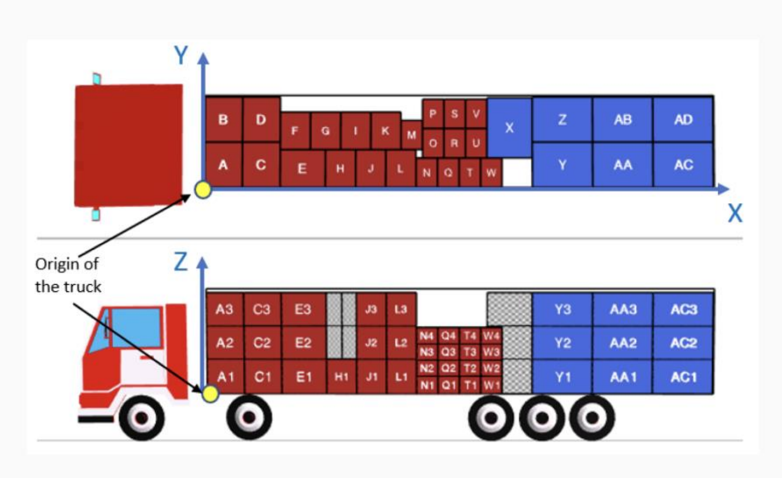
A Column Generation Heuristic for the Three-Dimensional Truck Loading Problem

Column generation1

Rick Willemsen, Bart Van Rossum



- **Three-dimensional truck-loading problem** with heterogeneous items/trucks and practical constraints—supplier/plant order, weight balance, and front-placement.
- Presents the **column-generation framework**, selecting complete truck loadings in the master problem while heuristically creating new loadings in the sub-problems.
- Builds a **three-stage solution process** that simultaneously yields tight bounds and high-quality feasible solutions.
- Develops a **labelling-based pricing algorithm** on a dynamic stack graph with aggressive dominance and roulette-wheel rotation strategies, efficiently embedding weight-balance and order constraints.
- **Scales to industrial instances** of up to 32k items and 3.7k trucks within a 60 min.

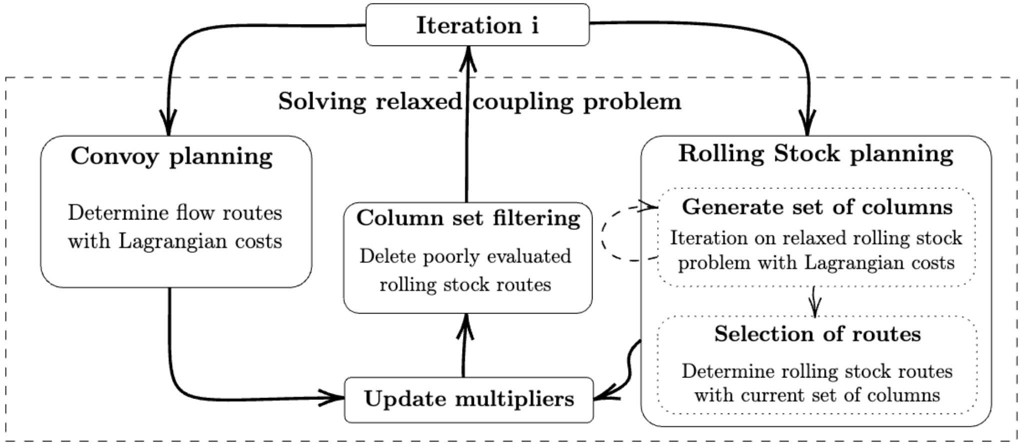
Keywords

Truck loading, Three-dimensional bin packing, Practical loading constraints, Column generation

Combining Lagrangian relaxation and a two-set column generation model for integrated railway freight planning

Louis Fourcade, Stéphane Dauzère-Pérès

- Lagrangian relaxation and a two-set column-generation model to **simultaneously plan train paths and rolling stock** for freight rail.
- Formulates freight flow and rolling-stock routes on a **space-time graph**, linking them through weight-balance coupling constraints.
- The algorithm iterates between solving relaxed flow and rolling-stock sub-problems to optimality and updating multipliers via a sub-gradient method.
- On real French-network instances, the **Lagrangian heuristic (CGL) cuts CPU time by ≈ 50 %** relative to the benchmark.



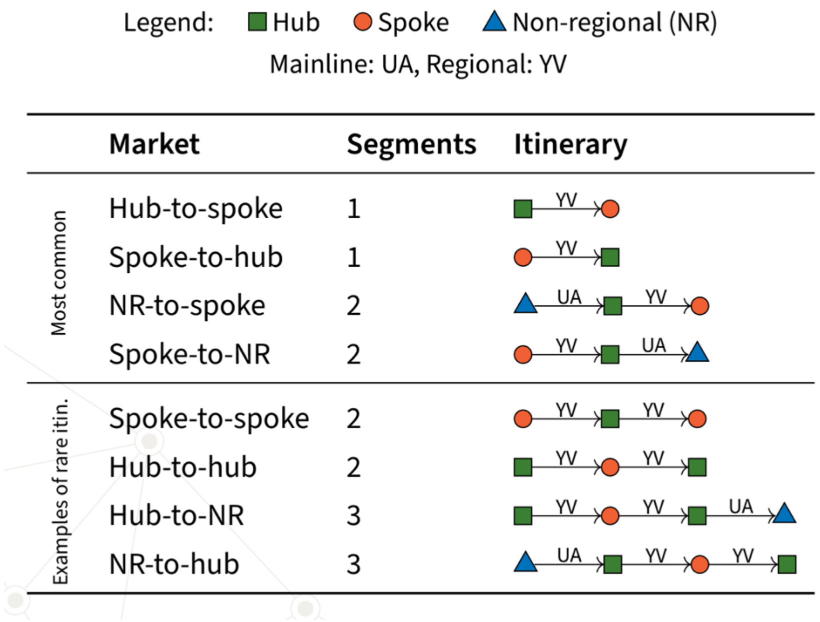
Keywords

Railway Freight Transportation, Column Generation, Lagrangian Heuristic, Train Routing

Integrated Regional Airline Scheduling Via Column Generation

Alberto Santini, Vikrant Vaze

- **Integrated optimization model for regional airline scheduling**, jointly deciding frequency, timetable, fleet assignment, and some route aspects.
- Introduces a **composite-variable formulation** modeling all non-stop flights between airport pairs.
- Develops a **DP–based pricing algorithm** to accelerate column generation.
- Achieves **provably near-optimal solutions** for large-scale real-world networks within three hours, outperforming prior methods that rely on heuristics.
- Validates the approach through extensive ablation and sensitivity analyses, revealing which components are most critical.



Keywords

Timetable development, Fleet assignment, Passenger choice, Column generation

Line Planning Under Crowding: A Row-and-Column Generation Approach

Column Generation 2

Yahan Lu (TU Delft), Rolf van Lieshout (Eindhoven University of Technology), Layla Martin (Eindhoven University of Technology), Lixing Yang (Beijing Jiaotong University)

- Proposes a **novel line planning model incorporating crowding effects** into perceived travel times using a quadratic penalty term.
- Reformulates the problem as a mixed-integer second-order cone program (MISOCP) and solves it via convex reformulation and cutting planes.
- Develops a scalable row-and-column generation algorithm combined with a diving heuristic for efficient solution of large-scale instances.
- Demonstrates that accounting for crowding yields structurally different, passenger-friendlier line plans with fewer lines and higher frequencies.
- Finds negligible deviation between system-optimal and user-equilibrium routing suggesting no additional need to model selfish routing.

Keywords

Line planning, crowding, row-and-column generation,

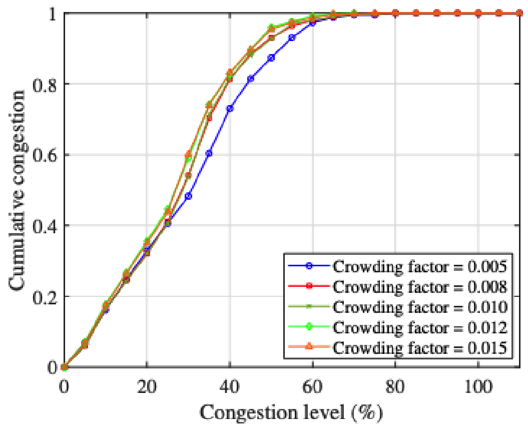
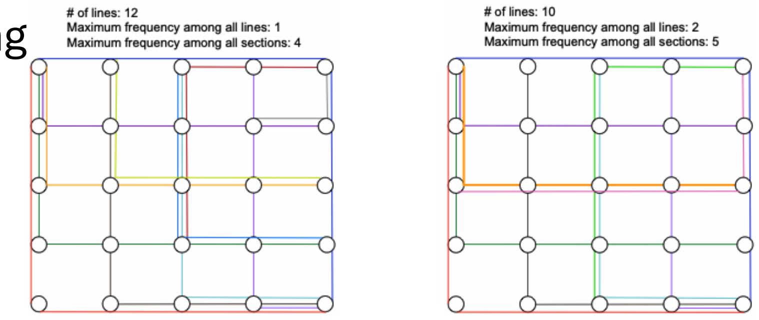


Figure 1 – *The cumulative distribution of congestion levels under optimized line plans with various crowding factors.*



(a) *Crowding factor = 0* (b) *Crowding factor = 0.20*

Figure 2 – *Optimal line plans without and with incorporating crowding effects*

Optimizing Shared Mobility: A Penalized Column Generation Model for Peer-to-Peer Ride-Sharing

N. Alisoltani, Y. Delhoum, M. Ameli, M. Zargayouna (University Gustave Eiffel)

- Proposes a **dynamic pricing model for P2P ride-sharing** that adjusts fares based on distance, passenger count, and traffic conditions.
- Develops a Penalized Column Generation algorithm for real-time matching of drivers and riders, balancing revenue and fare limits.
- Integrates fare penalties for exceeding rider fare limits, allowing soft constraint flexibility.
- Simulates the system using MATSim on Lyon's urban network, demonstrating substantial reductions in car trips and travel distances.
- Achieves high matching rates (up to 98.2%) and significant traffic and environmental benefits with increasing driver participation.

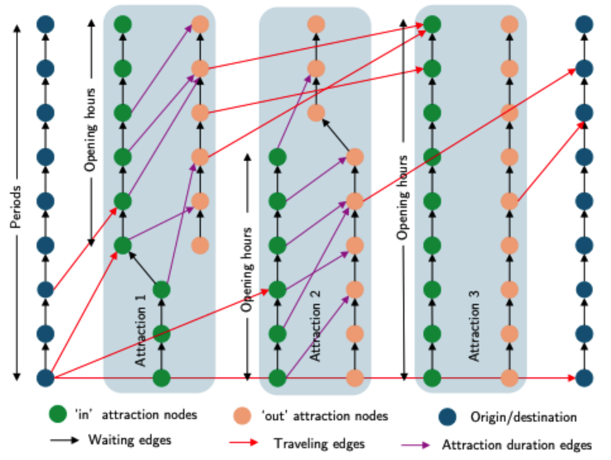


Figure 1 – *Time expanded graph for the pricing problem*

Keywords

Peer-to-peer ride-sharing, dynamic pricing, column generation,

Table 2 – *Objective value (runtime in s or GAP in % when terminated early). INF: Infeasible, NFS: No feasible solution found. 1-day solutions were infeasible.*

Days	2		3		4		5	
Attr.	MIP	CG	MIP	CG	MIP	CG	MIP	CG
5	51 (2.3)	51 (1.2)	51 (11.6)	51 (1.9)	51 (34.9)	51 (4.9)	51 (42.3)	51 (6.0)
10	124.5 (0.8)	124.5 (17.9)	124.5 (0.8)	124.5 (25.6)	125.5 (2.3)	124.5 (40.7)	125.5 (2.3)	124.5 (54.3)
15	NFS	NFS	NFS	163 (34.7)	NFS	163 (69.4)	171 (11.6)	163 (81.7)
20	NFS	NFS	NFS	185 (87.8)	NFS	185 (112.7)	NFS	185 (140.1)
25	NFS	NFS	NFS	NFS	NFS	211 (161.0)	NFS	211 (210.2)

Optimized Itinerary Planning for Tourist Attractions

Tarun Rambha (Indian Institute of Science)

- Develops an integer programming model for optimizing **tourist itineraries considering time-dependent travel times and attraction schedules**.
- Introduces a column generation approach on a time-expanded graph to efficiently solve large-scale instances of the problem.
- Captures complex factors like non-FIFO travel times, variable visit durations, and opening/closing times of attractions.
- Demonstrates superior computational performance of the column generation method over direct integer programming on test cases with Paris attractions.
- Lays groundwork for future extensions including multimodal travel integration and branch-and-price solutions.

Table 1 – *Simulation Results - Drivers and Riders*

Scenario	Drivers			Riders		
	Number	Matched	Rev/Trip (€)	Number	Matched	Fare/Trip (€)
1	0	0	0.00	24046	0	0.00
2	1500	1410	22.42	22546	2602	12.15
3	1842	1725	22.51	22204	3198	12.14
4	3685	3393	22.64	20361	6245	12.30
5	7370	6701	22.79	16676	12279	12.44
6	8790	7685	22.66	15256	13932	12.50
7	11055	7110	22.49	12991	12763	12.53

Table 2 – *Simulation Results - Personal Cars*

Scenario	Personal Cars		All Cars	
	Trips	Tot Dist (km)	Tot NumTrips	TotDist (km)
1	97356	849909	97356	849909
2	93254	817074	94664	835491
3	92316	809470	94041	831939
4	87426	770290	90819	815653
5	77707	691690	84408	783631
6	74634	665571	82319	773441
7	73538	657514	80648	781961

Keywords

Itinerary planning, column generation, time-dependent graph,

Designing Relay-Hub Networks for Consolidation Planning Under Demand Uncertainty

Onkar Kulkarni (Amazon), Mathieu Dahan and Benoit Montreuil (Georgia Institute of Technology)

- Builds a two-stage stochastic model that selects relay-hub sites/capacities first and optimises consolidated truck flows per demand scenario.
- Captures driver-hour rules by limiting every leg to a single-day out-and-back trip.
- Proposes a tri-stage decomposition-based branch-and-cut algorithm with nested Benders decomposition and integer L-shaped cuts for mixed-integer recourse.
- Solves five industrial-scale instances within 96 h, closing the first two to optimality and keeping the worst gap at ≈10 %.
- Beats a “classical” decomposition, trimming optimality gaps from 47-81 % down to 0-10 %.
- Shows consolidation-aware design cuts average delivery cost 10 % versus continuous-flow routing, without higher hub investment.

Keywords

Relay-Hub, two-stage, Benders decomposition, integer L-shaped cuts

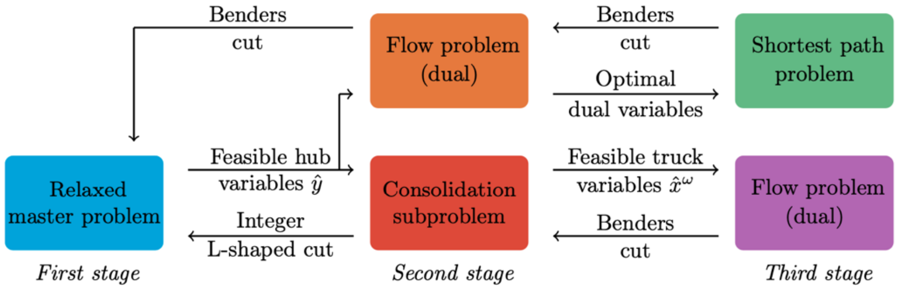


Figure 1 – *Overview of the proposed tri-stage decomposition-based branch-and-cut algorithm*

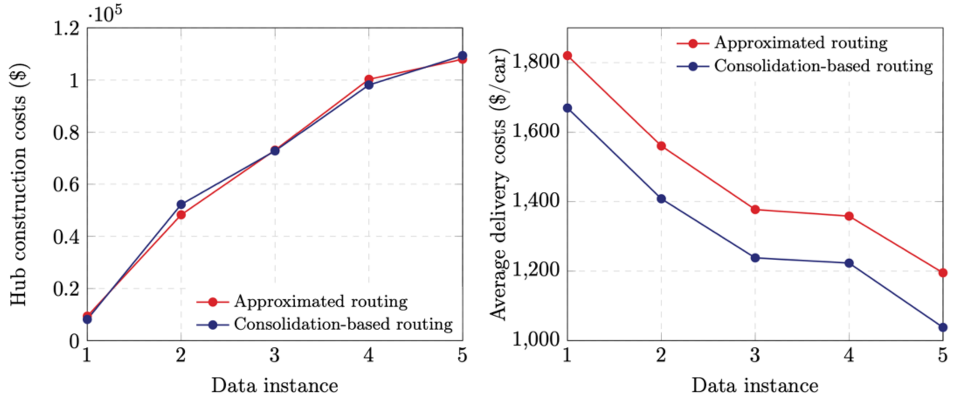


Figure 2 – *Logistics costs of relay networks designed with approximated routing (red) vs. consolidation-based routing (blue)*

Multi-layer Network Design for Consolidation-based Transportation Planning

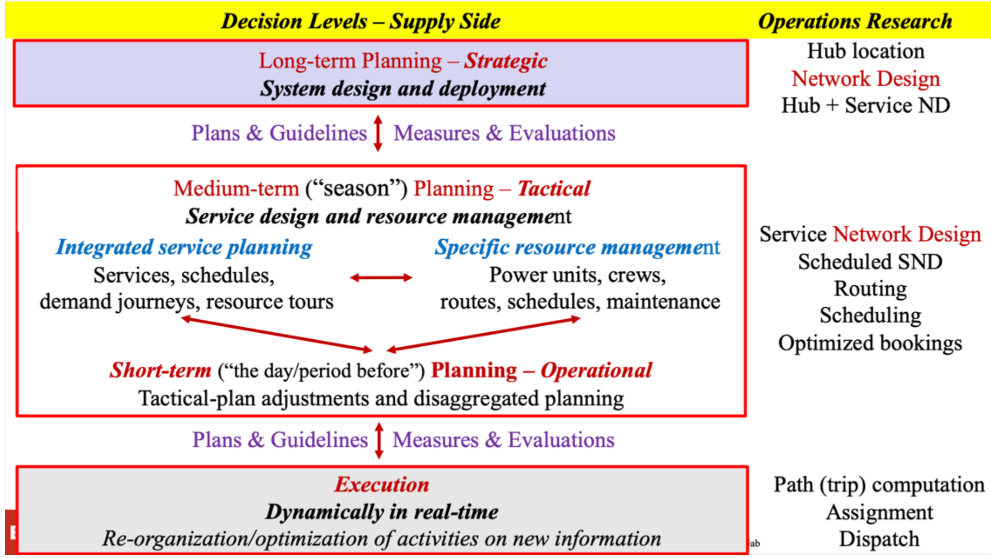
Consolidation-Based Freight Services

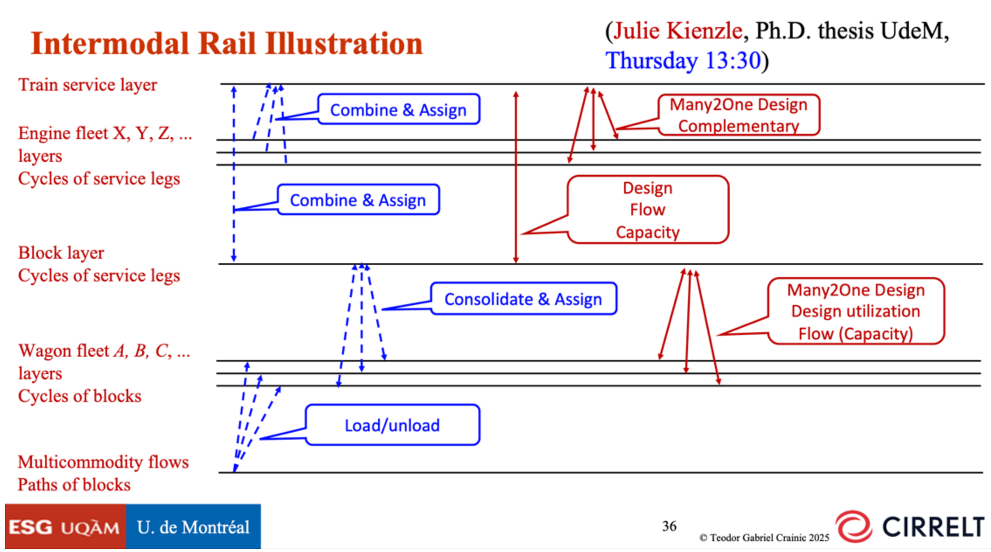
Teodor Gabriel Crainic (Université du Qubec à Montrál)

- Provides a comprehensive taxonomy and generic formulation for multi-layer network design (MLND) in freight systems.
- Defines arc-definition, flow- and attribute-connectivity across layers, extending classic design and capacity constraints.
- Introduces rich many-to-one and one-to-many connectivity classes to model engines, crews, and multimodal services simultaneously.
- Presents a multicommodity fixed-cost capacitated MLND model covering selection, capacity sizing and flow assignment on all layers.
- Highlights tactical applications like Scheduled Service Network Design, showing how MLND supports platoons, intermodal blocks and resource substitution.
- Identifies open research challenges—dynamic generation of supported arcs, attribute-linked capacities, and scalable optimisation of rich MLNDs.

Keywords

multi-layer, rail service planning, connectivity





Hub location and service network design under uncertainty

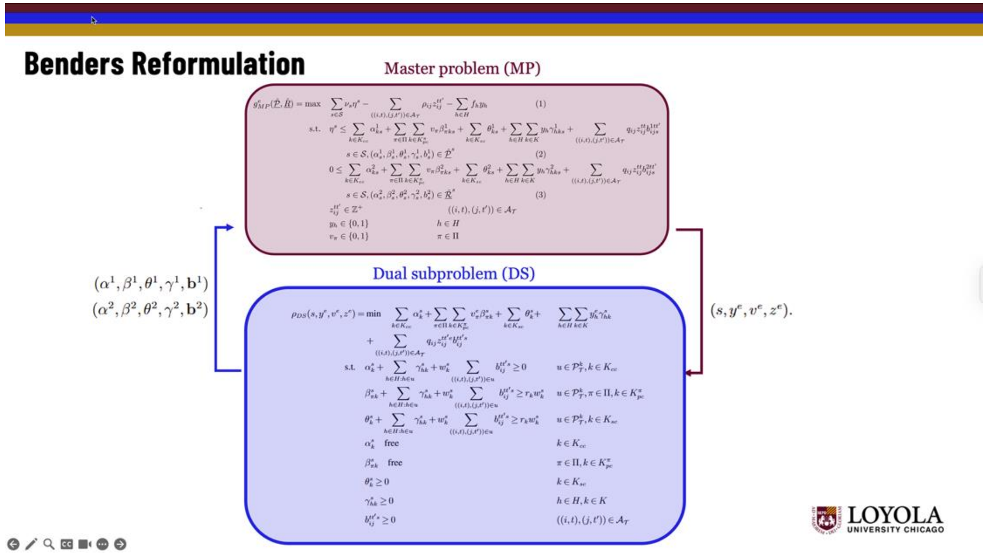
Consolidation-Based Freight Services

Hao Li[a], Gita Taherkhani[b], Mike Hewitt[b], and Sibel A. Alumur[a] ([a]University of Waterloo, [b]Loyola University)

- Integrates strategic hub siting with tactical schedule design in a two-stage stochastic profit-maximization model for LTL carriers.
- Uses a time-expanded network to synchronise dispatch times while partially contracting guaranteed vs optional shipments.
- Combines sample-average approximation (SAA), k-means++ scenario clustering, and a tailored Benders algorithm with valid inequalities.
- Pre-processing prunes unnecessary time-space arcs, slashing model size and enabling solutions for up to 100 commodities.
- Outperforms CPLEX and its built-in Benders, delivering optimal or near-optimal solutions where solvers found none.
- Case study on a 24-node Midwest network reveals stochastic planning boosts profit and service reliability compared with deterministic plans.

Keywords

sample-average approximation, Enhanced Benders decomposition



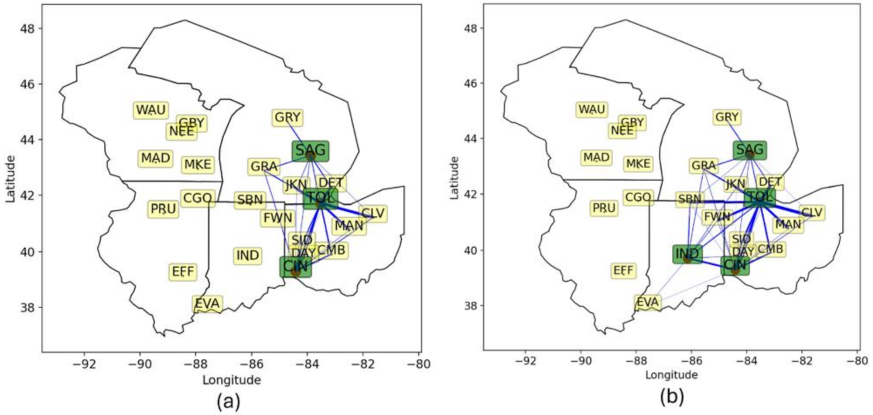


Figure 5 (a) Network serving Michigan and Ohio. (b) Network after expansion into Indiana.

The Scheduled Service Network Design Problem with Bin Packing and Heterogenous Fleets

Consolidation-Based Freight Services

Mike Hewitt (Loyola University Chicago), Simon Belieres (Toulouse Business School), and François Clautiaux (Université de Bordeaux)

- Formalises the Scheduled Service Network Design Problem with Bin Packing and Heterogenous Fleets (SSNDP-BPHF), uniting schedule design, shipment-level bin-packing and mixed-size fleets in one MIP.
- Introduces "consolidation-profile" variables that dominate earlier consolidations and give a tighter LP relaxation.
- Develops a branch-and-price algorithm whose quadratic pricing sub-problem handles heterogeneous bin-packing exactly.
- Outperforms a time-expanded network model—solving 283/400 benchmark cases vs 158 and cutting average gap from 176 % to 2.8 %.
- Provides the first SSNDP results that jointly choose dispatch times and right-size vehicles for each arc.

