product availability across different demand regions. The model incorporates decisions related to inventory holding, distribution, and design of manufacturers and warehouses. Realistic data from a vaccine distribution problem is used to validate the model. Preliminary findings highlight important trade-offs between economic performance and social equity. Managerial insights are provided to improve equity with minimal impact on costs.

Session 2.3 –Scheduling / 60

Learning Dispatching Rules for a Large-Scale Scheduling Problem of a Maintenance Provider

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Nowadays, companies desire to offer customised products and services to their customers. At the same time, they want to address customers'requests as fast as possible. In addition, operations are

often subject to high uncertainty and frequent disruptions, such as urgent order arrivals, resource unavailability, and product defects. Under these conditions, companies need to schedule tasks quickly, often in real-time, and therefore use dispatching rules. However, the performance of those rules depends on the objectives, settings, and conditions for which they were designed. Generating rules by hand for the several possibilities is burdensome. Consequently, using artificial intelligence to find new dispatching rules became common. This work uses genetic programming to find new rules in a large-scale scheduling problem of a real-world maintenance provider. This problem was modelled as a Dynamic Resource-Constrained Multi-Project Scheduling Problem. It includes several sources of uncertainty, such as unexpected arrivals, uncertain processing times and unplanned work. Genetic programming rendered dispatching rules around 10% better tardiness-wise than existing ones from the literature while maintaining a compact size.

Session 2.3 –Scheduling / 98

Learning to schedule from demonstrations: What we lose by only imitating the best?

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Early success of Deep Reinforcement Learning (DRL) was rooted in arcade and board games, where expert behavior could be readily captured from top players. In these settings, demonstrations were used to bootstrap learning and accelerate policy convergence. In contrast, in combinatorial optimization problems, such as the Flexible Job-shop Scheduling Problem (FJSP), optimal demonstrations are costly to obtain. In this work, we build on a state-of-the-art DRL framework to investigate how the quality and diversity of demonstrations from FJSP solutions affect learning dynamics and policy generalization. We argue that representativity of the action space is more beneficial for pretraining than strict optimality. To that end, we consider an efficient Constraint Programming (CP) method and several composite heuristic rules as candidate experts. These were evaluated based on the final policy performance, the generalization to unseen instances, and the time required to gather expert FJSP solutions. Preliminary results show that agents pre-trained with diverse sub-optimal demonstrations converge faster to near-optimal policies than those trained solely on solver-based solutions. Moreover, combining CP and heuristic demonstrations leads to superior robustness to unseen instances. These findings suggest that diversity and representativeness in expert behavior may be more critical than optimality alone.

Session 2.3 –Scheduling / 107

Efficient nesting via Fast Fourier Transforms to solve the production scheduling problem in Additive Manufacturing

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The interdependence of nesting and production scheduling problems in Additive Manufacturing (AM) systems poses a significant computational challenge when considering traditional optimization methods. This work addresses the AM scheduling problem (AMSP), with a particular focus on

the nesting component, which remains the major computational bottleneck in existing approaches. Current nesting methods frequently rely on complex and computationally intensive preprocessing and struggle to scale efficiently or handle multiple part rotations. Building on an in-depth review of geometric tools for handling part geometry and no-overlap constraints, we propose a nesting framework that builds on raster-based representations and exploits the Convolution Theorem by employing Fast Fourier Transforms on modern computing hardware to quickly identify feasible part placements. Contrary to the expectations, results show that finer raster resolutions and a predefined number of rotations do not significantly impact run time, highlighting the scalability and efficiency of the method. This nesting framework is integrated into a Biased Random-Key Genetic Algorithm (BRKGA) to address the AMSP in a unified manner. Initial experiments on benchmark datasets showcase the competitiveness of our approach compared to state-of-the-art methods, offering a promising path toward scalable and efficient AM scheduling.

Session 2.4 - Bilevel optimization / **49**

A bilevel approach to enhance flexibility in retailer-supplier agreements for perishable products

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One key condition in these retailer-supplier agreements is the Minimum Life On Receipt (MLOR) rule, which defines the maximum product age acceptable by the retailer to pay the full price. In this study, we propose a model that helps negotiate the retailer-supplier agreement's conditions to make them more flexible. Specifically, we define the share of orders that may be accepted by the retailer beyond the MLOR at a discount.
We formulate the problem as a bilevel program considering the individual objectives of the retailer (leader) and the supplier (follower), as well as a consumer demand driven by prices and product freshness. The bilevel problem is solved with a reformulation-and-decomposition algorithm. We compare the supply chain benefits of solving the bilevel program with those of optimizing the retailer's and supplier's objectives jointly in a centralized approach. We also compare it with the standard contracted terms, in which products are returned if the supplier fails to comply with the MLOR. Our results highlight the advantages of adopting these flexible agreements, with an average increase of profits of up to 4% for the retailer and up to 13% for the supplier. We also provide suggestions on how to design a new clause in these agreements according to consumer demand variability and the retailer's order frequency.

Session 2.5 - AI and OR in healthcare / **50**

Public hospitals five-star rating considering interactions in pairs of access and quality criteria

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In pursuit of a more sustainable future, populations and economies need to be protected by stronger and more resilient health systems. Their complexity requests adequate assessment frameworks for improving the access and quality of their services. Due to the multidimensional nature of health systems, this study presents a collaborative multi-criteria decision-aiding framework to assess the performance and classify public hospitals' performance in terms of service quality and access using a five-star rating system. Existent studies in this area usually assume criteria independence, besides modelling criteria interactions could be more realistic. However, this notion has not yet been entirely understood, nor have there been any applications to the health sector. Thus, our framework innovates by modelling interactions in some pairs of criteria, identified by the decision-maker, using the ELECTRE TRI-nC method. We obtained a five-star rating for 26 Portuguese public hospitals. The majority hospitals were assigned to '2 stars' ('poor') and '3 stars' ('average') categories over the considered 4-year period. We conclude that assuming criteria dependence reveals more realistic results in comparison to a criteria independence assumption. We observed that the number of doctors and nurses does not influence the assignment of the hospitals to the categories. Robustness analyses evidence the framework's credibility.

Session 2.5 - AI and OR in healthcare / **7**

Predicting hospital efficiency through integrated Data Envelopment Analysis and machine learning

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Health systems are under growing pressure due to resource constraints and increasing demand. Measuring hospital efficiency is therefore crucial to support effective management and evidence-based policymaking. This study introduces an innovative framework that combines Data Envelopment Analysis (DEA) with machine learning (ML) techniques to assess and predict the efficiency of Portuguese public hospitals. Efficiency scores were obtained using the Super Efficiency Slacks-Based Measure DEA model, applied to a ten-year dataset from 2014 to 2023. Results indicate that 76.82% of hospital units operated inefficiently, with marked disparities across regions, particularly in the south and interior areas. To enhance the model's predictive capacity, ten ML algorithms were evaluated, with XGBoost achieving the highest accuracy. The integrated SuperSBM-DEA and XGBoost model enables the simulation of improvement scenarios for underperforming hospitals and anticipates the efficiency impact of managerial decisions. Beyond its predictive performance, the framework offers actionable insights and holds strong potential for integration into national healthcare policy. The findings suggest the feasibility of a centralised, data-driven system for dynamic resource allocation, contributing to a more equitable and efficient provision of care across regions.

Session 2.5 - AI and OR in healthcare / **70**

Explainable Machine Learning For Healthcare Cost Optimization: A Time-Driven Approach

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Efficient cost and resource allocation in healthcare is essential for the sustainability of hospital operations and patient-centered initiatives. However, this can be a complex issue due to the extensive scope of work and the difficulty in maintaining economic models designed for these evaluations. In recent years, machine learning (ML) has been increasingly adopted to support healthcare decision-making, but despite its predictive power, a major limitation remains: the lack of interpretability in many models, which hinders trust and usability by medical personnel.

In this study, we use the electronic medical records of 2800 cardiothoracic surgery patients of Santa Marta's Hospital and propose a novel approach that integrates ML with mathematical optimization to provide interpretable insights for healthcare cost analysis. Our methodology incorporates set covers within a clustering algorithm to identify representative patient cohorts, addressing the explainability gap in current ML approaches. Subsequently, we apply the Time-Driven Activity-Based Costing model to estimate the cost of each patient type by mapping clinical activities to time-based resource consumption. By combining optimization techniques with interpretable machine learning, our approach provides a transparent framework for healthcare cost analysis. This supports more informed decision-making, aligns with the growing demand for explainable ML in healthcare, and enhances communication between technical and clinical stakeholders.

