

# ISOLDE XVI

## International Symposium on Locational Decisions

June 25 to 30, 2023
Kaiserslautern and Baden-Baden, Germany

Organized by

RPTU Rheinland-Pfälzische Technische Universität Kaiserslautern Landau

Fraunhofer ITWM

# FOREWORD

Dear Locators,

Following recent global events that have prevented the ISOLDE meeting from taking place in 2020 as planned, we had a wonderful ISOLDE XV *Online* in 2021 organized by the University of Wuppertal. It is our great pleasure to welcome you to Kaiserslautern and Baden-Baden for this event in 2023. This continues the long tradition of hosting the conference as an in-person event at two different locations.

This year's edition of the conference (ISOLDE XVI) is held concurrently with the XXVIII meeting of the EURO Working Group on Locational Analysis (EWGLA).

The success of past editions is evidence of the continuing great interest of the scientific community in Location Science. The current edition includes more than 100 participants and 78 papers presenting the latest research on a wide range of topics. These presentations are complemented by two plenary talks given by the distinguished scholars Elena Fernández (University of Cádiz, Spain) and Horst Hamacher (University of Kaiserslautern-Landau (RPTU), Germany).

The participation of authors from 18 countries worldwide confirms that ISOLDE meetings provide an exceptional opportunity for exchanging research results, both at the theoretical and practical levels, as well as for sharing experiences. In addition, this event also strengthens the bond among the members of the community and stimulates future collaboration on research activities.

We would like to thank all the colleagues of the Organizing and Program Committees as well as the team of Fraunhofer ITWM and the EWGLA board for their support in preparing the conference. Moreover, special thanks are also due to Bernard Fortz for his assistance with the EURO Conference software. Finally, we gratefully acknowledge the support of several sponsoring institutions.

*Anita Schöbel* (conference chair)

*Stefan Nickel* (program chair)

*Teresa Melo* (program co-chair)






# CONTENTS

# PROGRAM COMMITTEE

**STEFAN NICKEL (chair)**
Karlsruhe Institute of Technology (KIT), Germany

**TERESA MELO (co-chair)**
Saarland University of Applied Sciences, Germany

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University of Szeged, Hungary

# ORGANIZING COMMITTEE

**ANITA SCHÖBEL (chair)**
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**STEFAN NICKEL**
Karlsruhe Institute of Technology (KIT), Germany

# PROGRAM OVERVIEW

## SUNDAY, JUNE 25
## KAISERSLAUTERN

**5:00 PM**
**REGISTRATION**
Fraunhofer ITWM, Lobby

**6:00 – 8:45 PM**
**WELCOME RECEPTION**
Drinks & Snacks
Fraunhofer ITWM, Atrium

**8:00 PM**
**BUS TRANSFER**
From Fraunhofer ITWM (main entrance) to the city center

**8:45 PM**
**BUS TRANSFER**
From Fraunhofer ITWM (main entrance) to the city center

## MONDAY, JUNE 26
## KAISERSLAUTERN

**8:30 – 9:15 AM**
**REGISTRATION**
Fraunhofer ITWM, Lobby

**9:15 – 9:30 AM**
**OPENING SESSION**
Fraunhofer ITWM, Hörsaal

**9:30 – 10:30 AM**
**PLENARY SESSION**
Fraunhofer ITWM, Hörsaal

**10:30 – 11:00 AM**
**COFFEE BREAK**
Fraunhofer ITWM, Lobby

**11:00 AM – 12:45 PM**

| | |
|---|---|
| **HUB LOCATION PROBLEMS AND MOBILITY**<br>Seminarraum | **COMPETITIVE LOCATION**<br>Hertz |

**12:45 – 2:00 PM**
**LUNCH**
Fraunhofer ITWM, Cafeteria

**2:00 – 3:45 PM**

| | |
|---|---|
| **DISCRETE LOCATION PROBLEMS I**<br>Seminarraum | **CONTINUOUS LOCATION PROBLEMS**<br>Hertz |

**3:45 – 4:15 PM**
**COFFEE BREAK**
Fraunhofer ITWM, Lobby

**4:15 – 6:00 PM**

| | |
|---|---|
| **MITIGATING DISRUPTIONS**<br>Seminarraum | **NOVEL APPLICATIONS**<br>Hertz |

## TUESDAY, JUNE 27
## KAISERSLAUTERN

**9:00 – 10:45 AM**

| | |
|---|---|
| **DISTRICTING PROBLEMS**<br>Seminarraum | **GREEN LOGISTICS**<br>Hertz |

**10:45 – 11:15 AM**
**COFFEE BREAK**
Fraunhofer ITWM, Lobby

**11:15 AM – 12:30 PM**

| | |
|---|---|
| **DISTRIBUTION NETWORK DESIGN**<br>Seminarraum | **LAYOUT & BUILDINGS**<br>Hertz |

**12:30 PM**
**GROUP PHOTO**
Fraunhofer ITWM, Atrium

**12:45 – 1:45 PM**
**LUNCH**
Fraunhofer ITWM, Cafeteria

**1:45 – 3:30 PM**

| | |
|---|---|
| **DISCRETE LOCATION PROBLEMS II**<br>Seminarraum | **CONTINUOUS P-MEDIAN PROBLEMS**<br>Hertz |

**3:30 – 4:00 PM**
**COFFEE BREAK**
Fraunhofer ITWM, Lobby

**4:00 – 5:15 PM**

| | |
|---|---|
| **HUB LOCATION PROBLEMS UNDER UNCERTAINTY**<br>Seminarraum | **LOCATION-ROUTING PROBLEMS**<br>Hertz |

**7:00 PM**
**GET-TOGETHER DINNER**
Restaurant TwentyOne

# PROGRAM OVERVIEW

## WEDNESDAY, JUNE 28

**8:15 AM – 7:00 PM**
**EXCURSION AND TRANSFER TO BADEN-BADEN**

## THURSDAY, JUNE 29
## BADEN-BADEN

**9:00 – 10:45 AM**

| | |
|---|---|
| **STOCHASTIC FACILITY LOCATION**<br>Malersaal | **LOCATION & COVERING**<br>Musikersaal |

**10:45 – 11:15 AM**
**COFFEE BREAK**
Maison Messmer, Kaminbar

**11:15 AM – 12:30 PM**

| | |
|---|---|
| **TIME AND UNCERTAINTY**<br>Malersaal | **PUBLIC TRANS-PORTATION**<br>Musikersaal |

**12:30 – 1:45 PM**
**LUNCH**
Maison Messmer, Brasserie

**1:45 – 2:45 PM**
**PLENARY SESSION**
Maison Messmer, Malersaal

**2:45 – 3:15 PM**
**COFFEE BREAK**
Maison Messmer, Kaminbar

**3:15 – 5:00 PM**

| |
|---|
| **PUBLIC & SERVICE LOCATION PROBLEMS**<br>Malersaal |

## FRIDAY, JUNE 30
## BADEN-BADEN

**9:00 – 10:45 AM**

| |
|---|
| **HUMANITARIAN LOGISTICS**<br>Malersaal |

**10:45 – 11:15 AM**
**COFFEE BREAK**
Maison Messmer, Kaminbar

**11:15 AM – 1:00 PM**

| |
|---|
| **HEALTH CARE APPLICATIONS**<br>Malersaal |

**1:00 – 2:00 PM**
**LUNCH**
Maison Messmer, Brasserie

**2:00 – 2:30 PM**
**CLOSING SESSION**
Maison Messmer, Malersaal

**2:30 – 3:00 PM**
**EWGLA SESSION**
Maison Messmer, Malersaal

**7:00 PM**
**FAREWELL DINNER**
Maison Messmer, Malersaal

# DETAILED SCHEDULE

# MONDAY JUNE 26, 2023

**9:15 – 9:30 AM** **OPENING SESSION** Fraunhofer ITWM, Hörsaal

**OPENING SESSION**

**Chair: ANITA SCHÖBEL**

**9:30 – 10:30 AM** **PLENARY SESSION** Fraunhofer ITWM, Hörsaal

**Chair: ANITA SCHÖBEL**

**LOCATION SCIENCE: OLD LOVE NEVER DIES (A PERSONAL HISTORY OF A FASCINATING AREA OF RESEARCH AND APPLICATIONS)**

**HORST HAMACHER**

**10:30 – 11:00 AM** **COFFEE BREAK** Fraunhofer ITWM, Lobby

**11:00 AM – 12:45 PM** **SESSIONS** Fraunhofer ITWM

## HUB LOCATION PROBLEMS AND MOBILITY

**Chair: ELENA FERNÁNDEZ**

Room: Seminarraum

**DATA-DRIVEN HUB NETWORK DESIGN FOR RIDESHARING**
**SIBEL A. ALUMUR**

**A FURTHER STUDY OF THE PROFIT-ORIENTED HUB LINE LOCATION PROBLEM WITH ELASTIC DEMAND**
**ANTONIO MANUEL RODRIGUEZ-CHIA**

**SINGLE-ALLOCATION HUB NETWORK DESIGN DECISION WITH UPGRADING**
**JUAN MANUEL MUÑOZ-OCAÑA**

**DESIGN OF AN INTERMODAL RIVER/ROUTE PHYSICAL INTERNET NETWORK**
**OSCAR ARIZTEGUI-BELTRAN**

## COMPETITIVE LOCATION

**Chair: ARMIN LÜER-VILLAGRA**

Room: Hertz

**EXPERIMENTAL COMPARISON OF RANDOM UTILITY CHOICE RULES FOR COMPETITIVE FACILITY LOCATION**
**VLADIMIR MARIANOV**

**THE FOLLOWER COMPETITIVE FACILITY LOCATION PROBLEM WITH COMPARISON SHOPPING UNDER A THREE-LEVEL NESTED LOGIT RULE**
**GONZALO MENDEZ-VOGEL**

**ANALYZING DIFFERENT APPROACHES TO CONSTRUCT BILEVEL-FEASIBLE SOLUTIONS OF A COMPETITIVE FACILITY LOCATION PROBLEM**
**JOSÉ-FERNANDO CAMACHO-VALLEJO**

**RECENT REFINEMENTS OF THE GRAVITY (HUFF) MODEL FOR COMPETITIVE FACILITIES LOCATION**
**ZVI DREZNER**

**12:45 – 2:00 PM** **LUNCH** Fraunhofer ITWM, Cafeteria

**2:00 – 3:45 PM** **SESSIONS** Fraunhofer ITWM

## DISCRETE LOCATION PROBLEMS I

**Chair: HORST HAMACHER**

Room: Seminarraum

**ORDINAL LOCATION PROBLEMS ON GRAPHS**
KATHRIN KLAMROTH

**ORDERED MEDIAN PROBLEMS AND FAIRNESS IN LOCATION THEORY**
ALBERTO TORREJÓN VALENZUELA

**INTEGER PROGRAMMING APPROACHES FOR THE DISCRETE ALPHA-NEIGHBOR P-CENTER PROBLEM**
MARKUS SINNL

**AN EFFICIENT BENDERS DECOMPOSITION FOR THE P-MEDIAN PROBLEM**
CRISTIAN DURAN MATELUNA

## CONTINUOUS LOCATION PROBLEMS

**Chair: ZVI DREZNER**

Room: Hertz

**THE TWO-STAGED PRODUCTION PROBLEM OF WEBER**
RICHARD CHURCH

**REVISITING THE WEIGHTED REGION PROBLEM: SHORTEST PATHS AND RELATED LOCATION PROBLEMS**
JUSTO PUERTO

**LOCATING MULTIPLE OBNOXIOUS FACILITIES WITH VARIABLE CAPACITIES**
PAWEL KALCZYNSKI

**PLANAR LOCATION PROBLEMS WITH UNCERTAIN DEMAND POINTS: ROBUSTNESS CONCEPTS**
JUAN A. MESA

**3:45 – 4:15 PM** **COFFEE BREAK** Fraunhofer ITWM, Lobby

**4:15 – 6:00 PM** **SESSIONS** Fraunhofer ITWM

## MITIGATING DISRUPTIONS

**Chair: GIUSEPPE BRUNO**

Room: Seminarraum

**MULTISTAGE STOCHASTIC FACILITY LOCATION UNDER FACILITY DISRUPTION UNCERTAINTY**
BONN KLEIFORD SERANILLA

**OPTIMAL NUMBER OF HIERARCHICAL FACILITIES WITH FAILURES**
MASASHI MIYAGAWA

**SPATIOTEMPORAL NETWORK VULNERABILITY IDENTIFICATION FOR THE MATERIAL ROUTING PROBLEM: A BILEVEL PROGRAMMING APPROACH**
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**ALLOCATING ADDITIONAL SERVERS IN AN EXISTING SPATIALLY DISTRIBUTED QUEUING SYSTEM**
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## NOVEL APPLICATIONS

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Room: Hertz

**LOCATION MODELING TO MITIGATE WILDFIRE RISK**
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**OPTIMAL PLACEMENT OF LOG PILE TRAPS FOR OAK WILT DISEASE**
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**A QUBO APPROACH FOR THE FACILITY LOCATION PROBLEM**
HAITAO LI

**GROUP COUNTERFACTUAL EXPLANATIONS: FROM EXPLAINABLE MACHINE LEARNING TO LOCATIONAL ANALYSIS (AND BACK)**
EMILIO CARRIZOSA

# TUESDAY JUNE 27, 2023

**9:00 – 10:45 PM** **SESSIONS** Fraunhofer ITWM

## DISTRICTING PROBLEMS

**Chair: JÖRG KALCSICS**

Room: Seminarraum

**THE VOTING PRECINCT DESIGN PROBLEM**
MICHAEL KUBY

**THE OPTIMAL CONSOLIDATION OF POLLING LOCATIONS**
LAURA ALBERT

**MODULAR CAPACITATED SALES FORCE DEPLOYMENT PROBLEM**
SVEN MÜLLER

**A SAMPLING PROCEDURE FOR CHANCE-CONSTRAINED DISTRICTING PROBLEMS**
ANTONIO DIGLIO

## GREEN LOGISTICS

**Chair: VLADIMIR MARIANOV**

Room: Hertz

**MULTI-PERIOD SUPPLY NETWORK DESIGN WITH CARBON TARIFFS AND LOCATION-SPECIFIC CARBON POLICIES**
JENS CHRISTIAN

**HUB LOCATION PROBLEM WITH A MIXED GREEN FLEET**
OKAN DÜKKANCI

**NEW OPTIMAL LOCATION MODEL ON IN-MOTION WIRELESS POWER TRANSFER SYSTEM FOR LONG-DISTANCE TRIPS BY ELECTRIC VEHICLES**
YUDAI HONMA

**INCORPORATING ENERGY CONSUMPTION INTO LOCATION DECISIONS IN CONTAINER YARDS**
CIHAN BUTUN

**10:45 – 11:15 AM** **COFFEE BREAK** Fraunhofer ITWM, Lobby

**11:15 AM – 12:30 PM** **SESSIONS** Fraunhofer ITWM

## DISTRIBUTION NETWORK DESIGN

**Chair: OLIVIER PÉTON**

Room: Seminarraum

**MULTI-PERIOD DISTRIBUTION NETWORK DESIGN UNDER FLEXIBLE CONDITIONS FOR SHORT-TERM LOCATION PLANNING**
TERESA MELO

**A MATHEURISTIC FOR A MULTI-PERIOD DISTRIBUTION NETWORK DESIGN PROBLEM WITH SHORT-TERM CAPACITY ADJUSTMENTS**
ISABEL CORREIA

**FULFILL AND SHIP-FROM STORE IN OMNICHANNEL DISTRIBUTION NETWORK DESIGN**
IMEN BEN MOHAMED

## LAYOUT & BUILDINGS

**Chair: SVEN MÜLLER**

Room: Hertz

**THE DECONSTRUCTION SITE LAYOUT PLANNING - A NEW CONCEPT TO EFFICIENTLY LOCATE WORKSTATION AND MATERIAL STORAGES INDOORS**
NIKLAS BRAUN

**MATHEMATICAL MODEL FOR OPTIMIZING CONVERSION STRATEGIES FOR HISTORIC BUILDINGS BASED ON LOCATIONAL CHARACTERISTICS**
KAORI ISAWA

**AN OPTIMIZATION METHOD FOR EVALUATING FACILITIES WITH INACCESSIBLE LOCATIONS THROUGH INVERSE SHORTEST PATHS PROBLEM**
HIROYUKI HASADA

**12:30 – 12:45 PM** **GROUP PHOTO** Fraunhofer ITWM, Atrium

**12:45 – 1:45 PM** **LUNCH** Fraunhofer ITWM, Cafeteria

**1:45 – 3:30 PM** **SESSIONS** Fraunhofer ITWM

## DISCRETE LOCATION PROBLEMS II

**Chair: JUSTO PUERTO**

Room: Seminarraum

**NETWORKS PARTITIONING BASED ON EDGE DENSITY USING THE MINIMUM NORMALIZED CUTS**
**FRANCISCO TEMPRANO GARCÍA**

**VALID INEQUALITIES AND PREPROCESSING FOR THE CAPACITATED FACILITY LOCATION PROBLEM WITH PREFERENCE CONSTRAINTS**
**SOPHIA WREDE**

**THE HIERARCHICAL NESTED COOPERATIVE LOCATION PROBLEM: CHALLENGES FROM MODELING AND SOLUTION PERSPECTIVES**
**SILVIA BALDASSARRE**

