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EWGLA XXVII

14-16 September 2022
Aveiro, Portugal

Book of Abstracts of the XXVII EURO Working Group on Locational Analysis

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BOOK OF ABSTRACTS OF THE XXVII EURO WORKING GROUP ON LOCATIONAL ANALYSIS MEETING

Edited by
Rui Borges Lopes and Carlos Ferreira
University of Aveiro

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Welcome

Dear Locators,

Welcome to the XXVII EWGLA Meeting in Aveiro. The meetings of the EURO Working Group on Locational Analysis aim to bring together researchers and practitioners working in the wide area of location science through the proposal of models and methods to solve theoretical and practical problems. These meetings traditionally combine a strong scientific value with a very enjoyable and friendly come together of a enthusiastic and energetic group, where old friends meet again and new members are heartily welcomed.

The success of these meetings over the years is proof of a continuing interest of the research community in locational analysis. This meeting features 41 contributions covering a broad range of topics, starting from classical topics like continuous and discrete location, over hub location and location-routing, to network design and various applications. During the three days of the meeting the works will be presented in parallel sessions, with around 50 participants from 12 different countries from America, Asia, and Europe attending the event. It represents a great opportunity to build new and enrich existing relationships, and to share experiences among locators from all over the world.

We would like to thank all the members of the Organizing Committee for their valuable help in the organization, and we are very grateful for the colleagues of the Scientific Committee for so kindly agreeing to review the submitted abstracts. We also would like to thank the sponsors EWGLA, University of Aveiro, APDIO, CIDMA, and GOVCOPP for their support.

We wish you all a successful and fruitful meeting, with new ideas and collaborations, and a pleasant stay in Aveiro.

Rui Borges Lopes and Carlos Ferreira

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Detailed Program

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10:45 – 12:00 Multi-objective *(23.1.6)*
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Building a Web System for Sectorization p.29
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15:10 – 15:25 Coffee Break

15:25 – 16:40 Location-Routing *(23.1.5)*

Chair: Rui Borges Lopes

15:25 – 16:40 Continuous Location *(23.1.6)*

Chair: Diego Ponce

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Thursday, 15 September

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Chair: Juan A. Mesa

9:30 – 11:10 Covering Problems *(23.1.6)*

Chair: Boglárka G.-Tóth

11:10 – 11:45 Coffee Break & Photo

11:45 – 13:00 Discrete Location *(23.1.5)*

Chair: Alfredo Marín

11:45 – 13:00 Applications I *(23.1.6)*
Chair: Ana Catarina Nunes

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18:00 – 23:00 Optional Social Dinner *(Vista Alegre)*

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9:30 – 11:10 Applications II *(23.1.5)*

Chair: Joana Dias

11:10 – 11:25 Coffee Break

11:25 – 12:25 Plenary Keynote *(23.1.5)*

Chair: Rui Borges Lopes

12:25 – 14:00 Lunch *(Santiago Cantina)*

14:00 – 15:15 Network Design III *(23.1.5)*

Chair: Alberto Torrejón Valenzuela

14:00 – 15:15 Competitive Location *(23.1.6)*
Chair: Armin Lüer-Villagra

15:15 – 15:30 Coffee Break

15:30 – 16:30 EWGLA Session *(23.1.5)*

19:00 – 23:00 Conference Dinner *(Casa de São Sebastião)*

Plenary Keynote

Recent multi-objective branch and bound algorithms and an example in facility location

Anthony Przybylski and Xavier Gandibleux

Nantes Université, France

On the timeline of branch and bound algorithms, the first complete multi-objective branch and bound algorithm has been proposed by Kiziltan and Yucaoglu in 1983. And until recently, rather few multi-objective branch and bound algorithms have been proposed. This situation is not surprising as the contributions on the extensions of the components of branch and bound for multi-objective optimization are recent. For example, the concept of bound sets, which extends the classic notion of bounds, has been mentioned by Villarreal and Karwan in 1981. But it was only developed for the first time in 2001 by Ehrgott and Gandibleux, and fully defined in 2007. In this talk, we present a selection of multi-objective branch and bound, covering concepts, components and recent algorithms devoted to linear optimization problems and aiming to compute a complete set of efficient solutions. We discuss an example of multi-objective branch and bound that we have developed for the two objectives binary uncapacitated facility location problem.

Lot-sizing and Sustainability

Safia Kedad-Sidhoum

Conservatoire National des Arts et Métiers, France

The talk will focus on lot-sizing problems related to sustainability. Starting from some basic results on simple lot-sizing problems, we will illustrate some recent applications under this scope. We will show how to integrate some environmental aspects in the classical deterministic lot-sizing models and particularly how to consider carbon emissions in production and distribution planning problems. We will also consider stochastic lot-sizing models within the framework of reverse logistics where the classical economic lot-sizing problems have been extended with a remanufacturing option which allows reprocessing of used products to obtain like-new products. For the considered problems, we will propose mathematical formulations, highlight some complexity issues, structural properties, polynomial and exact algorithms and exhibit some open and promising questions.

Abstracts

A rapid transit network design problem considering deterministic users' utility functions and route attributes

Helmuth Raddatz-García,[1] and Armin Lüer-Villagra,[2]

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Keywords: network design, rapid transit, utility functions, maximum utility constraints, column generation

Public transportation allows massive transportation of users, usually requiring dedicated infrastructure. One kind of infrastructure is rapid transit networks.

Given a graph, transportation demand, and parameters such as network design and operative costs, the rapid transit network design (RTND) problem is to design one or more corridors from different terminals and allocate users to the designed infrastructure.

The most common approach to designing rapid transit networks has been mixed-integer mathematical programming models [1,2], most of them multi-objective. A possible reason is the existence of clear trade-offs between decision-maker's goals and users'.

We begin with an RTND problem from the literature [2]. Our contributions to the literature are multiple. We:

1) Reformulate a rapid transit network design model from the

literature using path variables.

2) Include users' decision process using deterministic utility functions, considering route attributes such as the number of stops, transfer time between corridors, tariff, etc. We use maximum utility constraints [3] for this purpose.
3) Propose a column generation-based heuristic to provide feasible solutions for the resulting model.

We implemented our procedures using Python programming language together with Gurobi Optimizer.

Preliminary results show that the computational performance of our approach is appropriate and that the consideration of different users' utility functions would impact the resulting network design while improving the users' experience from a theoretical standpoint.

Future research lines are implementing a branch-and-price solution approach, including randomness to the users' utility functions and the parallelization of our procedures.

This research is supported by FONDECYT grant 1200706.

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Location with network design for wildfire surveillance and response

Filipe Alvelos[1,2], Eduardo Nunes[2], David Neto[2], Susete Marques[3,4], Isabel Martins[3,5], Mariana Dias[3], António Bento-Gonçalves[6], António Vieira[6], Sarah Moura[6]

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Keywords: Location, Network design, Wildfire, Mixed integer programming, multi-objective optimization

We consider a framework for the integration of location and network design. The locations of the facilities are chosen, among a finite set of candidate locations, for satisfying a set of demands. The selected facilities must be connected according to a given topology.

The introduced type of problems is related with hub location problems [1] given the presence of connections between facilities/hubs. However, we consider user-facility demands (opposed to user-user in hub location) and a given topology for the intermediate facilities/hubs must be used (in hub location, typically, routing is limited to no more than two intermediate hubs and no network topology is imposed). In [2], location and network design problems are surveyed.

In [3], a metaheuristic is proposed for a problem also with connections between facilities. Constraints on the network design are imposed by a maximum distance between a facility and a central facility or between two facilities and not by a topology.

We propose a mixed integer programming set of models for covering, p-median and p-center variants with tree (with a fixed central facility) and ring topologies (modelled as spanning trees and a Hamiltonian cycles).

Objectives related to the network length are also considered in a multi-objective setting.

The motivation for addressing these problems comes for locating bases (facilities) to accommodate resources for wildfire surveillance and response, given a set of potential ignitions (users demand). Example of resources are firewatch towers, sensors, drones, thermal and video cameras, equipment and personnel.

Connections between bases allow the movement of resources between them effectively (e.g. large vehicles) and/or faster (e.g. in an initial attack setting). Figure 1 illustrates optimal solutions for a p-median problem.

We present computational results for two case studies (forest of Paiva and Entre Douro e Sousa and Municipality of Baião).

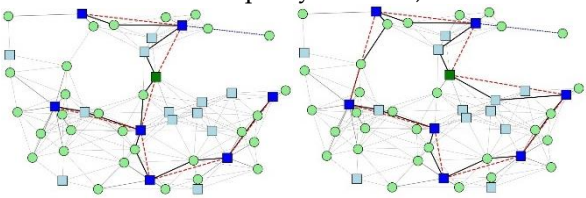

Figure 1. Two examples of the location and network design. Green circles represent potential ignitions. Squares are potential base locations. Dark blue squares are optimal locations for bases. Optimal links between selected bases are represented in dashed red (logical) and black (physical). Left: Network is a tree. Right: Network is a ring.