Session 3.1 - Optimization in networks / **46**

Optimização da supressão de incêndios florestais

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Desde o final da década de 1950 que a Investigação Operacional tem contribuido para a gestão de incêndios florestais. Em anos recentes, têm sido propostas diversas aborgadens para o problema de supressão que, genericamente, consiste em decidir onde colocar os meios disponíveis para atacar o incêndio da forma mais consequente.
Nesta apresentação discutem-se abordagens baseadas em programação inteira mista para lidar com esse problema considerando diversas variantes: ataque inicial, ataque estendido directo e indirecto, meios terrestres e aéreos.
A modelação baseia-se na definição de uma rede relativa à propagação do incêndio e de outras redes para movimentação e ataque dos meios. Um mesmo modelo integra as diversas redes e as decisões a elas associadas.
Apresentam-se resultados de experiências computacionais e discutem-se direcções para reforçar a aplicabilidade das abordagens propostas.

Session 3.1 - Optimization in networks / **64**

Patrolling Routes for the Amazonas River Navigation System

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The Amazon River and its tributaries form an extensive and complex network exceeding 10,000 km, comprising several significant tributaries. These rivers are crucial for connectivity, facilitating trade and commerce, and providing access to services for local communities. Patrolling these waterways is essential to curb illegal activities, protect biodiversity, and safeguard local communities. The aim of this research is to develop patrolling routes for the Amazon River navigation system, conceptualized as a variation of the periodic arc routing problem. This study considers factors such as the navigation time span, which can make some routes exceptionally long, seasonal variations (floods and droughts) that restrict route availability, and varying visitation frequencies for each river stretch. This issue is also approached as a profit-collection problem, with benefits derived from the arcs monitored and secured. Different Mixed Integer Programming (MIP) formulations are proposed and evaluated, taking into account decisions regarding fleet size and base positioning. Results are obtained using real data.

Session 3.1 - Optimization in networks / **63**

Network-Based Resource Planning for Wildfire Management

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This work addresses the design of networks to support wildfire preparedness activities, namely surveillance, detection, and suppression. The problem is defined over a graph where nodes represent potential locations for positioning resources (e.g., watchtowers or firefighting crews), and arcs denote direct connections (e.g., roads) between these locations.
We propose a mixed-integer programming model that integrates two decision layers: covering (selecting resource positions to ensure area coverage) and network design (selecting arcs to define the network structure). The model supports different topological configurations, including spanning trees, shortest-path trees, and Hamiltonian circuits. Different objectives are considered, such as maximizing coverage and minimizing the total network length.
Computational experiments are conducted on a real-world landscape to evaluate the performance and flexibility of the proposed approach. The results highlight the trade-offs between coverage and network compactness and show how the model can adapt to different planning priorities and operational constraints.
This integrated formulation offers a general and extensible framework for designing spatially distributed wildfire preparedness systems, with potential applicability to other emergency response planning contexts.

Session 3.1 - Optimization in networks / **34**

Inspecting Electric Lines with Drones

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This study addresses the routing for the inspection of electric lines with drones in Portugal, managed by EDP Labelec, the partner company in this project. There is a set of electrical lines that need to be

inspected and a set of points where the drone operator can stop managing the drone for inspecting those lines. The objective is to determine an inspection plan —that is, the points where the drone operator stops and the routes performed by the drone —to inspect all the service lines, that minimizes the inspection time. This problem is modeled as an Extended Capacitated Arc Routing Problem (ECARP). The CARP is known to be NP-hard, as is this ECARP since it generalizes the CARP. The developed model is solved using CPLEX on smaller real instances generated using a GIS (Geographic Information System) available at the EDP Labelec. The quality of the solutions generated is assessed by the total inspection time, as well as feedback from the EDP Labelec team. This team evaluates the practical adequacy of the solutions, a crucial aspect for trips that need to be accepted by practitioners. Computational analysis will provide new insights for the development of new methodology to solve larger instances that feat the dimensions of the real ones.
Acknowledgments: research supported by Portuguese National Funding from FCT - Fundação para a Ciência e a Tecnologia, under project ISEG-Research - UID/06522/2023

Session 3.2 - OR in waste management / **72**

Strategic decisions in the valorization of subproducts

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The recovery of food waste is a trend in the current context of sustainability, circular economy, and waste reduction. For example, it is possible to use peels, seeds, and non-standard fruit to produce new products such as jams, teas, flour, or transform them into animal feed, biofertilizers, or cosmetics. The literature on food waste and losses along the food supply chain is vast, but quantitative studies that support the decision of which are the best valorization solutions for food waste and losses are limited. Based on this literature gap, the main objective of this work is to identify efficient matches between food subproducts and the most suitable recovery strategies. Using multi-criteria decision models, we will analyze viable strategies capable of producing value while guaranteeing relevant logistical constraints. Developing valorization strategies in environmental, operational, and economic terms can contribute directly to reducing food waste and food losses along the production and supply chains.

Session 3.2 - OR in waste management / **82**

From Blind Collection to Smart Routing: A Data-Driven Analysis of Waste Collection in Figueira da Foz

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This study analyzes the waste collection operations of the municipality of Figueira da Foz, Portugal, using real operational data from February 2020 to April 2024. The objective is to evaluate and optimize the current system through four distinct scenarios. First, we establish a baseline by examining the existing system, which operates on fixed schedules and routes - a method commonly referred to as blind collection. In the second scenario, we automate collection frequency and routing by clustering containers according to their historical filling patterns, aiming to reduce inefficiencies and unnecessary trips. The third scenario simulates a fully sensorized system, where real-time data

from all containers enables a highly dynamic and responsive routing process. Finally, we explore a partially sensorized network, where only selected containers are equipped with sensors. The data from these containers is used to infer the behavior of similar, non-sensorized containers within the same cluster. For each scenario, we solve a Vehicle Routing Problem with Profits (VRPP) to optimize collection routes and maximize efficiency. The results demonstrate that partial sensorization, combined with behavioral clustering, can significantly enhance operational performance and reduce costs, even without full sensor coverage.

Session 3.2 - OR in waste management / **92**

Nova abordagem para a otimização da gestão de resíduos de construção e demolição (com componente temporal)

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Os impactos causados pelos resíduos de construção e demolição (RCD) podem ser elevados caso não se efetue uma gestão eficaz dos mesmos. Em consequência, as preocupações relacionadas com esta gestão têm aumentado nos últimos anos, estimulando a elaboração de estudos sobre o assunto.
Este trabalho deu continuidade aos trabalhos de Correia (2013) e Andrade (2015), que desenvolveram uma nova abordagem para o planeamento de uma rede de reciclagem de RCD, utilizando um modelo de programação linear inteira mista visando a minimização de custos. Neste trabalho foi adicionada uma componente temporal à formulação matemática, possibilitando a modelação dos fluxos de materiais entre os diversos processos para cada um dos períodos do horizonte temporal considerado.
O modelo foi validado utilizando um conjunto de dados reduzido, sendo consideradas apenas 10 freguesias e, em seguida, foi aplicado às 211 freguesias que compõem a Área Metropolitana de Lisboa, com a geração de múltiplos cenários e um análise de sensibilidade aos parâmetros mais relevantes. Embora tenha sido aplicado a nível regional, a formulação é genérica ao ponto de poder ser utilizada a nível nacional.
Os resultados obtidos indicam que, do ponto de vista económico, é mais viável depositar os RCD em aterro do que reciclar. Além disso, é possível concluir que o custo de deposição em aterro dos resíduos possui elevada influência na quantidade de RCD reciclados.

Session 3.2 - OR in waste management / **87**

Stochastic Waste Collection Routing with Profit: A two-stage framework

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This study addresses the Waste Collection Vehicle Routing Problem with Profit (WCVRP) while considering uncertainty in bin fill levels a critical challenge for municipalities and waste management

providers aiming to enhance service efficiency. In real-world conditions, bins fill levels fluctuate unpredictably, leading to inefficient routing, unnecessary trips, or uncollected waste. To tackle these issues, we propose a Two-Stage WCVRP that incorporates uncertainty through a scenario-based approach. Scenarios are generated from residuals of predictive models, capturing realistic variations in bins waste usage.

The model employs a single recourse strategy: an overflow penalty is incurred when containers exceed their capacity and waste remains uncollected. This approach avoids the need for vehicle return trips and reflects practical constraints in urban collection systems. The objective is to maximize profits by balancing collection revenues, travel costs, and penalty costs. Formulated as a variant of the Capacitated Vehicle Routing Problem with Profit (CVRPP), the model performance is evaluated using indicators such as total profit, total distance traveled, and total waste collected.

Stochastic metrics, including the Expected Value of Perfect Information (EVPI) and the Value of the Stochastic Solution (VSS), are also calculated to assess the value of explicitly modeling uncertainty. A preliminary case study in Rio Maior, Portugal,demonstrates the applicability of the developed approach.