**NEW FORMULATIONS OF THE GRAY PATTERN PROBLEM**
**PAWEL KALCZYNSKI**

## CONTINUOUS P-MEDIAN PROBLEMS

**Chair: KATHRIN KLAMROTH**

Room: Hertz

**P-MEDIAN LOCATION PROBLEMS IN TIMETABLING**
**ANITA SCHÖBEL**

**A TRAJECTORY BASED HEURISTIC FOR THE PLANAR P-MEDIAN PROBLEM**
**ZVI DREZNER**

**THE P-MEDIAN PROBLEM IN THE PRESENCE OF A RIVER WITH BRIDGES**
**ATSUO SUZUKI**

**MULTI-FACILITY CONTINUOUS MINISUM LOCATION PROBLEMS IN WHICH POTENTIAL FACILITY SITES AND DEMAND POINTS ARE RESTRICTED TO POLYGONS**
**KEN-ICHI TANAKA**

**3:30 – 4:00 PM** **COFFEE BREAK** Fraunhofer ITWM, Lobby

**4:00 – 5:15 PM** **SESSIONS** Fraunhofer ITWM

## HUB LOCATION PROBLEMS UNDER UNCERTAINTY

**Chair: SIBEL ALUMUR**

Room: Seminarraum

**SUSTAINABLE HUB LOCATION UNDER UNCERTAINTY**
**GITA TAHERKHANI**

**RECOURSE POLICIES ASSESSMENT FOR A MULTI-PERIOD HUB LOCATION PROBLEM UNDER STOCHASTIC TRANSSHIPMENT CAPACITY**
**RICCARDO GIUSTI**

**HUB LOCATION PROBLEMS WITH EXPLICIT REDUNDANCY REQUIREMENTS**
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## LOCATION-ROUTING PROBLEMS

**Chair: ALAN MURRAY**

Room: Hertz

**A MULTIPLE ASSET-TYPE, COLLABORATIVE VEHICLE ROUTING PROBLEM WITH PROXIMAL SERVICING OF DEMANDS**
**STEPHEN DONNEL**

**A HYBRID ALNS-DRL APPROACH FOR SOLVING A LOCATION AND ROUTING PROBLEM**
**SYU-NING JOHNN**

**MULTI-PERIOD SINGLE-ALLOCATION HUB LOCATION-ROUTING: MODELS AND HEURISTIC SOLUTIONS**
**AFAF ALOULLAL**

# THURSDAY JUNE 29, 2023

**9:00 – 10:45 PM** **SESSIONS** Maison Messmer

## STOCHASTIC FACILITY LOCATION

**Chair: TERESA MELO**

Room: Malersaal

**MINIMIZING MAXIMUM REGRET IN TWO-STAGE FACILITY LOCATION WITH SITE PREPARATION COSTS**
RONALD MCGARVEY

**FACILITY LOCATION PROBLEM UNDER UNCERTAINTY WITH SERVICE LEVEL CONSTRAINTS**
HAOYUE ZHANG

**MULTI-PERIOD FACILITY LOCATION PROBLEM WITH CAPACITY ADJUSTMENTS UNDER UNCERTAIN DEMAND**
ŠÁRKA ŠTÁDLEROVÁ

**STOCHASTIC FACILITY LOCATION PROBLEMS IN REVERSE LOGISTICS**
RUURD BUIJS

## LOCATION & COVERING

**Chair: RICHARD CHURCH**

Room: Musikersaal

**COVERAGE OBJECTIVE AND ITS GENERALIZATIONS IN LOCATION ANALYSIS**
DMITRY KRASS

**MULTI-PRODUCT MAXIMAL COVERING SECOND-LEVEL FACILITY LOCATION PROBLEM**
MARTA BALDOMERO-NARANJO

**OPTIMAL COVERAGE-BASED PLACEMENT OF STATIC LEAK DETECTION DEVICES FOR PIPELINE WATER SUPPLY NETWORKS**
MIGUEL MARTÍNEZ-ANTÓN

**CAPTURING UNCERTAINTY IN THE HYBRIDIZED MAXIMAL COVERING LOCATION PROBLEM**
RICARDO GÁZQUEZ

**10:45 – 11:15 AM** **COFFEE BREAK** Maison Messmer, Kaminbar

**11:15 AM – 12:30 PM** **SESSIONS** Maison Messmer

## TIME AND UNCERTAINTY

**Chair: FRANCISCO SALDANHA-DA-GAMA**

Room: Malersaal

**THE VALUE OF THE MULTI-PERIOD SOLUTION REVISITED: HOW TO MODEL TIME IN CAPACITATED LOCATION PROBLEMS**
HANNAH BAKKER

**NEW INSIGHTS ON DECISION AND FORECAST HORIZONS FOR MULTI-PERIOD FACILITY LOCATION UNDER UNCERTAINTY**
PAULO MOREIRA

**OPTIMIZATION MODELS FOR LOCATING AND ASSIGNING WAREHOUSES FOR LARGE CUSTOMERS UNDER UNCERTAIN DEMANDS**
HARSHIT YADAV

## PUBLIC TRANSPORTATION

**Chair: ANITA SCHÖBEL**

Room: Musikersaal

**LOCATION PLANNING IN INTERMODAL NETWORKS: THE ACCESSIBILITY OF LOCAL SUPPLY**
NICOLAS FRÖHLICH

**DETERMINING THE STOPS AND RING ROUTES OF THE SUBURBAN TRAIN LINE: AN ALTERNATIVE TRANSPORTATION FOR INDUSTRIAL WORKERS**
EREN ÖZCEYLAN

**THE OPTIMAL LOCATION OF A RAPID TRANSIT LINE IN A RECTILINEAR CITY**
THOMAS BYRNE

**12:30 – 1:45 PM** **LUNCH** Maison Messmer, Brasserie

**1:45 – 2:45 PM** **PLENARY SESSION** Maison Messmer, Malersaal

**Chair: STEFAN NICKEL**

**LOCATION SCIENCE: NEW LOVE WILL NEVER DIE**

**ELENA FERNÁNDEZ**

**2:45 – 3:15 PM** **COFFEE BREAK** Maison Messmer, Kaminbar

**3:15 – 5:00 PM** **SESSION** Maison Messmer

**PUBLIC & SERVICE LOCATION PROBLEMS**

**Chair: IOANNIS GIANNIKOS**

Room: Malersaal

**NETWORK DESIGN RECYCLING WASTE COLLECTION BINS BY A COMMUNE IN CHILE**
**SEBASTIÁN DÁVILA**

**A SOFT-CONSTRAINED MULTI-OBJECTIVE FACILITY LOCATION APPROACH TO DESIGN HOUSEHOLD WASTE RECYCLING CENTRES NETWORKS IN SOUTH YORKSHIRE: ANALYSES AND MANAGERIAL INSIGHTS**
**SERENA FUGARO**

**STRATEGIES FOR REDESIGNING THE LAST-MILE LOGISTIC SYSTEM OF A POSTAL COMPANY: AN APPLICATION TO THE ITALIAN CASE**
**EDUARDO PIPICELLI**

**ALLOCATING TEACHING STAFF TO SCHOOLS IN WESTERN GREECE**
**IOANNIS GIANNIKOS**

# FRIDAY JUNE 30, 2023

**9:00 – 10:45 PM** **SESSION** Maison Messmer

## HUMANITARIAN LOGISTICS

**Chair: BAHAR YETIS KARA**

Room: Malersaal

**RELIEF SUPPLY CHAIN PLANNING: THE EFFECT OF LOCATION DECISIONS ON FAIR ALLOCATIONS OF DONATIONS UNDER UNCERTAINTY**
**ZEHRANAZ DÖNMEZ**

**ON THE QUICKEST EVACUATION LOCATION PROBLEM IN HUMANITARIAN OPERATIONS: MULTI-OBJECTIVE MODELLING AND MATHEURISTIC SOLUTION**
**ANTONINO SGALAMBRO**

**A LOCATION-ALLOCATION MODEL FOR MEAL KIT DISTRIBUTION IN POST-DISASTER ENVIRONMENTS**
**DIANA RAMIREZ-RIOS**

**NEW LOCATION ROUTING PROBLEMS LEARNED FROM KAHRAMANMARAŞ EARTHQUAKE**
**BAHAR YETIS KARA**

**10:45 – 11:15 AM** **COFFEE BREAK** Maison Messmer, Kaminbar

**11:15 AM – 1:00 PM** **SESSION** Maison Messmer

## HEALTH CARE APPLICATIONS

**Chair: STEFAN NICKEL**

Room: Malersaal

**ANALYZING THE CHALLENGES OF PLANNING THE EMERGENCY MEDICAL SERVICE LOCATIONS FOR THE METROPOLITAN REGION RUHR**
**ISABEL WIEMER**

**AMBULANCE LOCATION-ALLOCATION OPTIMIZATION UNDER STOCHASTIC TRAVEL TIMES**
**IMANOL GAGO**

**OPTIMIZING MULTI-ECHELON FACILITY LOCATION TO ENHANCE REGIONAL BLOOD SUPPLY CHAIN**
**ANDREA MANCUSO**

**A MULTI-PERIOD LOCATION-ALLOCATION MODEL FOR HEALTHCARE FACILITY PLANNING UNDER ACCESSIBILITY RESTRICTION**
**SACHIN BODKE**

**1:00 – 2:00 PM** **LUNCH** Maison Messmer, Brasserie

**2:00 – 2:30 PM** **CLOSING SESSION** Maison Messmer, Malersaal

**Chair: ANITA SCHÖBEL**

**2:30 – 3:00 PM** **EWGLA SESSION** Maison Messmer, Malersaal

**Chair: JÖRG KALCSICS**

# ISOLDE XVI and EWGLA XXVIII

Abstracts

# TECHNICAL PROGRAM

## Monday, 9:15-9:30

### ■ MA-01

*Monday, 9:15-9:30 - Hörsaal*

**Opening session**

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## Monday, 9:30-10:30

### ■ MB-01

*Monday, 9:30-10:30 - Hörsaal*

**Location Science: Old Love Never Dies (Personal History of a Fascinating Area of Research and Applications)**

*Plenary session*

Chair: *Anita Schöbel*

**1 - Location Science: Old Love Never Dies (Personal History of a Fascinating Area of Research and Applications)**

*Horst W. Hamacher*

It is hard to imagine that anyone of the participants of ISOLDE 2023 will not agree with the message in the subtitle of this talk (why would you be here otherwise?): Location Science is, indeed, one of the most fascinating areas of research and applications.

But most likely, all of us have different reasons for this statement. In this talk, I will summarize some very personal reasons. Most of them are related to my tenure at the University of Kaiserslautern, and the colleagues and students I have had the luck and pleasure to work with during this time.

If you want to hear (success and failure) stories, see photographs, and digest some results related to the last 30 years of my life as a location scientist, you are welcome to listen to my talk. If you decide to go, instead, for coffee and cookies, you can be sure to have my fullest and deepest understanding.

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# Monday, 11:00-12:45

## ■ MC-01

*Monday, 11:00-12:45 - Seminarraum*

### Hub Location Problems and Mobility

*Contributed session*

Chair: *Elena Fernández*

**1 - Data-driven Hub Network Design for Ridesharing**

*Sibel A. Alumur, Gita Taherkhani, Bissan Ghaddar*

This paper studies the design of ridesharing hub networks to promote shared transportation. Given a set of passenger trips in an urban area, the problem is to determine the origins and destinations of a fixed number of ridesharing connections to maximize the potential users of the system. The problem is formulated as a maximal covering hub arc location model and solved to optimality using Benders decomposition. Several algorithmic enhancements, including using reduction tests to eliminate variables and adding multiple Pareto-optimal cuts, are proposed to improve the convergence of the Benders decomposition algorithm. Additionally, two data-driven clustering-based methodologies are adapted and implemented to compare with the solutions of the optimization model. All methodologies are tested using the New York City taxi trip data. Several computational experiments are conducted to compare optimization and data-driven approaches under key performance metrics that include the total number of commuters that use the ridesharing system, the percentage of satisfied trips by ridesharing, the utilization of ridesharing trips, and the driving and walking distances. The results from the optimization model yield more satisfied trips through the ridesharing system and also a more balanced utilization of the ridesharing connections compared with the results obtained from either of the clustering-based methodologies. Our results show that operating even a few ridesharing connections in the city of New York (around 20 connections) can result in reducing a significant number of individual rides and the total driving distance of the commuters without incurring a walking distance above 1 km per passenger.

**2 - A Further Study of the Profit-oriented Hub Line Location Problem with Elastic Demand**

*Antonio Manuel Rodriguez-Chia, Brenda Cobeña, Ivan Contreras, Luisa I. Martínez-Merino*

This presentation deals with an extension of the hub line location problem considering demand elasticity with respect to travel times. The proposed model aims to capture the impact the hub network topology has on demand. This new model introduces an objective function based on gravity models to include demand elasticity. The objective of this model is to maximize the total reduction time of the commodities when using the hub line. We propose mixed-integer nonlinear formulations to model this problem. We study some properties of the nonlinear objective function associated with these formulations. Due to the inherent complexity involved in solving these nonlinear formulations with state-of-the-art solvers, we also present alternative mixed-integer linear programming formulations. These MILP formulations assume that all the candidate paths for the commodities are known. In order to obtain all path candidates, we have developed an algorithm which takes into account the time reductions appearing in hub lines. Computational results compare the proposed formulations and the benefits of the presented model using benchmark instances commonly used in hub location. These computational results showed that MILP formulations outperform the running times of the nonlinear ones. Moreover, a sensitivity analysis study is carried out with real data from the city of Montreal, Canada, to demonstrate the added value of incorporating demand elasticity when using the proposed model for public transportation planning.

**3 - Single-allocation Hub Network Design Decision with Upgrading**

*Juan Manuel Muñoz-Ocaña, Mercedes Landete, Antonio Manuel Rodriguez-Chia, Francisco Saldanha-da-Gama*

We will talk about different formulations for the uncapacitated single allocation hub location problem with upgraded connections and incomplete hub networks. Upgrading connections aims to reduce the transportation costs between sites that are connected by the upgraded edges. Two types of connections are considered to be upgraded: inter-hubs edges and edges that connect origin/destination points to hubs.

Single-allocation hub location models can be classified into two families: path-based formulations and flow based formulations. We propose different formulations inspired by the former ones to model the upgrading version of this problem considering complete and incomplete networks. Observe that in this problem, the decision variables are the locations of hubs, the allocations of the nodes to the hubs, the connections used between hubs, and the edges to be upgraded. The network obtained must be connected since any site can send flow to any other site. Moreover, the number of inter-hub edges as well as the number of connections between origin/destination points and hubs to be upgraded, are established as parameters. For the resulting formulations, valid inequalities and an ad-hoc preprocessing phase is developed to strengthen them. We report on a series of computational tests performed to assess the models proposed and their enhancements.

S. Alumur, J. F. Campbell, I. Contreras, B. Kara, V. Marianov, and M. E. O'Kelly. Perspectives on modeling hub location problems. European Journal of Operational Research, 291(1):1-17, 2021.

M. Baldomero-Naranjo, J. Kalcsics, A. Marín and A. M. Rodríguez-Chía. Upgrading edges in the Maximal Covering Location Problem. European Journal of Operational Research, 303:14-36, 2022.

**4 - Design of an Intermodal River/Route Physical Internet Network**

*Oscar Ariztegui-Beltran, Olivier Péton, Mehrdad Mohammadi, William Guerrero, David L. Cortés-Murcia*

The design of Physical Internet (PI) networks aims at synchronizing all logistics networks to create a collaborative and robust global transportation network. In this context, we study the design of an intermodal logistics network using a combination of road and waterways. We assume an existing road network and a network of navigable rivers in which river hubs must be located. The cargo consists of a set of commodities from and to a set of cities connected to the rivers by a road network.

The goal is to design a minimal cost logistics network to carry the set of commodities. We propose a hub location formulation, in which the main decision variables are the location of hubs in the river network and the allocation of cities and (river) spokes to hubs. Due to the specific topology of river networks, two classical assumptions of the hub location problem are relaxed. First, the river network forms a tree, so that the inter-hub network is also a tree and a complete graph. Second, also due to the tree topology, some inter-hub trips are likely to pass through non-hub nodes. Thus, we allow inter-hub trips to stop at intermediate non-hub nodes, called stopovers.

We propose a mixed integer mathematical formulation. The objective function minimizes the sum of the total expected transportation costs and the total fixed costs associated with hubs and stopovers. We assume capacitated hubs, single allocation of spokes to hubs & multiple allocation of cities to hubs. We report the results of computational experiments on a set of instances derived from classical benchmarks as well as case studies. Small instances are solved with the Gurobi Optimizer, whereas larger instances are solved with a decomposition-based heuristic.

# ■ MC-02

*Monday, 11:00-12:45 - Hertz*

## Competitive Location

*Contributed session*

Chair: *Armin Lüer-Villagra*

### 1 - Experimental Comparison of Random Utility Choice Rules for Competitive Facility Location

*Vladimir Marianov*, *Gonzalo Mendez-Vogel*, *Armin Lüer-Villagra*

In competitive facility location problems, customers decide what facility to visit to satisfy their needs by using some choice rule. Different formulas have been proposed in the literature to model customers' choice rules. The most popular ones are based on the probabilistic gravity rule, and the random utility rules, in particular, the multinomial logit rule. This last one represents the utility obtained by a customer for performing a certain action by a deterministic and a random component.

