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BERGISCHE UNIVERSITÄT WUPPERTAL

ISOLDE XV online

University of Wuppertal, Germany
5 – 9 July 2021

ISOLDE XV & EWGLA XXVI

Conference Program

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University of Wuppertal, Germany
5 – 9 July 2021

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W Click on the round symbol to enter the virtual room of your session.

Parallel Sessions MB Click on the parallel sessions header to find out more.

Always download the latest version of this program & in case you intend to switch sessions follow last minute changes here.

Conference Days & Sessions

Monday, July 5 – Day 1

16:00 – 18:00

Parallel Sessions MB

MB-01: Hub Location

Chair: Sibel A. Alumur

Wuppertal

On the p-Hub Interdiction Problem, **Thomas Ullmert**

Incorporating Shipment Consolidation Decisions in Hub Network Design with Multi-period Demands, **Khaled Shah**

The Capacitated Multi-period Hub Location and Routing Problem Under Uncertainty, **Cihan Butun**

Robust-stochastic models for profit maximizing hub location problems, **Gita Taherkhani**

MB-02: Competitive Models I

Chair: Zvi Drezner

Toronto

Improved Formulations of the Gravity Model for Competitive Facility Location, **Dawit Zerom**

Multiple Obnoxious Facilities Location: A Cooperative Model, **Tammy Drezner**

Product Line Optimization with Multiples Sites, **Sebastián Dávila**

Sequential Competitive Facility Location: Exact and Approximate Algorithms, **Ruiwei Jiang**

MB-03: Covering Models I

Chair: Mark Daskin

Naples

Improving Influence Maximization by Covering Models, **Gyöngyvér Vass**

Upgrading Location Problems: An Approach using Integer Programming, **Marta Baldomero-Naranjo**

Discrete Cooperative Coverage Models with Alternative Facility Types in a Probabilistic Setting: a Computational Study, **Ioannis Giannikos**

Using Margin of Error Census Data in Location Modeling: the P-Median and Maximum Covering Cases, **Mark Daskin**

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Conference Days & Sessions

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TA-01: Discrete Models I

Chair: Justo Puerto

Wuppertal

Ordinal Facility Location Planning, **Nicolas Fröhlich**

A Classification of Location Problems with Edge Interdiction, **Stefan Ruzika**

Dynamically Second-Preferred p-Center Problem, **Justo Puerto**

TA-02: Continuous Models I

Chair: Kathrin Klamroth

Toronto

l1-norm Mathematical Programming Model Applied to STEM Tomography, **Juan Manuel Muñoz-Ocaña**

Single-Facility Weber Location Problem with Different Norms at Different Regions, **Moisés Rodríguez-Madrena**

A Branch and Price Approach for the Multifacility Continuous Monotone Ordered Median Location Problem, **Ricardo Gazquez**

TA-03: Location & Transportation I

Chair: Gilbert Laporte

Naples

Hub Location Model of Platoon Formation Center for Truck Platooning, **Saw Aung**

Optimizing the Deployment of Mobile Eco-Points for a Selective Collection of Municipal Waste, **Ramón Piedra de la Cuadra**

Public Transport-based Crowd-shipping with Backup Transfers, **Kerim Uygur Kızıl**

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Chair: David Sayah

Wuppertal

A Stochastic Dynamic Facility Location Problem with Modular Capacity Adjustments and Delayed Demand Satisfaction, **Teresa Melo**

A Two-Stage Stochastic Programming Model for Locating-Relocating of Fixed and Mobile Ambulance Stations, **Ehsan Nikbakhsh**

Drones for Relief Logistics under Demand Uncertainty, **Okan Dukkanci**

TB-02: Districting Models

Chair: Jörg Kalcsics

Toronto

A Novel Territory Design Approach for On-time Last-mile Express Delivery Services, **Roger Z. Rios-Mercado**

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Solutions for Districting Problems with Chance-Constrained Balancing Requirements, **Antonio Diglio**

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Chair: Stefan Nickel

Wuppertal

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Minimum Cost b-Matching Problems with Nonconvex Neighborhoods, **Inmaculada Espejo**

Location and Routing Decisions for the Determination of Long Paths in Board Games, **Konstantin Kraus**

WA-02: Applications I

Chair: Olivier Péton

Toronto

Multi-channel Distribution in the Banking Sector and Network Restructuring, **Silvia Baldassarre**

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Conference Days & Sessions

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WB-01: Continuous Models II

Chair: Lin Dearing

Wuppertal

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Balanced Facility Location and the Stackelberg Game, **Thomas Byrne**

WB-02: Applications II

Chair: Rajan Batta

Toronto

Location Models for Ammunition Support Activities, **Lawrence V. Snyder**

Server Positioning and Response Strategies for Spatially Arriving Jobs with Degradation: Light and Medium Traffic Cases, **Rajan Batta**

Location Analytics for Strategic Defense in Baseball, **Alan Murray**

WB-03: Location & Transportation II

Chair: Boglárka G.-Tóth

Naples

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On the Impact of Traffic Changes for Facility Location Problems, **Ágnes Vida**

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Conference Days & Sessions

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14:00 – 15:30

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HA-01: GIS-related Problems

Chair: Michael Kuby

Wuppertal

Multi-objective Location Problem of Japanese Roadside Stations with Detailed GIS Data, **Yudai Honma**

Collaborative "Geodesign" for Alternative Fuel Station Location Using Open-Source COLLABLOCATION Software, **Michael Kuby**

HA-02: Location & Transportation III

Chair: Elena Fernández

Toronto

Linear Programming to Estimate Cognitive Location Costs from Observed Paths, **Hiroyuki Hasada**

Electric Vehicle Charging Station Location Problem Considering Congestion and Waiting Times, **Omer Kinay**

Lifted Inequalities for the Refueling Station Location Problem with Routing, **Paul Göpfert**

HA-03: Covering Models II

Chair: Ioannis Giannikos

Naples

Maximal Covering Pattern of Source and Receiver Placement, **Takamori Ukai**

Planar Maximum Coverage Location Problem with Partial Coverage, Spatial Demand, and Adjustable QoS , **Manish Bansal**

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Conference Days & Sessions

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HB-01: Drone Applications

Chair: James Campbell

Wuppertal

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Drone Locations and Logistics for Delivery of Humanitarian Aid to Uncertain Demands of Disaster-impacted Populations, **Zabih Ghelichi**

Extending Coordination Models: The Mothership and Drone Routing Problem with Graphs, **Carlos Valverde**

HB-02: Location & Pandemics

Chair: Sibel Salman

Toronto

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Logistics of Half-Mobile Testing Booths for COVID-19, **Çağla Dursunoğlu**

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Conference Days & Sessions

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Chair: Vladimir Marianov

Wuppertal

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The Leader Multipurpose Shopping Location Problem, **Armin Lüer-Villagra**

Mobile Service Facilities with Customer Choice, **Viktor Bindewald**

Point-to-point Airline Network Design under Cooperation and Competition, **Jinha Hibino**

FA-02: Humanitarian Logistics

Chair: Bahar Y. Kara

Toronto

Location of Water Taps and Design of a Water Distribution Network in Nepal, **Jessica Rodríguez-Pereira**

Districting for Integration of Syrian Refugees into the Turkish Education System, **Şebnem Manolya Demir**

Humanitarian Supply Chain Planning: The Effect of Location Decisions on Fair Allocation of Donations, **Zehranaz Donmez**

A Progressive Hedging Algorithm for Two-Stage Stochastic Blood Supply Chain Network Design in Humanitarian Logistics, **Morteza Lotfi**

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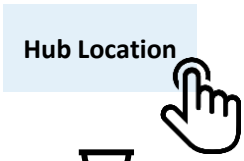
How to... Conference

Find your way

ISOLDE XV takes place via Zoom. Click on the oval symbols to enter the sessions you would like to join.



Navigate within the program using hyperlinks to explore the sessions & abstracts.

As a speaker or session chair please enter your session 10 minutes ahead of starting time for technical checks.

As a participant kindly mute your audio during presentations.

Each speaker has a time slot of 30 minutes, consisting of 20 minutes for presentation & 10 minutes for discussion.

Join for the group photo

- What? Be part of a longstanding ISOLDE tradition: the group photo, this year as a screenshot from Zoom.
- When? Tuesday, July 6, 17:30, Lounge room
- How? Please use one of the following virtual Zoom backgrounds for the moment of the photo, so that we can create a colorful collage.

Click to download

How to... Conference

Take a break

ISOLDE XV offers two break formats:

Lounge

The Coffee Break is an open meeting room, where you can also ask for a private break out room to talk with colleagues.

Gym

The Active Break is a 15 minute instructed opportunity to stretch your body and mind, no equipment is needed.

Ask questions

During sessions you may ask your scientific questions in the:

Zoom Chat during the presentation (followed up by the session chair).

Discussion after the presentation,

... then please turn on your webcam when asking your question.

Each session is supported by a technical assistant (black t-shirt & green background). For any further technical questions you may reach us via:

Email: isolde-online@math.uni-wuppertal.de

Telephone: +49 202 439 5296

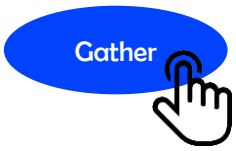
Slack Chat: click here

How to... Gather

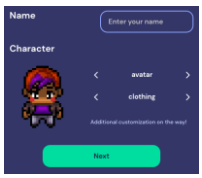
- What? Gather.town is an online meeting platform, which allows to interact in a virtual landscape using an avatar.
- When? During conference days we will use Gather.town twice for social events:

  Social Break: Monday, July 5, 15:30

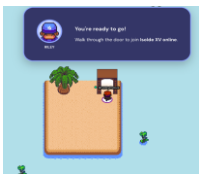
  Social Evening: Wednesday, July 7, 17:30
- How? Gather.town is new for most of us, yet easy to use. During the general information on Monday, we will give detailed instructions on how to enter the first social break together by following these easy steps:



Click or copy the link https://gather.town/i/Fbm3sYHB into your Firefox or Chrome browser (supported). Then click on 'Or continue in browser'.



Enter your full name and choose an avatar. Allow Gather to access your microphone & camera.* You will get the best audio with headphones. Then click on 'Join the Gathering'.



Follow the short tutorial and enter the meeting room through the door.

Like in reality, Gather.town allows you to see, hear and talk to the people closest to you. You can either approach just one person or join a private space (shown as sitting area). Outside that area, people will not see your video or hear you.

If you would like to speak to the whole room, you may step on one of the two spotlight tiles which represent the podium.

*If you miss to allow the access to microphone or camera you may later adjust your settings. Click and allow.

Monday, July 5, 14:15-15:15

■ MA-01

Monday, 14:15-15:15 - Wuppertal

Plenary Talk

Stream: Plenary Session
Contributed session
Chair: *Horst Hamacher*

1 - Hub Networks
Morton O'Kelly

This paper reviews some salient aspects of the location of hub facilities and network design. Contrasts between idealized models and observed airline networks are shown. While early research emphasized what is known as a single allocation version of the problem, this paper shows that empirical airline networks are likely to have incomplete backbone connections; multiple allocations to hubs; and incidental direct connections between some of the nodes. Some airlines are close to theoretically ideal one-hub configurations, but the majority are much more complex.

The paper reviews and contrasts empirically observed cases and idealized models. In a detailed example, the multiple allocation uncapacitated hub location problem is solved using Benders decomposition. Sample solutions are shown with an emphasis on interpreting the results and extracting good understanding of the parameters that are consistent with the observed network structures. When a = 0, we have the special case of nearest hub assignment and the p-median, single allocation, and multiple allocation models all give the same result. When a = 1, we have no discount, and no incentive to move on the inter-hub network. Because of the triangle inequality, we expect that the linkages make one intermediate hub stop (at most).

Solving the multiple allocation problem with a large number of parameter variants yields a tradeoff curve between the inter-hub discount factor and the allocation count, (1,2,...,p). For example, a network with a very efficient and low-cost backbone would be expected to have strong leaning towards a median-like single allocation, while a network with virtually no saving in inter-hub flow would lean towards multiple allocation, and in the extreme case might have assignment to all p hubs.

