RESEARCH CENTRE

Inria Center at the University of Lille

IN PARTNERSHIP WITH:

Ecole Centrale de Lille, Université Libre de Bruxelles

2022
ACTIVITY REPORT

Project-Team
INOCS

INtegrated Optimization with Complex Structure

DOMAIN

Applied Mathematics, Computation and Simulation

THEME

Optimization, machine learning and statistical methods

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

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Other research topics and application domains

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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, HDR]
- Helene Le Cadre [INRIA, Researcher]

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- Bernard Fortz [Université Libre de Bruxelles, Professor]
- Martine Labbé [Université Libre de Bruxelles, Professor]
- Maxime Ogier [CENTRALE LILLE, Associate Professor]
- Frederic Semet [CENTRALE LILLE, Professor, HDR]

PhD Students

- Haider Ali [CENTRALE LILLE]
- Tifaout Almeftah [INRIA]
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- Wenjiao Sun [Bourse CSC]
- Pablo Torrealba Gonzalez [CENTRALE LILLE]

Technical Staff

- Sylvain Clay [INRIA, Engineer, from Feb 2022]
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Interns and Apprentices

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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 types of decision 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. [59, 60], Gendron et al. [61, 62, 63], and Strack et al. [64]). 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:

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

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 problem where two types of decision 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:

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

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. $Y(x) = \arg\min \{h(x,y) | y \in Y_2, (x,y) \in XY_2\}$ 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 non convexity and non differentiability. 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 cars 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 has a bilevel one where the lower lever 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 lever 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 it targets. 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 smartgrid 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

The following awards have been obtained in 2022:

- Scientific prize ROADEF/EURO Challenge 2020: Diego Cattaruzza, Martine Labbé, Matteo Petris.
- Marguerite Frank Award for the best paper published in the journal *EURO Journal on Computational Optimization*, 2021: Martine Labbé.
- Best paper award of *Mathematical Methods of Operations Research*, 2021: Martine Labbé.

7 New software and platforms

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 2022, we addressed different problems/challenges related to the three lines of research: large scale complex structure optimization, bilevel programming, robust/stochastic programming. The main contributions are summarized in the next sections. In addition, besides these contributions, additional results([20],[22], [23]) were obtained which are not discussed hereafter in order to keep the presentation focused on the main achievements.

8.1 Large scale complex structure optimization

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

8.1.1 Telecommunication and network optimization.

Several classes of models have been proposed in the literature for the Steiner tree problem with hop constraints. One class is characterized by having hop-indexed arc variables. Although such models have proved to have a very strong linear programming bound, they are not easy to use because of the huge number of variables. This has motivated some studies with models involving fewer variables that use, instead of the hop-indexed arc variables, hop-indexed node variables. We contextualized the linear programming relaxation of these node-based models in terms of the linear programming relaxation of known arc-based models. We showed that the linear programming relaxation of a general node-based model is implied by the linear programming relaxation of a straightforward arc-based model [17].

8.1.2 Logistics and warehouse management.

Picking is the process of retrieving products from inventory. It is considered the most expensive of warehouse management operations. In INOCS, we addressed the Joint Order Batching and Picker Routing Problem (JOBPRP) that is a challenging optimization problem with two integrated decisions: customer orders are grouped into batches (order batching problem) that are collected by pickers who travel the shortest possible distance (picker routing problem). Human pickers often perform picking, so we proposed to explicitly consider human factors in the JOBPRP, by first studying the consideration of congestion effects when several pickers share the same space at the same time [42, 31]. These congestion situations are really stressful for the pickers, and considering them in mathematical models is really challenging since a temporal aspect must be included.

We also started to address an extension of the JOBPRP that includes the sequencing question, i.e. the additional assignment and sequencing of batches for each picker to meet the required deadlines of orders. We show that a bin-packing formulation permits solving the problem with a column generation approach efficiently [32].

Another relevant problem we study in INOCS is the Operational Storage Location Assignment Problem, which asks to optimize the location of products in warehouses to minimize the distance walked by the picker [27].

8.1.3 Logistics network design problem.

Planning transportation operations within a supply chain is a difficult task often outsourced to logistics providers. At the tactical level, the problem of distributing products through a multi-echelon network is defined in the literature as the Logistics Service Network Design Problem (LSNDP). To solve the LSNDP, we propose a solution approach based on Benders decomposition. In a previous paper [58], we proposed an enhanced Benders decomposition algorithm for solving the LSNDP, which consists in strengthening the master problem with variables and constraints that model the need to route a super-product derived from the aggregation of all the products to be transported. We developed a more elaborated algorithmic strategy that exploits this partial Benders decomposition by intelligently varying the amount of subproblem information used to formulate the master problem. We refer to this strategy as

Meta Partial Benders Decomposition (Meta-PBD). Meta-PBD operates in two steps, with the first aiming to explore different areas within the feasible region of the original problem and to quickly determine high-quality solutions. To do so, the number of super-products used to formulate the master problem changes dynamically while respecting a threshold value to ensure computational tractability. Next, a second phase aims to close the optimality gap. This second phase increases the amount of subproblem information used to formulate the master problem, such that the latter becomes provably equivalent to the original problem. While this master problem is computationally challenging, high-quality solutions generated through the first phase enable many nodes of the resulting branch-and-bound search tree to be pruned, accelerating convergence [12].