Using random utility rules results in facility location models with a nonlinear objective. Ten years ago, Haase and Müller (2014) numerically compared several existing linearizations of Multinomial Logit Choice Models. Since that time, new linearizations and solution methods have been proposed. Among others, tightened versions of previous linearizations, B&C approaches using generalized Benders' decomposition, B&C schemes using efficient cuts based on the sub-modularity property or the convexity property of the objective of the facility location problem, B&C approaches based on outer approximations, cutting plane methods based on outer approximation cuts, mixed-integer conic quadratic programming, and a B&C method using what the authors call one-opt cuts.

We compare several of these different linearizations of the multinomial logit rule from the point of view of the location of the facilities and the computational time required to solve the competitive facility location problem and provide information on possible extensions to other rules.

Reference Haase, K. , & Müller, S. (2014). A comparison of linear reformulations for multinomial logit choice probabilities in facility location models. European Journal of Operational Research, 232 (3), 689-691.

### 2 - The Follower Competitive Facility Location Problem with Comparison Shopping under a Three-level Nested Logit Rule

*Gonzalo Mendez-Vogel*, *Vladimir Marianov*, *Pascual Fernandez*, *Blas Pelegrin*, *Armin Lüer-Villagra*

In the follower competitive facility location problem, a newcomer firm that wants to maximize its market share, enters the market by locating a given number of stores and offering a product that is a substitute for the competition. One of the most important factors to consider is customer behavior, as incorrect modeling of this concept leads to wrong market estimation, which could result in poor location decisions. It is generally assumed that the customer, from the place of origin (home or workplace), visits a single store knowing all the information beforehand, buys the product, and returns. However, when products are non-homogeneous substitutes, it is normal to assume that customers have a comparison-shopping behavior. That is, they visit more than one store to obtain detailed information and compare products before making a decision. Moreover, decisions are often made sequentially as stores are visited. We are the first to consider these behaviors by including a three-level nested logit rule in a duopoly. In this probabilistic rule, the customer makes decisions at three levels. At the place of origin (which store to visit first), at the first store visited (whether to buy or not, or to continue comparing), and at the second store visited (whether to purchase or not and in which store). We also include in the customers' utility the value of the gathered information and the time spent in the stores. We propose a linear formulation with an efficient branch-and-cut approach. We analyze the location patterns in randomly generated instances, as well as in a case study on municipalities in Spain. The three-level nested, two-level nested, and multinomial logit rules are compared. We claim that our proposed rule represents reality better than the current state of the art.

### 3 - Analyzing Different Approaches to Construct Bilevel-feasible Solutions of a Competitive Facility Location Problem

*José-Fernando Camacho-Vallejo*, *Carlos Corpus*

Competitive facility location is an important research direction that helps companies to optimize their operations, increase profitability, and remain competitive in the market. Additionally, sometimes the involved companies interact in the market under a predefined hierarchy due to their size, economic strength, and branding, among others. In this research, we are considering a problem under that framework. We are considering two competitive companies that must locate a predefined number of facilities each. The bigger company will be called the leader and the smaller one the follower. The leader aims to maximize its profit, while the follower aims to maximize its profit but also to maximize the minimum distance of its newly located facilities. Under this framework, the decision made by the leader directly affects the decision of the follower since the customers are assigned to their closest located facility. A bilevel programming model is proposed to study this problem, which is based on the well-known (r|p)-centroid problem. Also, the lower level can be seen as a variant of the p-dispersion problem. In a bilevel programming problem, the lower level must be optimally solved to obtain the follower's reaction to a fixed leader's decision. In our problem, this is not straightforward since the lower level consists of a biobjective problem. Therefore, a Pareto front is obtained and it is unclear which solution will be chosen by the follower. An analysis of these efficient solutions is made towards looking for bilevel feasibility. Moreover, optimistic, pessimistic, and other particular approaches will be discussed.

### 4 - Recent Refinements of the Gravity (Huff) Model for Competitive Facilities Location

*Zvi Drezner*, *Tammy Drezner*, *Dawit Zerom*

The competitive facilities location problem is to find the best locations for one or more facilities among existing competing facilities, maximizing the market share captured. The proportion of the demand attracted to a facility is proportional to the facility's attractiveness A, and to a distance decay function with a parameter t. In the standard formulation the distance decay function has the same t for all facilities regardless of their attractiveness level. Drezner et al. (2018) suggested that attractiveness levels are not constants but follow some probability distribution. Drezner et al. (2020) suggested to replace the attractiveness multiplier A by a facility dependent distance decay parameter t. The parameter t determines the pace of the decline in attracted demand as a function of the distance. The assumption is that the decline in attracted demand of more attractive facilities is slower. Drezner et al. (2022) proposed, to extend the Drezner et al. (2020) model, by adding an extra distance parameter reflecting time spent at the facility. All distances are increased by the same extra distance. Drezner et al. (2023) investigated locating a competing facility which is also obnoxious to residents.

References:

Drezner, T., Drezner, Z., and Zerom, D. (2018). Competitive facility location with random attractiveness. Operations Research Letters, 46:312-317.

Drezner, T., Drezner, Z., and Zerom, D. (2020). Facility dependent distance decay in competitive location. Networks and Spatial Economics, 20:915-934.

Drezner, T., Drezner, Z., and Zerom, D. (2022). An extension of the gravity model. Journal of the Operational Research Society, 73:2732-2740.

Drezner Z., T. Drezner, and Zerom D. (2023) The obnoxious competitive facility location model. In review.

# Monday, 14:00-15:45

## ■ MD-01

*Monday, 14:00-15:45 - Seminarraum*

## Discrete Location Problems I

*Contributed session*

Chair: *Horst W. Hamacher*

### 1 - Ordinal Location Problems on Graphs

*Kathrin Klamroth, Michael Stiglmayr, Julia Sudhoff*

We consider ordinal location problems on graphs where, in addition to the edge length, a category is associated with each edge. As an example, assume that traveling is realized by a bicycle. Then the safety of an edge can be categorized into one of the three categories safe (green), medium safe (orange) or unsafe (red). A green edge may, for example, be reserved for cyclists only, an orange edge may have a separate bike lane, and a red edge could be a major road without a sidewalk or bike lane. While a value function that assigns monetary costs to the categories is generally not known, green is always preferred over orange and orange is always preferred over red. Route choices then depend on the preferences of the decision maker(s), and there may not exist a unique optimal path between a customer and a new facility location in general.

Motivated by recent results on ordinal combinatorial optimization problems, we introduce ordinal location problems on graphs and analyze their relation to associated multiobjective location problems. Ordinally (or Pareto) optimal facility locations are now considered together with associated ordinally (or Pareto) optimal customer-to-facility-routes. We distinguish central choice (cc) models, where one central decision maker makes the route choice for all customers (like in the case of a pizza service), and distributed choice (dc) models where each customer may have independent preferences concerning the safety of his or her route (e.g., to a restaurant at the new facility location). We discuss ordinal median and ordinal center problems and analyze the impact of the graph structure on the solution sets.

### 2 - Ordered Median Problems and Fairness in Location Theory

*Alberto Torrejón Valenzuela, Ivana Ljubic, Miguel Angel Pozo, Justo Puerto*

Effectiveness and efficiency are concepts that have been successfully included in optimization problems. However, a third relevant concept to consider in order to generate acceptable decisions is the principle of fairness, of equity.

Fairness is a complicated concept for which there is no consensus on its measurement, different measures of fairness can lead to very different conclusions. On the other hand, it is not a concept that fits naturally in the context of optimization and may conflict with some others, for example, it is well known that focusing only on fairness can degrade the efficiency of solutions.

Ordered optimization plays an important role in generating a framework for analyzing fairness measures in optimization problems. In the specific case of location problems, the Discrete Ordered Median Problem (DOMP) allows not only to generalize location problems, being able to consider various objectives (median, center, etc.) but also to create a common framework for inclusion and analysis of the concept of equity in location problems.

In this talk, we will present the recent works on discrete ordered location problems, reviewing the latest enhancements in algorithmic efficiency by embedding the state-of-the-art formulation for general weight vectors (non-monotonous and negative) into a Benders decomposition, how to include system connection by means of a tree modelization between facilities and giving some insights on how we can use DOMP to create fairer solutions in location problems.

### 3 - Integer Programming Approaches for the Discrete Alpha-neighbor p-Center Problem

*Markus Sinnl, Elisabeth Gaar*

The discrete alpha-neighbor p-center problem is an emerging variant of the classical p-center problem which recently got attention in literature. In this problem, we are given a discrete set of points and we need to locate p facilities on these points in such a way that the maximum distance between each point where no facility is located and its alpha-closest facility is minimized. The only existing algorithms in literature for solving the problem are approximation algorithms and two recently proposed heuristics.

In this talk, we present two integer programming formulations for the discrete alpha-neighbor p-center problem, together with lifting of inequalities, valid inequalities, inequalities that do not change the optimal objective function value and variable fixing procedures. We describe theoretical results on the strength of the formulations and present convergence results for the lower bounds obtained after applying the lifting procedures or the variable fixing procedures in an iterative fashion.

We also present branch-and-cut (B&C) algorithms based on our formulations and our theoretical results. These algorithms are further enhanced with a starting heuristic and a primal heuristic. We evaluate the effectiveness of our B&C algorithms using instances from literature. Our algorithms are able to solve 116 out of 194 instances from literature to proven optimality, with a runtime of under a minute for most of them. By doing so, we also provide improved solution values for 116 instances.

### 4 - An Efficient Benders Decomposition for the p-Median Problem

*Cristian Duran Mateluna, Sourour Elloumi, Zacharie Ales*

The p-median problem (pMP) is one of the fundamental discrete location problems. In the (pMP), we have to choose p sites from a set of candidate sites to allocate them a set of clients in order to minimize the sum of their allocation distances. This problem has various applications and several heuristic methods have been proposed to solve it. However, its exact solution remains a challenge for large-scale instances. The previously most effective exact approach in the literature was able to solve instances up to 85900 clients and sites.

We performed a Benders decomposition of the most efficient formulation of the p-median problem. The efficiency of our decomposition comes from a fast algorithm for the solution of the sub-problems in conjunction with improvements in a two-phase solution implementation. In the first phase, the integrity constraints are relaxed and in the second phase, the problem is solved in a branch-and-cut approach.

Our approach outperforms the state-of-the-art exact methods. We solve for the first time to optimality instances having up to 89600 and 238025 clients and sites from the BIRCH and TSP libraries, respectively. We tested our decomposition algorithm on other p-median instances: RW instances which do not satisfy triangle inequality and ODM instances in which some allocations are not allowed between certain clients and sites. For the RW instances, we were able to solve instances of up to 1000 clients with a large value of p. For ODM instances with 3773 clients, we solve previously unsolved instances within 10 hours. We also adapt our approach to test it on the difficult KG instances of the uncapacitated facility location problem obtaining relatively small optimality gaps.

# ■ MD-02

*Monday, 14:00-15:45 - Hertz*

## Continuous Location Problems

*Contributed session*

Chair: *Zvi Drezner*

### 1 - The Two-staged Production Problem of Weber

*Richard Church*

Weber has been "pigeonholed" in terms of the widely held view that his locational construct consisted of a triangle composed of two raw materials and a market and where the objective was to find the location of a manufacturing facility that minimizes all transport costs. This simple construct was used to convey the principal elements of the simplest form of Weber's paradigm. In fact, it was only one of several constructs that he proposed in the location of manufacturing facilities (Church, 2018). Several aspects of Weber's constructs have been the subject of recent work (Murray, et al. (2020) and Church et al. (2022)). Perhaps one of the more intriguing constructs raised by Weber was the notion that production of an item may not all take place at the same location. In this paper, we present a two-staged form of Weber's manufacturing location problem on a Cartesian plane. We also propose a solution process and give computational examples. Our discussion includes a comparison of the classic one-stage result with that of a two-stage model, demonstrating the genius of Weber's work as a pioneer in supply chain design.

References:

Church, R. L. (2019). Understanding the Weber location paradigm. In Contributions to Location Analysis (pp. 69-88). Springer, Cham.

Church, R. L., Drezner, Z., & Tamir, A. (2022). Extensions to the Weber problem. Computers & Operations Research, 143, 105786.

Murray, A. T., Church, R. L., & Feng, X. (2020). Single facility siting involving allocation decisions. European Journal of Operational Research, 284(3), 834-846.

### 2 - Revisiting the Weighted Region Problem: Shortest Paths and Related Location Problems

*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. The WRP was originally introduced in 1991 by Mitchell and Papadimitriou and, besides its mathematical interest, it was motivated as a model to design the route of robots through zones with different terrains that are traversed at different speeds (e.g. grassland, blacktop, water,...). In this talk, we propose a solution scheme for the problem completely different from the ones proposed for the WRP and its variants previously considered. This scheme consists of the representation of the problem as a mixed-integer second-order cone problem (MISOCP), which is achieved using the l_p-norms modeling procedure given in Blanco et al. 2014. MISOCPs can be solved nowadays up to any degree of accuracy with commercial solvers.

Based on that representation, we address two different related problems: 1) we study the problem of finding a simple shortest path in a d-dimensional real space subdivided in several polyhedra endowed with different l_p-norms; 2) we consider the continuous single facility location problem that results in this subdivision of l_p-normed polyhedra. Structural properties of these problems are studied, giving rise to mixed-integer second-order cone formulations. Extensive computational results support the applicability of our approach.

### 3 - Locating Multiple Obnoxious Facilities with Variable Capacities

*Pawel Kalczynski, Zvi Drezner*

The problem of 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 capacity (size).

In this paper, we propose to construct facilities of different capacities. Such an important extension leads to a complicated formulation that we were able to simplify. The simplified formulations resulted in much better solutions in shorter run times.

Two models are proposed and investigated. In the first model, the minimum weighted distance to the facilities is maximized. In the second model, the facilities "cooperate" in inflicting the negative impact, and the total negative impact inflicted by all facilities on the most affected community is minimized.

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

In our extensive computational experiments, we found in some cases that the negative impact on the most affected community is reduced by more than 50% when facilities of different capacities are established.

### 4 - Planar Location Problems with Uncertain Demand Points: Robustness Concepts

*Juan A. Mesa, Anita Schöbel*

A calculation or process is said to be robust if the result is largely independent of certain aspects of the input. Robust Optimization is the branch of Mathematical Optimization that deals with problems where the parameters or input are uncertain and is not known or is not applicable to this uncertainty a known probability distribution. Finding robust solutions to an optimization problem is an important issue in practice. In many applications, data and parameters are not precisely known. The uncertainty can have many different reasons, two of which are unknown data (due to measurement errors or some behavior of customers that only can be estimated) or disturbances/perturbations produced by environmental to system effects. In Location Science, weights allocated to demand points, distances from the demand points to facilities, and their position are often not exactly known. Thus, several questions arise when dealing with robustness: which are the parameters affected by the uncertainty? To which set do the values of the uncertain parameters belong? How strict should the applied concept be? In this paper, we suppose that the coordinates of the demand points are uncertain, but they belong to a given neighborhood of the nominal scenarios. We apply several approaches of robust optimization to a broad class of planar location problems. Various concepts on how to define the robustness of an algorithm or of a solution have been suggested; strict, cardinality-constrained, adjustable, light, or recoverable robustness. In this work, we present explicit examples and algorithms for planar center problems and compare their solutions for the different robustness concepts.

# Monday, 16:15-18:00

## ■ ME-01

*Monday, 16:15-18:00 - Seminarraum*

### Mitigating Disruptions

*Contributed session*

Chair: *Giuseppe Bruno*

**1 - Multistage Stochastic Facility Location under Facility Disruption Uncertainty**

*Bonn Kleiford Seranilla, Nils Löhndorf*

Facility location problem (FLP) is a well-studied problem in operations research aiming to optimally locate facilities in order to provide services to and satisfy demands of customers. In this article, we consider facility location decisions accounting for facility disruptions. Incidents like power outages, industrial accidents, problems with the transportation infrastructure, and natural catastrophes disrupt facilities and may cause facility failures. The impact of these events and the probability of their occurrences are difficult to estimate due to the lack of high-quality historical data. Facility location decisions are long-term and difficult to rectify. Thus, it is important to take into account future disruption uncertainties to assure that facility location decisions are sufficiently robust to avert significant costs in the future. We describe a multistage variant of the classic stochastic facility location problem under facility disruption uncertainty. Although there exists a stream of literature covering this subject, reliable facility location models, they only cover single- and two-stage models. Some disruptions may occur multiple times across the planning horizon and some facilities need to be re-opened when disruptions are overcome. We present the multistage stochastic facility location problem under facility disruptions as multistage stochastic mixed-integer program. Numerical results from the state-of-the-art algorithm to solve such class of problems, Stochastic Dual Dynamic Integer Programming, show inferiority over a proposed novel solution algorithm based on training parameters of the linear value function approximation which minimises an upper bound of the optimal objective value.

**2 - Optimal Number of Hierarchical Facilities with Failures**

*Masashi Miyagawa*

Facility systems have a hierarchy consisting of several different levels of facilities. For example, a health care system consists of clinics, hospitals, and medical centers. Lower-level facilities provide frequently required services, whereas higher-level facilities provide more specialized services. Designing the optimal hierarchy is significant for improving services.