Acknowledgment: This work is supported by FCT - Fundacão para a Ciência e Tecnologia through project PCIF/GRF/0141/2019 "O3F - An Optimization Framework to reduce Forest Fire".

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Location of overlapping groups in graphs based on internal edge density

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Keywords: Integer Programming, subdivision, Modularity, complex network

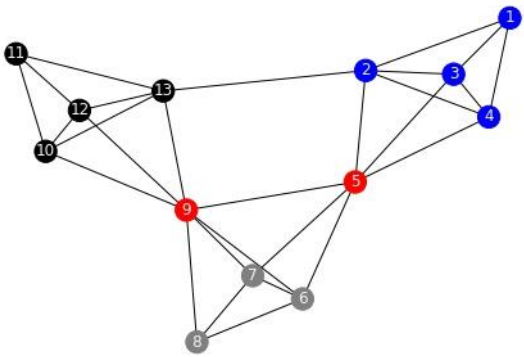

Figure 1. Graph subdivision.

We propose a new optimization model to detect overlapping groups in networks. The model elaborates suggestions contained in Zhang et al. (2007), in which overlapping groups were identified through the use of a fuzzy membership function, calculated as the outcome of a mathematical programming problem. In

our approach, we retain the idea of using both mathematical programming and fuzzy membership to detect overlapping subdivision, but we replace the fuzzy objective function proposed there with another one, based on the Newman and Girvan's definition of modularity. Next, we formulate a new mixed-integer linear programming model to calculate optimal overlapping communities. After some computational tests, we provide some evidence that our new proposal can fix some biases of the previous model, that is, its tendency of calculating communities composed of almost all nodes. Conversely, our new model can reveal other structural properties, such as nodes acting as bridges between groups. Finally, as mathematical programming can be used only for moderate size networks due to its computation time, we proposed two heuristic algorithms to solve the largest instances, that compare favourably to other methodologies.

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Building a Web System for Sectorization

Öztürk E.G.[1,5], Rocha P.F.[1], Lima M.M.[2], Rodrigues A.M.[1,2], Ferreira J.S.[1,4], Lopes I.C.[2], Oliveira C.T.[2], Nunes A.C.[3,6]

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Keywords: Decision Support System, Sectorization, Evolutionary Algorithms, Multi-objective Decision Making, Web System

Sectorization is the division of a whole into smaller parts considering certain objectives. The extent of sectorization problems is very broad which covers health and school (re)districting, territory design, maintenance or delivery services, locating new facilities. This diversity in the application fields creates serious challenges for solution procedures. Sectorization can help handling and simplifying complex location problems.

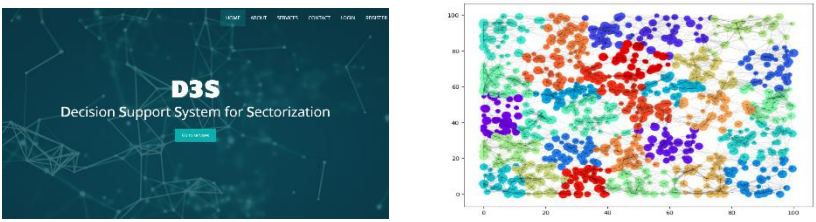
Decision support systems (DSS) are computer systems that help decision-makers quickly solve specific problems in different scenarios and are user-friendly.

This project presents a web-based DSS for sectorization, D3S (see *Figure 1a* for outlook), to help researchers and decision-makers deal with their problems. D3S is designed as a very inclusive platform as it can solve

sectorization problems with different natures. Initially, sectorization problems are divided into four groups:

- *Basic Sectorization:* Does not consider any predetermined service centers nor plans to determine one.
- *Sectorization with Service Centers:* Considers predetermined service centers or plans to locate one.
- *Resectorization:* Aims to redesign an existing solution
- *Dynamic Sectorization:* Provides a solution for several time windows while allowing changes in the instance over time.

The users are led to a related group by responding to a short survey. Each group has several problem-solvers adequate for different scenarios and specifications. Evolutionary algorithms are used in multi-objective solution procedures. The users can obtain the digitized performance and the visualization of the results (see *Figure 1b*) on their user-specific page anytime.



(a) *(b)*

Figure 1. (a) Outlook to D3S, and *(b)* a solution provided by D3S

To the best of our knowledge, there is no resembling DSS for sectorization. With D3S, the authors wish to help researchers in the field and contribute to the literature on sectorization by dealing with real-life cases considering different objectives and scenarios.

Acknowledgement : This work is financed by the ERDF - European Regional Development Fund through the Operational Programme for Competitiveness and Internationalization – COMPETE 2020 Programme and by National Funds through the Portuguese funding agency, FCT- Fundação para a Ciência e a Tecnologia in project `POCI-01-0145-FEDER-031671'.

Resectorization Problems

Lima, M.M.[1], Öztürk, E.G.[2,4], Rocha, P.[2], Lopes, I.C.[1], Oliveira, C.T.[1], Rodrigues, A.M.[1,2], Ferreira,J.S.[2,3], and Nunes, A.C.[5,6]

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Keywords: sectorization, resectorization, multi-objective optimization

Sectorization intends to group the units that constitute a territory into sectors to improve its organization or better deal with some associated complexity. Sectorization problems usually involve different planning criteria, such as equilibrium, compactness, and contiguity.

In many cases, a sectorization that results from the practice is already in use in daily life. However, changes can frequently arise, which make the current sectorization probably not efficient anymore.

Resectorization purposes to do another sectorization based on an existing territory design, according to some new conditions, but avoiding substantial modifications to facilitate the adaptation to change.

This talk discusses resectorization problems and presents a solution approach based on the multi-objective optimization method named Non-

dominated Sorting Genetic Algorithm NSGA-II [1].
In resectorization, it is important to measure how different the new sectorization is from the original one. The similarity is a measure to evaluate the resemblance, or coincidence, between two solutions. The similarity measure used in this work is the percentage of unchanged regions, which is used as a constraint. The decision-maker will define the preferred minimum similarity level.
In a constantly changing world, it is important to be able to adapt old solutions to new scenarios and resectorization can therefore play a relevant role. Resectorization has been applied in diverse contexts, such as the redesign of humanitarian districted logistics networks [2], school redistricting [3] and improving the existing sectorization of the fire brigades [4].

Acknowledgement This work is financed by the ERDF - European Regional Development Fund through the Operational Programme for Competitiveness and Internationalization - COMPETE 2020 Programme and by National Funds through the Portuguese funding agency, FCT - Fundação para a Ciência e a Tecnologia within projects POCI-01-0145-FEDER-031671 and. UIDB/05422/2020.

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Humanitarian Supply Chain Planning: The effect of location decisions on fair allocations of donations

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Keywords: Humanitarian Logistics, Fair allocation, Location-Inventory, Multi-period facility location, Multi-criteria facility location

This study focuses on a problem emerging at the response phase in the aftermath of a disaster event. The problem consists of finding a fair mechanism to distribute a scarce relief item among different demand points in need, such as shelter sites during a finite planning horizon.
The problem is cast as a multi-criteria multi-period location-relocation-inventory problem with a coverage constraint.
In particular, two decisions are to be made here-and-now for every period of the planning horizon: (i) where to locate a limited number of mobile

depots and (ii) what quantity to deliver to each demand node. The total supply available is time-dependent.
In search for fair solutions, three criteria are considered. The first two involve the so-called deprivation cost, which is a measure of the ``suffering'' of a population for facing shortage of the relief item. The third objective is related with travel time or distance for reaching the demand nodes throughout the planning horizon.
A modeling framework is proposed for the problem. Two resulting vectorial optimization models are solved using the epsilon-constrained method[1]. Computational results are presented that result from applying the methodological developments proposed to an instance of the problem using a mixed data structure consisting of real and generated parts.
Location and allocation schemes leading to the pay-off table are analyzed as well as more balanced solutions of the bi-objective settings. So as to observe the effect of location decision on the solutions, two versions of the problem are analyzed: location of static versus mobile depots.
Overall, the results show that the models proposed can better support the decision making process when fairness is of relevance. Further results and observations will be shared during the presentation.
Supply during the post disaster operations usually consists of donations which are mostly uncertain in terms of type, timing and amount. Due to this uncertainty, future work consists of formulating and solving stochastic versions of the bi-objective models.

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Including elastic demand in the hub line location problem

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Keywords: Location, hub line, elastic demand

The hub line location problem (HLLP) aims to locate p hubs connected by a path that is composed by p-1 hub arcs in such a way that the total travel time of the origin-destination pairs is minimized. If the direct travel time between an origin-destination is smaller than any path using the line, the demand is routed without using the hub line. HLLP assumes that demand between each origin and destination can be a priori estimated and that the resulting constructed hub line network does not have any effect on the demand.