Table 1 – *Results considering a homogenous fleet*

$\lvert\mathcal{K}\rvert$	Time-expanded network formulation		Consolidation formulation		Consolidation profile formulation	
	# Solved	Gap unsolved	# Solved	Gap unsolved	# Solved	Gap unsolved
40	89	85%	126	N/A	126	N/A
100	57	88%	100	2.03%	124	1.46%
200	0	174%	11	4.33%	19	2.26%
400	0	355%	0	19.84%	14	3.42%
Summary	158	176%	237	10.98%	283	2.75%

Keywords

Scheduled Service Network Design Problem, Bin packing, branch-and-price algorithm

Collaborative generative adversarial networks for fusing household travel survey and smart card data to generate heterogeneous activity schedules

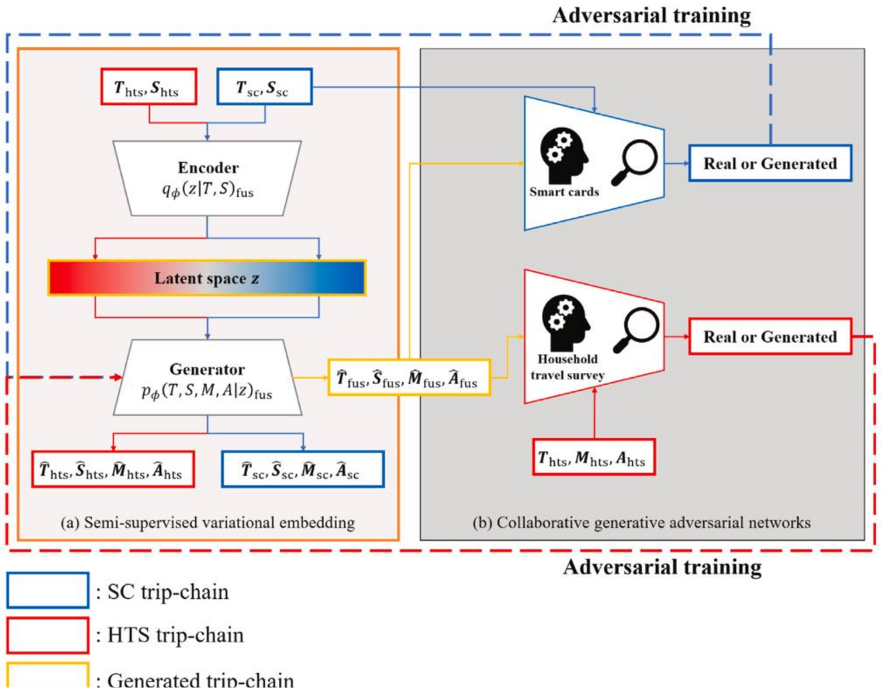
Data Driven Analysis 1

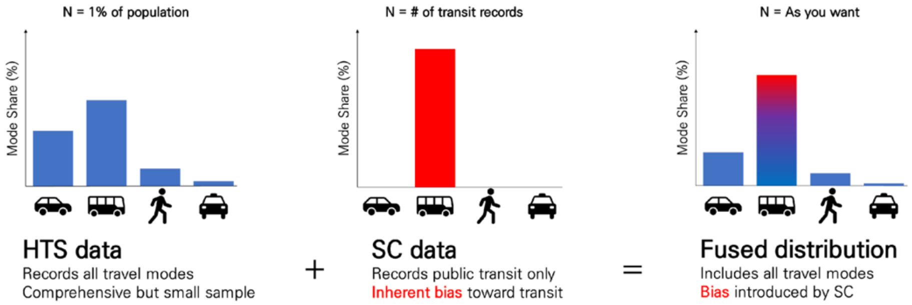
Huichang Lee, Prateek Bansal, Khoa D. Vo and Eui-Jin Kim

- Generates activity scheduling paths by **fusing household travel survey (HTS) data and smart card (SC) data** based on **adversarial learning.**
- HST contains trip data with place, activity purpose, traffic mode, and timestamp on a specific day, providing **rich i**nformation on activity scheduling.
- SC captures the history of usage **only of transit**, but their information is **up-to-date**.
- Consideration of socio-demographic heterogeneity and day-to-day dynamics is a focus of their future work.

Keywords

Deep generative model, Activity-based model, Data fusion, Smart card



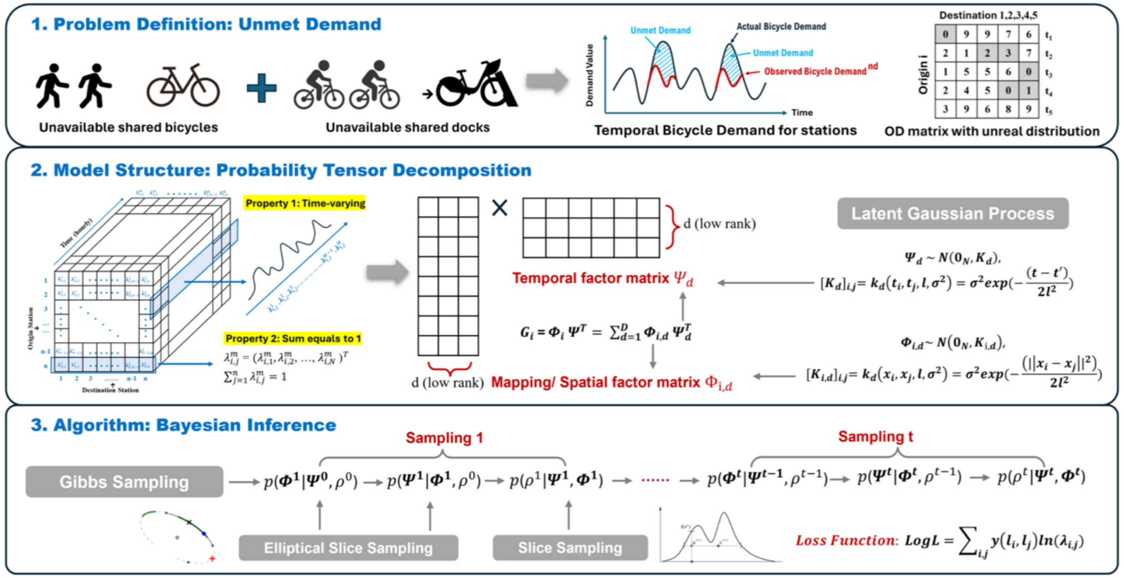


Uncovering Unmet Demand in Bike-sharing Systems Based on Bayesian Gaussian Decomposition of Time-varying OD Tensor

Data Driven Analysis 1

Xinghang Zhu, Xiaoxu Chen, Luis Miranda-Moreno, Lijun Sun

- Estimates **unmet demands** of bike-sharing system, which is different from **observed** demands.
- Destination (bike port) choice is modeled by a **multinomial distribution**.
- Probabilities of choosing destination *d* at time *m* are estimated by **Softmax parameterization** with a **Gaussian Process.**
- To decrease dimension, **tensor decomposition** is used.
- The parameter estimation algorithm is based on **MCMC (Gibbs sampling and Elliptical Slice sampling).**



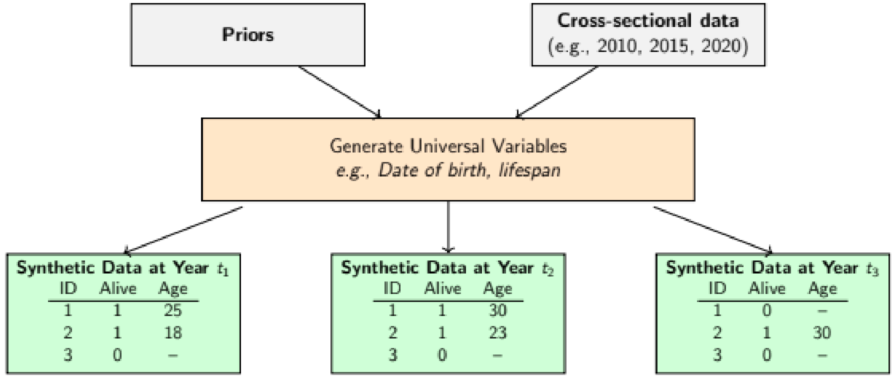
Keywords

Bike-sharing system, Unmet demand, Bayesian Inference, Gaussian Process, Markov Chain Monte Carlo

Simulation Framework for Longitudinal Synthetic Population Generation

Marija Kukic and Michel Bierlaire

- Current synthetic population methods create static snapshots that become outdated quickly, requiring costly regeneration.
- The proposed approach uses a Gibbs sampler to generate longitudinal synthetic individuals, tracking the same individuals over time.
- By generating a universal set of time-independent variables, the model derives time-dependent data efficiently, **avoiding full data regeneration**.
- Captures **individual-level** changes, providing longitudinal insights and simulating the impacts of hypothetical scenarios like pandemics.



Mincer's equation

$$\ln(\text{Income}(t)) = \underbrace{\ln(w_0)}_{\text{base salary}} + \underbrace{\rho \cdot \text{Schooling}(t)}_{\text{years of education}} + \underbrace{\beta_1 \cdot \text{Experience}(t)}_{\text{years employed}} + \underbrace{\beta_2 \cdot \text{Experience}(t)^2}_{\text{diminishing returns}} + \underbrace{\varepsilon}_{\text{randomness}}$$

Keywords

Population synthesis and dynamics, Longitudinal data, Disaster scenario simulation

Deep Generative Networks for Synthesizing Data on Electric Vehicle Driving and Charging Events

Zhi Li, Ma Wei, Monica Menendez, Zhibin Chen, Minghui Zhong

- Proposes a generative AI-based model for synthesizing electric vehicle (EV) data while preserving privacy.
- Represents EV driving and charging behaviors using generative models trained on real-world data.
- Introduces a privacy-preserving mechanism using diffusion models to generate synthetic time-series data.
- Compares four models with variations in joint variable distribution modeling: Gibbs sampling, VAE, WGAN, and Bayes decomposition.
- While slightly lagging behind Transformer+WGAN on the univariate distribution metric, the Transformer+Gibbs model significantly outperforms others in capturing complex multivariate relationships.

Table 2 – *Comparative analysis of different model performances*

Model	Layer	d_{model}	ρ_1	ρ_2	ρ_3
Transformer+Gibbs	48	128	0.18	**0.47**	**0.97**
Transformer+WGAN	48	128	**0.13**	0.81	1.10
Transformer+Bayes	48	128	1.18	0.88	1.55
Transformer+VAE	48	128	0.82	2.04	1.17

Keywords

Generative Networks, Electric Vehicle, Data Synthesis, Charging Behavior Simulation

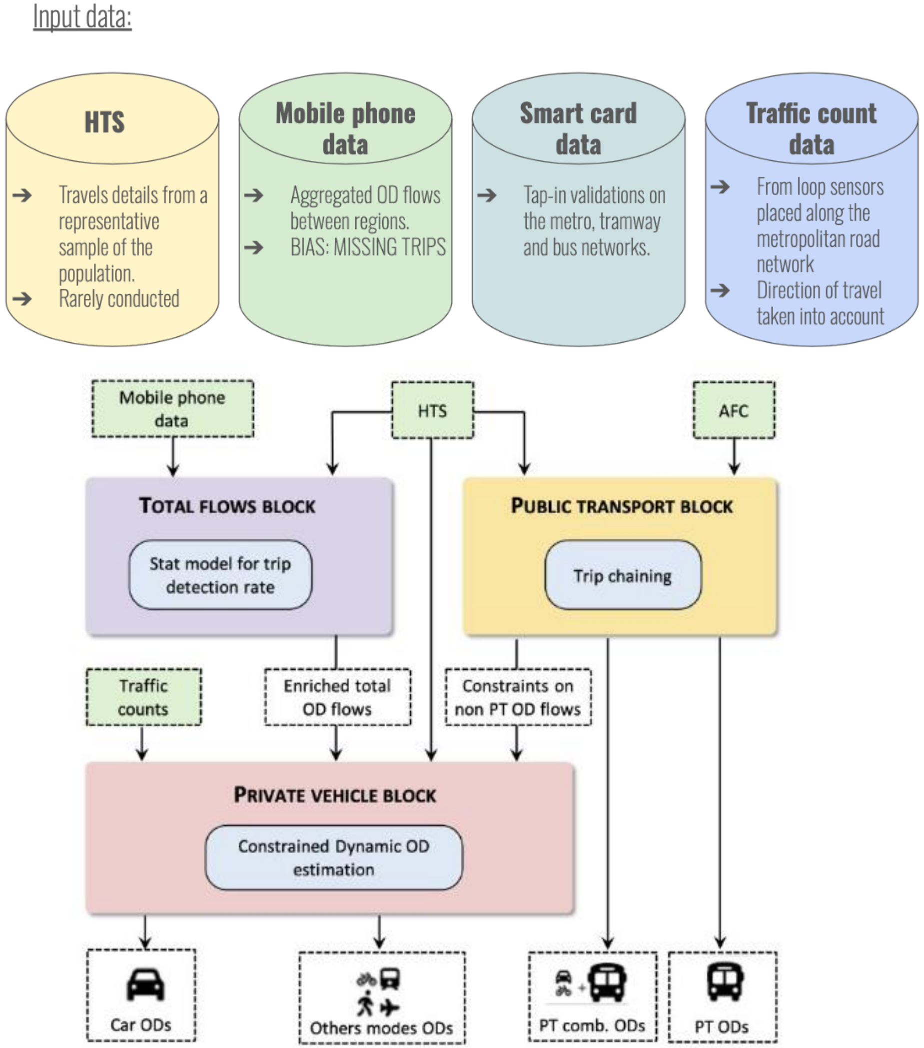
A data fusion framework for the estimation of dynamic multimodal OD flows within urban areas

Paul de Nailly, Etienne Côme, Angelo Furno, Latifa Oukhellou

- Estimating car OD flows from traffic count data is an underdetermined optimization problem (Cascetta et al., 2013). Very few studies use traffic count data for estimating OD flows between regions.
- Embed the car OD flows estimation problem within a data fusion framework that helps reduce the solution space while enabling the estimation of OD volumes for public transports and other modes.
- Data fusion framework generalizable to others cities where smart card, mobile phone, traffic counts and optionaly a travel survey are available.
- Flexible framework: each block includes a method that can be modified or replaced.

Keywords

data fusion, modal shares, dynamic OD estimation

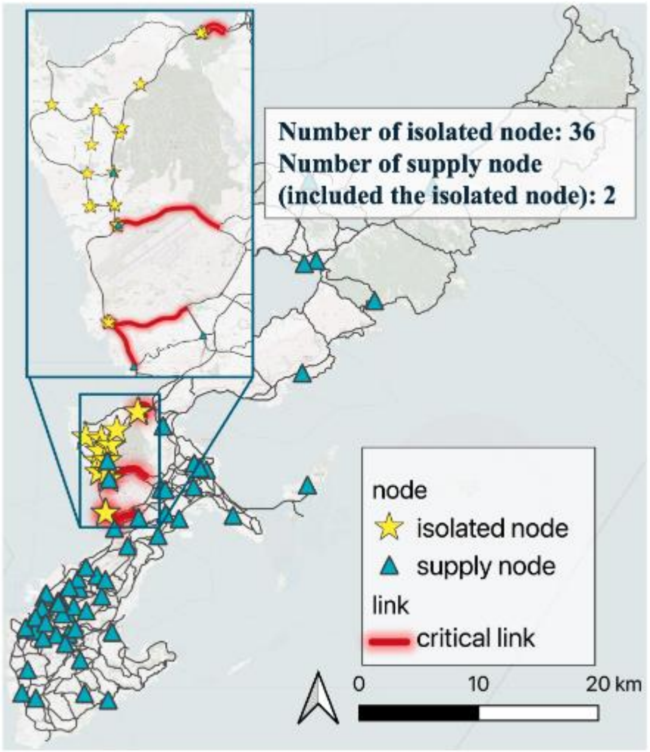


Excess-demand isolation vulnerability analysis based on a bipartitioning minimum cut

Disaster Management

Ruri Sase, Satoshi Sugiura

- Proposes a method for identifying **critical link sets** whose disruption can isolate large subgraphs in a network, causing excess-demand isolation under disasters.
- Extends prior single-node isolation studies to analyze **many-to-many isolation scenarios**, considering multiple simultaneously disconnected nodes.
- Formulates an **integer linear programming model** to maximize excess demand in isolated areas, subject to a limited number of disrupted links.
- Ensures isolated areas form a **single connected component** via auxiliary network flows and dummy nodes.
- Demonstrates applicability on Okinawa road network, showing how the method reveals regions vulnerable to large-scale isolation under link disruptions.



(b) *Scenario of 9 critical links, 36 isolated nodes and 38,644 excess demand cases*

Keywords

Excess-demand isolation vulnerability, Connectivity vulnerability, Relief supply, Graph cut

Prompt and Reliable Medical Evacuation with Air Ambulances

Miguel Lejeune, Francois Margot, Alan Delgado de Oliveira

- Develops a **chance-constrained optimization model** for air ambulance deployment and dispatch to maximize timely MEDEVAC operations.
- Models both **exogenous uncertainty** (random MEDEVAC resource availability) and **endogenous uncertainty** (busy probabilities depending on decisions).
- **Boolean-based reformulation** to efficiently handle complex joint chance constraints with endogenous uncertainty, reducing computational burden.
- Introduces a **nonlinear branch-and-bound algorithm** with conic relaxations and a novel smallest-domain branching rule for fast solution times.
- Validates the approach using data from the Afghanistan theater, showing that the proposed methods solve previously intractable large-scale instances.

Equivalent Boolean-based MINLP reformulation for **CC-DD**:

$$
\begin{aligned}
\max \quad & e^{\mathsf{T}} y \\
& \sum_{i \in I} \gamma_{i \bar{\ell}^k(i)+1} \geq 1 && k \in K^- \\
& \gamma_{i,l-1} \geq \gamma_{il} && i \in I,\ 2 \leq l \leq n_i \\
& \gamma_{i1} = 1 && i \in I \\
& \gamma_{il} \in \{0, 1\} && i \in I,\ 1 \leq l \leq n_i \\
& \lambda_i (1 - \zeta_i) \geq y_i \left(\sum_{l=1}^{n_i} o_{il} \gamma_{il} \right) && i \in I \\
& (y, \tilde{x}, \lambda, z) \in \mathcal{X}_{\mathcal{S}} \\
& (\tilde{x}, \zeta, \lambda) \in \mathcal{C}_{\mathcal{S}}
\end{aligned}
$$

- $|I|$ nonconvex constraints regardless of number of scenarios (instead of $|I| \times |\Omega|$ for scenario approach).
- n binary variables (instead of $|\Omega|$ for scenario approach).

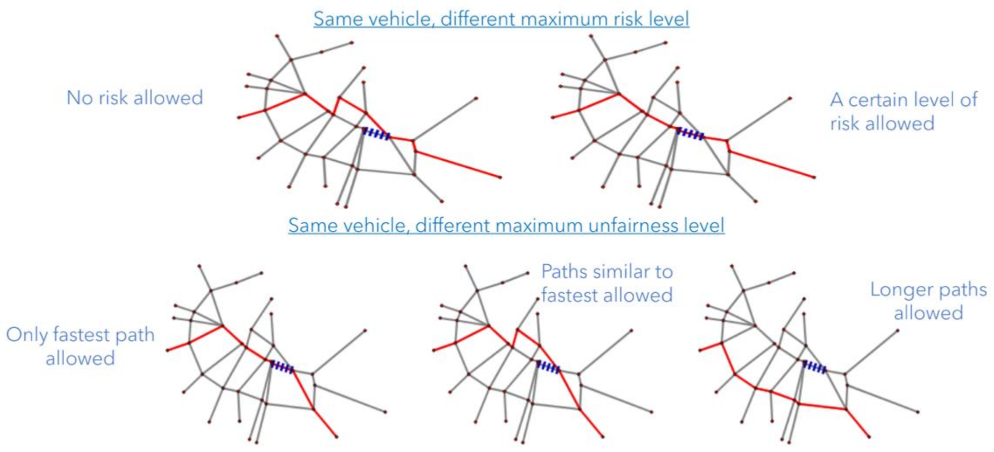
Keywords

Medical evacuation, Chance constraint, Endogenous uncertainty, Air ambulances

Real-time control of traffic flows under disruptive events

Disaster Management

Valentina Morandi, M. Grazia Speranza, Lorenzo Peirano



- Proposes a real-time traffic management system to **minimize infrastructure risk** during disruptive events like bridge failures.
- **TRANS model**, a MILP minimizing risk and congestion impacts in networks.
- Models risk as a convex, more-than-linear function increasing when traffic exceeds defined thresholds, aiming to prevent critical conditions necessitating closures.
- Integrates **real-time data** and vehicle arrivals to dynamically update traffic assignments and avoid excessive risks on vulnerable links.
- Demonstrates through simulations that allowing slight detours reduces risk significantly without severe congestion impacts.

Keywords

Coordinated traffic assignment, Risk-Avoidance, MILP, Real-time traffic management

Perturbed utility Markovian choice model: choice probability generation function and estimation

Rui Yao and Kenan Zhang (EPFL)

- Proposes a Markovian choice model for route choice based on perturbed utility theory.
- Represents traveler decisions using state-action (Q-value) functions in a Markov framework.
- Introduces a choice probability generation function with an invertible gradient mapping.
- Constraint optimization problem: Given Q-value, optimal policy is directly given by the Jacobian function.
- Simply value iteration solves optimal values.
- **Closed-form** least square estimator avoids solving Bellman equations.

$$\nabla H_s(Q(s,\cdot)) = \arg \max_{\pi(\cdot|s)\in \text{int}(\Delta_s)} \mathbb{E}_{a\sim\pi(\cdot|s)}\left[Q(s,a)\right] - H_s^*(\pi(\cdot|s)).$$

The perturbed utility maximization problem

Keywords

perturbed utility, Markov decision process, dynamic discrete choice, estimation

An exponentiated random utility model (ERUM): Properties and application to bounded travel choice

Yu Gu and Anthony Chen (The Hong Kong Polytechnic University)

- Proposes an exponentiated random utility model (ERUM) for travel choice under cost bounds.
- Uses a doubly bounded Kumaraswamy distribution to capture perception errors.
- Models both lower and upper cost bounds within the utility and decision process.
- Retains a closed-form Luce-type probability expression for analytical tractability.
- Enhances behavioral realism beyond traditional logit and weibit models.
- Suitable for choice contexts where individuals have good knowledge of the **lower and upper bounds of utility**, e.g., the future transportation system equipped with the advanced traveler information system and connected vehicles.

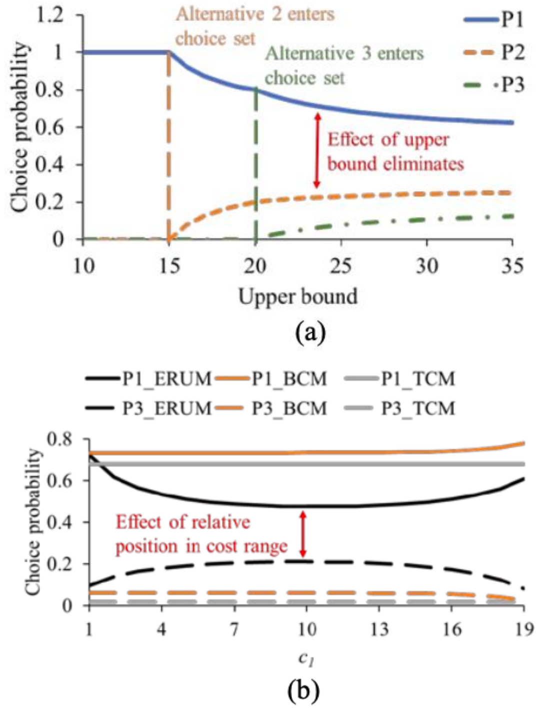


Figure. Effects of (a) upper bound and (b) upper bounds in the Kumaraswamy-based ERUM

$$f(x) = abx^{a-1}\left(1-x^a\right)^{b-1}, 0 < x < 1,$$

$$F(x) = 1-\left(1-x^a\right)^b, 0 < x < 1,$$

Kumaraswamy distribution

Keywords

Random utility model, Exponentiated utility function, Bounded travel perception, Kumaraswamy distribution

The theoretical role of the pure transfer penalty when determining whether to split a public transport line

Valentina Gomez Z ú ñiga, Andr és Fielbaum Schnitzler, and Sergio Jara D ıáz

- Public transport systems often use models for optimizing decisions like frequency and subsidies, but little focus has been placed on network structures such as single vs. divided lines.
- A new divisibility index (DI) is introduced to determine where to split a line, with algorithms to apply it.
- The division algorithms are tested in a linear city model inspired by the parametric city model (PCM), with demand driven by parameters α, β, and γ to simulate monocentric, polycentric, and dispersed cities.
- Three conditions for a divided line to be better: few transfers, significant peak flow differences, and longer lower-flow sections.

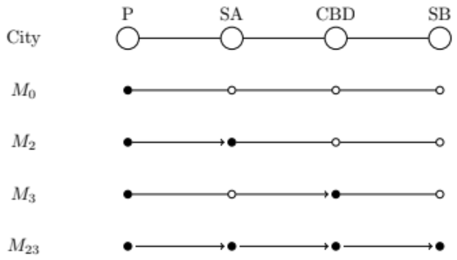


Figure: Line structures in the Parametric Linear City.

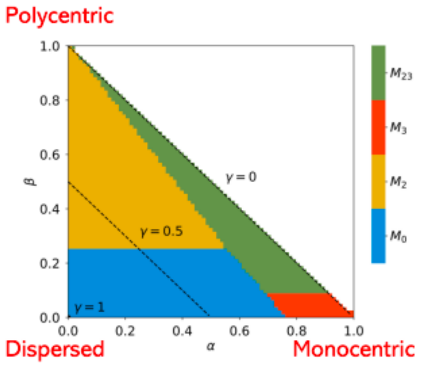


Figure: Dominant structures.

Divisibility index (DI)

$$I_{N,l}(i) := \left\| \max_{1\leq n\leq i} \zeta_{N,l}(n) - \max_{k\geq n\geq i} \zeta_{N,l}(n)\right\| (1-\tau_{N,l}(i)d_1)\left(1+\left(\|l_i\| + \frac{\|l_i\|}{\|l\|}\right)d_2\right)$$

where:
$\zeta_{N,l}(j)$: load factor of the j-th segment.
$\tau_{N,l}(j)$: transfers at node j.
$|l_i|$: length of the section with lower maximum flow.

Keywords

Public transport, line division, pure transfer penalty, divisibility index.

Estimating the Joint Accessibility of Group Travel: A Case Study of Leisure Activities in The Greater Tokyo Area

Giancarlos Parady (The University of Tokyo), Joanna Ji (Technical University of Munich), Kiyoshi Takami (The University of Tokyo)

- Empirically **estimates joint accessibility parameters for group travel** in the Greater Tokyo Area using data from actual group schedules.
- Proposes a destination choice model that integrates location attractiveness, available joint activity time, and group travel impedance.
- Utilizes data from Tokyo Metropolitan Area joint eating-out activities, transit travel times, and restaurant location data.
- Finds that traditional Tokyo subcenters (Shinjuku, Ikebukuro, Tokyo) offer the highest location benefits for group activities.
- Suggests that joint accessibility measures can enhance agent-based travel models by integrating social network dynamics.

Keywords

Social networks, joint accessibility, travel behavior,

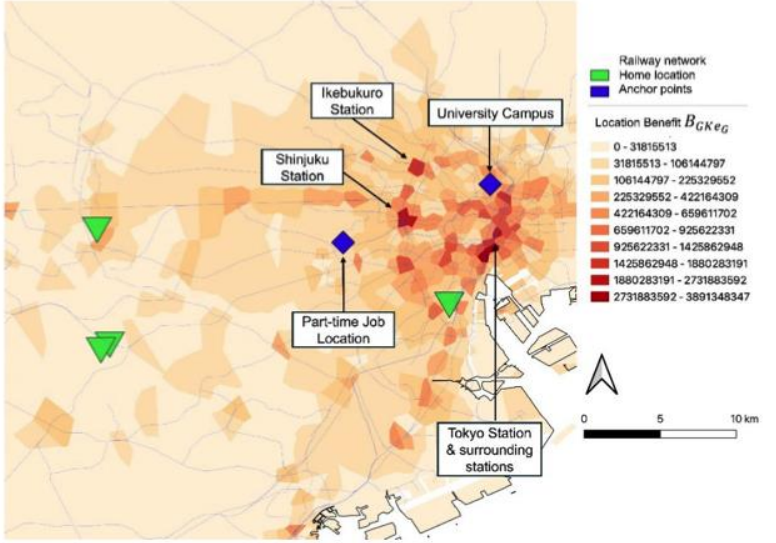


Figure 1 – *Location Benefit of zones k to group G for the available activity/travel budget*

Table 1 – *Estimation results of joint destination choice model*

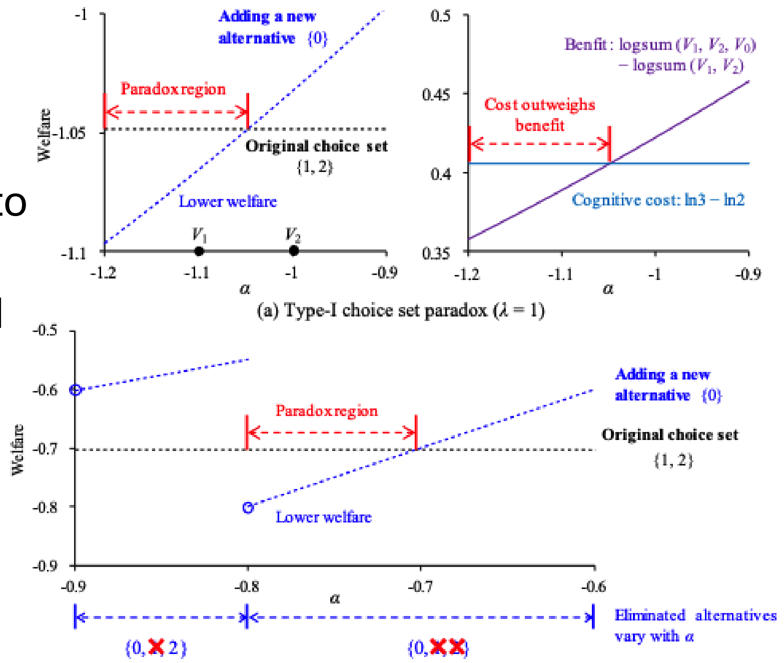
Variable	*Coefficient*	*t-statistic*
Travel time $t_{e_G k}$	-0.12	-9.21
ln available time interval $T_{e_G k}$	4.17	2.15
ln attractiveness a_k	0.97	18.89
Sample size	205	
LL(0)	-1482.25	
LL(β)	-891.71	
Rho-square	0.398	

Are Travelers More Satisfied with More Options Offered? A Choice Set Paradox

Discrete Choice Model 2

Heqing Tan (Tongji University, The Hong Kong Polytechnic University), Yu Gu (The Hong Kong Polytechnic University), Anthony Chen (The Hong Kong Polytechnic University), Xiangdong Xu (Tongji University)

- Challenges the assumption in random utility models (RUMs) that larger choice sets always increase traveler satisfaction.
- Proposes the "**choice set paradox**," where adding options can reduce welfare due to cognitive costs or overlooked alternatives.
- Develops a **Threshold Choice Model (TCM)** that incorporates utility thresholds and cognitive costs into the decision process.
- Identifies two types of paradox: adding inferior options that increase cognitive cost without benefit and adding superior options that overshadow others and reduce welfare.
- Provides theoretical and illustrative examples showing how larger choice sets can undermine traveler satisfaction.