This paper presents a continuous approximation model for determining the number of hierarchical facilities when lower-level facilities are subject to failures. The average distance from customers to the nearest open facility is derived for two types of customer behavior. The optimal number of facilities that minimizes the average distance is then obtained. The analytical solution demonstrates how the location of facilities, the failure probability, and the customer behavior affect the optimal number of facilities and the average distance. The result shows that introducing the hierarchy can reduce the average distance if the failure probability is small and the penalty for failing to use facilities is large.

The model is useful for designing hierarchical facility systems as follows. First, the average distance helps planners estimate the number of facilities required to achieve a certain level of service. The estimated number of facilities can be used as an input into hierarchical facility location models. Second, the optimal number of facilities allows us to evaluate the number of existing facilities, thereby supporting decisions about opening new facilities and closing existing facilities. Finally, comparing the effects on the average distance is useful to prioritize investments for improving services.

**3 - Spatiotemporal Network Vulnerability Identification for the Material Routing Problem: a Bilevel Programming Approach**

*Carson Long, Brian Lunday, Phillip Jenkins*

The routing of material over a distribution network is subject to man-made and natural disruptions, and it is important to understand the network's spatiotemporal vulnerabilities, i.e., when and where such disruptions will notably affect outcomes. Knowledge of these vulnerabilities can inform mitigation efforts to ensure the shipments are routed efficiently while meeting any delivery deadlines. This research formulates and examines the bilevel material routing problem, wherein an upper-level problem identifies the time and location for a limited number of fixed-duration attacks on arcs within a distribution network, and a lower-level problem subsequently routes shipments over the network between respective origins and destinations. The defender seeks to minimize a combination of the weighted distance traveled, the transport time of shipments, and penalties for delivering shipments outside of desired time windows, while meeting required delivery deadlines. This research develops a customized genetic algorithm to search the attacker's feasible region and develop high-quality solutions. For a realistic scenario, testing examines the robustness of alternative assumptions a distance-maximizing attacker may make about the defender's priorities over the objective functions in the lower-level problem. For most the most robust attacker assumption, subsequent testing examines for a range of attacker capabilities the spatiotemporal disruptions an effective attacker would make, i.e., the network vulnerabilities that merit mitigation by a defender.

**4 - Allocating Additional Servers in an Existing Spatially Distributed Queuing System**

*Rajan Batta, Monir Sabbaghtorkan*

We study the problem of server allocation to functioning facilities which are modeled as spatially distributed queuing systems. Unlike general server allocation problems that allocate a variable number of servers to empty facilities (no servers), here we allocate a variable number of new servers to existing functioning facilities that already have some servers in them. To model this problem, we propose six optimization models for different types of queuing systems and assumptions. We propose two types of models: stationary models that assume that changes in the number of servers will not affect the existing demand distribution, and interactive models that assume that changes in the number of servers will impact demand distribution. For interactive models, we adjust and use the gravity rule to model customer facility selection behavior. The six models gradually get more complicated and closer to reality. The queuing system of the first four models follows two typical assumptions: all facilities are stable, and they have an infinite capacity for holding customers. In the queuing system of Model 5, the assumption of facilities' stability is removed, and the problem of interest is modeled as an optimization model with the primary objective function of maximizing the number of stable facilities, and a secondary objective function of minimizing the total customer queue waiting time. In Model 6, the facilities follow the M/M/c/N queuing system, which has a limited capacity ($N$) and is always stable. Finally, as the case study, we study the problem of allocating fuel trucks to gas stations as additional servers to cope with gas station congestion and high gas demand during a hurricane evacuation in St Johns county, Florida.

# ■ ME-02

*Monday, 16:15-18:00 - Hertz*

## Novel Applications

*Contributed session*

Chair: *Emilio Carrizosa*

### 1 - Location Modeling to Mitigate Wildfire Risk

*Alan Murray, Jiwon Baik, Vanessa Echeverri, Darlene Rini*

Over the past two decades, California has experienced an increase in scale, frequency and intensity of wildfires, posing a significant threat to communities in coastal communities like Santa Barbara. As a result, it has become increasingly vital to develop analytical tools, risk reduction strategies and operational plans to enhance wildfire resilience. One such wildfire resiliency approach is the use of vegetation treatment, which may involve prescribed burns, strategic fuel breaks, mastication and other measures. A challenge is selecting the best areas for vegetation treatment, where viable projects must be contiguous and manageable in size. Location modeling has much potential for addressing this problem, enabling the formalization of the planning problem as well as offering approaches for identifying the best solutions possible. However, challenges remain as the underlying geographical detail and spatio-temporal characteristics are formidable. This paper highlights the geographic analytics to support vegetation treatment planning, including the use of remote sensing, topography, climate, weather and fire behavior simulation, along with a location model that reflects the intent to identify the best project areas. The analysis involves millions of spatial raster cells, resulting in a location model with decision variables corresponding to over 27 thousand land parcels. Application results for the Santa Barbara region are detailed, demonstrating the importance of contiguity in location modeling as well as strategic coordination possible through planning efforts like this.

### 2 - Optimal Placement of Log Pile Traps for Oak Wilt Disease

*Shizu Itaka, Mirai Tanaka, Shoichi Saito*

Oak wilt disease is transmitted by oak bark beetles (Platypus quercivorus). One of the most effective methods to control this disease is the so-called log pile trap method. It uses pheromones with piled oak logs to attract beetles. In this study, we propose an optimization model for determining the location of the traps. We assumed that if at least one trap is placed within 500 meters from a group of damaged trees, then emergent beetles will be attracted to one of the traps and exterminated. Based on this modeling, we formulated a problem of determining the location of traps to efficiently control the disease as a problem of finding the location of a trap that covers as many damaged trees as possible. Furthermore, we modeled the effect of the healthy oak trees in the 80 meters radius circle centered on the trap, because when the traps are placed in the vicinity of healthy oak trees, attracted beetles may attack them. We considered three models: a model in which the effect of the pheromone of a trap does not change within a 500 meters radius circle (model S (step)), a model in which the effect decays according to a Gaussian kernel with distance from the trap (model G (Gaussian)), and an empirical model in which the effect decays according to a piecewise linear function (model PL (piecewise linear)). We determined which model is appropriate by numerical experiments using actual data. Model S avoided overlapping of pheromone effective areas by covering many damaged trees as possible. Model G allowed the overlapping of pheromone effective areas. Model PL was an intermediate arrangement between models S and G. By comparing these results based on the knowledge of an expert in the log pile trap method, we evaluated the result of model PL as the most realistic.

### 3 - A QUBO Approach for the Facility Location Problem

*Haitao Li*

Quantum computing is a transformational way of solving NP-hard combinatorial optimization problems. It relies on the so-called quadratic unconstrainted binary optimization (QUBO) model of an optimization problem, and uses quantum computer and solver to find solutions. Our research was motivated by the emerging use of quantum computing for solving various NP-hard optimization problems in logistics and supply chains, and we choose the well-known facility location problem (FLP) as an initial attempt, due to its important role in strategic supply chain network design, and its binary integer programming (BIP) formulation which is amenable for QUBO transformation.

In this presentation, we provide an overview of the mechanism of quantum computing and QUBO, and show how to transform the BIP formulation of FLP to a QUBO model, called QUBO-FLP, in two approaches: (i) by specifying the QUBO formulation using the penalty functions for the constraints in the BIP model; and (ii) by deriving properties for the Q-matrix in the xQx formulation of the QUBO model and constructing the Q-matrix explicitly. The QUBO-FLP models built via the two approaches differ in implementation effort and the amount of memory required. Both models were implemented in Python and solved by the QUBO solver in Gurobi and the D-Wave quantum computing solver. Computational results on solution quality and time of the QUBO-FLP approach are reported and compared to the traditional BIP approach using branch-and-bound and branch-and-cut in Gurobi.

### 4 - Group Counterfactual Explanations: From Explainable Machine Learning to Locational Analysis (and Back)

*Emilio Carrizosa, Jasone Ramírez-Ayerbe, Dolores Romero Morales*

Counterfactual Analysis has shown to be a powerful tool in the burgeoning field of Explainable Artificial Intelligence. In Supervised Classification, this means associating with each record a so-called counterfactual explanation: an instance that is close to the record and whose probability of being classified in the positive class by a given classifier is high.

Most papers in the literature focus on the problem of finding one counterfactual for one record. In this talk, we study the more general setting in which we are given a group of instances and we seek a group of counterfactual explanations for them. From a stakeholder perspective, there are different reasons to perform a group counterfactual analysis, preventing one to solve a series of counterfactual models independently. These include the existence of constraints linking instances and counterfactuals (e.g., one might want to have close counterfactuals for close instances, or to have for one record several counterfactuals showing a high diversity), or required outputs by the stakeholders (e.g., detecting a small group of counterfactuals to be seen as benchmarks for the population, or identifying a small set of features that, when perturbed, increase for the instances their probability of being classified as positive). We introduce some mathematical optimization models as illustration, and we identify a number of connections between this class of problems and Locational Analysis, both in Continuous and Discrete Location.

# Tuesday, 9:00-10:45

## ■ TA-01

*Tuesday, 9:00-10:45 - Seminarraum*

## Districting Problems

*Contributed session*

Chair: *Jörg Kalcsics*

### 1 - The Voting Precinct Design Problem

*Michael Kuby, Wangshu Mu, Daoqin Tong, Fangwu Wei, Srivatsav Kandala, Jon Miller*

For purposes of conducting elections, cities and counties are subdivided into voting precincts. Traditionally, each precinct has one or more polling places, where voters may vote using a ballot designed for the races relevant to that area. Precincts are also the smallest geographic units at which election results are reported to the public.

The precinct design problem is distinct from but related to the redistricting problem. Both divide a region into districts of roughly (or exactly) equal population. Contiguity is essential to both problems, while compactness is desirable. Unlike for redistricting, there is negligible political advantage gained in drawing precincts. One key difference is in the role played by the legislative districts that elect representatives to the national, state, province, county, and city legislatures and councils. Such districts are the output of redistricting, but are inputs to precinct design. A key goal in designing precincts is to avoid having two or more of the same kind of legislative district within a single precinct, which would increase costs by requiring multiple ballot designs listing the different candidates for the different districts. To avoid this, precinct boundaries may need to be redesigned after each round of post-census redistricting. New precincts may also need to be added between censuses when new housing developments are occupied.

This paper introduces the precinct design problem and proposes a multiobjective formulation minimizing the number of precincts, a compactness metric, and the number of unique ballot designs required. The model is tested on simulated datasets. We also report on a patented spatial decision support system that includes GIS preprocessing tools, manual editing, and a heuristic algorithm.

### 2 - The Optimal Consolidation of Polling Locations

*Laura Albert*

Many logistical and financial challenges of facilitating an election in the United States lead election officials to consolidate polling locations. However, determining when it is appropriate to consolidate polling locations and how to consolidate polling locations if necessary is a difficult and high-stakes decision that influences voter participation. We formalize the set of constraints and criteria election officials should follow as the polling location consolidation problem (PLCP), which is formulated as an integer programming model. The PLCP simultaneously selects which polling locations will be used in the upcoming election, reassigns voter precincts to polling locations, and allocates critical resources to the selected polling locations. The PLCP minimizes the increased distance that voters must travel to their updated polling location. Since empirical research also demonstrates the importance of reducing the voters' wait times, we require that most voters do not wait longer than a pre-specified limit, such as 30 minutes, using a chance constraint. We prove that identifying a feasible solution to PLCP is NP-complete, which demonstrates the difficulty in making consolidation decisions as well as the importance of optimization for this problem. This paper introduces a structured and transparent approach to support election officials in making informed, data-driven decisions regarding how and when to consolidate polling locations that minimally impacts voter and encourages voter participation. The approach could be used to develop pre-approved contingency plans that could be employed if there are major disruptions to an election.

### 3 - Modular Capacitated Sales Force Deployment Problem

*Sven Müller, Lorena Reyes-Rubiano, Lucas Weber*

The sales force deployment problem is a profit-maximizing planning problem. It deals with the simultaneous solution of four interrelated sub-problems: sizing of the salesforce, locating the sales representatives, sales territory design, and resource allocation. We extended cite-Haase2014 study by introducing different modes of locations, i.e., we allow sales territories to be handled by sales-teams instead of only one sales representative. We consider a concave sales response function assuming the marginal rate of generated sales decreases with increasing resource expenditure. In this case, the resource is the selling time sales representatives assign to their customers. We developed a MIP model with an infinite number of binary variables, each related to the point of selling time in a continuous time interval. Based on Haase and Müller (2014), we develop a branch-and-price algorithm to solve the modular capacitated sales force deployment problem. All sub-problems are solved simultaneously to maximize the total profit as a function of sales, travel, and fixed costs. We solve a linear relaxation of the MIP via column generation (CG); each column represents a new selling time. We perform CG in each node of a branch-and-bound tree to obtain integer solutions. We generate an artificial sales area where the SCUs are aligned on an oblique square. The preliminary results of our study show that allowing for more than one salesperson to be responsible for a territory leads to a fairer distribution of expected profit contributions across sales representatives as well as an overall higher objective function of profit contribution and fixed cost.

### 4 - A Sampling Procedure for Chance-constrained Districting Problems

*Antonio Diglio, Silvia Baldassarre, Giuseppe Bruno, Carmela Piccolo*

In this talk, a Districting Problem with chance-constraints balancing requirements is investigated. The goal is to partition a set of basic Territorial Units into a predefined number of contiguous and compact districts such that their probability of being balanced is above a minimum threshold. For such a problem, an approximate counterpart is considered. Assuming that the demand in each district can be represented by a random variable with a given cumulative distribution function, we devise this approximate model by sampling a finite set of scenarios for the demand (i.e., a complete set of demand realizations), possibly of very large cardinality. For such a random sample, an estimate for the probability of a given districting solution to be balanced is the proportion of scenarios for which the solution is balanced. For each scenario, binary variables are introduced to indicate if the corresponding balancing constraints are violated. This way, a linear formulation of the model is obtained. In practice, our probabilistic problem is cast as a sample approximation problem. In order to solve the latter, a new heuristic algorithm is devised. The proposed procedure exploits a location-allocation scheme coupled with a so-called "balancing constraints-generation" procedure. In other words, the sample approximation problem is iteratively solved by adding demand scenarios (and, hence, the corresponding balancing constraints) on the fly. Several measures to drive the selection of such scenarios and embed them into the problem during the solution process are introduced and discussed. Extensive computational experiments on testbed instances from the literature prove the validity of the devised procedure and its competitiveness against existing heuristic methods.

# ■ TA-02

*Tuesday, 9:00-10:45 - Hertz*

## Green Logistics

*Contributed session*

Chair: *Vladimir Marianov*

### 1 - Multi-period Supply Network Design with Carbon Tariffs and Location-specific Carbon Policies

*Jens Christian, Florian Sahling*

Carbon policies are often limited to certain regions. Consequently, unadjusted regions offer a higher degree of flexibility to companies. Therefore, carbon leakage leads to a shift in production locations to regions without carbon policies. To prevent carbon leakage, carbon tariffs are imposed on carbon emissions imported into regulated regions.

We present a new mixed-integer linear model formulation for multi-period supply network design subject to carbon tariffs and location-specific carbon policies (MPFLP-CT-CP). Consequently, locations differ in whether and how carbon policies are active at the respective location. Here, we include carbon tax, carbon cap-and-trade, and carbon caps as location-specific carbon policies. In contrast, carbon tariffs are imposed on emissions imported from unregulated locations. To measure the relevant carbon emissions, we use carbon footprints. Within the presented MPFLP-CT-CP, the locations of manufacturing plants and distribution centers and transport between corresponding locations are planned. The objective of the MPFLP-CT-CP is to generate a supply network configuration that minimizes the net present value.

To solve the MPFLP-CT-CP, we apply a mathematical programming-based heuristic. Our numerical study demonstrates that the presented heuristic provides high-quality solutions in a reasonable time frame. Furthermore, we conclude that combining carbon tariffs with location-specific carbon policies fundamentally changes the economic and ecological consequences concerning the network configuration. Therefore, we examine the influence of different combinations and characteristics of carbon tariffs and carbon policies.

### 2 - Hub Location Problem with a Mixed Green Fleet

*Okan Dukkanci, Achim Koberstein, James Campbell*

This talk will introduce a novel hub location problem with a mixed fleet of vehicles consisting of diesel-based conventional vehicles and alternative fuel vehicles including electric vehicles and unmanned aerial vehicles. Compared to diesel-based vehicles, the driving range of alternative fuel vehicles in terms of travel distance is more limited. To deal with range limitations, we consider different recharging options that result in different recharging costs and recharging times. In addition to the range, the proposed problem also captures the capacity limitations of these vehicles. The objective function of the problem minimizes the total cost including the fixed cost of locating hubs and the transportation cost of different vehicle types. The latter cost component consists of the recharging cost associated with energy (fuel) consumption depending on the traveled distance, the recharging fee costs depending on the number of visits to recharging stations, and also the waiting cost for drivers and vehicles due to the recharging time of vehicles. We develop a mixed-integer linear programming formulation and an exact solution approach to solve the problem. Several extensions of the problem will be discussed, including an energy-minimizing objective function and a stochastic version. The talk will present computational results over the CAB, TR, and the newly introduced German datasets to analyze the impact of a mixed fleet of range and capacity-limited vehicles on optimal hub location and allocation decisions.