This problem was introduced in [1] and it has relevant applications in public transportation planning design (tram, subways, express bus lane, etc.) and road network design.

In this work, we introduce the profit-oriented hub line location problem with elastic demand (ED-HLLP). This model is an extension of the HLLP

that uses a gravity model to include the elasticity of demand. Gravity models have been previously used to model elastic demand in network design problems, see [2]. The aim of ED-HLLP is to maximize the revenue of the total time reduction provided by the hub line considering elastic demand. Thus, this new model takes into account the long-term impact on the demands that opening a hub line can have.

We propose different non-linear formulations to address this problem. The main difference between them is the way in which the line structure is modeled. Due to the limitations that these formulations present, we introduce three main linear formulations. These linear formulations use the possible paths using the hub line as variables. Consequently, it is necessary to use a preprocessing phase that calculates the candidate paths for each origin-destination. For this preprocessing phase, we provide efficient algorithms to create all possible candidate paths. Finally, we also present a computational experience that evaluates the strengths and limits of these formulations for ED-HLLP.

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A further study of single allocation hub location problem

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Keywords: hub location, single allocation, discrete optimization

We will talk about a new formulation for uncapacitated single allocation hub location problems. In the uncapacitated single allocation p-hub median problem (USApHMP), the aim is to choose p hubs and assign every site to them minimizing the overall transportation costs between origins and destinations through the hubs. Alternatively, the uncapacitated single allocation hub location problem (USAHLP) considers a cost for setting a hub being the number of hubs a decision variable. In this case, the aim is to locate the hubs and to assign the remaining sites to the hubs minimizing the overall installation and transportation costs. O'Kelly (1987) [1] presented the first mathematical formulation for these problems. Since then, different linearization strategies have been used in the literature to handle the quadratic term in the objective function of this model.

We introduce a new formulation to solve the USApHMP and the USAHLP with fewer variables than the previous Integer Linear Programming formulations known in the literature. Our formulation includes a general

cost structure that does not require costs based on distances neither satisfaction of the triangle inequality. This allows us to model more realistic cases in transportation systems where, for instance, fares are not proportional to travel distances or longer trips may have lower ticket prices than shorter trips. Moreover, some of the existing formulations for the USApHMP need to have the overall transportation cost from origin to destination disaggregated in the three components: origin-hub, hub-hub, hub-destination. We develop formulations for both cases, with aggregated/disaggregated transportation costs. The formulation is strengthened by means of valid inequalities and different families of cuts are developed and added through effective separation procedures.
A comparison of the performance of the most efficient solution methods existing in the literature ([2], [3] and [4]), shows the efficiency of our methodology, solving large-scale instances in competitive times.

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A profit-maximizing hub location problem with explicit users' utility functions

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Keywords: Hub location, Profit-maximizing, Deterministic utility functions.

Hub location problems are a well-known family of problems within General Network Design, which combine location and design decisions [1].

In general, entities that interact with a network are considered to be passive, i.e., their actions are based on the design decisions taken by a Company.

When the entities are humans, their preferences will not necessarily match with those of the Company. For this reason, it is interesting to study how these individual decisions influence the performance of an existing network and the design of a new one.

The above idea is developed by modelling users' decisions through deterministic utility functions [2]. Users try to maximize their utility when travelling from their Origin to their Destination, meanwhile the Company tries to maximize its profits.

We propose an extension of the Hub network design problem with profits presented in Alibeyg et. al. 2016 [3] in which the users' preferences are incorporated through the inclusion of Maximum Utility Constraints [4].

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Profit-maximizing hub network design with hub congestion and time-sensitive demands

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Keywords: hub location, hub congestion, time-sensitive demand, profit maximizing

Hub location is an active research area, as shown by the frequent literature reviews [2, 4]. Current topics of interest include extensions of earlier models like, for instance, incorporating capacity selection and/or congestion [3, 5], explicitly considering sensitive demands [6], or moving from cost minimization to profit maximization [1].
To the best of our knowledge, no previous studies jointly consider the above three modelling aspects. Our contribution is to formulate and solve a profit-maximizing hub network design problem that incorporates simultaneously hub congestion, time-sensitive demands through step-wise functions, where service paths with one or two stops are allowed. A stepwise function on transportation times is used to model demand. Hub congestion is expressed in terms of transit times at the hubs, which are also modelled as a stepwise function.

A profit is obtained from captured demand, while costs include fixed setup cost for enabling hubs and inter-hub edges, as well as the usual transportation costs.
We develop a set of conditions to either fix variables or add additional constraints to the formulation. Families of valid inequalities are also presented together with their separation procedures. These allow us to improve the LP bound of our formulation, decreasing the computational time required. Preliminary results are encouraging.

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Dealing with congestion in the Battery Swapping Station Location Problem

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Keywords: Covering location, Stochastic demand Queuing, Quadratic integer programming, Battery swapping station

In this study, we introduce a maximal covering location problem under congestion to maximize the service effect of ready-to-build facilities facing stochastic demand. Specifically, in this problem, demand for service follows a Poisson distribution. Multiple facilities with different costs and endogenous capacities are allowed to be built in different potential sites under a preset budget. Customers are assumed to patronize the nearest facility for getting the service. Congestion occurs at any facility when an arriving customer finds that the facility busy, i.e., with another customer being served and possibly others already waiting in a queue. Customer losses are assumed when the waiting time exceeds a maximum threshold.

Therefore, by combining covering facility location ([1], [2], [3]) with the planning and management of a single-server queuing system ([4], [5], and

[6]), a facility location problem under congestion is introduced with the goal of maximizing the maximal covered demand. The problem can be formulated mathematically as a non-convex integer programming model. Nevertheless, we show that the problem can be reformulated as a mixed-integer quadratically-constrained programming problem. This makes the model suitable for being tackled by a general purpose solver.

The investigated problem has many applications such as the location of gas stations, automatic car washing facilities, and charging and battery swapping station for electric vehicles, to mention a few. Based on the previous collaboration between the authors and a company providing battery swapping services in Beijing, we conduct a detailed experimental analysis using the actual operational data that includes GPS location of taxis. The obtained results are reported.

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Heuristics for districting problems with probabilistic constraints

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Keywords: Districting, Stochastic demand, Chance-constraints, Heuristics

Districting Problems (DPs) aim at partitioning a set of basic geographic areas, named Territorial Units (TUs), into a set of larger clusters, called districts, according to some planning criteria. The latter typically refer to balancing, contiguity, and compactness ([1]). In this work, a DP with stochastic demand is investigated. Chance-constraints are used to model the balancing requirements, and explicit contiguity constraints are also considered. The problem, in practice, is the same as in [2]. In that paper, the authors proposed a simheuristic, combining simulation and optimization, to find feasible solutions to the problem. Due to the general shape of the underlying cumulative distribution function, simulation was carried out for assessing the probabilistic constraints. Also, this represented the main burden to derive an approximate deterministic counterpart for the problem. Here, we try to overcome this limitation. Assuming that the demand in each district can be represented by a random

variable with a given cumulative distribution function, we devise a deterministic equivalent model by sampling a finite set of scenarios for the demand (i.e., a complete set of demand realizations), say Ω, possibly of very large cardinality. For such a random sample, an estimate for the probability of a given districting solution to be balanced is the proportion of scenarios for which the solution is balanced. An approximate solution to our problem can thus be found as a solution that is balanced for at least $\gamma|\Omega|$ of its elements, with γ denoting the desired probability one wants the balancing requirement to hold. To derive a deterministic equivalent model, we introduce a binary variable for each scenario to indicate if the balancing constraint is violated. Using these variables, a linear formulation of the model is obtained. This approximate deterministic counterpart is the core of new solution algorithms devised. The latter are based upon a location-allocation scheme, whose first step consists of considering either a problem with a sample of scenarios or a sample of single-scenario problems. This leads to two variants of a new heuristic. The second version calls for the use of a so-called attractiveness function to find a good trade-off between the (approximate) solutions obtained for the single-scenario problems. Results from extensive computational tests are reported.

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Insights on Decision and Forecast Horizons for Multi-Period Facility Location under Uncertainty

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Keywords: Forecast Horizons; Decision Horizons; Multi-period Facility Location; Stochastic Facility Location.