Session 3.3 - Retail and sales / **31**

The introduction of online operations to brick-and-mortar grocery stores and its impact on spoilage

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Omnichannel grocery retailers often use stores to fulfill online orders for a variety of reasons (e.g., faster deliveries, labor availability). This strategy influences inventory management, particularly the spoilage ratio (defined as the ratio of loss to sales) in two opposing ways. Fulfilling online orders has the potential to increase the sales-to-stock ratio thereby improving turnover and, consequently, the spoilage ratio. However, the last-expired-first-out picking policies used by store employees to serve online customers may generate higher levels of spoilage in the store. Using granular data from a grocery retailer, we study the impact that introducing online fulfillment to existing stores has on spoilage. Our empirical methods include a staggered difference-in-difference approach to account for the way in which online fulfillment was adopted throughout the chain. We find the spoilage ratio to increase, on average, with the introduction of online fulfillment at brick-and-mortar stores. However, substantial heterogeneity in this increase exists across product categories and stores. We exploit this heterogeneity to understand more about the dynamics of online order fulfillment and to caution retailers about several unforeseen performance impacts of online operations.

Session 3.3 - Retail and sales / **39**

Forecast-Driven Sales and Operations Planning for Balancing Supply and Demand in the Rice Industry

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Industrial companies often struggle to balance supply and demand, leading to excess inventory, stockouts, and reactive decision-making. This case study examines a rice company that lacked formal demand planning and relied on siloed, unsophisticated forecasts. The main research goal was to improve decision-making, operational efficiency, and strategic alignment in the company. This was pursued by identifying deficiencies in demand planning and defining solutions to surpass them. Data were gathered from the company's database and through interviews across multiple organizational levels. Analysis of the current situation lead to implementing a Sales & Operations Planning (S&OP) process underpinned by a forecasting pipeline. The proposed S&OP process entails monthly compilation of demand and market data, forecast validation, and a mid-month meeting outputting a consensus sales plan. The forecasting pipeline begins with baseline-driven forecasts, which undergo optimal hierarchical reconciliation and weekly disaggregation using historical proportions. Demand spikes—stemming from promotions and non-Gregorian seasonality—are modeled respectively with random forests and exponential smoothing. Finally, on-hand orders are incorporated to further refine forecasts. The S&OP cycle enhances cross-functional alignment and proactive decision-making. The forecasting pipeline markedly outperforms the prior budget-based forecasts. Future work could introduce two-fold forecasting for intermittent series, production strategy optimization and portfolio rationalization.

Session 3.3 - Retail and sales / **40**

Balancing Fulfillment Costs with Vendor Goals: Optimizing Order Allocation in Online Marketplaces with Reinforcement Learning

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Online marketplaces provide a platform that connects suppliers with customers, allowing vendors to sell their products to a broader audience. To streamline customer experience, some marketplaces allocate a set of fulfillment vendors and stockpoints at the moment a customer is placing an order in the platform. This order allocation decision impacts not only fulfillment costs and customer satisfaction but also sales volume received by suppliers, directly impacting supplier retention on the platform. We introduce the Multi-Item Order Fulfillment Problem in Online Marketplaces, which considers suppliers' perspective by incorporating sales targets over a selling season.
Reinforcement Learning is applied to the problem by means of the Deep Controlled Learning algorithm, which hybridizes Approximate Policy Iteration with Supervised Learning. As a benchmark, two families of solution methods are considered: various myopic rule-based policies, popular in practice, and two randomized policies with attractive asymptotic properties.
We compare these policies on real-world-based instances tailored based on past interactions with an online marketplace. We find that our approach is superior when demand per item is relatively low, while achieving balanced outcomes on the multiple perspectives (cost, supplier and customer satisfaction).

Session 3.3 - Retail and sales / **52**

Integrating perishables' short life into assortment optimization

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Retailers' product mix selection is a key determinant of market share, profitability, and long-term success. While a broader assortment increases the likelihood of meeting diverse customer preferences, it raises inventory-related costs and stockout risks, ultimately affecting operational performance and customer loyalty. This challenge is amplified for perishable goods, where limited shelf life narrows the selling window and increases spoilage risks. Despite extensive research on assortment optimization, existing models fail to integrate perishability dynamics. The few studies that consider shelf life treat it as a constraint rather than a factor influencing substitution patterns and retailers' profitability. However, ignoring perishability can lead to suboptimal product selection, excessive waste, and lost revenue. This study introduces an assortment optimization framework that integrates remaining shelf life into decision-making. Unlike conventional models, it accounts for shelf-life-sensitive demand and substitution effects, helping retailers balance waste reduction, profitability, and service levels. Using historical data from a European grocery retailer, we assess the framework's effectiveness and quantify the profitability and waste gap. Our findings highlight the importance of shelf life in assortment planning, introduce new heuristics for perishable product selection, and offer actionable insights to improve retail efficiency, sustainability and financial performance.

Session 3.4 - Artificial Intelligence and OR / 112

Forecasting UK Socioeconomic Indicators under Political Uncertainty: Classical vs Deep Learning Approaches

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Abstract

The growing uncertainty of the international economic and political landscape, accentuated by phenomena such as Brexit and the pandemic, highlights the importance of robust and interpretable decision-support tools. In this environment, operational research (OR) is crucial for designing sustainable and innovative solutions for both society and businesses. This study contributes to this goal by applying advanced time series modelling techniques to inform evidence-based strategic decisions in socio-economic contexts. Time series data on UK job vacancies and 10-year bond yields are analysed alongside the political uncertainty index to explore forecast accuracy and causal relationships. A wide range of forecasting models were evaluated, including classical models (ARIMA and ETS) and deep learning architectures (GRU, LSTM, CNN and a hybrid approach). Performance was assessed across multiple forecast horizons using walk-forward validation and error metrics (sMAPE and R^2). The results demonstrate that classical models outperform deep learning models in the short term, while GRUs demonstrate superior performance in the long term. Granger causality tests confirmed statistically significant relationships between political uncertainty and the economic indicators studied. These findings emphasise the value of integrating OR and AI-based modelling to make resilient and sustainable decisions in uncertain situations and provide valuable insights for designing policies and planning strategies in dynamic economic environments.

Keywords: Socioeconomic Indicators; Political Uncertainty; Time Series Forecasting; ARIMA and ETS Models; Deep Learning Models; Causal Inference

Session 3.4 - Artificial Intelligence and OR / 57

Reframing Signal Drift: An AI-Based Approach for Functionalized Graphene Sensors

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Graphene field-effect transistors (GFETs) are powerful tools for detecting a variety of biological and chemical substances, including ions, glucose, DNA, and proteins, due to their exceptional sensitivity to electric fields. Although non-functionalized GFETs have performed well, especially when combined with Artificial Intelligence (AI), this study centers on the use of functionalized GFETs. These devices incorporate molecular probes that selectively bind to target DNA sequences on the graphene surface, enabling highly specific detection at extremely low concentrations. Despite their enhanced selectivity, functionalized GFETs remain susceptible to interference and signal drift. This study explores their application in detecting bacterial DNA and evaluates their performance under realistic conditions. A major limitation of conventional detection methods is the tendency to simplify analysis by focusing only on limited regions of the sensor's output, discarding complex signal segments that may hold valuable information. Rather than aiming to generalize across devices, the primary objective of this study is to investigate whether the typically discarded regions of GFET signal data contain meaningful patterns. By applying Deep Learning to the complete "V"-shaped transfer curves, this approach reveals insights into the operational behavior of functionalized GFETs, improving data utilization and informing the design of more robust biosensing systems.

Session 3.4 - Artificial Intelligence and OR / **37**

Diferenciação de Espécies Bacterianas com Inteligência Artificial a partir de Compostos Orgânicos Voláteis

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As infeções associadas aos cuidados de saúde representam uma ameaça significativa à saúde pública, agravada pela sua resistência antimicrobiana. Métodos tradicionais de deteção apresentam várias limitações, incluindo baixa sensibilidade e custos elevados. Uma alternativa promissora é a deteção de compostos orgânicos voláteis (VOCs) emitidos por bactérias, que atuam como uma "impressão digital"única.
Este estudo recorre ao *Few-Shot Learning* (FSL), uma abordagem de *Machine Learning* eficaz em contextos com poucos dados rotulados, para analisar imagens geradas a partir de padrões distintos de corrente de ionização dos VOCs libertados. Esses padrões são obtidos através de um método de deteção bacteriana com um detetor fotoionizante multiplexado por comprimento de onda (PID).
Para extrair características das imagens, utiliza-se uma rede neuronal convolucional (CNN) pré-treinada, especificamente a *ResNet-18*. Em seguida, aplica-se a *Prototypical Networks* para classificar as espécies bacterianas, comparando amostras com protótipos representativos de cada classe. Esta abordagem baseada em inteligência artificial oferece uma solução promissora para a deteção bacteriana em tempo real, especialmente no diagnóstico clínico e no controlo de infeções, onde a escassez de dados representa um desafio significativo.

Session 3.4 - Artificial Intelligence and OR / **105**

How integration of generative AI and optimization methods can accelerate product design and manufacturing process development?