8.1.4 Complex routing problems.

Vehicle Routing Problems (VRPs) are classical optimization problems in transportation and logistics. In INOCS, we address complex routing problems generalizing the VRP or combining the VRP with another optimization problem. We studied an extension of the VRP in a context where customers require several commodities that can be transported in the same vehicle, and each customer is allowed to be visited multiple times. However, the demand for a single commodity must be delivered by one vehicle only. The problem is coined as the Commodity constrained Split Delivery VRP (C-SDVRP). We developed a heuristic column generation with performance guarantee to solve the C-SDVRP [39]. We also studied an extension of the C-SDVRP in a two-echelon context and multiple intermediate depots. The first echelon considers collecting several commodities with direct trips while the second is a multi-depot version of the C-SDVRP. To solve this complex problem, we first proposed a generic sequential approach with a comparison of different strategies [18]. Then, we also developed an exact branch-price-and-cut algorithm to solve the problem [38].

Another extension of the VRP that we addressed is an integrated production scheduling problem and multi-trip VRPTW, where the products have a limited lifespan so they have to be delivered shortly after their production. Hence, the scheduling and the routing problems are really interrelated, and finding feasible solutions with a sequential approach is not trivial. This problem finds an application in home chemotherapy with a limited lifespan of the drugs. To solve this problem, we developed a dedicated large neighborhood search approach where production and routing sequences are iteratively modified while a linear program is used to determine optimal start times of the production and routing tasks [44].

Last, we explore the operational planning and the real-time management of a fleet of highly automated agriculture vehicles that perform tasks throughout multiple fields potentially owned by different farmers and/or enterprises. In this context, the concepts of fairness and equity must be considered to balance the execution of tasks between vehicles and also between farmers. We studied new variants of the operational planning problem that maximize utilitarian, egalitarian, and elitist social welfare and balance workload and efficiency of the fleet [26].

8.1.5 Public transportation networks.

Infrastructure network design constitutes a major step in the planning of a transportation network whose purpose is to improve the mobility of the inhabitants of a city or metropolitan area. In the area of passengers transportation, the aim is to get the infrastructure close to potential customers. In this case, one might select a sub(network) from an underlying network to capture or cover as much traffic for a reasonable construction cost. The paper [14] is devoted to this problem, and considers the Maximum Covering Network Design Problem (MC) as well as the closely related Partial Covering Network Design Problem (PC), in which one minimizes the network design cost for building the network under the constraint that a minimum percentage of the total traffic demand is covered. Models for problems (MC) and (PC), as well as exact methods based on Benders decomposition are provided and compared through computational experiments.

8.1.6 Machine learning application.

Feature selection is an important issue to avoid overfitting when applying a support vector machine (SVM) approach. The classical SVM model minimizes a compromise between the structural risk and the empirical risk. In [11], we consider the Support Vector Machine with feature selection and we design and implement a bi-objective evolutionary algorithm for approximating the Pareto optimal frontier of the two objectives.

8.2 Bilevel Programming

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

8.2.1 Strategic bidding in price coupled regions.

With the emerging deregulated electricity markets, a part of the electricity trading takes place in day-ahead markets where producers and retailers place bids in order to maximize their profit. We present a price-maker model for strategic bidding from the perspective of a producer in Price Coupled Regions (PCR) considering a capacitated transmission network between local day-ahead markets. The aim for the bidder is to establish a production plan and set its bids taking into consideration the reaction of the market. We consider the problem as deterministic, that is, the bids of the competitors are known in advance. We are facing a bilevel optimization problem where the first level is a Unit Commitment problem, modeled as a Mixed Integer Linear Program (MILP), and the second level models a market equilibrium problem through a Linear Program. The problem is first reformulated as a single level problem. Properties of the optimal spot prices are studied to obtain an extended formulation that is linearized and tightened using new valid inequalities. Several properties of the spot prices allow to reduce significantly the number of binary variables. Two novel heuristics are proposed [13].

8.2.2 Equilibrium analysis of risk-hedging strategies in decentralized electricity markets.

In [52], we investigate equilibrium problems arising in various decentralized designs of the electricity market involving risk-averse prosumers. The prosumers have the possibility to hedge their risks through financial contracts that they can trade with peers or purchase from an insurance company. We build several market designs of increasing complexity, from a one-stage market design with inter-agent financial contract trading to a Stackelberg game where an insurance company acts as a leader and prosumers are followers. We derive risk-hedging pricing scheme for each model and show that the Stackelberg game pessimistic formulation might have no solution. We propose an equivalent reformulation as a parametrized generalized Nash equilibrium problem, and characterize the set of equilibria. We prove that the insurance company can design price incentives that guarantee the existence of a solution of the pessimistic formulation, which is ε close to the optimistic one. We then derive economic properties of the Stackelberg equilibria such as fairness, equity, and efficiency. We also quantify the impact of the insurance company incomplete information on the prosumers' risk-aversion levels on its cost and social cost.

8.2.3 Bilevel location problems.

We consider the problem faced by a retail chain that must select what mutual-substitute items to display in each one of its stores to maximize revenues. The number of items cannot exceed the limit space capacity of each store. Customers purchase the one product that maximizes their utility, which depends on the product price, travel cost to the store, and reservation price, known to the retailer. The retailer solves a mixed-integer bilevel optimization problem, which can be formulated as a single-level optimization problem. In [16], we propose Branch and Cut and Cut and Branch methods and include a family of valid inequalities to solve the problem.

