RESEARCH CENTRE

Inria Centre at the University of Lille

IN PARTNERSHIP WITH:

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2024
ACTIVITY REPORT

Project-Team
INOCS

INtegrated Optimization with Complex Structure

DOMAIN

Applied Mathematics, Computation and Simulation

THEME

Optimization, machine learning and statistical methods

Inria

Contents

Project-Team INOCS

Creation of the Project-Team: 2019 May 01

Keywords

Computer sciences and digital sciences

A6. – Modeling, simulation and control

A6.1. – Methods in mathematical modeling

A6.2. – Scientific computing, Numerical Analysis & Optimization

A6.2.6. – Optimization

A9. – Artificial intelligence

A9.6. – Decision support

Other research topics and application domains

B2. – Health

B4. – Energy

B6. – IT and telecom

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B7.1.2. – Road traffic

B7.2. – Smart travel

B8.1. – Smart building/home

B8.1.1. – Energy for smart buildings

B8.2. – Connected city

B8.4. – Security and personal assistance

1 Team members, visitors, external collaborators

Research Scientists

- Luce Brotcorne [Team leader, INRIA, Senior Researcher]
- Hélène Le Cadre [INRIA, Researcher]

Faculty Members

- Diego Cattaruzza [CENTRALE LILLE, Associate Professor]
- Bernard Fortz [ULB, Professor]
- Martine Labbé [ULB, Professor]
- Maxime Ogier [CENTRALE LILLE, Associate Professor]
- Frédéric Semet [CENTRALE LILLE, Professor]
- Yue Su [UNIV LILLE, Associate Professor, from Sep 2024]

Post-Doctoral Fellows

- Sebastian Andres Davila Galvez [INRIA, Post-Doctoral Fellow, from Feb 2024]
- Gaël Guillot [INRIA, Post-Doctoral Fellow, from Sep 2024]
- Ashok Krishnan [INRIA, from Sep 2024, Inria Paris Center]
- Fredy Vale Manuel Pokou [INRIA, Post-Doctoral Fellow, from Feb 2024]

PhD Students

- Haider Ali [CENTRALE LILLE, until Aug 2024]
- Tifaout Almeftah [INRIA]
- Adrien Belfer [INRIA, from Sep 2024]
- Salma Janati [INRIA, from Oct 2024]
- Mesut Can Koseoglu [INRIA, from Feb 2024]
- Aitor Lopez Sanchez [CENTRALE LILLE, Rey Juan Carlos University, until Jun 2024]
- Francesco Morri [UNIV LILLE]
- Luis Antonio Rojo Gonzalez [Universidad de Santiago de Chile, from Oct 2024]
- Luis Antonio Rojo Gonzalez [INRIA, until Sep 2024]
- Juan Pablo Sepulveda Adriazola [INRIA]
- Wenjiao Sun [CENTRALE LILLE]
- Pablo Torrealba Gonzalez [CENTRALE LILLE]
- Nathalia Isabel Wolf Garcia [INRIA]
- Zhenyu Wu [INRIA, from Mar 2024]

Technical Staff

- Sylvain Clay [INRIA, Engineer, until Jan 2024]
- Gaël Guillot [INRIA, Engineer, until Aug 2024]

Interns and Apprentices

- Ahmed Jed Boufaied [INRIA, Intern, until Mar 2024]
- Erick Maximiliano Ibacache Velasquez [INRIA, Intern, from Mar 2024 until Jun 2024]

Administrative Assistants

- Nathalie Bonte [INRIA]
- Karine Lewandowski [INRIA]

External Collaborator

- Pierre Gruet [EDF]

2 Overall objectives

2.1 Introduction

INOCS is a cross-border "France-Belgium" project team in the Applied Mathematics Computation and Simulation Inria domain. The main goal of this team is the study of optimization problems involving complex structures. The scientific objectives of INOCS are related to modeling and methodological concerns. The INOCS team focuses on:

(i) integrated models for problems with Complex Structure (CS) taking into account the whole structure of the problem;

(ii) the development of solution methods taking explicitly into account *the nature and the structure of the decisions as well as the properties of the problem.*

Even if CS problems are in general NP-hard due to their complex nature, exact solution methods or matheuristics (heuristics based on exact optimization methods) are developed by INOCS. The scientific contribution of INOCS will result in a toolbox of models and methods to solve challenging real-life problems.

2.2 Schedule of tasks

The research program development of INOCS is to move alternatively:

- *from problems towards new approaches in optimization*: models and solution algorithms will be developed to fit the structure and properties of the problem; from them, new generic approaches will be used to optimize problems with similar properties;
- *from innovative approaches towards problems*: the relevance of the proposed approaches will be assessed by designing new models and/or solution methods for various classes of problems; these models and methods will be based on the extension and integration of specific, well-studied models and methods.

Even if these two axes are developed sequentially in a first phase, their interactions will lead us to explore them jointly in the mid-term.

3 Research program

3.1 Introduction

An optimization problem consists in finding a best solution from a set of feasible solutions. Such a problem can be typically modeled as a mathematical program in which decision variables must (i) satisfy a set of constraints that translate the feasibility of the solution and (ii) optimize some (or several) objective function(s). Optimization problems are usually classified into *strategic*, *tactical* and *operational* problems, according to the types of decisions to be taken.

We consider that an optimization problem presents a *Complex Structure* (CS) when it involves decisions of different types/nature (i.e. strategic, tactical or operational) and/or presents some hierarchical leader-follower structure. The set of constraints may usually be partitioned into *global constraints*, linking variables associated with the different types/nature of decision, and constraints involving each type of variables *separately*. Optimization problems with complex structure lead to extremely challenging problems since a global optimum with respect to the whole sets of decision variables and of constraints must be determined.

Significant progress has been made in optimization to solve academic problems. Nowadays large-scale instances of some NP-hard problems are routinely solved to optimality. *Our vision within INOCS is to make the same advances while addressing CS optimization problems.* To achieve this goal we aim to develop global solution approaches at the opposite of the current trend. INOCS team members have already proposed some successful methods following this research lines to model and solve CS problems (e.g. ANR project RESPET, Brotcorne et al. [52, 53], Gendron et al. [54, 55, 56], and Strack et al. [57]). However, these are preliminary attempts and a number of challenges regarding modeling and methodological issues have still to be met.

3.2 Modeling problems with complex structures

A classical optimization problem can be formulated as follows:

$$\begin{aligned} \min \quad & f(x) \\ s.t. \quad & x \in X. \end{aligned} \tag{1}$$

In this problem, X is the set of feasible solutions. Typically, in mathematical programming, X is defined by a set of constraints. x may be also limited to non-negative integer values.

The INOCS team plans to address optimization problems where two types of decisions are addressed jointly and are interrelated. More precisely, let us assume that variables x and y are associated with these decisions. A generic model for CS problems is the following:

$$\begin{aligned} \min \quad & g(x,y) \\ s.t. \quad & x \in X, \\ & (x,y) \in XY, \\ & y \in Y(x). \end{aligned} \tag{2}$$

In this model, X is the set of feasible values for x. XY is the set of feasible values for x and y jointly. This set is typically modeled through linking constraints. Last, $Y(x)$ is the set of feasible values for y for a given x. In INOCS, we do not assume that $Y(x)$ has any properties.

The INOCS team plans to model optimization CS problems according to three types of optimization paradigms: large scale complex structures optimization, bilevel optimization and robust/stochastic optimization. These paradigms instantiate specific variants of the generic model.