### 3 - New Optimal Location Model on In-motion Wireless Power Transfer System for Long-distance Trips by Electric Vehicles

*Yudai Honma, Daisuke Hasegawa, Katsuhiro Hata, Takashi Oguchi*

The popularization of electric vehicles (EVs) is limited by their driving range and long charging times. To address this, in-motion wireless power transfer systems (WPTSs) are currently attracting attention as a new power supply system. In-motion WPTSs have coils embedded under the road to transfer power from the WPTSs to EVs while driving. However, the main drawback of WPTSs is its large investment, especially in supporting the long-distance trips of EVs on expressways. Therefore, this study proposes a new mixed-integer programming model (MIP) to determine the optimal location of WPTSs for maximized total feasible flow demand. By focusing on long-distance trips on expressways, we proposed the first flow-capturing model for WPTS locations that can (i) solve for the distance of WPTS installed as continuous variables, and (ii) solve problems based on real-scale data using a general MIP solver. Our method is extended to a discussion of WPTS installations on expressways in Japan. We found that WPTS has strong potential as an EV power supply system in terms of coverage and economic rationality. In particular, WPTS has economic rationality not only in busy networks but also in sparsely populated networks that connect urban and rural areas. The results also highlighted the flexibilities for optimal location of WPTS and the resulting heat map of the amount of electricity supplied to EVs, which can aid decision-makers in developing an effective WPTS network design for widespread use of EVs with uneven distribution of electricity supply. Thus, this study clarified the important insights of WPTSs in improving their effectiveness to narrow down the demand and ensure the flexibility in the locations of WPTS.

### 4 - Incorporating Energy Consumption into Location Decisions in Container Yards

*Cihan Butun, Afshin Mansouri, Ran Wang*

Container terminals play a key role in maritime supply chains. The growing trends in global containerized trade and container ship sizes compel terminal operators to improve their operational productivity for better service. Ports and terminals are under pressure from society and legislators to mitigate their environmental externalities. As such, carbon footprint reduction of operations has become a priority along with efficiency. The productivity and sustainability goals often conflict with each other. The trucks and the cranes that move and place containers within the storage yard are leading contributors to the greenhouse gas emissions of terminals. In this paper, we study the location decisions of individual import containers, which we define as a multi-objective optimization problem. The problem is to assign a storage slot position to incoming import containers to minimize the number of future container relocations and the total energy consumed by the trucks and cranes. We formulate the problem as a multi-objective mixed integer linear programming model and develop a Pareto-Archived Evolution Strategy (PAES) algorithm to find a diverse set of non-dominated solutions. We analyze a case study at Vigo's Container Terminal in Spain to validate the potential impact of the proposed algorithm on the productivity and sustainability of the internal container movements. The results show that the set of solutions produced by our approach can reduce the number of relocations by as much as 74% and the energy consumption by 26% on average.

# Tuesday, 11:15-12:30

## ■ TB-01

*Tuesday, 11:15-12:30 - Seminarraum*

### Distribution Network Design

*Contributed session*

Chair: *Olivier Péton*

**1 - Multi-period Distribution Network Design under Flexible Conditions for Short-term Location Planning**

*Teresa Melo, Isabel Correia*

On-demand warehousing has emerged as a flexible alternative to classic warehouse rental, the latter being governed by rigid conditions regarding the duration and price of lease contracts. Through this new business model, companies have access to additional storage capacity in the locations where they need it and for the desired length of time. We incorporate this trend into a two-echelon, multi-commodity distribution network design problem. Over a planning horizon divided into a finite number of periods, it has to be decided which company-owned warehouses should be retained and where, when, and for how long new warehouse lease agreements should be signed. The latter may be in place at the same location for non-consecutive time periods. Furthermore, decisions concerning the inventory levels at the warehouses and the flow of products from upstream sources (i.e., suppliers) to downstream destinations (i.e., customers) through the operating warehouses must be taken in each time period. The objective is to find the least costly network configuration to meet customer demand. We develop a mixed-integer linear programming formulation for this problem and propose various families of additional inequalities that prove to be very useful for a general-purpose optimization solver to find high-quality solutions. To measure the impact of incorporating on-demand warehousing into facility location planning, we also study alternative approaches for leasing warehouses that are often found in practice and have limited flexibility and scalability. Our computational study gives useful insights into the trade-offs achieved by each of the different approaches with respect to total cost, network design decisions, and various logistics functions.

**2 - A Matheuristic for a Multi-period Distribution Network Design Problem with Short-term Capacity Adjustments**

*Isabel Correia, Teresa Melo*

We address a two-echelon distribution network design problem that determines the location and size of new storage facilities, the removal of existing facilities, the quantities of various types of products to be stored in each facility, and the assignment of suppliers as well as customers to the open facilities. A distinctive feature of our problem is that new storage facilities operate with modular capacities that can be expanded or contracted over several periods, the latter not necessarily having to be consecutive. Moreover, in every time period, the demand of each customer for a given product type has to be satisfied by a single storage facility. The objective is to determine the least costly network configuration to meet customer demand. This problem arises in the context of on-demand warehousing, a business model that offers flexible conditions with respect to the amount of capacity to be leased and the length of the lease agreement. We develop a mixed-integer linear programming formulation and propose a matheuristic to solve this problem, which successively assigns customers to storage facilities for the supply of particular products. The assignment decisions use information provided by the linear relaxation of the original problem. Numerical results obtained for randomly generated instances indicate the effectiveness of the proposed matheuristic. While a general-purpose optimization solver fails to find feasible solutions to almost one-fourth of the instances within a pre-specified time limit, the matheuristic identifies feasible solutions to all instances in significantly shorter computing times. Moreover, solutions with higher quality than those returned by the solver are available for nearly half of the test instances.

**3 - Fulfill and Ship-From Store in Omnichannel Distribution Network Design**

*Imen Ben Mohamed, Walid Klibi, Florian Bertrand*

Given the continuous growth of online sales, bricks-and-mortar retailers are responding to these developments by expanding their online services while trying to leverage their store network, thus, moving towards an 'omnichannel' retailing approach. In this context, omnichannel retailers are looking at implementing the Ship-From-Store (SFS) strategy to expand their service offers in their stores' network. Thus, the stores, as the core of omnichannel retailing, are used for both satisfying the in-store customers' demand and fulfilling online orders. In this paper, we introduce the Fulfillment and Ship-From-Store in an omnichannel distribution network design under uncertainty where online orders are prepared, packed, and shipped to the customer directly from a nearby store rather than a fulfillment hub. The paper studies the implementation of the SFS from fulfillment and distribution perspectives. The problem is a hierarchical decision problem due to the temporal hierarchy between the tactical implementation decisions and the operational order fulfillment and delivery decisions. Given the nature of the problem in the optimization framework, we consider a two-stage stochastic program with mixed-integer recourse. Our model considers two types of decisions: those that are here-and-now, namely, the selection of stores for SFS with the in-store fulfillment process as well as the determination of carrier pickup time, and those that are wait-and-see concerning the operations of this distribution network. To solve the two-stage stochastic model, an exact solution approach combining scenario sampling and the integer L-Shaped method is proposed. Numerical results, inspired by a retailer real case, are conducted to validate our model and to evaluate the efficiency of our approach.

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## ■ TB-02

*Tuesday, 11:15-12:30 - Hertz*

### Layout & Buildings

*Contributed session*

Chair: *Sven Müller*

**1 - The Deconstruction Site Layout Planning - a New Concept to Efficiently Locate Workstation and Material Storages Indoors**

*Niklas Braun, Rebekka Volk, Frank Schultmann*

The building landscape is changing. In particular, industrial facilities such as old power and chemical plants are reaching the end of their technical life cycle or are becoming obsolete due to economic and political developments. Therefore, the dismantling of many large building facilities, e.g., (nuclear) power plants, is imminent in Germany and Europe. Their dismantling represents a complex and demanding planning challenge, especially in the logistical area. Due to economic and often also regulatory reasons, many processes must take place inside the facility, which leads to the decision problem of where to best position the working machines and material storage. In the current literature, there are established models for solving this problem in the field of construction site layout planning. While there are different versions of the construction site layout planning, these all assume open areas without access restrictions, such as walls and doors. In this paper, we develop the deconstruction site layout planning as a transformation of the classical construction site layout planning. This new concept allows to represent the layout inside buildings and can be used for the first time to optimize the locations of working machines and material storages in the deconstruction of, e.g., nuclear power plants. The optimization model set up is a quadratic mixed integer problem. Using our newly developed concept, we solve a numerical case study and demonstrate the high potential of the deconstruction site layout planning.

**2 - Mathematical Model for Optimizing Conversion Strategies for Historic Buildings Based on Locational Characteristics**

*Kaori Isawa, Hiroko Watanabe, Yudai Honma*

The issue of architectural conservation in Japan has garnered significant international attention. Major news websites, such as the BBC and DEZEEN, have reported on demolishing noteworthy Japanese architecture, including the Nakagin Capsule Tower and the Kagawa Prefectural Gymnasium. This is due to the fact that "old" is often associated with low economic value in Japan, as a result of the country's postwar recovery and new construction dominance.

To address this situation, converting historic architecture into profit-making facilities has become a primary conservation approach in Japan. However, the economic viability of such conversions depends on locational characteristics. This study proposes a mathematical model to calculate the optimal amount of conservation construction cost based on location-specific conversion strategies for historic architecture into profit-making facilities. The model incorporates parameters such as 20-year net income, conservation construction cost, and income coefficient according to location, and is formulated as an optimization problem to derive the amount of conservation construction cost that maximizes the net income from the income coefficient.

Our analysis reveals that conversion is more economically viable than the status quo or new construction under certain conditions, which contradicts the prevailing Japanese practice. To validate the model, we analyze actual cases in Kyoto City and confirm that it is possible to estimate common parameters for a location. This study provides a mathematical optimization approach to capture the locational characteristics of urban changes and contributes to a better understanding of how location influences the success of conversion strategies.

**3 - An Optimization Method for Evaluating Facilities with Inaccessible Locations through Inverse Shortest Paths Problem**

*Hiroyuki Hasada, Daisuke Hasegawa, Yudai Honma*

With the increasing availability of GPS data, it has become easier to quantify the number of visitors and assess the facilities they visit. However, some attractive public facilities located in rural and inaccessible areas are often overlooked. Therefore, it is necessary to evaluate public facilities not only based on the number of visitors but also on how they have traveled to visit them. In this paper, we propose an optimization method for estimating the utility value, which is the overall attractiveness, of each facility and its consumer surplus. The surplus for a visitor to a facility is calculated by subtracting the travel cost from the utility value of the facility. To maximize the surplus, we implement a linear integer programming model that compares it to that of another facility. This means that the utility value of a distant facility is higher the more the travel cost is spent by a visitor who chooses to visit it instead of a nearby facility. To account for heterogeneity, visitors are classified into segments that share the estimated utility value, resulting in a novel inverse shortest paths problem model. We apply this method to the evaluation of "Michi-no-Eki", which are public facilities located along roads in Japan. We develop trip data from the origin to the destination of each visitor to a roadside station, using the ETC2.0 data recording vehicle probe provided by the road administrator. Through this evaluation, we identify valuable roadside stations in Ibaraki Prefecture that had only a few visitors, particularly track drivers, due to their remote locations far from the metropolitan Tokyo. Our proposed method contributes to the accurate evaluation and updated location of facilities that are geographically inaccessible but useful for logistics operators.

# Tuesday, 13:45-15:30

## ■ TC-01

*Tuesday, 13:45-15:30 - Seminarraum*

### Discrete Location Problems II

*Contributed session*

Chair: *Justo Puerto*

**1 - Networks Partitioning Based on Edge Density Using the Minimum Normalized Cuts**

*Francisco Temprano Garcia, Justo Puerto, Diego Ponce*

This paper deals with the k-way normalized cut problem in networks. The normalized cut function was defined to solve some issues concerning the interpretability of the minimum cut problem, which is a classical problem in graph theory whose aim is to provide the bipartition that minimizes the number of edges between nodes from different subsets, applied to partitioning and districting problems. Instead of considering just the number of external edges of each subset, the minimum k-way normalized cut problem tries to minimize the external edge density of each subset of a k-partition, also considering the number of internal edges. In addition, the problem can be extended to a weighted graph in order to minimize the sum of external weight density of the subsets. The minimum k-way normalized cut allows us to locate groups of nodes that accumulate a high internal weight density. Considering that these weights can represent a large number of different interesting parameters, this organization is really useful as facility location planning in order to locate in each of the clusters a facility that accumulates a high weight density. We show several applications of the minimum k-way normalized problem to facility location. We present a methodology using mathematical optimization to provide mixed integer linear programming formulations for the problem. The paper also develops a branch-and-price algorithm for the above mentioned problem which scales better than the compact formulations. Extensive computational experiments assess the usefulness of these methods to solve the k-way normalized cut problem over different location problems on large graphs and random graphs. In addition, all methods have been analysed and studied in order to try to improve them as much as possible.

**2 - Valid Inequalities and Preprocessing for the Capacitated Facility Location Problem with Preference Constraints**

*Sophia Wrede, Christina Büsing, Markus Leitner*

In the classical Capacitated Facility Location Problem (CFLP), a set of facilities needs to be chosen in order to cover the demand of customers. Customers are assigned to any open facility such that the capacity constraint of the facility is not exceeded. However, in many applications, customers are not willing to travel to any open facility assigned to them but want to select an open facility according to their preferences. The Capacitated Facility Location Problem with Preference Constraints (CFLP-PC) takes this behavior into account by assigning each customer to their most preferred open facility.

Both the CFLP and CFLP-PC are strongly NP-complete. Preference constraints, however, imply certain structures in solutions which do not occur in CFLPs. While these structures have already been studied for Uncapacitated Facility Location Problems with Preference Constraints, their use for the capacitated case is not yet well explored. These implied structures render some previously NP-complete special cases of the CFLP easy to solve; this highlights the potential of these insights for improving the MIP formulation. In this talk, we discuss these structures as well as how to use them in combination with capacities in order to derive new valid inequalities for a classical MIP formulation for the CFLP-PC. Furthermore, we propose problem specific preprocessing procedures, which are also based on the combination of structures induced by preference constraints and capacities. Eventually, we show in a computational study that these approaches have a positive impact on the computational run-time for solving the MIP.

**3 - The Hierarchical Nested Cooperative Location Problem: Challenges from Modeling and Solution Perspectives**
*Silvia Baldassarre, Giuseppe Bruno, Ioannis Giannikos, Maria Michopoulou, Carmela Piccolo*

In this work, we discuss the Hierarchical Nested Cooperative Location (HNCL) problem. It aims to locate different types of facilities organized in a two-level nested hierarchy, with the facilities at the lower level providing a subset of the services offered by those at the higher one. The coverage level of each facility decreases over the distance according to a decay function that varies between the hierarchical levels. We assume that facilities cooperate in order to cover the demand. In particular, cooperation occurs between facilities at the same level (intra-level cooperation) and facilities at different levels (inter-level cooperation) of the hierarchy. Such cooperation mechanisms are modeled through different aggregation functions. We assume that a demand point is appropriately covered if its overall aggregate coverage level exceeds a certain threshold. The objective is to determine locations for the facilities of different hierarchical levels to maximize the covered demand, subject to appropriate budget constraints. Since the HNCL problem may be challenging from a computational point of view, we discuss ways to improve the original HNCL formulation by reducing the problem to a more compact form. In addition, we present solution approaches taking into account the structure of the problem that may be easily solved by inspection. We discuss the theoretical properties of these approaches. We also experiment with different classes of randomly generated problems and investigate the solutions with respect to coverage quality and computing times. Preliminary results seem to indicate that the approach produces good solutions in a shorter time.

**4 - New Formulations of the Gray Pattern Problem**
*Pawel Kalczynski, Jack Brimberg, Zvi Drezner*

The Gray Pattern Problem (GPP), first proposed by Taillard (1995), requires finding a uniformly dispersed pattern of p black dots within a small rectangle of dimensions n1 x n2, where the remaining dots (or pixels) remain white. A "gray pattern" is then created by packing a large area (visualize the whole plane) with a large number of identical-looking small rectangles that are placed adjacent to each other. The black dots are placed in the same relative locations in all the rectangles. Taillard formulated the GPP based on the principle of minimum entropy in Physics. The model requires minimizing a sum over all pairs of black dots of the reciprocal of the closest squared Euclidean distance between the two points, taking into account their positions in the central rectangle and the eight surrounding (identical) rectangles. The model is formulated as a binary integer linear program. In our study, we propose alternate objective functions that improve the tractability of the problem while providing gray patterns of comparable and often better quality. The best results in terms of tractability are obtained with a MAXMINMIN criterion. Optimal solutions to Taillard's model are effectively limited to the 8 x 8 central square, with solutions for 16 x 16 and 32 x 32 limited to very small values of p. Thanks to the new formulations, gray patterns are now available for much larger instances. A generalization of Taillard's model is also proposed where exponent 2 of the Euclidean distance is replaced by a parameter b. Values of b as high as 8 are investigated. An interesting relation is found between this model with arbitrarily large b and MAXMINMIN. Some computational results are shown for discussion.