Monday, July 5, 16:00-18:00

■ MB-01

Monday, 16:00-18:00 - Wuppertal

Hub Location

Stream: ISOLDE
Contributed session
Chair: *Sibel A. Alumur*

1 - On the p-Hub Interdiction Problem
Thomas Ullmert, Stefan Ruzika, Anita Schöbel

In recent years, communication networks have become important in everyday life. This implies that damage to such networks can have a dramatic impact on the quality of services, such as cloud services or satellite networks which are expected to be functioning. The consequences can reach up to total failure of the services. A property which most of these networks share is that there is no direct connection between all participants of the network. Instead, most of the traffic is routed via so-called hubs leading to cheaper total connection cost. However, if one or more of these hubs fail, this can cause a re-routing of the traffic and, as a result, lead to an increase of routing cost. In extreme cases, a total failure of the service may occur. In this talk we formulate this problem as a tri-level mixed integer program, which we than reformulate as bi-level mixed integer program. In the reformulation, in the first level the locator decides on the choice of hubs, whereas in the second level the so-called interdictor decides on a strict subset of the hubs he wants to damage, to cause the greatest increase in routing cost. We assume the size of the subset to be given and solve the problem to optimality with a method based on row-generation. We use this method to provide exact solutions for the famous CAB-data set and parts of the AP-data set. Further, we show that the problem of the second level (that is to decide which subset of hubs of a given size causes the biggest increase in routing cost if all hubs of the subset fail) is already NP-hard.

2 - Incorporating Shipment Consolidation Decisions in Hub Network Design with Multi-period Demands
Khaled Shah, Sibel A. Alumur, James Bookbinder

The long-term strategic decisions, such as the placement of hubs in the supply chain network may be influenced by decisions of shipment consolidation and inventory holding. Thus, optimization in hub network design may be achieved by considering the operational characteristics of the network and strategic decisions of facility placement together. We incorporate shipment consolidation decisions in hub location problems so as to optimize the locations of hubs, frequency of vehicles to operate between them, and inventory holding decisions. Unlike existing hub models, we consider demands spread over a multi-period planning horizon.

In this research, we develop mixed-integer optimization models for the single and multiple allocation variants of the hub location problem investigating the impact of shipment scheduling decisions on hub network design. The formulations decide on the optimal location of hubs, allocation of O-D nodes to hubs, inventory to be held at hubs in different time periods, and the type and number of vehicles to be dispatched on inter-hub links in different time periods while ensuring delivery within a promised time. In an alternative mixed-integer formulation, we model the allocation of origin-destination flows to hub arcs, and the type and frequency of vehicles to be dispatched on different links while taking into account vehicle capacities and promised time for delivery.

The proposed formulations may be used in applications such as LTL freight transportation. We evaluate these models on different instances of the USAF data set under variations of parameter values used for numerical experiments.

3 - The Capacitated Multi-period Hub Location and Routing Problem Under Uncertainty
Cihan Butun, Sanja Petrovic, Luc Muyldermans

Concentration of container flows in a hub-and-spoke network offers cost and service benefits to shipping lines when implemented in parallel with other strategic moves such as deployment of ultra-large container vessels and vertical integration in container terminal operations. The choice of hub ports and liner service design has long-term consequences, and as such require the consideration of a long planning horizon and uncertainties associated with data imprecision. In this presentation, we study the hub-and-spoke network design problem in liner shipping sector by considering multiple planning periods and uncertainty. At any given planning period, the problem includes the following decisions: the opening of hubs by buying or leasing a container terminal ; the closing of selected hubs; hub capacity modification ; construction of a directed cyclic hub-level network; allocation of non-hub ports to hubs; and the routing of cargo in the network. We assume that the decision maker does not know the exact values of certain problem parameters but can specify a range of plausible values they can take, which are represented with trapezoidal possibility distributions. We formulate the problem with a possibilistic mixed integer linear programming model and employ a fuzzy-measure based approach to convert the possibilistic model into its equivalent auxiliary crisp counterpart. Computational experiments are studied to examine: the changes in hub locations and capacities over the planning period; the impact of uncertainty on the optimal hub-and-spoke network design and costs; and the trend in network costs for different levels of decision maker's attitude towards uncertainty and desired confidence level.

4 - Robust-stochastic Models for Profit Maximizing Hub Location Problems
Gita Taherkhani, Sibel A. Alumur

This presentation introduces robust-stochastic models for profit maximizing capacitated hub location problems in which two different types of uncertainty including stochastic demand and uncertain revenue are simultaneously incorporated into the problem. First, a two-stage stochastic program is presented where demand and revenue are jointly stochastic. Next, robust-stochastic models are developed to better model uncertainty in the revenue while keeping the demand stochastic. Two particular cases are studied based on the dependency between demand and revenue. In the first case, a robust-stochastic model with a min-max regret objective is developed assuming a finite set of scenarios that describe uncertainty associated with the revenue under a revenue-elastic demand setting. For the case when demand and revenue are independent, robust-stochastic models with a max-min criterion and a min-max regret objective are formulated considering both interval uncertainty and discrete scenarios, respectively. Exact algorithms based on Benders decomposition coupled with sample average approximation scheme are proposed. Exploiting the repetitive nature of sample average approximation, generic acceleration methodologies are developed to enhance the performance of the algorithms enabling them to solve large-scale intractable instances. Extensive computational experiments are performed to consider the efficiency of the proposed algorithms and also to analyze the effects of uncertainty under different settings. The qualities of the solutions obtained from different modeling approaches are compared under various parameter settings. Computational results justify the need to solve robust-stochastic models to embed uncertainty in decision making to design resilient hub networks.

■ MB-02

Monday, 16:00-18:00 - Toronto

Competitive Models I

Stream: ISOLDE
Contributed session
Chair: *Zvi Drezner*

1 - Improved Formulations of the Gravity Model for Competitive Facility Location
Dawit Zerom, Zvi Drezner, Tammy Drezner

We propose two modifications to the gravity model. (i) As the distance increases, the decay in patronage by more attractive facilities is slower than the decay by less attractive facilities. The decay function of the distance is different for different facilities rather than being the same for all facilities. This implies that by using only the distribution patterns of neighborhoods from which facility's patrons originated, the facility dependent decay approach implicitly accounts for the varying degrees of facilities' attractiveness. (ii) In addition, we propose to add a constant to the distance traveled to the facility. The total time spent on the shopping trip consists of the distance plus the time required for shopping which is constant. For example, suppose that a grocery store is half a mile away and it takes 3 minutes to get to it and drive back. In addition to these three minutes, there is time spent at the store and paying for the products, parking the car, unloading the purchase from the car, and so on. If these extra activities take 15 minutes, the shopping trip takes 18 minutes. Another retail outlet is four times farther and it takes 12 minutes to get there and back. However, the additional activities take the same 15 minutes for a total of 27 minutes. The extra 15 minutes is treated as an additional distance so the ratio of the distances is only 1.5 which is more realistic than a ratio of 4.

The proposed models are easy to implement and the location decisions are expected to be more accurate. No modifications are required in order to apply existing solution algorithms to the new models. The effectiveness and accuracy of the new approaches are demonstrated using a real data set.

2 - Multiple Obnoxious Facilities Location: A Cooperative Model
Tammy Drezner, Zvi Drezner, Pawel Kalczynski

A given number of communities exist in an area. Several obnoxious facilities, such as polluting factories, garbage dumps, need to be located in the area. The nuisance emitted by the facilities declines by the square of the distance from the facility and is cumulative. This means that each community is inflicted by the sum of the nuisances emitted by the facilities. The objective is to minimize the nuisance inflicted on the most affected community. This problem is useful for planners who frequently face the challenge of locating obnoxious facilities and have no easy way to determine a good set of locations for these facilities. No existing model considers the cumulative effect of nuisance generated by the facilities.

A multi-start approach by the SNOPT and IPOPT solvers in Matlab, which are considered to be the best available general-purpose nonlinear solvers, gave poor results. However, an innovative, specially designed Voronoi based heuristic produced much better results in a small fraction of the run time. In many cases, nuisance is cut by more than half, and run time is more than a hundred times faster. For example, locating 20 facilities among 1000 communities required 9 minutes by SNOPT starting at 1000 randomly generated solutions, and the solution was 117% solution which is more than double above the best known solution which is more than double that was found by Voronoi based heuristic in less than half a minute. We show applications of our methodology that extend beyond the model presented here.

3 - Product Line Optimization with Multiple Sites

Sebastián Dávila, Vladimir Marianov, Fernando Ordonez, Frédéric Semet, Martine Labbé

The product line optimization problem (PLOP) consists of finding the best product assortment to display in a store in such a way as to fit both the consumers' preferences and the limited available space in that store. Assortment optimization is especially relevant for products with slow turnover as appliances (e.g., washers, refrigerators, TV sets, among others) because of the space they take in the store. This problem is usually solved for a single store. We consider the problem faced by a retail chain who must select what mutual-substitute items to display in each one of its stores to maximize revenues. The number of items cannot exceed the limited space capacity of each store. Customers purchase at most one product that maximizes their utility, which depends on the product price, travel cost to the store, and reservation price, known to the retailer. The problem described above is a generalization of the PLOP for the case of multiple stores. The retailer considers customers' decisions and solves a mixed-integer bilevel optimization problem, which can be formulated as a single-level optimization problem by using optimality conditions for the lower level. This formulation is similar to a Facility Location with clients' preference problems. The families of valid inequalities that belong to the last problem are adapted for our model, and a new valid inequality is proposed. In order to solve large instances, we propose to embed some of the valid inequalities into Branch & Cut and Cut & Branch methods. We compare the results with those of a Benders Decomposition method that has shown the best results for the case of a single store. Our computational results show that the proposed Cut and Branch method obtains the best performance and improves the current state of the art.

4 - Sequential Competitive Facility Location: Exact and Approximate Algorithms

Ruiwei Jiang, Mingyao Qi, Siqian Shen

We study a competitive facility location problem (CFLP), in which two firms sequentially select locations of new facilities, in order to maximize their market shares of customer demand that follows a probabilistic choice model. This process is a Stackelberg game and admits a bilevel mixed-integer nonlinear program (MINLP) formulation.

Through integer programming methods, we derive an equivalent, single-level MINLP reformulation by appropriately revising the objective function. In addition, we exploit the problem structures and derive two classes of valid inequalities. The first class exploits the submodularity of the revised objective function. In addition, we "bulge up" this function to make it concave without losing any exactness. This yields a class of bulge inequalities. Inspired by robust optimization, we further derive an approximate separation of these valid inequalities that only consumes a sorting procedure to compute. We apply these inequalities in a branch-and-cut algorithm to find a globally optimal solution to CFLP.

Furthermore, we propose an approximation algorithm for solving CFLP that is computationally more effective. Notably, this algorithm admits a constant approximation guarantee.

Through extensive computational experiments, we demonstrate that our valid inequalities can significantly accelerate the solving of sequential CFLP. For example, our approach is able to solve instances with 100 candidate facilities and 2,000 customer nodes in minutes, which has never been achieved in the past (even by heuristic approaches). In addition, our approximation algorithm can obtain near-optimal solutions even more quickly.

■ MB-03

Monday, 16:00-18:00 - Naples

Covering Models I

Stream: ISOLDE
Contributed session
Chair: *Mark Daskin*

1 - Improving Influence Maximization by Covering Models

Gyöngyvér Vass, Boglárka G.-Tóth

Influence maximization is a very popular problem in social sciences. It seeks a given number of seed points (vertices) in a network to maximize the number of influenced vertices starting from the seeds. Influencing may occur through the edges, which indicate the connection between people (vertices). There are different ways to define influence, but finding the seeds from which maximal influence can be reached is a difficult task in general.

Covering models belong to facility location problems, where facilities are to be located such that the covered demand points (vertices in a graph within a given distance) are maximized. These models are motivated by problems where some services are only available within a fixed radius, like ambulances or fast food delivery. These problems are solvable for large graphs, and our long term aim is to use the most appropriate and/or adjusted covering models for solving influence maximization problems.

We have compared influence maximization and coverage models and analyzed their differences. We have found that the Triggering influence maximization model can be made equivalent to a maximal covering model. For the Independent Cascade model, we defined the edge lengths from the probabilities of the influence, and showed experimentally that the solution of the maximal covering model gives very good approximation for the maximal influencers. The computational results also showed that even solving exactly the covering model is much faster than the widely used greedy method.

In this talk we also plan to study the reality-based cases when the cost of influencing each node is given together with a fixed budget, and when we need to choose the seed points far from each other.