Large scale complex structures optimization problems can be formulated through the simplest variant of the generic model given above. In this case, it is assumed that $Y(x)$ does not depend on x. In such models, X and Y are associated with constraints on x and on y, XY are the linking constraints. x and y can take continuous or integer values. Note that all the problem data are deterministically known.

Bilevel programs allow the modeling of situations in which a decision-maker, hereafter the leader, optimizes his objective by taking explicitly into account the response of another decision maker or set of decision makers (the follower) to their decisions. Bilevel programs are closely related to Stackelberg (leader-follower) games as well as to the principal-agent paradigm in economics. In other words, bilevel programs can be considered as demand-offer equilibrium models where the demand is the result of another mathematical problem. Bilevel problems can be formulated through the generic CS model when $Y(x)$ corresponds to the optimal solutions of a mathematical program defined for a given x, i.e. $Y(x) = \arg\min\left\{h(x, y) | y \in Y_2, (x, y) \in XY_2\right\}$ where Y_2 is defined by a set of constraints on y, and XY_2 is associated with the linking constraints.

In robust/stochastic optimization, it is assumed that the data related to a problem are subject to uncertainty. In stochastic optimization, probability distributions governing the data are known, and the objective function involves mathematical expectation(s). In robust optimization, uncertain data take value within specified sets, and the function to optimize is formulated in terms of a min-max objective typically (the solution must be optimal for the worst-case scenario). A standard modeling of uncertainty on data is obtained by defining a set of possible scenarios that can be described explicitly or implicitly. In stochastic optimization, in addition, a probability of occurrence is associated with each scenario and the expected objective value is optimized.

3.3 Solving problems with complex structures

Standard solution methods developed for CS problems solve independent subproblems associated with each type of variables without explicitly integrating their interactions or integrating them iteratively in a heuristic way. However these subproblems are intrinsically linked and should be addressed jointly. In *mathematical optimization* a classical approach is to approximate the convex hull of the integer solutions of the model by its linear relaxation. The main solution methods are (1) polyhedral solution methods which strengthen this linear relaxation by adding valid inequalities, (2) decomposition solution methods (Dantzig Wolfe, Lagrangian Relaxation, Benders decomposition) which aim to obtain a better approximation and solve it by generating extreme points/rays. Main challenges are (1) the analysis of the strength of the cuts and their separations for polyhedral solution methods, (2) the decomposition schemes and (3) the extreme points/rays generations for the decomposition solution methods.

The main difficulty in solving *bilevel problems* is due to their nonconvexity and nondifferentiability. Even linear bilevel programs, where all functions involved are affine, are computationally challenging despite their apparent simplicity. Up to now, much research has been devoted to bilevel problems with linear or convex follower problems. In this case, the problem can be reformulated as a single-level program involving complementarity constraints, exemplifying the dual nature, continuous and combinatorial, of bilevel programs.

4 Application domains

4.1 Energy

In energy, the team mainly focuses on pricing models for demand side management, on bids definition in the energy market and on the design and pricing of electric car charging stations.

Demand side management methods are traditionally used to control electricity demand which became quite irregular recently and resulted in inefficiency in supply. We have explored the relationship between energy suppliers and customers who are connected to a smart grid. The smart grid technology allows customers to keep track of hourly prices and shift their demand accordingly, and allows the provider to observe the actual demand response to its pricing strategy. We tackle pricing problems in energy according to the bilevel optimization approaches. Some research works in this domain are supported by bilateral grants with EDF.

The increasing number of agents, with different characteristics interacting on the energy market leads to the definition of new types of bidding process. We have modeled this problem as a bilevel one where the lower level is the instance allocating the bids (the ISO).

The proliferation of electric cars in cities has lead to the challenging problem of designing and pricing charging stations in order to smooth the demand over time. We are modeling this problem as a bilevel one where the lower level represents the choice of users in a preference list.

4.2 Transportation and logistics

In transportation and logistics, the team addresses mainly integrated problems, which require taking into account simultaneously different types of decision. Examples are location and routing, inventory management and routing or staff scheduling and warehouse operations management. Such problems occur from the supply chain design level to the logistic facility level.

4.3 Telecommunications

In telecommunications, the team mainly focuses on network design problems and on routing problems. Such problems are optimization problems with complex structure, since the optimization of capacity installation and traffic flow routing have to be addressed simultaneously.

5 Social and environmental responsibility

The research works developed in the INOCS team have environmental and societal impacts through the application areas they target. At the environmental level, the works on the optimization of transportation systems aim at reducing the impact of transportation on society. The applied works in energy aim at a better use of the smart grid and the optimization of electricity production from renewable sources. At the societal level, the works developed in the framework of the ANR AGIRE project takes into account musculoskeletal disorders in the activity of employees within a warehouse. Finally, in health, the works conducted on group testing allow the development of effective campaigns of testing of the population in preventive medicine for example.

6 Highlights of the year

6.1 Awards

Yue Su is Laureate of the **YoungWomen4OR** Award from the EURO and WISDOM 2024-25.

7 New software, platforms, open data

7.1 New software

7.1.1 GroupTesting

Keywords: Linear optimization, Group Testing, Graph algorithmics

Functional Description: Group testing is a screening strategy that involves dividing a population into several disjoint groups of subjects. In its simplest implementation, each group is tested with a single test in the first phase, while in the second phase only subjects in positive groups, if any, need to be tested again individually.

To contribute to the effort to tackle the COVID-19 sanitary crisis, we developed this software which allows to create groups of individuals to test via the group testing technique while minimizing a linear combination of the expected number of false negative and false positive classifications.

The test design problem is modeled as a constrained shortest path problem on a specific graph and we design and implement an ad hoc algorithm to solve this problem. We validate the algorithm on instances based on Santé Publique France data on COVID-19 screening tests.

Contact: Frederic Semet

7.1.2 INOCSBox

Keywords: Linear optimization, Operational research, Toolbox

Functional Description: This software is a toolbox that contains algorithms that are frequently used to solve optimization problems tackled by (but not only) the team.

The objective of the toolbox is to contain a set of code skeletons that allow researchers to integrate adequate data structures and basic algorithms for different structures complexity that appears in the optimization problems we study. The current version of the toolbox contains classical heuristic tools (generic local search) to solve, among others, the vehicle rouring problem and its variants. It also contain a code to exactly and heuristically solve the Shortest Path Problem with Ressource Constraints that is usually encountered in the resolution of problem with Branch-and-Price algorithms.

The future objective is to include automatic reformulation tools for bi-level optimization problems and state-of-the-art codes for the development of decomposition methods.

Contact: Tifaout Almeftah

8 New results

During the year 2024, we addressed different problems/challenges related to the three lines of research: large scale complex structure optimization, bilevel programming and game theory, robust/stochastic programming. The main contributions are summarized in the next sections.

8.1 Large scale complex structure optimization

Participants: Luce Brotcorne, Diego Cattaruzza, Bernard Fortz, Martine Labbé, Maxime Ogier, Frédéric Semet.

8.1.1 Distribution network design

Retailers which deliver products directly to their customer locations often rely on Logistics Service Intermediaries (LSI) for order management, warehousing, transportation and distribution services. Usually, the LSI acts as a shipper and subcontracts the transportation to carriers for long-haul and last-mile delivery services. All agents interact and are connected through cross-docking facilities. As the demand from customers may vary significantly over time, the shipper's requirements for transportation evolve at the tactical level. This creates opportunities for the shipper to take advantage of medium-term contracts with the carriers at prices lower than those offered by the spot market. In [14], we focus on the tactical design, through dynamic contracts, of a suitable network of cross-docking facilities and related transportation capacities (belonging to different carriers) to reduce the shipper's operational costs. In this article, we propose a Mixed Integer Linear Programming (MILP) formulation for the multi-period planning problem with minimum purchase commitment contracts faced by the shipper. We propose exact and heuristic decomposition methods for the the model, respectively, based on combinatorial Benders cuts and on relax-and-repair approaches. The performance of these algorithms is experimentally compared to that of commercial solvers. The numerical results show that our methods perform comparatively well for the solution of large size instances and brings economic benefits to the shipper. This work was motivated by a real-life case which is described in [39].