8.2.4 Equilibrium Learning in strategic resource pricing games

In [15], we consider a marketplace in the context of 5G network slicing, where Application Service Providers (ASP), i.e., slice tenants, providing heterogeneous services, are in competition for the access to the virtualized network resource owned by a Network Slice Provider (NSP), who relies on network slicing.

We model the interactions between the end users (followers) and the ASPs (leaders) as a Stackelberg game. We prove that the competition between the ASPs results in a multi-resource Tullock rent-seeking game. To determine resource pricing and allocation, we devise two innovative market mechanisms. First, we assume that the ASPs are pre-assigned with fixed shares (budgets) of infrastructure, and rely on a trading post mechanism to allocate the resource. Under this mechanism, the ASPs can redistribute their budgets in bids and customise their allocations to maximize their profits. In case a single resource is considered, we prove that the ASPs' coupled decision problems give rise to a unique Nash equilibrium. Second, when ASPs have no bound on their budget, we formulate the problem as a pricing game with coupling constraints capturing the shared resource finite capacities, and derive the market prices as the duals of the coupling constraints. In addition, we prove that the pricing game admits a unique variational equilibrium. We implement two online learning algorithms to compute solutions of the market mechanisms. A third fully distributed algorithm based on a proximal method is proposed to compute the Variational equilibrium solution of the pricing game. Finally, we run numerical simulations to analyse the market mechanism's economic properties and the convergence rates of the algorithms.

8.3 Robust/Stochastic programming

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

8.3.1 Deciding feasibility of a booking in the European Gas Market.

During the last decades, the European gas market has undergone ongoing liberalization, resulting in the so-called entry-exit market system. The main goal of this market reorganization is the decoupling of trading and actual gas transport. To achieve this goal within the European entry-exit market, gas traders interact with transport system operators (TSOs) via bookings and nominations. A booking is a capacity-right contract in which a trader reserves a maximum injection or withdrawal capacity at an entry or exit node of the TSO's network. On a day-ahead basis, these traders are then allowed to nominate an actual load flow up to the booked capacity. To this end, the traders specify the actual amount of gas to be injected to or withdrawn from the network such that the total injection and withdrawal quantities are balanced. On the other hand, the TSO is responsible for the transport of the nominated amounts of gas. By having signed the booking contract, the TSO guarantees that the nominated amounts can actually be transported through the network. More precisely, the TSO needs to be able to transport every set of nominations that complies with the signed booking contracts. Thus, an infinite number of possible nominations must be anticipated and checked for feasibility when the TSO accepts bookings. As a consequence, the entry-exit market decouples trading and transport. However, it also introduces many new challenges, e.g. the checking of feasibility of bookings or the computation of bookable capacities on the network.

In [21], we consider networks with linearly modeled active elements such as compressors and control valves that do not lie on cycles of the network. Since these active elements allow the TSO to control the gas flow, the single-level approaches from the literature are no longer applicable. We thus present a bilevel approach to decide the feasibility of bookings in networks with active elements. Besides the classical Karush–Kuhn–Tucker reformulation, we obtain three problem-specific optimal-value-function reformulations, which also lead to novel characterizations of feasible bookings in active networks. We compare the performance of our methods by a case study based on data from the GasLib.

8.3.2 Mixed-Integer Quantile Minimization Problems.

In this work 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 real-world 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 [46].

8.3.3 Transaction fees optimization in the Ethereum blockchain.

In blockchains, transaction fees are fixed by the users. The probability for a transaction to be processed quickly increases with the fee level. We studied the transaction fee optimization problem in the Ethereum blockchain. This problem consists of determining the minimum price a user should pay so that its transaction is processed with a given probability in a given amount of time. To reach this goal, we define a new solution method based on a Monte Carlo approach to predict the probability that a transaction will be mined within a given time limit. Numerical results on real data highlight the quality of the results [19].

8.3.4 Balancing efficiency and privacy in a decision-dependent network game.

We consider a network game, where End Users (EUs) minimize their cost by computing their demand and generation while satisfying a set of local and coupling constraints. Their nominal demand constitutes sensitive information, that they might want to keep private. We prove that the network game admits a unique Variational Equilibrium, which depends on the private information of all the EUs. A data aggregator is introduced, which aims to learn the EUs' private information. The EUs might have incentives to report biased and noisy readings to preserve their privacy, which creates shifts in their strategies. Relying on performative prediction, we define a decision-dependent game G^{stoch} to couple the network game with a data market. Two variants of the Repeated Stochastic Gradient Method (RSGM) are proposed to compute the Performatively Stable Equilibrium solution of G^{stoch}, that outperform RSGM with respect to efficiency gap minimization, privacy preservation, and convergence rates in numerical simulations [54]. Convergence proofs of the algorithms will be detailed in further work, and rely on stochastic approximation theory.

9 Bilateral contracts and grants with industry

9.1 Bilateral contracts with industry

Urban hub (2019-2023) Development of an integrated tool for warehouse management and delivery to the end customer: www.urbanhub.fr.