# ■ TC-02

*Tuesday, 13:45-15:30 - Hertz*

## Continuous p-Median Problems

*Contributed session*

Chair: *Kathrin Klamroth*

**1 - p-Median Location Problems in Timetabling**
*Anita Schöbel*

Finding timetables for bus or railway services is a challenging problem in public transport optimization. A major goal is to provide a good service, i.e., small journey times, for the passengers. The journey time of a passenger includes the traveling time and the waiting time at the first station. There are two types of timetables: periodic and non-periodic ones. Periodic timetables are repeated, e.g., every hour and provide a reliable and easily memorable service. Non-periodic timetables schedule the vehicle trips irregularly over the day.

It is an ongoing discussion if periodic or non-periodic timetables are better. Since periodicity is an additional restriction, the journey time of an optimal periodic timetable is higher as the journey time of an optimal non-periodic timetable. The question hence is how much quality one loses by requiring that a timetable is periodic. Unfortunately, periodic timetabling is an intrinsically hard problem such that this question cannot be answered easily.

In this talk we analyze periodic and non-periodic timetables for the case of a single bus or railway line. We show that in this case, the hard problem of finding good timetables can be reduced to variants of the p-median problem, namely, to the classic/directed p-median problem along a line and to the classic/directed p-median problem on a circle in the periodic case. We discuss properties of these location problems, identify a finite candidate set and provide algorithms that can solve the periodic and non-periodic timetabling problem. In our experimental evaluation we finally discuss the differences of the resulting periodic and non-periodic timetables.

**2 - A Trajectory Based Heuristic for the Planar p-Median Problem**
*Zvi Drezner, Jack Brimberg, Anita Schöbel*

This paper presents a novel approach for solving the planar p-median problem. In the distributed p-median problem (Brimberg et al. (2021), customers do not necessarily patronize the closest facility. They patronize the closest facility with a given probability, the second closest with another probability, and so on. A sub-class of the distributed p-median problem is identified. A parameter alpha between 0 and 1 is given. The probability of patronizing the second facility is equal to the probability of patronizing the first facility times alpha, and each subsequent facility is patronized with a probability of the previous facility times alpha. For alpha=0 each customer patronizes the closest facility which is the original p-median problem. For alpha=1, all facilities are located at the Weber location. A continuous trajectory of local optima is constructed as a parameter alpha decreases from 1 to 0. The trajectory converges to a local optimum of the planar p-median problem as alpha approaches 0. Computational results are very encouraging. For larger instances tested, the proposed trajectory method finds better solutions in a small fraction of the time taken by a conventional multi-start local search. The methodology is readily extended to continuous p-median problems in higher dimensional spaces.

Brimberg, J., Maier, A., and Schoebel, A. (2021). When closest is not always the best: The distributed p-median problem. Journal of the Operational Research Society, 72:200–216.

**3 - The p-Median Problem in the Presence of a River with Bridges**
*Atsuo Suzuki, Thomas Byrne, Pawel Kalczynski, Zvi Drezner*

We consider a variation of the p-median problem. The problem is the p-median problem with the existence of a river with bridges. In many cities, there is at least one large river: take for example the Tama River in Tokyo, the River Thames in London, the River Seine in Paris, etc.

For location problems in these cities, we need to consider the river as a barrier for the customers who live in the city. In order to find the optimal location of a facility here, we should assume that customers can cross the river only at the river's bridges. In this talk, we assume that distances across the city are measured using the Euclidean distance and we wish to obtain the optimal locations of a number of facilities which minimize the total travelling distance of the customers to their closest facility. This problem is a variation of the Weber problem; however, while the objective function of the original Weber problem is convex, the objective function in the presence of a river is nonconvex even for the single facility problem. Due to this reason, descent methods such as the Weiszfeld method do not work in finding the optimal solution. Instead, we use the Big Triangle Small Triangle (BTST) method to find the optimal locations: a method designed for location problems whose objective function is nonconvex. It has been shown that the BTST method is effective for many location problems including the Weber problem with attraction and repulsion, obnoxious facility location, the Weber problem on the sphere, the p-median problem with Manhattan distance, etc. We utilize the BTST method to solve the p-median problem with the existence of a river with bridges and show the effectiveness of the method using computational experiments.

**4 - Multi-facility Continuous Minisum Location Problems in which Potential Facility Sites and Demand Points are Restricted to Polygons**
*Ken-ichi Tanaka, Yuki Hiraoka, Osamu Kurita, Yasushi Narushima*

We address two multi-facility minisum location problems in the presence of multiple non-convex polygons. We assume that demand points are uniformly and continuously distributed in the polygons, and facilities can only be located inside the polygons. Each demand is assumed to be serviced by the nearest facility. Two objective functions are considered: the expected Euclidean distance and the expected squared Euclidean distance between every demand point to the nearest facility. We construct a heuristic solution method for each of the proposed models that alternately optimize demand allocation and facility location. In the allocation phase, a Voronoi diagram is used to specify the set of demand points serviced by each facility. Since input polygons are multiple non-convex polygons, the set of demand points allocated to each facility is composed of disconnected non-convex polygons. In the locational optimization phase, a set of the single-facility location problem for the demand points allocated to each facility is solved and their locations are simultaneously updated. In the Euclidean distance model, disconnected non-convex polygons are decomposed into a set of convex polygons, and a set of convex programming problems are solved assuming that a facility exists within each convex polygon. The best solution among the set of convex programming problems becomes the optimal solution to the single-facility location problem. In the squared Euclidean distance model, the corresponding single-facility location problem can be solved efficiently by exploiting the fact that the contour of the objective function is a circle. As a numerical example, we apply the proposed methods to location problems in which some of the actual Japanese islands are represented as a set of polygons.

# Tuesday, 16:00-17:15

## ■ TD-01

*Tuesday, 16:00-17:15 - Seminarraum*

### Hub Location Problems under Uncertainty

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

**1 - Sustainable Hub Location under Uncertainty**
*Gita Taherkhani, Seyed Mojtaba Hosseini, Sibel A. Alumur*

In this paper, we study the sustainable design of hub networks under uncertainty for truckload and less-than-truckload transportation. In particular, we study a profit-maximizing hub network design problem in which the demand of some origin-destination pairs can remain unserved, where satisfying the demand depends on the profit to be obtained from serving it. We additionally focus on sustainability by modeling both a carbon tax and a carbon cap in our problem setting. We develop a model in which, in addition to transportation and hub installation costs, the carbon tax is also explicitly included in the objective function. Moreover, to ensure that the total amount of greenhouse gas emissions emitted by trucks does not exceed the carbon cap, we incorporate an emission limit on the entire transportation network. We model emission on each arc as a convex function of transport load on the arc and consider separable and non-separable cases to cover a wide range of practical aspects, including different carbon cap policies as well as the robustness of solutions. We provide piecewise linear approximations to these emission functions to ensure the feasibility and tractability of our models. To provide a more reliable solution framework for this problem, we take the demands as stochastic parameters and then develop a Benders-decomposition-based algorithm coupled with a sample average approximation scheme for solving our stochastic problem. We implement several enhancement techniques beyond standard implementations of these algorithms to guarantee scalability to large-scale instances.

**2 - Recourse Policies Assessment for a Multi-period Hub Location Problem under Stochastic Transshipment Capacity**
*Riccardo Giusti, Daniele Manerba*

We study a logistics setting where a company producing a commodity in many origins needs to fulfill the demand for such a commodity for multiple destinations. Origins and destinations are sparse in a vast area, thus making direct shipping a too expensive option, especially when large quantities must be shipped. For this reason, the company adopts economies of scale and consolidation mechanisms by shipping the commodity through transshipment terminals, such as ports and railway stations. This involves, apart from the classical operational decisions on commodity transportation, some tactical decisions consisting in securing contracts with terminals long in advance to guarantee that enough capacity will be available during transshipment operations. The contracts make it possible for the company to schedule similar repeated operations over a sufficiently long horizon. However, the actual capacity can be less than the contracted one in a specific time period for many reasons (e.g., terminal overloading, backlogs). This issue requires that the company is ready to find other alternatives to complete the shipments on time. We model this setting as a stochastic variant of the Hub Location Problem in which the location decisions regard the selection of transshipment nodes and their usage in each time period. We propose various two-stage Stochastic Programming (SP) formulations considering different possible recourse actions, such as acquiring extra transportation and transshipment capacity, and assess their impact in effectively dealing with the uncertainty. The assessment is done by solving the models and deriving well-known SP indicators (e.g., VSS, EVPI, LUSS, LUDS) over a representative set of realistic scenarios.

**3 - Hub Location Problems with Explicit Redundancy Requirements**
*Armin Lüer-Villagra*, *Guillermo Latorre*

Hub location models are commonly used to design networks where multiple origin-destination (OD) pairs must be economically served. It is addressed by locating special facilities called hubs, where consolidation, sorting, or routing happens. Hubs are typically interconnected using high-capacity links to achieve economies of scale. The resulting network topology, called hub-and-spoke, allows the connection of multiple OD pairs using fewer links than direct interconnection.

In telecommunications, the main goal is to design resilient and cost-effective networks. However, there is a trade-off between resilience and cost. On the one hand, resilience can be achieved by equipment and link redundancy, making networks more complex and expensive to maintain. On the other hand, cost-effective networks consolidate traffic in high-capacity links, making the network more fragile, i.e., less resilient.

Hub location models only sometimes consider the resilience of the resulting network. Literature suggests that resilience can be addressed through stochastic and robust programming, modeling the situation as a Stackelberg game, etc.

We propose to design hub-and-spoke networks for telecommunications considering explicit redundancy requirements in the network, i.e., a minimum number of disjoint paths must connect an origin-destination (OD) pair in other to serve its demand.

We study the impact of adding these redundancy requirements on the network structure, providing preliminary results regarding estimating the network's resilience and costs under this approach.

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# ■ TD-02

*Tuesday, 16:00-17:15 - Hertz*

## Location-Routing Problems

*Contributed session*

Chair: *Alan Murray*

**1 - A Multiple Asset-type, Collaborative Vehicle Routing Problem with Proximal Servicing of Demands**
*Stephen Donnel*, *Brian Lunday*

This research examines the problem of routing multiple assets of different types over a network to service demands collaboratively. The servicing is collaborative in that, when servicing a demand, the different asset types must do so nearly simultaneously. Moreover, whereas some asset types must service demands by visiting them, others may provide service proximally, i.e., from any specified location within a range of a demand. This study sets forth a mixed-integer linear program to model this variant of a vehicle routing problem. In addition to directly solving problem instances via a commercial solver, this research proposes two permutations of a model decomposition heuristic, as well as two preprocessing techniques to impose instance-specific bounds on selected decision variables. Comparative testing evaluates nine combinations of solution methods and preprocessing options to solve a set of 216 instances that vary significant parameters. Results manifest trade-offs between the likelihood of finding a feasible solution and the relative quality of solutions identified. For larger networks, the preprocessing technique leveraging a nearest neighbor heuristic in combination with any solution method most frequently identified feasible solutions for the set of test instances (i.e., 90% of instances), with lesser solution quality (i.e., within 15% of the best solutions identified, on average). Worst performing for larger networks was a model decomposition technique that first routes assets providing service proximally, and omitting either preprocessing technique; although this combination yielded the best solutions when it identified a feasible solution, it only did so for 55% of instances. Other solution method performances exhibit noteworthy nuance.

**2 - A Hybrid ALNS-DRL Approach for Solving a Location and Routing Problem**
*Syu-Ning Johnn*, *Victor-Alexandru Darvariu*, *Julia Handl*, *Jörg Kalcsics*

Nowadays, most restaurants in large city zones rely on food replenishment services transferring food products from outside the urban area. An integrated logistic system is essential for efficient transportation that ensures food perishability. Two decisions play a central role in optimising this food distribution network, including establishing intermediate transport points and end-to-end shipment routing. Together they form a location-routing problem, which embeds a strategic Facility Location Problem carrying a long-term effect on urban construction, and an operational Vehicle Routing Problem computing daily delivery routes.

In this work, we propose a hybrid approach based on Adaptive Large Neighbourhood Search (ALNS) metaheuristic and Deep Reinforcement Learning (DRL) to produce good-quality solutions for such a location-routing problem. We formulate the choice of operators as a Markov Decision Process and propose an operator selection mechanism based on DRL to enhance the performance of the classical ALNS framework. Specifically, the operator selection process is conditioned on the individual solution, which enables us to gain insight into the dynamic contribution of each operator in navigating the search towards promising neighbourhoods.

Experiments results show that our proposed DRL approach achieves better performance than the classic ALNS with the embedded adaptive layer. We demonstrate the potential of using Graph Neural Networks to train our RL agent on graph-structured data, thus being able to scale the model to large problem instances. Furthermore, our results highlight the impact of the operator portfolio size and the destroy scale on performance.

**3 - Multi-period Single-Allocation Hub Location-Routing: Models and Heuristic Solutions**
*Afaf Aloullal*, *Francisco Saldanha-da-Gama*, *Raca Todosijevic*

The study investigates the use of time-dependent decisions in the context of hub-location routing. Instead of setting up the entire system at once, a planning horizon is partitioned into several periods during which the system is to be phased in. In addition to installing the hubs, decisions are also to be made concerning the hub-level network, namely, the hub edges to use. The origin-destination flows are assumed to be time-dependent, as well as the costs underlying the problem, which include set-up costs for hubs and hub edges and variable operational costs at the hubs. A mathematical model is developed for the problem that can be solved up to proven optimality with a general-purpose solver for small instances of the problem. A four-phase matheuristic that combines principles of relax-and-fix, variable neighborhood descent, and local branching schemes is proposed for larger instances. In addition, two variants of the matheuristic have been developed. The above model and methodology are tested using data generated by extending existing hub location instances to our problem. The obtained results are detailed and analyzed in depth. The major conclusion is that by capturing time in the decision-making process, one may find solutions that better hedge against parameter changes throughout time. Furthermore, the overall procedure presented in this work is quite general in the sense that it can be easily adapted to other multi-period decision-making problems and different objective functions.

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# Thursday, 9:00-10:45

## ■ HA-01

*Thursday, 9:00-10:45 - Malersaal*

### Stochastic Facility Location

*Contributed session*

Chair: *Teresa Melo*

**1 - Minimizing Maximum Regret in Two-stage Facility Location with Site Preparation Costs**

*Ronald McGarvey, Andreas Thorsen*

Consider a situation in which an initial decision is made to prepare a set J of locations for potential future use supporting a set of customers under uncertain demand. Once the demand is revealed, the decision maker then makes a recourse decision selecting the set K of actual facility locations to be opened, where K is a subset of J. Let Aj denote the cost to prepare site j during the first stage. During the second stage, let Bj denote the cost to open site j if site j had been prepared during the first stage. We present robust MILP formulations of this problem, assuming an objective function that minimizes the maximum regret. A budgeted uncertainty set is assumed, in which the realized demand is assumed to be equal to a most-likely value Mj plus a potential positive deviation Pj minus a potential negative deviation Nj. Use of a regret-based objective function has a significant impact on the solution time when directly solving with a commercial MILP solver. In part, this is due to the fact that we assume demand could potentially be less than the expected value at any customer, unlike most research in the robust facility location domain, which typically is concerned with situations in which demand is assumed to vary such that it may only exceed the most-likely value. We then develop a computationally-efficient solution algorithm, based on a column-and-constraint generation (CCG) approach, and examine numerical test instances to identify the relationship between problem conditions (e.g., relative magnitude of Aj versus Bj, relative magnitude of transportation versus facility opening costs, relative magnitude of Mj versus Pj and Nj) and the optimal solution's ratio of cardinalities of K and J.

**2 - Facility Location Problem under Uncertainty with Service Level Constraints**

*Haoyue Zhang, Jörg Kalcsics*

In facility location, most models assume customer demands to be deterministic. However, in practice, there is often a large degree of uncertainty about future demands, especially given the strategic nature of location problems where decisions have to be made for the next twenty or thirty years. Stochastic programming models are widely applied to solve FLPs under uncertainty. However, since all the demand has to be satisfied in every scenario, the models sometimes give conservative results.

In this work, we present a novel service level model that includes service levels through chance constraints in the stochastic programming model and solves with scenario generation, allowing for a certain probability and a certain percentage of the demand to be unsatisfied. In the model, the alpha service level is applied both locally and globally while the beta service level constraints take the expected value, as well as the maximum value of the excess into account.

We carry out experiments on randomly generated data sets to compare the performance of models with different combinations of service levels with each other, as well as with a penalty model from the literature as benchmark. Compared with the penalty model, the chance-constrained model is straightforward and interpretable. It does not require parameter tuning and enables the decision maker to have more control over the risk levels. Finally, Benders' Decomposition and a modified Sample Average Approximation algorithm with Concentration Set are also implemented in order to solve the model more efficiently.

**3 - Multi-period Facility Location Problem with Capacity Adjustments under Uncertain Demand**

*Šárka Štádlerová, Peter Schütz, Sanjay Dominik Jena*

We study the problem of where to locate production facilities, which capacity to install in, when to expand and when to reduce the installed capacity and how to allocate customers' demand. We formulate our problem as a multi-stage stochastic multi-period facility location problem with capacity adjustments and compare it with a two-stage rolling horizon approach. In the first stage, only the opening of new facilities is allowed whereas in the second and third stage, opening and capacity adjustment of existing facilities is possible. The objective is to minimize total expected costs consisting of investment and capacity adjustment costs, production costs, and distribution costs. We present a model with modular capacities and specific non-linear production costs for each capacity level. In our model formulation, minimum production requirements can be considered as well.