8.1.2 Home chemotherapy delivery: an integrated production scheduling and multi-trip vehicle routing problem.

Home chemotherapy systems allow the administration of cancer treatments at a patient's residence, avoiding an admission to inpatient care facilities. This innovative health care model is interesting both economically and on a human level. It also raises several logistical challenges. In the paper [11], we focus on one of the optimization problems arising in the context of home chemotherapy services, where a complex scheduling problem underlies the operational planning process. Indeed, some injectable chemotherapy drugs may remain stable only during a few hours after being produced. Consequently, their production has to be carefully scheduled jointly with their administration, which takes place at the patients homes during a predefined time window. This gives rise to an integrated production scheduling and vehicle routing problem, that we address using a large neighborhood search approach. Production and administration sequences are iteratively modified, while a linear program is used to determine optimal production and administration start times for the candidate sequences. We analyze the impact of the linear program and establish that it is a crucial component of the proposed method. We assess the performance of the proposed method by comparing its solutions with those obtained through a compact mathematical formulation. We then provide insights about the cost of taking into consideration time-related aspects of the problem, i.e., integrated planning horizons, drug stability times, and administration time windows.

8.1.3 A review of optimization of human-aware manufacturing and logistics systems

Historically, Operations Research (OR) discipline has mainly been focusing on economic concerns. Since the early 2000s, human considerations are gaining increasing attention, pushed by the growing societal concerns of sustainable development on the same terms as the economic and ecological ones. In this work, we aim at reviewing the efforts dedicated by the OR community to the integration of human factors into logistics and manufacturing systems. In a first survey [20], a focus is put on the modeling and solution approaches used to consider human characteristics, their practical relevance, and the complexity induced by their integration within optimization models. The material presented in this work has been retrieved through a semi-systematic search of the literature. Then, a comprehensive analysis of the retrieved corpus is carried out to map the related literature by class of problems encountered in logistics and manufacturing. These include warehousing, vehicle routing, scheduling, production planning, and workforce scheduling and management. We investigate the mathematical programming techniques used to integrate human factors into optimization models. Finally, a number of gaps in the literature are identified, and new suggestions on how to suitably integrate human factors in OR problems encountered in logistics and manufacturing systems are discussed. In a second survey [21], a focus is put on the models proposed to represent and quantify human characteristics, their practical relevance, and the complexity induced by their integration with mathematical optimization models. In this paper, the techniques used in the OR literature to represent the human considerations encountered in logistics and manufacturing systems are surveyed. The existing Human-Aware Models (HAM) are classified and reviewed by domain. Particular attention is paid to the field validity of each method, its relevance to specific use cases, the required data collection, and its usability within mathematical optimization models. Since the surveyed HAMs rely on concepts originating from different related scientific disciplines (e.g., ergonomics, occupational medicine), a brief introduction of these fields of study is proposed together with a work of contextualization that is carried out during the analysis.

8.1.4 Commodity constrained split delivery vehicle routing problems

We propose a survey [15] on vehicle routing problems with multiple commodities. In most routing problems, only one commodity is explicitly considered. This may be due to the fact that, indeed, a single commodity is involved, or multiple commodities are transported, but they are aggregated and modeled as a single commodity, as no specific requirement imposes their explicit consideration. However, there exist cases in which this aggregation is not possible due to the characteristics of the commodities or to the fact that it would lead to sub-optimal routing plans. The survey focuses on the analysis of the settings of the problems and the features of the commodities that require explicit consideration of disaggregated commodities in routing problems. We show that problem settings are inherently different with respect to the single commodity problems, and this has a consequence on both models and solution approaches, which cannot be straightforwardly adapted from the single commodity cases. We propose a classification of the routing problems with multiple commodities and discuss the motivations that force considering the presence of multiple commodities explicitly. Specifically, we focus on the modeling perspective by proposing a general formulation for routing problems with multiple commodities and showing how this formulation can be adapted to the different features that characterize the problem classes discussed in the survey. Also, for each major class of problems, promising future research directions are discussed by analyzing what has been studied in the current literature and focusing on challenging topics not covered yet.

We address two specific routing problems with multiple commodities. The Commodity constrained Split Delivery Vehicle Routing Problem (C-SDVRP) is a routing problem where customer demands are composed of multiple commodities. A fleet of capacitated vehicles must serve customer demands in a way that minimizes the total routing costs. Vehicles can transport any set of commodities and customers are allowed to be visited multiple times. However, the demand for a single commodity must be delivered by one vehicle only. In this work, we developed a heuristic with a performance guarantee to solve the C-SDVRP. The proposed heuristic is based on a set covering formulation, where the exponentially-many variables correspond to routes. First, a subset of the variables is obtained by solving the linear relaxation of the formulation by means of a column generation approach which embeds a new pricing heuristic aimed to reduce the computational time. Solving the linear relaxation gives a valid lower bound used as a performance guarantee for the heuristic. Then, we devise a restricted master heuristic to provide good upper bounds: the formulation is restricted to the subset of variables found so far and solved as an integer program with a commercial solver. A local search based on a mathematical programming operator is applied to improve the solution. We test the heuristic algorithm on benchmark instances from the literature. The comparison with the state-of-the-art heuristics for solving the C-SDVRP shows that our approach significantly improves the solution time, while keeping a comparable solution quality and improving some best-known solutions. In addition, our approach is able to solve large instances with 100 customers and six commodities, and also provides very good quality lower bounds. Furthermore, an instance of the C-SDVRP can be transformed into a CVRP instance by simply duplicating each customer as many times as the requested commodities and by assigning as demand the demand of the single commodity. Hence, we compare heuristics for the C-SDVRP against the state-of-the-art heuristic for the Capacitated Vehicle Routing Problem (CVRP). The latter approach revealed to have the best performance. However, our approach provides solutions of comparable quality and has the interest of providing a performance guarantee [19].

An extended variant of the C-SDVRP is the Multi-Commodity two-echelon Distribution Problem (MC2DP). In the MC2DP, multiple commodities are distributed in a two-echelon distribution system involving suppliers, distribution centres and customers. Each supplier may provide different commodities and each customer may request several commodities as well. In the first echelon, capacitated vehicles perform direct trips to transport the commodities from the suppliers to the distribution centres for consolidation purposes. In the second echelon, each distribution centre owns a fleet of capacitated vehicles to deliver the commodities to the customers through multi-stop routes. Commodities are compatible, i.e., they can be mixed in the vehicles. Finally, customer requests can be split by commodities, that is, a customer can be visited by several vehicles, but the total amount of each commodity has to be delivered by a single vehicle. The aim of the MC2DP is to minimize the total transportation cost to satisfy customer demands. In the paper [18], we propose a set covering formulation for the MC2DP where the exponential number of variables relates to the routes in the delivery echelon. We develop a Branch-Price-and-Cut algorithm (BPC) to solve the problem. The pricing problem results in solving an Elementary Shortest Path Problem with Resource Constraints (ESPPRC) per distribution centre. We tackle the ESPPRC with a label setting dynamic programming algorithm which incorporates ng-path relaxation and a bidirectional labelling search. Pricing heuristics are invoked to speed up the procedure. In addition, the formulation is strengthened by integrating capacity cuts and two families of valid inequalities specific for the multiple commodities aspect of the problem. Our approach solves to optimality 439 over the 736 benchmark instances from the literature. The optimality gap of the unsolved instances is 2.1%, on average.