9.2 Exploratory Research Actions and Technological Development Actions

INRIA Défi with OVH Cloud (2021-2025). Until now, cloud computing operators, such as OVHcloud, have applied pricing strategies driven by the reservation of virtualized resources. More precisely, OVHcloud offers two types of services to its customers: VPS (virtual private server) and Public Cloud. VPS is a cost-effective solution for pre-production and production environments that do not require constant performance. The PublicCloud of OVHcloud offers a multi-server infrastructure with high machine availability. Unfortunately, the resources reserved in the Public Cloud are underutilized, which can lead to energy inefficiency in the infrastructure, while the VPS favors an over-allocation of hardware resources, not allowing resources, which does not provide any guarantee of performance for customers. The research activity in this project aims at identifying a viable balance between these 2 options to allow customers to benefit from guaranteed performance while minimizing the energy footprint of the OVHcloud infrastructure. In particular, we want to determine discounts to offer to customers to encourage them to free up resources when they do not need them, to offer these available resources to other customers-or services-while smoothing the demand.

Through this new offer, and its dynamic pricing, we wish to maintain a high performance criterion while eliminating the waste of underutilized resources.

This problem is a hierarchical decision making process between a leader (OVH) and followers (the two type of customers). Bilevel optimizations models are defined and solved to answer these questions. The collaboration with the INRIA Spirals team aims to measure cloud services energy consumptions.

In the medium term, the integration of renewable energy production in the demand smoothing process could be another research issue for this work. This will lead to the resolution of stochastic bilevel optimization problems. www.inria.fr/fr/inria-ovhcloud

9.3 Bilateral grants with industry

Program PGMO funded by the Fondation Mathématiques Jacques Hadamard. Stackelberg Games for Flexibility (Dis)Aggregation (2022 – 2024).

Program PGMO funded by the Fondation Mathématiques Jacques Hadamard. A generic framework for routing and scheduling problems (2019 – 2022).

Program PGMO funded by the Fondation Mathématiques Jacques Hadamard. Integrated models for the dimensioning and location of charging electric vehicles stations in the presence of renewable energy sources: Models and Algorithms (2019 – 2022).

PEPS project granted by AMIES, “Models and Decision-Support Algorithms for the Reinsurance Market”, in collaboration with Bifrost (June-September 2022).

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 -2023

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 optimization 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 optimization models and efficient algorithms to solve them will be developed.

10.1.2 Participation in other International Programs

CityFreight

CityFreight — Freight logistics in sustainable cities

Partner Institutions:

- University of Bergen – Centre for Climate and Energy Transformation
- The Norwegian Public Roads Administration
- Sparebanken Vest

- City of Bergen
- Vestland County, Bergen Chamber of Commerce and Industry, Nordic Edge AS (Norway)
- Centrale Lille
- The Polytechnic University of Turin (Italy)
- Sichuan University, Chengdu (China)

Duration: 2020 – 2024

Additional info: The primary objective of this project is to provide public authorities, particularly in smaller, topologically complicated, cities and initially the City of Bergen, with a toolbox for realistically evaluating major decisions that would make a city more energy efficient and sustainable in terms of freight transportation

10.2 International research visitors

10.2.1 Visits of international scientists

Pamela, Bustamante

Status Ph.D. student

Institution of origin: Pontificia Universidad Catolica de Chile

Country: Chile

Dates: March 2022 - January 2023

Context of the visit: Stackelberg games

Mobility program/type of mobility: research stay - Ph.D. co-supervision

Miguel, Anjos

Status Professor

Institution of origin: School of Mathematics, University of Edinburgh

Country: United Kingdom

Dates: March

Context of the visit: Optimization in energy

Mobility program/type of mobility: research stay

Davila, Sebastian

Status Professor

Institution of origin: Universidad De Santiago de Chile

Country: Chile

Dates: July

Context of the visit: Bilevel optimization

Mobility program/type of mobility: research stay

Escalona, Pablo

Status Professor

Institution of origin: Universidad Tecnica Federico Santa Maria

Country: Chile

Dates: September

Context of the visit: Combinatorial optimization

Mobility program/type of mobility: research stay

Guido, Perboli

Status Professor

Institution of origin: Politecnico di Torino

Country: Italy

Dates: September

Context of the visit: Bilevel optimization. Application in transportation.

Mobility program/type of mobility: research stay

10.2.2 Visits to international teams

Research stays abroad

- L. Brotcorne, Universidad Tecnica Federico Santa Maria and Universidad de Chile (Chile), Université de Montréal (Canada), one week visits.
- M. Labbé and F. Semet, Universidad de Chile and Pontificia Universidad Catolica de Chile, one week visit.

10.3 European initiatives

10.3.1 Horizon Europe

CHIST-ERA SEC-OREA project: "Supporting Energy Communities-Operational Research and Energy Analytics". (2020 – 2023) SEC-OREA aims to enable local energy communities (LECs) to participate in the decarbonisation of the energy sector by developing advanced efficient algorithms and analytics technologies.
Partners: INRIA- INOCS (France), Université Libre de Bruxelles (Belgique), Uuniversity college Dublin (Ireland), Riga technical University (Lithuania)

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), IFSTTAR (Champs-sur-Marne), HappyChic (Tourcoing).