We solve the problem using Lagrangian relaxation. The relaxed problem is separable in facility location and can be formulated as an expected shortest path problem and solved efficiently using dynamic programming. To obtain a feasible solution, we develop a heuristic based on the solution to the relaxed problem.

We solve the real case problem of locating hydrogen production facilities in Norway under uncertain demand. Hydrogen is considered a way to decarbonize the transportation sector which is an important step to achieve the goals set in the Paris agreement. Total customer demand is expected to increase over the next years but is also the main source of uncertainty. Demand at some customer locations can decrease as well. However, the overall demand level remains unchanged.

**4 - Stochastic Facility Location Problems in Reverse Logistics**

*Ruurd Buijs, Rob van der Mei, Elenna Dugundji, Sandjai Bhulai*

Due to the increasing focus on sustainability, many interesting optimization problems arise. One example of sustainability-driven optimization is the analysis and design of reverse supply chains. Our study concerns the reverse supply chain of rigid polyurethane (PU) foam waste that is retrieved from insulation panels and from refrigerators. In this context, we investigate a facility location problem. The goal of this endeavor is to strategically place regional waste collection and processing sites, which will ultimately facilitate an analysis on economic feasibility of setting up a PU recycling pipeline. Since we are dealing with construction and demolition waste, uncertainty is one of the key aspects which increases the complexity of making strategic facility location decisions. Some of the most important modeling parameters, like the location, quality, and quantity of waste offered, are prone to a high degree of uncertainty. In order to incorporate the interests of different stakeholders within the reverse supply chain, we apply multi-objective optimization. Our stochastic Mixed Integer Linear Program formulation takes into account the stochastic nature of the waste quantity. Currently, our focus is mainly on accurately modeling the uncertainty in waste demand in a facility location setting for recycling PU in the Amsterdam region, with other uncertain aspects in mind for further research. Furthermore, our model reflects on the decision to compress the material at certain facilities, which is a feature that has (to the best of our knowledge) not yet been addressed in earlier literature. We present some new insights into how sustainability considerations can be integrated into facility location models and how uncertainties typical to this setting can be addressed.

# ■ HA-02

*Thursday, 9:00-10:45 - Musikersaal*

## Location & Covering

*Contributed session*

Chair: *Richard Church*

### 1 - Coverage Objective and its Generalizations in Location Analysis

*Dmitry Krass, Oded Berman*

Coverage is one of the two classical objective functions in location analysis. The idea is both simple and appealing: instead of worrying about exact travel patterns of customers to facilities, we simply focus on whether a particular location configuration ensures that there is a facility sufficiently close to each customer location.

This has both practical and computational advantages: on the practical side, the potential applications range from public service facilities to retail stores. On the computational side, the coverage focus allows for significant simplification of the underlying optimization models.

The classic coverage objective makes several strong implicit assumptions: (1) coverage is an "all or nothing" phenomenon, (2) coverage is determined by the facility that is closest to the customer, (3) coverage (or its absence) is deterministic. In recent years models have been proposed relaxing some or all of these assumptions by examining the very idea of "coverage".

One of the earliest generalizations was the idea of "gradual cover", relaxing assumption (1). Concepts such as "cooperative cover" and "multi-cover", relaxing assumptions (2) and (3) followed. Another extension is that of "robust cover", ensuring that adequate coverage is maintained even if some parts of the transportation network fail. The price of relaxing these assumptions are models that are significantly more challenging, particularly when the decision space and/or the demand space are not discrete.

In this talk, we will review both the classical models and many of the extensions, review some exact and heuristic solution approaches, and outline some open problems and directions for future research.

### 2 - Multi-product Maximal Covering Second-level Facility Location Problem

*Marta Baldomero-Naranjo, Maria Albareda Sambola, Luisa I. Martínez-Merino, Antonio Manuel Rodriguez-Chia*

In hierarchical facility location problems, the goal is to locate a set of interacting facilities at different levels of a hierarchical framework. In this context, we introduce a model which considers a first- (or highest-) level system of already established services (factories, product sources, etc.), a second-level system of facilities to locate, and a third- (or lowest-) level system of clients demanding different products produced in the first-level and provided by the second-level facilities. The set of clients has different product demands and distinct preferences depending on the first-level facility producing the product.

The aim of this model is to locate a set of second-level facilities (warehouses, shops, etc.) in such a way that the covered clients' demand is maximized. Therefore, in order to satisfy a customer's demand, there must be double coverage, the customer must be covered by a second-level facility, and this, in turn, by a first-level facility.

In this model, called multi-product maximal covering second-level facility location problem, there is a maximum number of different products that can be offered at each second-level facility and also a budget constraint for the total cost of the facility locations. We derive a mixed integer formulation for this problem. Furthermore, we develop several families of valid inequalities to reinforce the model. In addition, we propose a heuristic procedure that provides good feasible solutions. Finally, we present several computational results that show the enhancement produced by the inclusion of valid inequalities in the formulation and the high-quality solution given by the heuristic algorithm.

### 3 - Optimal Coverage-based Placement of Static Leak Detection Devices for Pipeline Water Supply Networks

*Miguel Martínez-Antón, Víctor Blanco*

The design of leak detection systems on water supply networks has attracted great interest due to the economic and environmental impact associated with the systematic loss of this resource all around the world. In this work, we provide a mathematical optimization-based approach to determine the (continuous) location of leak detection devices, taking into account the length coverage of the pipeline supply network. In contrast to other covering location models in the literature, we do not assume that the devices are to be located in the nodes or edges of the network but in the whole space where the network is embedded, resulting in more flexible decision making models. Furthermore, we provide a general framework where the coverage areas are either lp-norm or polyhedral-norm balls that can be extended to more sophisticated shapes by means of disjunctive formulations. We develop two different types of models. In the first model, the number of devices is given, and the goal is to locate them to maximize the volume coverage of the pipelines in the network. The second model minimizes the number of devices to be located to partially cover the network. For these models, we derive different mixed integer p-order cone optimization formulations (and second-order cone reformulations), as well as math-heuristics approaches that exploit the nature of the single-device location problem, which is further analyzed. We report the results of an extensive battery of computational experiments performed on real-world urban pipeline water supply networks.

### 4 - Capturing Uncertainty in the Hybridized Maximal Covering Location Problem

*Ricardo Gázquez, Víctor Blanco, Francisco Saldanha-da-Gama*

Our work focuses on maximal covering facility location, a branch of Location Science that was first proposed by R. Church and C. ReVelle in 1974. Recently, the work by V. Blanco, R. Gázquez and F. Saldanha-da-Gama in 2023, has motivated the use of different types of facilities for maximal covering location problems (MCLP) in discrete and continuous spaces, with several applications such as telecommunications or surveillance activities, among others.

Our talk specializes in a two-stage MCLP under uncertainty. In the first stage, a set of initial facilities is selected from a finite set, adopting a discrete facility location setting. In the second stage, additional facility locations are chosen in the whole space underlying the problem, and the number of facilities to locate is not known beforehand, depending on an unknown budget. The overall problem is cast as a MCLP with two types of facilities and uncertainty in the maximum number of second-stage facilities.

We present in this talk different ways of dealing with uncertainty, such as the max-min and max-min regret measures of robustness in the absence of probability distributions, and the expected coverage model when a probability distribution is provided. We also discuss the use of reliability sets, which are subsets of scenarios with a joint probability threshold, and the Conditional Value at Risk (CVaR) approach that minimizes a convex combination of the maximum regret and expected regret with respect to the scenarios in a reliability set. Finally, we show how these various approaches affect decisions on the location of first and second stage facilities through experimental results.

# Thursday, 11:15-12:30

## ■ HB-01

*Thursday, 11:15-12:30 - Malersaal*

### Time and Uncertainty

*Contributed session*

Chair: *Francisco Saldanha-da-Gama*

**1 - The Value of the Multi-period Solution Revisited: How to Model Time in Capacitated Location Problems**
*Hannah Bakker, Stefan Nickel*

Location decisions are often long-lasting and multi-period models have received considerable attention. The price to pay for the increased flexibility in decision-making is increased complexity. When facilities are capacitated, multi-period models impose additional restrictions regarding when to use resources. The value of the multi-period solution (VMPS) was introduced to quantify the benefit of shifting to a multi-period model by setting its objective value in relation to that of a static counterpart. As the latter is not uniquely defined, different types of VMPS are reported in the literature. In the present study, we show that different static counterparts require different interpretations and evaluate different aspects of the aforementioned trade-off. We discuss how relaxing time-dependent constraints and deriving periods from the problem's data allows decision-makers to exploit the benefits of increased flexibility while limiting the drawbacks arising from multi-period modeling. We validate all propositions in a set of experiments based on multiple data sets from the literature and observe that, in particular, when capacities are restrictive, i.e., facilities exhibit a high utilization, the effects of shifting to a multi-period model can be positive or negative. We present means to determine an appropriate model of time based on the particular requirements of individual instances. We conclude that more does not necessarily translate to better when it comes to modeling time.

**2 - New Insights on Decision and Forecast Horizons for Multi-Period Facility Location under Uncertainty**
*Paulo Moreira, Francisco Saldanha-da-Gama*

This work focuses on determining forecast and decision horizons for stochastic multi-period facility location problems. A planning horizon is considered that is divided into time periods. The problem consists of deciding where to have facilities operating in each time period so that the demand of a set of customers can be satisfied. The objective is to minimize the total cost throughout the planning horizon, which is divided into the cost of operating the facilities and of supplying the customers. Additionally, a set of potential locations exists where new facilities can be installed during the planning horizon. However, it is assumed that the configuration of each location cannot change more than once over time. In a simplified way, a scenario in a decision problem consists of a possible future, which we may have a previous notion that could happen, but we are not sure if it will happen. The work targets large (possibly infinite) planning horizons; thus, a discount factor is assumed for the monetary values. Uncertainty is assumed for costs and demands. The resulting problem can be formulated as a multi-stage stochastic programming problem. From observing the existing literature, it is still scarce work capturing stochastic multi-period facility location in a multi-stage stochastic programming modeling framework on infinite time horizons. Seeking forecast horizons is a means to overcome the cumbersome size of the models one easily gets. In this work, we address this gap in the literature. Computational tests are reported on to assess the contribution provided by the results of this work.

**3 - Optimization Models for Locating and Assigning Warehouses for Large Customers under Uncertain Demands**
*Harshit Yadav, Ashutosh Mahajan, Avinash Bhardwaj, Narayan Rangaraj, Harshit Gupta, Vishal Sunkishala, Dhruv Thakral*

Facility location is an important decision in planning the logistics of a supply chain, and it is difficult to revert such decisions due to the high costs. Our study models the problem of locating a given number of warehouses so that the outbound logistics are optimized. Location decisions are formulated using a mathematical model. Mathematical modeling is preferred over other methods because it allows for a systematic understanding of the system being modeled, enables better system control, design, and the effective application of computational tools. Under the given conditions, the cost of opening and operating warehouses is not considered, rather a budget of the number of new facilities is given. Warehouses are initially assumed to be uncapacitated. Customer locations are fixed and known. Past demand data is available for estimating demand scenarios in the future. Rectilinear distance measure is used to model the travel cost from warehouse locations from plants and to customers. In the uncapacitated case, a deterministic equivalent of the stochastic greenfield model is formulated and solved to get the expected transportation cost. The model is nonlinear but can be converted into a mixed-integer linear optimization model using some transformations. Scalability studies are carried out to understand the size of the problem that can be solved directly by existing MILP solvers. A cluster-based heuristic is proposed for bigger problems that can arise in practice. Experiments show that even if the heuristic misses the optimal solution, it is quite near to it. Ongoing work on the case of capacitated warehouses and other practical constraints will also be discussed.

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## ■ HB-02

*Thursday, 11:15-12:30 - Musikersaal*

### Public Transportation

*Contributed session*

Chair: *Anita Schöbel*

**1 - Location Planning in Intermodal Networks: the Accessibility of Local Supply**
*Nicolas Fröhlich, Tobias Dietz, Nils Hausbrandt, Stefan Ruzika*

The 15-minute city concept states that everyone should be able to reach (the most important) public services and local amenities within 15 minutes. However, the mobility behavior of the different population groups is very heterogeneous: While some people are very active and like to do errands by bicycle or on foot, others resort to the car; others have to rely on the use of public transport. Locational decisions should therefore take all these different user groups into account at the same time, if possible, and on the other hand, it must be weighed up in which situations longer travel times have to be accepted. As part of our work, we are creating user profiles that will map the different intermodal usage patterns of the population and with respect to which locational decisions will be evaluated. To this end, we resort, among others, to variants of the Regular Language Constraint Shortest Path Problem used in the literature for this purpose. From a location planning perspective, several questions arise: How are locations evaluated from an intermodal perspective? In particular, how is timetable dependency dealt with when using public transport? How can the intermodal accessibility of local supply be improved by resource-saving interventions? Do new locations have to be set for this purpose, or do the connections or usage options of individual means of transport have to be expanded? In this talk, we present a modeling of the problem, analyze the local supply infrastructure exemplarily for a selection of German cities, and present solution approaches that improve the intermodal accessibility of public services.

**2 - Determining the Stops and Ring Routes of the Suburban Train Line: An Alternative Transportation for Industrial Workers**
*Eren Özceylan*

Gaziantep, a city in the South Anatolia of Türkiye, has seven organized industrial zones and is the fifth largest exporting province. Every day, 250 thousand workers commute from the city center to the industrial zones in order to provide the necessary manufacturing in the factories. The largest part of this transportation is provided by approximately 2500-3000 shuttles. It is clear that traffic jams, air pollution, and other negative effects caused by shuttles have become an unbearable burden for the city. In order to solve these problems, there is a suburban train line project to go from the city center to the organized industrial zones, and the workers are requested to provide their transportation by using this train line. Therefore, where will be the locations of the stops on the train line and on which routes the rings that will feed these stops will travel are some of the questions that need to be answered. Within the scope of this study, the locations of the stops on the train line will be determined upon the request of Gaziantep Municipality and which stops will be fed by ring services. For this purpose, a three-stage solution approach will be applied. In the first stage, the addresses of the workers will be written on the map (using Esri ArcGIS) over the pilot region in order to see the demand intensity. In the second stage, the potential stops will be evaluated (using maximum coverage location) according to the maximum number of covered workers. In the last stage, ring routes (considering capacitated vehicle routing problem) will be determined taking into account the selected stops. The results to be obtained and different scenarios will be presented to Gaziantep Municipality as a policy developer.

**3 - The Optimal Location of a Rapid Transit Line in a Rectilinear City**
*Thomas Byrne*

As the world becomes more technologically advanced, the way people value their travel time has changed. The average cost of a unit of time is rising and populations are increasingly willing to pay more in order to save time as time becomes one of the rarest resources they possess. It is therefore naturally a focus of city planners to reduce travel times within an urban area and good transport infrastructure design is imperative for the effective and efficient usage and experience of a space.

To this end, the optimal location is investigated for a rapid transit line which can be accessed at either endpoint (resembling, for example, a new train or bus line across the city, or the building of a new inter-city road). We propose its placement within a rectangular city across which it is assumed that travel obeys the Manhattan metric; the block norm is a convenient approximation of travel distances within most urban settings. The objective here is to choose the location of the rapid transit line in order to maximise the inter-connectivity of the city by minimising the average distance between any two points within the city. To accomplish this, the geometric properties of shortest paths in the presence of a rapid transit line must be studied, exploring how the optimal locations and orientations of such a line is affected by the average speed along the transit line, the length of the transit line, and the angle that the line makes with typical west-east (or north-south) oriented paths. Such a result allows for better understanding of the impact of new transport initiatives, for easier assessment of the likely impact of potential infrastructure schemes, and ultimately for the identification of the optimal development of rapid transit lines.

# Thursday, 13:45-14:45

## ■ HC-01

*Thursday, 13:45-14:45 - Malersaal*

### Location Science: New Love Will Never Die

*Plenary session*

Chair: *Stefan Nickel*

**1 - Location Science: New Love Will Never Die**
*Elena Fernández*

Indeed, after some years in the business, we all fully agree with Horst's statement. Still . . . some of the youngest participants at ISOLDE 2023 may have some doubts on why they should attend this meeting. Even worse, they may wonder whether Location Science will ever become their true old love.

In this talk, I would like to reassure them that this will certainly happen. I will reveal why, after more than 35 years, Location Science still makes my heart beat strong: Learning every day from students and colleagues, and being continuously surprised by new questions and problems are not minor matters. Knowing where to strategically organize conferences is neither a minor issue!

I will share with you some aspects of Location Science that still make me look ahead. I only have a few pictures and my memory is terrible, but I certainly have convincing reasons that explain why I feel so privileged for having the opportunity of giving this talk.

# Thursday, 15:15-17:00

## ■ HD-01

*Thursday, 15:15-17:00 - Malersaal*

### Public & Service Location Problems

*Contributed session*

Chair: *Ioannis Giannikos*

**1 - Network Design Recycling Waste Collection Bins by a Commune in Chile**

*Sebastián Dávila, Franco Quezada, Marcela López G., Sebastián San Martin C.*

The increased populations in urban zones have increased waste generation and taken measures to authorities to decrease the amount of waste finished in a landfill without being recycled prejudices the environment and raising the cost of treatment.