8.1.5 The joint order batching and picker routing problem

We address the Joint Order Batching and Picker Routing Problem (JOBPRP). Given a set of orders to collect, each order being composed of several items located in a warehouse, the JOBPRP consists in batching orders into capacitated trolleys such that the total travelled distance to collect all the items of the orders is minimized. We are interested in algorithms based on column generation. A bottleneck of such approaches is to efficiently solve the pricing problem, that is a profitable order picking problem where all products of an order must be collected together in the same tour and a price is gained for collecting an order. At the core of this pricing problem lies a profitable Traveling Salesman Problem (TSP) in a rectangular warehouse. Dynamic Programming (DP) approaches can solve efficiently this TSP for such layouts. In the work [33], we extend the DP approach to the profitable variant. The directed acyclic graph underlying the DP can be used to provide a powerful Mixed Integer Programming (MIP) formulation where the order requirements (all products of an order must be collected together) can be taken into account with linking constraints. Such MIP formulation has been studied for the special case of warehouses with a single bloc of aisles. We generalize to the case with several blocks, and propose state space restrictions of the DP to heuristically solve the pricing problem. The proposed approach is validated on instances from the literature.

In the context of warehosue operations, picker-to-part systems are operational setups in which operators, commmonly called pickers, navigate around the warehouse collecting all the necessary products to prepare customer orders. In the Operations Research scope, a common assumption is to consider a complete independent operation scenario for each picker, neglecting potential interactions between pickers. Nowadays, given the changes on the behavior of customers it is common to see a large number of pickers operating simultaneously. This frame can lead to undesirable situations in which congestion appears. Congestion occurs when two or more pickers compete for the use of a shared space, delaying operational times and impacting overall performance. In the work [31], we propose a mathematical and computational approach to estimate the delay produced by congestion on the total operation times. We analyze in [38] the delay in terms of the main factors and different storage policies and evaluate the effect of approximating it by using a time discretization. Finally, in [30] we present a column generation based solving procedure to optimize order batching and picker routing decisions, explicitly considering the impact of congestion on the total completion times.

8.1.6 A column generation based heuristic for the integrated vehicle routing and driver scheduling problem

Integrated vehicle Routing and driver Scheduling Problems (RSPs) consist in simultaneously planning routes for vehicles and drivers' schedules. Usually, classical routing problems assume that each vehicle is associated with a single driver throughout its entire route. However, when planning over a large horizon, vehicles can be used without interruption over the whole horizon, while drivers have to rest. Hence, in order to better use the vehicles, in this work, we consider that each of them can be driven by different drivers during the planning horizon. RSPs have been investigated in different transportation applications, including airline industry, railway, trucks, buses. Although these transportation applications have different characteristics, they all share several main similarities. We denote by task a trip from two locations with predetermined departure and arrival times. A task has to be performed by one or several combined vehicles, and one driver has to be driving. The combined vehicle case typically appears for trains and trucks with trailers. Note that drivers can also be passengers on the vehicle. Given a set of tasks, the aim is to plan the sequence of tasks to be performed by each vehicle and each driver such that each task is performed by the required number of vehicles and at least one driver. We propose in [37] a generic compact formulation for these different applications. To handle large-size instances in a reasonable amount of time, we decompose the integrated RSP into two subproblems (1) a driver scheduling problem, and (2) a vehicle routing problem. We then solve the RSP with a two phases heuristic : first, we solve the driver scheduling subproblem, and then, knowing the driver schedules, we solve the vehicle routing sub-problem. We evaluated the quality of the solution with respect to optimal solutions for small-size instances. The two-phases approach provides very good results in general, except for some instances.

8.1.7 Fair and efficient cooperative vehicle routing

In addition to reducing their own consumption, communities often allow the socialization of total costs among their members. In this setting, a recurrent question is related to the design of fair cost allocation mechanisms. In [17], a cooperative is modeled as a business entity whose primary purpose is to provide benefits, services, and goods to its members, who both own and democratically control it. In the context of a cooperative, a fleet typically consists of vehicles owned by self-concerned, individually rational owners who prioritize their own efficiency and the fairness of the system. This fairness refers to how their individual gain aligns with the gain of others. In this paper, we focus on the routing of such cooperative fleets. If we consider only the efficiency of the fleet in terms of minimizing its total cost, the problem studied corresponds to the Multiple Traveling Salesman Problem (MTSP). However, our interest lies in finding both efficient and fair solutions, so we propose two new variants of this problem that integrate and maximize the egalitarian and elitist social welfare. Additionally, to enhance the balance between fleet efficiency and fairness, we propose the systematic elitist and systematic egalitarian social welfare optimization algorithm. Through simulation results, we observe a wide diversity of routes depending on the approach considered. Therefore, a cooperative may choose a model that best balances criteria of efficiency maximization and fairness for its fleet based on its specific requirements.

In [22] we propose a model and a solution method for the Dynamic Vehicle Routing Problem with Fair Profits and Time Windows (DVRP-FPTW). The goal is to dynamically optimize routes for a fleet of vehicles to perform tasks within assigned time windows, emphasizing fair and efficient solutions. The DVRP-FPTW accounts for unforeseen events, such as task changes or vehicle breakdowns, and ensures compliance with task demands, vehicle capacities, and autonomies. The proposed model incorporates mandatory and optional tasks, including optional tasks in operational vehicle routes when it does not affect vehicle profits. Incorporating asynchronous and distributed column generation heuristics, the proposed multi-agent architecture for the DVRP-FPTW dynamically adapts to unforeseen events. Systematic Egalitarian Social Welfare Optimization (SESWO) is used to iteratively maximize the profit of the least profitable vehicle, prioritizing fairness across the fleet in the face of unforeseen events. This improves upon existing dynamic and multi-period VRP models that rely on prior knowledge of demand changes. Our approach allows vehicle agents to maintain privacy while sharing minimal local data with a fleet coordinator agent. We propose publicly available benchmark instances for both static and dynamic VRP FPTW. Simulation results demonstrate the effectiveness of our VRP-FPTW model and our multi-agent system solution approach in coordinating large, dynamically evolving, cooperative autonomous fleets fairly and efficiently in near real time.

8.1.8 λ-cent-dians and generalized-center for network design

In this work [43], we extend the notions of λ-cent-dian and generalized-center from Facility Location Theory to the more intricate domain of network design. Our focus is on the task of designing a sub-network within a given underlying network while adhering to a budget constraint. This sub-network is intended to efficiently serve a collection of origin/destination pairs of demand rather than individual points. The λ-cent-dian problem studies the balance between efficiency and equity. We investigate the properties of the λ-cent-dian and generalized-center solution networks under the lens of equity, efficiency, and Pareto-optimality. We provide a mathematical formulation for $\lambda \geq 0$ and discuss the bilevel structure of this problem for $\lambda > 1$. Furthermore, we describe a procedure to obtain a complete parametrization of the Pareto-optimality set based on solving two mixed integer linear formulations by introducing the concept of maximum λ-cent-dian. We evaluate the quality of the different solution concepts using some inequality measures. Finally, for $\lambda \in [0,1]$, we study the implementation of a Benders decomposition method to solve it at scale.

8.2 Bilevel programming and game theory

Participants: Luce Brotcorne, Diego Cattaruzza, Bernard Fortz, Martine Labbé, Hélène Le Cadre, Frédéric Semet.