(b) Type-II choice set paradox (λ = 0.2)

Figure 1. Illustration of two types of choice set paradox

Keywords

Random utility, choice set paradox, cognitive cost,

Rationally Inattentive Route Choice: A Link-Based Model

Bo Zhou (Chongqing Jiaotong University), Ronghui Liu (University of Leeds)

- Proposes **a link-based rationally inattentive (RI) route choice model** that overcomes the dimensionality and computational challenges of route-based RI models.
- Models traveler decision-making by sequentially acquiring link-level information, reducing information costs compared to route-level information acquisition.
- Provides closed-form solutions that bridge the gap between RI choice behavior models and random utility models (RUMs).
- Demonstrates through numerical examples that the link-based model significantly improves computational efficiency while maintaining behavioral realism.
- Shows that incorporating background information allows the model to transition smoothly between RI and RUM frameworks.

Keywords

Rational inattention, route choice, information acquisition,

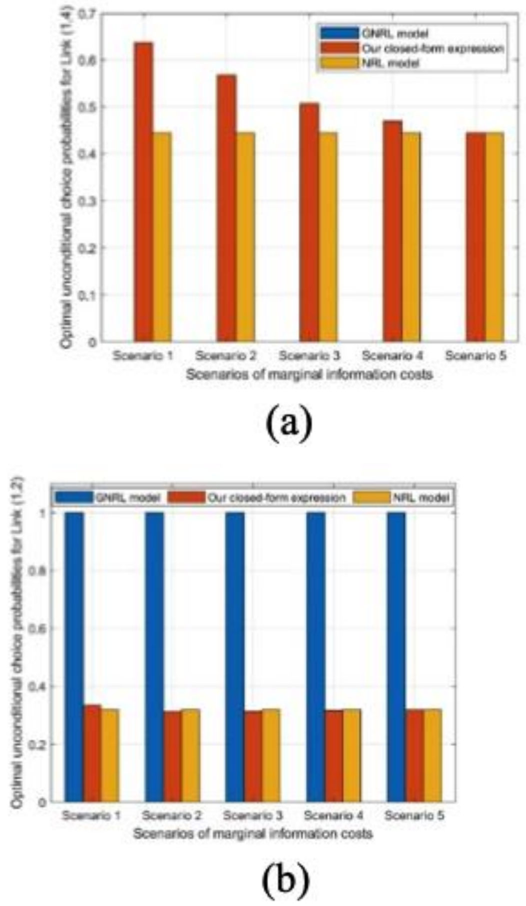


Figure 2 – *Unconditional choice probabilities for partial candidate links in* $\mathcal{A}_1^{\dagger}$. *(a) Link (1,2); (b) Link (1,5).*

Communication-free Distributed Model Predictive Control for Autonomous Vehicles at Lane-free and Signal-free Intersections

Distributed Control and Decentralized Allocation

Alireza Soltani , David M. Levinson, and Mohsen Ramezani (The University of Sydney)

- Propose a novel distributed **MPC framework** for AVs at lane-free, signal-free intersections that operate without communication, relying only on onboard sensors.
- The vehicle dynamics are represented by a simplified **kinematic bicycle model.** Physical limits, including maximum acceleration, steering angle, speed, and road boundaries, constrain the optimization problem for each AV
- The **distributed MPC** approach allows each AV to function independently, enhancing scalability and reducing computational burden.

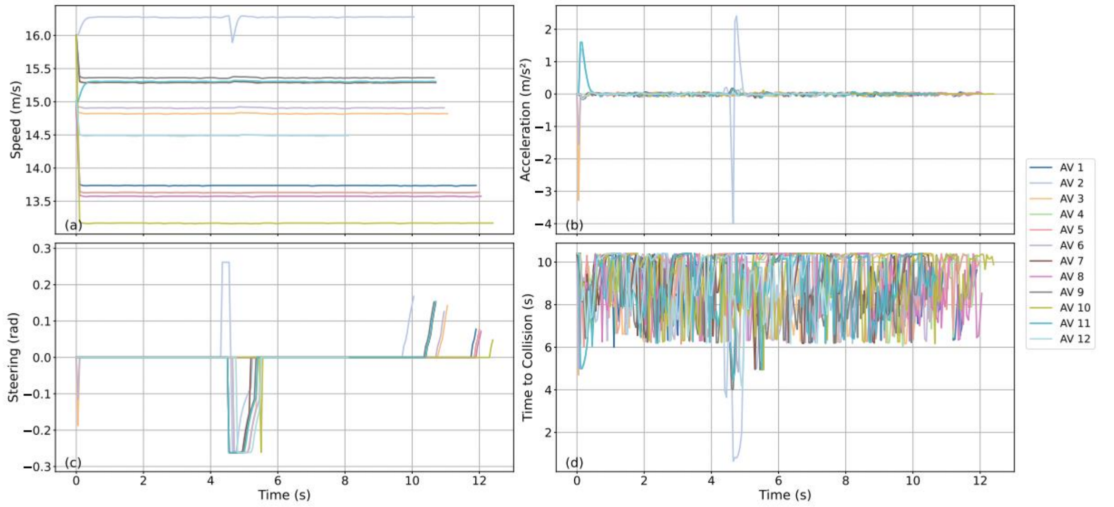


Figure 1 – *Speed (a), acceleration (b), and steering (c) profiles show smooth transitions with minimal fluctuations, indicating efficient handling of manoeuvres. The time-to-collision (d) shows that collisions are prevented by manoeuvres in advance, with a minimum TTC of 0.5 seconds, confirming collision-free operation in the system.*

Keywords

Automated vehicles, Signal-free Intersection, Decentralized agent, Lane-free Traffic

First-come-first-served Decentralized Assignment of Capacitated Resources with Partially Observable User Preference

Distributed Control and Decentralized Allocation

Yuhao Liu, Zhibin Chen, Joseph Y. J. Chow , and Xi Lin (NYU Shanghai etc.)

- Establish a **utility-free user equilibrium (UE)** model with the **FCFS (First-come-first-served)** principle.
- Propose a **restricted sequential assignment (RSA)** framework that serves as an insightful analysis tool for the proposed UE and a bedrock for efficient algorithms for UE related computations.
- the RSA framework and the derived DP enable us to analytically explore the Price of Anarchy.
- Explore the relation between the system parameters and the worst-case misplaced demand.

Proposition 1. (UE Condition) *A feasible assignment $\boldsymbol{x} \in \mathcal{X}$ is a UE assignment if and only if $\exists\, u^k \in \mathbb{R}(\forall k)$ and $v^{kw} \in \{0,1\}(\forall k \neq w)$ such that*

$$0 < \sum_{w \neq k} x^{kw} \perp \left(C^k - \sum_{w} x^{wk} \right) > 0,\ \forall k \in \mathcal{K} \tag{1}$$

$$u^k - u^w \leq (1 - v^{kw})|\mathcal{K}| - 1,\ \forall k \neq w \tag{2}$$

$$x^{kw} \leq Q^k v^{kw},\ \forall k \neq w \tag{3}$$

Proposition 2. $\max_{\boldsymbol{x} \in \mathcal{X}_{UE}} z(\boldsymbol{x}) = V_{\mathcal{D}}(\mathcal{D}) + V_{\mathcal{S}}(\mathcal{S})$, *where $V_{\mathcal{D}}(\mathcal{D})$ and $V_{\mathcal{S}}(\mathcal{S})$ are the optimal value of following DPs, respectively.*
$V_{\mathcal{D}}(\mathcal{H}) = \max_{k \in \mathcal{H}} \left\{ \min \left\{ \sum_{k \in \mathcal{D} \setminus \mathcal{H}} (Q^k - C^k), C^k \right\} + V_{\mathcal{D}}(\mathcal{H} \setminus \{k\}) \right\}, \forall \mathcal{H} \subset \mathcal{D}$, *and*
$V_{\mathcal{S}}(\mathcal{H}) = \max_{k \in \mathcal{H}} \left\{ \min \left\{ \left[\sum_{k \in \mathcal{D}} (Q^k - C^k) - \sum_{k \in \mathcal{S} \setminus \mathcal{H}} (C^k - Q^k) \right]^+, C^k \right\} + V_{\mathcal{S}}(\mathcal{H} \setminus \{k\}) \right\}, \forall \mathcal{H} \subset \mathcal{S}$.

Keywords

decentralized assignment, first-come-first-served user equilibrium, dynamic programming, price of anarchy, resource allocation

Modeling paradigm for adaptive decentralized traffic control via a rollout reinforcement learning approach

Distributed Control and Decentralized Allocation

Zhongyang Lu, Andy H.F. Chow (City University of Hong Kong)

- Present a modeling paradigm for decentralized adaptive network traffic control using **rollout reinforcement learning**.
- The optimal control problem is formulated to minimize network delays.
- To address the computational complexity in policy evaluation, the model-based simulation is further broken down into a **decentralized approach**, allowing local intersections to simulate asynchronously.
- Conduct a **comparative analysis** of traffic performance under scenarios with and without the data-driven value function approximation.

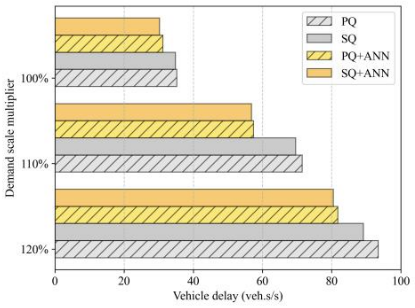


Figure 1 – *Comparison of solution methods with and without ANN approximation.*

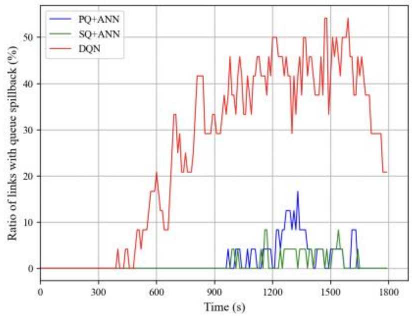


Figure 2 – *Ratio of links with queue spillback*

Keywords

Decentralized adaptive traffic control, rollout reinforcement learning, Markov decision process, spatial queue modeling, model-plant mismatch

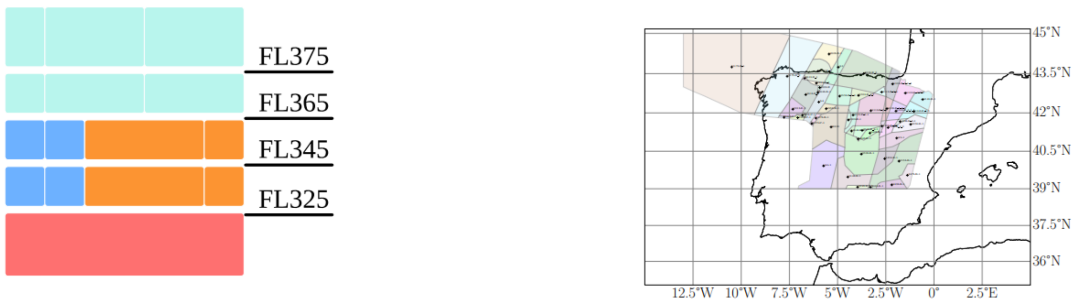
A mixed integer programming approach for airspace sector design problem

Drone and Air Mobility Control 1

Go Nam Lui and Guglielmo Lulli

Lancaster University Management School, LA1 4XY Lancaster (UK)

- create a comprehensive catalog of optimized sectors that can be dynamically selected based on varying traffic patterns, weather conditions, and operational requirements. This catalog will serve as a valuable resource for Air Navigation Service Providers (ANSPs) to implement more flexible and efficient airspace management strategies.
- Develop a mathematical program that designs multiple sectors simultaneously.



(a) *Abstract vertical profile for the five layers of Madrid airspace.*

(b) *2D projection of basic volumes.*

Figure 1 – *Configuration of Madrid Airspace.*

Keywords

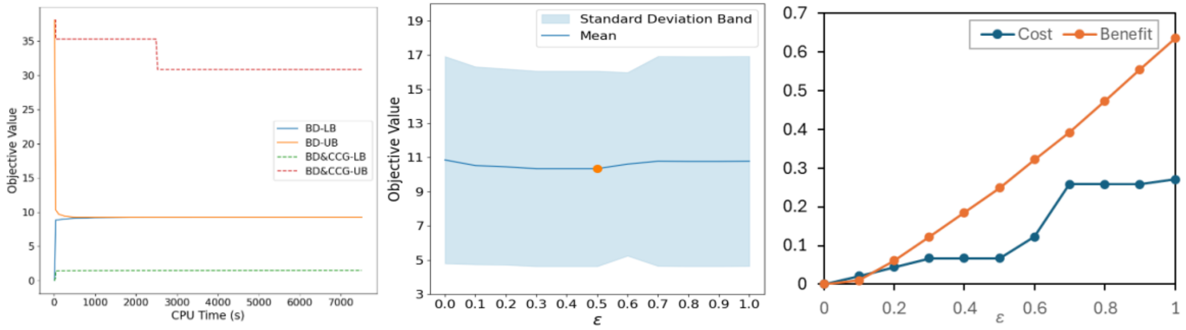
Mixed integer programming, airspace sector design, air traffic management

Drone Delivery Network Design with Uncertainties

Wenjia Zeng[a] , Ruiwei Jiang[b] , Hai Yang[a] , Hai Wang[c]

a The Hong Kong University of Science and Technology, Hong Kong, China
b University of Michigan, Michigan, USA
c Singapore Management University, Singapore

- Studying a drone delivery network problem in an urban low-altitude scenario that involves tactical decisions on hub locations, capacities, and the establishment of flight arcs.
- minimizing the investment cost of network infrastructures and the operational costs of drone delivery while accounting for both soft and hard time windows for parcels and the capacity of drone parking and charging facilities



(a) Convergence curves (b) Performance under various ε (c) Cost-benefit test

Figure 1 – *Test performance of DRO*

Keywords

Drone delivery; urban low-altitude economy; network optimization; distributionally robust optimization; demand uncertainty

Risk-based truck-drone delivery optimization

Wenxuan Wang, Mai Zhang, Ethan Beech, Arnab Majumdar, Washington Ochieng, Jose Escribano

- Integrates risk assessment into drone routing: The study introduces a novel framework that embeds operational risk evaluation directly into the route and pathfinding algorithms for drone-assisted last-mile delivery.
- Balances safety and efficiency: It demonstrates that including risk constraints can significantly reduce ground-level risks from drone operations, while maintaining cost-effective logistics performance.
- Advances safe drone logistics planning: The work lays the groundwork for future integration with Unmanned Air Traffic systems, considering factors like separation rules and emergency scenarios for safer drone deployment.

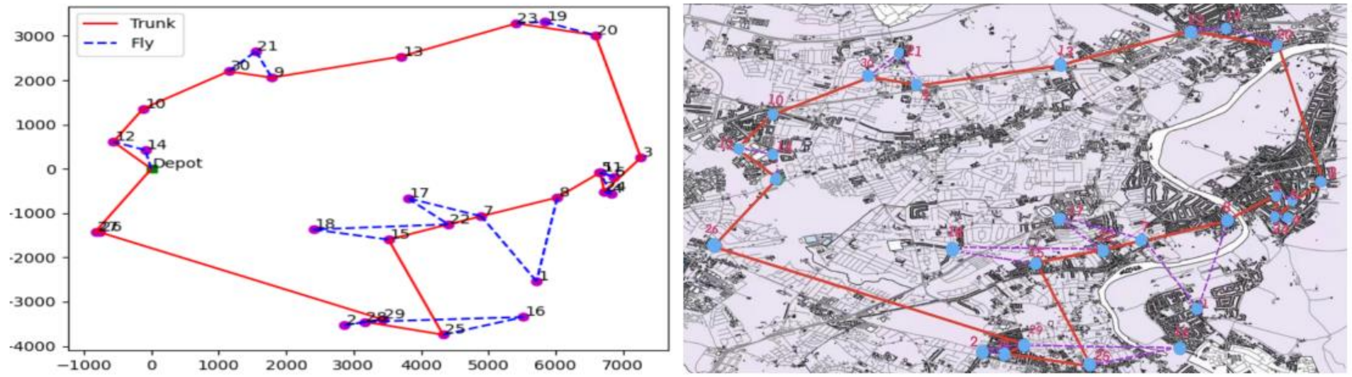


Figure 1 – *Risk-aware vehicle routes*

Keywords

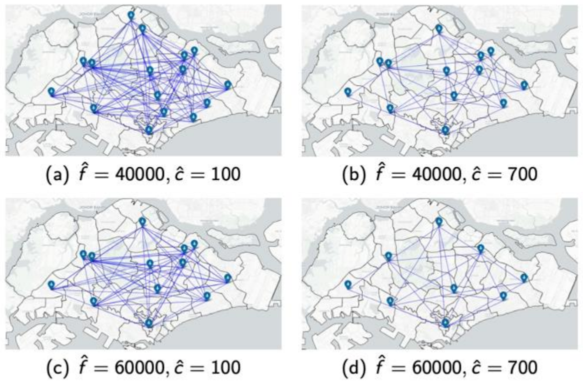
last-mile delivery, truck-drone delivery, drone risk assessment, vehicle routing, drone pathfinding

Urban Air Mobility Service Network Design: Ridership Maximization and Exact Solution Algorithm

Drone and Air Mobility Control 2

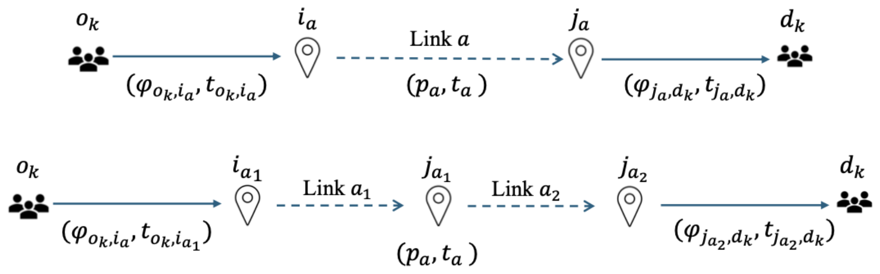
Yun Hui Lin (A*STAR), Qingyun Tian (Nanyang Technological University), Haodong Yin (Beijing Jiaotong University), and Jianjun Wu (Dalian University of Technology)

- Urban Air Mobility Service Network Design Problem (UAM-ANDP)
- Users' **choice** of whether to use the UAM route or the shortest ground-only route is modeled using **a binomial model**. In calculating the utility for the UAM route, the route with the highest utility is used (not stochastic choice, but decisive)
- Benders Decomposition is used. Using Benders Cut, the master problem can be relaxed and is solved via (Warm-start) Branch and Cut algorithm.
- Sensitivity analysis for network design cost parameters and trip distance was conducted.
- As for computational performance, Benders approaches significantly outperform Gurobi.



- $\hat{f}$: cost of operating a skyport $\hat{c}$: cost of maintaining a skyroad per km

- UAM route: Ground → Skyport → Aerial Link → Skyport → Ground



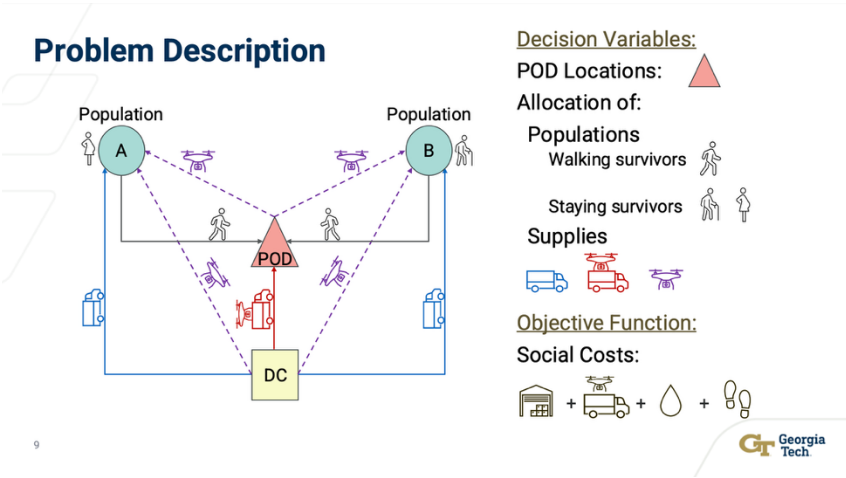
Keywords

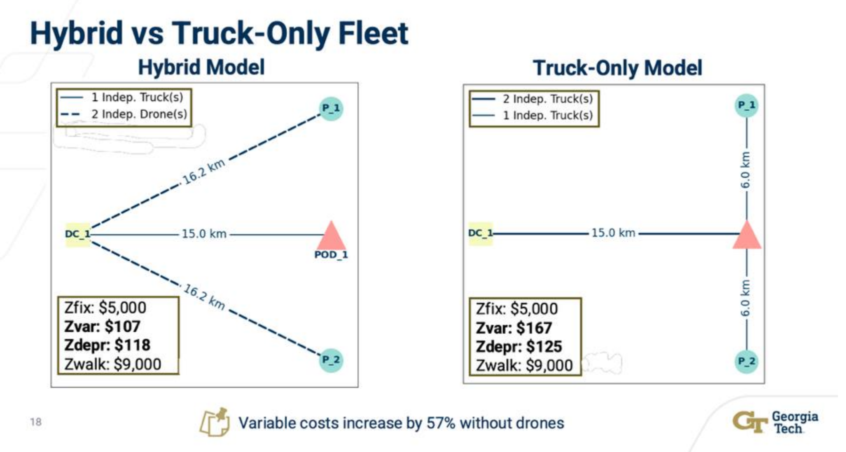
UAM, Service Network Design Problem, Benders Decomposition/Cut,

Optimization of Drone and Truck Operations for Socially Optimal Disaster Relief Distribution

R. Modregoa, S. Pérez-Guzmán (Georgia Institute of Technology)

- Considers the Drone and Truck Hybrid Operations of Disaster Response Logistics.
- Solves the MILP with a simple formulation. This primarily determines the location of the POD (Place Of Distribution) and the Supplying network.
- The estimated deprivation cost function is exponential.
- The important contribution of this paper is to optimize the allocation, routing, and facility location simultaneously (as decision variables).
- In numerical experiments, she compares the optimal solutions between some scenarios. Hybrid fleet leads to lower social costs than trucks-only fleet in every scenario.





Keywords

Disaster Response Logistics, Drone and Truck Hybrid Operation

Analysis and mitigation of discriminatory behaviour in fleet management algorithms

Dynamic Fleet Management

Tarek Chouaki, Sebastian Hörl (IRT SystemX)

- Studying the discriminatory behavior of an insertion-based dispatch algorithm that is broadly used in the literature.
- proposing and evaluating mitigation measures

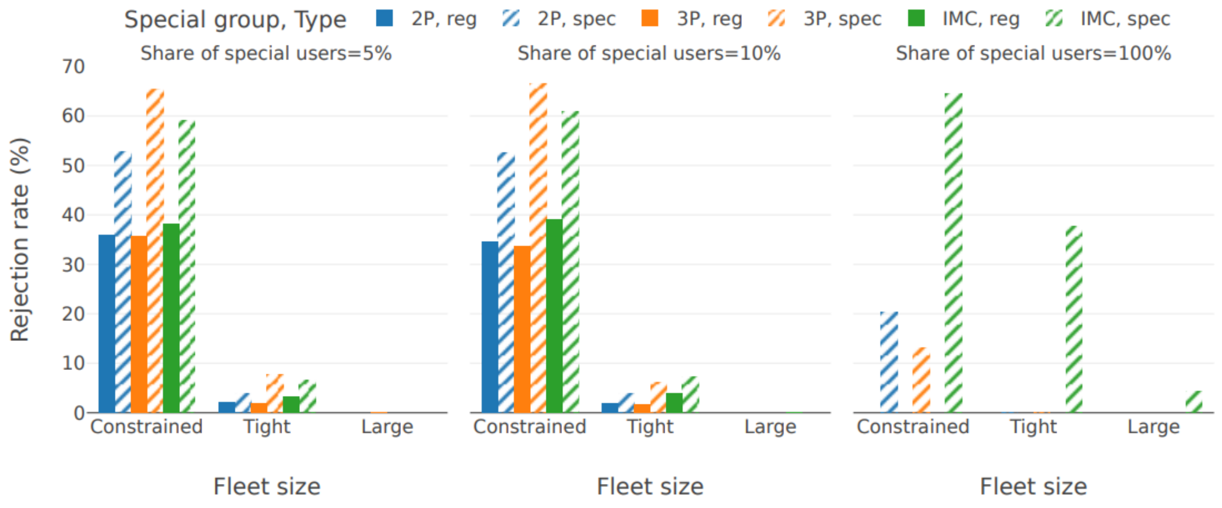


Figure 1 – *Assessment of rejection rates for regular and special users in the baseline case.*

Keywords

fairness, fleet management, on-demand mobility, simulation

Blocking and Railcar Fleet Management for Intermodal Rail Transportation

Dynamic Fleet Management

Julie Kienzle (Université de Montréal, CIRRELT), Serge Bisaillon (CIRRELT), Teodor Gabriel Crainic (Université du Québec à Montréal, Université de Montréal, CIRRELT) and Emma Frejinger (Université de Montréal, CIRRELT)

- Introduce a new problem for intermodal railway traffic that encompasses the blocking problem, the management of a limited heterogeneous railcar fleet with multiple resource types, the loading problem, and the addition of extra trains to the schedule.
- showing that an exact iterative variable fixing scheme allows to solve large-scale instances with a general-purpose solver.
- reporting an extensive computational study and providing managerial insights.