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Current methods in product development and industrialization are rigid, resource-intensive, and reliant on expert intuition. Integrating Artificial Intelligence (AI), particularly Generative AI (GenAI), with combinatorial optimization presents significant potential to address these challenges. Such integration can enable data-driven, automated decision-making across the product lifecycle—from early-stage design and optimization to scale-up, transitioning a product or process from the development stage into full-scale manufacturing.
Despite this potential, effective application in engineering domains requires the incorporation of domain-specific knowledge, the handling of complex constraints, and the delivery of actionable outcomes. This work presents a preliminary analysis of how GenAI can be combined with optimization techniques to support complex engineering design and industrialization tasks. It includes a critical review of integration strategies, such as embedding engineering constraints, leveraging expert input to guide AI exploration, and translating AI-generated solutions into accessible and effective decisions. We conclude with a discussion on the role of these technologies in engineering workflows, evaluating their suitability for full automation versus their use as co-pilot systems in hybrid human–AI teams.

Session 3.5 - Data Envelopment Analysis / **84**

Avaliação da Eficiência das Universidades Europeias

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A pandemia de COVID-19 provocou mudanças significativas no ensino superior, obrigando as universidades a adaptarem-se rapidamente ao ensino remoto e à gestão eficiente de recursos. A crise colocou à prova a capacidade das instituições de rever processos, otimizar o uso de recursos e manter a qualidade do ensino e da investigação.
Este trabalho tem como objetivo avaliar a eficiência do ensino superior europeu durante a pandemia, identificando ineficiências nas universidades e analisando o impacto da crise. A amostra inclui 30 universidades europeias, nos anos de 2019 e 2020, considerando duas perspetivas: operacional e financeira.
A metodologia utilizada foi a Value-Based Data Envelopment Analysis, complementada com o Índice de Produtividade Total dos Fatores, que permite medir variações de produtividade ao longo do tempo. Os resultados sugerem que a pandemia poderá ter tido um impacto positivo na eficiência universitária. Em 2019, 16 universidades foram consideradas eficientes do ponto de vista operacional, aumentando para 19 em 2020. Na vertente financeira, o número passou de 17 para 18. A eficiência operacional associa-se à redução de doutoramentos e ao aumento de licenciados e mestres, enquanto a eficiência financeira relaciona-se com a minimização de despesas de capital.

Session 3.5 - Data Envelopment Analysis / 108

A eficiência bancária na europa –uma análise ao período 2014-2022

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O setor bancário europeu atravessou um período de profundas transformações entre 2014 e 2022, impulsionado por choques como a pandemia de COVID-19, regulamentações supranacionais e a aceleração digital. Este estudo analisa a eficiência operacional de 96 bancos sistémicos sob supervisão direta do Banco Central Europeu, utilizando a metodologia Value-Based Data Envelopment Analysis e Window Analysis. Através da avaliação de inputs como custos com pessoal e ativos fixos, face a outputs como empréstimos e ativos rentáveis, investigam-se padrões de eficiência ao longo do tempo. Os resultados revelam uma melhoria sustentada da eficiência média, com destaque positivo para bancos franceses e neerlandeses. Em contrapartida, instituições de países periféricos, como Portugal, Grécia e Espanha, apresentam desempenhos inferiores. O BNP Paribas destaca-se como o banco mais eficiente, seguido pelo Santander, ambos com forte enfoque na digitalização e qualidade dos ativos. Este trabalho reforça a relevância da inovação tecnológica e da gestão estratégica de risco como pilares da eficiência no setor bancário europeu.

Session 4.1 –Transportation and Delivery / 58

A new effective heuristic for the Prisoner transportation problem

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The Prisoner Transportation Problem is an NP-hard combinatorial problem and a complex variant of the Dial-a-Ride Problem. Given a set of requests for pick-up and delivery and a homogeneous fleet, it consists of assigning requests to vehicles to serve all requests, respecting the problem constraints such as route duration, capacity, ride time, time windows, multi-compartment assignment of conflicting prisoners and simultaneous services in order to optimize a given objective function.

We present a new solution framework to address this problem that leads to an efficient heuristic. A comparison with computational results from previous papers shows that the heuristic is very competitive for some classes of benchmark instances from the literature and clearly superior in the remaining cases. Finally, suggestions for future studies are presented.

Session 4.1 –Transportation and Delivery / 43

Last-mile Delivery with Crowdshipping: a multi-objective approach

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Crowdshipping has emerged as an innovative solution for last-mile delivery, in which customers can receive their groceries, parcels, or other purchases delivered by ordinary individuals (occasional couriers) instead of by a professional courier. This strategy offers faster, more cost-effective same-day delivery and greater flexibility to meet fluctuating demand. Occasional couriers (OCs) can be categorized as dedicated OCs, who register with platforms and accept delivery tasks proactively, or en-route OCs, who are in-store customers delivering goods along their usual routes. While most research has focused on minimizing delivery costs, customer satisfaction is also vital to the success of this model. This study adopts a multi-objective approach to minimize total delivery costs while maximizing service levels. The first objective includes costs associated with professional fleets, en-route OCs, and dedicated OCs. The second focuses on improving service by minimizing deviations from customers' preferred time windows. We developed a bi-objective heuristic based on the Greedy Randomized Adaptive Search Procedure (GRASP) to address these objectives, incorporating multi-directional improvement strategies. The heuristic explores the solution space using a combination of intra-route (relocate, exchange, 2-opt) and inter-route (insert, crossover, swap) operators during the local search. This method effectively approximates the Pareto front.

Session 4.1 –Transportation and Delivery / 83

A pickup and delivery problem with automated guided vehicles - modelling approaches

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Pickup and Delivery Problems (PDP) and their variants are commonly found in logistics and transportation systems. This work addresses a logistic transport problem where homogeneous vehicles must fulfill transportation requests between pickup and delivery nodes, subject to service level agreements (SLAs). We compare the performance of two Mixed-Integer Linear Programming (MILP) models: one formulated as a natural PDP and the other as a sequencing problem. Results show that the sequencing-based formulation is more efficient in terms of computational performance.
Furthermore, as the overall objective is to minimize both empty vehicle travel and delivery delays, we decompose the original multi-objective function into two separate single-objective models. This decomposition enables a clearer analysis of the individual impact of each objective component on the quality and structure of the solutions.

This work has been supported by national funds through FCT –Fundação para a Ciência e Tecnologia through project UIDB/04728/2020.

Session 4.1 –Transportation and Delivery / 33

Two-index formulations for the Traveling Purchaser Problem with Incompatibility Constraints

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The Traveling Purchaser Problem with Incompatibility Constraints (TPP-IC) generalizes the classical Traveling Purchaser Problem (TPP) by introducing constraints that prevent certain items from being transported together. This problem arises in various real-world applications, such as hazardous materials transportation, where incompatible products must be handled separately to ensure safety and compliance.
In this study, we propose a novel mixed-integer programming (MIP) formulation that models item incompatibilities using compatibility graphs. Compatibility graphs are used to model the incompatibility constraints implicitly, which makes it possible to use two-index formulations rather than a traditional three-index formulation to formulate the TPP-IC. Several compact and non-compact formulations are proposed for the TPP-IC, which are compared both theoretically and empirically. Additionally, valid inequalities are used to improve the quality of the linear programming relaxation values obtained by the formulations. A branch-and-cut framework is used to address the non-compact models.
Preliminary computational results show that the two-index formulations provide better linear programming relaxation values than the three-index formulation, which we hope will contribute to the two-index models being more efficient than the three-index models in obtaining the optimal values.

Session 4.2 - Sustainable supply chains / 62

A Sustainable Approach to Urban Last-Mile Logistics: Modeling and Analysis of a Green Two-Echelon Location-Routing Problem with Eco-Conscious Customer Behavior

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The rapid expansion of e-commerce has placed unprecedented pressure on urban logistics: Last-Mile Delivery (LMD) now poses a significant environmental impact contributing to over 30% of total CO2 emissions in the delivery sector and worsening congestion. We propose a Green Two-Echelon Location-Routing Problem (G2E-LRP), explicitly integrating (i) a heterogeneous fleet with both conventional and zero-emission vehicles of varying capacity, and (ii) eco-conscious customer decisions: clients may either receive home delivery or travel to a nearby hub, based on their individual emission rate, package size and a maximum walking/traveling green distance. The problem is formulated as a MILP and multiple cases are analyzed under varying zero-emission vehicles capacities to assess their impact on system-wide emissions and delivery distances. Exact methods were used to solve small instances, while a decomposition-based heuristic approach enabled the resolution of medium-sized cases. The model was applied to a Portuguese company offering last-mile delivery services. Results gives insights on the ability of the proposed model in balancing distances and reducing emissions.