8.2.1 On stability of nonlinear armsbuilding security games

We formulate a security game in a context of mixed armament acquisition, involving a finite set of Nations in strategic relationship, with utility functions which are nonlinear and non-differentiable on the boundary of their sets of definition [16, 50]. Since we want to study the long-term effect of the Nations' investment in nuclear weapons, we focus on the steady-state analysis of the game. This requires us to extend the classical results from Rosen on compact-concave games, to unbounded concave games, relying on the uniform coercivity property of the Nations' utility functions. In addition, we prove the existence and uniqueness, under mild assumptions, of an interior point Nash Equilibrium solution of the game. To learn the interior point Nash Equilibrium, we provide a decentralized proximal point-type algorithm, and derive a closed form expression of its convergence rate. Simulations are performed in case of a duopoly, illustrating the utility improvement and stabilizing effects of nuclear armaments, by comparison with the conventional-only setting. We subsequently generalize this result to an arbitrarily large, but finite, number of Nations. The problem is extended further by allowing arms trades between Nations, split into suppliers on the one side, and recipients-interpreted as opponents-on the other side. It is widely recognized that arms trades can have negative externalities on the supplier Nations' security, and there are benefits to cooperate. Forming an export coalition enables the socialization of the operational costs among the coalition members and reallocation according to an ex-post cost allocation mechanism, while ensuring the maximization of the sum of the coalition members' security functions. For a given coalition structure, we develop a partial equilibrium model of the international arms market. We prove the existence and uniqueness of a market equilibrium in arms trade prices and supply. Finally, we derive conditions on the exports, arms trade prices, and cost allocation mechanism guaranteeing the stability of the export coalition, thus highlighting the viability of a common defense policy for the export coalition.

8.2.2 Noncooperative games with prospect theoretic preferences

We study noncooperative stochastic games, where agents display irrational behaviors in response to underlying risk factors in [44]. Our formulation incorporates prospect theory, a behavioral model used to describe agents' risk attitude, into the equilibrium theory of noncooperative N-agent games. We show that the resulting non-convex non-smooth game admits equilibria and provide convergence guarantees for their computation. Further, the concept of "price of irrationality" is introduced to quantify the suboptimality induced by irrational behaviors. Finally, we provide bounds on the performance of a class of prospect theoretic aggregative games and illustrate our results on an electricity market involving strategic end users exposed to risk.

Prospect-theoretic games are also studied in the context of the design of optimal sanctions in [28, 23].

8.2.3 A reverse Stackelberg model for demand response in local energy markets

In an era where renewable energy resources are increasingly integrated into our power systems, and consumer-centric approaches gain traction, local energy markets emerge as a pivotal mechanism for empowering prosumers. In [49], we present a novel bilevel optimization model that uniquely blends the dynamics of peer–to–peer energy markets with the physical realities of power distribution networks. The innovation stems from introducing a tariff design approach based on affine functions to shape prosumer behavior towards operationally efficient and secure energy exchanges. This is critical as previous market designs often overlooked the physical constraints of power flows, leading to potential risks in voltage regulation and economic efficiency. The lower level of the model encapsulates the interactions among prosumers in a Generalized Nash Equilibrium Problem (GNEP), modeling active and reactive power injections of prosumers. The upper level, representing the role of the distribution system operator, strategically computes tariffs to steer the market to an operationally efficient equilibrium. The paper relies on the classical Nikaido–Isoda (NI) reformulation to characterize the GNEP, a key aspect in leveraging a proof of strong stability of the lower–level solution. Computational experiments on various IEEE test feeder instances reveal the model's capacity to efficiently align prosumer behavior with operational objectives, utilizing only the tariff information, thereby simplifying the decision-making process in complex distribution systems.

8.2.4 Forecast trading as a means to reach social optimum on a peer-to-peer market

In [29], we investigate the coupling between a peer-to-peer (P2P) electricity market and a forecast market to alleviate the uncertainty faced by prosumers regarding their Renewable Energy Sources (RES) generation. The work generalizes the analysis from Gaussian-distributed RES production to arbitrary distributions. The P2P trading is modeled as a generalized Nash equilibrium problem, where prosumers trade energy in a decentralized manner. Each agent has the option to purchase a forecast on the forecast market before trading on the electricity market. We establish conditions on arbitrary Probability Density

Functions (PDFs) under which the prosumers have incentives to purchase forecasts on the forecast market. Connected with the previous results, this allows us to prove the economic efficiency of the P2P electricity market, i.e., that a social optimum can be reached among the prosumers.

8.3 Robust/stochastic programming

Participants: Luce Brotcorne, Diego Cattaruzza, Bernard Fortz, Martine Labbé, Hélène Le Cadre.

8.3.1 Learning in Stackelberg games with application to strategic bidding in the electricity market

We formulate a two-stage electricity market involving conventional and renewable producers strategically bidding in the day-ahead market, to maximize their profits while anticipating the market clearing performed by an Independent System Operator (ISO), as a multi-leader single follower Stackelberg game [27]. In this game, producers are interpreted as leaders, while the ISO acts as a follower. To compute an equilibrium, the classical approach is to cast the Stackelberg game as a Generalized Nash Game (GNG), replacing the ISO's optimization problem by its KKT constraints. To solve this reformulated problem, we can either rely on the Gauss-Seidel Best-Response method (GS-BR), or, on the Alternating Direction Method of Multipliers (ADMM). However, both approaches are implemented in a centralized setting since they require the existence of a coordinator which keeps track of the history of agents' strategies and sequential updates, or, is responsible for the Lagrange multiplier updates following the augmented Lagrangian. To allow the agents to selfishly optimize their utility functions in a decentralized setting, we introduce a variant of an actor-critic Multi-Agent deep Reinforcement Learning (MARL) algorithm with provable convergence. Our algorithm is innovative in that it allows different levels of coordination among the actors and the critic, thus capturing different information structures of the Stackelberg game. We conclude this work by comparing GS-BR and ADMM, both used as benchmark, to the MARL, on a dataset from the French electricity market, relying on metrics such as the efficiency loss and the accuracy of the solution.

8.3.2 Winning the 2023 CityLearn challenge: a community-based hierarchical energy systems coordiantion algorithm

The effective management and control of building energy systems are crucial for reducing the energy consumption peak loads, CO_2 emissions, and ensuring the stability of the power grid, while maintaining optimal comfort levels within buildings. The difficulty to accommodate this trade-off is amplified by dynamic environmental conditions and the need for scalable solutions that can adapt across various building types and geographic locations. Acknowledging the importance of this problem, NeurIPS conference hosted since 2020 the CityLearn control challenge to foster the design of innovative solutions in building energy management. Participants were tasked with developing strategies that not only enhance energy efficiency but also prioritize sustainability and occupant comfort. In [24], we introduce the Community-based Hierarchical Energy Systems Coordination Algorithm (CHESCA), the winning approach of the 2023 edition. We rely on a hierarchical approach adaptable to an arbitrary number of buildings, first optimizing building-level metrics individually, and later refining these through a central community-level controller to improve grid-related metrics. Compared to the other high-ranked competitors, our approach demonstrated fast inference capabilities like learning-based methods, while offering a better interpretability and a superior generalization capabilities with minimal data requirements. This paper details our approach, supported by comprehensive experimental results and ablation studies.