This work focuses on determining forecast and decision horizon for stochastic multi-period facility location problems. A planning horizon is considered that is divided into time periods. The problem consists of deciding where to have facilities operating in each time period so that the demand of a set of customers can be satisfied. The objective is to minimize the total cost throughout the planning horizon, which is dived into the cost for operating the facilities and the cost for supplying the customers. Additionally, a set of potential locations exist where new facilities can be installed during the planning horizon. However, during the planning horizon, it is assumed that the configuration of each location cannot change more than once. The work targets large (possibly infinite) planning horizons and thus a discount factor is assumed for the monetary values. Uncertainty is assumed for all parameters: costs, demands and discount factor. The resulting problem can be formulated as a multi-stage stochastic programming problem.

In a simplified way, a scenario in a decision problem consists of a possible future, which we may have a previous notion that could happen, but we are not sure if it will happen. According to Correia and Saldanha-da-Gama (2019), if uncertain parameters can be represented by random variables, a probability can be

associated with each scenario. The authors also refer that several decision problems, such as the Facility Location Problem (FLP) case, may require a considerable time interval to make the decisions. Over time, some uncertainties are revealed, thus allowing the decision maker to adapt their answers, depending on the observation of the uncertainty materialized. Thus, another fundamental aspect arises in the analysis of a decision problem: the time.

A few comments can be drawn from observing the existing literature: (i) the literature is still scarce when it comes to capturing stochastic multi-period facility location in a multi-stage stochastic programming modeling framework. (ii) Working with multi-period facility location problem for a large number of periods is still tantalizing. Seeking forecast horizons is a means to overcome the cumbersome size of the models one easily gets. This is even more relevant under uncertainty namely, with stochastic parameters.

In this paper we address this gap in the literature by considering a stochastic multi-period facility location problem that we formulate as a multi-stage stochastic programming model. For the resulting problem we investigate the existence of exact or approximate forecast and decision horizons.

For this problem, a mechanism is devised for finding approximate forecast and decision horizons. Computational tests are reported on to assess the contribution provided by this work.

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Multi-period facility location and capacity planning under uncertainty

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Keywords: distribution network design, dynamic capacity adjustment, delivery lateness, demand uncertainty, valid inequalities

We consider a stochastic multi-period facility location problem with two customer segments, each having specific service requirements. While customers in one segment receive preferred service, customers in the second segment accept late deliveries as long as lateness does not exceed a pre-specified threshold. The objective is to define a schedule for facility deployment and capacity scalability that satisfies all customer demands at minimum cost. Facilities can have their capacities adjusted over the planning horizon through incrementally increasing or reducing the number of modular units they hold. For the case of uncertain customer demand, we propose two stochastic models that differ in the framework in which capacity adjustments can be planned. The first two-stage stochastic model follows the natural approach of defining all decisions related to the design of the facility network as first-stage decisions.
Demand allocation decisions are deferred to the second stage. This model is suitable to real-world settings where opening facilities and sizing their capacities are time-consuming and require substantial capital investment. The second model presents an alternative strategy, which is particularly

relevant when capacity scalability decisions have a tactical nature, e.g., when short commitment horizons for lease or rental contracts are offered. In this case, first-stage decisions include the selection of locations to open facilities and setting their initial capacities. The phased expansion and contraction of capacity at operating facilities along with demand allocation represent the recourse decisions. We develop the extensive forms of the two stochastic programs for the case of demand uncertainty being captured by a finite set of scenarios. Additional inequalities are derived to enhance the original formulations, which substantially increase the capability of an optimization solver to identify optimal solutions in much shorter computing times, as demonstrated by our numerical study with randomly generated instances [1]. Moreover, improved solution quality is also achieved for instances for which the specified time limit is reached without guaranteed optimality. Deferring the decisions on capacity upgrading and downgrading to the second-stage problem results in network configurations with noticeable lower total cost. This cost advantage arises due to the possibility of adapting the network configuration to particular demand realizations. However, this approach leads to considerably larger models, which, in turn, require higher computational burden.

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Solving the Location-Routing-Districting Problem

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Keywords: location-routing problem, integrated logistics system, adaptive large neighbourhood search, reinforcement learning

Nowadays, most of the local restaurants in large city zones rely on food delivery services from outside the urban area for food replenishment. However, allowing heavy trucks to travel directly to the city centres can seriously bring up the environmental effect by increasing traffic congestion and pollution [1]. One way to mitigate this problem is to introduce a two-echelon integrated logistic system, which replaces heavy trucks with smaller agile vehicles operating from intermediate depots near the centre. Another way is to form driver-based districts that break the customer set into smaller, more manageable clusters, each served by a single driver. The consistency of driver-customer allocation increases each driver's familiarity with customers and therefore service efficiency.

In this work, we deal with a *Location-Routing-Districting* (LoRD) problem, which can be considered as a generalisation of the two-echelon *Location Routing Problem* with clustering aspects. There are several interdependent

subproblems embedded within the model: a strategic *Facility Location Problem* carrying a long-term effect on urban construction, a tactical *Districting Problem* creating delivery zones by allocating individual customers to drivers and drivers to opened city depots, and an operational *Vehicle Routing Problem* computing daily delivery routes.

We first derive a *mixed-integer linear programming* model and solve small-scale instances using CPLEX with the exponential subtour and path elimination constraints added in a cutting-plane fashion. A tailored heuristic approach based on the *adaptive large neighbourhood search* (ALNS) meta-heuristic is proposed to solve the larger instances within a reasonable time. We further implemented an online learning mechanism based on a deep neural network to improve the adaptiveness and flexibility of a classical meta-heuristic blackbox. Our hybrid meta-heuristic with online learning shows competitive performance with increased sensitivity to make valid decisions.

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An extended model of coordination of an all-terrain vehicle and a multivisit drone

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Keywords: Routing, Networks, Logistics, Drones, Mixed integer conic programming

In this work, a model that combines the movement of a multi-visit drone with a limited endurance and a base vehicle that can move freely in the continuous space is considered. The mothership is used to charge the battery of the drone, whereas the drone performs the task of visiting multiple targets of distinct shapes: points and polygonal chains. For polygonal chains, it is required to traverse a given fraction of its lengths that represent surveillance/inspection activities like traffic or post-disaster monitoring. At each operation, the drone must be launched from the base vehicle (the launching points must be determined) and it must be retrieved when its battery needs to be recharged (the rendezvous points also must be determined). The goal of the problem is to minimize the overall weighted distance traveled by both vehicles. A mixed integer second-order cone program is developed and strengthened by using valid

inequalities and giving good bounds for the Big-M constants that appear in the model.
A refined matheuristic that provides reasonable solutions in short computing time is also established. The quality of the solutions provided by both approaches is compared and analyzed on an extensive battery of instances with different number and shapes of targets that shows the usefulness of our approach and its applicability in different situations.

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Sustainability and resilience in a Location-Routing Problem

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Keywords: location-routing, mixed-integer linear programming, sustainability, resilience

To ensure sustainable competitiveness in the current global market, companies must face different challenges and complexities. The Sustainable Supply Chain has become an important concept due to the increased awareness to environmental and social concerns. The aim is to support organizations to balance their profits with the impacts in the community and on the planet [1,2]. In addition, resilience can represent an important source of competitive advantage in the context of globalized supply chains that are more exposed to several disruptive events. A Resilient Supply Chain can prepare, respond, and recover from different types of disturbances, ensuring a positive and stable operation at an adequate cost and time [4]. Sustainability and resilience are therefore important issues related to logistics.

This work tries to incorporate both concepts in a multi-objective Location-Routing Problem (LRP), exploring new objective functions and analyzing the impact that these factors represent on economic goals. The LRP is a class of problems that combines three major logistic decisions: the selection of facilities; the assignment of demand points to the facilities, and the

design of vehicle routes that must serve these points [3]. This study focuses on the LRP variant with capacity constraints in facilities and vehicles, named Capacitated LRP (CLRP). In addition to the total cost minimization objective, the minimization of negative environmental impacts of CO_2 emissions resulting from the distribution activity is also considered. Furthermore, the objective of maximizing the resilience of the network is considered by maximizing the number of alternative paths that could connect its different nodes. This objective aims to increase the flexibility of the system to quickly adjust the routes in the face of disruptive events and avoid the non-satisfaction of demand elements.
Two instances based on real data derived from a distribution company in the Aveiro region in Portugal are solved using CPLEX, results are analyzed, and some preliminary conclusions are drawn.

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The Continuous Capacitated p-Median Problem with Supplier Selection in a Sustainable Supply Chain network

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Keywords: Capacitated continuous location problem, Sustainability, Supplier selection, Supply chain

This research studies joint decision problems for facility location and supplier selection in a three-tier supply chain network by considering CO2 emission. The aims of the study are three-fold: (i) to locate facilities (i.e., distribution centeres) in a continuous space in the presence of capacity limitations and opening costs, (ii) to select suitable suppliers under an incremental quantity discount scheme, and (iii) to select various transportation modes to minimise carbon emission cost. Here, variable carbon emission cost is taken into consideration with respect to the variable locations of facilities and the amount of distributed products. The problem is formulated as a mixed-integer linear programming. This study hybridised a greedy randomised adaptive search (GRASP) and variable neighborhood search (VNS) to deal with the problem. To evaluate the performance of the proposed method, the well-known datasets from the

literature are used and adapted. Computational results show that the proposed hybrid method produces encouraging results. Some future research avenues based on this study are also highlighted.