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Optimising Insect-Production Facility Location: A Bi-objective Cost–Sustainability Model

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The insect-production industry has been growing rapidly, creating a demand for new decision-support tools. Locating insect-production facilities, however, is difficult because site choice directly affects the cost savings and sustainability benefits that can be achieved. A poor location can undermine a project: if a plant is not close to sources of insect feed, transporting the necessary by-products becomes much more expensive and reduces the overall sustainability of the supply chain.
Facility-location and supply-chain studies already address multi-objective trade-offs between cost and sustainability, but little research does so for the insect industry while taking its unique production traits into account. We set our work apart by allowing the rearing substrate to consist of a mix of by-products to represent flexibility in substrate production.
In this study we formulate a bi-objective mixed-integer linear model that minimizes total cost and the environmental impact associated with each by-product. The model employs the AUGMECON ε-constraint strategy, enabling decision-makers to generate Pareto-efficient solutions and explore cost–sustainability trade-offs. To test the model, we will use the Gurobi solver in Python to compare scenarios for small, medium and large production facilities.

This work has been supported by national funds through FCT –Fundação para a Ciência e Tecnologia through project UIDB/04728/2020.

Session 4.2 - Sustainable supply chains / 104

Design and planning of sustainable supply chains regulated by government incentives

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The design of modern supply chains should account for stimulating economic growth by establishing efficient material and information flows. Yet, the same economic growth trend that fuels supply chains is also contributing to the unsustainable use of resources. This challenge provides the conceptual leverage for this work: to model the government's role as a central agent in the transition toward more sustainable supply chains. The problem is formulated as a mixed-integer bi-level optimization problem. The government is the leader that allocates financial incentives aiming to minimize the environmental impact of technologies and transport modes, favoring low-emission options. The supply chain is the follower that decides on facility openings, technology assignments, production and transportation quantities, and selects transport modes to minimize total costs responding to those incentives. To solve this problem, we propose a deterministic bounding procedure, which

is adapted to the hierarchical characteristics of our problem where upper-level constraints include lower-level variables. The convergence is obtained by iteratively computing upper and lower bounds to the leader's objective function.

Session 4.2 - Sustainable supply chains / 28

Collaborative Strategies for Efficient Environmental Cost Distribution in Sustainable Supply Chains

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Growing environmental concerns and increasingly stringent regulations have compelled supply chains (SC) to rethink how they distribute the costs of environmental impacts. However, this is a complex challenge, especially when trying to balance sustainability with financial performance and fair cost-sharing among stakeholders. This paper addresses this challenge by developing a decision support tool that combines a Mixed Integer Linear Programming (MILP) model with cooperative game theory to achieve efficient cost allocations among key SC participants. The MILP model optimises network design and planning decisions to maximise the overall Net Present Value, while also monetising logistic environmental impacts, ensuring that these costs are assessed alongside conventional financial metrics. To fairly allocate these costs among suppliers, manufacturers, retailers, and logistics providers, we apply two cooperative game theory methods: the Core solution and the Shapley value. These ensure both stable and equitable cost-sharing based on collaboration and contribution. Using a real-world base case study, we show how our approach significantly reduces total environmental costs compared to non-cooperative strategies. Moreover, the Shapley value helps distribute costs more fairly, especially benefiting financially constrained stakeholders. This research offers a structured and collaborative way of building more sustainable systems through fair cost allocation.

Session 4.3 - Teams management and scheduling / 68

Optimization of home care visits: A study case on family support organizations

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Family dynamics play a crucial role in the development of children and youth. When these dynamics are negative, they can put children at risk, potentially resulting in the loss of parental rights and subsequent institutionalization, an outcome that has been recognized as undesirable. Consequently, there has been a growing emphasis on early intervention, aiming to work with families to develop the skills needed to improve their relationships and prevent institutionalization.
Some organizations are responsible for providing this type of support. However, the growing number of families in need, combined with a fixed number of professionals, heavy bureaucratic workloads, limited availability of both families and workers, and manual scheduling due to a lack of resources, creates significant challenges. These factors complicate the assignment of workers to

families, and scheduling and execution of visits, making it difficult to meet families'needs and comply with court-ordered deadlines.
To address these challenges, this work proposes a Mixed Integer Linear Programming (MILP) model to improve visit planning. By providing tactical plans that determine which professionals visit which families and when, the model aims to maximize completed visits, balance workloads, and promote a healthier work-life balance for staff. Ultimately, this approach enhances service delivery and better support of vulnerable families.

Session 4.3 - Teams management and scheduling / 73

Scheduling crew reserve duties with flexible time windows

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The crew reserve duty scheduling problem involves generating reserve duties months in advance. These duties are daily periods where crew members are on call at their operational bases, ready to perform jobs assigned to them by dispatchers, that are handling disruptions typically during the day of operation.
This optimisation problem is challenging because the exact time and place where a reserve duty is needed is unpredictable and can vary throughout the year.
We address a new variant of this problem where reserve duties have a flexible time window that will be fixed closer to the day of operation.
The fixed duties can be different for different days according to what is more likely to be the reserve needs on those days.
In order to solve this problem we propose several alternative approaches combining in different ways greedy heuristics, integer linear programming, stochastic simulation and possibly other methods. We compare their performance based on evaluation tests performed with data from a major Northern European passenger railway operator. We also compare scenarios with flexible time windows against those with rigid ones.

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Revisão de literatura sobre escalonamento cíclico de turnos com rotação de folgas e horários fixos

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No problema de escalonamento cíclico de turnos com rotação de folgas e horários fixos o objetivo é alocar trabalhadores em ciclos que combinem turnos fixos (manhã, tarde, noite) e folgas rotativas, garantindo operações ininterruptas em setores como saúde e indústria. O problema envolve elevada complexidade computacional (sendo classificado como NP-difícil) devido a múltiplas restrições: legais (limite de dias consecutivos, descanso semanal), operacionais (cobertura total de turnos, equidade de carga horária, minimização de custos) e humanas (respeito aos ritmos biológicos, evitando impactos à saúde como fadiga).

Nesta apresentação será abordada uma revisão de literatura sobre o tema, com foco na classificação dos diferentes tipos de problemas, modelos existentes na literatura, bem como nas principais características que eles abordam. Serão também discutidas lacunas na literatura e oportunidades para pesquisas futuras.

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Workforce Strategic Productivity Analysis and Optimization in a Retail Company

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Labor costs account for a significant portion of operational expenses in the food retail sector, making workforce optimization a strategic priority. This work develops a data-driven methodology to determine the optimal number of Full-Time Equivalents (FTEs) needed per store, function, and week, balancing operational efficiency with service level. The proposed framework consists of two complementary components. The first is an efficiency model based on Mixed-Integer Linear Programming (MILP), which estimates the minimum FTEs required based on a store's operational characteristics. The second component is a service level model that utilizes second-degree regression to predict the additional FTEs required to maintain historical service standards. Both models are applied independently by function and within store clusters sharing similar operational profiles. The methodology was implemented in a real-world setting across more than 350 stores of a major Portuguese food retailer, using large-scale datasets processed with PySpark and optimized with Gurobi. Results demonstrate the ability to decompose observed labor usage into efficiency, service, and inefficiency, offering actionable insights for strategic workforce planning. In addition to retrospective evaluation, the framework supports forward-looking simulations under varying service level targets and store scenarios. This work contributes a scalable, interpretable, and robust approach to labor productivity management in complex retail environments.

Session 4.4 - Operations management and logistics / 86

Otimização Não Linear para a Geração de Robôs Antropomórficos em Tarefas de Reposição

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Os modelos de otimização desempenham um papel essencial em ambientes industriais, especialmente na Indústria 5.0, onde os sistemas robóticos avançados são fundamentais para aumentar a eficiência e a adaptabilidade. Este trabalho aborda problemas de otimização de grande escala e altamente não lineares, que surgem na geração de movimentos semelhantes aos humanos para um robô antropomórfico a realizar tarefas de reposição de prateleiras. A geração destes movimentos implica a formulação e resolução de problemas de otimização complexos relacionados com as posturas angulares dos braços e a evitar a colisão com obstáculos no espaço de trabalho do robô. O impacto de diferentes níveis de simplificação na eficiência computacional é avaliado através de técnicas numéricas de otimização adaptadas a problemas de grande escala. Os resultados demonstram que níveis moderados de simplificação reduzem significativamente o tempo de computação, enquanto níveis mais elevados podem comprometer o desempenho. As análises estatísticas efetuadas confirmam a importância de equilibrar a redução do número de restrições e variáveis de decisão com a eficiência do solver ao lidar com problemas tão exigentes do ponto de vista computacional. As conclusões evidenciam os desafios e as oportunidades na otimização de movimentos robóticos para aplicações

industriais, contribuindo para o desenvolvimento de sistemas robóticos mais eficientes e com comportamentos mais semelhantes aos humanos no retalho inteligente e para além dele.