8.3.3 Exact and heuristic solution techniques for mixed-integer quantile minimization problems

We consider mixed-integer linear quantile minimization problems that yield large-scale problems that are very hard to solve for real-world instances. We motivate the study of this problem class by two important realworld problems: a maintenance planning problem for electricity networks and a quantile-based variant of the classic portfolio optimization problem. For these problems, we develop valid inequalities and present an overlapping alternating direction method. Moreover, we discuss an adaptive scenario clustering method for which we prove that it terminates after a finite number of iterations with a global optimal solution. We study the computational impact of all presented techniques and finally show that their combination leads to an overall method that can solve the maintenance planning problem on large-scale real-world instances provided by the EURO/ROADEF challenge 2020 and that they also lead to significant improvements when solving a quantile-version of the classic portfolio optimization problem [13].

9 Bilateral contracts and grants with industry

9.1 Bilateral contracts with industry

Within the Défi Inria-EDF, Ashok Krishnan started a postdoc on incentive design under bounded rationality in October 2024. He is co-supervised at Inria by Hélène Le Cadre and Ana Busic.

Participants: Ashok Krishnan, Hélène Le Cadre, Ana Busic, Pierre Gruet.

9.2 Bilateral grants with industry

SAMOA, Stackelberg Games for Flexibility (Dis)Aggregation

Participants: Hélène Le Cadre (PI), Luce Brotcorne, Yezekael Hayel (University of Avignon), Olivier Beaude (EDF).

This project has been extended up to July 2025.

Distribution network design - La poste

Participants: Gaël Guillot, Diego Cattaruzza, Frédéric Semet, Olivier Beaude (EDF).

(January to December 2024). A PhD thesis related to this project will start in 2025.

10 Partnerships and cooperations

10.1 International initiatives

10.1.1 Associate teams in the framework of an Inria international lab or in the framework of an Inria international program

BIO-SEL

Title: BIlevel Optimization in Security, Energy and Logistics

Duration: 2020 – 2024

Coordinator: Vladimir Marianov (marianov@ing.puc.cl)

Partners:

- Pontificia Universidad Católica de Chile Santiago (Chili)

Inria contact: Martine Labbé

Summary: This projet is devoted to bilevel optimisation problems with application in the security, energy, and logistics domains. Stackelberg games, including one defender and several followers, bidding problems in energy supply markets and product selection problems will be considered. Mixed integer optimisation models and efficient algorithms to solve them will be developed.

10.1.2 Inria associate team not involved in an IIL or an international program

GALANGAL

Title: Game theoretic learning and opitmization for networked electricity markets

Duration: 2022 – 2024

Coordinators: Hélène Le Cadre, Michel Gendreau

Partners:

- Polytechnique Montréal

Inria contact: Hélène Le Cadre

Summary: Reinforcement learning (actor-critic) algorithms are used to compute Stackelberg equilibrium in a distirbuted fashion. Convergence guarantees are provided. The algorithms are applied to strategic bidding on the day-ahead electricity market. Extension to the ancillary service market will be considered.

10.1.3 STIC/MATH/CLIMAT AmSud projects

SOGGA

Title: Stochastic optimization, generalized games and applications

Program: MATH-AmSud

Duration: 2024 – 2025

Local supervisor: Luce Brotcorne

Partners:

- Universidad de O'Higgins
- Salas (Chili)
- Universidad del Pacífico

Inria contact: Luce Brotcorne

Summary: Chile, Peru and France, as well as many countries in South America and Europe, share a very similar system to deal with their electricity markets. In parallel, all three countries (together with the rest of the world) are being affected by climate change in many aspects, such as scarcity of water, intense droughts, pollution and the greenhouse effect, the necessity of new energy sources, just to name a few. To face these challenges, we need new technology coming from many fields of science. One of such fields is mathematics and in particular, stochastic optimization and game theory. These theoretical fields allow us to model economic interactions, management solutions, optimal design and operations, among many other relevant aspects of natural resources and energy management. In the present project, we propose to develop new theoretical and numerical advances in four research lines, concerning stochastic optimization and game theory. Namely, we will work on: 1) Continuity-like properties in Equilibrium problems; 2) Regularity in Generalized Equilibrium problems; 3) Bilevel games with decision-dependent uncertainty; and 4) Algorithms and mechanism design in learning games. The four research lines are strongly motivated by the aforementioned applications.

10.2 International research visitors

10.2.1 Visits of international scientists

Other international visits to the team

Alejandro Jofre

Status Professor

Institution of origin: CMM - Universidad de Chile

Country: Chile

Dates: February

Context of the visit: Learning games

Mobility program/type of mobility: research stay

Erick Velasquez

Visited institution: Inria

Country: PUC Chile

Dates: March-June 2024

Context of the visit: Erick Velasquez visited Hélène Le Cadre and Francesco Morri in the context of an international exchange program with Chile

Mobility program/type of mobility: internship

Walter Rei

Status Professor

Institution of origin: Quebec University at Montréal

Country: Canada

Dates: September

Context of the visit: Stochastic optimization

Mobility program/type of mobility: Research stay - Masters internship co-supervision

Benjamín Eduardo Valdés Vera

Status Master student

Institution of origin: Universidad de Chile

Country: Chile

Dates: January-March

Context of the visit: Learning games

Mobility program/type of mobility: research stay

Matías Andree Villalobos Vera

Status Master student

Institution of origin: Universidad de Chile

Country: Chile

Dates: January-March

Context of the visit: Learning games

Mobility program/type of mobility: research stay

Alejandro Zarzuelo Urdiales

Status Master student

Institution of origin: Universidad de Oviedo

Country: Spain

Dates: August-September

Context of the visit: Network design

Mobility program/type of mobility: research stay

10.3 European initiatives

10.3.1 Horizon Europe

SUM SUM project on cordis.europa.eu

Title: Seamless shared Urban Mobility (SUM)

Duration: From June 1, 2023 to May 31, 2026

Partners:

- Institut National de Recherche en Informatique et Automatique (Inria), France
- Transports Publics Genevois, Switzerland
- Sixt GmbH & Co. Autovermietung KG, Germany
- Hydrolift Smart City Ferries AS, Norway
- Fredrikstad Kommune, Norway
- Siemens Mobility BV, Netherlands
- Rotterdamse Elektrische Tram NV (RET NV), Netherlands
- Ethnicon Metsovion Polytechinion (National Technical University of Athens - NTUA), Greece
- Institut Vedecom (Vedecom), France
- Technische Universitaet Muenchen (TUM), Germany
- Dimos Pentelis (Municipality of Penteli), Greece
- Gmina Miejska Krakow - Miasto na Prawach Powiatu (Municipality of Krakow UMK), Poland
- Universiteit Twente (Universiteit Twente), Netherlands
- Polis (Polis), Belgium
- Municipality of Jerusalem, Israel
- Free Now Hellas Monoprosopi AE (FreeNow Hellas Single Member SA), Greece

- Servicos Municipalizados de Transportes Urbanos de Coimbra (SMTUC), Portugal
- Camara Municipal de Coimbra (CMC), Portugal
- Tel Aviv University (TAU), Israel
- Nextbike Cy Ltd, Cyprus
- Lpt Larnaca Public Transport Services and Operations Limited, Cyprus
- Concesiones Unificadas SL (Concesiones Unificadas Slu), Spain
- European Road Transport Telematics Implementation Coordination Organisation - Intelligent Transport Systems & Services Europe (Ertico ITS Europe), Belgium
- Moby X Software Limited (Moby), Cyprus
- Landeshauptstadt Muenchen, Germany
- Technische Universiteit Delft (TU Delft), Netherlands
- Sigma 6 Ltd, Israel
- ZF CV Systems Global GmbH (ZF CV Systems Global GmbH), Switzerland
- Uniwersytet Jagiellonski, Poland
- Chalmers Tekniska Hogskola AB, Sweden

Inria contact: Luce Brotcorne

Summary: The objective of SUM is to transform current mobility networks towards innovative and Novel Shared Mobility systems (NSM) integrated with Public Transport (PT) in more than 15 European cities by 2026 reaching 30 by 2030. Intermodality, interconnectivity, sustainability, safety, and resilience are at the core of this innovation. The outcomes of the project offer affordable and reliable solutions considering the needs of all stakeholders such as end users, private companies, public urban authorities. SUM project will develop five pillars consisting of technological, co-creation, and policy tools to tackle the identified NSM barriers for a typical, car-focused family. These five pillars can increase the modal share of NSM via targeted push/pull measures and policy recommendations. SUM will introduce a federation of solutions including prediction, scheduling, integrated NSM-PT ticketing, and real-time NSM management. This created ecosystem will reduce the total door-to-door travel times using integrated NSM-PT. This can change the behavior of 34% of travelers using cars and 17% of travelers sceptic about using NSM. The partners in this diverse consortium have access to innovative tools and expertise making them uniquely positioned to tackle the barriers in 9 living labs and 30 organizations across Europe.