Keywords

Railroad, Intermodal Traffic, Network Design, ILP, Real Instances

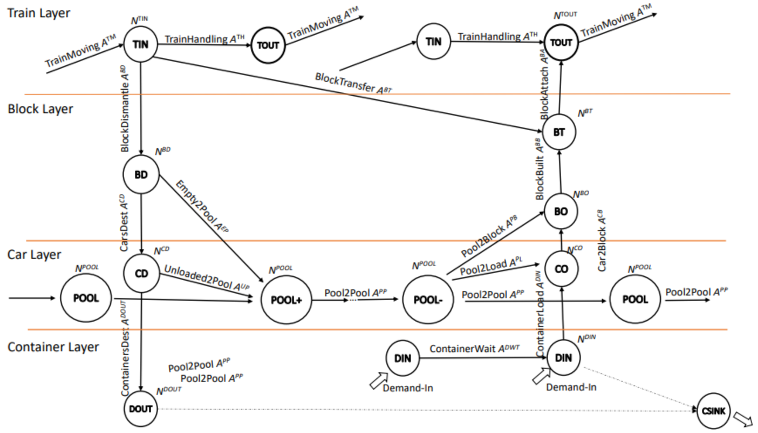


Figure 1 – *Four-Layer (Train, Block, Car, Container) Time-Space Network Illustration*

Coordinated vehicle dispatching and charging scheduling for electric ridehailing fleet under charging congestion

Dynamic Fleet Management

Tai-Yu Ma[a] , Richard D. Connors [b] , Francesco Viti[c]
a - Luxembourg Institute of Science and Technology (LIST), Luxembourg
b - University of Luxembourg, Luxembourg
c - Luxembourg Institute of Socio-Economic Research (LISER), Luxembourg

- Addressing Operational Uncertainty in EV Fleet Dispatching and Charging.
- Recognition of Infrastructure and Pricing Constraints.
- Critique of Existing Decomposition-Based Optimization Methods
- Towards More Integrated and Realistic Dispatch-Charge Coordinatio

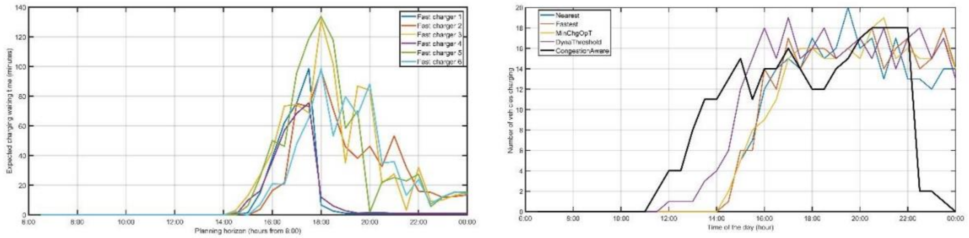


Figure 1 – *Expected charging waiting time on chargers (Left) and the number of vehicles charging during the day for different charging policies (Right)(# of customers=3000).*

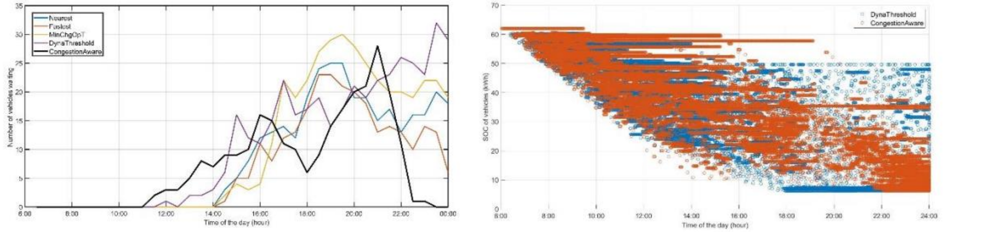


Figure 2 –*Number of vehicles waiting during the day for different charging policies (Left), and SoC of the fleet over time (# of customers=3000).*

Keywords

ride-hailing, electric vehicle, charging management, capacitated charging network, time-of-use energy prices

Minimum Multi-Service Fleet Size Problem: Shareability Graph and Network Flow Approach

Dingtong Yang[a] , Yubin Liu[a] , Hai Wang[b], *, Jinhua Zhao[c] , Hamsa Balakrishnan[c]
a - Singapore – MIT Alliance for Research and Technology Center,
b - Singapore Management University,
c - Massachusetts Institute of Technology

Figure 1 – *Illustration of a Multi-Service Fleet*

- Construct a shareability hypergraph to indicate whether two or more orders can be served in one vehicle trip.
- proposing a network flow model to assign trips obtained from the first step to vehicles, with the objective of minimizing multi-service fleet size or vehicle mileage.
- Describe a framework to model vehicle sharing across different types of services in a multi-service fleet.
- propose a scalable algorithm that builds a shareability hypergraph between orders and solves the minimum fleet problem using a network flow model.
- answering important questions regarding how efficient a multi-service fleet could be in terms of fleet reduction and vehicle miles travelled (VMT) savings

Keywords

vehicle-based multi-service, minimum fleet size, ride-hailing, crowdsourced delivery, network graph

Multimodal Transportation Pricing Alliance Design: Large-Scale Optimization for Rapid Gains

Equity-Based Transportation Management

Kayla Cummings (Massachusetts Institute of Technology),
Vikrant Vaze (Thayer School of Engineering at Dartmouth),
Özlem Ergun (Northeastern University),
Cynthia Barnhart (Massachusetts Institute of Technology)

- Proposes a pricing alliance framework to enable cooperation between **transit agencies and mobility-on-demand (MOD) operators**.
- Develops a mixed-integer non-convex optimization model with a two-stage decomposition for tractable large-scale fare setting.
- Introduces a tailored SOS2 coordinate descent algorithm with acceleration strategies for solving the first-stage problem efficiently.
- Demonstrates practical benefits through a Greater Boston case study, showing significant ridership and equity improvements under different alliance priorities.
- Designs a profit allocation mechanism to ensure MOD operators' participation while aligning with transit goals like VMT reduction and increased passenger utility.

Keywords

Public transit, pricing, alliance design,

$$\max_{\boldsymbol{x},\boldsymbol{\beta},\boldsymbol{\mu},\Lambda} \quad \text{Weighted Sum of Passenger Utility, Operator Profit, and VMT Reduction} \tag{1}$$

$$\text{s.t.} \quad \text{Route Fare} = \text{Base} + \text{Markup} \times \text{Distance} \qquad \forall \text{ Discount-Ineligible Routes} \tag{2}$$

$$\text{Route Fare} = (1 - \Lambda \boldsymbol{x}) \times \text{Base} + \text{Markup} \times \text{Distance} \qquad \forall \text{ Discount-Eligible Routes} \tag{3}$$

$$\text{Route Share} = \frac{e^{\text{Route Utility} - \text{Fare}}}{e^{\text{OO Utility}} + \sum_{\text{Routes}} e^{\text{Route Util.} - \text{Fare}}} \qquad \forall \text{ Routes, Time Periods} \tag{4}$$

$$\text{OO Share} = \frac{e^{\text{OO Utility}}}{e^{\text{OO Utility}} + \sum_{\text{Routes}} e^{\text{Route Util.} - \text{Fare}}} \qquad \forall \text{ Markets, Time Periods} \tag{5}$$

$$\text{Lower bounds} \leq \boldsymbol{\beta}, \boldsymbol{\mu}, \Lambda \leq \text{Upper bounds}, \boldsymbol{x} \text{ binary} \qquad \forall \text{ Operators} \tag{6}$$

Table 1 – *Objective function statistics (surplus compared to the 1-hour BO performance).*

Time budget	Algorithm	Trajectories Min	Trajectories Avg	Trajectories Max	Objective (Thousand USD) Min	Objective (Thousand USD) Avg	Objective (Thousand USD) Max
1 hour	BO	-	-	-	−28.0	0*	18.6
	SOS2-CD	2.0	3.8	5.0	−103.8	13.5	24.1
	SOS2-CD-MD	2.0	4.0	7.0	**−5.7**	**19.3**	24.1
	SOS2-CD-R	2.0	3.8	5.0	−77.6	17.1	**24.4**
	SOS2-CD-MD-R	2.0	4.2	6.0	−20.5	19.0	23.7
6 hours	BO	-	-	-	7.7	17.9	23.9
	SOS2-CD	16.0	20.1	25.0	−2.7	22.3	24.3
	SOS2-CD-MD	15.0	21.3	28.0	22.0	23.3	24.1
	SOS2-CD-R	13.0	19.7	24.0	**22.4**	**23.8**	24.4
	SOS2-CD-MD-R	15.0	21.4	26.0	21.1	23.3	24.3
12 hours	BO	-	-	-	18.7	21.9	23.9
	SOS2-CD	32.0	39.6	50.0	22.0	23.7	24.3
	SOS2-CD-MD	32.0	42.4	54.0	22.8	23.7	24.2
	SOS2-CD-R	26.0	38.2	47.0	**23.5**	**24.0**	24.4
	SOS2-CD-MD-R	31.0	42.7	52.0	22.2	23.7	24.4

Shared mobility services: exploring their impact on equity in multimodal transportation systems

Equity-Based Transportation Management

K. Kadem, M. Ameli, C.L. Azevedo, M. Zargayouna, L. Oukhellou (University Gustave Eiffel; Technical University of Denmark)

- Proposes a dynamic modeling framework to assess **shared mobility services' (SMSs) impacts on equity** within multimodal systems.
- Integrates multi-class user equilibrium and intermodal traffic assignment, considering heterogeneous traveler preferences.
- Uses rolling horizon technique for dynamic traffic assignment and SMS optimization with external matching algorithms.
- Demonstrates through simulations (Sioux Falls network) that SMS integration improves spatial equity, especially for low-income users.
- Shows that incentivizing SMS-public transport intermodality further enhances equity and reduces congestion.

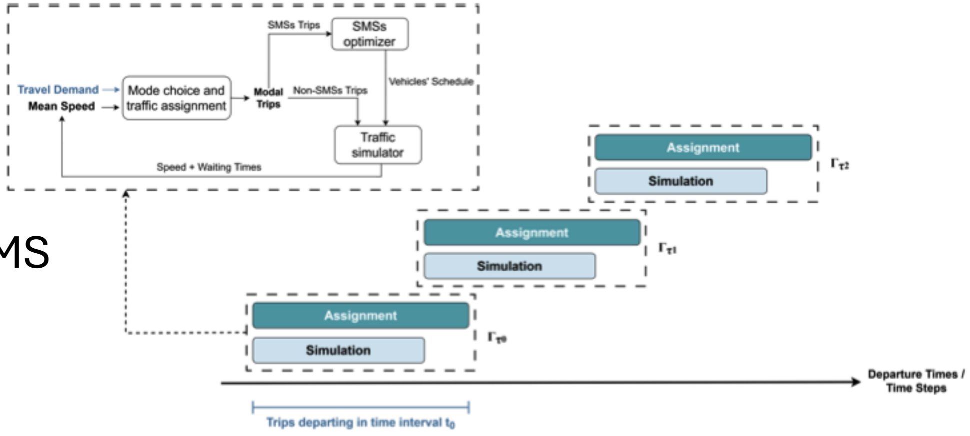


Figure 1 – *Dynamic Modeling framework for multimodal transportation systems*

Keywords

Spatial equity, inter-modality, public transport,

Regulating Autonomous Ride-Hailing Services for an Equitable Multimodal Transportation Network

Equity-Based Transportation Management

Jing Gao, Sen Li (The Hong Kong University of Science and Technology)

- Develops a **game-theoretic model to analyze interactions between autonomous ride-hailing services, public transit, and passengers** with different income levels.
- Demonstrates that without regulation, autonomous vehicles (AVs) improve overall mobility but worsen both spatial and social equity.
- Evaluates two regulatory policies: minimum service-level requirements for ride-hailing (improving spatial equity but risking greater social inequity) and transit subsidies funded by ride-hailing taxes (enhancing both spatial and social equity).
- Uses numerical studies for San Francisco to validate results and quantify equity impacts using the Theil index.
- Proposes policy guidance balancing trade-offs between mobility gains, spatial equity, and social equity in future AV-integrated transport networks.

Passenger behavior model

$$\lambda_{ij,k}^{t} = \lambda_{ij,k}^{0} \frac{\exp\left(-\mu c_{ij,k}^{t}\right)}{\sum_{t' \in \mathcal{T}} \exp\left(-\mu c_{ij,k}^{t'}\right)}, \quad t \in \mathcal{T},$$

TNC platform model

$$\max_{b,\mathbf{r^a},\mathbf{N^I},N} \sum_{i=1}^{M}\sum_{j=1}^{M}\sum_{k=1}^{K} \lambda_{ij,k}^{a}\left(b + r_i^a l_{ij}^a\right) + \lambda_{ij,k}^{b_1}\left(b + r_i^a d_{i,k}^{b_1}\right) + \lambda_{ij,k}^{b_2}\left(b + r_j^a d_{j,k}^{b_2}\right)$$
$$+ \lambda_{ij,k}^{b_3}\left(2b + r_i^a d_{i,k}^{b_3} + r_j^a d_{j,k}^{b_3}\right) - NC_{av}$$

Transit agency model

$$\max_{r^p,\mathbf{f}} \sum_{i=1}^{M}\sum_{j=1}^{M}\sum_{k=1}^{K} \lambda_{ij,k}^{p} + \lambda_{ij,k}^{b_1} + \lambda_{ij,k}^{b_2} + \lambda_{ij,k}^{b_3}$$

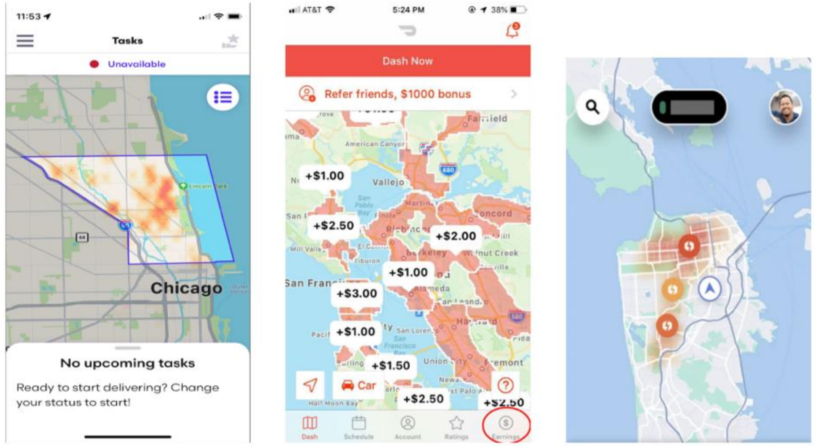
Keywords

Transportation network company, autonomous vehicles, transport equity,

Information design for spatial resource allocation

Ozan Candogan, Manxi Wu

- **Information design** as a tool for influencing strategic agent repositioning in spatial resource allocation.
- Develops a game-theoretic model where a platform reveals partial demand information to agents to shape their relocation decisions, thereby maximizing the platform's revenue.
- Proves that under practical conditions, **a simple monotone partitional information mechanism is optimal**: fully revealing demand when very high or low, and concealing it in intermediate ranges.
- Shows that equilibrium agent distributions and platform objectives can be expressed as **piecewise linear functions** of posterior demand beliefs, enabling efficient convex optimization formulations.



(a) Grubhub (b) Doordash (c) Uber

Figure 1: Examples of heat maps used by different platforms.

Keywords

Information design, On-demand mobility platforms, Monotone partitional information mechanisms.

Game Theory 1

Dispatching and Pricing in Two-Sided Spatial Queues

Ang Xu, Chiwei Yan

- **Two-sided spatial queue model** for ride-hailing, where both drivers and riders can wait, enabling more flexible dispatching and pricing decisions than prior one-sided models.
- Develops a **continuous-time Markov model** capturing state-dependent service times and dynamic pricing, linking pickup times to queue lengths and idle driver counts.
- Defines a **zigzag dispatching policy** with a structured threshold form, simplifying policy computation and transforming the problem into a tractable birth-death process.
- Designs a **dynamic programming algorithm** exploiting the zigzag structure, achieving near-optimal solutions significantly faster than classical value iteration methods.
- Demonstrates via numerical experiments that zigzag policies under dynamic pricing **substantially outperform naïve and static policies**, improving revenue and reducing computational times across varied penalty scenarios.

l \ m	0	1	2	3	4
0	0	1	1	1	1
1	0	0	1	1	1
2	0	0	0	0	1
3	0	0	0	0	0

Table 1 – *An example of a zigzag dispatching policy.*

Keywords

Matching, Pricing, Ride-hailing platforms, Spatial queues

Mean-Field Game Optimization in Bounded-Acceleration Traffic Models for CAVs

Game Theory 1

Negin Alisoltani, Mostafa Ameli, Megan Khoshyaran, Jean-Patrick Lebacque

- **Mean-Field Game framework** adapted for bounded-acceleration (BA) traffic models, aiming to optimize CAV .
- Models traffic as two phases—**equilibrium and BA**—where acceleration belongs to a set depending on whether the vehicle speed is above or below the equilibrium velocity.
- Reformulates the bounded-acceleration problem by defining acceleration as a **control variable constrained by a set,** not a fixed function.
- Derives a Hamiltonian formulation to ensure that optimized accelerations remain within allowable bounds for safe CAV operation.
- Solves the coupled PDEs in the MFG system using **fictitious play and fixed-point algorithms, enabling convergence to an ε-Nash equilibrium.**

The motion of the mass is necessarily the result of what each player does.

Reaction of each player to the mass	The mass moves accordingly to what players do
Hamilton-Jacobi-Bellman	*Fokker-Planck-Kolmogorov*
Control theory	Statistical mechanics

Keywords

Connected Autonomous Vehicles, Traffic flow optimization, Vehicle trajectory plan

Autonomous vehicle control on lane-free roads: A level-k game approach

Game Theory 1

Zhaohan Wang, Mohsen Ramezani, David Levinson

- **Decentralized, game-theoretic control framework** for AVs operating on lane-free roads, enabling more flexible two-dimensional movements.
- Models vehicle motion using a **kinematic bicycle model**, with receding horizon optimization solving nonlinear dynamics and costs under collision-avoidance constraints.
- Introduces a **level-k game-theoretic approach** to predict and react to the behavior of other vehicles, iteratively computing strategies under varying rationality levels.
- Implements the control framework in simulations, showing that vehicles successfully avoid collisions, adjust speeds appropriately, and leverage lateral space to bypass slower vehicles.

Keywords

Autonomous vehicle, Lane-free, Receding horizon optimization, Game theory

Designing High-Occupancy Toll Lanes: A Game-Theoretic Analysis

Zhanhao Zhang, Ruifan Yang, Manxi Wu

- Develops a **game-theoretic model of High-Occupancy Toll (HOT) lane usage**, accounting for heterogeneous traveler values of time and disutility of carpooling.
- Characterizes equilibrium regimes under varying toll levels, identifying thresholds where drivers switch between toll-paying, carpooling, or ordinary lane usage.
- Proves **unique Wardrop equilibria** exist and derives comparative statics, showing how changes in tolls and lane allocations affect traffic distribution and congestion.
- Calibrates the model using real-world data from California's I-880 HOT lanes, applying **inverse optimization** to infer travelers' preferences and demand.
- Demonstrates through numerical experiments that **optimized tolling schemes** can significantly reduce travel times, congestion, and improve revenue compared to current practices.

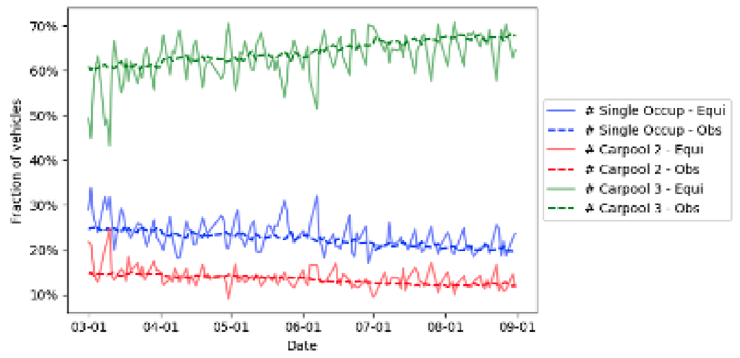


Figure 2 – *Comparison between equilibrium and actual percentage of travelers with each occupancy level.*

Keywords

High occupancy toll lane design, Non-atomic games, Equilibrium analysis with heterogeneous preferences

Privacy-Preserving Contextual Personalized Dynamic Pricing for Ride-Hailing Platforms

Game Theory 2

Bing Song, Sisi Jian

- **Privacy-preserving algorithm** for personalized dynamic pricing in ride-hailing, addressing risks of privacy leakage from pricing signals.
- Models passengers' ride valuations as a linear function of observable trip features plus individual preference shocks, framed as an online learning problem with binary feedback (accept/reject).
- Introduces a novel approach combining **differential privacy (DP)** with online convex optimization, ensuring passenger data confidentiality while enabling adaptive price updates.
- Utilizes the **Tree-Based Aggregation Protocol (TBAP)** to generate DP-protected gradient updates, controlling the trade-off between privacy guarantees and learning performance.
- Highlights practical potential for integrating the algorithm into ride-hailing platforms, allowing personalized pricing without compromising user privacy.

Algorithm 1 Privacy-Preserving Contextual Personalized Pricing

Inputs:
1. Trip features $\{\mathbf{x_t}\}_{t\geq 1}$ 2. Set $\boldsymbol{\Theta}$, pricing function $\Lambda(\cdot)$ 3. privacy budget ϵ, Lipschitz parameter u_F, strong convexity parameter K

Algorithm Steps:
4. Set an arbitrary $\hat{\boldsymbol{\theta}}_{\mathbf{1}} \in \boldsymbol{\Theta}$ and price $p_1 = 0$
5. $\hat{\boldsymbol{\tau}}_1 \leftarrow TBAP(u_F, \epsilon, \nabla l_1^K(\hat{\theta}_1))$
for t = 1, ... **do**
    6. $\hat{\theta}_{t+1} \leftarrow argmin_{\boldsymbol{\theta}\in\boldsymbol{\Theta}} \langle \hat{\tau}_t, \boldsymbol{\theta} \rangle + \frac{K}{2} \sum_{\omega=1}^{t} ||\boldsymbol{\theta} - \hat{\boldsymbol{\theta}}_\omega||^2$
    7. $p_{t+1} \leftarrow \Lambda(\langle x_{t+1}, \hat{\boldsymbol{\theta}}_{t+1})$, observe y_{t+1}
    8. $\tau_{t+1} \leftarrow TBAP(u_F, \epsilon, \nabla l_{t+1}^K(\hat{\theta}_{t+1}))$
end for

Keywords

Contextual personalized dynamic pricing, Differential privacy, Privacy preserving, Online convex optimization

Population Markov Potential Game: An Alternative Framework for Markovian Traffic Assignment

Xuhang Liu, Kenan Zhang, Rui Yao

- Introduces the **Population Markov Potential Game (PMPG)** as a novel framework for dynamic, stochastic traffic assignment, extending population and Markov potential games.
- Unlike prior Markovian traffic assignment models, PMPG allows **state transitions to depend on aggregate behaviors** rather than fixed deterministic routes.
- Establishes theoretical results showing that PMPG equilibria correspond to solutions of a global potential maximization problem, enabling efficient computation.
- Proposes a **policy gradient algorithm** to solve PMPGs, demonstrating significantly faster convergence than traditional value iteration methods in large-scale traffic networks.

Definition 1. *A Markov population game is a population Markov potential game (PMPG) if there exists a potential function* $\Phi(\mu, \pi)$ *such that*

$$\frac{\partial \Phi(\mu, \pi)}{\partial \pi_{n,t}(s,a)} = \gamma^t \mu_t(s) R(s, a, \mu_t, \pi_t), \quad \forall n \in \mathcal{N}, s \in \mathcal{S}, a \in \mathcal{A}. \tag{5}$$

- Forward loading: Compute population state distribution μ using the current policy π.
- Policy update: Evaluate the gradient $\nabla_{\pi_n} \Phi(\mu, \pi) = \left(\frac{\partial \Phi(\mu,\pi)}{\partial \pi_{n,t}(s,a)}\right)_{t \in \mathcal{T}, s \in \mathcal{S}, a \in \mathcal{A}}$ as per Eq. (5) and update policy of representative agent according to

$$\pi_n \leftarrow \mathrm{Proj}_{\Pi}\left[\pi_n + \alpha \nabla_{\pi_n} \Phi(\mu, \pi)\right], \tag{9}$$

where α is the step-size and $\mathrm{Proj}_{\Pi}[\cdot]$ denotes a projection on to Π.

Keywords

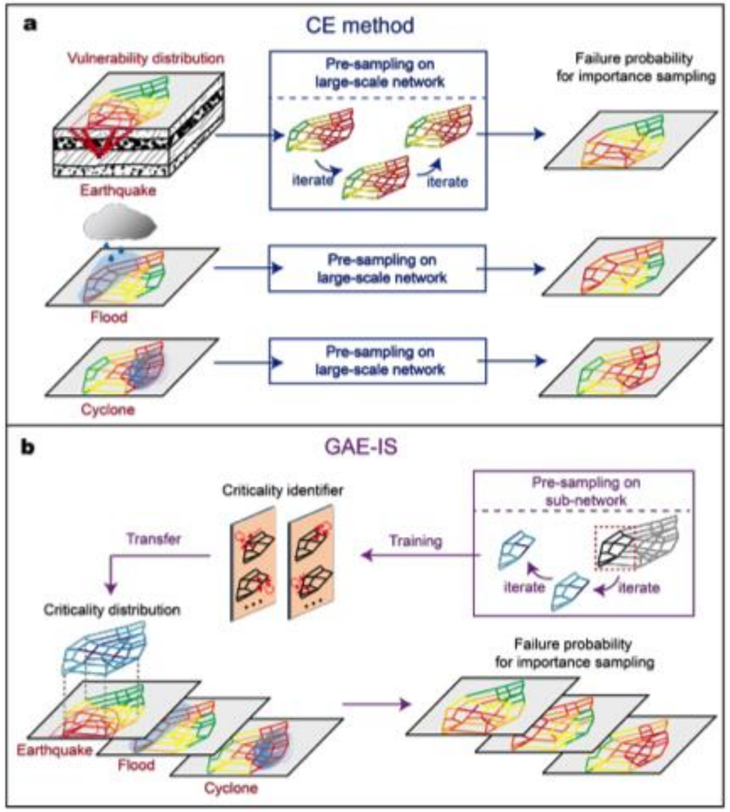
Traffic assignment problem, Markov potential game, Population game

Discovering and Quantifying Extreme Failure Scenarios through Graph Learning for Road Transportation Systems

Graph Neural Network

Mingxue Guo, Tingting Zhao, Jianxi Gao, Xin Meng, Ziyou Gao (Beijing Jiaotong University; Rensselaer Polytechnic Institute)

- Proposes a novel framework, Importance Sampling based on **Graph Auto-Encoder (GAE-IS)**, to efficiently estimate probabilities of extreme failures in large-scale transportation networks.
- Integrates graph learning to identify critical network components, decoupling functional criticality from failure risk to enhance sampling efficiency.
- Demonstrates improved sampling performance (1–2 orders of magnitude) over crude Monte Carlo simulation in case studies on Berlin, Anaheim, Northern Gold Coast, and Chicago networks.
- Shows that the remaining capacity of nodes is the most significant feature for link criticality, revealed through perturbation experiments.
- The GAE-IS framework is transferable and applicable to various infrastructure systems, including water, power, and communication networks, supporting resilient infrastructure design and operation.



Keywords

Extreme Cases, Importance Sampling, Graph Auto-Encoder,

Aggregated Knowledge Learning for Dynamic Vehicle-Task Assignment in Emergency Medical Services

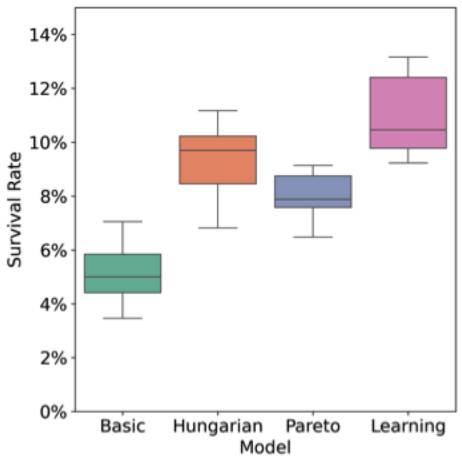
Graph Neural Network

Changle Song, David Levinson, Emily Moylan (The University of Sydney)

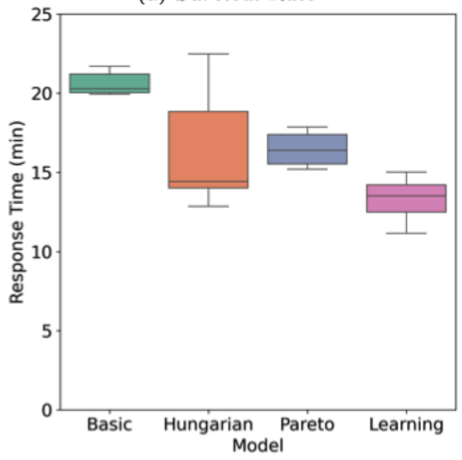
- Proposes **Aggregated Knowledge Learning (AKL),** a novel training method that integrates outputs from multiple traditional assignment models (Hungarian, Pareto, No Reassignment) to create high-quality training data for Graph Neural Networks (GNNs).
- Demonstrates that the AKL-GNN model significantly improves survival rates and reduces response times compared to baseline models in EMS vehicle-task assignments.
- Shows that the model maintains superior performance under varying load conditions (30, 40, and 50 incidents), demonstrating scalability and robustness.
- Highlights that AKL's modular structure supports integration of advanced models (e.g., reinforcement learning) without changing the training process and facilitates knowledge distillation for smaller learners.
- Confirms that the supervised AKL approach outperforms reinforcement learning in training efficiency while achieving high-quality decisions in dynamic, heterogeneous EMS environments.