2 - Upgrading Location Problems: An Approach using Integer Programming

Marta Baldomero-Naranjo, Jörg Kalcsics, Alfredo Marín, Antonio Manuel Rodriguez-Chia

In this presentation, we concentrated our study on the upgrading version of the maximal covering location problem with edge length modifications in networks. Given a fixed coverage radius, we say that a node is covered by a facility if the distance between them is lower than or equal to this radius. Therefore, the upgrading maximal covering location problem with edge length modifications aims at locating p facilities on the nodes of the network to maximize coverage, considering that the length of the edges can be reduced within a budget. Note that for each edge an upper limit on the maximum reduction of its length and the cost per unit of reduction is given. Hence, we seek both solutions: the optimal location of p facilities and the optimal edge length reductions. This problem is NP-hard on general graphs. In this talk, we propose three different mixed-integer formulations to solve the problem on general graphs. Moreover, we provide a preprocessing phase for fixing several variables and removing some constraints. Furthermore, we develop several sets of valid inequalities to enhance the formulations. Finally, we present computational experiments in which we analyze the performance of the three formulations. First, we test the usefulness of the preprocessing phase, showing the great improvement in computational times that this produces. Then, we compare the proposed formulations by testing their performance on a set of networks, outlining the strengths and weaknesses of each formulation. We also test the efficiency of the developed valid inequalities.

3 - Discrete Cooperative Coverage Models with Alternative Facility Types in a Probabilistic Setting: a Computational Study
Ioannis Giannikos, Maria Michopoulou

In this talk, we discuss location problems where the objective is to locate a given number of facilities of different types in order to appropriately cover a given set of demand points. The coverage provided to each demand point is the result of the cooperation (or the interference) among the located facilities. Facility locations may be selected from a discrete set of pre-determined candidate sites. The different types of facility refer to the coverage radius or quality of coverage that each type may provide. We assume that each candidate site and each facility type may offer coverage according to a probability distribution and that the operation of each facility may be correlated to the operation of other facilities, located at different sites. Such situations may arise in applications where the operation of the facilities may be disrupted by adverse weather conditions, technical malfunctions, or other problems beyond the control of the system planners. We present a non-linear formulation of the problem where the objective is to maximize the number of demand points that are appropriately covered. We then show how the model can be linearized based on a representation of probabilities through a network structure. We then experiment with different classes of randomly generated problems and explore the effect of different parameters on the final solution. Preliminary results seem to indicate that the number of different facility types and their distribution as well as the correlation between the located facilities are major contributing factors in the final system configuration.

4 - Using Margin of Error Census Data in Location Modeling: the P-Median and Maximum Covering Cases
Mark Daskin, Daoqin Tong, Ruiwei Jiang, Sadie Cox

Every 10 years, the U.S. Census Bureau releases a detailed census of the United States. In addition to the decennial census, every year, the Census Bureau samples over 3.5 million housing unit addresses. This Census Bureau publishes annual estimates of the population within different geographic regions as well as a margin of error or the 90% confidence interval associated with the point estimate of the population. The variability of the population estimates for the block groups (which are constituent parts of tracts) is considerably higher than is the variability of the population estimates for the tracts, as expected.

This study explores the impact that margins of error have on facility location decisions and modeling. We adopt a robust optimization approach to find locations that optimize a criterion when the realized demands are as bad as possible while remaining within the error bounds. We are interested in the following questions:

a) When we account for the margin of error, do the selected locations change? b) How does the margin of error impact the objective function values? c) How bad are the facility locations that we obtain when ignoring the margins of error if the data are subject to errors? d) Do the answers to these questions depend on the model's objective? e) Do the answers to these questions depend on the magnitude of the margin of error?

We formulate several variants of robust median and robust covering problems. The models are tested using Census Bureau data for the city of Ann Arbor, MI. Our results suggest that a failure to account for margins of error in demand estimates can result in the selection of inferior facility sites and in significant errors in the estimated objective function values.

Tuesday, July 6, 14:00-15:30

■ TA-01

Tuesday, 14:00-15:30 - Wuppertal

Discrete Models I

Stream: ISOLDE
Contributed session
Chair: *Justo Puerto*

1 - Ordinal Facility Location Planning
Nicolas Fröhlich, Stefan Ruzika

Commonly, models on facility location planning are based on scalar criteria such as distance, travel time, profits, or costs. However, in many practical applications, this information is not accessible or not ascertainable. Instead, one may have qualitative or ordinal data available. For instance, links between customers and candidate facilities may be assessed as "secure" or "insecure" in the context of security related topics, or as "high potential", "medium potential" and "low potential" in the context of sales forecasting. As the data is entirely ordinal, different solutions may be optimal and are not comparable: is it better to choose a location that implies some clients linked with high potential and some linked with low potential or is it better to link all customers with medium potential? These thoughts result in a set of "ordinally efficient solutions" - similar but not equal to multicriteria optimization. In this talk, we introduce a basic framework for discrete facility location planning with ordinal criteria and highlight similarities and differences to multicriteria location planning. We analyze the theoretical properties such as the number of ordinally efficient solutions or the number of different ordinally non-dominated image vectors. We show that in general, it is NP-hard to compute an ordinal efficient solution and present an integer programming formulation based on weighted sum that facilitates the computation of two distinct solutions. Finally, we investigate a polynomial-time solvable special case on instances that satisfy an ordinal version of the triangle inequality.

2 - A Classification of Location Problems with Edge Interdiction
Stefan Ruzika, Nicolas Fröhlich

In this talk, we consider network location problems where a second player, called the interdictor, may interdict a subset of the edges of the network in order to impair the locational decisions of a decision maker (also called the locator) as much as possible. The optimal strategy of both the locator and the interdictor essentially depends on the objective function of the locator, for example the center, the median or the covering objective function. In the context of interdiction, four different problems can occur depending on the order of the actions of the two opponents and the perspective of optimization: either the locator has to locate the facilities without knowing where the interdictor will interdict the network, which is closely related to robust optimization, or the interdictor has to interdict the network without knowledge of the final locations of the facilities. Both problems can be studied on the one hand from the point of view of the interdictor and on the other hand from the point of view of the locator. In practical application, the results support locating critical facilities in a robust fashion and identifying weak spots with respect to locational decisions. We present a classification scheme for these problems and inform about their complexity. As a result, the problems of the follower can be stated as an integer program, while the problems of the leader cannot be stated as a single-level program of polynomial size. We also investigate the interdictor's problem on tree networks, which is identified as a polynomial special case.

3 - Dynamically Second-Preferred p-Center Problem
Justo Puerto, Yolanda Hinojosa, Alfredo Marín

The next p-center problem was introduced in [1]. The al results reported in that paper show that exact methods are limited and so some papers have proposed heuristics for the p-next center. In this model it is assumed that centers can fail, and thus, customers make their decision taking into account not only their most favorite centers but also a close second opportunity. These results have been applied to a well-known problem in software defined networks: the controller placement Problem. This problem consists in determining on a network the optimal location of controllers and assignment of the switches to the controllers.

This talk elaborates upon the p-next center model. Here, we extend that model to deal with the Dynamically Second-preferred p-center Problem (DSpP). This problem aims at choosing at most p centers so that each demand point can visit at least two acceptable centers and the maximum sum of distances from any demand point to any of its preferred centers plus the distance from any of the preferred centers to any of the centers the user prefers once he is there is minimized. We present three different mixed-integer linear programming formulations that are valid for the problem. We study some strengthening using valid inequalities and some variable fixing criteria that can be applied when valid upper bounds are available. Finally, a computational experience has been performed to compare their utility to solve DSpP using standard solvers for MIP.

[1] Albareda-Sambola M, Hinojosa Y, Marín A, Puerto J. "When centers can fail: A close second opportunity". Computers & Operations Research 2015; 62:145-156.

■ TA-02

Tuesday, 14:00-15:30 - Toronto

Continuous Models I

Stream: ISOLDE
Contributed session
Chair: *Kathrin Klamroth*

1 - l1-norm Mathematical Programming Model Applied to STEM Tomography
Juan Manuel Muñoz-Ocaña, Jose J. Calvino, Elena Fernandez, Miguel López-Haro, Antonio Manuel Rodriguez-Chia

Electron tomography is an image processing technique for reconstructing three-dimensional structures of materials at nanometer scale. These reconstructions are obtained thanks to STEM images (projections) provided by a microscope from different tilt angles. These projections are obtained by a group of parallel electron beams which go through the object modifying their intensities. The microscopes record the intensities on a detector creating sinograms which are the inputs of our reconstruction models.

In the last years, electron tomography reconstruction models are based on total variation minimization considering the sum of the l2-norm of the image gradient as well as the deviation of the reconstructed sinogram with respect to the original data, measured with the l2-norm. We propose to consider an l1-norm total variation model which provides good quality reconstructions. The solutions obtained by the l1-norm model achieve accurate results with respect to the original objects and remove a high level of noise from the reconstruction recovered. This model contains a large number of variables and constraints, therefore, some linear programming techniques are used to provide one efficient way of solving this model for real experiments. Computational results are shown to validate the performance of this linear model to reconstruct electron tomography objects artificially produced. Finally, an experimental tomography reconstruction is carried out to check the quality of the object obtained.

2 - Single-Facility Weber Location Problem with Different Norms at Different Regions
Moisés Rodríguez-Madrena, Martine Labbé, Justo Puerto

The Weighted Region Problem (WRP) is a generalization of the shortest path problem considered in a geometric domain where the travel distance is region-dependent. More precisely, given a subdivision of the plane in polyhedra with different associated weights, the WRP asks for the Euclidean shortest path between two points but taking into account that the distance traversed along a polyhedron has to be multiplied by its associated weight.

In this talk we consider a variant of the WRP in which each polyhedron of the subdivision is endowed with a different lp-norm and feasible paths are restricted to be simple, i.e. a path can visit each polyhedron at most once. We propose a solution scheme for the problem completely different from the ones proposed for the WRP and its previously considered variants. This solution scheme consists in the representation of the problem as a Mixed-Integer Second Order Cone Problem (MISOCP), which is achieved using the lp-norms modeling procedure given in [1]. MISOCPs can be solved nowadays up to any degree of accuracy with commercial solvers.

We also study the single-facility Weber location problem that results in this subdivision of lp-normed polyhedra. The resulting continuous location problem in the subdivision generalizes other Weber problems in the literature, in particular those in which distances between points are measured in two different ways depending on which of two regions the points are located. We present two MISOCP formulations for the problem, theoretically compare their properties, and propose a preprocessing scheme to improve their performance. The usefulness of our approach is validated reporting some preliminary computational experiments.

[1] Blanco et al. (Comput Optim Appl 58(3):563-595, 2014).

3 - A Branch and Price Approach for the Multifacility Continuous Monotone Ordered Median Location Problem
Ricardo Gazquez, Víctor Blanco, Diego Ponce, Justo Puerto

The Ordered Median Problem is a modeling tool, that provides flexible representations of a large variety of problems, which include most of the classical location problems considered in the literature. While most of the attention in Location Theory has been paid to discrete location problems (p-median, p-center, etc.), the mathematical origins of this theory are closer to Continuous Location, through the classical Fermat-Torricelli or Weber problems. In this presentation, we analyze a very general family of Continuous Location problems, namely multifacility continuous monotone ordered median location problems (COMP, for short), in which a given finite set of demand points is provided and the goal is to find the optimal location of a given number of new facilities in the space such that: (1) each demand point is allocated to a single facility; (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. We consider a general framework for the problem, in which the ordered median functions are assumed to be defined by means of nonnegative monotone weights. A compact Mixed Integer Linear (or Non Linear) programming formulation is presented for the problem and we explore a different strategy to solve efficiently the COMP family of problems by means of a set partitioning formulation. We develop a column generation procedure embedded within a branch-and-price approach to solve it, which includes the design of exact and heuristic resolution procedures of a pricing problem and the determination of an adequate branching rule. We report the results of an extensive battery of computational experiments.

■ TA-03

Tuesday, 14:00-15:30 - Naples

Location & Transportation I

Stream: ISOLDE
Contributed session
Chair: *Gilbert Laporte*

1 - Hub Location Model of Platoon Formation Center for Truck Platooning
Saw Aung, Daisuke Watanabe

Truck Platooning is a grouping of freight vehicles into connected vehicle convoys using electronic coupling as an application in automated driving technology with the aim of saving fuel, reducing travel costs, and improving infrastructure efficiency. Therefore, it is critical to locate platoon formation centers (PFCs) for forming and deforming platoons. In this study, we will apply the hub location model to find the optimal location of PFCs. The objective is to minimize the total travel cost for each origin-destination pair via two PFCs. Unlike commonly used discount factor calculation due to economies of scales in the previous studies, we will consider the benefits solely thanks to the platooning process. Two different types of locational data, which represent uniform or less uniform distribution across the interest region, are used for optimization analysis. Three different platooning scenarios— all manually-driven platooning trucks, one manually-driven leading truck, and the following automated trucks, and all fully automated trucks are considered for the optimization process. All the trucks from a certain origin are assigned to single or multiple PFCs for (de)formation of platoons. Moreover, the number of platooning trucks is hypothetically varied from 3 to 10 for optimization. In addition, the number of PFCs is also varied for analysis. All these aforementioned methods can decrease the total travel cost, from which we can conclude the general characteristics of the platooning optimization.