Fairness in Maximal Covering Facility Location Problems

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This paper provides a general mathematical programming based framework to incorporate fairness measures from the facilities' perspective to Discrete and Continuous Maximal Covering Location Problems. The main ingredients to construct a function measuring fairness in this problem are the use of: (1) ordered weighted averaging operators, a family of aggregation criteria very popular to solve multiobjective combinatorial optimization problems, and (2) α-fairness operators which allow to generalize most of the equity measures. A general mathematical programming model is derived which captures the notion of fairness in maximal covering location problems. The models are firstly formulated as Mixed Integer Non-Linear programming problems for both the discrete and the continuous frameworks. Suitable Mixed Integer Second Order Cone programming reformulations are derived using geometric properties of the problem. Finally, the paper concludes with the results obtained on an extensive battery of computational experiments. The obtained results support the convenience of the proposed approach.

A branch-and-price for the continuous multifacility monotone ordered median problem

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Keywords: Combinatorial optimization, Continuous Location, Ordered median problems, Mixed Integer Nonlinear Programming, Branch-and-price

The goal of this paper is to analyze the *Continuous Multifacility Monotone Ordered Median Problem* (MFMOMP, for short), in which we are given a finite set of demand points, A, and the goal is to find the optimal location of p new facilities such that: (1) each demand point is allocated to a single facility; and (2) the measure of the goodness of the solution is an ordered weighted aggregation of the distances of the demand points to their closest facility [3]. We consider a general framework for the problem, in which the demand points (and the new facilities) lie in R^d, the distances between points and facilities are polyhedral- or l^q-norms for q<=1, and the ordered median functions are assumed to be defined by non-decreasing monotone weights. These problems are analyzed in [1], in which the authors provide a Mixed Integer Second Order Cone Optimization (MISOCO) reformulation of the problem able to solve, for the first time, problems of small to medium size (up to 50 demand points), using off-the-shelf solvers.

Our contribution in this paper is to introduce a new set partitioning-like (with side constraints) reformulation for this family of problems, inspired by [2], that allows us to develop a branch-and-price algorithm for solving it. This approach gives rise to a decomposition of the original problem into a master problem (set partitioning with side constraints), and a pricing problem that consists of a special form of the maximal weighted independent set problem combined with a single facility location problem. We compare this new strategy with the one obtained by solving Mixed Integer Nonlinear Programming (MINLP) formulations using standard solvers. Our results show that it is worth to use the new reformulation since it allows us to solve larger instances and reduce the gap when the time limit is reached. Moreover, we also exploit the structure of the branch-and-price approach to develop some new matheuristics for the problem that provide good quality feasible solutions for fairly large instances of several hundreds of demand points.

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A large neighborhood search for a value-oriented supply chain design

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Keywords: Supply Chain, Logistics, Finance, Large Neighborhood Search

Supply Chain Network Design (SCND) models deal with determining the strategic decisions such as where and when to locate facilities, the facilities' capacity and the product flows in the network. Classically these models are optimized either by minimizing the total logistics costs or maximizing the profit generated by the distribution of goods. These models often omit financial considerations.
Locating new facilities and running an international logistics network requires investments, which can be financed in different ways. The way of financing substantially affects the company's financial situation and future value.

In [1], a mathematical model maximizing the company's value through the Adjusted Present Value (APV) was proposed. The main contribution of this study is to solve this model with a Large Neighborhood Search (LNS) metaheuristic [2]. LNS explores a complex neighborhood through the

iterative use of *destroy* and *repair* heuristic operators. LNS has wide applications and has been applied to the SCND problems [3], [4]. This research extends the previous studies by adapting the LNS algorithm to a dynamic SCND model.

Our solution approach is to select the open facilities through dedicated destroy and repair operators, while the allocation variables and the financial variables are set by specific heuristics or relaxed LP models.

We assess the quality of the proposed solution method on a generated set of benchmark instances with up to 480 customers and 48 facilities. We present the results of our LNS implementation and prove its efficiency by comparing them with the result obtained by Cplex.

We also show how this single objective LNS can be embedded in a multi-directional local search (MDLS) algorithm that separately optimizes logistic and financial objective functions.

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Benefit Maximizing Network Design in the Public Sector

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Keywords: Location of Public Facilities, Stochastic facility Location, Service System Design

Governments around the globe are actively involved in providing essential services, such as healthcare, transportation, education, and utilities. In contrast with the private sectors' mission to maximize profit, governments' mandate is to maximize the societal benefit by acting as *public agents*. When designing service systems, many models in public sector focus on maximizing accessibility to public services to increase societal benefit. The idea is to (re)design the public service to maximize the number of people who will benefit from the program given a limited budget, thus using accessibility as a proxy for benefit. Such models fail to capture the *marginal benefits* -- savings in costs to taxpayers by adding an extra unit of service capacity.

In this work, we study the problem of determining the optimal number, locations, and capacities of a network of facilities to maximize the public's *overall benefit*. We define the overall benefit as the difference in savings for the public by participating in services and the cost of the provided service capacity. In our work, the consumers would like to maximize their utility (minimize their disutility) when choosing which facility to patronize. Therefore, we consider a user-equilibrium problem, where at equilibrium, consumers have no incentive to change their choices. We formulate this benefit maximization problem as a nonlinear mixed-integer program and discuss linearization techniques to solve the problem efficiently. We demonstrate how this problem can also be extended to the private sector. Through a simple illustrative example and a realistic case study of assigning facilities to serve the residents of San Diego, we provide further insight into our modeling approach and various model parameters.

Multi-period distribution network redesign under flexible conditions

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Keywords: distribution network redesign, short-term storage space rental, mixed-integer linear programming, additional inequalities

E-commerce is growing at a fast pace. This trend is gradually driving retailers to shift from typical warehouse rental contracts with rigid conditions and long-term commitments to flexible alternatives that provide storage space on demand. This strategy gives retailers the ability to respond dynamically to variations in demand, thereby improving customer service. We address this trend by considering a two-echelon, multi-commodity distribution network operated by a retailer and whose configuration can be changed over a multi-period planning horizon.
Location decisions concern the intermediate facilities and are framed by flexible and scalable conditions. Accordingly, the retailer needs to decide which company-owned facilities should be retained, and where, when and for how long new facilities should be leased from a set of potential sites with given capacities. In addition to location decisions, also procurement, inventory, and distribution decisions need to be made to satisfy customer demand at minimum total cost. We develop a mixed-integer linear programming formulation for this problem and propose various families of additional inequalities that prove to be very useful to find high-quality

solutions. To measure the impact of the new business model, we also consider alternative approaches with limited flexibility and scalability that are frequently encountered in practice. Our computational study gives useful insights on the trade-offs achieved by each of the different approaches with respect to total cost, network redesign decisions, and various logistics functions.

Covering Multilayer Network Design Problems

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Keywords: Multilayer Networks, Network Design, Covering

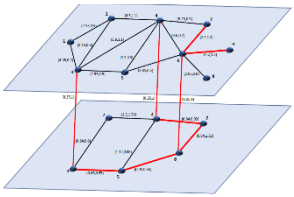
Nowadays, most of the social, technological, and scientific systems, among others, are interrelated. Systems that consist of a set of entities with relationships among them have been traditionally represented and analyzed by the application of Graph Theory. However, when a system consists of several interconnected subsystems, then the tool to be applied is that of Multilayer Networks.

During the last two decades, there has been a special effort to formalize and unify the spread of knowledge of Multilayer Networks [1]. A multilayer network is a set of networks that are interconnected. Thus, each layer consists of a graph and some of its nodes are connected with nodes of other layers. Thus, a multilayer network consists of a set of nodes and two types of arcs (or edges): intralayer and interlayer. Therefore, a multilayer network is a set M=(G,C), where $G=\{G_\alpha, \alpha \in M\}$ is the set of layers, each one consists of a graph $G_\alpha=(V_\alpha,E_\alpha)$, and
$C=\{E_{\alpha\beta}, \alpha,\beta \in M, , \alpha\neq\beta\}$ is the interlayer edge set.

Multilayer networks have been applied to better understand the modeled systems. Besides, static and dynamic properties of multilayer networks have been studied from the viewpoint of complex network science.

However, not much research has been devoted to prescriptive problems. In particular, little attention has been paid to multilayer network design problems.