Keywords

Aggregated Knowledge Learning, Assignment Problem, Graph Neural Networks,



(a) *Survival Rate*



(b) *Response Time*

Figure 1 – *Performance Comparison with 30 Incidents and 10 Vehicles*

Machine Learning Surrogates for Optimizing Transportation Policies with Agent-Based Models

Graph Neural Network

Elena Natterer, Roman Engelhardt, Sebastian Hörl, Klaus Bogenberger (Technical University of Munich; Institut de Recherche Technologique SystemX)

- Proposes the use **of Graph Neural Networks (GNNs) as machine learning surrogates** for agent-based transportation models to enable fast evaluation of policy interventions.
- Demonstrates the feasibility of GNN surrogates through a Paris case study (30,000 nodes), accurately predicting the impacts of capacity reduction policies on traffic flow within 0.1 seconds per scenario.
- Achieves strong performance, with R^2 = 0.76 overall and R^2 = 0.92 on roads with policy interventions, significantly reducing mean squared error compared to naïve baselines
- Highlights the model’s potential to support large-scale simulation-based optimization and real-time control applications in transportation policy.
- Identifies future directions, including extending to multimodal impacts, dynamic scenarios, and cross-city transferability for generalizability of the surrogate model.

Keywords

Graph Neural Networks, Agent-based simulations, Surrogate Models,

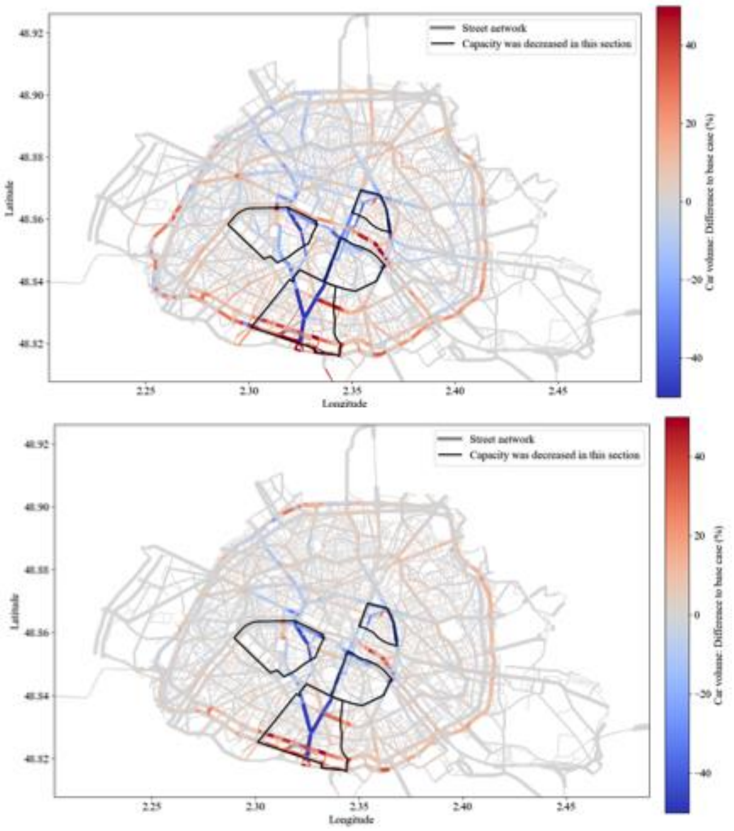


Figure 2 – Randomly chosen test data: Actual (top) and predicted (right) change in car volume

Multi-stage distributionally robust optimization for pre- and post-disaster humanitarian logistics with information constraints

Humanitarian Logistics

Authors

•Riki Kawase

Author's affiliation

•Department of Civil and Environmental Engineering, Institute of Science Tokyo, Tokyo, Japan

•Highlights

✓ The study develops a multi-stage problem that formulates pre-disaster planning and subsequently determines post-disaster.

✓ It addresses the limitations which often lack appropriate information availability and information ambiguity due to damaged communication infrastructure and inadequate historical data.

✓ A multi-stage Distributionally Robust Optimization (DRO) model is presented to address information availability and ambiguity in pre- and post-disaster HL.

✓ Numerical experiments demonstrate that considering information availability and ambiguity in the HL model significantly **improves** its out-of-sample performance.

Methodological contribution

•Dynamic programming

•Stochastic programming

•Distributionally robust optimization

•Wasserstein metric

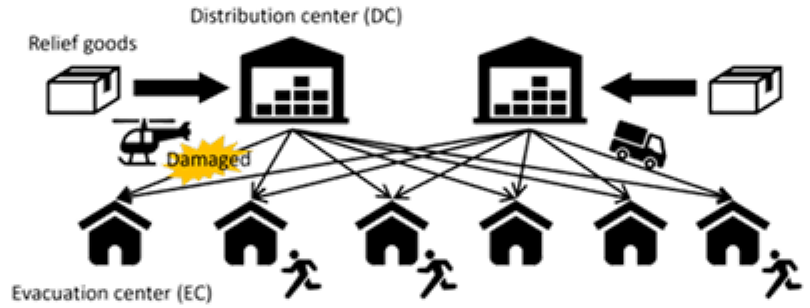
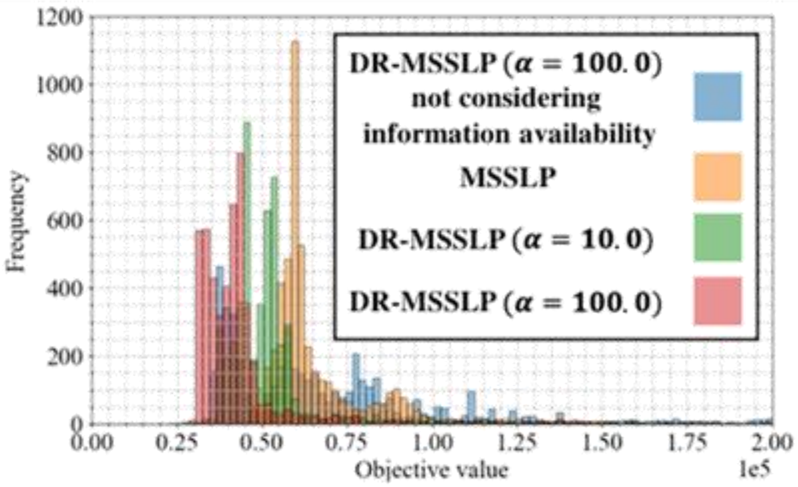


Figure 2 – *An example of humanitarian logistics network*



(b) *Histograms of out-of-sample objective values*

Optimizing Customized Bus Routing and Maximum Seat Occupancy Rate Under the Influence of Epidemic Outbreaks

Humanitarian Logistics

Authors

Yiqi Cai, S Sun, Shuxian Hao, Haohan Xiao

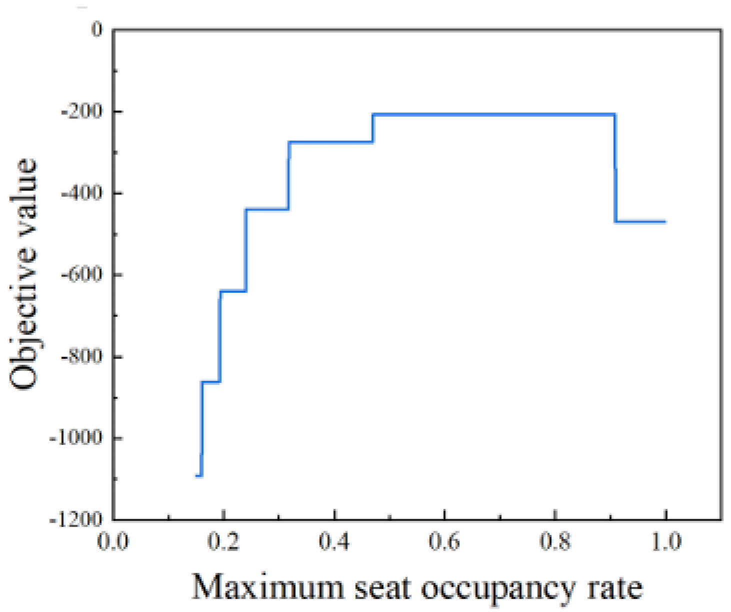
Author's affiliation

•Highlights

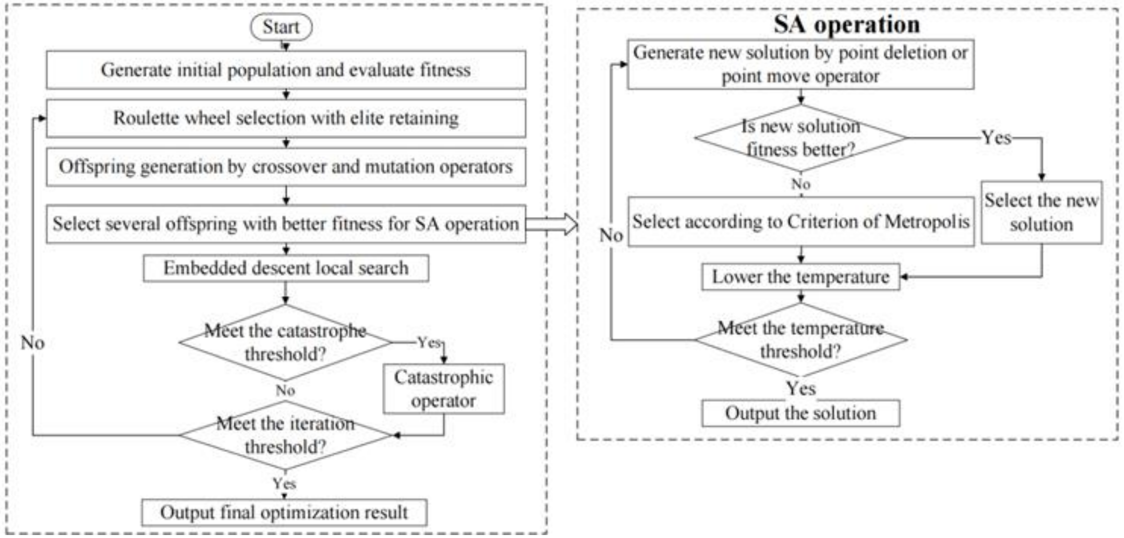
- ✓ integrates the maximum seat occupancy rate setting problem into the Customized Bus (CB) **route planning model** under the assumption of elastic demand.
- ✓ The **proposed model**(modified Wells-Riley) aims to maximize the operator's profit while also considering their social responsibility for epidemic prevention during outbreaks.
- ✓ A hybrid algorithm, M-SAGA, is adopted to solve the integrated route planning and seat occupancy rate optimization problem.
- ✓ Numerical studies show that jointly optimizing routing and maximum seat occupancy rate significantly improves the profitability of CB while controlling total infection risk.

Methodological contribution

- Customized bus
- Vehicle routing problem
- Seat occupancy rate optimization
- Wells-Riley model
- Genetic algorithm



SOLUTION ALGORITHM



UAV Search and Routing Planning In a Disaster Area

Humanitarian Logistics

Authors

Nastaran Oladzad, Esther Jose, Rajan Batta and Miguel Lejeune

Author's affiliation

University at Buffalo , George Washington University

•Highlights

- ✓ The study optimizes UAV search and routing planning (SRP) to maximize detected casualties in disaster areas within limited mission durations.
- ✓ It addresses uncertainties in the number of casualties and the coordination of multiple UAVs, with **impact explored through a case study based on the 2023 Turkey-Syria earthquake**.
- ✓ A clustering-based heuristic is developed to solve larger instances, by first identifying clusters to visit and their order, along with search times per cluster.
- ✓ To model non-deterministic casualties, the number of casualties per region is considered a uniform random variable, and equations are provided for probability and expected value of found casualties.

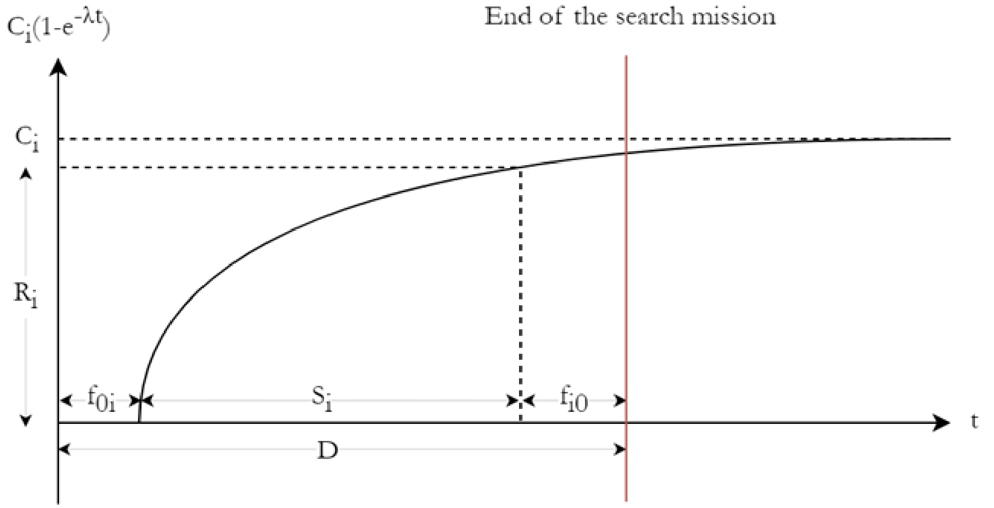
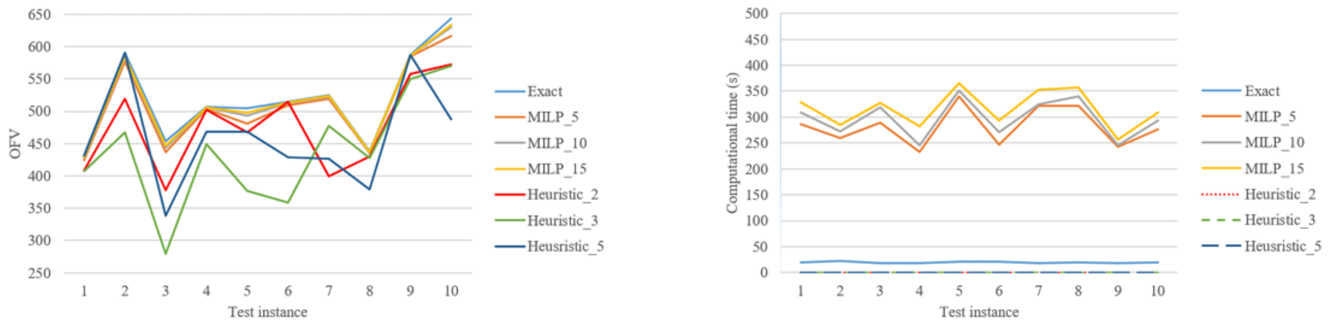


Figure 1 – *Model for detection of casualties.*

Methodological contribution

- Stochastic search and routing planning
- Disaster relief
- Humanitarian operations Search
- rescue Multiple UAV collaboration



(a) *OFV* (b) *Computational time*

Figure 3 – *Performance of different solution methods for instances of the size 10.*

Dynamic capacity allocation for cargo-hitching in urban public transportation systems

Paul Bischoff[1], Benedikt Lienkamp[1], Tarun Rambha[2], Maximilian Schiffe [1,3]

1 - School of Management, Technical University of Munich, Germany,
2 - Department of Civil Engineering & Center for Infrastructure, Sustainable Transportation and Urban Planning, Indian Institute of Science, India
3 - Munich Data Science Institute, Technical University of Munich, Germany

- Introduce a new algorithmic framework with a state-of-the-art graph expansion and develop both a Price-and-branch (P&B) and Branch-and-price (B&P) algorithm to solve real-world problem instances.
- Define a novel strategic planning problem for a municipality enabling cargo-hitching with dynamic capacity allocation to increase the system utilization during off-peak hours.

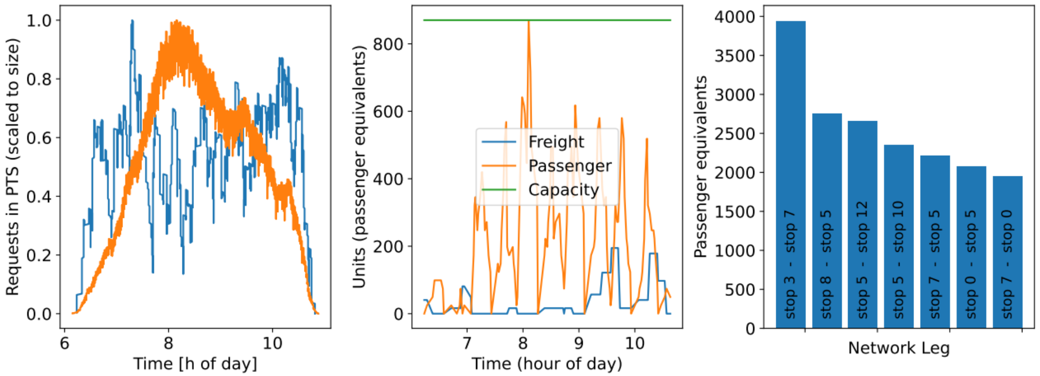


Figure 2 – *System utilization, single vehicle utilization, and network analysis*

Keywords

cargo-hitching, intermodal freight transportation, capacitated network design

Group-and-Match vs. Route-then-Insert? Order Dispatching in Vehicle-Based Dual Services (VeDuS)

Yue Lin[a], Hai Yang[a], Hai Wang[b]

a - Department of Civil and Environmental Engineering, The Hong Kong University of Science and Technology
b - (School of Computing and Information Systems, Singapore Management University)

- Investigates order-dispatching strategies for VeDuS and explores how various factors influence their performance.
- Providing Practical suggestions and valuable insights.

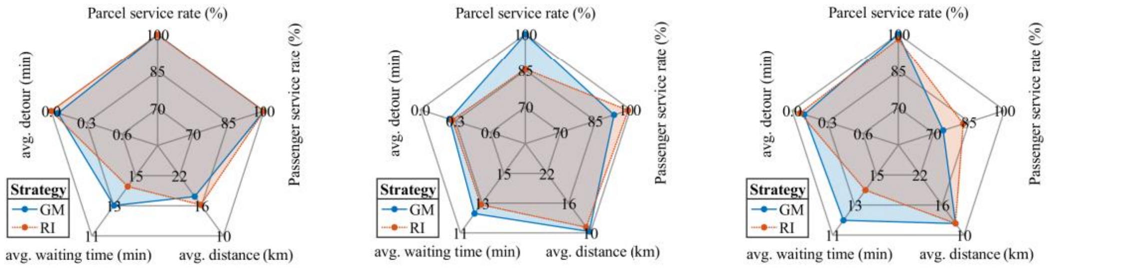


Figure 3 – *Performance in 3 instances: (a) Low demand level, passenger ratio 20%; (b) High demand level, passenger ratio 20%; (c) High demand level, passenger ratio 80%*

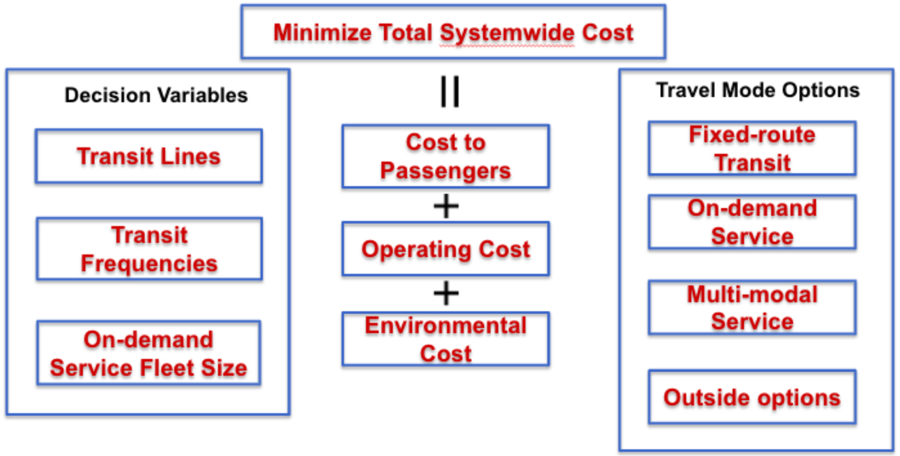
Keywords

Vehicle-Based Dual Services, Passenger Mobility, Parcel Delivery, Order Dispatching

Integrated Urban Transportation Network Design for Alleviating Transit Deserts

Yifei Sun, Vikrant Vaze

- Integrated planning of fixed-route transit and on-demand ride-sharing services to minimize systemwide costs.
- Optimize transit line design, transit frequencies, on-demand fleet size, under passenger choice.
- Original two-phase solution approach combining domain-inspired rounding, iterative linearization and delayed constraints generation: strong ablation performance
- Greater Boston area case studies: 2.8%-6.2% cost reduction, saving $5 million annually
- Disproportionately larger benefits to the underserved communities



$$\Delta = f(d^R, b^R)$$

$$d^R = \sum_{od \in \mathcal{OD}} ((s^R_{od} + s^M_{od}) D_{od})$$

Non-convex MINLO Formulation: Ride-sharing travel time constraints

Keywords

Transit network design, on-demand services, transit deserts, large-scale optimization

Capacity planning for demand-responsive multimodal transit

Bernardo Martin-Iradi, Francesco Cormana, Nikolas Geroliminisb

- Introduces a two-stage problem formulation for On-Demand Multimodal Transit Systems (ODMTS), addressing fleet sizing, scheduling, and passenger routing under demand uncertainty.
- Strategic decisions (fleet sizing, scheduling) are made in the first stage, while operational decisions (on-demand vehicle routing) are handled in the second stage.
- Proposes an exact algorithm using Benders decomposition and column generation to solve large-scale problems, demonstrated through a case study in Zurich.
- The results show that the method outperforms commercial solvers, especially when compared to unimodal, fleet-homogeneous, and deterministic models.
- Highlights the benefits of considering stochastic demand and heterogeneous fleets for improving system capacity efficiency, service levels, and reducing operational costs.

$$
\begin{aligned}
\min \quad & \text{Transit fleet and schedule costs} + \text{expected operational and travel costs} && (1)\\
\text{s.t.} \quad & \text{Passenger mode assignment constraints} && (2)\\
& \text{Mode service operating constraints} && (3)\\
& \text{Vehicle capacity constraints} && (4)\\
& \text{Passenger flow constraints} && (5)
\end{aligned}
$$

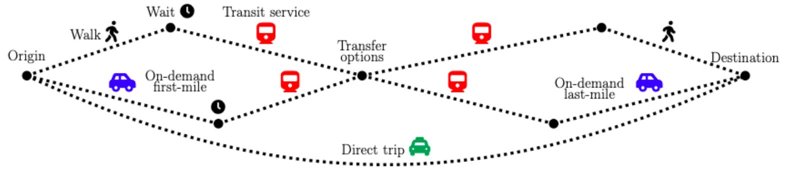


Figure 1 – *Example of a passenger graph where transit legs are shown in red, first and last-mile services in blue, and direct trips in green.*

Keywords

Multimodal transit, Public transport, On-demand mobility, Stochastic optimization

Deviated Fixed-route Microtransit: Design and Operations

Bernardo Martin-Iradi, Alexandria Schmid*, Kayla Cummings, Alexandre Jacquillat

- Proposes a scalable two-stage stochastic optimization methodology for designing and operating deviated fixed-route microtransit systems.
- MiND-VRP problem (vehicle routing) is primarily addressed, with extensions to MiND-DAR problem (dial-a-ride).
- Introduces a subpath-based representation to handle on-demand operations, improving formulation effectiveness compared to segment- and path-based benchmarks.
- Subpath-based formulation significantly reduces variables, terminates faster, and outperforms path/segment-based benchmarks for small instances (up to 10 candidate lines).

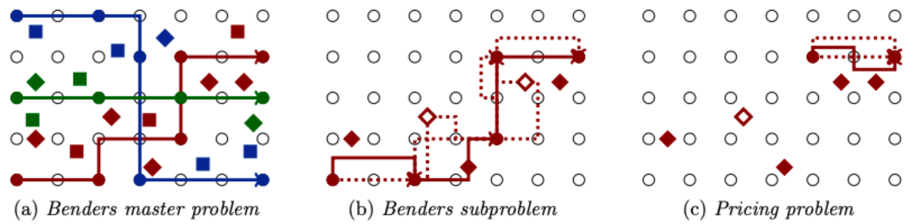


Figure 1 – *Double-decomposition algorithm.* **Left:** *Benders master problem with three reference lines (blue, red, green); passenger requests in two scenarios (squares, diamonds) with their first-stage assignments (colors).* **Middle:** *Benders subproblem for one reference trip and one scenario; full diamonds encode passengers served; solid lines characterize selected subpaths.* **Right:** *Pricing problem to generate new subpath between checkpoints (solid line).*

Keywords

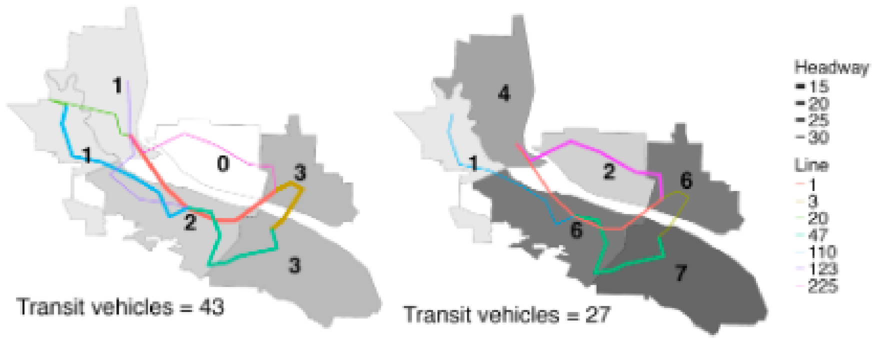
Microtransit, stochastic optimization, Benders decomposition, column generation

Microtransit design: fixed-line transit, on-demand mobility, or both?

Alexandre Jacquillat, Julia Yan, Arthur Delaruec and Shriya Karam

- Proposes a data-driven optimization approach to co-design transit and on-demand systems, emphasizing flexibility based on demand and fleet size for better service quality and efficiency.
- Provides theoretical results on optimizing first- and last-mile on-demand services, with key propositions showing that **larger fleet sizes and demand favor hybrid solutions and that global-hybrid models offer significant benefits over local transit-only or on-demand-only operations.**
- Develops an optimization model using historical data from Tri-cities, Washington, for hybrid transportation design.
- Hybrid models improve costs by 14.58% under constrained budgets and offer savings of 62.58% to 55.37% with flexible budgets.

A joint fleet allocation between across modes capitalizes on high ridership lines.