2 - Optimizing the Deployment of Mobile Eco-Points for a Selective Collection of Municipal Waste
Ramón Piedra de la Cuadra, Guido Marseglia, Juan A. Mesa, Francisco A. Ortega Riejos

The rapid and constant increase in urban population has led to implied a drastic rise in urban solid waste production with worrying consequences for the environment and society. In many cities, an efficient waste management combined with a suitable design of vehicle routes (VR) can lead to benefits in the environmental, economic, and social impacts. The general population are becoming increasingly aware of the need for the separation of the various categories of municipal solid waste. The numerous materials collected include glass, PET or batteries, and electric components, which are sorted at the eco-points. The management of eco-points gives rise to several problems that can be formulated analytically. The location and number of eco-point containers, the determination of the fleet size for picking up the collected waste, and the design of itineraries are all intertwined, but present computationally difficult problems, and therefore must be solved in a sequential way. A mathematical model has been formulated in this presentation, based on the Bin Packing (BP) and VR schemes, for the deployment of routes of mobile containers in the selective collection of urban solid waste. A heuristic algorithm has also been developed, which considers two different configurations of the containers to solve the proposed mathematical programming model. The results obtained from the numerical simulations show the validation of the proposed methodology carried out for the specific real case study.

3 - Public Transport-based Crowd-shipping with Backup Transfers
Kerim Uygur Kızıl, Barış Yıldız

With the rising urbanization and booming e-commerce, traditional last-mile delivery systems fail to keep up with the exploding demand and to satisfy the need for faster, cheaper, and more environmentally friendly deliveries. Several new approaches are put forward as an alternative to classical delivery systems in this regard, yet none of them offers the same level of flexibility, capacity, and managerial control by itself. This paper proposes a new last-mile delivery model that combines several new approaches and technologies to address this issue. More precisely, we suggest using public transit as a backbone network completed by automated service points, crowd-shipping, and backup transfers with zero-emission vehicles to provide a low-cost express delivery service. The design problem for the envisioned system is formulated as a two-stage stochastic program where first-stage decisions correspond to the locations of the public transportation connections selected from a finite set, similar to a hub location problem. On the other hand, second-stage decisions correspond to routing decisions. A branch-and-price (BP) algorithm is devised to solve the design problem. Taking advantage of the nearly decomposable structure that would emerge in possible real-world applications, our study presents the first example of using decomposition branching in a BP framework to enhance computational efficiency. Extensive computational studies on realistic problem instances reveal valuable managerial insights for the proposed system and attest to the efficacy of the suggested methodology.

Tuesday, July 6, 16:00-17:30

■ TB-01

Tuesday, 16:00-17:30 - Wuppertal

Stochastic Models

Stream: ISOLDE
Contributed session
Chair: *David Sayah*

1 - A Stochastic Dynamic Facility Location Problem with Modular Capacity Adjustments and Delayed Demand Satisfaction
Teresa Melo, Isabel Correia

We consider a stochastic multi-period facility location problem with two customer segments, each having specific service requirements for uncertain demand. 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. We propose two stochastic models that differ in the framework for capacity adjustment. In the first two-stage stochastic model, all decisions related to the design of the facility network are modeled as first-stage decisions. Demand allocation decisions are deferred to the second stage. The second model presents an alternative strategy, which is particularly relevant when capacity adjustment decisions have a tactical nature. In this case, first-stage decisions define a schedule for opening facilities and setting their initial capacities. The phased capacity expansion and contraction of facilities along with demand allocation represent the recourse decisions. We develop the extensive forms of the associated 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. Numerical experiments with randomly generated instances demonstrate the usefulness of the proposed enhancements. Useful insights are also provided on the impact of the two different frameworks for planning capacity adjustments on the network configuration and its total cost.

2 - A Two-Stage Stochastic Programming Model for Locating-Relocating of Fixed and Mobile Ambulance Stations
Ehsan Nikbakhsh, Sepideh Mirsaeedi

Emergency medical services (EMS) aim to reduce human mortality, disability, and suffering during emergencies. Due to increased demand and time to provide service in metropolitan areas, many EMS calls are delayed every day worldwide, which has a substantial social and economic impact on societies. This situation could be improved via carefully locating ambulance stations and hence reducing service time and consequently fatalities. This study proposes a dynamic ambulance location-relocation model to minimize the fixed investment costs, ambulance maintenance costs, and penalties for relocation and locating mobile stations. The optimal locations of fixed and mobile ambulance stations are determined considering demand and travel time uncertainty. Relocation of ambulances between stations could compensate for the lack of resources and spatial-varying demand during the day. A two-stage stochastic programming model and a progressive hedging algorithm are proposed to tackle the problem. The proposed model and method are applied to a real dataset obtained from the Tehran EMS center. The computational results demonstrate that mobile stations positively impact system performance, ensuring proper demand coverage and an acceptable total cost. Moreover, relocating mobile stations leads to the maximum demand coverage when having a small number of ambulances. Finally, the proposed progressive hedging algorithm is shown to be competitive against commercial optimization packages in terms of CPU time and solution quality.

3 - Drones for Relief Logistics under Demand Uncertainty
Okan Dukkanci, Achim Koberstein, Bahar Yetis Kara

This study presents a humanitarian delivery problem, where critical relief items are distributed to the affected people gathered at population points after a disaster in particular an earthquake. Since roads may be blocked by possible debris after an earthquake, two different sizes of drones will be used as a primary transportation mode; small drones operating with the help of trucks and big drones operating directly from the depot(s). As the exact time, location and magnitude of an earthquake cannot be predicted, it is a highly stochastic event. Therefore, the demand uncertainty is considered based on different earthquake scenarios in terms of their location and magnitude. The objective is to minimize the total unsatisfied demand subject to a time bound constraint on deliveries and range and capacity limitations of drones. A two-stage stochastic programming formulation and its deterministic equivalent problem formulation are presented. As an exact solution approach, the scenario decomposition algorithm is implemented. To apply this study to a real-life application, a case study is conducted based on western (European) side of Istanbul, Turkey. One of the main reasons is to choose Istanbul is that geological studies and surveys indicate in a near future, a major earthquake is expected to happen in Istanbul. The talk will present computational results on the performance of the scenario decomposition algorithm, value of stochasticity and expected value of perfect information under different parametric settings.

■ TB-02

Tuesday, 16:00-17:30 - Toronto

Districting Models

Stream: ISOLDE
Contributed session
Chair: *Jörg Kalcsics*

1 - A Novel Territory Design Approach for On-time Last-mile Express Delivery Services
Roger Z. Rios-Mercado, Gabriela Sandoval, Eduardo Álvarez-Miranda, Jordi Pereira, Juan Díaz

Last-mile logistics correspond to the last leg of the supply chain, i.e., the delivery of goods to final customers, and they comprise the core activities of postal and courier companies. In this work we address a last-mile logistic design problem faced by an express delivery firm in Chile. The operational structure of the company is based on the division of an urban area into smaller territories (districts) and the outsourcing of the delivery operation of each territory to a last-mile contractor. Due to the increasing volume of postal traffic and a decreasing performance of the service, in particular for the case of express deliveries, the company is forced to redesign its current territorial arrangement. Such redesign results in a novel optimization problem that resembles a classical districting problem with additional quality of service requirements. In contrast with traditional approaches seeking to minimize routing costs, here we aim at maximizing the number of on-time deliveries. This novel problem is first formulated as a mathematical programming model and then a specially tailored heuristic is designed for solving it. The proposed approach is tested on real-world instances. The results indicate significant improvements in terms of the percentage of on-time deliveries achieved by the proposed solution when compared to the current districting design of the company. Furthermore, by performing a sensitivity analysis with respect to different levels of demand, we show that the proposed approach is effective in providing districting designs capable of handling significant increases in the demand for express postal services.

2 - Design of a Zone Tariff System in Public Transportation
Lorena Reyes-Rubiano, Sven Müller, Knut Haase

The design of tariff systems greatly determines the expected revenue of public transport organizations. This paper presents a novel approach to design a counting zones tariff system that maximizes the expected revenue for a given price system. The proposed approach aims to partition the transport network into zones and determine a price per zone. We assume that the price per zone takes a discrete set of values, the number of public transport trips depends on the price system, public transport passengers always choose the time-shortest path. In this paper, the counting zones tariff system ensures contiguous zones using primal and dual graphs based on the public transport network. Additionally, this paper presents a strategy to reduce the complexity of the problem by reducing connections in the public transportation network. The proposed approach heuristically selects a set of connections to be considered to solve the tariff zone planning problem. In extensive numerical studies, we optimally solve artificial test instances of size 36, 81 and 121 zones (nodes) and evaluate which of the proposed approaches perform best. For each instance size, we consider ten different networks are evaluated (10 seeds), in which the demand and travel times differs between networks. The results demonstrate that expected revenue can be maximized without decreasing transit ridership. Also, this paper sheds light to public service providers on how to enforce contiguous tariff zones to maximize the expected total revenue.

3 - Solutions for Districting Problems with Chance-Constrained Balancing Requirements
Antonio Diglio, Juanjo Peiró, Carmela Piccolo, Francisco Saldanha-da-Gama

In this talk, a districting problem with stochastic demands is investigated. The goal is to divide a geographic area into p contiguous districts such that, with some given probability, the districts are balanced with respect to some given lower and upper thresholds. The problem is cast as a p-median problem with contiguity constraints that is further enhanced with chance-constrained balancing requirements. The total assignment cost of the territorial units to the representatives of the corresponding districts is used as a surrogate compactness measure to be optimized. Due to the tantalizing purpose of deriving a deterministic equivalent for the problem, a two-phase heuristic is developed. In the first phase, the chance-constraints are ignored and a feasible solution is constructed for the relaxed problem; in the second phase, the solution is corrected if it does not meet the chance-constraints. In this case, a simulation procedure is proposed for estimating the probability of a given solution to yield a balanced districting. That procedure also provides information for guiding the changes to make in the solution. The results of a series of computational tests performed are discussed based upon a set of testbed instances randomly generated. Different families of probability distributions for the demands are also investigated, namely: Uniform, Log-normal, Exponential, and Poisson. The obtained results show the capability of the proposed procedure to obtain high-quality solutions to the problem for most of the considered instances in limited computational times.

Wednesday, July 7, 14:00-15:30

■ WA-01

Wednesday, 14:00-15:30 - Wuppertal

Discrete Models II

Stream: ISOLDE
Contributed session
Chair: *Stefan Nickel*

1 - Robust Kernels in Capacitated Facility Location Problems
Hannah Bakker, Stefan Nickel

The systematic relationship between the performance of certain location decisions and the spatial characteristics of the underlying problem instance has been implicitly exploited in various solution procedures, e.g., kernel search heuristics. Yet, the analysis of spatial patterns and their effect on the optimality of certain location decisions has received little attention when it comes to the modeling of location problems. An explorative analysis of capacitated facility location problems shows that certain decisions account for large parts of the solution quality, while others are less relevant. These location decisions are not only robust towards significant data perturbations but also appear in multiple optimal solutions or sets of k-best solutions. We refer to this set of decisions as robust kernels. In this talk, we present a way to define robust kernels as well as a means to quantify their relevance in a given facility location instance. We systematically explore, which spatial properties of an instance contribute to the existence of robust kernels on a wide range of self-generated problem instances. It shows that robust kernels can be found in the instances of several well-known data sets from literature. Furthermore, we explore the likelihood of different facilities belonging to such a robust kernel and assign them a kernel likelihood value. We then examine the correlation between this likelihood and other facility characteristics. We conclude by highlighting ways to exploit the existence of robust kernels and the kernel likelihood not only in the solution procedure but already at a modeling stage.