In this paper, we consider an underlying multilayer network from which we want to select a sub-network in accordance with the coverage criterion. More specifically, we assume that each layer corresponds to a mode of public transportation. Besides, an alternative (private) mode of transportation competes with the sub-network to be constructed in order to capture the origin-destination demand. Given an available budget, the problem consists of the selection of intralayer and interlayer edges so that the coverage of the public mode is maximized. Since the problem is NP-hard [2], metaheuristics or efficient exact methods [3] have to be applied. In the Figure, a toy example with two layers is shown. For each edge, the time of traversing and the cost of constructing are depicted. A possible solution is the subnetwork represented in red. Other data such as the origin-destination demand and the utility of the competing mode matrices are not shown because of the lack of space.



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A Hierarchical Nested Cooperative Location model

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Keywords: Hierarchical Facility Location, Multi-type Facilities, Discrete Location, Cooperative, Covering

This work introduces the Hierarchical Nested Cooperative Location (HCLP) problem, extending the available literature on discrete cooperative covering problems [1]. We analyse the problem of locating different types of facilities, arranged in a nested hierarchy, that cooperate to guarantee a given coverage level to the demand.

We consider a two-level nested hierarchy; lower-level facilities provide a subset of services provided by upper-level facilities [2]. It is assumed that each facility provides a coverage level for that subset of services that decays over distance according to a coverage decay function. We thus introduce two different coverage decay functions, each associated with a hierarchical level. Cooperation occurs between facilities at the same level (the intra-level cooperation) and facilities at different levels (the inter-level cooperation) of the hierarchy. The intra-level and inter-level cooperations are ruled by different aggregation functions modelled as joint coverage functions [3]. We assume that a demand node is covered if its coverage level by all facilities exceeds a certain threshold. The objective is to design

a network by locating facilities of different hierarchical levels to maximise the covered demand. Two budget constraints are introduced for the total cost that the decision-maker is willing to incur for locating facilities of each level. Conversely, according to the traditional coverage definition, services exclusively provided by upper-level facilities are guaranteed within a fixed distance. The HCLP problem is first formulated as a mixed-integer nonlinear programming (MINLP) model; then, an equivalent mixed-integer linear program (MILP) is developed by extending the linearisation proposed by [4].

We tested the HCLP model on randomly generated instances to verify its capability to provide meaningful solutions. Furthermore, we applied the HCLP model to a real-world case study related to a distribution network system operating in an urban context. Specifically, we considered a retail company involved in outsourcing logistic services by integrating the network of internal facilities (upper-level facilities) with existing external facilities (lower-level facilities). Finally, the results, obtained using CPLEX, are discussed to provide fruitful managerial implications.

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The upgrading version of the Maximal Covering Location Problem: an algorithmic approach

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Keywords: location, covering problems, upgrading, complexity, networks.

In this talk, we analyze the upgrading version of the maximal covering location problem with edge length modifications on networks (Up-MCLP). The Up-MCLP aims at locating p facilities to maximize the coverage taking into account that the length of the edges can be reduced subject to a budget constraint. Therefore, we look for both solutions: the optimal location of p facilities and the optimal upgraded network.

Note that for each edge, we are given its current length, an upper bound on the maximal reduction of its length, and a cost per unit of reduction (which can be different for each edge). Furthermore, a total budget for reductions is given.

In [1] several Mixed-Integer Programming formulations were proposed to solve this problem on general networks, on which the problem is NP-hard. In this talk, we turn our attention to particular networks such as stars, paths, and trees and study the complexity of this problem. Moreover, we provide polynomial and pseudo-polynomial time algorithms to solve the problem under different assumptions for the parameters.

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Multi-Objective Covering Location Problems with advanced connectivity features and zonal requirements: Exact and Matheuristic approaches

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Keywords: Multi-objective Optimisation, Maximal Covering Location, MILP, Augmented epsilon-constraint Method, Matheuristics

Real-world facility location problems often demand to tackle simultaneously zonal requirements and facility interconnection issues; these may arise from administrative, managerial and operational needs, aiming to ensure an equal distribution of services, while concurrently securing an efficient flow of goods, people or information among the located facilities. As the literature appears rather limited at addressing this challenge, in this work we bridge such a gap by exploring the integration of the Maximal Covering Location Problem with spatial-related requirements and advanced connectivity features.

We adopt a broad modeling perspective, accounting for structural and economic aspects of these connectivity attributes, while allowing for the choice of one or more depots to serve and feed the networks of located facilities, and containing the maximal distance between any located facility and such depots. Under these modeling assumptions, the objectives to be fulfilled are multiple and mutually conflicting. In order to enhance decision-making in this scenario, we introduce a novel class of Multi-

objective Covering Location problems, prove their NP-hardness, and devise original MILP models for their mathematical formulations. To efficiently explore the corresponding Pareto Sets, we adapt the robust version of the AUGMEnted epsilon-CONstraint method (AUGMECON-R) [1]. Additionally, to allow its scalability, we integrate this scheme with a Matheuristic procedure, designed by exploiting the mathematical properties of the introduced problems. We conduct a comprehensive computational study on benchmark instances adapted from the extant literature on Location Problems with interconnected facilities and Clustered Shortest Path Problems. The experiments provide a proof of concept of the proposed models and highlight the challenging nature of the advanced connectivity features, particularly in the presence of multiple depots. Both approaches give a thorough approximation of the relevant Pareto Sets for medium sized problems, while the Matheuristic shows a highly scalable performance when tackling large sized instances and multiple depot configurations.

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Upgrading connections in the p-center location problem

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Keywords: Discrete Facility Location, p-center; Connection upgrading, MILP models.

The p-center problem is a classic discrete location problem that is still current due to the constant expansion of communication networks. In this work we address the problem of devoting part of the budget to the improvement of some network connections. Improving connections can consist of activities as diverse as paving a road or installing a more powerful router. These improvements modify the characteristics of the network and therefore lead to different solutions of the p-center problem. In this work, we propose several ways to improve connections and for each mode we propose several MILP models. Likewise, we propose algorithms to calculate upper and lower bounds of the problems. Extensive computational experiments are reported highlighting the relevance of upgrading connections or facilities in the context of the p-center problem.

The major conclusion drawn from all the work done is that a significant decrease in the optimal covering cost can be attained by upgrading connections or facilities. Therefore, the information provided by the new models proposed in this work can be extremely useful to a decision-maker

because together with the location decision, the models directly provide information on which are the network connections that, if improved, allow a better final solution of the problem.

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Constraint Relaxation for the Discrete Ordered Median Problem

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Keywords: Discrete Ordered Median Problem, Branch-and-cut, Constraint relaxation, Row generation.

Recently, the Discrete Ordered Median Problem (DOMP) (see [3] for a detailed description of the problem) has been formulated using set packing constraints to model the sorting among the allocation costs (see [2]). These constraints are also known as *Strong Order Constraints* (SOC). Due to the large number of these constraints, $O(n^3)$, an aggregation of them, namely the *Weak Order Constraints* (WOC), was used in previous research to provide valid formulations for DOMP.

Combining the use of WOC and SOC in branch-and-cut algorithms, one could start with a valid formulation for the problem (DOMP_{WOC}) and improve the lower bound using SOC. This technique was studied in [1] and [2]. This former paper developed a column generation embedded in a branch-and-price-and-cut to solve the DOMP.

In this work, we explore a new paradigm for DOMP: a row generation algorithm. We propose a branch-and-cut procedure starting from a formulation with none of SOC or WOC, i.e., a constraint relaxation of the DOMP. Specifically, we consider a constraint relaxation of the DOMP where SOC are not included and we add them iteratively using row

generation techniques to certify feasibility and optimality. We present some computational results that compare this procedure with other formulations and solution methods to solve DOMP.

Furthermore, we compare our SOC separation algorithm to identify valid inequalities (or model constraints) with the automatic row generation provided by commercial solvers.

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Insights on the p-center problem

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Keywords: discrete location, p-center

Although the p-center problem has been largely studied in the literature of discrete location (see for instance [1] and [3]), new formulations and best computational results ([2], [4]) have been recently presented. We analyze all the existing formulations to improve them and develop a new method with good computational results.

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A multilayer line planning model for the design/expansion of public transportation systems

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Keywords: Line planning, Frequency setting, Multilayer networks

The objective of this work is the analysis of a new planning model for urban public transport lines. The proposed model is based on the a priori design of a pool of candidate lines of sufficient size and under certain design characteristics. From this initial set of lines, the network will be formed by selecting a subset of lines that will be selected in such a way as to guarantee the greatest possible coverage and the minimum number of transfers. The fundamental feature of the proposed model is the possibility of composing multimodal routes for users, considering not only the movements in public transport but the combination of pedestrian and bus mode for the realization of the routes. The problem is modeled using a multilayer network, which links each node of the pedestrian network with

a set of counterpart nodes (if they exist) in the potential public transport network, as many nodes as lines in the line pool. The nodes of this second network, which are located at multiple sublayers, are only activated if they are crossed by an active bus or metro line, depending on whether a bus network or a railway network is designed. The proposed approach aims to serve as a first approach to the design of networks of greater complexity in which different modes coexist (bus, metro, pedestrian, bicycles, private vehicle, etc.). The application of the proposed model is illustrated using the main network of the city of Seville.