This project addresses human resources management in warehouses which supply either sale points (B2B) or final consumers (B2C). 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 grant from the région Hauts-de-France SITAR (2022-2025): "Impact of Information Structures on Services Pricing". The objective of SITAR is to refine the approach by menus with levels of priority. The problem will be formalized as a decision-dependent game, involving on the one side end users which minimize their cost while satisfying a set of local and coupling constraints. Their nominal demand constitutes sensitive information, that they might want to keep private, and on the other side a data aggregator, which aims to learn the end users' private information. The end users might have incentives to report biased and noisy readings to preserve their privacy, which creates shifts in their strategies. The contributions will be on (1) the methodological side, to advance the understanding of theoretical properties of decision-dependent games, (2) the alogrithmic side to develop distributed algorithms enabling to approximate equilibria, (3) on the service pricing side, to understand how local objectives like individual privacy might impact the optimal design of menus.

11 Dissemination

11.1 Promoting scientific activities

11.1.1 Scientific events: organisation

Member of the organizing committees

- Dagstuhl Seminar, Optimization at the Second Level, November 2022: Luce Brotcorne.

11.1.2 Scientific events: selection

Chair of conference program committees

- Cluster Chair INFORMS ENRE Section: 2019, 2022: Luce Brotcorne.

Member of the conference program committees

- LIV Brazilian Symposium on Operational Research (LIV SBPO), Juiz de Fora, Brazil, November 2022: Martine Labbé.

- ORBEL 2022, Ghent, Belgium, September 2022: Bernard Fortz.
- 32nd European Conference on Operational Research (EURO 2022), Espoo, Finland, July, 2022: Bernard Fortz.
- INOC 2022, International Network Optimization Conference, Aachen, Germany, June 2022: Bernard Fortz.
- TRISTAN XI - Triennial Symposium on Transportation Analysis, Mauritius, June 2022: Luce Brotcorne, Martine Labbé, Frédéric Semet.
- 10th INFORMS Transportation Science and Logistics Society Workshop, Bergen, Norway, June 2022: Luce Brotcorne, Frédéric Semet.
- ODYSSEUS - 8th International Workshop on Freight Transportation and Logistics, Tangier, Morocco, May 2022: Frédéric Semet.
- Congrès de la Société Française de Recherche Opérationnelle - ROADEF 2022, Lyon, France, February 2022: Diego Cattaruzza.

11.1.3 Journal

Member of the editorial boards

- EURO Journal on Computational Optimization: Martine Labbé, Bernard Fortz - Associate editors.
- Computers and Operations Research: Luce Brotcorne - Associate editor.
- INFORMS Journal on Computing: Bernard Fortz - Associate editor.
- International Transactions in Operations Research: Luce Brotcorne, Bernard Fortz, Martine Labbé - Associate editors.
- Transportation Science: Martine Labbé - Member of the Advisory Board.
- Journal of Optimization Theory and Applications: Martine Labbé - Area Editor; Bernard Fortz, Diego Cattaruzza - Associate editors.

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, 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.

11.1.4 Invited talks

- Plenary speaker at French, German, Portuguese Optimization Conference, Porto, May 2022, Luce Brotcorne

11.1.5 Leadership within the scientific community

- Informs, Energy Natural Resources and the Environment Section, Luce Brotcorne, Secretary-Treasurer, 2022-2024.
- EURO Working Group "Pricing and Revenue Management": Luce Brotcorne - coordinator.
- PGMO, Fondation Gaspard Monge: Luce Brotcorne - Member of the scientific committee.

- EURO Working Group "European Network Optimization Group (ENOG)": Bernard Fortz - coordinator.
- EURO Working Group "Vehicle routing and logistics optimization (VEROLOG)": Frédéric Semet - Member of the board.
- SIAG/Optimization Prize committee: Martine Labbé - Chair.
- ORBEL (Belgian Operations Research Society): Bernard Fortz - Member of the administration board.
- ORBEL representative for EURO: Bernard Fortz
- CNRS GdR 3002 : Operations Research: Frédéric Semet - 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.
- NSERC Evaluation Group 1509: Bernard Fortz.
- INFORMS, ENRE, Early Career Best Paper award, president of the commission: Luce Brotcorne.
- Evaluation committee for INRIA/MITACS Exchange Program: Luce Brotcorne - Member.
- Evaluation committee COST GTRI: Luce Brotcorne - Member.
- President of the FRIA PE1 - jury 1: Bernard Fortz - Chair.
- Scientific orientation committee of the Interuniversity Centre on Entreprise Networks, Transportation and Logistics (CIRRELT), Canada: Bernard Fortz, Frédéric Semet - Members.
- Internal selection committee of Logistics in Wallonia : Bernard Fortz - Member.
- Selection committee for the ORBEL award for the best OR thesis: Bernard Fortz, Martine Labbé.
- Member of the PE6 panel for the evaluation of ERC Consolidator grants : Martine Labbé
- Scientific Advisory Board of IWR and its Graduate school HGS MathComp, Heidelberg University: Martine Labbé - Member.
- Centro de Matemática, Aplicaçoes Fundamentais e Investigaçao Operacional, University of Lisbon: Martine Labbé - Member.
- IVADO International consultative committee, Montreal, Canada: Martine Labbé
- Selection committee for the SEIO-BBVA Awards: Martine Labbé.
- Selection committee for the prize Jean-Jacques Moreau from the Société Mathématique de France: Martine Labbé.
- Panel member for the Research Council of Norway: Frédéric Semet.