2 - Minimum Cost b-Matching Problems with Nonconvex Neighborhoods
Inmaculada Espejo, Raúl Páez, Justo Puerto, Antonio Manuel Rodriguez-Chia

Matching problems are among the most well studied problems in combinatorial optimization. Many applications of the matching problems can be formulated as optimization problems defined on networks. In many real world applications, the exact location of the nodes is unknown and the assumption of modelling the nodes by points should be revised. In this sense, we propose to consider uncertainty regions or neighborhoods in which we are assured the points will lie. In this talk, we deal with minimum cost b-matching problems on graphs where nodes are represented by non-necessarily convex neighborhoods and the costs represent distances between neighborhoods. The goal is twofold. On the one hand, find a b-matching in the graph and on the second hand, a point should be identified in each neighborhood to be connection point among the edges determining the b-matching. In addition, these points should verify that the sum of the length (cost) of the edges defining the b-matching is minimized. Different variants of the minimum cost b-matching problem are considered depending on the criteria of matching: perfect matching problem, maximum cardinality matching problem, maximal matching problem and the a-b matching problem. The theoretical complexities of solving each one of these problems are analyzed. Different mixed integer non linear programming formulations are proposed for each of the considered problems and then reformulated as SOC formulations. An extensive computational experience shows the efficiency of the formulations to solve the proposed problems.

3 - Location and Routing Decisions for the Determination of Long Paths in Board Games
Konstantin Kraus, Kathrin Klamroth, Michael Stiglmayr

In the board game Thurn & Taxis, players aim to build the most rewarding postal carrier routes across Bavaria and some surrounding regions. The board displays a map of selected cities (nodes) with a connecting road network (edges). Players build acyclic paths modeling, e.g., postal carrier or taxi routes, one at a time, by consecutively collecting city cards that extend the currently active path. While aiming at longest paths in general, there is a trade-off between hoping for suitable cities to become available, and scoring (and hence closing) an intermediate path to reduce the risk of not being able to extend it any further, in which case the path is discarded. In this talk, we focus on the location and routing decisions that have to be made in this game, and hence omit further details regarding the rules. The problem of selecting the next city from a finite candidate set of available cards is modeled as a discrete location problem. Since the reward increases superlinearly with the length of a path, the objective is defined by the probability of being able to further extend a path in the subsequent iterations. This probability depends, on one hand, on the degree of the considered nodes, and on the other hand on the number and type of city cards that remain available in the deck. We introduce the concept of tentacular paths to estimate the likelihood of long extensions and discuss modeling aspects as well as different solution approaches. We present preliminary numerical results for exact and heuristic approaches.

■ WA-02

Wednesday, 14:00-15:30 - Toronto

Applications I

Stream: ISOLDE
Contributed session
Chair: *Olivier Péton*

1 - Multi-channel Distribution in the Banking Sector and Network Restructuring
Silvia Baldassarre, Giuseppe Bruno, Carmela Piccolo, Diego Ruiz-Hernandez

Banking groups in Europe are facing the challenge of restructuring their branch networks. This phenomenon is due to (i) the market overlapping strategies adopted during the 1990s, which produced oversized networks, and to (ii) the digital transformation, that led to the integration of digital and physical channels in the service delivery models (i.g., mobile banking). In the new emerging scenario, banks aim to leverage digital channels for the delivery of basic service (i.g., cash transactions), thus dedicating branches to more complex and added-value operations (i.g. loans). In order to adapt the branch networks to the new business model, they are undertaking different actions: (i) closing existing branches; (ii) introducing different specialized branch formats; (iii) outsourcing basic services. This work aims to formulate a mathematical programming model able to support the branch network restructuring process. The model considers three types of branches, providing different categories of services. They are organized according to a three-level hierarchical structure and each level is associated with a covering radius, representing the related user accessibility condition to be guaranteed. A further category of facilities is considered, namely external facilities, which may support internal ones in the provision of a subset of services. The objective is to identify the network structure able to serve all the demand and minimize the total operating costs. A specific parameter is introduced to regulate the outsourcing level that the bank is willing to achieve. The model is tested by considering the case of an existing network in an Italian city. The obtained results show the capability of the model to provide interesting scenarios and fruitful managerial implications.

2 - Facility Location with Financial Decisions through Adjusted Present Value
Hamidreza Rezaei, Nathalie Bostel, Vincent Hovelaque, Olivier Péton, Jean-Laurent Viviani

The way of financing large investments over a long-term horizon has a strong impact on the company's financial situation and future value. However, financial considerations are generally omitted in supply chain network design models. This work extends previous researches by jointly considering the cash flows arising from logistics and financial decisions. The objective function is to maximize the value of the company. To do so, the Adjusted Present Value (APV) of the company is identified as a relevant indicator.

We propose a mathematical model that enhances classical facility location models by considering the tax shield benefit related to the value of the debt and its associated expected bankruptcy cost. We propose two optimization approaches: a direct (called integrated) approach which maximizes the APV in a single step, and a decomposition approach (called sequential) consisting of first optimizing the logistical decisions by maximizing the Net Present Value (NPV), and then optimizing the financial decisions through APV maximization.

The performance of the proposed model is evaluated through a set of generated instances. Both approaches are compared on various relevant logistical and financial indicators. We show that the sequential approach is more tractable and yields very close results to those of the integrated approach. We also show how the integrated approach tends to be less conservative and favors larger or earlier investments. This analysis shows that coordination between supply chain decisions and financial decisions slightly alters the supply chain network configuration and increases the firm value.

3 - A Deep Reinforcement Learning Algorithm for Dynamic Location-Allocation Problem in Vertical Heterogeneous Communication Networks
Cihan Tugrul Cicek

There is a growing interest in the next generation communication architectures, especially in vertical heterogeneous networks (vHetNets), which consist of multiple layers such as low-altitude platforms (LAPS), high-altitude platforms (HAPS), and satellites. Different from the legacy terrestrial networks, this new architecture brings many challenges due to the involvement of a massively large number of flying vehicles that require well-organized orchestration to allow each component in the network to function in harmony. For efficient orchestration, the network must be autonomous, intelligent, resilient, self-organizing, and self-controlling to reduce the cost and risk of human intervention. In this study, we address and develop efficient solution algorithms to solve one of the significant problems arising in dynamic vHetNets. We consider a multi-level dynamic location-allocation problem in which different components functioning in a vHetNet, e.g. ground base stations, LAPS, HAPS, and satellites, are organized to satisfy uncertain user demand. We develop a Discrete-Time Markov Process (DTMP) to minimize the total network cost by determining the location of flying vehicles, recharging decisions, bandwidth allocations, and user associations. We propose a deep reinforcement learning (DRL) algorithm in which each component is trained individually but feeds a shared central memory to allow all other components in the network would exploit the environment. Our computational study shows that the proposed DRL algorithm outperforms several metaheuristics over synthetically generated datasets. We further perform a case study with a real dataset in which call detailed records of users are provided. We show that the DP approach would decrease the network cost by 11% on average.

Wednesday, July 7, 16:00-17:30

■ WB-01

Wednesday, 16:00-17:30 - Wuppertal

Continuous Models II

Stream: ISOLDE
Contributed session
Chair: *Lin Dearing*

1 - Computational Results for Primal and Dual Algorithms Used to Solve Three, Continuous, One-Center Location Problems with Euclidean Distance in n-Dimensions
Lin Dearing, *Mark Cawood*

Computational results are presented for primal and dual algorithms, recently developed by the authors, to solve three continuous one-center location problems using Euclidean distance in n-dimensions. The problems are the min-max location problem with respect to a set of points (the minimum covering ball of a set of points), the min-max location problem with respect to a set of points plus a fixed distance for each point (the minimum covering ball of a set of balls), and the min-max location problem with respect to a set of points and weighted distances (minimum covering weighted ball of points). The common approach for each algorithm is a path-search method, where the path is determined by the intersection of bisectors of pairs of points in a set of active points at each iteration. The algorithms differ in that the search path is either a ray, for the min-max location problem, the arc of a circle in n-dimensions for the min-max location problem with weighted distances, or a two-dimensional conic section (hyperbola, ellipse, or parabola), for the min-max location problem with fixed distances. In each case, complementary slackness is maintained for points on the search path. Also, primal feasibility is maintained for the primal algorithms, and dual feasibility is maintained for the dual algorithms. The step size is computed explicitly at each iteration. The presentation includes a brief overview of the common properties of each problem and the structure of the algorithms. Computational results are presented for each algorithm and problem type with dimensions up to 1,000, and up to 10,000 points.

2 - Variable Facility Size in the Multiple Obnoxious Facilities Location Model
Pawel Kalczynski, *Zvi Drezner*

The obnoxious facilities location problem (locating facilities that have a negative impact on surrounding communities) was initiated in the 1970s and intensively analyzed in the literature. In the models proposed in the literature, it is assumed that all facilities have the same size. In this paper, we propose to construct facilities of different sizes. Facilities closer to communities should be smaller so that their impact will be lower, while farther facilities can be larger without increasing the impact on the most affected community. We consider two continuous location models: (1) the closest facility and (2) cooperative and propose starting solutions for improvement algorithms for these models.

We compare the results with variable facility sizes to those with fixed-size facilities. In extensive computational experiments on pseudo-random instances with 100 and 1000 demand points, we found in some cases that the negative impact on the most affected community is reduced by more than 50% when facilities of variable sizes are established. In addition, our approach is illustrated with a case study of 355 cities and 55 national and state parks in Colorado.

When competent practitioners are asked to find locations for obnoxious facilities, such as landfills or polluting factories, they should be able to formulate it as a non-linear program and solve it by available software. The specially designed algorithms proposed in this paper find much better configurations that significantly reduce the negative impact on communities and the environment.

3 - Balanced Facility Location and the Stackelberg Game
Thomas Byrne, *Jörg Kalcsics*

A common concern of service providers is that a fairness of service provision is met, to ensure that their facilities are not overloaded or that there is not a noticeable disparity between the customers under the care of one of their facility's agents. When considering this concern it is often the specific districting (cell of the Voronoi diagram) that communicates the quality of a solution; a perfect location to secure demand may not be useful if it causes congestion in a particular facility. In these cases the fairness, or balance, of the solution is of great importance. Perhaps surprisingly, these non-competitive enterprises have convenient links to competing ones. In the case of facility location under competition, often the positions of existing facilities are known and optimal placements are found in response to these. However, of equal importance are the decisions as to where the first locator should place their facilities knowing that other competitors will follow their lead. A game-theoretic approach to the market share problem is the Stackelberg game, in which two players place points within a playing arena. Each player wins the fraction of the board for which one of their points is closest and each player's goal is to maximise their total area. While a simplification of this game, where each player wishes only to win more than the other player, has recently been solved, the Stackelberg game proves far more complex with a great deal resting on the structure of the Voronoi diagrams. In this talk we explore 'balanced' facility location according to Manhattan distance in a rectangular playing arena across which demand is uniformly and continuously distributed, and discover how this can help us find and prove optimal strategies in the one-round Stackelberg game.

■ WB-02

Wednesday, 16:00-17:30 - Toronto

Applications II

Stream: ISOLDE
Contributed session
Chair: *Rajan Batta*

1 - Location Models for Ammunition Support Activities
Larry Snyder, *Yihe Zhuo*, *Robert Storer*, *Luis Zuluaga*

We consider the problem of locating ammunition stockpiles ("pads") at a military base in order to minimize the risk of a chain reaction if one of the stockpiles should explode (due to an accident or attack). The optimization considers the amount and hazard class of material to be stored, land restrictions, risk, and stock retrieval times while meeting separation distance safety requirements (distance to inhabited buildings, public traffic routes, etc.).

Although the true problems are essentially continuous location problems (pads may be located at any point within a feasible region), we discretize the feasible region by overlaying a grid on it and allow pads to be located only at the grid points. We develop several mixed-integer optimization models with alternate objective functions representing different desired characteristics of ammunition layouts. For example, some of our models attempt to spread the pads out in order to maximize the distances among them, while others attempt to place them close together (while satisfying standoff distance requirements) in order to maximize the land that is left available for other uses. Similarly, some of our models assume that the pads must be arranged along pre-established "access roads," while others assume the pads may be placed at any feasible point.

In addition to our MIP models, we develop heuristics that execute quickly. Some of our heuristics are based on greedy-type approaches, while others use approximations for the MIP models themselves. We test our approaches on real-world instances. Finally, we discuss how our approach can be extended to classical facility location problems such as the p-dispersion sum problem.

2 - Server Positioning and Response Strategies for Spatially Arriving Jobs with Degradation: Light and Medium Traffic Cases
Rajan Batta, Fatemeh Aarabi

Job scheduling has an extensive range of application that range from scheduling jobs in industry to public-sector applications such as responding to medical emergencies. In most of the previous studies, the processing time of jobs is considered to be a fixed amount of time, but in reality, there are situations that processing time is a function of the "start" time. In many applications, there are two system characteristics that should be considered simultaneously: (a) jobs have degradation rate, and (b) jobs are distributed spatially. We aim to solve different categories of spatially distributed jobs with degradation. Common examples of these problems are fire fighting, pothole repair, and humanitarian relief to victims after a disaster. In scheduling problems with spatially distributed jobs with degradation, time is a critical aspect.