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Human-Centered Optimization in Logistics: A Case-Based MILP Model for Safer Picking

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Increasing performance while minimizing operational risk is essential for successful logistics operations. However, these objectives often conflict—particularly in distribution centers, where picking operators are exposed to fatigue and injury risks that compromise both safety and individual efficiency. This study presents a first modelling approach to address this trade-off, based on a real-world case study from a food retail company. The proposed mixed-integer linear programming (MILP) model optimizes the assignment of picking tasks to simultaneously enhance operator performance and reduce injury risk. In doing so, it contributes to the broader goal of sustainable entrepreneurship by aligning operational effectiveness with worker health and well-being—two critical pillars of long-term organizational resilience. The case study demonstrates how analytical models can be tailored to address complex, human-centered operational challenges. By integrating performance and safety into a unified decision-support tool, this research underscores the potential of operations research to promote more balanced and sustainable logistics systems.

Session 4.4 - Operations management and logistics / 111

Modelo de otimização robusta para a gestão da cadeia de abastecimento agroflorestal residual

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Este estudo propõe um modelo de otimização multi-período para um problema de Gestão da Cadeia de Abastecimento de Biomassa Residual. O modelo aborda os desafios associados à acumulação de biomassa, à logística de transporte e à capacidade de armazenamento, assegurando simultaneamente a viabilidade económica. É utilizada uma abordagem de otimização robusta baseada em cenários para ter em conta as incertezas na disponibilidade da biomassa, e as flutuações da procura, refletindo diferentes condições de funcionamento. São apresentados resultados para uma instância baseada num estudo de caso real no Centro de Portugal, demonstrando a sua aplicabilidade prática na otimização da logística da biomassa. Este estudo contribui para a literatura ao colmatar a lacuna entre os modelos teóricos de otimização e a gestão prática da cadeia de abastecimento, oferecendo uma ferramenta robusta de apoio à decisão para os decisores políticos e as partes interessadas da indústria.

Session 4.4 - Operations management and logistics / 99

A Hybrid Framework for the Integrated Production and Routing Problem with Sequence-Dependent Setups and Multi-Period Constraints

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This work addresses the Integrated Production Routing Problem (IPRP), a challenging combinatorial optimization problem inspired by the real-world operations of a Brazilian furniture manufacturer. The IPRP involves coordinating production and distribution decisions over a finite planning horizon, divided into periods, for multiple products characterized by heterogeneous attributes, such as weight, size, and number of components. This IPRP incorporates several constraints, including sequence-dependent setups, safety stocks and limited production capacity during periods, heterogeneous vehicle fleets, multi-period routing, and customers with multiple time windows and deadlines. The objective is to minimize the total cost, which comprises setup costs, inventory holding, and transportation expenses. This integration of production and distribution decisions introduces temporal and spatial interdependencies rendering the problem NP-hard and computationally intractable for realistic instances when using exact methods. To tackle this problem, we propose a hybrid approach that combines a Variable Neighborhood Search metaheuristic with an embedded Integer Programming model. The proposed approach is evaluated through extensive computational experiments on benchmark instances, demonstrating its effectiveness in solving the IPRP and handling its inherent combinatorial complexity.

Session 5.1 - Vehicle routing / 32

Route planning in a condominium company using mathematical optimization

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This work focuses on planning daily routes for a group of employees from a condominium company.

Given a set of employees and a set of customers with pre-scheduled visits, we want to build double-open routes to guarantee visits to all customers, ensuring that each customer is visited by an employee with the appropriate skills to carry out the required activity. The travel times between customers and the service time at each customer are known. The problem includes time windows for visiting customers, each employee has a maximum working time and the daily working period is between 9 AM and 6:30 PM. The routes respect the lunch period if they extend from morning to afternoon. The aim is to minimize the distance covered by all routes.

The distances and times between customers are collected via an API to Microsoft Azure; and the solutions are then displayed on Bing Maps.

The results obtained show the operational advantages of an efficient and effective vehicle route planning in a specific condominium management company. The model can be extended to other service provider companies.

Session 5.1 - Vehicle routing / 41

One Model, Many Constraints: Multi-task learning for Multi-depot Vehicle Routing Problems

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The Vehicle Routing Problem (VRP) is a fundamental combinatorial optimization challenge with wide-ranging applications in logistics and transportation. While machine learning has recently gained traction as a scalable alternative to traditional solvers, most existing methods are designed for a single specific VRP variant, limiting their generalizability to solve a diverse range of VRP problems. To address this, Multi-task learning (MTL) —a learning paradigm in which a single model is trained to solve multiple related tasks —has emerged as a promising method, enabling shared learning across different VRP formulations. However, prior MTL efforts have focused mainly on single-depot VRPs, overlooking the more realistic and complex Multi-Depot VRP (MDVRP). In this work, we introduce a reinforcement learning-based MTL model capable of solving not only the classic MDVRP, but also other variants incorporating backhauls, open routes, route duration limits, time windows, and any combination of these constraints. In total, our unified model can solve 16 distinct MDVRP formulations without requiring architectural changes or retraining. Extensive experiments show that our approach achieves minimal solution gaps compared to state-of-the-art meta-heuristics, while operating at a fraction of their computational time.

Session 5.1 - Vehicle routing / 61

A hybrid optimisation method for vehicle routing in a fleet of multi-compartment vehicles with controlled temperature settings

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This work addresses the Multi-Compartment Vehicle Routing Problem (MCVRP), relevant for transporting goods that must remain separated or require distinct temperature conditions. We consider a predefined fleet consisting of three vehicle types: room temperature, refrigerated, and dual-compartment (room temperature and refrigerated). The distribution scenario involves multiple pick-up points and a single logistics center. The primary objective is to minimize total operational costs, which include fixed vehicle expenses, maintenance, and time-related costs associated with transportation and loading activities. Another factor to consider is the increased energy consumption of refrigerated compartments, which require more fuel or electricity to cool, impacting the cost structure even more. To address this, we propose a three-step hybrid solution approach. First, demand points are grouped in an optimal number of clusters. Then, we perform route optimization within each cluster, taking into account vehicle capacity and demand compatibility. In the final step, each

cluster is treated as a single node, and inter-cluster routing is optimized. Linear programming is applied in the latter two steps. This method combines the strengths of exact and heuristic techniques, delivering high-quality solutions while ensuring cost-effective fleet utilization.

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A Rich and Heterogeneous Fleet Vehicle Routing Problem for Fuel Lane Management and Wildfire Prevention

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Wildfires pose a significant threat to ecosystems, frequently having detrimental effects on the environment and the economy. One of the main reasons for their ignition and propagation is the abundance of unmanaged vegetation, particularly close to linear infrastructures. Countries prone to these hazards have established fuel lane management strategies to mitigate fire risks. Fuel lane management has received special attention in Portugal, as it has particularly low productivity and performance in forest management operations.
This project addresses these problems by developing a model for fuel lane management operations, integrating heuristics, namely *Adaptive Large Neighborhood Search* (ALNS). The plan schedules the allocation of specific machines to different plots over multiple periods, considering operational and environmental costs. The available machines are heterogeneous thus, for different area types, they provide different productivity, which leads to varying service times. Additionally, this problem can be characterized as a Vehicle Routing Problem (VRP) with a limited heterogeneous fleet, making it essential to determine optimal assignments that balance effectiveness and efficiency. Unlike traditional VRP models, whose main objective is to minimize travel costs, this problem incorporates additional constraints related to the fire risk of each plot. Fire risk is crucial in determining the priority of clearing operations, even if this results in a less efficient route.
This research focuses on a case-study in Portugal, exploring the best routes for forest plot clearing operations that satisfy both operational demands and the environmental context of the region.

Session 5.2 - OR in Energy 2 / 38

Integrated Battery Management in Photovoltaic Power Plants: A Real Case Study

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The transition to renewable energy presents significant challenges in managing production and consumption efficiently. This study addresses the optimization of the energy usage for owners of photovoltaic plants equipped with storage systems. The main objective is to develop a decision-support model that maximizes profitability by intelligently and dynamically managing consumption and storage of electricity, by considering OMIE market prices and consumption costs.
The research is supported by real operational data from a photovoltaic installation with battery storage. Historical data on electricity consumption, solar energy production, and market prices were analyzed to identify inefficiencies in conventional reactive management strategies. A predictive approach was proposed, integrating forecasts of market prices, weather conditions, and consumption

patterns.
A Mixed-Integer Linear Programming (MILP) model is currently being developed to optimize the charge and discharge cycles of the batteries. This model considers technical constraints and market dynamics to generate cost-effective energy management strategies. Preliminary results indicate that strategic battery usage significantly reduces operational costs, improves energy autonomy, and increases profitability. The approach is scalable and adaptable, offering a replicable framework for other small-scale renewable energy producers aiming to enhance sustainability and efficiency.

Acknowledgement:
This work has been supported by national funds through FCT - Fundação para a Ciência e Tecnologia, under the projects UIDP/04728/2020 and UIDB/04728/2020.