11.1.7 Research administration

- Deputy-director of CRIStAL: Frédéric Semet.
- Elected member of the Scientific Council of Centrale Lille: Diego Cattaruzza.
- Member of the OPTIMA Scientific Council: Diego Cattaruzza.

11.2 Teaching - Supervision - Juries

11.2.1 Teaching

- Master: Bernard Fortz, Recherche Opérationnelle et 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, Object-Oriented Programming, 48hrs, M1, Centrale Lille.
- Master: Diego Cattaruzza, Operations Research, 16hrs, M1, Centrale Lille.
- Licence: Diego Cattaruzza, Maxime Ogier, Object-Oriented Programming, 40hrs, L3, Centrale Lille.
- Licence: Frédéric Semet, Advanced programming and Complexity, 24hrs, L3, Centrale Lille.
- Licence: Diego Cattaruzza, Maxime Ogier, Object-Oriented Programming, 44hrs, L2, Centrale Lille.
- Licence: Bernard Fortz, Algorithmique 1, 12hrs, L1, Université libre de Bruxelles, Belgium.
- Licence: Bernard Fortz, Algorithmique et Recherche Opérationnelle, 24hrs, L3, Université libre de Bruxelles, Belgium.

11.2.2 Supervision

- PhD completed: Luis Alberto Salazar Zendeja, Models and algorithms for network interdiction problems, December 2022, Diego Cattaruzza, Martine Labbé, Frédéric Semet.
- PhD in progress: Matteo Petris, Column generation approaches for integrated operationnal problems, from October 2019, Diego Cattaruzza, Maxime Ogier, Frédéric Semet.
- PhD in progress: Ilia Shilov, Algorithmic game and distributed learning for peer-to-peer energy market, from December 2019, Hélène Le Cadre, Ana Busic (Inria/ENS Paris), Goncalo Terca (VITO).
- PhD in progress: Thibault Prunet, Models and algorithm for tactical problems in warehouses with human factor considerations, from February 2020, Nabil Absi (Ecole des Mines de Saint Etienne), Valeria Borodin (Ecole des Mines de Saint Etienne), Diego Cattaruzza.
- PhD in progress: Natividad Gonzales Blanco, Exact and heuristic approaches for network design problems, from 2020, Bernard Fortz, Martine Labbé, Juan Antonio Mesa Lopez-Colmenar (University of Sevilla, Spain).
- PhD in progress: Moises Rodriguez Madrena, Design problems in continous spaces with different norms, from 2020, Bernard Fortz, Martine Labbé, Justo Puerto (University of Sevilla, Spain).
- PhD in progress: Pablo Torrealba Gonzalez, Batching and picker routing problems in warehouses taking into account human factors, from February 2021, Dominique Feillet (Ecole des Mines de Saint Etienne), Maxime Ogier, Frédéric Semet.

- PhD in progress: Cristian Aguayo, Supporting Energy Communities - Operational Research and Energy Analytics, from July 2021, Bernard Fortz.
- PhD in progress: Wenjiao Sun, Integrated optimization algorithms for routing and scheduling problems, from October 2021, Maxime Ogier, Frédéric Semet.
- PhD in progress: Luis Pablo Rojo, Incentive mechanisms for electric vehicle charging, from October 2021, Luce Brotcorne, Michel Gendreau (Polytehcnique Montréal, Canada), Miguel Anjos (University of Edinburgh, UK).
- PhD in progress: Haider Ali,Optimal techniques for charging autonomous electric vehicles with renewable energy sources, from October 2021, Luce Brotcorne, Bruno François (Centrale Lille).
- PhD in progress: Clement Legrand, Integration of machine learning into multi objective optimization problems, from October 2021, Marie-Eleonore Kessaci (Ecole Polytechnique de Lille), Laetitia Jourdan (Université de Lille), Diego Cattaruzza.
- PhD in progress: Juan Sepulveda, New optimization models and algorithms for local energy communities, from December 2021, Luce Brotcorne, Hélène Le Cadre.
- PhD in progress: Tifaout Almeftah, Models and algorithms for group testing, from December 2021, Diego Cattaruzza, Martine Labbé, Frédéric Semet.

11.2.3 Juries

- Xavier Blanchot, PhD, Université de Bordeaux, Résolution de problèmes d'optimisation stochastique de grande taille: application à des problèmes d'investissement dans les réseaux électriques: Luce Brotcorne - Reviewer
- Alyssia Dong, PhD, Ecole Normale Supérieure de Rennes, Algorithmes asynchrones pour la gestion décentralisée des réseaux électriques soumis aux aléas de communication: Luce Brotcorne - Member
- Andrea Di Placido, PhD, Universitá degli Studi del Molise, Italy, The Close Enough Traveling Salesman Problem: enhanced heuristics, applications and variants: Diego Cattaruzza - Member
- Gauthier Soleilhac, PhD, École Nationale Supérieure Mines-Télécom Atlantique Bretagne Pays-de-la-Loire - IMT Atlantique, Optimisation de la distribution de marchandises avec soustraitance du transport : une problématique chargeur: Diego Cattaruzza - Member
- Mahmoud Parham, PhD, University of Vienna, Austria, Algorithms for Traffic Control Challenges in Softwarized Networks: Bernard Fortz - Reviewer
- Nicola Morandi, PhD, KU Leuven, Belgium,Routing problems with node prizes and truck-drones synchronization: Bernard Fortz - Member
- Christian Biefel, PhD, Friedrich-Alexander-Universität Erlangen-Nürnberg, Contributions to Robust Optimization: Network Flows, Market Equilibria, Linear Complementarity Problems, and Pareto Optimality: Martine Labbé, reviewer.
- Niels Govaerts, PhD, KU Leuven, Distribution grid tariffs for active consumers, Hélène Le Cadre : reviewer
- Alexandre Borges de Jesus, PhD, University of Coimbra, Portugal, Algorithm selection for multi-objective optimization: Frédéric Semet – Member.