The main contributions of this paper are as follows:

1. A queuing framework is developed to analyze job scheduling for situations that simultaneously have spatially distributed jobs and degradation effects.

2. Three situations relative to the queuing framework are highlighted, light traffic, medium traffic and heavy traffic, with solutions presented for the light and medium traffic cases.

3. It is shown that the p-median problem provides the optimal set of server locations for the case of light traffic; no server cooperation is needed in this case.

4. An extended Hypercube queuing model tailored to handle spatially distributed jobs with degradation rate is formulated for the medium traffic case. The main finding is that higher job degradation rates and higher cost of assigning a job to a backup server result in lower server cooperation.

3 - Location Analytics for Strategic Defense in Baseball
Alan Murray, Antonio Ortiz, Seonga Cho

The game of baseball is uniquely American in many ways, but shares similarities to cricket and rounders, among other games, and as a result there has been considerable historical speculation about its origins. Nevertheless, the popularity of modern baseball extends worldwide, both in terms of participants and spectators, among the most popular sports in many countries. Estimates of over 25 million athletes play the sport (baseball or softball). Baseball is a game played by two teams involving a pitched ball that a batter attempts to hit. Upon a hit, the batter tries to advance across three bases in order to return to home plate without being tagged out. Doing so records one run. There are many rules and requirements for play, but the essence of the game is that when a batter is able to hit the ball in the area of play, they may advance bases. A hit that is caught by the opposing team registers an out. Otherwise, the batter may run to consecutive bases as long as they are not tagged by an opposing player that has possession of the ball. Standing on a base without being tagged en route constitutes safe advance of the bases. Of strategic significance is that the fielding team must position players in order to catch or field a hit ball, seeking an out (either by catching a hit ball before it touches the ground or by tagging a batter before they reach a base). Statistics and analytics have played an increasingly important role in baseball, enabling insights and gains in predictive capabilities. This talk explores the potential of location analytics in the strategic positioning of players.

■ WB-03

Wednesday, 16:00-17:30 - Naples

Location & Transportation II

Stream: ISOLDE
Contributed session
Chair: *Boglárka G.-Tóth*

1 - The Location-or-routing Problem
Okan Arslan

The facility location and vehicle routing are two closely related problems in operations research. In this talk, we uncover a new connection between the location and routing decisions by introducing the location-or-routing problem, in which a customer can be covered either by a facility or by a vehicle visit, hence the problem name. Each selected facility covers the customers in the neighborhood around itself defined by a coverage range, similar to the covering location problem. If a customer lies beyond the coverage range of any open facility, they are served by capacitated vehicles dispatched from the open facilities. This new problem has applications in location optimization of retail stores, supermarkets, shopping malls, schools, urban delivery centers and medical testing centers. We present a set covering model with an exponential number of variables for solving the problem. As a solution method, we develop an exact branch-and-price algorithm and provide insights on the total costs. We show that the facility range is an important determinant of the number and location of open facilities. We find that the vehicle routes play a decreasing role on the total cost as the facility range increases. Furthermore, experiments on random graphs show that the total cost decreases almost linearly as the facility coverage range increases. We discuss the reasons behind this observation using arguments from asymptotic analysis and find that it is a common property when the customers are uniformly distributed.

2 - On the Impact of Traffic Changes for Facility Location Problems
Ágnes Vida, Boglárka G.-Tóth

Network location problems are commonly associated with real world situations such as locating a new facility in a city or setting up a new server in a computer network. In these real world situations, changes can come up quite often, such as a busy road because of morning hours, or a broken connection in a computer network. This kind of problems give the motivation of our research.

During our previous work, we inspected how a network operates, when we block different amounts of random edges, or modify edge weights near dedicated vertices, where it is more likely to have high traffic. We have studied how these changes influence the solution of the p-median or p-center problem.

In this work we continue our research by analyzing the results of the p-median problem when both the morning and the afternoon traffic is taken into account. With these we have solved two new models, the weighted mean of the different cases and where we bound the maximum change. In the latter, the motivation was to see, how the solution varies if we set a maximal change rate that we can still tolerate during the morning or in the afternoon traffic. We also plan to investigate a model, where the robust solution is sought on such dynamic networks for the p-median problem. It would be interesting to compare the solutions by the different new models, and find for each model the best situation where it is worth to use. During our work, we used different road graphs to get a complex picture about the results, which will be discussed in the talk.

3 - Event-based MILP Model for Ride-hailing Applications
Daniela Gaul, Michael Stiglmayr, Kathrin Klamroth

Cities are increasingly suffering from particulate pollution and congestion. One way for cities to address these challenges is the concept of ride hailing: an 'on-demand ride hailing service' is a taxi-like service, typically operated by mini-buses, where customers submit pick-up and drop-off locations via their smartphone. Customers with similar origin or destination are assigned to the same ride whenever this is economically or ecologically useful. Ride-hailing services require efficient optimization algorithms to simultaneously plan routes and pool users in shared rides. We consider a static dial-a-ride problem (DARP) where a series of origin destination requests have to be assigned to routes of a fleet of vehicles. Thereby, all requests have associated time windows for pick-up and delivery, and may be denied if they can not be serviced in reasonable time or at reasonable cost. At the beginning all vehicles are situated at the vehicle depot, a central location, waiting for requests. Rather than using a spatial representation of the transportation network we suggest an event-based formulation of the problem: nodes in the event-based graph represent feasible allocations of users to vehicles and arcs describe the transition from one user allocation to another. The event-based formulation results in significantly improved computational times. While the corresponding MILP requires more variables than standard models, it has the advantage that capacity, pairing and precedence constraints are handled implicitly. The approach is tested and validated using a standard IP-solver on benchmark data from the literature. Moreover, the impact of, and the trade-off between, different optimization goals is evaluated on a case study in the city of Wuppertal (Germany).

Thursday, July 8,14:00-15:30

■ HA-01

Thursday, 14:00-15:30 - Wuppertal

GIS-related Problems

Stream: ISOLDE
Contributed session
Chair: *Michael Kuby*

1 - Multi-objective Location Problem of Japanese Roadside Stations with Detailed GIS Data
Yudai Honma, Shinichiro Kai, Ryota Horiguchi, Kazushi Sano, Takashi Oguchi

In Japan, there are plenty of "Roadside Stations," which are government-designated rest areas along roads and highways. Their basic concepts are proposed by the Ministry of Land, Infrastructure, Transport, and Tourism (MLIT) and are regarded as one of the most successful examples of government-oriented business models. The facilities provide market and communication spaces, and they are utilized not only by travelers but also by local residents. Since there are various usages, the optimality of their locations depends on the situations. Accordingly, as a part of MLIT's official projects, we have been evaluating the desirability of their locations based on multi-objective optimizations. This research focused on the greater Tokyo region with 12 prefectures and solved the optimal locations of roadside stations. In formulations, we prepared 2*2*2=8 objective functions as a combination of the following factors; (i) minimizing the travel time or maximizing coverage, (ii) population-based demands or flow-based demands, (iii) optimizing the nearest facility or the second-nearest facility. These eight functions were optimized not only as single-objectives but also as multi-objectives. We also introduced very detailed GIS data, including the actual road networks with nearly 1 million links, population database with 47,340 meshes, and flow database with 45,868 pairs. In the computation, we eliminated several far-allocation variables (this technique is based on the paper by R.L. Church in 2018) to solve them in a shorter time. These results will be an essential reference to determine future transportation policy in Japan.

2 - Collaborative "Geodesign" for Alternative Fuel Station Location Using Open-Source COLLABLOCATION Software
Michael Kuby, Fangwu Wei, Oscar Jaramillo Lopez, Keiron Bailey, John Fowler, Scott Kelley, Darren Ruddell, Rhian Stotts, Daoqin Tong

Geodesign is a collaborative GIS planning method for use in stakeholder workshops. Geodesign generally consists of three interrelated components: 1. Workshop participants with local knowledge and industry expertise from different stakeholder perspectives 2. An easy-to-use mapping platform that participants can use to visualize relevant map layers, create new geographic solutions ("designs"), save and evaluate their solutions using scientific data, and share and compare solutions across different breakout groups. 3. A structured workshop process for the participants to use the tool to converge towards a consensus recommendation by the end of the workshop. Originally developed for land-use planning, we have adapted the geodesign approach to multi-facility location problems. This presentation introduces our platform called COLLABLOCATION: a collaborative laboratory for location planning (https://collablocation.shinyapps.io/home/). It is an open-source, intuitive, online mapping tool built with R, Shiny, MongoDB, and Open Street Maps for working with points, not polygons. The generalizable structure of the software includes features found in single-user spatial decision support systems (SDSS) plus specialized capabilities for handling multiple groups in real time at a workshop. This presentation presents the tool and results of two workshops for planning a network of alternative-fuel stations. Applications were built

for planning compressed natural gas truck stops across the southwestern USA and hydrogen station planning in Hartford, Connecticut. Beyond these alternative-fuel applications, the basic features of the software could be applied to a variety of facility types at any geographic scale.

■ HA-02

Thursday, 14:00-15:30 - Toronto

Location & Transportation III

Stream: ISOLDE
Contributed session
Chair: *Elena Fernandez*

1 - Linear Programming to Estimate Cognitive Location Costs from Observed Paths
Hiroyuki Hasada, Yudai Honma, Daisuke Hasegawa

When moving from an origin through some locations to a destination in urban networks, we usually try to transport as rationally as possible. Though its path often differs from the real shortest path, it should be the shortest path based on his/her cognitive costs of locations on the network. The purpose of this research is to estimate such cognitive costs from observed paths. This model enables us to find locations where congestions or accidents happen. Moreover, it is also helpful to understand how people recognize spatial locations in cities. Our mathematical concept is an inverse problem (IP) of the shortest path problem (SPP); an observed path P for OD pair is given and find link costs so that P becomes its shortest path. Our objective function minimizes the gap between the cost of the observed path and that of the real shortest path. We focus on the dual problem of SPP, which can be regarded as the maximization of the potential of nodes. Since one SPP is normal minimization and another SPP becomes a maximization, we can successfully join two objectives as linear programming. In addition to examining the theoretical characters of the problem, we also calculate a numerical example based on a small network with hypothetical path observations. In the field of urban planning, it is an important topic to understand how attractive the facilities are where people stop over. Our method can be utilized to estimate their cognitive costs, namely their attractiveness. Moreover, the estimate is based on real observed paths, which is one of the most important information for the facility location. Solving our method in large networks with real trip data, including car-probe data, is essential future work.

2 - Electric Vehicle Charging Station Location Problem Considering Congestion and Waiting Times
Omer Kinay, Sibel A. Alumur, Fatma Gzara

The global adoption rate of electric vehicles (EVs) is still low, and the capacities of the established charging station locations are not being fully utilized. Therefore, most of the research on charging station location problem for EVs have been considering an uncapacitated modeling framework. However, incorporating capacity deployment decisions and waiting times in the queues to this problem will soon be crucial considering the exponential growth of EV sales.

Motivated by this, we introduce a new mathematical model to support long-distance travel with EVs and design the charging infrastructure considering service congestion. This model decides on the locations and capacities of the charging stations as well as the routes of each origin-destination (OD) pair so that total establishment cost is minimized. The stochastic demand of each OD pair is assumed to be a Poisson process with a given rate. The typical single queue - multi (parallel) server structure of charging stations constitutes the basis of our queuing system models of these facilities. Capacity of a charging station is defined as the number of parallel servers (power outlets) available at that facility. Consequently, each facility is modeled as an M/M/c queue which, in turn, establishes a queuing network for the system. We introduce probabilistic service level constraints to incorporate the congestion at each facility using queuing theory results. With these constraints, we ensure that majority of the users of a facility are not expected to wait in queue longer than a predefined threshold. We solve this optimization model on benchmark instances and discuss cost and congestion tradeoffs under various problem settings.

3 - Lifted Inequalities for the Refueling Station Location Problem with Routing
Paul Göpfert, Stefan Bock

In order to leverage a widespread use of electric vehicles, an appropriate charging infrastructure is necessary for long distance demands. The Refueling Station Location Problem with Routing (RSLP-R) is an optimization problem that tries to address this challenge by selecting a limited set of stations from a candidate set. The aim of the problem is the maximization of demand coverage. A station set covers a demand, if a driver can reach its destination without a violation of the imposed range and deviation restrictions. Recent promising Branch-and-Cut approaches to this problem shift this complicating routing aspect into the cut separation routines. However, the basic inequalities of these approaches address only one demand at a time. In this talk, we introduce further valid inequalities for the RSLP-R that consider a small set of demands simultaneously. Furthermore, we exploit the fact, that more than one charging stop might be necessary to properly cover a demand. Unfortunately, the resulting inequalities are only valid under strong conditions on the full set of candidate sites. Hence, we use the well known lifting technique in order to obtain a valid inequality for the full candidate set from a valid inequality for a proper subset. The proposed separation routines try also to find a lifting sequence that maximizes the violation of the new cuts. Computational results on two real world road networks underline the strength of the inequalities and the efficiency of the separation algorithms.