10.4 National initiatives

10.4.1 ANR

ANR project AGIRE (2020-2024): "Decision system for smart management of resources in warehouses" in collaboration with Ecole des Mines de Saint-Etienne (Gardanne), Université Gustave Eiffel (Champs-sur-Marne), HappyChic (Tourcoing). This project addresses human resources management in warehouses which supply either sale points or final consumers. Nowadays, such warehouses are under pressure. This is mainly due to the no inventory policy at the sale points and to the constant growth of e-commerce sales in France and Europe. In terms of logistics, this translates into an increasing number of parcels to prepare and to ship to satisfy an order, which is known typically a few hours before. Moreover, the total number of products to be packed varies very significantly from day-to-day by a factor of at least 3. The novelty of the project is twofold: (1) The human factor is explicitly be taken into account. It is integrated in the mathematical models and algorithms that are developed for the project. The aim is to improve the quality of employees' work ensuring the efficiency of the logistic system; (2) Problems at different decision levels are integrated and tackled jointly. At the tactical level, the main issues are workload smoothing and the management of the storage zone. At operational level, the major issues concern the rearrangement of the picking zone, the picking tours, and the dynamic reorganization of activities to manage uncertainties.

ANR project ADELE (2022-2025): "Resource Allocation in City Logistics with Demand Uncertainty" in collaboration with LCOMS (Univ. of Lorraine), Toulouse Business School, Colisweb. A central issue in City Logistics (CL) is to design logistics systems that move goods to, from, and within urban areas while meeting sustainability goals. A central role is played by the orchestrator. The orchestrator is the stakeholder that operates and organizes a CL system when multiple stakeholders are implied. In ADELE, we tackle the planning problem faced by the orchestrator in coordinating and managing the resources offered by carriers or logistics service providers. The problem aims to determine what logistics facilities should be used and when and where the vehicles of the carriers should be assigned to cover the demand in the most efficient way. A key feature is that demand is uncertain. We consider two main variants depending on whether the CL system is one or two tiers. ADELE aims to develop new efficient mathematical models and decision support methods. We aim to design and implement ad-hoc optimization algorithms based on mathematical modeling. This project is a continuation of the INRIA Innovation Lab Colinocs.

10.5 Regional initiatives

STaRS project SITAR (2022-2025): The SITAR project funded by the région Hauts-de-France, focuses on behavioral game theory and bounded rationality. Within this project, we study noncooperative stochastic games, where agents display irrational behaviors in response to underlying risk factors. Our formulation incorporates prospect theory, a behavioral model used to describe agents' risk attitude, into the equilibrium theory of noncooperative N-agent games. Extensions to optimal sanction design are studied.

11 Dissemination

11.1 Promoting scientific activities

11.1.1 Scientific events: organisation

General chair, scientific chair

- General chair of the first workshop on warehouse management and logistics, Lille, October 3-4 2024: Diego Cattaruzza, Maxime Ogier, Frédéric Semet, Pablo Torrealba.
- General chair of the 11th International Conference on Network Games, Artifical Intelligence, Control and Optimization (NETGCOOP 2024), Lille, France, October 9-11 2024: Hélène Le Cadre.

11.1.2 Scientific events: selection

Member of the conference program committees

- NETGCOOP 2024: Hélène Le Cadre.
- ROADEF 2024: Luce Brotcorne, Diego Cattaruzza, Maxime Ogier, Frédéric Semet.
- Odysseus 2024: Frédéric Semet.
- IEEE/IFAC CoDIT2024: Frédéric Semet.
- Variational Analysis and Applications for Modeling of Energy Exchange - VAME 2024: Martine Labbé.

11.1.3 Journal

Member of the editorial boards

- Computers & Operations Research Optimization: Luce Brotcorne – Member of the editorial advisory board.

- International Transactions in Operations Research: Luce Brotcorne – Associate editor.
- Journal of Optimization Theory and Applications (JOTA): Diego Cattaruzza - Associate editor; Bernard Fortz - Associate editor; Martine Labbé - Area editor.
- Open Journal of Mathematical Optimization: Martine Labbé - Member of the steering committee.
- Transportation Science: Martine Labbé - Member of the advisory board.
- International Transactions in Operations Research: Bernard Fortz - Associate editor; Martine Labbé - Associate editor.
- European Journal of Computational Optimization: Bernard Fortz - Associate editor; Martine Labbé - Associate editor.
- Networks: Bernard Fortz - Associate editor.
- INFORMS Journal on Computing: Bernard Fortz - Associate editor.

Reviewer - reviewing activities Annals of Operations Research, Applied Computing and Informatics, Central European Journal of Operations Research, Computers & Operations Research, Computational Optimization and Applications, Discrete Applied Mathematics, EURO Journal on Transportation and Logistics, European Journal of Operational Research, IISE Transactions, INFORMS Journal on Computing, International Journal of Management Science and Engineering Management, International Transactions in Operational Research, Journal of Optimization Theory and Applications, Mathematical Programming Computation, Networks, Omega, Operations Research, Optimization and Engineering, RAIRO - Operations Research, Transportation Science, IEEE Transactions on Automatic Control: Luce Brotcorne, Diego Cattaruzza, Bernard Fortz,Martine Labbé, Hélène Le Cadre, Maxime Ogier, Frédéric Semet, Yue Su.

11.1.4 Invited talks

- 29th POC seminar - Combinatorial Optimization and Supply-Chain: Frédéric Semet.
- EURO 2024: Hélène Le Cadre, Fredy Vale Manuel Pokou.

11.1.5 Leadership within the scientific community

- ROADEF (French OR association): Maxime Ogier, member of the board.
- PGMO: Luce Brotcorne, member of the scientific committee.
- INFORMS, Energy Natural Resources and the Environmentatl Section: Luce Brotcorne, secretary & treasurer.
- EURO Working Group “Pricing and revenue management”: Luce Brotcorne, coordinator.
- EURO Working Group “Vehicle Routing and Logistics Optimization (VEROLOG)”: Frédéric Semet, member of the board.
- GdR Recherche Opérationnelle et Décision: Frédéric Semet, member of the board.
- NETGCOOP: Hélène Le Cadre, member of the steering committee.