11.3 Popularization

11.3.1 Internal Inria responsibilities

- Présidente de la commission CDT, Inria Lille: Luce Brotcorne.
- Membre élue de la commission d'évaluation Inria: Luce Brotcorne.

11.3.2 Education

- "Filles, maths et informatique : une équation lumineuse", Dunkerque , octobre 2022, Tifaout Almeftah.
- "Rendez-vous des Jeunes Mathématiciennes et Informaticiennes (RJMI)", Lille ,novembre 2022, Tifaout Almeftah.

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] S. Afsar, L. Brotcorne, P. Marcotte and G. Savard. 'Achieving an optimal trade-off between revenue and energy peak within a smart grid environment'. In: *Renewable Energy* (Mar. 2016). URL: https://hal.inria.fr/hal-01230915.

[3] 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.

[4] 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.

[5] L. Brotcorne, M. Labbé, P. Marcotte and G. Savard. 'Joint design and pricing on a network'. In: *Operation Research* 56 (2008), pp. 1104–1115. URL: https://dx.doi.org/10.1287/opre.1080.0617.

[6] 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.

[7] C. Casorrán, B. Fortz, M. Labbé and F. Ordóñez. 'A study of general and security Stackelberg game formulations'. In: *European Journal of Operational Research* 278.3 (2019), pp. 855–868. DOI: 10.1016/j.ejor.2019.05.012. URL: https://hal.inria.fr/hal-01917798.

[8] V. Dal Sasso, L. De Giovanni and M. Labbé. 'Strengthened Formulations and Valid Inequalities for Single Delay Management in Public Transportation'. In: *Transportation Science* 53.5 (2019), pp. 1213–1499. URL: https://hal.inria.fr/hal-01925451.

[9] B. Fortz, E. Gorgone and D. Papadimitriou. 'A Lagrangian heuristic algorithm for the time-dependent combined network design and routing problem'. In: *Networks* 69.1 (2017), pp. 110–123. DOI: 10.1002/net.21721. URL: http://dx.doi.org/10.1002/net.21721.

[10] M. Restrepo, F. Semet and T. Pocreau. 'Integrated Shift Scheduling and Load Assignment Optimization for Attended Home Delivery'. In: *Transportation Science* 53 (2019), pp. 917–1212. URL: https://hal.inria.fr/hal-01963916.

12.2 Publications of the year

International journals

[11] J. Alcaraz, M. Labbé and M. Landete. 'Support Vector Machine with feature selection: A multiobjective approach'. In: *Expert Systems with Applications* 204 (11th May 2022), p. 117485. DOI: 10.1016/j.eswa.2022.117485. URL: https://hal-cnrs.archives-ouvertes.fr/hal-03824598.

[12] S. Belieres, M. Hewitt, N. Jozefowiez and F. Semet. 'Meta Partial Benders Decomposition for the Logistics Service Network Design Problem'. In: *European Journal of Operational Research* 300.2 (July 2022), pp. 473–489. DOI: 10.1016/j.ejor.2021.07.056. URL: https://hal.univ-lorraine.fr/hal-02951456.

[13] J. de Boeck, L. Brotcorne and B. Fortz. 'Strategic bidding in price coupled regions'. In: *Mathematical Methods of Operations Research* 95 (2022), pp. 365–407. DOI: 10.1007/s00186-021-00768-4. URL: https://hal.inria.fr/hal-03504986.

[14] V. Bucarey, B. Fortz, N. González-Blanco, M. Labbé and J. A. Mesa. 'Benders decomposition for Network Design Covering Problems'. In: *Computers and Operations Research* (2022). URL: https://hal.inria.fr/hal-03137944.

[15] M. Datar, E. Altman and H. Le Cadre. 'Strategic Resource Pricing and Allocation in a 5G Network Slicing Stackelberg Game'. In: *IEEE Transactions on Network and Service Management* (2022). DOI: 10.1109/TNSM.2022.3216588. URL: https://hal.inria.fr/hal-03824540.

[16] S. Dávila, M. Labbé, V. Marianov, F. Ordóñez and F. Semet. 'Product line optimization with multiples sites'. In: *Computers and Operations Research* 148.105978 (Dec. 2022). URL: https://hal.inria.fr/hal-03000086.

[17] B. Fortz, L. Gouveia and P. Moura. 'A comparison of node-based and arc-based hop-indexed formulations for the Steiner tree problem with hop constraints'. In: *Networks* 80.2 (Sept. 2022), pp. 178–192. DOI: 10.1002/net.22086. URL: https://hal.inria.fr/hal-03839783.