■ HA-03

Thursday, 14:00-15:30 - Naples

Covering Models II

Stream: ISOLDE
Contributed session
Chair: *Ioannis Giannikos*

1 - Maximal Covering Pattern of Source and Receiver Placement
Takamori Ukai, Shinichi Watanabe

Water has physical property that light/electromagnetic is absorbed. Therefore, optical instruments are not effective for some activities in underwater. In order to detecting underwater objects, sound is mainly used. The mechanism of detecting using sound in underwater is same as optical way. When an object itself makes sound, one can detect it by listening. This is same as someone uses torch in darkness. For a silent object, one makes a sound and collects its reflection. In the optical way, we can see an object by receiving light reflected with object. Loudness, energy, of sound decrease as distance between source and receiver increase. Here, we assume that one can detect object if loudness of reflection exceeds certain threshold. Then, the region in which object can be detected is determined depending on the location of source and receiver. It may be natural that one wants to know the location of source/receiver to maximize an area of detecting region. However, detecting region becomes complex form. Therefore, the problem which maximizes the area of detecting region is formulated as non-linear optimization, straightforward. For this problem, we formulate as a variant of maximal covering problem. In our formulation, area of study region is divided into sub-regions of square with same size. Then, we regard centroids of square as representing sub-regions. It can be determined if a sub-region is in detection area or not by checking the relation between target sub-region and combination of source and receiver location.

2 - Planar Maximum Coverage Location Problem with Partial Coverage, Spatial Demand, and Adjustable QoS
Manish Bansal

We consider a generalization of the classical planar maximum coverage location problem (PMCLP) in which partial coverage is allowed, facilities have adjustable quality of service (QoS) or service range, and demand zones and service zone of each facility are represented by two-dimensional spatial objects such as rectangles, circles, polygons, etc. We denote this generalization by PMCLP-PC-QoS. A key challenge in this problem is to simultaneously decide position of multiple facilities on a continuous two-dimensional plane and their QoS. We present a greedy algorithm and a pseudo-greedy algorithm for it, and showcase that the solution value corresponding to the greedy approach is within a factor of 0.623 of the optimal solution value. We also investigate theoretical properties and propose exact algorithms for solving: (1) PMCLP-PC-QoS where demand and service zones are represented by axis-parallel rectangles (denoted by PMCLP-PCR-QoS), which also has applications in camera surveillance and satellite imaging; and (2) one dimensional PMCLP-PC-QoS with non-homogeneous set of QoSs (denoted by 1D-PMCLP-PC-QoS), which has applications in river cleanups. These results extend and strengthen the only known exact algorithm for PMCLP-PCR-QoS with fixed and same QoS in [1]. We present results of our computational experiments conducted to evaluate the performance of our proposed exact and approximation algorithms.

[1] M. Bansal, K. Kianfar, "Planar maximum coverage location problem with partial coverage and rectangular demand and service zones," INFORMS Journal on Computing, 29(1), 152-169, 2017.

3 - A Directional Approach to Gradual Cover
Zvi Drezner, Tammy Drezner, Pawel Kalczynski

The objective of classic cover location models is for facilities to cover demand within a given distance. Locating a given number of facilities to cover as much demand as possible is referred to as max-cover. Finding the minimum number of facilities required to cover all the demand is the set covering problem. The gradual (or partial) cover replaces abrupt drop from full cover to no cover by defining gradual decline in cover. If classic cover models consider 3 miles as the cover distance, then at 2.99 miles a demand point is fully covered while at 3.01 miles it is not covered at all. In gradual cover, a cover range is set. For example, up to 2 miles the demand is fully covered, beyond 4 miles it is not covered at all, and between 2 and 4 miles it is partially covered. We propose, analyze, and test a new rule for calculating the joint cover of a demand point which is partially covered by several facilities. Every facility covers points within a given radius. Each demand "point" is defined as a circle with a given radius. The proportion of the demand point covered by a facility is the fraction of the area of the demand circle covered by the facility. The total cover by several facilities is the union of the covered areas. The rule considers the directions of the facilities providing partial cover and not just the proportions of the partial covers. The proposed approach is tested on a case study of locating cell-phone towers in Orange County, California. The new approach provided better total cover than the cover obtained by existing procedures.

Thursday, July 8, 16:00-17:30

■ HB-01

Thursday, 16:00-17:30 - Wuppertal

Drone Applications

Stream: ISOLDE
Contributed session
Chair: *James Campbell*

1 - Network Design for Vaccine Delivery with Drones in Less-Developed Countries
James Campbell, Shakiba Enayati, Deng Pan, Haitao Li

Vaccine delivery in less-developed countries is challenging due to the remote populations, lack of transport infrastructure, unreliable and slow transportation, and the need to maintain the cold chain (such as limiting vaccines to a maximum of 8 hours outside of a freezer). Transportation in such settings is typically by boat, truck, motorcycle, walking, or plane. Drones (unmanned aerial vehicles) provide new opportunities to better serve remote populations by taking advantage of the drone's fast speed, low cost and limited infrastructure requirements for delivery.

This research develops an MILP model to optimize the multi-modal national vaccine supply network, including the use of drones. This is a multi-modal facility location and fixed charge network design problem with relays. Decisions include locating distribution centers (vaccine destinations) in each health zone, locating drone bases for housing and launching drones, locating relay stations to recharge drones, and determining the flow of vaccines across multiple transport modes. The model includes multi-stop drone paths that allow recharging of drones at relay stations to overcome the drone flight range limit, while still satisfying the cold chain requirements. Solutions are provided for two different types of drones using a new data set for the island nation of Vanuatu, which consists of over 60 inhabited islands scattered across 1000 km in the South Pacific. Results show the potential value from using drones to both reduce cost and improve service measures. Results also highlight the important role of the fixed costs for optimizing drone operations.

2 - Drone Locations and Logistics for Delivery of Humanitarian Aid to Uncertain Demands of Disaster-impacted Populations
Zabih Ghelichi, Monica Gentili, Pitu Mirchandani

The complexities of locating the drone take-off platforms, and routing and scheduling of deliveries include limited coverage range, energy consumption, distance and drone specifications, and the timeliness as the deliveries of aid packages. In this study, we will present a stochastic optimization model to address these challenges when the set of demand locations is unknown. The main problem is to locate a set of drone take-off platforms so that with a given probability α, the maximum total cost (or disutility) under all realizations of the demand locations is minimized. We assume the set of demand points is subject to uncertainty, and the uncertainty set is comprised of a set of discrete demand scenarios. A Chance Constrained Programming (CCP) model is developed to determine a set of platform locations whose disutility distribution has the minimum α percentile. We formulate and solve a time-space drone scheduling mathematical model for a large set of scenarios to build up the total disutility distributions. We propose an algorithmic solution approach which decomposes the problem into three tractable subproblems. The first stage identifies a set of most preferable drone platform combinations. In this stage, we solve the drone scheduling model for each location combination and demand scenario. Owing to the large number of iterations and the computational complexity of the drone scheduling problem, we develop an approximation algorithm based on a greedy approach and Sample Average Approximation (SAA) to mitigate the required computation efforts. The last stage builds upon the properties of the SAA method and of the CCP

formulation to select the combination of platforms that produces the minimum α percentile.

3 - Extending Coordination Models: The Mothership and Drone Routing Problem with Graphs
Carlos Valverde, Lavinia Amorosi, Justo Puerto

In recent years the progress in the field of automation has led to the increasingly widespread use of drone technology in many sectors. Depending on the application, these devices are used to support or replace humans in carrying out operations, and also in the cases of lack of infrastructures. We can find several examples of this phenomenon in the telecommunication field, where drones can be used to provide connectivity in rural areas, without antennas, or in areas affected by natural disasters which have compromised existing infrastructure. This presentation addresses the optimization of routing problems with drones. It analyzes the coordination of one mothership with one drone to obtain optimal routes that have to visit some target objects modeled as general graphs. The goal is to allocate points where the drone is launched and retrieved that minimizes the overall weighted distance traveled by both vehicles while satisfying the requirements in terms of percentages of visits to targets. We discuss different approaches depending on the assumption made on the route followed by the mothership: i) the mothership can move on a continuous framework (the Euclidean plane), ii) on a connected piecewise linear polygonal chain or iii) on a general graph. In all cases, we develop exact formulations resorting to mixed integer second order cone programs that are compared on a testbed of instances to asses their performance. The high complexity of the exact methods makes it difficult to find optimal solutions in short computing time. For that reason, besides the exact formulations we also provide a tailored matheuristic algorithm that allows one to obtain high quality solutions in reasonable time. Computational experiments show the usefulness of our methods in different scenarios.

■ HB-02

Thursday, 16:00-17:30 - Toronto

Location & Pandemics

Stream: ISOLDE
Contributed session
Chair: *Sibel Salman*

1 - Determining the Optimal COVID-19 Testing Centre Locations and Capacities Considering the Disease Dynamics and Target Populations
Esma Akgun, Sibel A. Alumur, Fatih Safa Erenay

Testing individuals at risk to identify COVID-19 infections and promptly putting them in isolation helps control and mitigate the pandemic. However, during the peaks of the pandemic, testing capacities may not be sufficient and thus, need to be expanded. To achieve this effectively, the locations and capacities of the testing centers should be determined through a detailed analysis of the combined effects of testing strategies, public health interventions, disease propagation, and the compliance of the population to testing. We propose a multi-period location and capacity allocation model that determines the optimal number and locations of pop-up testing centers, capacities of the existing centres, and assignments of demand regions to these testing centres. The objective is to minimize the total distance travelled subject to budget and capacity constraints, which will in turn maximize the accessibility to testing and reduce the burden of the COVID-19 pandemic. We estimate the demand for the location and capacity allocation model using an SEIR model considering the effects of changing disease prevalence, variants of concern, vaccination, and social and geographical factors on the population's attitude towards testing. We apply our model to the case of locating COVID-19 testing centres in Ontario, Canada using data from the Ontario Ministry of Health, public databases, and the literature. The proposed research may provide insights to the public health decision-makers on the timing of testing centre capacity expansions, the need for and effectiveness of pop-up testing centres, and the impact of effective testing strategies in mitigating the pandemic.

2 - Logistics of Half-Mobile Testing Booths for COVID-19
Çağla Dursunoğlu, Irmak Özdemir, Bahar Yetis Kara, Manoj Dora

There are distinct methods to detect infections to restrain the COVID-19 outbreak. Antibody testing is for diagnosing past infections. Antigen and viral tests are utilized to identify ongoing infection. The former is convenient and fast yet not sensitive compared to the latter. The primary official viral test for diagnosis is PCR, but it requires time and lab safety measurements. In addition to traditional testing procedures run primarily by the major hospitals, temporary testing centers, half/mobile, drive-through booths started to be utilized both to increase availability and decrease risks due to the use of public transportation. This study is motivated by the pioneering half/mobile testings in South Korea. The specific problem for COVID-19 testing booths should consider nodes to visit and cover while adopting a multi-objective approach. Half/mobile booths should stay in a location which should also be determined by the proposed model. A time limit is exposed since the collected samples must be taken back to testing centers after a predetermined time-bound. Since we aim to decide the tours of half-mobile booths, their locations, and the amount of time to stay in the location, the Covering Tour/Team Orienteering Problem is the most relevant OR problem from the literature. The proposed problem has similarities with Team Orienteering due to the maximization of sample collection within a time constraint, but the profit is dependent on the time stayed, which is a decision variable in our problem. We propose a linear mathematical model. The results on South Korean data will be discussed during the presentation.