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Dynamic Sectorization with time changing demand

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Keywords: sectorization, dynamic sectorization, AHP, genetic algorithms

Sectorization Problems, often known as territorial design problems, are characterized by dividing a large territory composed of basic units or indivisible areas into a certain number of small regions [1]. A set of planned criteria such as compactness or equilibrium guides this partitioning problem to a solution. These problems arise in many types of applications, such as political and school districting or sales territory design.

In Dynamic Sectorization, changes are allowed by adding a time dimension to Sectorization Problems; new requirements may appear over time, and, consequently, renewed solutions are necessary [2], [3]. This talk presents an application of Dynamic Sectorization to a parcel delivery service. The territorial design assigned to the teams must be adapted, according to changing demand, along the periods in which the time horizon is discretized. Some degree of similarity of sectorizations between

periods should be maintained as much as possible.
Genetic Algorithms combined with Analytic Hierarchy Process (AHP) were used to select a suitable solution for each period (Figure).

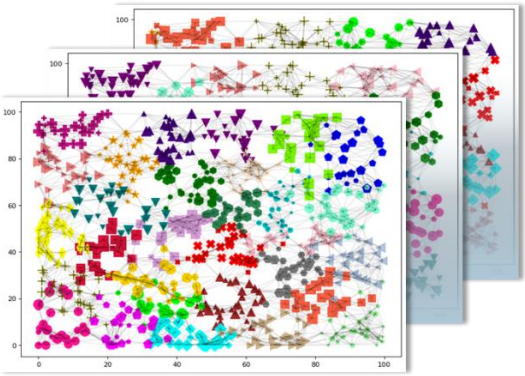

Figure. Dynamic Sectorization solutions.

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Facility location decisions for drone delivery: A literature review

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Keywords: facility location, drone delivery, UAV, UGV

With technological advances over the past 10 years, drones (unmanned vehicles) are starting to be used in many different applications including delivery, wireless communication, agriculture, sensing, inspection, security/surveillance, etc. Delivery applications for commercial, healthcare and humanitarian operations have attracted many researchers to study various problems involving unmanned vehicles, especially for optimizing routes. While the majority of this research considers unmanned aerial vehicles (UAVs), some proposes to use unmanned ground vehicles (UGVs) in deliveries. Recently, several comprehensive survey papers have reviewed drone delivery problems, especially routing aspects and systems that combine truck and drone delivery [1,2,3]. However, none of these survey papers pay special attention to the facility location problems associated with drone delivery. Therefore, this study aims to fill that gap and presents a comprehensive literature survey on facility location problems for drone (unmanned vehicle) delivery. The main goals of this review are to identify and categorize fundamental facility locations problems associated with drone delivery, to provide a connection between

the studies from different research fields that consider similar location problems, and to highlight promising areas for future research. We first discuss and classify the various types of facilities used for drone and hybrid vehicle-drone (e.g., truck-drone or transit-drone) delivery systems, including drone stations/bases (fixed or mobile), charging stations, rendezvous points, and riding points. Unlike traditional facility location problems for delivery systems with one vehicle type, hybrid vehicle-drone delivery systems usually require determining locations of rendezvous and riding points where the two vehicle types meet. The literature is then reviewed and categorized based on the types of facilities modeled, the drone operations and the location space (discrete or continuous). Each category is analyzed in terms of the modeling approach, decision(s), objective function(s), constraint(s) and additional feature(s). The talk will also present some future research directions.

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Location with Multipurpose Shopping and Partially Binary Logit rule

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Keywords: Location, Multipurpose shopping, Random utility models

We address retail store location in a duopoly. A firm, the so-called leader, has already located several stores, while a second firm, the follower that offers a different product, considers locating its stores in the same area. Both products have some degree of complementarity but are not substitutes. In a previous paper [1] we studied the same problem, but considering a customers' decision rule that is binary (winner-take-all) and deterministic (there are no uncertainties related to customers' behavior), as the one used in the well-known paper by Hotelling [2]. In that work, we concluded that multipurpose shopping has a strong influence on optimal store location and promotes agglomeration. This paper extends our previous work by introducing a more realistic random utility customer choice rule based on the Multinomial Logit model. Along these lines, we

propose the new Partially Binary Logit rule, applicable to the case in which all stores of a firm have very similar attributes, except for their location. In this case, a customer always chooses the least cost trip store of the firm to purchase its product. We propose one nonlinear and three linear formulations for the follower location problem, and a Branch and Cut method for one of them. Two of the formulations have a good performance for instances of up to at least 200 nodes. We compare the binary, Multinomial Logit, and Partially Binary Logit rules by analyzing the captured markets and location patterns for a large set of randomly generated 100-node instances.

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Exam location and room selection

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Keywords: Exam location, capacitated facility location, conflict graphs, integer programming, heuristics

The focus of this study is on room selection for exams with different equipment requirements, such as computers or projectors. Due to the large number of participants, it is not always possible to hold these exams in a single location and often they must be spread across multiple locations [1]. While doing so, both the fixed cost of utilizing rooms and an additional cost associated with the travelling distance of participants to their assigned exam location must be taken into account. The combination of these restrictions and cost factors leads to a challenging variant of the capacitated facility location problem which we refer to as the Exam Location and Room Selection Problem (ELRSP). Although the ELRSP does consider the timetabling of exams [2], location and room selection remains hard for human planners to tackle.

The ELRSP considers a set of exams which are a priori allocated to a set of time slots within a given time horizon. The set of participants for each exam and the location of each participant is known. For each exam, a set of rooms which are suitable for holding it must be selected. Rooms have a limited capacity and they may be geographically distributed across a district, a city or a country. The participants of a particular exam may be allocated to rooms in different locations. Rooms cannot be assigned to multiple exams for the same time slot. There is an upper limit on the number of different locations where an exam can take place and a room

cannot be used if the number of exam participants assigned is lower than a certain threshold. Each room incurs a fixed utilization cost and a variable cost associated with the travelling distance of each participant to the allocated exam location. We refer to the latter as the travelling cost of participants. The objective is to minimize the total sum of the fixed room costs and the travelling cost of participants.

We investigate different ELRSP variants where each exam must be assigned to a single location and the time slots of the exams can be shifted. We develop integer programming formulations and heuristic approaches for these problem variants. We also investigate the similarities of each variant to well-known location problems.

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Locating emergency vehicles considering delays in the arrival of assistance

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Keywords: OR in health services, emergency vehicles, uncertainty, stochastic optimization, heuristic

The quality and promptness of emergency assistance is highly dependent on the location of existing emergency vehicles. In this work, we propose a new model for optimizing emergency vehicles' location that takes into account the existence of different types of emergency vehicles and the level of care they can provide, the possibility of vehicles' substitution considering the hierarchy of levels of care and the explicit consideration of the progression of an emergency episode when the arrival of assistance suffers delays [1]. In [2, 3] the authors had already developed models that accounted for the possibility of one or more vehicles being able to substitute another one if necessary, guaranteeing equivalent level of care. However, it was assumed that there could be episodes not receiving any assistance at all if there were no vehicles available at the time of the occurrence. In practice, all the episodes that occur will receive assistance, even if not the most adequate one, or even if it arrives later than desired. If the assistance does not arrive promptly, then the emergency episode can evolve, the situation of the people in need can change, and this can also have an impact on the vehicles that are sent to the scene.

In this work, the evolution of each episode is represented by a discrete set

of fictitious episodes, that can consider different vehicles' needs. The inherent uncertainty that exists in emergency care is represented by a set of scenarios.

To assess the validity of the model, real data was used. It was necessary to develop a heuristic procedure due to the dimension of the instance generated. The calculated solution was then compared with the existing one, being possible to conclude that the former assures a better coverage of the episodes in an earlier period of distress. It is possible to improve coverage by relocating the existing vehicles in the geographical area under study, guaranteeing a more equitable access to this essential service, without increasing the total number of vehicles. This can be observed in both in-sample and out-of-sample data. The location of vehicles is indeed influenced by the explicit consideration of the impact of assistance time on the victims' conditions.

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The tree of hubs location problem with inter-hub stopovers

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Keywords: Hub Location, Network Design, Tree topology, Mixed Integer Programming, Single allocation

The Physical Internet (PI) has emerged as a promising paradigm to increase the sustainability of logistics network while preserving their efficiency. PI logistics systems emulate the principles of the digital internet to establish highly interconnected and collaborative networks to make better use of the resources. [1]

This research focuses on the strategic design of PI networks, in particular for waterborne transportation. We address the general problem of locating Physical Internet Hubs (PI-Hubs). In the special case of river transport, the underlying topology corresponds to a tree, thanks to the geographic characteristics, which will force the tree pattern.