Original routes   Re-selected routes

Keywords

Transit systems, on-demand mobility, continuous approximation, integer optimization

Batching and In-Building Delivery Routing with Capacitated Residential Parcel Lockers

Last-Mile Delivery 1

Dipayan Banerjeea, and Ignacio Erazob (Loyola University Chicago, Amazon)

- Optimize the operations of a parcel delivery firm that has access to an **RPL(Residential Parcel Locker)** in the lobby of a high-rise building by minimizing the expected time to deliver all of the building's parcels.
- Formulate building layout and elevator behavior.
- Define the **inter-floor TSP (IFTSP)** as the formal optimization problem of determining the quickest route through the building.
- Develop a **branch-and-price approach** to solve the full problem.
- Consider the delivery of 24 parcels to a building with 640 total apartments distributed across 20 residential floors, and solutions are compared.

Keywords

urban logistics, last-mile delivery, routing, branch-and-price

Credit: Swiftlane

		Mean expected delivery time (sec) and gap vs. OPT (%)			
q	c	OPT	TDH	RH	DO
6	6	1930.7	2091.1 (8.3%)	2029.7 (5.1%)	2376.1 (23.1%)
8	8	1631.7	1787.9 (9.6%)	1692.2 (3.7%)	2189.7 (34.2%)
12	12	1251.9	1391.8 (11.2%)	1259.3 (0.6%)	2002.9 (60%)

Table 1 – *Comparison of parcel batching policies*

Leveraging public transit for efficient last-mile delivery through crowdshipping

Last-Mile Delivery 1

Mikele Gajdaa, Filippo Ranzab Renata Mansinib , Olivier Gallay (HEC Lausanne, University of Brescia)

- This research advances the understanding of **PT-based crowdshipping**, offering insights into its potential to benefit urban logistics while addressing environmental concerns.
- **Three key actors** are involved in the PTCP: (i) the LSP (a Logistics Service Provider); (ii) crowdshippers, and (iii) recipients.
- The approach to solving the PTCP involves three main components: a **MILP formulation**, a **Branch-and-Cut** framework with valid inequalities (both implemented and solved in CPLEX), and an **ALNS** algorithm within an Iterative Simulated Annealing (ISA) framework.

Keywords

Crowdshipping, Last-Mile Delivery, Public Transportation Network, Adaptive Large Neighbo Search, Branch-and-Cut.

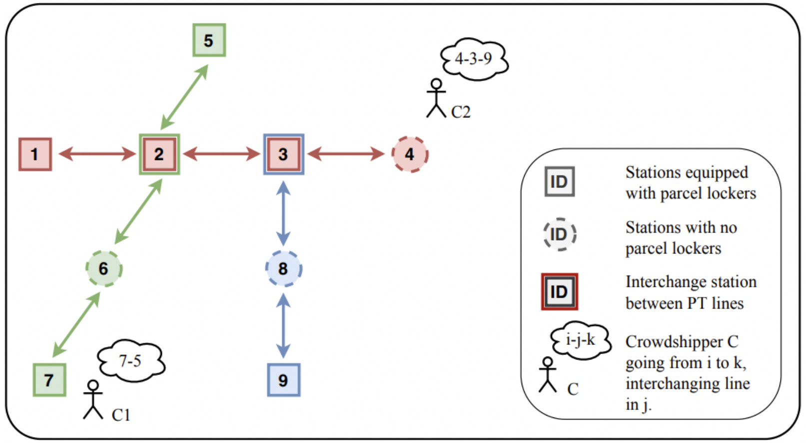


Figure 1 – *Example of the PTCP with three intersecting PT lines*

Table 1 – *CPLEX and ALNS results on instances solved to optimality*

$\|N\|$	ID	CPLEX	ALNS	Gap (%)	CPLEX [s]	ALNS [s]
44	3	715	715	0.00	4944	1
40	6	614	614	0.00	21020	57
44	2	716	716	0.00	4233	1
24	3	638	638	0.00	2718	9
40	4	647	647	0.00	43932	233
40	1	750	750	0.00	96	0
44	5	684	685	0.15	2603	0
40	2	617	618	0.16	29475	20
40	5	708	712	0.56	5264	1

Sustainable last-mile logistics with parcel lockers and autonomous delivery robots

Last-Mile Delivery 1

Gianpaolo Ghiani, Emanuela Guerriero, Emanuele Manni, Deborah Pareo (University of Salento, Italy)

- Propose a delivery system that leverages both public **drop-off boxes and ADRs**, with the aim to reduce costs, emissions, and delivery failures.
- Make use of tailored **destroy-and-repair operators** within a neighborhood-search framework.
- Provide some insights about the **environmental and economic** advantages of using ADRs.

Keywords

last-mile logistics; autonomous delivery robots; parcel lockers; metaheuristics

Algorithm 1 Destroy phase

```
procedure DESTROY(i_0, h)
    iteration ← 1; C' ← ∅; P' ← ∅; C'' ← {i_0}        ▷ initialization
    while iteration ≤ h do
        C_temp ← ∅                                    ▷ temporary data structure
        for i ∈ C'' do
            C' ← C' ∪ {i}                             ▷ update of C'
            for p ∈ L_i do
                C_temp ← C_temp ∪ {i' ∈ C : p(i') = p}
                P' ← P' ∪ {p}                         ▷ update of P'
            end for
        end for
        C'' ← C_temp
        iteration ← iteration + 1                     ▷ update of the iteration counter
    end while
    return (C', P')
end procedure
```

$$\min \sum_{i \in C'} \sum_{a \in L_i \cap P'} w_{ia} x_{ia}$$

$$\text{s.t.} \quad \sum_{a \in L_i \cap P'} x_{ia} = 1 \qquad \forall i \in C'$$

$$\sum_{i \in C' : a \in L_i} x_{ia} \leq Q'_a \qquad \forall a \in P'$$

$$x_{i_0 p(i_0)} = 0$$

$$x_{i,a} \in \{0,1\} \qquad \forall i \in C', a \in P'$$

A new MILP formulation and a Branch-and-cut Algorithm for the TSP with Release Dates and Drone Resupply

C. Archetti (University of Brescia), M. Boccia, A. Masone, C. Sterle (University Federico II of Naples)

- Proposes a novel **mixed-integer linear programming (MILP) formulation for the TSP** with Release Dates and Drone Resupply (TSPRD-DR) that avoids big-M constraints.
- Develops a branch-and-cut algorithm incorporating dynamically generated subtour elimination constraints and valid inequalities.
- Achieves significant delivery time savings using drone resupply, particularly when package release dates are early.
- Demonstrates that drone resupply outperforms traditional depot resupply in efficiency, but with increased computational complexity.
- Provides preliminary computational results showing the effectiveness of the proposed method on benchmark instances.

Table 1 – *Results on instances with 10 and 15 customers*

	|C| =10			|C| =15		
β	Saving	Time-TR	Time-DR	Saving	Time-TR	Time-DR
0.5	19.49	0.24	1.57	23.00	3.22	50.71
1	17.00	0.54	4.32	14.83	5.44	288.47
1.5	11.40	0.63	17.59	13.61	10.34	738.05
2	9.77	0.78	26.00	10.82	9.38	1520.70
2.5	7.50	0.86	18.18	8.06	11.93	1838.32
3	6.21	0.80	5.75	9.61	11.30	1486.66

Keywords

TSPRD-DR, branch-and-cut, drone resupply,

Food-Delivery Platforms: A Near-Optimal Policy for Capacity Sizing, Order Batching, and Spatial Routing

Yang Bo (The Chinese University of Hong Kong),
Milind Dawande, Ganesh Janakiraman (The University of Texas at Dallas)

- Analyzes a dynamic food-delivery system that integrates capacity sizing, order batching, and routing on the Euclidean plane.
- Develops a novel **anticipating group scheduling (AGS) policy** that achieves near-optimal cost and vanishing excess delay in an asymptotic regime.›
- Establishes a fundamental spatial-temporal trade-off inequality linking spatial economies of scale and order waiting time.
- Derives a safety staffing rule showing that $\Theta(\lambda^{2/3})$ overstaffing is optimal for spatial service systems, departing from the conventional square-root rule.
- Demonstrates through numerical results that AGS outperforms established benchmarks across a range of realistic scenarios.

Keywords

on-demand delivery, capacity sizing, spatial routing,

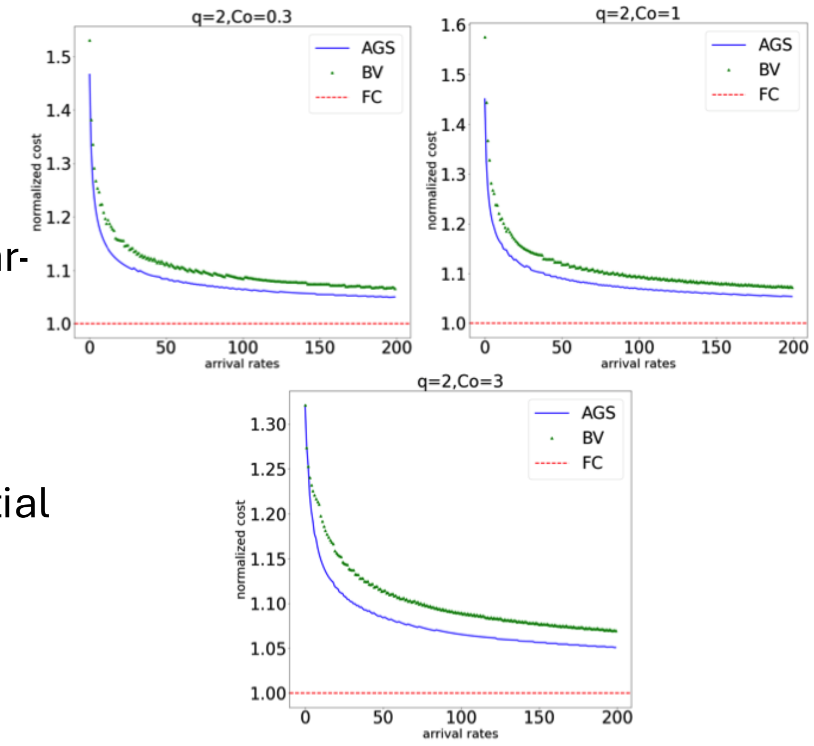


Figure 1 – The Performances of Policies in Instances $(q, c_o) = (2, 0.3), (2, 1)$, and $(2, 3)$. "FC" denotes a theoretical lower bound on the platform's cost normalized to one. The platform's cost under AGS (resp., the BV benchmark) is normalized by FC as well in the plots.

Scheduling and Routing for Multi-modal Last-mile Delivery under Multiple Uncertainties

Last-Mile Delivery 2

Minghao Chen (Columbia University), Ang Li (The Hong Kong Polytechnic University), Max Li (University of Michigan)

- Introduces the **Stochastic Heterogeneous Vehicle Scheduling and Routing Problem (SHVSRP)** for multi-modal last-mile delivery.
- Develops a mixed-integer programming model and a parallel 2-phase heuristic algorithm for robust routing and scheduling.
- Minimizes expected completion time and synchronization risks between trucks, drones, and tricycles under uncertainties.
- Demonstrates via simulations that tri-mode systems (truck-drone-tricycle) outperform truck-only and truck-drone systems in terms of makespan and failure rates, especially under adverse conditions.
- Provides operational insights on fleet sizing and mode selection under varying traffic and weather conditions.

Keywords

multi modal transportation system, stochastic optimization, last-mile delivery,

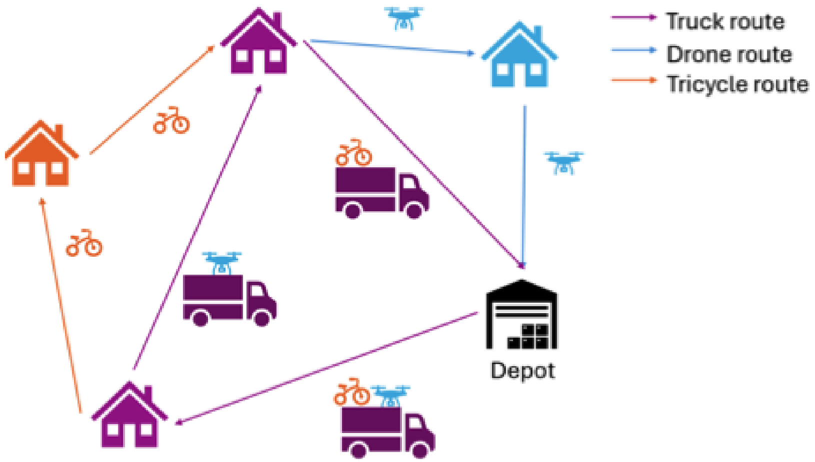


Figure 1 – *An illustration of a truck-tricycle-drone delivery system. The truck equipped with tricycles and drones start at the depot (black warehouse) and then deliver goods to customers. Drones and tricycles will be dispatched to complete service and be picked up at designated nodes.*

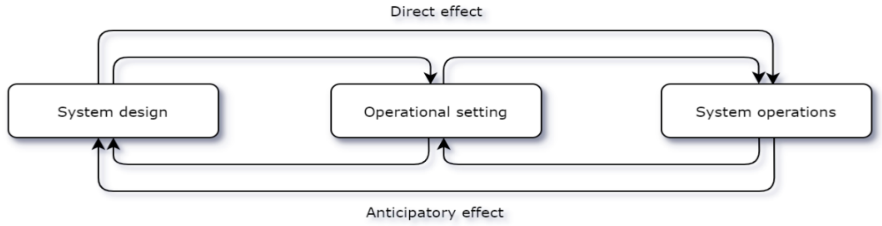
Table 1 – *Comparison of different delivery systems with different uncertainties on 20 customers. Results are averaged from 10 runs. T: trucks, D: drones, Tr: tricycles.*

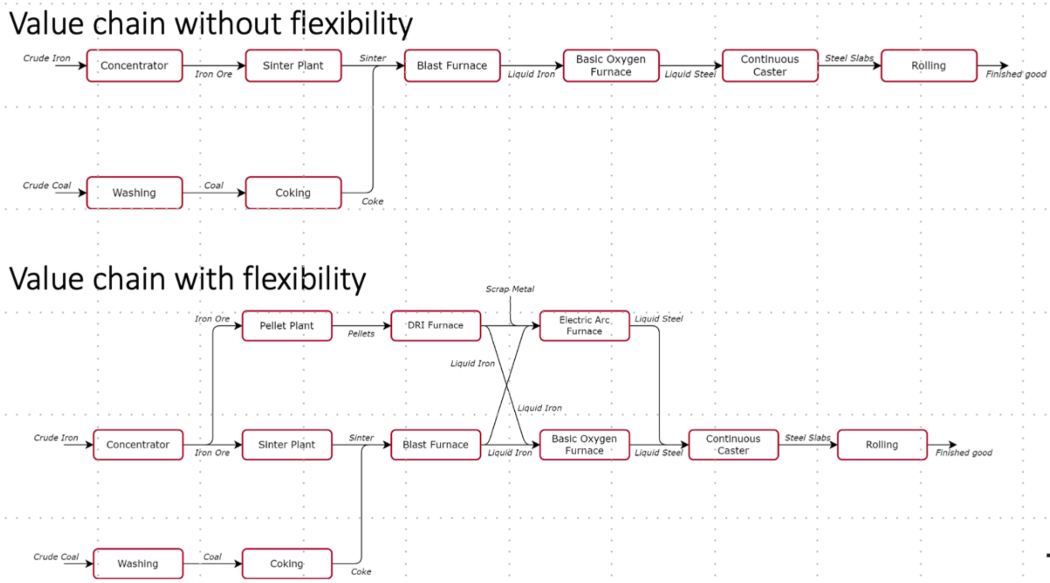
		Tri-mode System (2T-2D-2Tr)		Truck-Drone (2T-4D)		Truck Only (6T)	
Traffic	**Wind**	Exp. Makespan (min)	Failure Rate (%)	Exp. Makespan (min)	Failure Rate (%)	Exp. Makespan (min)	Failure Rate (%)
Moderate	Moderate	55.4	0	61.8	0	70.5	0
Moderate	Intensive	72.7	5.7	90.0	18.9	73.1	0
Intensive	Moderate	70.1	4.5	81.7	5.2	107.9	10.9
Intensive	Intensive	100.9	10.6	110.8	37.8	115.4	14.8

An Integrated Framework for Network-Wide Assessment and Improvement of Supply Chain Resilience

Yousef Maknoon, Maurice Hart Nibbrig, and Shadi Sharif Azadeh (Delft University of Technology)

- Introduces a tri-level Operator–Disruptor–Resilience-Designer framework for network-wide supply-chain resilience assessment.
- Treats disruptions as budget-bounded adversarial shocks, endogenously exposing the network's most critical nodes and links.
- Optimises redundancy and production-chain flexibility investments under a resilience budget to minimise post-shock operating cost.
- Uses a master–sub decomposition to solve the mixed-integer game, scaling to large multi-commodity networks quickly.
- Steel-chain case shows resilience rises up to 284 % when network and process flexibility are combined.





Keywords

Supply Chain Resilience, vulnerability assessments,

multi-commodity networks

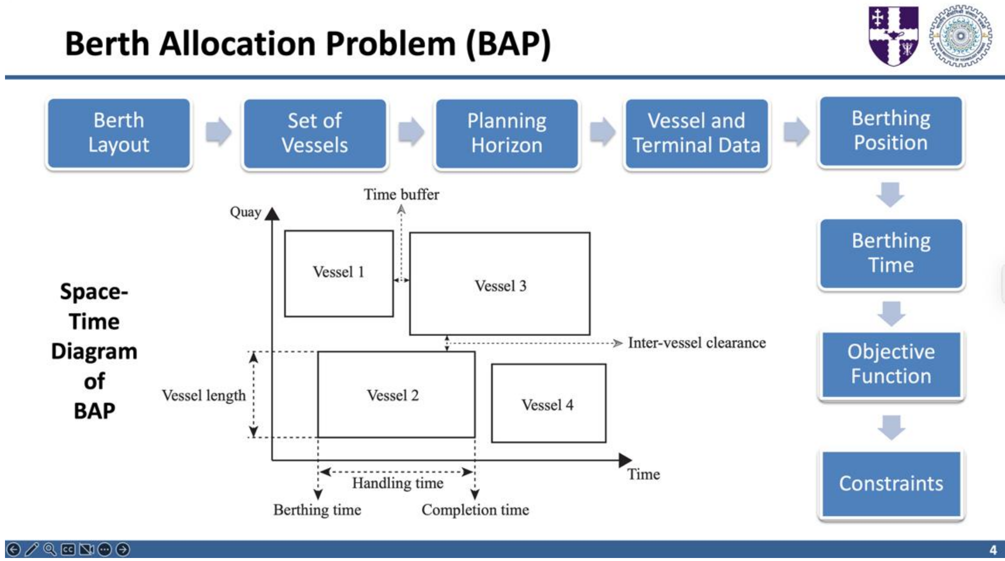
A Parallel Berth Allocation Problem in Multipurpose Inland Waterway Terminals

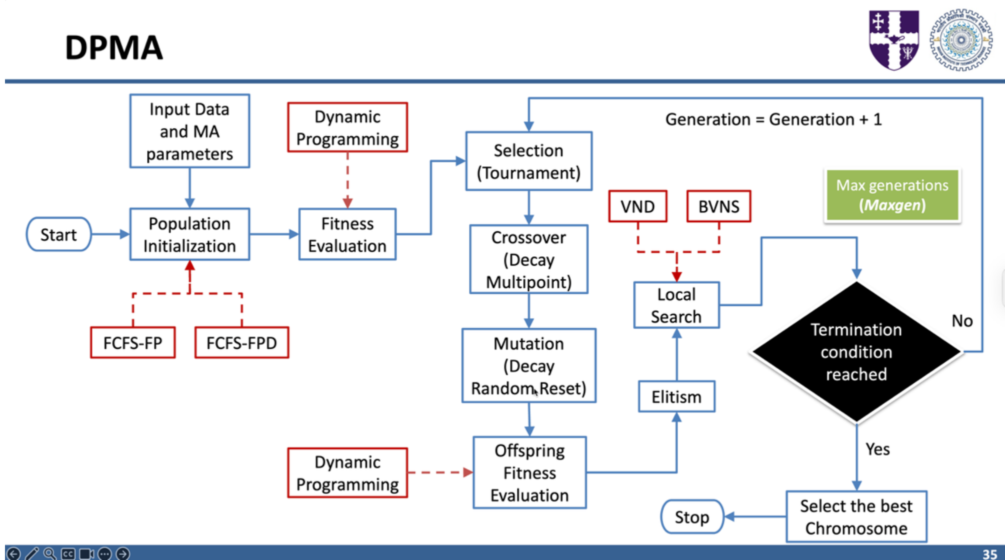
Adnan Pasha[a], Jiyin Liu[b], and Rajat Rastogi[a] ([a]Indian Institute of Technology Roorkee, [b]Loughborough University)

- Tackles berth-allocation for multipurpose IWT terminals that allow two barges to berth in parallel.
- Builds a MILP capturing spatial, temporal, handling-rate and parallel-berthing constraints; objective minimises completion + waiting time.
- Designs a dynamic-programming memetic algorithm (DPMA) with local search to solve large NP-hard instances fast.
- DPMA beats CPLEX on 28–40-barge cases (0.17 % gap in 35 s) and outperforms FCFS by 20–30 %.
- Parallel berthing cuts objective values by 13 % (small) to 18 % (large) versus single berthing.
- Sensitivity shows multipurpose berths and cargo-handling compatibility sharply reduce waiting and boost throughput.

Keywords

Berth Allocation Problem, dynamic-programming memetic algorithm





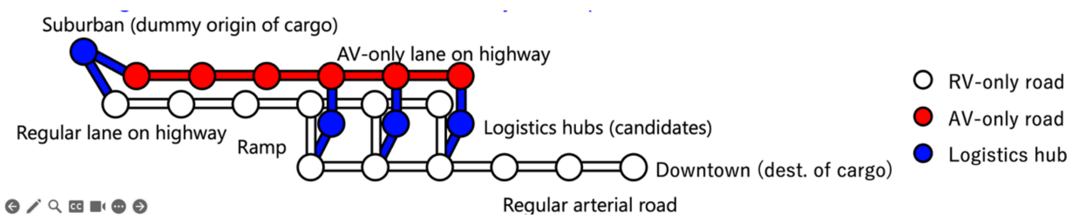
Facility and dynamic fare design for multimodal automated vehicle logistics system under traffic flow constraints

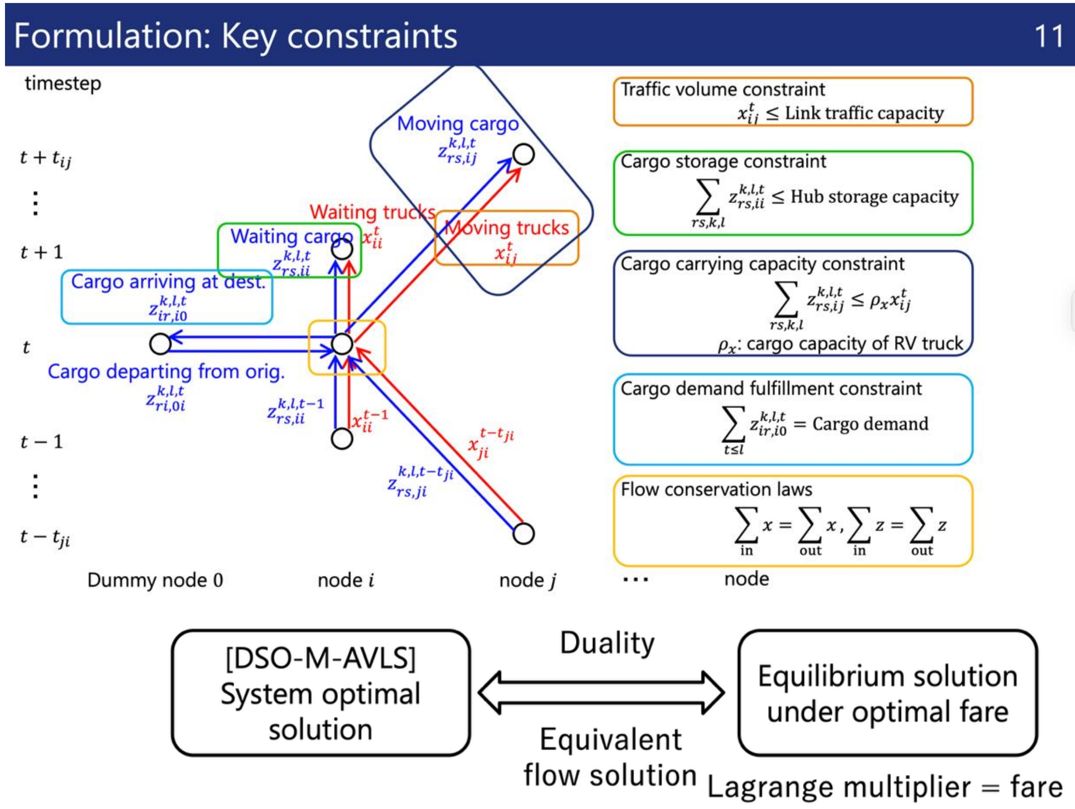
Toru Seo and Riki Kawase (Institute of Science Tokyo)

- Proposes a multimodal AV-RV logistics network with highway AV lanes, arterial RV legs and transfer hubs.
- Formulates DSO-M-AVLS: joint hub sizing, fleet levels, dynamic fares and time-dependent flows under road capacities.
- Model guarantees system-optimal social cost while each agent remains in user equilibrium (Wardrop's equilibrium condition) under optimal fare.
- Proves fares arise only at capacity-tight links/hubs and fully finance hub construction—logistics self-financing.
- Toy-network experiment shows peak-hour congestion shifts cargo to hubs and spikes arterial-road fares.
- Framework offers policy guidance for AV-RV integration, congestion pricing and scalable hub deployment.

Keywords

AV-RV logistics network, transfer hubs, user equilibrium





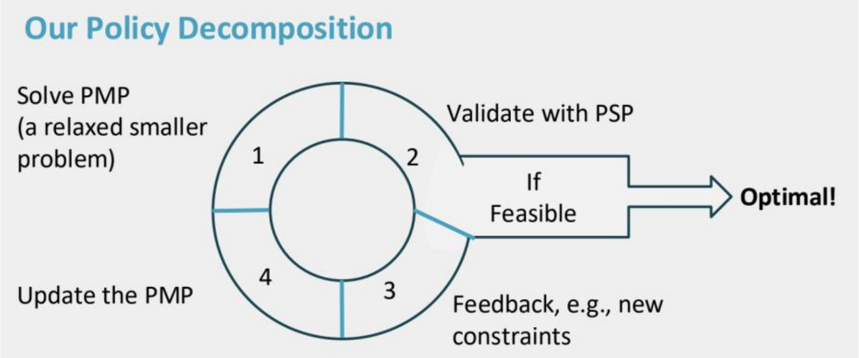
A General Optimization Framework for Dynamic Two-Stage Order Fulfillment Problems

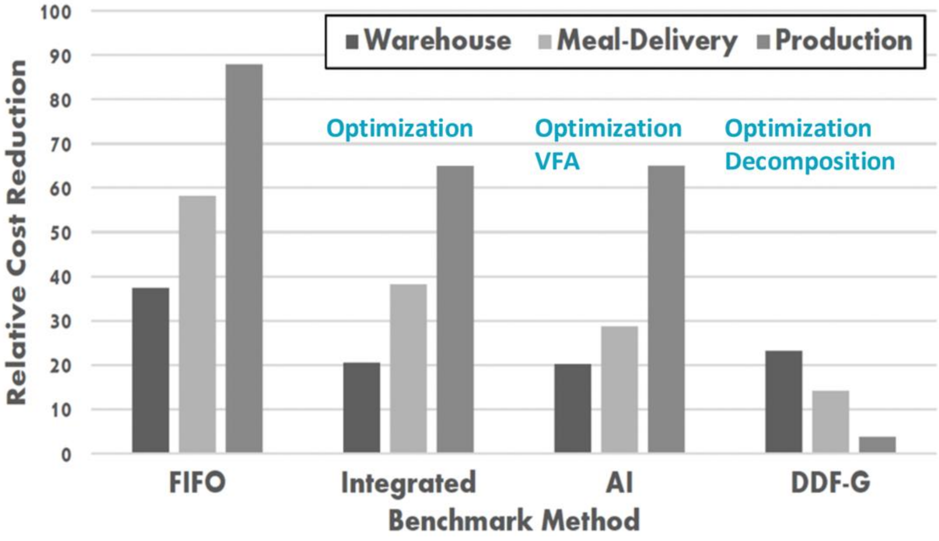
Gal Neria , Michal Tzur , Marlin W Ulmer (Tel Aviv University, Otto-von-Guericke Universität Magdeburg)

- Introduce the **Dynamic Two-Stage Order Fulfillment Problem (DTS-OFP),** a novel class that unifies traditionally distinct logistical challenges (e.g., warehousing, meal delivery, production) under a single cohesive framework.
- For effective decision-making, introduce the innovative Two-Stage Heuristic with **Value Function Approximation** (TSH-VFA) framework
- Develop a **Large Neighborhood Search (LNS)** framework that searches for effective and efficient delivery routes.
- Implement TSH-VFA for **three selected problems**, derived from the three major areas of warehousing, meal delivery, and production.