11.1.6 Scientific expertise

- ANID, Chile Evaluation Group: Luce Brotcorne.
- Scientific committee of France-Netherlands exchange program: Luce Brotcorne - Member.
- Evaluation committee for INRIA/MITACS exchange program: Luce Brotcorne - Member.
- Evaluation committee COST GTRI: Luce Brotcorne - Member.
- NSERC evaluation group 1509: Bernard Fortz.
- IVADO International Advisory Committee, Canada: Martine Labbé - Member.
- Scientific orientation committee of the Interuniversity Centre on Entreprise Networks, Transportation and Logistics (CIRRELT), Canada: Bernard Fortz, Frédéric Semet - Members.
- Research Council of Norway, Norway: Frédéric Semet - Panel member.
- EURO Doctoral Dissertation Award - Association of the European Operational Research Societies (EURO): Frédéric Semet - Member.
- PE6 panel for the evaluation of ERC Consolidator grants: Martine Labbé - Member.

11.1.7 Research administration

- Vice–president of the Inria evaluation committee: Luce Brotcorne.
- Elected Member of the Inria evaluation committee: Hélène Le Cadre.
- Member of the "Commission Emploi Recherche"(CER) at Inria Lille: Hélène Le Cadre.
- Mission Jeunes Chercheurs responsible for Inria Lille Center: Hélène Le Cadre.
- Deputy-director of CRIStAL: Frédéric Semet.
- Member of the OPTIMA scientific council: Diego Cattaruzza.

11.2 Teaching - Supervision - Juries

11.2.1 Teaching

- Master: Bernard Fortz, Operations Reserach and applications, 30hrs, M1, University of Mons (Charleroi campus), Belgium.
- Master: Bernard Fortz, Continuous Optimization, 24hrs, M1 & M2, Université libre de Bruxelles, Belgium.
- Master: Frédéric Semet, Supply Chain Management, 30hrs, M2, Centrale Lille.
- Master: Frédéric Semet, Operations Research, 28hrs, M2, Centrale Lille.
- Master: Luce Brotcorne, Optimisation, 14hrs, M1, Polytech Lille.
- Master: Luce Brotcorne, Recherche opérationnelle, 16hrs, M1 apprentissage, Polytech Lille.
- Master: Diego Cattaruzza, Frédéric Semet, Prescriptive analytics and optimization, 64hrs, M1, Centrale Lille.
- Master: Diego Cattaruzza, Maxime Ogier, Frédéric Semet, Object-Oriented Programming, 32hrs, M1, Centrale Lille.
- Master: Maxime Ogier, Operations Research, 24hrs, M1, Centrale Lille.

- Licence: Maxime Ogier, Object-Oriented Programming, 80hrs, L3, Centrale Lille.
- Licence: Frédéric Semet, Advanced programming and Complexity, 24hrs, L3, Centrale Lille.
- Licence: Maxime Ogier, Object-Oriented Programming, 96hrs, L2, Centrale Lille.
- Licence: Bernard Fortz, Algorithmic 1, 12hrs, L1, Université libre de Bruxelles, Belgium.
- Licence: Bernard Fortz, Algorithmic and Operations Research, 24hrs, L3, Université libre de Bruxelles, Belgium.
- Licence: Yue Su, Introduction to development, 27hrs, L1, Université de Lille, France.
- Licence: Yue Su, Introduction of database and SQL, 64hrs, L1, Université de Lille, France.
- Licence: Yue Su, New paradigms of database, 23hrs, L3, Université de Lille, France.
- Licence: Yue Su, Implementation the needs of clients (R1.01) - Dédoublement, 3hrs, L1, Université de Lille, France.
- Licence: Yue Su, Comparison algorithms, 5hrs, L1, Université de Lille, France.
- Licence: Yue Su, Creation of database, 8hrs, L1, Université de Lille, France.

11.2.2 Supervision

- PhD completed: Haider Ali, Optimal techniques for charging autonomous electric vehicles with renewable energy sources, December 2024, Luce Brotcorne, Bruno François (Centrale Lille).
- PhD completed: Clément Legrand, Intégration de machine learning pour la résolution de MO-VRPTWs, October 2024, Diego Cattaruzza, Marie-Eleonore Kessaci (Polytech Lile), Laetitia Jourdan (University of Lille).
- PhD completed: Thibault Prunet, Models and algorithm for tactical problems in warehouses with human factor considerations, January 2024, Nabil Absi (Mines de Saint Etienne), Valeria Borodin (Mines de Saint Etienne), Diego Cattaruzza.
- PhD in progress: Pablo Torrealba Gonzalez, Batching and picker routing problems in warehouses taking into account human factors, from February 2021, Dominique Feillet (Mines de Saint Etienne), Maxime Ogier, Frédéric Semet.
- PhD in progress: Wenjiao Sun, Exact methods for integrated routing and scheduling problems, from October 2021, Maxime Ogier, Frédéric Semet.
- PhD in progress: Francesco Morri, Game-theoretic learning in intelligent marketplaces, from October 2022, Hélène Le Cadre, Luce Brotcorne.
- PhD in progress: Juan Sepulveda, New optimization models and algorithms to represent energy exchanges in local energy communities, from December 2021, Hélène Le Cadre, Luce Brotcorne.
- PhD in progress: Cristian Aguayo, Models and algorithms for energy disptaching in local energy communities, from July 2021, Bernard Fortz.
- PhD in progress: Tifaout Almeftah, Models and algorithms for group testing, from December 2021, Diego Cattaruzza, Martine Labbé, Frédéric Semet.
- PhD in progress: Hugo Callebaut, Segment routing optimization, from September 2022, Bernard Fortz.
- PhD in progress: Aitor Lopez Sanchez, Distributed, scalable, and efficient fleet coordination for agriculture mobile robots, from September 2022, Frédéric Semet, Marin Lujak (University Rey Juan Carlos, Spain).

- PhD in progress: Luis Rojo, Incentive mechanisms for electric vehicle charging, from October 2021, Luce Brotcorne, Michel Gendreau (Polytechnique Montréal, Canada), Miguel Anjos (University of Edinburgh, UK).
- PhD in progress: Natalia Wolf, Towards energy-based pricing strategies for the cloud, from April 2023, Luce Brotcorne.
- PhD in progress: Salma Janati, Integration of forecasting methods into optimization algorithms: application to urban logistics, from October 2024, Luce Brotcorne, Frédéric Semet.

11.2.3 Juries

- Thibault Prunet, PhD, Mines de Saint-Etienne, Human-Aware Optimization of Integrated Order Picking Decisions in Warehousing Logistics: Maxime Ogier - Reviewer.
- Louise Sadoine, PhD, Mons University, Belgium, Noncooperative Game Theory for Resource Planning in Communities: Hélène Le Cadre - Reviewer.

12 Scientific production

12.1 Major publications

[1] N. Absi, D. Cattaruzza, D. Feillet, M. Ogier and F. Semet. 'A heuristic branch-cut-and-price algorithm for the ROADEF/EURO challenge on Inventory Routing'. In: *Transportation Science* (2019). URL: https://hal-emse.ccsd.cnrs.fr/emse-02163171.

[2] L. Brotcorne, D. Aussel, S. Lepaul and L. Von Niederhäusen. 'A Trilevel Model for Best Response in Energy Demand-Side Management'. In: *European Journal of Operational Research* (2020). URL: https://hal.inria.fr/hal-02414600.

[3] L. Brotcorne, F. Cirinei, P. Marcotte and G. Savard. 'An exact algorithm for the network pricing problem'. In: *Discrete Optimization* 8.2 (2011), pp. 246–258. URL: https://dx.doi.org/10.1016/j.disopt.2010.09.003.

[4] H. Calik and B. Fortz. 'A Benders decomposition method for locating stations in a one-way electric car sharing system under demand uncertainty'. In: *Transportation Research Part B: Methodological* 125 (July 2019), pp. 121–150. DOI: 10.1016/j.trb.2019.05.004. URL: https://hal.inria.fr/hal-02409510.

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