For aboard these challenges, authorities around the world have proposed different strategies to incentive recycling, such as recycling waste collection bins distributed in the city where the population can leave their recyclable residues (such as glass, cardboard, and plastic, among others) to that be carried to treatment centers, which finally convert in primal material it for a new use.

In order to have implementation effective recycling waste collection bins, the authorities must strategically decide the location, size, and type of bin (glass, cardboard, plastic, among others) according to user preferences. Later defines the frequency to avoid generating micro-dumps close to the bin due to exceeding its capacity and the routing to decrease logistic costs, including deciding the type and size of the collection trucks.

Then, this paper aims to optimize the location of the recycling waste collection bins to increase recycling and decrease transportation operations costs. We mathematically formulate the problem as a mixed-integer programming (MIP) model based on the periodic location-routing problem.

In order to test the formulation, we presented a study by a commune in Chile. According to evaluate different strategies of the decision maker, we test both the economic cost and increase of recycling through various scenarios with different penalize levels for the lost users and for the exceed to waste in the bins, to buy or lease collection trucks, changes in the transportation cost, and different levels of demand.

**2 - A Soft-Constrained Multi-Objective Facility Location Approach to Design Household Waste Recycling Centres Networks in South Yorkshire: Analyses and Managerial Insights**

*Serena Fugaro, Antonino Sgalambro, Filippo Santarelli*

Efficient Waste Management is among the key points of the 25 Year Environment Plan devised by the UK government in 2018. In this context, Household Waste Recycling Centres (HWRCs) represent essential components to reach the recycling rate goals of the Resource and Waste Strategy. With the aim of improving the design of HWRC networks while identifying the optimal location for current and future HWRC sites, this paper presents a novel multiple objective problem for locating HWRC facilities and allocating users. Specifically, our approach is based on mixed integer programming and is inspired by technical requirements and legal obligations for services of bulky waste collection, processing, and disposal, operated by a local authority in Sheffield, South Yorkshire, UK. Indeed, the decision-making process underlying the HWRC network design must be based on a comprehensive strategic approach, accounting for the interests of the various stakeholders involved: public authorities, service operators, and final users. In fact, multiple objectives are pursued, i.e., reducing operating costs and achieving high levels of user satisfaction while meeting specific legal obligations. Furthermore, to provide an accurate representation of the actual dynamics driving this particular design process, we devise a soft-constrained version of the resulting Capacitated Facility Location problem. Then, with the aim of providing sound support to decision-makers, we adopt the robust variant of the AUGMECON method for the efficient representation of the arising Pareto Sets. The experiments conducted on realistic instances based upon the Sheffield area, enable an insightful computational study and provides valuable managerial evidence for supporting the efficient design of HWRC networks.

**3 - Strategies for Redesigning the Last-mile Logistic System of a Postal Company: an Application to the Italian Case**

*Eduardo Pipicelli, Silvia Baldassarre, Giuseppe Bruno, Antonio Diglio, Carmela Piccolo*

This work is developed within a collaboration project with the major Italian Postal Provider (Poste Italiane S.p.A) and concerns the (re)design of its last-mile logistic system. In particular, the provider needs to define new delivery strategies to face the recent increase in parcel volumes by minimizing the impact on management costs and negative externalities on urban areas (i.e., congestion and pollution). The first solution being explored consists in the activation of innovative facilities named collection-and-delivery points (CDPs), where customers may self-collect their parcels. Such facilities would offer a more efficient, sustainable, and flexible alternative to deliveries at home as they would allow for avoiding delivery failures and enable tour optimization. Moreover, they are characterized by low activation costs as they are usually located at regularly-visited shops, such as supermarkets or tobacco shops, and require only a fee paid to the owners. However, the success of this strategy depends on the location of CDPs and their distances from customers, as they strongly affect their behavior and the probability they patronize such facilities. To tackle the problem of the optimal location of CDPs, we propose a facility location model aiming at maximizing the attracted demand. The attraction probability of a given demand point depends on the number of facilities located in its neighborhood and their relative distances. The model is applied using real data related to a specific Italian urban context, and the obtained results suggest insightful managerial implications for Poste Italiane. Indeed, through the model, different scenarios are generated and analyzed in order to evaluate the trade-off between the benefit achievable and the costs to be incurred.

**4 - Allocating Teaching Staff to Schools in Western Greece**

*Ioannis Giannikos, Konstantinos Gavriil*

In this paper, we present a case study concerning the allocation of temporary teaching staff to high schools in different geographic areas in Western Greece. Such staff is employed on an annual contract basis and is classified in different employment statuses and different specializations depending on the teachers' formal qualifications. Each temporary teacher is based at a certain school, determined at the beginning of the school year and may teach a range of subjects that are prioritized according to their relevance with the teacher's specialization. Typically, temporary teachers need to teach at more than one school to achieve the minimum quota, as determined by the legislation. In this case, the corresponding transportation costs are calculated with respect to the school where the teacher is based and are covered by the government. We present a multi-objective mixed integer programming formulation that determines the number of temporary teachers required and locates each of them at a base school, taking into account the following cost elements: (a) the total monetary cost that includes the cost of hiring teaching staff on contract basis, the cost of overtime and the transportation costs of assigning teachers to more than one school, (b) the total pedagogical cost of assigning teachers to teach subjects other than their specialization or sending them to more than one school. We explore the competitive nature of the different criteria and discuss solution methods for obtaining satisfactory solutions in reasonable computation time.

# Friday, 9:00-10:45

## ■ FA-01

*Friday, 9:00-10:45 - Malersaal*

### Humanitarian Logistics

*Contributed session*

Chair: *Bahar Yetis Kara*

**1 - Relief Supply Chain Planning: The Effect of Location Decisions on Fair Allocations of Donations under Uncertainty**

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

In this paper, we study the relief logistics problem that emerges in the response phase after a disaster occurs. The problem consists of finding a fair mechanism to distribute a scarce relief item with uncertain amount among different demand points in need, such as shelter sites, using mobile points of distribution. The available supply consists of voluntary donations, which are time-dependent and unknown in advance. The operations are to be executed during a finite planning horizon partitioned into time periods. The problem is cast as a multi-period location-inventory problem with a coverage constraint where the uncertainty is incorporated via multi-stage stochastic programming. In particular, two decisions are to be made for every period of the planning horizon: (i) where to locate a limited number of mobile facilities and (ii) what quantity to allocate to each demand node. A coverage radius is defined imposing that a mobile facility can only supply the demand nodes within that radius. The mobile facilities are capacitated and typically exist in a limited number (e.g., due to a budgetary constraint). In search for fair solutions, the so-called deprivation cost is considered, which is a measure of the "suffering" of a population for facing shortage of the relief item. The mathematical model is tested using instances built from real data available in the literature, using a set of scenario trees with different supply availability levels. Computational tests are made on these benchmark instances with various sizes of network and scenario trees. Overall, the results show that the models proposed can better support the decision making process when fairness is of relevance.

**2 - On the Quickest Evacuation Location Problem in Humanitarian Operations: Multi-Objective Modelling and Matheuristic Solution**

*Antonino Sgalambro, Xiaochen Feng, Diego Ruiz-Hernandez*

This work introduces the Quickest Evacuation Location problem (QELP), a novel optimisation problem aimed at supporting humanitarian operations by combining the quickest flow problem and the discrete facility location problem. Its scope falls into the field of evacuation planning and design, intending to enhance evacuation network design and planning by identifying, among a finite set of candidates, the set of shelters that would allow the quickest possible evacuation process. The QELP is first modelled by developing an ad-hoc network tool referred to as QELP-Time Expanded Network (QELP-TEN), which accounts for the lack of a predetermined set of sink nodes - as these need to be selected among the candidate sinks as part of the optimisation problem. To secure flexible and realistic decision support, a multi-objective mixed integer programming model is developed, aiming at minimising the evacuation makespan and the total budget required to install and operate the shelters while balancing the load of evacuees directed to each activated shelter. The Robust Augmented Epsilon-constraint method is adopted as a solution scheme, and it is successfully combined with a novel matheuristic approach to boost its performance while exploring the Pareto Set on increasing size networks. Despite the challenging complexity deriving from the use of time-expanded networks, experiments on realistic instances show scalable performance and the presence of regular trade-offs among the three objective functions (evacuation makespan, budget, and maximum load on shelters), thus confirming the suitability of the QELP to provide decision-makers with valuable support for real-world planning processes in humanitarian operations.

**3 - A Location-Allocation Model for Meal Kit Distribution in Post-Disaster Environments**

*Diana Ramirez-Rios, Esneyder Gonzalez, Trilce Encarnacion, Johanna Amaya*

This research focuses on the location and allocation of Points of Distribution (PODs) in a geographical region to serve the population impacted by a disaster, especially in the case of meal kit distribution. Consider a single large distribution center (DC) that handles the distribution of food at a regular basis, like a Food Bank. After a disaster, the DC aims at sending trucks with packaged meal kits that will be sent to strategic POD locations (i.e., food pantries and hubs from their food distribution network), where the population affected will get their meal kits either walking or by car. The location of these PODs and allocation to the population in need aims at minimizing the total social costs that involve the costs of the logistics operation and the deprivation costs caused by the delays in the distribution of kits. The deprivation costs are a function of the time it takes for the population to receive their relief. Prior empirical studies indicated that the function is non-linear and more specifically we include a polynomial function estimated from survey responses from people impacted by flooding. We developed a piecewise function of the empirical deprivation cost model and formulated the formulated a location-allocation model that minimizes total social costs. The mixed-integer programming model considers a fixed set of potential PODs in a region, which will serve families based on their ZIP code locations. We aim at the optimal POD locations from the set of pre-existing PODs that will be activated after a disaster and the ZIP codes allocated to these PODs. We implement the location-allocation model to the Houston Food Bank case and compare the results from the actual distribution after 2017 Hurricane Harvey.

**4 - New Location Routing Problems Learned from Kahramanmaraş Earthquake**

*Bahar Yetis Kara, Çağla Dursunoğlu*

There have been decades of research in the field of humanitarian logistics. Academics in the field of logistics are becoming more and more interested in it. That being said, we still acquire insight and identify new problems with each disaster. We observed various applications of the selective location routing problem during Covid-19, e.g., for PCR test sites and vaccination centers. The recent earthquake in Turkey, unfortunately, has led us to re-evaluate the response cycle of the disaster management. Close inspection reveals that this response phase actually leads to various applications of routing problems. The locations for the main distribution centers where the supply will be assured are crucial. The location decisions are selective; moreover, mobile vehicles departing from those centers can be efficiently used. Since the affected people may not always be able to reach out to large facilities, the mobile units can be utilized. Their general use includes the distribution of water bottles, food (such as soup), medicine, masks, etc. Based on our observations of the recent 2023 Maraş Earthquake in Turkey, we believe that the use of mobile units can be expanded even further. The applications of mobile units may include mobile shower trucks, WCs, internet centers, barbers, etc. Moreover, the locations of mobile units are important since they are required to serve people in the area and the neighbourhood areas by staying there for a while. The mentioned applications are just a few recent real-life application areas in which the selective routing problem can be integrated. In this study, we first try to categorize these potential services and then formally define the respective LRPs considering all problem dynamics.

# Friday, 11:15-13:00

## ■ FB-01

*Friday, 11:15-13:00 - Malersaal*

### Health Care Applications

*Contributed session*

Chair: *Stefan Nickel*

**1 - Analyzing the Challenges of Planning the Emergency Medical Service Locations for the Metropolitan Region Ruhr**

*Isabel Wiemer, Jutta Geldermann*

When optimizing the sites of emergency medical service (EMS), location planning models often distinguish between urban and rural areas and focus on the consequences of combining both types of geographic regions. To the best of our knowledge, the consideration of one congested urban area, such as the metropolitan region Ruhr, which is characterized by several large cities being located closely to each other with a high overall population density as well as densely populated city boundaries, has so far been insufficiently addressed in the context of EMS location planning. Therefore, we propose to analyze the EMS location planning under consideration of geographical and demographical characteristics of a metropolitan region in a systematic way. To do so, we adapt a well-known stochastic EMS location planning model for the application in the city of Duisburg. The chosen model takes forwarded emergency calls into account and models the expected coverage very precise compared to former models while maintaining a linear formulation. The special city structure of Duisburg, which spreads along both sides of the rivers Rhine and Ruhr with roughly 0.5 million inhabitants, represents an extra challenge in addition to the above mentioned characteristics of all cities in the metropolitan region Ruhr. We perform a case study based on real-world data of Duisburg to both examine the challenges caused by the geographical and demographical characteristics of the metropolitan region Ruhr and to show possible ways for the EMS in Duisburg how to deal with these challenges.

**2 - Ambulance Location-allocation Optimization under Stochastic Travel Times**

*Imanol Gago*

The precision of the response given to health emergencies is imperative. A rapid response can mean the difference between a patient's life and death in serious situations such as a heart attack. For the efficiency of emergency services, the location of ambulances is crucial, as is the allocation of ambulances to emergencies. Since the '70s, healthcare experts have started tackling the location-allocation problem. Nowadays, operational research plays a key role in helping decision-making. This work approaches the ambulance location-allocation problem in the geographical area of the Basque Country (Spain). To that end, a two-stage stochastic 0-1 integer linear programming model and its variations are presented.

In order to obtain realistic solutions, working with reliable data is as important as the correct definition of the mathematical model. Notoriously, considering deterministic ambulance travel times can lead to an oversimplified representation of ambulance management. Thus, we consider several methods to estimate and predict ambulance travel times: a Google API that proposes route planning and a General Additive Model (GAM) to transform historical data into ambulance-compliant travel times.

Concerning the satisfaction of the decision-makers and the quality of the EMS, the objectives to be pursued and the indicators to be met are numerous. We consider two alternative objective functions: (1) to maximize the number of emergencies responded to in target time and (2) to minimize the average response time. Additionally, we also consider equity and risk-averse measures to balance the efficiency between rural and urban areas and minimize worst-case scenarios, respectively. Some computational results are shown and compared.

**3 - Optimizing Multi-echelon Facility Location to Enhance Regional Blood Supply Chain**

*Andrea Mancuso, Maurizio Boccia, Adriano Masone, Claudio Sterle*

Blood is a vital resource for human beings, and its unavailability and waste can have serious consequences, such as postponed surgeries, untreated patients, and even deaths. For the past two decades, governments and healthcare stakeholders have been focused on effective blood supply chain (BSC) management, including policy-making, system design, and organization, to ensure that these resources are used efficiently and effectively. To improve BSC efficiency at the regional level and reduce costs, the Italian Healthcare Ministry has issued a decree with several indications and restrictions. In response, this work proposes a mathematical modeling framework based on single and multi-scenarios to design a BSC at the regional level. The framework aims to minimize system transportation costs, rationalize the number and type of facilities, ensure self-sufficiency, meet accessibility thresholds, satisfy imposed restrictions and system constraints, guaranteeing responsiveness to varying exogenous and endogenous conditions. We propose a reformulation of an existing MILP model by configuring a scenario-based multi-echelon facility location problem, integrated with several soft constraints, to envision the system objectives in a multi-objective manner. The work concludes with an experimentation on a real data set, pursuing a twofold aim: validating the effectiveness of the reformulation; making a performance comparison of different system configurations to derive useful managerial insights. Obtained results confirm the worth of the method as a decision support tool.

**4 - A Multi-Period Location-Allocation Model for Healthcare Facility Planning under Accessibility Restriction**

*Sachin Bodke, Narayan Rangaraj*

We propose a multi-period location allocation optimization model using GIS data. The model aims to minimize transportation, opening, closing, and operating costs while meeting demand within an accessible distance of S km. This capacitated location-allocation model will ensure that facilities open or close according to the demand patterns. The model is tested in the context of the Covid. The Covid-19 pandemic significantly impacted various industries, healthcare, manufacturing, and supply chain, etc. The restrictions on travel and gatherings made it challenging to locate facilities like healthcare, distribution center, manufacturing facilities, and warehouses, making it difficult to provide essential services to the public. We test our model on hemodialysis facilities which had to be set up during Covid-19, which is essential for end-stage kidney disease (ESKD) patients. The dialysis center allocation problem refers to selecting the most efficient and effective way to provide adequate and accessible care to Covid-19 infected ESKD patients. Using data from Mumbai, where approximately 10,000 people with ESKD require regular dialysis, we demonstrate the potential of using GIS data and mathematical modeling to address complex healthcare challenges during pandemics. Our proposed model provides a practical approach to allocating dialysis centers in a multi-period setting, considering travel restrictions, and minimizing costs while meeting the demand for service. The optimal locations identified by our model can help efficiently and effectively allocate dialysis centers to provide adequate and accessible care to Covid-19 infected patients in Mumbai. The proposed model can be used for other healthcare services and industries facing similar challenges during pandemics.

## Friday, 14:00-14:30

### ■ FC-01

*Friday, 14:00-14:30 - Malersaal*

**Closing session**

## Friday, 14:30-15:00

### ■ FD-01

*Friday, 14:30-15:00 - Malersaal*

**EWGLA Session**