Keywords

dynamic order fulfillment, real-time decision making, two stage optimization, machine learning.





Economics of Empty Trips and Collaborative Logistics

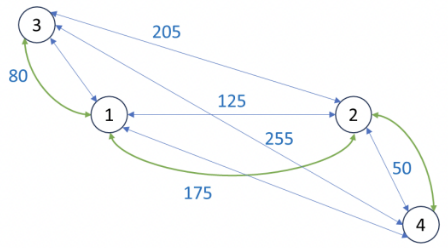
Ricardo Giesen, Dario Farren and Luis Ignacio Rizzi (Pontificia Universidad Católica de Chile)

- This work aims to enhance the understanding of **empty vehicle flows** by examining factors beyond load imbalances, such as competition, demand structure, and service differentiation.
- Develop a methodology that models equilibrium between geographically separated markets linked by a multimodal transportation network.
- The proposed method is divided into two stages. The first stage involves developing a microeconomic model.
- In the second stage, the model is expanded to include multiple geographically separated markets connected by a multimodal transportation network.

Keywords

Backhaul, empty vehicles, externalities, Bertrand and Cournot equilibrium.

Figure 1 – *Case 3: Four-Location and Multi-modality Models.*



The figure presents the operation of the multi-modal network, which connects Locations 3-1 and 2-4 by truck, while Locations 1-2 are linked by rail. Transfer centers between rail and trucks are established at Locations 1 and 2.

Figure 2 – *Potential Demand Cases 2 & 3.*

	L_1	L_2	L_3	L_4	Total
L_1	0	928	252	321	1501
L_2	465	0	77	330	872
L_3	163	377	0	322	862
L_4	350	146	164	0	660
Total	978	1451	493	973	3895

The table presents the potential demand for carriers in each market (origin-destination pair) for Cases 2 & 3

Table 1 – *Bertrand Equilibrium Results. Cases 2 & 3.*

	Case 2			Case 3							
	Mode t			Mode t				Mode r			
Market	y_{tj} (un)	e_{tj} (veh)	p_{tj} (US$/un)	y_{tj} (un)	e_{tj} (veh)	p_{tj} (US$/un)	MS (%)	y_{rj} (un)	e_{rj} (veh)	p_{rj} (US$/un)	MS (%)
M 12	0.43	0.14	547	0.34	0.17	566	79%	121.60	0.00	1003	13%
M 13	0.13	0.27	468	0.10	0.27	485	76%	41.80	17.01	801	17%
M 14	0.10	0.15	689	0.10	0.11	692	80%	37.17	0.00	1131	12%
M 21	0.21	0.41	483	0.17	0.33	488	76%	74.33	64.30	830	16%
M 23	0.02	0.00	738	0.03	0.00	769	75%	12.24	0.00	913	16%
M 24	0.17	0.06	511	0.11	0.05	553	77%	50.40	0.00	881	15%
M 31	0.04	0.18	457	0.07	0.13	482	78%	22.63	0.00	935	14%
M 32	0.14	0.00	791	0.10	0.00	797	80%	41.70	0.00	1193	11%
M 34	0.14	0.00	912	0.13	0.00	922	79%	33.98	0.00	1281	11%
M 41	0.11	0.27	606	0.12	0.27	591	76%	56.32	0.00	858	16%
M 42	0.09	0.06	482	0.05	0.03	519	76%	23.88	14.08	830	16%
M 43	0.08	0.00	848	0.04	0.00	815	74%	27.26	0.00	895	17%

The table presents Bertrand's equilibrium prices and quantities under free entry for Cases 2 and 3. The variable y_{tj} and y_{rj} represent the expected number of cargo units transported by each carrier in equilibrium on arc j. Meanwhile, e_{tj} and e_{rj} indicate the expected number of empty vehicles each carrier moves across arc j. The equilibrium price in market j is denoted as p_{tj} and p_{rj}. All of the above applies to modes t and r, respectively. MS corresponds to Market Share. The number of carriers in equilibrium in Case 2 is 2,250 and 2,080 in Case 3.

Two-echelon city logistics by integrating road and water transport: Amsterdam case study

Logistics Optimization 2

Cigdem Karademir and Bilge Atasoy (Delft University of Technology, The Netherlands)

- This study investigates the efficiency of **integrated water- and land-based transportation (IWLT)** systems in meeting the growing transport and logistics demand in urban areas.
- The considered IWLT system is formulated as a synchronized two-echelon problem: **Asynchronous systems (asynch)** and **Synchronized systems (synch)**.
- Develop a **decomposition method** to model and test different variants of IWLT systems: **an iterated Tabu Search (ITS).**
- The case study considers a delivery service in **Amsterdam**, the Netherlands, where inland waterways cover 25% of the city's land area.
- Evaluate various design options to obtain managerial insights about the trade-offs between **infrastructure investments and logistics costs** as well as the impact on **the livability** of the urban areas.

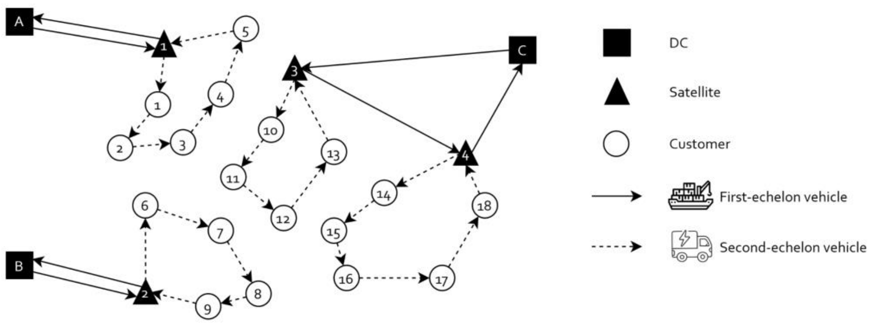


Figure 1 – *Illustration of the two-echelon IWLT system*

Algorithm 1 ITS($synch, n\_of\_start, max\_iter_{ITS}, max\_iter_{LS}, max\_iter_{ALNS}$)

$found\_list\_routes \leftarrow emty\_list$; $R^* \leftarrow best\_objective\_value \leftarrow inf$
$R_0 \leftarrow$ INITIALIZATION(n_of_start)
$found\_list\_routes \leftarrow$ LOCAL_SEARCH($R_0, max\_rep_{LS}, max\_iter_{LS}$)
$R^* \leftarrow$ UPDATE_TABU_ LIST($found\_list\_routes, T, synch$)
$its\_iter \leftarrow 1$
while $its\_iter \leq max\_iter_{ITS}$ **do**
  Diversification: $SAA \leftarrow \frac{SAA}{its\_iter}$ & initial scores
  $R_{ALNS} \leftarrow$ ALNS(R^*, max_iter_{ALNS})
  Intensification: $max\_iter_{LS} \leftarrow (its\_iter)(max\_iter_{LS})$
  $found\_list\_routes \leftarrow$ LOCAL_SEARCH($R_{ALNS}, max\_rep_{LS}, max\_iter_{LS}$)
  $R_{new} \leftarrow$ UPDATE_TABU_ LIST($found\_list\_routes, T, synch$)
  if $R_{new} < R^*$ **then**
    $R^* \leftarrow R^{new}$
  end if
end while
return R^*

Keywords

two-echelon routing, city logistics, decomposition methods, satellite synchronization.

Crowd shipping platform as an intermediary: Auction-based mechanism design for order allocation and payment schemes

Mechanism Design

Authors

Qingyang Li, Fangni Zhang

Author's affiliation

Department of Data and Systems Engineering, University of Hong Kong, Hong Kong, China

Highlights

- ✓ The study devises auction mechanisms for order allocation and payment on a crowd shipping platform, **considering the heterogeneity** among individual crowd carriers and their non-readily available preferences.
- ✓ It applies the Vickrey-Clarke-Groves (VCG) payment scheme to ensure incentive compatibility, individual rationality, and system efficiency in the Winner Determination Problem (WDP).
- ✓ Numerical experiments, using real-world data from the road network of Atlanta, US, show that **the Greedy mechanism approximates the VCG mechanism well in terms of evaluation metrics.**

Methodological contribution

- Matching
- Pricing
- Auction
- Mechanism design

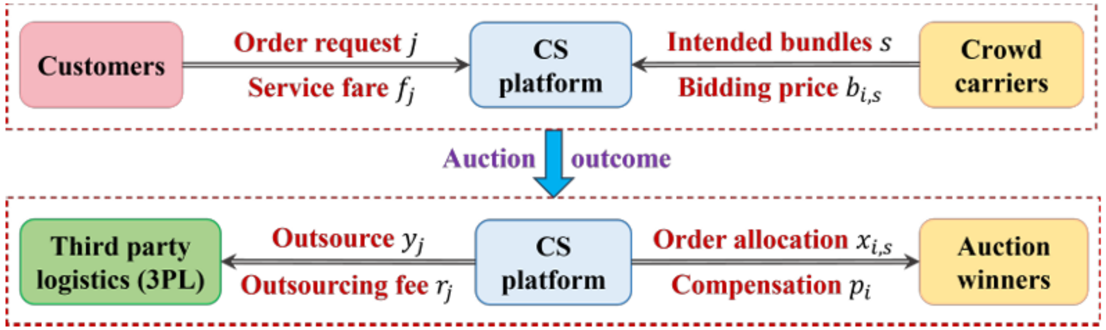


Figure 1 – *Auction setting in the crowdshipping system.*

The Winner Determination Problem (WDP)

$$\min_{x_{i,s},y_j} \sum_{i\in I}\sum_{s\in S_i} b_{i,s}x_{i,s} + \sum_{j\in J} r_j y_j \tag{1a}$$

$$\text{s.t.} \quad \sum_{s\in S_i} x_{i,s} \le 1 \quad \forall i \in I \tag{1b}$$

$$\sum_{i\in I}\sum_{s\ni j, s\in S_i} x_{i,s} + y_j = 1 \quad \forall j \in J \tag{1c}$$

$$x_{i,s} \in \{0,1\} \quad \forall i \in I, s \in S_i \tag{1d}$$

$$y_j \in \{0,1\} \quad \forall j \in J \tag{1e}$$

Table 1 – *The results of the benchmark (100 simulations)*

Evaluation metric	VCG	Greedy	Note
Matching rate	0.478 (0.022)	0.398 (0.023)	Matching outcome
Service rate (by crowd carriers)	0.998 (0.005)	0.885 (0.029)	
Total cost	735.409 (42.327)	1250.208 (132.507)	
Total payment	1115.146 (174.867)	815.930 (41.960)	Pricing outcome
Total profit	4371.064 (209.325)	4095.500 (155.345)	
Computation time	19.102 (10.488)	0.009 (0.004)	-

Preference learning for efficient bundle selection in horizontal transport collaborations

Mechanism Design

Authors

Steffen Elting1,*, Jan Fabian Ehmke1, and Margaretha Gansterer2

Author's affiliation

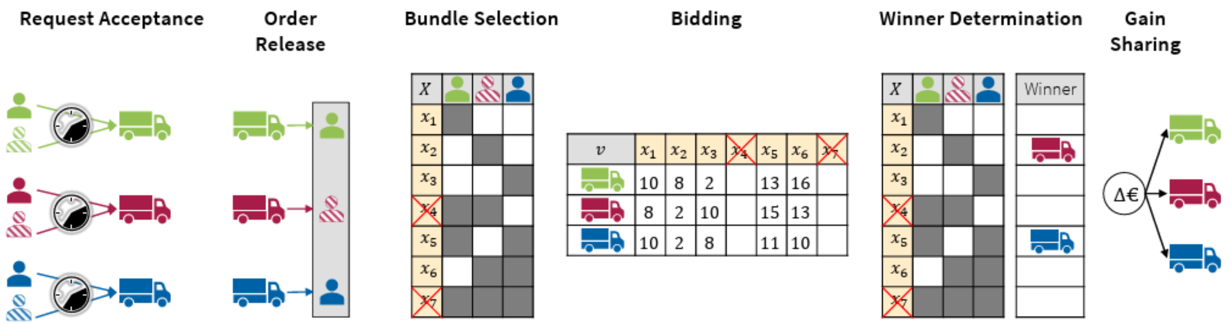
1.Department of Business Decisions and Analytics, University of Vienna , 2. Department of Production Management and Logistics, University of Klagenfurt.

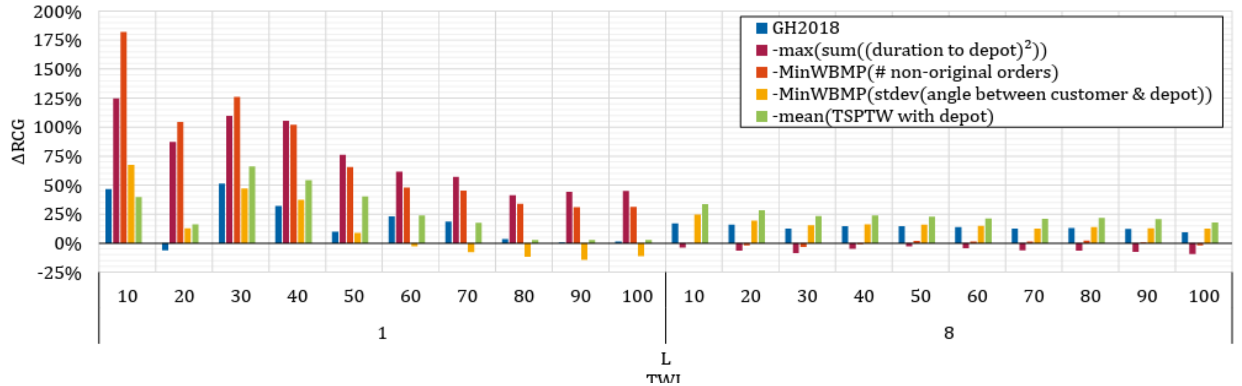
Highlights

- ✓ The study addresses the Bundle Selection Problem (BuSP) in horizontal carrier collaborations by applying methods from preference learning (PL).
- ✓ The research **demonstrates** the necessity of considering Winner Determination Problem (WDP) constraints during the bundle selection stage.
- ✓ Initial results indicate that **neglecting WDP** constraints in query selection can decrease relative collaboration gains by 8 to 12 percentage points.
- ✓ The study found that the iterative PL framework with parametric valuation models is superior to the one-shot approach when time window constraints are loose.

Methodological contribution

- Preference learning
- Collaborative transportation planning
- Combinatorial auction
- Vehicle routing problem with time windows





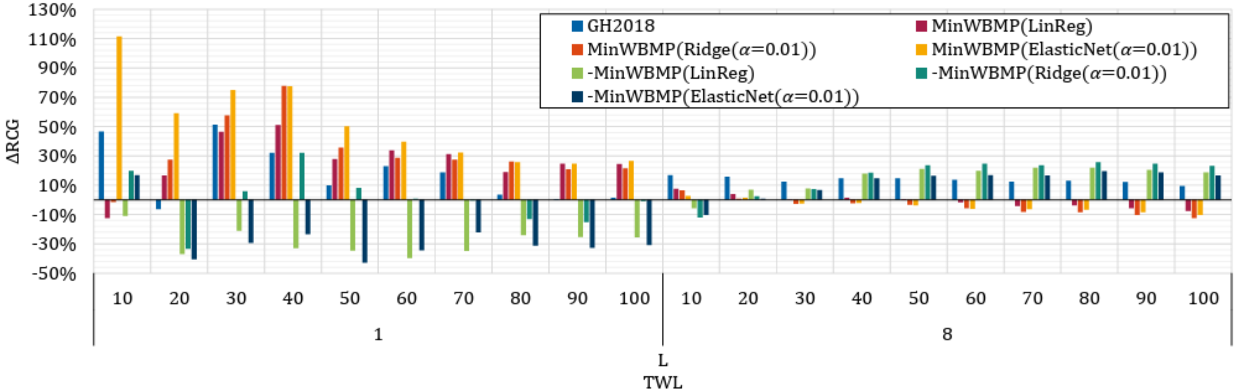


Figure3–ΔRCG of parametric models. For1-hour time windows, it is clearly better to stick to non-parametric alternatives.

An Enhanced Dynamic Discretization Discovery Algorithm for Continuous-Time Service Network Design Problem

Network Design 1

Shengnan Shu[a], Zhou Xu[b], Roberto Baldacci[c]

a - Department of Civil and Environmental Engineering, National University of Singapore, Singapore
b - Department of Logistics and Maritime Studies, The Hong Kong Polytechnic University, Hong Kong,
c - College of Science and Engineering, Hamad Bin Khalifa University, Qatar Foundation, Doha, Qatar,

- Introduce a new initial relaxation, based on timed-node-based time-expanded commodity networks for shipments
- Employ a novel MIP-based approach for computing an upper bound at each iteration based on a collection of relaxation solutions
- Introduce a new three-stage method to refine discretization, which involves removing newly identified structural patterns (known as minimum too-long paths) that cause the infeasibility of the relaxation solutions

Keywords

service network design, continuous time, dynamic discretization discovery, exact algorithm

Improving Dual Bounds for the Unsplittable Multicommodity Capacitated Network Design Problem

Network Design 1

Lacy M. Greening[1], Santanu S. Dey[2], Alan L. Erera[2]

1 - School of Computing and Augmented Intelligence, Arizona State University, Tempe, AZ
2- H. Milton Stewart School of Industrial and Systems Engineering, Georgia Institute of Technology

- Focuses on unsplittable multicommodity network design
- Introduces a new class of valid inequalities: To overcome the limitations of weak LP relaxations, the research develops novel valid inequalities that strengthen the formulation for both arc-based and path-based models.
- Improves solution quality for large-scale instances: By tightening the LP bounds, these inequalities help improve dual bounds, making it easier to evaluate and benchmark heuristic solutions for realistically sized logistics problems.

Keywords

network design, valid inequalities, fulfillment logistics

Recursive Partitioning and Batching for Massive-Scale Network Design with Service Time Guarantees

Network Design 1

Myungeun Eom, Alan Erera, Alejandro Toriello

Stewart School of Industrial and Systems Engineering, Georgia Tech, Atlanta, USA

- Studying a service network design problem with service time guarantees at a countrywide scale.
- Demonstrating the scalability and efficiency of our approach through computational studies on real-world instances from an industry partner.

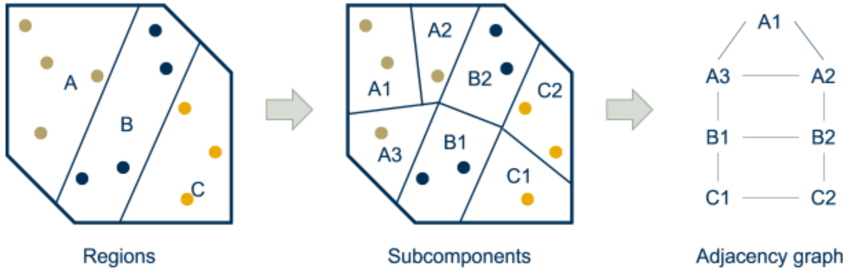


Figure 1 – *Construction of a subcomponent-based adjacency graph*

Keywords

freight transportation, service network design, heuristic, service guarantee

Vulnerability of Collaborative Transport Networks

Rob Zuidwijk, Camil Harter, Otto Koppius

1 - School of Computing and Augmented Intelligence, Arizona State University, Tempe, AZ
2- H. Milton Stewart School of Industrial and Systems Engineering, Georgia Institute of Technology

- Using complex network models to analyze vulnerabilities emerging from collaborative transportation.
- Modeling transportation systems with vertical collaboration between carriers, who each operate their own proprietary network of transport services.
- Develop an integrated transportation-collaboration model to analyze vulnerabilities that emerge from large-scale collaborative transportation systems.

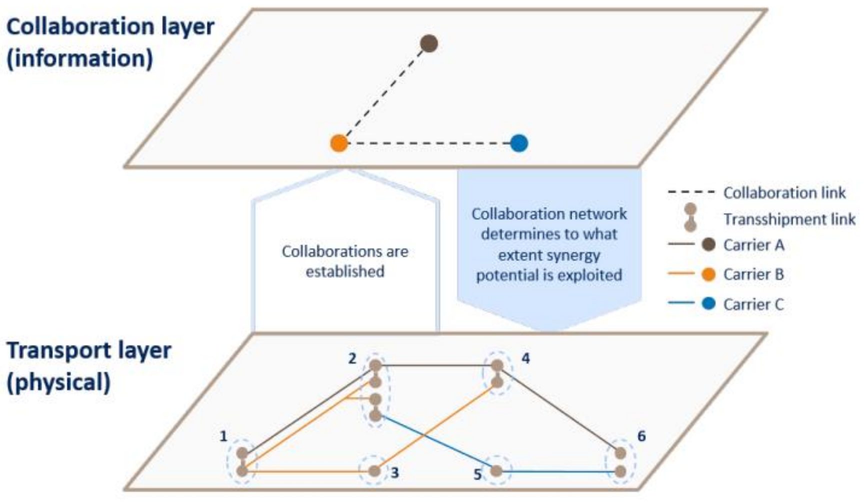


Figure 1 – *Two-layered network model*

Keywords

Collaboration, two-layered complex network, Multi-modal transport, Vulnerability

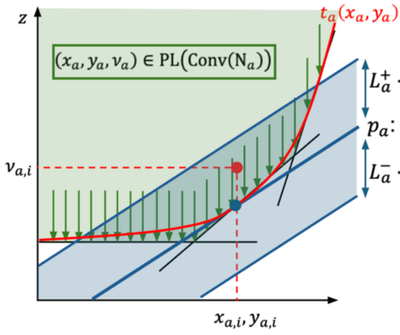
Fast heuristic for global optimization of continuous network design problem with stochastic user equilibrium

Sorachi Matsumoto, Ryuichi Tani, Kenetsu Uchida

- **Continuous Network Design Problem (CNDP)** under SUE, aiming for globally optimal capacity expansions on road networks.
- Overcomes the limitations of MILP-based exact approaches for large networks due to exponential growth of variables.
- Proposes a novel algorithm that solves a **linearly relaxed LP** version of the CNDP and then iteratively adjusts solutions to approximate feasibility under the original nonlinear SUE constraints.
- Avoids path enumeration and integer variables, relying instead on link-based formulations and piecewise-linear convex approximations.

Precise Approximation of Link Cost Function

Reduce feasible region of μ_a and ν_a, finally, $\nu_a = t_a, \mu_a + \nu_a = x_a \cdot t_a$



$$p_a - (1-\varepsilon_p)^{i+1} \cdot L_a^- \le \nu_a \le p_a + (1-\varepsilon_p)^{i+1} \cdot L_a^+ \quad \forall a \in A (18)$$

$L_a^+ \cdot (1-\varepsilon_p)^{i+1}$: Narrows with each iteration

p_a: Tangent plane of $t_a(x_a, y_a)$ at $(x_{a,i}, y_{a,i})$

$L_a^- \cdot (1-\varepsilon_p)^{i+1}$: Narrows with each iteration

* i: iteration number, L_a^+, L_a^-: large positive value

✓**No integer variables**
✓**Link cost function w.o. approx.**

Keywords

Continuous network design problem, Stochastic user equilibrium, Linear programming

Integration of Hub Capacity Acquisition Decisions in the Scheduled Service Network Design Problem

Network Design 2

Simon Belieres, Yannick Oskar Scherr, Mike Hewitt

- Focuses on the **Scheduled Service Network Design Problem (SSNDP)** for LTL freight, integrating hub capacity acquisition decisions into tactical planning.
- Addresses operational challenges of 4PLs who lease terminal capacity (e.g., dock doors) rather than owning assets, enabling more dynamic and cost-effective network design.
- Proposes a new mathematical model for **SSNDP with Hub Capacity Acquisition (SSNDP-HCA)**, capturing how terminal capacity limits affect routing, timing, and vehicle flows.
- Develops an **IP-based Local Search (IPBLS)** heuristic that iteratively solves restricted MIPs, enabling high-quality solutions much faster than solving the full MIP.
- Empirical results on real US network data show IPBLS achieves solutions on average **6.7% better** than commercial solvers, especially for large instances where MIP fails to converge.
- Demonstrates that integrating hub capacity decisions can reduce total logistics costs by up to **10%**, compared to traditional sequential decision-making approaches.

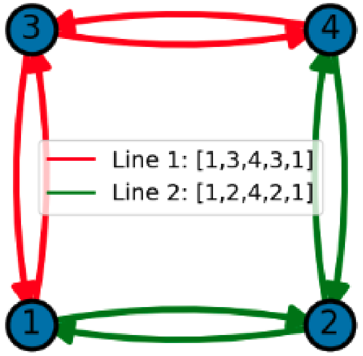
Keywords

Service Network Design; Hub capacity; Fourth-party logistics; IP-based heuristics

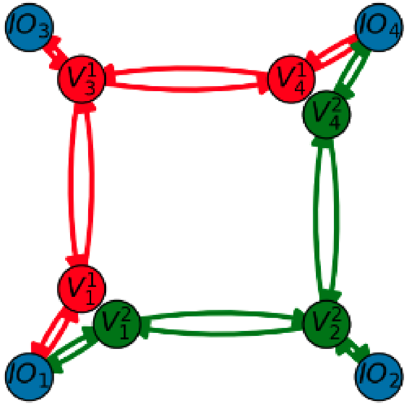
Line Network Design for Parcel Routing with Handling Times

Gabriel Deza, Michal Tzur, Tal Raviv

- Addresses **line network design** for parcel delivery systems where parcels may transfer across multiple service points (SPs), incorporating realistic handling times at each stop.
- Develops a hyperconnected network concept, contrasting it with traditional tree-like networks, to better exploit **transshipment opportunities** and improve consolidation.
- Introduces handling times as key decision variables, reflecting real-world delays from loading/unloading parcels at SPs, significantly impacting delivery times.
- Formulates a non-convex **Quadratically Constrained Quadratic Program (QCQP)** and proposes a guided large neighborhood search.
- Numerical results show advantages of hyperconnected networks over tree-like structures, achieving faster parcel deliveries, when re-optimizing parcel routes and vehicle lines.