Thus, the location problem is related to a *tree of hubs location problem* [2], which is a variant of the well-known hub location problem relying on a tree topology, which is already given in the river network.

Our main contribution is to introduce potential stopovers at ports located

between two hubs. These stopovers increase the traveling time but do not significantly increase the traveled distance. Moreover, using stopovers avoid some transshipment. Although our formulation can build a tree network in general instances like the AP data set, this study is focused on the location and allocation problem for the tree network already established in the river transportation system.

We present a mathematical formulation of the *tree of hubs location problem with inter-hub stopovers*. In this problem, hubs and spokes play the same role as in the usual hub location problem. Stopovers are located between hubs. Cargo can be loaded or unloaded there, but not transshipped from one boat to another. *Figure* 1 illustrates the proposed topology with two possible paths to traverse the network, the classical one using hubs {*k, l*}, or a new one using stopovers {*k, a, b, l*}.

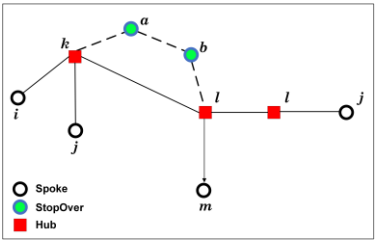

Figure 1. Topology of the tree of hubs with stopovers

We show the practical difficulty through experiments with Cplex on instances from the literature. We also present a case study generated from the main transportation river in Colombia and waterborne networks in Europe.

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Bilevel optimization for the location of charging stations in corridors

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Keywords: Bilevel Optimization, Location Models, Charging Stations.

Industrial firms that manage gas stations are currently undergoing a general process of adaptation with the aim of installing recharging points for electric cars at their service stations. These energy companies develop strategic plans for adapting their infrastructures with the aim that drivers of electric vehicles can have refueling points distributed throughout the territory for recharging energy, these being not very far from each other to make it possible to circulate with supply guarantees along any corridor contained in the territory.

The European Commission's 2018 strategy emphasizes the importance of the transition to low-carbon modes and zero-emission vehicles, underlines the central role of electrification and renewable energy sources, and Drives improved operational efficiency.

From the public point of view, it is in the interest of guaranteeing that the trip between origin and destination points within a transport corridor can

be carried out by means of an electric vehicle. To do this, a subset of service stations (initially, gasoline fuel supply points) will be selected to establish electrical recharging facilities for vehicles that require it. This action will have a cost for the distribution companies that would be partially subsidized by the government. Therefore, it is reasonable to use a criterion of minimizing the total number of installations to be adapted to provide recharging for electric vehicles, additionally guaranteeing coverage of this service that includes an alternative to failures. To prevent eventualities would mean to having a second option of recharging point that would not be too far from the one initially selected by the customer.

From a private point of view, the service stations that would be chosen to establish electric recharging facilities should be those that could serve a greater number of potential customers. The budgetary restrictions would be determined by a global economic cost and, additionally, others on the number of admissible recharging points within each service station.

For the first objective (public interest perspective) a conditional covering model will be applied. For the second objective (private perspective), a bounded knapsack model will be formulated. For this, we propose a bilevel model that minimizes the number of refueling points necessary to guarantee a reinforced service coverage for all users who transit from their origin to destination and, as a second level, maximize the volume of demand subject to budget restrictions.

Location, connection, and order in discrete networks

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Keywords: Discrete Networks, MILP formulations, Ordered Median Problem, Minimum Spanning Tree.

Network location problems have been extensively studied in the literature from various perspectives, being mathematical programming one of the most consolidated tools for their resolution. The inclusion of new features to be modeled in the networks (flow, capacity, fairness, evolution, etc.) or the use of these problems for other purposes (industrial problems, portfolio selection, machine learning, data analysis, etc.), currently maintain interest in this discipline.

In this talk we present the Ordered Median Problem (OMT), a single-allocation facility location problem where p facilities must be placed on a network connected by a non-directed tree. The objective is to minimize the ordered weighted average allocation cost plus the facilities tree connection average cost. We present different MILP formulations for the OMT based on properties of the Minimum Spanning Tree Problem and the ordered optimization, see [1] and [2] as reference. In addition, we introduce a branch-and-Benders-cut decomposition algorithm for the OMT. We

establish an empirical comparison between these new formulations and we also provide enhancements that allow to solve larger size instances on general random graphs.

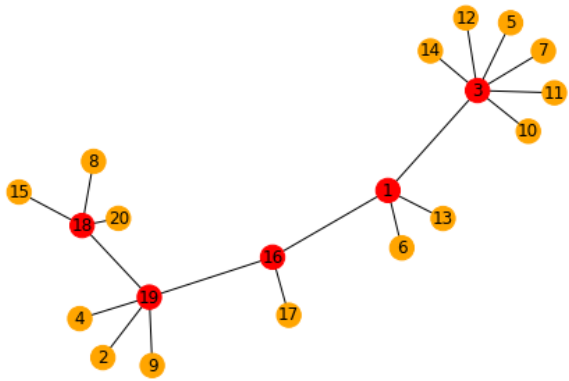

Figure. OMT solution example.

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Costumer selection rules in competitive facility location

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Keywords: competitive location, costumer selection rule

When locating a new facility, one of the most important considerations is whether there are competitors in the market offering the same goods or services. If there are competitors in the area, then the locating firm will have to compete for the market, and the profit that the firm makes will be affected by the decisions of its competitors. Therefore, maximizing profit is a much more difficult problem to solve in the presence of competitors than in a monopolistic scenario.

Knowing how customers purchase goods among existing facilities helps to estimate the *market share* captured by each facility (see [1-2]). An often used rule is that customers only travel to the *nearest/cheapest facility* to make their purchases, as occurs in Hotelling-like models [3]. In other models, individuals travel farther than necessary to purchase goods, or occasionally do not shop at the lowest price. Another rule frequently used in retailing is that each customer patronizes all available facilities offering the goods in a *probabilistic way*, with a probability proportional to her/his *attraction* to each facility, as in Huff-like models [4].

In this talk, we deal with static competitive facility location problems, in which demand is assumed to be inelastic and concentrated on a finite set of demand points. The attraction function follows a Huff pattern, and thus depends on both the location and the quality of the facilities, which are the variables of the problems. Prices are not considered as decision variables,

but they can be taken into account as part of the attraction factors determining the qualities of the facilities. Most of the existing models of this type focus on maximizing market share, although profit maximization has also used in many works lately.

A number of different customer selection rules have been presented in the literature and are now reviewed:

- *Huff probabilistic rule:* demand points split their buying power among the facilities proportionally to the attraction they feel for them.
- *Multi-deterministic or Partially binary rule:* assuming that there are several chains present in the market, customers split their demand among all the chains, but are served only from the most attractive facilities of each chain. The demand is split probabilistically among the most attractive facilities of each firm.
- *Partially probabilistic rule:* only the facilities with a minimum utility level serve a customer, and among those facilities the demand is split probabilistically.
- *Pareto-Huff rule:* for each costumer, the facilities on the Pareto-front by minimizing distance and maximizing quality can gain its demand. Demand is split probabilistically among these facilities.
- *Brand preference:* a customer splits its demand among all the facilities of its favourite brand probabilistically.

Our goal is to unify these rules, and build a possible solution procedure on the unified model.

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An exact method for the competitive facility location problem under the nested logit choice rule

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Keywords: Competitive location, Nested logit, Random utility models.

We study the competitive facility location problem in which a new company aims to enter the market by locating a given number of stores to maximize its market capture. Each firm offers a non-essential product among all its stores, which is also a substitute for those of other companies. In order to include random variables and better represent customers' purchase probabilities, several articles have provided exact methods to solve the CFLP under the multinomial logit (MNL) choice rule. This rule assumes that the purchase alternatives are independent, leading in several cases to an incorrect estimation of the market. The Nested Logit (NL) rule considers correlations between alternatives and has gained relevance in the location field in recent years. However, there are no exact methods since no concavity of the problem has been demonstrated. In this work, we

formulate a mixed-integer nonlinear programming problem under an NL rule that considers that all the stores of the newcomer firm belong to the same nest and shows that the problem is concave. We use a branch-and-cut approach based on three sets of valid cuts, two already known, outer-approximation cuts and submodular cuts, proposing a tighter version of the latter, and a new one, one-opt cuts, managing to obtain optimal solutions for large instances in a reasonable time. Finally, we compare the optimal locations with the MNL and NL rules. The results indicate that the locations under the NL rule better represent reality.

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