Session 5.2 - OR in Energy 2 / **44**

A comprehensive optimization framework for designing hybrid offshore renewable energy systems

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Hybrid offshore renewable energy systems (HRES) offer a promising solution to mitigate the variability of renewable energy sources. Specifically, combining offshore wind turbines, solar photovoltaics, and wave energy converters enhances power stability by leveraging their complementary characteristics. However, designing an efficient HRES requires a comprehensive approach that addresses key challenges across the entire project lifecycle. Nevertheless, existing studies often address these challenges separately and rely on oversimplified assumptions that fail to reflect real-world conditions, resulting in design decisions that may compromise economic viability. To address this, we propose an integrated optimization framework that simultaneously optimizes layout, sizing, and cable-routing decisions, while accounting for realistic operation and maintenance factors. In particular, the model determines the optimal number and placement of devices and selects the most appropriate type and configuration of both inter-array and export cables to maximize the project's net present value. A Markov-based model is incorporated to represent critical system states throughout the lifecycle, including operational, degraded, and failed conditions, as well as preventive and corrective maintenance. This enables more accurate estimations of availability, accessibility, energy output, and overall economic performance. Case studies based on real-world examples provide practical insights to support informed investment and planning decisions for HRES.

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Decision support system for sustainable implementation of hydrogen supply chains in Brazil

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Hydrogen is a key element in the global transition toward a low-carbon economy, with green hydrogen offering significant potential to decarbonize industries and energy systems. This study aims to develop a decision support system for the optimized implementation of a Hydrogen Supply Chain (HSC) in Brazil. Key aspects identified in the literature will be addressed, including the need for efficient optimization models, the integration of the social pillar of sustainability, and the notable lack of research focused on Brazil as a study area.
The proposed decision support system is structured in two stages. The first formulates the HSC as a Mixed-Integer Linear Programming (MILP) problem, considering decisions related to facility location, production capacity, transportation, and hydrogen storage, while integrating uncertainties in input availability and demand. The second stage employs a Mixed-Integer Nonlinear Programming (MINLP) model to more accurately represent the nonlinearities of hydrogen production processes, thereby improving decision-making precision.
Preliminary results indicate that economies of scale play a critical role, reducing both financial costs and greenhouse gas (GHG) emissions compared to alternative scenarios. The study underscores the importance of aligning production strategies with regional renewable energy resources to enhance cost-effectiveness and sustainability.

Session 5.2 - OR in Energy 2 / **95**

Avaliação da Pobreza Energética na União Europeia: Uma Abordagem Multidimensional e Dinâmica (2015–2023)

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A pobreza energética permanece uma preocupação relevante na União Europeia, agravada pela falta de uma definição harmonizada e de metodologias comparáveis entre países. Este estudo propõe a construção de um indicador composto e multidimensional, com base no modelo Value-Based Data Envelopment Analysis e na sua extensão dinâmica Window Analysis, complementado pela abordagem de Club Convergence. A análise considera cinco dimensões essenciais: dificuldade em manter a casa aquecida, dívidas em serviços básicos, condições habitacionais degradadas, consumo energético ajustado ao clima e risco de pobreza ou exclusão social.
Com dados do Eurostat e do EPAH, tratados em Python, foram avaliados os 27 Estados-Membros entre 2015 e 2023. Os resultados revelam fortes assimetrias regionais: países do Norte e Centro da Europa, como Suécia e Alemanha, apresentaram os melhores níveis de eficiência, enquanto países do Leste e Sul, como Roménia e Grécia, enfrentam desafios estruturais contínuos. Portugal e Lituânia destacam-se pela melhoria sustentada, fruto de políticas de reabilitação urbana e tarifas sociais. A Polónia registou avanços recentes significativos.
A análise de convergência identificou três grupos distintos, evidenciando divergência crescente entre países. A inovação deste estudo reside na articulação metodológica entre o Value-Based Data Envelopment Analysis dinâmico e a club convergence, permitindo captar a evolução contextual da pobreza energética. Conclui-se que são necessárias políticas diferenciadas para garantir um progresso mais equitativo em direção ao ODS 7 —com foco em programas de eficiência no Sul e investimentos estruturais no Leste da Europa.

Session 5.3 - Hard optimization problems / **81**

A Novel Derivative-Free Method with Improved Complexity for Nonsmooth Convex and Strongly Convex Optimization

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Derivative-free methods—also known as black-box or zero-order methods—are crucial when derivative information is unavailable or unreliable. We introduce a novel algorithm that, for nonsmooth convex objectives, achieves a worst-case complexity bound proportional to the inverse square of a specified accuracy tolerance—substantially improving over a previously developed method in the literature. For nonsmooth strongly convex objectives, our method further improves to a complexity bound that grows only logarithmically with the inverse of the accuracy tolerance. Importantly, in the general nonsmooth nonconvex setting, our algorithm matches the complexity bound of a closely related existing method.

Session 5.3 - Hard optimization problems / **54**

A mathematical formulation for the imaging and communication scheduling problem for super-agile Earth observation satellites

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Earth Observation Satellites (EOSs) are designed to collect images of Earth's surface for a wide range of applications, such as disaster response, environmental monitoring and resource management. With the increasing number of orbiting EOSs, efficient scheduling of satellite operations has become a critical challenge. To ensure effective use of these complex systems, it is essential to develop advanced scheduling methods that manage both image acquisition and data transmission. However, due to the rapid development of new generations of satellites, Super-Agile EOSs (SAEOSs), capable of dynamic maneuverability and real-time attitude control, existing scheduling approaches must be revisited. Thus, the literature on SAEOS scheduling is growing to meet these new demands. Still, current studies focus only on image acquisition, neglecting that all collected data must be transmitted to the ground. Furthermore, when realistic constraints such as multiple SAEOSs, diverse imaging targets, and energy and memory limitations are considered, the problem becomes even more complex. In this sense, this paper investigates and formally defines the imaging and communication scheduling problem for SAEOSs in multi-type target scenarios, while considering energy and memory constraints. This work lays a foundational step toward the development of efficient optimization strategies for this emerging class of NP-hard scheduling problems.

Session 5.3 - Hard optimization problems / **113**

Sobre clutters minimalmente não ideais

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Um {\em clutter\/} é um par $calC \equiv (V, E)$, onde E (os elementos de
Cl) denota uma família de subconjuntos, de um conjunto não vazio e finito V (os vértices de
Cl),
tal que nenhum dos elementos está contido noutro.
A teoria de clutters, outrora referida como {\em blocking\/} e {\em antiblocking\/} (Fulkerson'70), permite abordar, de modo elegante, questões diversas relacionadas com problemas de {\em set packing\/} e
{\em set covering\/}, nomeadamente a caraterização de integralidade dos poliedros subjacentes a esses problemas e o estabelecimento de relações to tipo min-max em problemas de otimização combinatória (o valor
mínimo de um problema é igual ao valor máximo de um outro).

Um clutter $calC$ é ideal se o poliedro (das coberturas de
Cl) $Q(A) \equiv \{\mathbf{x}\colon A\mathbf{x} \geq \mathbf{1}, \mathbf{x} \geq \mathbf{0}\}$ é inteiro, onde $A \equiv M(calC)$ denota uma matriz de zeros e uns cujas linhas são os vetores característicos dos elementos de
Cl.
Um menor de
Cl é um outro clutter que resulta de $calC$ após uma ou mais operações de {\em remoção\/} ou {\em contração\/} de um vértice de
Cl.

Um clutter é minimalmente não ideal, ou simplesmente mni, se não for ideal mas todos os seus menores forem. Lehman'79 provou que todos os clutters mni têm uma estrutura precisa, são
a extensão de clutters definidos por uma matriz de Lehman. Uma matriz de Lehman é uma matriz Y r-regular de zeros e uns tal que $YZ^T = dI + \mathbf{1}\mathbf{1}^T$, para algum
inteiro positivo d e alguma matriz Z de zeros e uns. Nesta palestra mostraremos que as matrizes associadas a planos projetivos, embora sendo definidas por matrizes de Lehman, não podem desempenhar esse papel.

Session 5.3 - Hard optimization problems / **29**

New ideas on Monte Carlo tree search for optimization

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Monte Carlo tree search (MCTS) has shown significant success in game playing, achieving state-of-the-art results in many complex domains. While there are known applications in optimization, they often don't fully capitalize on the problem-specific knowledge available. This work addresses this gap by proposing adaptations of MCTS tailored for optimization problems. We focus on enhancing the exploitation of problem-specific heuristics, exploring methods to integrate these heuristics directly into the selection and expansion phases of the MCTS algorithm.

We also introduce strategies for a more elaborate exploitation of the incumbent solution. This involves incorporating ideas from local search techniques into the MCTS framework. By strategically exploring the vicinity of promising solutions, we aim to improve the quality of the final result.

Finally, we propose the adoption of non-deterministic selection rules within the MCTS algorithm. These rules are designed to promote a more diversified exploration of the search tree, particularly at the topmost levels. By introducing stochasticity into the selection process, we aim to mitigate stagnation caused by excessive breadth at those levels.