3 - Infectious Waste Management with Demand Uncertainty During a Pandemic
Ginger Y. Ke, Jiahong Zhao

The global COVID-19 pandemic attracts public attention to the management of waste generated by health-care activities. Due to the hazardous nature, infectious waste requires the design of a multi-tiered system to provide cost-efficient and eco-friendly services of waste collection, transportation, treatment, and final disposal. However, the impact of uncertainties has not been well studied in the existing literature. Considering the presence of random waste generation during a pandemic, we aim to answer the following questions: 1) where to locate temporary transfer stations and temporary treatment centers; 2) how to plan collection tours among the small generation nodes and temporary transfer stations; 3) how to plan the direct transportation from large generation nodes to treatment centers; 4) how to transport waste from temporary transfer stations to treatment centers, and 5) how to transport wastes from treatment centers to disposal facilities. The relevant cost and associated risk are respectively formulated and assessed using a scenario-based bi-objective robust approach. The complexity of the resulting mathematical model motivated the adaption and comparison of three multi-objective optimization approaches, including the goal programming method, a lexicographic weighted Tchebycheff approach, and an augmented ϵ-constraint solution technique. A case study based on the real situation in Wuhan, China, during the COVID-19 outbreak is conducted to demonstrate the workability of the proposed model and provide managerial insights for infectious waste management. The computational results show that our proposed model can more than double the demand fulfillment rate at an approximately 40% lower cost when facing a distinctively high increment in infectious waste amount.

Friday, July 9, 14:00-16:00

■ FA-01

Friday, 14:00-16:00 - Wuppertal

Competitive Models II

Stream: ISOLDE
Contributed session
Chair: *Vladimir Marianov*

1 - Store Location with Multipurpose Shopping Trips and a Random Utility Consumers' Choice Model
Gonzalo Mendez-Vogel, Vladimir Marianov, Armin Lüer-Villagra, H.a. Eiselt

In the retail store location, the most critical factor to consider is consumer behavior. Firms that manage to understand this concept can perceive increased gains. However, the stores are currently located based on intuition or heuristics since, as incredible as it may seem, optimal location models have modeled only simplified customer behaviors. We study two firms that offer a different product, which may have some degree of complementarity with each other. In this case, it is normal for the consumer to buy both products on a multipurpose trip. Only [1] has considered this behavior with non-essential products, managing to represent real locations better. However, the authors assume that customer decisions are binary (do not change over time), and their utilities are deterministic. Actually, consumer choices do change over time, and there are random components that have to be included in the customer utilities. We extend the model in [1] by introducing the multinomial Logit model (MNL). In addition, based on the MNL, we propose the partially binary Logit (PBL) rule. This new decision rule uses random utilities and assumes that the purchases of one or two products are made in the least cost trip, making sense if each firm sells the same product in all its stores. We analyze the captured markets and location patterns in different instances of 100 nodes with the PBL, MNL, and binary rules to find the best customer choice rule. Results indicate that the PBL better represents consumer behavior, and there are optimal location decisions that cannot be reached by simple intuition.

[1] V. Marianov, H.A. Eiselt and A. Lüer-Villagra (2018). Effects of Multipurpose Shopping Trips on Retail Store Location in a Duopoly. European Journal of Operational Research 269(2), 782-792.

2 - The Leader Multipurpose Shopping Location Problem
Armin Lüer-Villagra, Vladimir Marianov, H.a. Eiselt, Gonzalo Mendez-Vogel

A large proportion of the shopping trips, customers visit multiple sites to purchase more than one item, i.e., they engage in multipurpose, multi-stop trips, supported by empirical evidence. However, popular models for facility location always assume single-purpose, single-stop shopping trips. To the best of our knowledge, the first authors aiming to locate retail stores considering multipurpose shopping were Khapugin and Melnikov (2019) and Marianov et al. (2018). In Marianov et al. (2018), two companies sell non-mutual-substitute non-essential products where the first company, the leader, is already located, and the goal is to locate the stores of the second company, the follower. There is no competition between the two firms, other than that because consumers must choose one of the possible shopping trips. We extend the follower's retail store location problem of Marianov et al., (2018) to include the leader's decisions. The leader locates its stores knowing that a follower will enter the market later, offering a different product. Both maximize their markets, given that customers can purchase none, one, or two products on the same trip. We focus on non-essential products. The paper determines the best locations for first and second entrants through exact and approximated procedures. It turns out that, by locating with foresight, a first entrant can increase the total business in an area for himself and subsequent entrants. We solve the binary programming bi-level resulting problem for small instances modifying an ad-hoc procedure. Furthermore, a new bi-level reactive GRASP procedure finds solutions for instances of up to 100 nodes in under 3,600 seconds of CPU time.

3 - Mobile Service Facilities with Customer Choice (MSFCC)
Viktor Bindewald, Stefan Nickel, David Sayah

In this talk we present a new multi-period facility location problem: Mobile service facilities with customer choice (MSFCC) which consists in closing, reopening, and relocating mobile service facilities within a given discrete planning horizon. Furthermore, MSFCC allows multiple capacity levels at a candidate location, thereby enabling location planners to react to varying customer demand over time by dynamically increasing or decreasing service staff, necessary equipment etc. Customer choice behavior is modeled using the well-known multinomial logit (MNL) choice model. In particular, the parameters of the MNL model may depend on the distance between the customer and a service facility as well as the point in time he or she chooses to patronize a facility. The customers can also decide to opt out, i.e., to decide in favor of the competition. MSFCC is fairly versatile supporting location planners in a variety of application contexts, e.g., positioning and staffing mobile public libraries, healthcare facilities, polling stations, pop-up stores or food trucks. Since the problem is a difficult MINLP, solving MSFCC is computationally challenging when using an state-of-the-box NLP solver to solve already medium-sized instances. Therefore, we also present an exact solution approach to MSFCC problem which is based on a generalized Benders decomposition. We conclude the talk by presenting preliminary computational results indicating the competitiveness of our decomposition approach.

4 - Point-to-point Airline Network Design under Cooperation and Competition
Jinha Hibino, Shungo Koichi, Takehiro Furuta, Mihiro Sasaki

Airline networks can be classified into two types. One is based on a hub-and-spoke network, and the other is based on a point-to-point network. The major advantage of hub-and-spoke networks is that it enables efficient transportation networks to capture widely spread demand by consolidating flows in hubs; however, it sometimes restricts the flexibility in designing a network. Point-to-point airline network design problems (PPANP) are proposed to design a flexible network by locating a given number of arcs instead of hubs. An important feature of PPANP is that it considers the company's revenue and convenience for passengers simultaneously. We propose a new model as a natural extension of PPANP. We consider the case that a new entrant company plans to enter a market where an existing company has already provided operating routes. Cooperation and competition are important factors when considering multiple companies in a market. We describe a balance of cooperation and competition by introducing a parameter representing how easy/difficult to transfer to a flight operated by the other company. When the companies have cooperative relations, passengers may easily enjoy transferring to the other company's routes on the way to the destination. Since a new entry is usually allowed under regulation rules in an actual situation, we prohibit the entrant company from stealing too much revenue from the existing company. This rule guarantees a certain level of the existing company's revenue, which leads to a good result from a view of the sustainability of the entire airline market. Computational results show that moderate cooperation among the companies makes additional revenue to both companies, though the results greatly depend on the existing company's network.

■ FA-02

Friday, 14:00-16:00 - Toronto

Humanitarian Logistics

Stream: ISOLDE
Contributed session
Chair: *Bahar Yetis Kara*

1 - Location of Water Taps and Design of a Water Distribution Network in Nepal

Jessica Rodríguez-Pereira, Gilbert Laporte, Marie-Ève Rancourt, Selene Silvestri

The lack of access to drinking water is one of the most important humanitarian problems, mainly in remote areas of developing countries. Only one out of three users of safely managed water lives in a rural area. The Sustainable Development Goal "6 Clean water and sanitation", seeks to achieve universal and equitable access to safe and affordable drinking water for all. After the 2015 Nepal earthquake, more than 1.1 million people were left without access to a protected water source, as the water supply systems were destroyed, specially in rural areas. The main goal is to model and solve a Water Supply System Design Problem (WSSDP) based on a gravity-fed system. This is a hierarchical problem, whose primary objective is to determine the number and locations of community water taps (WTs) and the assignment of households under certain technical standards, while the secondary objective is to identify a minimum cost network connection from the water sources (WSs) to the WTs. For that, we develop a matheuristic based on the decomposition of the problem in two sequential parts, reflecting the hierarchical nature of the WSSDP objective. First, the Water Tap Location-Allocation Problem is a facility location and allocation problem, and then the Water Distribution Network Problem consists of a network design problem to connect the WSs to the WTs identified in the first subproblem. We describe and solve an integer linear programming model for the first subproblem and we develop a cluster-first tree-second heuristic to solve the second subproblem. KEYWORDS: Location, Network design, Steiner forest, Humanitarian aid, Earthquake, Matheuristic

2 - Districting for Integration of Syrian Refugees into the Turkish Education System

Şebnem Manolya Demir, Bahar Yetis Kara, Feyza Sahinyazan

Syrian War has forced 5.5 million Syrians to seek for asylum. Turkey hosts 3.6 million refugees, 47 % of which are children, with over one million in the schooling age. Even though the schooling rate of Syrian refugee children has increased from its initial value of 30 % in 2014, there are still more than 400 thousand children distanced from education. In 2014, temporary measurements taken by the Ministry of Education suggested that children could either attend Turkish Public Schools or Temporary Education Centers (TECs), which are opened to catch Syrian children up with the Syrian syllabus so that they can continue their education once they go back to their country. However, as the Syrian War does not seem to end soon, permanent solutions are now being enforced, involving the closing of the TECs to include all Syrian refugee children into the Turkish education system. Unfortunately, due to the lack of planning, socio-economic and psychological factors this transition is not made smoothly. This study offers a planning strategy that involves transforming TECs into Turkish public schools for Syrian refugee children. It provides an exact model that decides on the locations of central schools and TECs, as well as the assignments of refugee districts to these schools and their mode of transportation. While taking into account the Ministry regulations for education; our model maximizes the number of children with access to education. An immediate extension of this problem is a unique selective location routing model, where location decisions create selectiveness in transportation. Experimental analysis conducted with real data of Kilis, the city with the highest percentage of refugees, will be presented.

3 - Humanitarian Supply Chain Planning: The Effect of Location Decisions on Fair Allocation of Donations

Zehranaz Donmez, Bahar Yetis Kara, Ozlem Karsu, Francisco Saldanha-da-Gama

Disaster logistics operations aim to minimize the damage of disaster-victims quickly in highly uncertain circumstances. To that end, needs of disaster victims should be accommodated and their needs should be met as soon as possible in an efficient and fair manner. In humanitarian supply chains, the demand comes from disaster victims while supply mostly consists of donations. In this talk, the main focus is locating the depots which are used to store the donated items and fair allocation of donations to those shelter sites. Note that primary concerns and restrictive elements change rapidly throughout the response phase, where the donation allocation decisions take place, affecting the structure of the problems substantially. Therefore, to construct the problems in an accurate way and capture these changes, the response stage should be divided into sub-phases based on the donation management dynamics. We aim to define and classify the types of problems that are faced in different phases based on phase-specific characteristics (such as the objectives and the type of the commodities considered). After defining the sub-phases of the post-disaster response stage and the corresponding problems for each sub phase, a multi-stage deterministic mathematical model is developed to locate the temporary depots and distribute the donations in an efficient and fair manner. To analyze the trade-off between those two objectives a bi-objective model is constructed and Pareto solutions are investigated. Since donations are mostly uncertain in terms of type, timing and amount, future work consists of formulating and solving a stochastic version of the bi-objective model.

4 - A Progressive Hedging Algorithm for Two-Stage Stochastic Blood Supply Chain Network Design in Humanitarian Logistics

Morteza Lotfi, Ehsan Nikbakhsh

Disasters are a series of adverse, large-scale events that lead to significant negative impacts on society's health and economy. Due to the chaotic nature of the disaster and the inherent uncertainties, designing a cost-efficient relief network for timely delivery of relief items could be challenging. This study aims to present a mathematical model to distribute blood during the aftermath of an earthquake. The proposed network includes various nodes in the network, namely blood donors, mobile and permanent blood donation centers, the blood transfusion organization (BTO), field distribution hubs, and hospitals. As the blood collection facilities are limited in both number and capacity, congestion is modeled using the M/M/m queuing model. Finally, the collected blood is shipped to the BTO for testing and processing and then shipped to field distribution hubs and hospitals to fulfill hospitals demand of the affected areas. To tackle this problem, we proposed a two-stage stochastic programming model and a progressive hedging algorithm (PHA) to solve large instances of a realistic case of an earthquake in Tehran city. The computational experiments demonstrate the efficiency and effectiveness of the proposed model and algorithm. In particular, the proposed stochastic model could result in up to 11% reduction of the total costs. In addition, using sensitivity analysis, people's tendency to donate blood and the capacity of blood donation centers are identified as important factors affecting the system performance.

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