[18] W. Gu, C. Archetti, D. Cattaruzza, M. Ogier, F. Semet and M. G. Speranza. 'A sequential approach for a multi-commodity two-echelon distribution problem'. In: *Computers & Industrial Engineering* 163 (Jan. 2022), p. 107793. URL: https://hal.science/hal-03167379.

[19] A. Laurent, L. Brotcorne and B. Fortz. 'Transaction fees optimization in the Ethereum blockchain'. In: *Blockchain: Research and Applications* 3.3 (Sept. 2022), p. 100074. DOI: 10.1016/j.bcra.2022.100074. URL: https://hal.inria.fr/hal-03839797.

[20] S. Nasini, M. Labbé and L. Brotcorne. 'Multi-market portfolio optimization with conditional value at risk'. In: *European Journal of Operational Research* 300.1 (7th Nov. 2022), pp. 350–365. URL: https://hal.inria.fr/hal-03841789.

[21] F. Plein, J. Thürauf, M. Labbé and M. Schmidt. 'A Bilevel Optimization Approach to Decide the Feasibility of Bookings in the European Gas Market'. In: *Mathematical Methods of Operations Research* 95.3 (2022), pp. 409–449. URL: https://hal.inria.fr/hal-03124598.

[22] A. Ratha, P. Pinson, H. Le Cadre, A. Virag and J. Kazempour. 'Moving from Linear to Conic Markets for Electricity'. In: *European Journal of Operational Research* (2022). URL: https://hal.inria.fr/hal-03799767.

[23] A. Sanjab, H. Le Cadre and Y. Mou. 'TSO-DSOs Stable Cost Allocation for the Joint Procurement of Flexibility: A Cooperative Game Approach'. In: *IEEE Transactions on Smart Grid* (2022). DOI: 10.1109/tsg.2022.3166350. URL: https://hal.archives-ouvertes.fr/hal-03449923.

International peer-reviewed conferences

[24] L. Brotcorne, B. Francois and H. Ali. 'Optimal siting and sizing of charging stations for autonomous electric vehicle fleet with local renewable energy generation'. In: CIRED Porto Workshop 2022: E-mobility and power distribution systems. Porto, Portugal, 2022. URL: https://hal.inria.fr/hal-03841874.

[25] C. Legrand, D. Cattaruzza, L. Jourdan and M.-E. Kessaci. 'Machine Learning for Multi-Objective Problems'. In: 23ème congrès annuel de la Société Française de Recherche Opérationnelle et d'Aide à la Décision. Villeurbanne - Lyon, France, 23rd Feb. 2022. URL: https://hal.science/hal-03595321.

[26] A. López Sánchez, M. Lujak, F. Semet and H. Billhardt. 'On balancing fairness and efficiency in routing of cooperative vehicle fleets'. In: Twelfth International Workshop on Agents in Traffic and Transportation co-located with the 31st International Joint Conference on Artificial Intelligence and the 25th European Conference on Artificial Intelligence (IJCAI-ECAI 2022). Vol. 3173. ATT 2022 Agents in Traffic and Transportation. Vienne, Austria, 25th July 2022. URL: https://hal.archives-ouvertes.fr/hal-03778786.

[27] T. Prunet, N. Absi, V. Borodin and D. Cattaruzza. 'Branch-Cut-and-Price algorithm for an Operational Storage Location Assignment Problem'. In: 23ème congrès annuel de la Société Française de Recherche Opérationnelle et d'Aide à la Décision. Villeurbanne - Lyon, France, 23rd Feb. 2022. URL: https://hal.science/hal-03595258.

[28] I. Shilov, H. Le Cadre and A. Bušić. 'A Generalized Nash Equilibrium analysis of the interaction between a peer-to-peer financial market and the distribution grid'. In: ROADEF 2022 - 23ème congrès annuel de la Société Française de Recherche Opérationnelle et d'Aide à la Décision. Villeurbanne - Lyon, France, 23rd Feb. 2022. URL: https://hal.archives-ouvertes.fr/hal-03596153.

National peer-reviewed Conferences

[29] A. Laurent, L. Brotcorne and B. Fortz. 'Modèle bi-niveau pour la tarification de ressources de cloud computing'. In: ROADEF 2022 - 23ème congrès annuel de la Société Française de Recherche Opérationnelle et d'Aide à la Décision. Villeurbanne - Lyon, France, 23rd Feb. 2022. URL: https://hal.science/hal-03596193.

[30] M. Petris, C. Archetti, D. Cattaruzza, M. Ogier and F. Semet. 'A branch-price-and-cut approach for the Multi-Commodity two-echelon Distribution Problem'. In: 23ème congrès annuel de la Société Française de Recherche Opérationnelle et d'Aide à la Décision. Villeurbanne - Lyon, France, 23rd Feb. 2022. URL: https://hal.science/hal-03595207.

[31] P. Torrealba-González, D. Feillet, M. Ogier and F. Semet. 'Joint Order Batching and Picker Routing Problem including congestion'. In: 23ème congrès annuel de la Société Française de Recherche Opérationnelle et d'Aide à la Décision. Villeurbanne - Lyon, France, 23rd Feb. 2022. URL: https://hal.science/hal-03595306.

Conferences without proceedings

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