These ideas will be illustrated with the graph coloring problem, and some applications on timetabling will be analyzed.

Session 5.4 - Optimization with uncertainty / 79

Evolutionary Adaptive Policies for the Stochastic Dynamic Inventory-Routing Problem

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The stochastic dynamic inventory-routing problem (SDIRP) integrates inventory management and vehicle routing under uncertainty, where customer demands are revealed progressively over time. This research aims to provide new insights into resolving an SDIRP, focusing on a central warehouse that periodically distributes homogeneous goods to a set of geographically dispersed customers. Decision-making involves a three-step policy: calculating a delivery priority for each customer, determining delivery quantities based on an (s, S) inventory rule, and computing a vehicle route via an exact method.
A simulator was developed to replicate the problem's dynamics and enable policy training and evaluation across multiple scenarios.
The priority rule is obtained as a combination of key features extracted from the problem instances, relying on two evolutionary methods: Genetic Programming and Genetic Algorithms.
Our policies were evaluated on problem instances with up to 50 customers and 20 periods, considering multiple demand uncertainties, holding and shortage costs, and vehicle capacities. The obtained results highlight a competitive performance in total cost reduction compared to several myopic and direct lookahead benchmarks, enhancing stock balance and minimizing travel distances.

Session 5.4 - Optimization with uncertainty / 100

Bi-objective Pollution Routing Problem with Uncertain Demand and Travel Time

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The Vehicle Routing Problem and its many variants have been extensively studied over the years due to the various gains enabled by efficient route planning. However, many routing models consider cost minimization by focusing solely on factors such as distance traveled or the number of vehicles utilized, often neglecting other considerations that affect costs and disregarding the environmental impact of solutions. This fact has motivated the proposal of novel formulations aimed at better capturing the complexities of real-world logistical operations. Moreover, the inherent uncertainty in several factors has led to increasing interest in models capable of handling uncertain data, thereby providing solutions that are more useful in practice. In this presentation, we study the Pollution Routing Problem, a variant of the VRP Problem designed to account for driver wages and fuel consumption costs, and we introduce a bi-objective model that considers environmental impact and operational expenses while accounting for uncertainties in travel times and customer demand. We perform extensive computational experiments on benchmark instances to assess the impact of hedging against uncertainty on solution quality and the Pareto front.

Session 5.4 - Optimization with uncertainty / **80**

Managing Supply Chain Disruptions through Design Science Research: A Mathematical Modeling and Simulation Approach

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This study examines supply chain dynamics through the development of a mathematical optimization model—considered as a research artifact—designed to analyze supply chain behavior under various disruption scenarios. These may affect supply, demand, or pricing conditions. A mathematical formulation of the problem was developed and implemented using the python programming language. To validate the proposed model, a case study concerning the production of coffee capsules was conducted, simulating multiple operational scenarios across the supply chain. These scenarios encompass the key stages of the chain—namely supplier, manufacturer, distributor, and retailer—as well as distinct planning and operational requirements. The Design Science Research (DSR) methodology guided the research process, enabling a systematic evaluation of the impacts of disruptive factors (e.g., supply failures, delivery delays, price fluctuations), their magnitude (total, partial, or other disruptions), and the duration of these occurrences. This work contributes to a deeper understanding of supply chain dynamics, particularly in terms of decision-making and operational planning under uncertainty and disruption.

Session 5.4 - Optimization with uncertainty / **78**

Fleet Composition under Uncertainty: A Multi-Objective Optimization Approach

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This study tackles the fleet composition problem for a transport operator facing uncertainties in energy prices, vehicle costs, and operational expenses over a defined planning horizon. With a limited budget, the decision-maker must choose among vehicle types—such as diesel with lower upfront costs but higher running expenses, and electric with the opposite profile.
To manage long-term cost and risk, the research proposes a multi-objective mixed-integer quadratic programming (MO-MIQP) model. This model minimizes total cost of ownership (including purchase, energy, maintenance, depreciation, and emissions) while also reducing financial risk linked to uncertain parameters.
A Pareto front guides trade-off decisions between cost and risk. The model incorporates ARIMA-based forecasts for energy and vehicle prices, integrating them into both cost and risk functions. This approach offers practical insights into balancing economic and environmental considerations in fleet planning, supporting resilient, data-driven decision-making.

Sessions 2 / **53**

Uma abordagem de otimização em dois níveis para a agregação da flexibilidade no consumo de energia elétrica

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A flexibilidade é fundamental para a gestão de sistemas de energia, tendo como objetivo incentivar a alteração dos padrões de consumo de eletricidade face à crescente produção renovável variável. Os agregadores desempenham um papel importante, recolhendo a flexibilidade dos consumidores/produtores, que pode depois ser transacionada em mercados, criando benefícios económicos e operacionais para todas as partes interessadas. A interação agregador-consumidores pode ser modelada como um problema de otimização em dois níveis de multi-seguidor. O agregador, no nível superior, estabelece incentivos financeiros, enquanto os consumidores, no nível inferior, otimizam a utilização de energia em resposta a estes incentivos e preços da eletricidade, tendo em conta preferências de conforto. Para resolver este problema, propomos uma abordagem híbrida que combina otimização por enxame de partículas para o problema de nível superior com um solver exato para o problema de nível inferior de programação inteira-mista. Apresentam-se experiências computacionais para um conjunto de consumidores residenciais típicos, considerando diferentes eletrodomésticos, veículo elétrico, baterias e microgeração.

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A bilevel approach to hyperparameter optimization for a support vector machine classifier

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In this work, a hyperparameter (kernel and C) optimization model for a support vector machine (SVM) classifier applied to handwritten digit recognition is presented. The kernel determines how the data is transformed and separated, which directly affects the model's ability to capture complex patterns. The regularization parameter controls the balance between fitting the training data and maintaining the model's ability to generalize to new data.
We developed a bilevel optimization framework where the lower level minimizes the SVM loss using a deterministic algorithm (L-BFGS-B), and the upper level searches for the optimal hyperparameter values using a particle swarm optimization metaheuristic. Cross-validation with three folds is used to evaluate model performance, reporting mean accuracy and standard deviation.
We compare the bilevel approach with other automated hyperparameter tuning methods, including grid search, random search, Hyperband, and Bayesian optimization. Preliminary results suggest that the bilevel framework can achieve superior classification performance, although the tradeoff between the quality of results and the computational effort should be further investigated. These experiments highlight the potential of bilevel optimization for tuning hyperparameters in complex machine learning models.
We acknowledge the support of the HarmonicAI project, which contributed to the development of this work.

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Integrating electric vehicles into urban car-sharing systems: addressing grid constraints and operational challenges for sustainable mobility

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Urbanization is accelerating, creating challenges in transportation, energy use, and emissions. Car-sharing can lower private car ownership and greenhouse gas emissions, while electric vehicles (EVs) produce zero emissions and can use renewable energy. Combining EVs with car-sharing offers a sustainable transport solution. However, the rising electricity demand from widespread EV adoption may threaten grid stability and capacity, complicating their integration into car-sharing services. This study tackles the challenge of optimizing fleet operations while maintaining grid reliability. It presents a framework that addresses car-sharing operational issues and includes strategies to minimize charging impacts on distribution grids. Key strategies involve active management of EVs through coordination between distribution system operators and car-sharing companies to match charging with network demands and incorporating distributed generation, such as renewable energy and vehicle-to-grid technology. These strategies allow EVs to support the grid by considering the grid conditions while satisfying the needs of car-sharing systems. By modeling grid-aware EV car-sharing systems, this research provides actionable insights for improving system resilience and sustainability. The findings aim to support mobility operators and policymakers in developing efficient, scalable, and grid-compatible urban mobility solutions.

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Using OR to tackle health and climate challenges in the Global South

The 2030 Agenda for Sustainable Development presents an ambitious call to action for ending poverty, improving health and well-being, and addressing the climate emergency. These global challenges are especially acute in the Global South, where systemic vulnerabilities and resource constraints demand innovative, context-sensitive solutions. Operational Research, and optimisation in particular, can play a critical role in shaping data-driven, locally grounded interventions that build resilience and promote sustainable development.

In this talk, I will present some research projects that apply OR to real-world development challenges in Southeast Asia and Sub-Saharan Africa. Specific examples include designing adaptive flood mitigation strategies for rapidly urbanising cities in Vietnam (the GCRF-OSIRIS project), building OR research capacity for sustainable development in Southeast Asia (CREST-OR project) and optimising health delivery in refugee camps in Ethiopia (a collaboration with Doctors with Africa CUAMM).

Rather than focusing solely on technical results, I will reflect on what these projects have taught us about the importance of people-centred, interdisciplinary approaches. The aim of the talk is to highlight how Operational Research, when embedded in real-world collaborations, can make a tangible difference to the lives of vulnerable communities and contribute to a more resilient and sustainable future.