(a) *Line Concept*



(b) *Extended Network representation*

Keywords

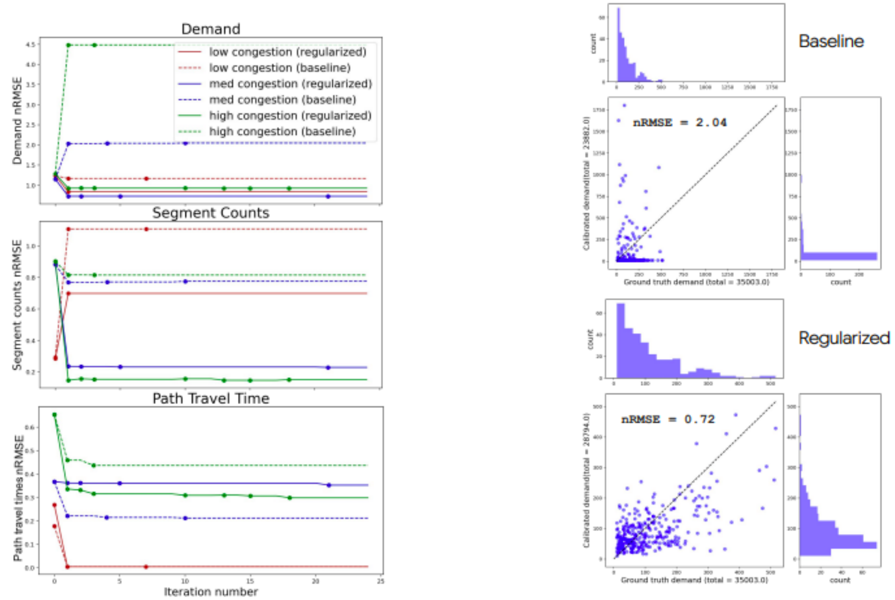
Service Network Design; Hub capacity; Fourth-party logistics; IP-based heuristics

OD Estimation

Improving simulation-based origin-destination demand calibration using sample segment counts data

Arwa Alanqary, Chao Zhang, Yechen Li, Neha Arora, and Carolina Osorio

- Proposes a novel calibration method that integrates path and segment-level traffic statistics, improving demand accuracy by regularizing observed count deviations while preserving scalability and efficiency.
- The calibration problem is **high-dimensional, stochastic, non-linear, and underdetermined**, requiring advanced optimization techniques like SPSA, genetic algorithms, and simulation-based optimization.
- Traditional traffic data from loop detectors is supplemented with new data sources, including mobile phone calls, Bluetooth data, and license plate recognition.
- These data sources provide detailed traffic flow statistics, but challenges remain due to limited penetration and incomplete measurements.



(a) *The performance of the calibrated demand across the three metrics at each iteration of the algorithm*

(b) *Scatter plot of the ground truth vs. calibrated demand vector (medium congestion).*

Figure 1 – *Comparison of the baseline and proposed regularized solver performance across different metrics and scenarios*

$$\min_{0\le d\le d_{max}} F(d) = \frac{w_1}{|\mathcal{P}|}\sum_{p\in\mathcal{P}}\left(y_p^{\mathrm{GT}} - \mathbb{E}[Y_p(d;u)]\right)^2 + \frac{w_2}{|\mathcal{I}|}\sum_{i\in\mathcal{I}}\left(\frac{\mathbb{E}[X_i(d;u)]}{x_i^{\mathrm{GT}}} - \frac{1}{|\mathcal{I}|}\sum_{j\in\mathcal{I}}\frac{\mathbb{E}[X_j(d;u)]}{x_j^{\mathrm{GT}}}\right)^2,$$

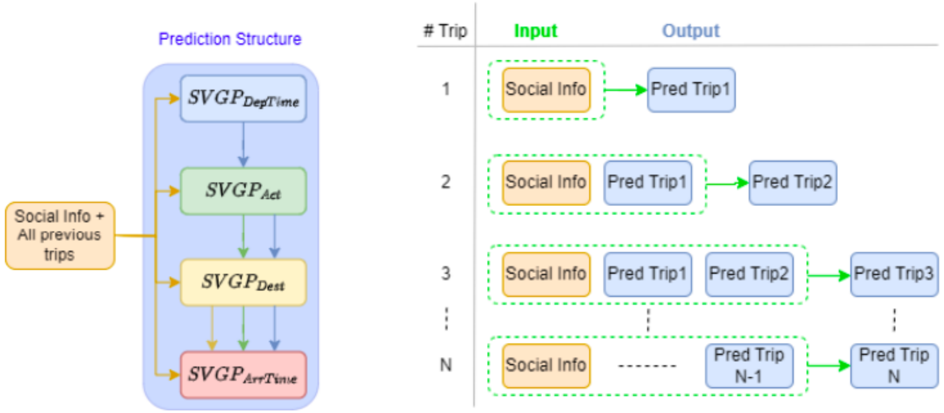
Keywords

simulation-based optimization, demand calibration, operations research

Dynamic OD matrix estimation using data-driven modelling under data-scarcity: An application of Gaussian Processes

Giovanni Tataranno, Federico Bigi, Francesco Viti

- **Probabilistic data-driven models** are emerging as a strong alternative, especially in data-scarce scenarios, focusing on underlying distributions rather than raw data.
- Gaussian Process (GP) is a statistical model for estimating probability distributions in both linear and non-linear data but suffers from high computational complexity ($O(n^3)$).
- Sparse Variational Gaussian Processes (SVGP) are used to reduce this complexity by approximating the full GP, making it more computationally efficient without significantly compromising accuracy.
- Predicts trip-related variables without relying on assumptions about route choices or data distributions, ensuring more unbiased results



(a) *Single Trip Prediction* (b) *Full Trip Prediction*
Figure 1 – *Proposed trip prediction structure.*

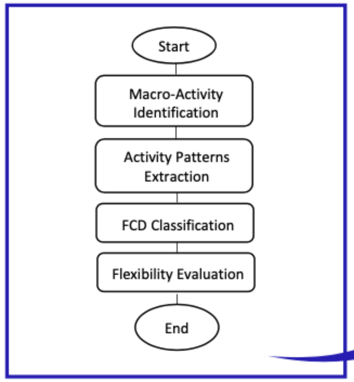
Keywords

OD estimation; gaussian processes; data-driven modelling; demand modelling; data scarcity

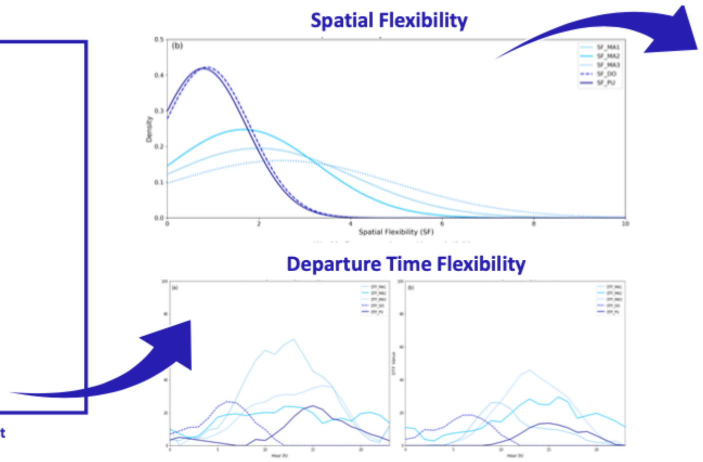
Advancing Dynamic Origin-Destination Matrices Estimation Models Using Crowd-Sourced Flexibility Data

Marisdea Castiglione, Guido Cantelmo, Ernesto Cipriani, Marialisa Nigro

- Enhance the accuracy of traditional ODME models by incorporating spatio-temporal flexibility insights obtained from crowd-sourced data.
- Extension of the traditional GLS model for ODME that allows the inclusion of multiple demand components C with varying levels of flexibility
- The Flex-GLS model has been shown to outperform traditional GLS in different scenarios of data reliability as it effectively utilizes the refined demand components data to achieve more accurate estimates
- The performance of the Flex-GLS model varies with network congestion, emphasizing the need to adapt spatio-temporal flexibility parameters dynamically



Methodology Flowchart



Flex-GLS Objective Function

$$d^* = \arg\min_{d^*}\left(\sum_t\left(\sum_l w_l \cdot (v_l(d^*) - \hat{v}_l)^2 + \sum_{od}\sum_C w_C \cdot \left(d^*_{C,t,od} - \hat{d}_{C,t,od}\right)^2\right)\right)$$

Keywords

OD Matrices Estimation; Spatio-Temporal Flexibility; Crowd-Sourced Data; Floating Car Data; Trip Purpose.

Selecting an optimal set of shared ridepooling stops

Francisco Vilches, Cristan Cortes (Universidad de Chile)
Andres Fielbaum (The University of Sydney)

- Proposes methods for **pre-selecting shared ride pooling stops (SRS)** to balance system efficiency and user predictability.
- Develops selection techniques based only on the street network, independent of variable operational characteristics (e.g., demand patterns or weather).
- Compares node ranking approaches: contraction hierarchy, convex hierarchy (combining node degree and local speed), and random hierarchy.
- Simulation results demonstrate significant performance gains over door-to-door service by concentrating pickup/dropoff activity and reducing unnecessary vehicle stops.
- Findings highlight the dual benefit of SRS: improved vehicle routing and greater service efficiency through user clustering at stops.

Keywords

Ridepooling, Shared mobility, Virtual stops,

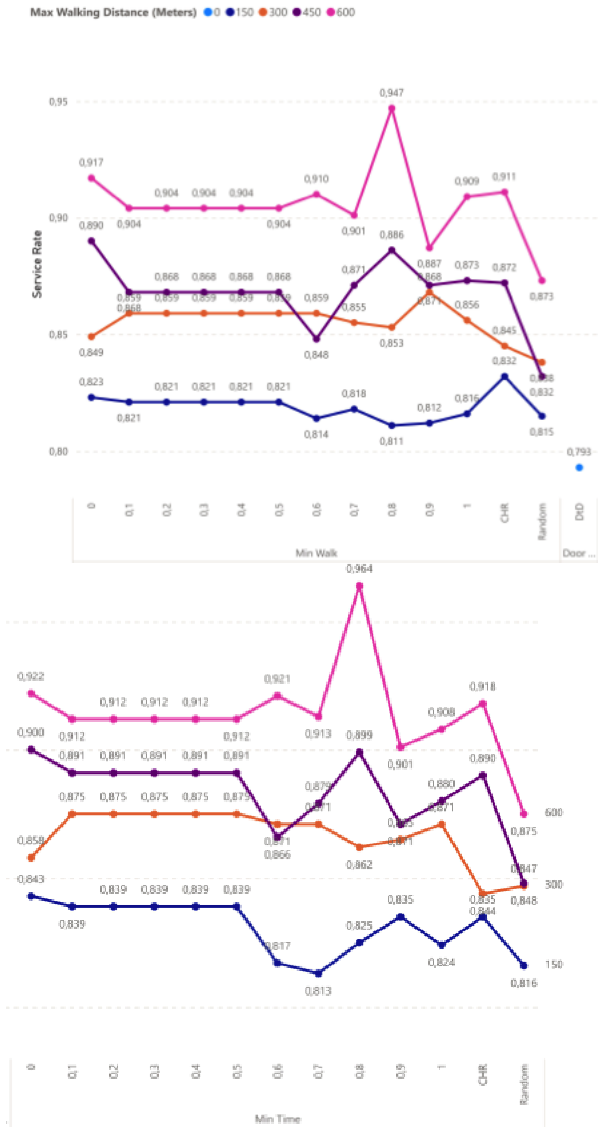


Figure 2 – *Results of the simulations.*

Continuous Approximation Model for a Demand Responsive Feeder Service with Meeting Points

On-demand Mobility 1

Richard D. Connors (Luxembourg Institute of Science and Technology)
Haruko Nakao (University of Luxembourg)
Tai-Yu Ma (Luxembourg Institute of Socio-Economic Research)
Francesco Viti (University of Luxembourg)

- Proposes a **continuous approximation (CA) model** for vehicle kilometers (KMs) of demand-responsive feeder services (DRFS) with meeting points (MPs), incorporating a detour factor constraint for individual-level service guarantees.
- Derives nested analytical expressions for both the number of active meeting points and vehicle KMs as functions of demand, operating area, walking distance, and detour factor.
- Uses Latin hypercube sampling and metaheuristic optimization to generate and solve 82 diverse DRFS scenarios, with multiple demand realizations to quantify stochastic variability.
- The CA model achieves high predictive accuracy (MAPE ~9% for vehicle KMs), significantly outperforming generalized linear models (MAPE ~26%).
- Demonstrates applicability of the CA model for rapid design, configuration, and decision support in DRFS planning, especially in meeting-point-based systems.

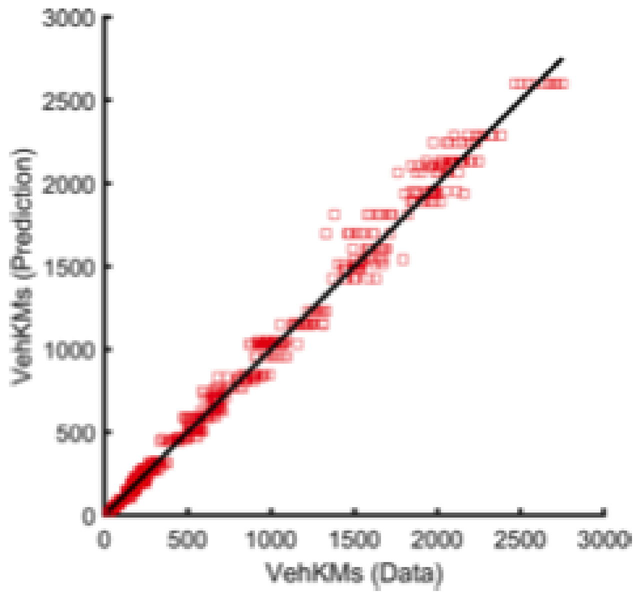


Figure 2 – *Data vs CA Model for VehKMs*

Keywords

Demand-Responsive Transport, Meeting Points, Continuous Approximation,

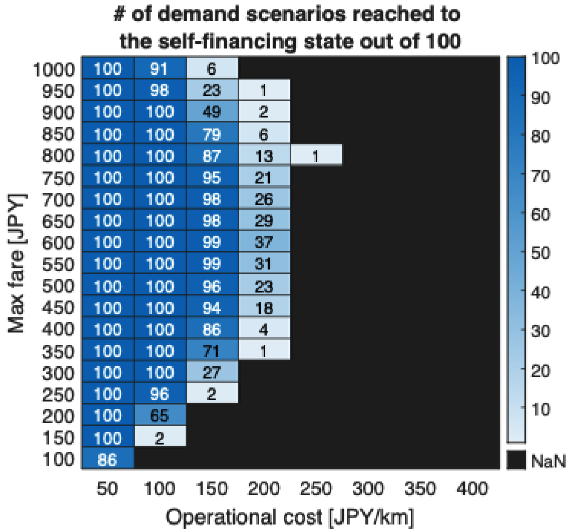
Evolutionary process of self-financed shared mobility systems

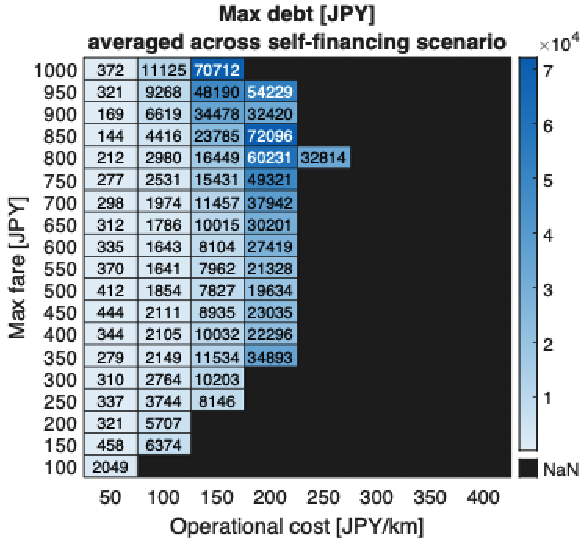
Haruko Nakao (University of Luxembourg)
Koki Satsukawa (Kanazawa University)
Takamasa Iryo, Sowa Suzuki (Tohoku University)
Richard D. Connors (Luxembourg Institute of Science and Technology)

- Proposes a dynamic pricing scheme for **community-owned shared transport (CST)** aimed at achieving self-financing status in rural mobility systems where traditional mass transit is inefficient.
- Develops an evolutionary model where users make myopic mode choices between CST and private car, with CST fares adjusting over time to cover operational costs and repay initial deficits.
- Simulates the system over 1000-day periods using 100 demand patterns and varied combinations of fare caps and operational costs, identifying conditions under which CST can sustainably finance itself.
- Results show that appropriate combinations of fare caps and cost per kilometer enable CST to transition from initial debt to profitability, with outcomes robust for most parameter ranges but sensitive in certain edge cases.
- Provides a foundation for implementing web-based CST services that evolve organically without requiring prior community consensus on cost sharing, facilitating practical deployment in rural areas.

Keywords

On-demand shared mobility, Evolutionary process, Community-owned transport,





Improving the convergence of Schedule-Based Dynamic Transit Assignment Models with capacity constraints

On-demand Mobility 1

Lory Michelle Bresciani Miristice, Guido Gentile (University of Rome La Sapienza)

- Formulates a fixed-point model for schedule-based dynamic transit assignment (DTA) with capacity constraints, incorporating fail-to-board probabilities and strategic route choice.
- Proposes **the Adaptive Trust Contraction (TC-A) algorithm**, enhancing the Gradient Projection (GP) approach to achieve linear convergence and faster, more precise solutions than traditional methods.
- Demonstrates that TC-A significantly outperforms the Method of Successive Averages (MSA), particularly under capacity constraints, by reducing oscillations and accelerating convergence.
- Validates TC-A on both small and medium-sized networks (including a 38,000-passenger Singapore case), achieving computation time reductions and higher precision in dynamic user equilibrium solutions.
- Highlights TC-A's suitability for real-time transit optimization, offering improved performance for large, congested transit networks.

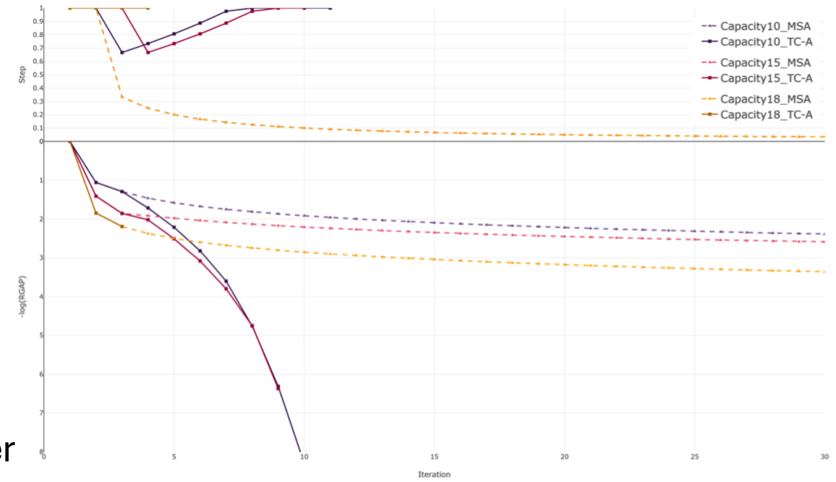


Figure 1 – *Convergence and step size trends of MSA and TC-A across different congestion levels. The trends of step size for congested MSA (capacity 18, 15, and 10) overlap.*

Keywords

Dynamic user equilibrium, Congested public transport, Fixed-point algorithms,

Learning to Prune: Fast Feasible Trip Generation for High-capacity Ridepooling

Youngseo Kim, Sirui Li, Hins Hu, Wenbin Ouyang, Samitha Samaranayake, Cathy Wu

- Introduces the Request-Trip-Vehicle (RTV) framework, a state-of-the-art approach for solving high-capacity mobility-on-demand vehicle dispatching.
- Decomposes the NP-hard problem into tractable matching and routing problems by constructing an RTV graph.
- Key technique involves generating shareable combinations of requests (trips) rather than considering all combinations of requests
- Proposes an extension for offline problems, such as day-ahead scheduling in prebooking systems, expanding the range of applications.

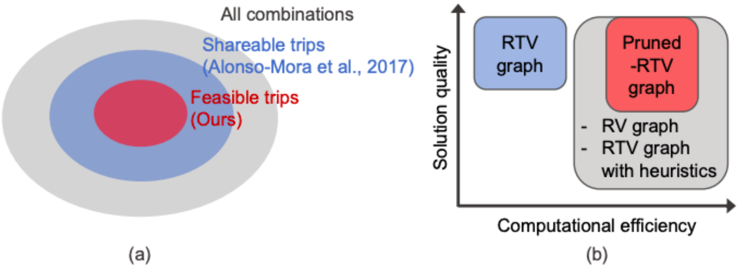


Figure 1 – *RTV vs Pruned-RTV: (a) Our method generates feasible trips as a subset of shareable trips, and (b) Pruned-RTV improves computational efficiency while maintaining solution quality.*

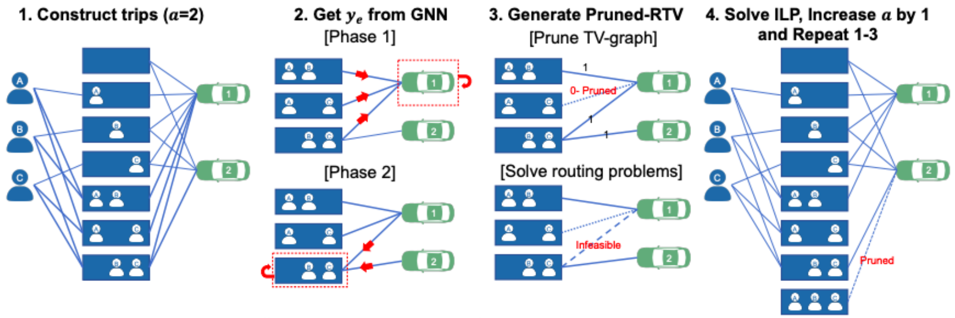


Figure 2 – *Schematic overview of generating Pruned-RTV graph*

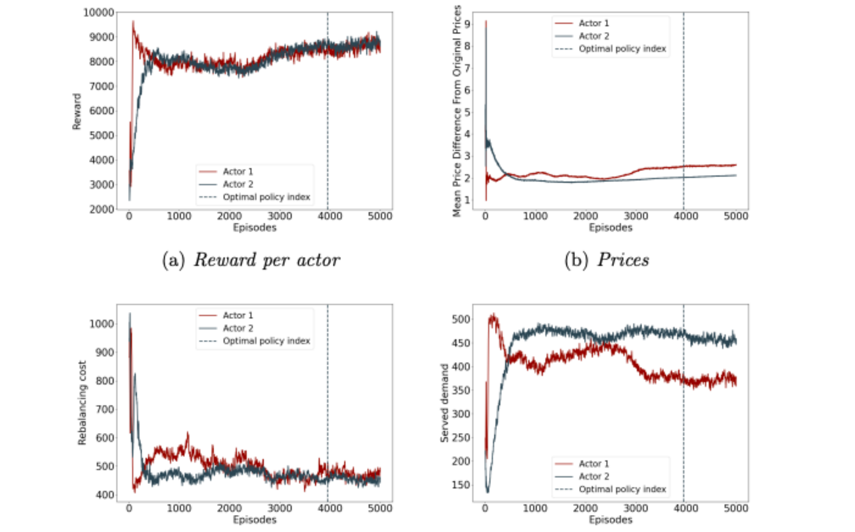
Keywords

Learning-guided Discrete Optimization, High-capacity Ridepooling, Request-TripVehicle Graph, Graph Neural Network

Learning-based control of AMoD in competitive environments

Joachim Andreasen, Frederik Sørensen, Asger Tang, Carolin Schmidt, Daniele Gammelli, Francisco Pereira, Filipe Rodrigues

- Proposes an Autonomous Mobility-on-Demand (AMoD) system offering personalized mobility while eliminating private vehicle ownership costs.
- Addresses the spatio-temporal challenges of urban mobility, where demand is **asymmetrically distributed** (e.g., peak-hour commuting).
- Shifts focus to learning-based approaches, offering scalability and adaptability to dynamic, stochastic environments, in contrast to traditional heuristics and optimization.
- Presents a multi-agent reinforcement learning (RL) approach, where each operator controls its fleet independently without knowledge of competitors' states and actions.
- Demonstrates for the first time that learning-based methods can rebalance fleets and set dynamic prices while accounting for competitors, converging to an equilibrium.



(a) *Reward per actor* (b) *Prices* (c) *Rebalancing cost* (d) *Served demand*

Figure 2 – *Average rewards, prices, rebalancing costs, and served demand over the training.*

Keywords

AMoD, reinforcement learning, multi-agent systems, dynamic pricing, rebalancing

A Reinforcement Learning Approach to Plan Charging Stations for Shared Electric Vehicles

Reinforcement Learning

Qiming Ye , Prateek Bansal , Bryan T. Adey(Singapore-ETH Centre, ETH Zürich, National University of Singapore)

- Propose the first **multi-phase framework for long-term fast charging station planning**.
- Formulate a stochastic sequential decision problem and employed the reinforcement learning method to solve it. Specifically, **the deep deterministic policy gradient (DDPG)** algorithm is applied.
- The model incorporates **fleet size decisions** which evolve over time.
- An **agent-based model** was incorporated to simulate complex SEV fleet operations involving vehicle assignment, charging dispatch, queuing for changing at the stations, and repositioning.
- Improve on the state-of-the-art methods.

Keywords

Shared electric vehicles, Charging infrastructure planning, Reinforcement learning, Stochastic sequential decision problem, Deep deterministic policy gradient

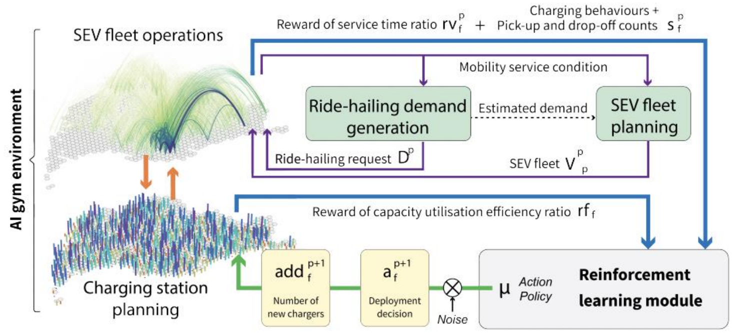


Figure 1 – *A reinforcement learning-integrated multi-phase fast-charging station planning framework*

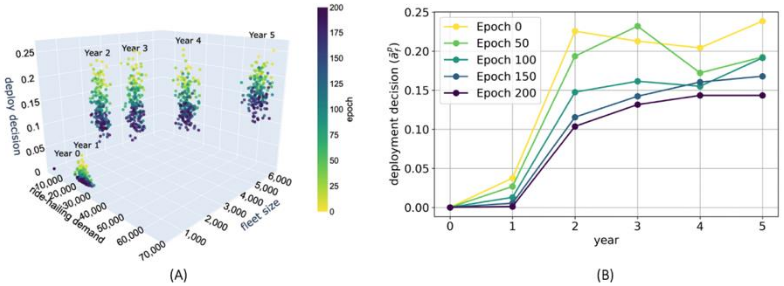


Figure 2 – *Fast charger deployment decisions per station: (A) Patterns under all ride-hailing demand and SEV fleet sizes. (B) Patterns of featured training epochs*

Atomic Proximal Policy Optimization for Electric Robo-Taxi Dispatch and Charger Allocation

Reinforcement Learning

Jim Daia , Manxi Wub , Zhanhao Zhang(Cornell University, Berkeley)

- Model robo-taxi fleet operations as a **Markov Decision Process (MDP)**
- Propose a deep reinforcement learning algorithm called **Atomic-PPO** to compute the optimal policy.
- Atomic-PPO builds on the classical PPO algorithm but introduces a novel **decomposition of the fleet routing policy** by assigning atomic actions sequentially to individual vehicles.
- This approach reduces the action space from being exponential in fleet size to being a constant, significantly lowers the complexity of policy training.

Keywords

Deep Reinforcement Learning, Electric Vehicles, Ride-Hailing Services

Algorithm 1: The Atomic-PPO Algorithm

Inputs: Number of policy iterations J, number of episodes K, initial policy $\tilde{\pi}_{\theta_0}$.

for *policy iteration* $j = 1, \ldots, J$ **do**

Run policy $\tilde{\pi}_{\theta_{j-1}}$ for K episodes each of which is a single day operations.

Store trajectory of system state $s_n^{t,(k)}$, vehicle type $c_n^{t,(k)}$, atomic action $\tilde{a}_n^{t,(k)}$, and reward $r^t(\tilde{a}_n^{t,(k)}, c_n^{t,(k)})$ for each assignment n, time step $t \in T$ and episode $k \in K$.

Compute empirical estimate of value function $\hat{V}_n^{t,(k)}(\tilde{s}_n^{t,(k)})$ as the accumulated reward of realized trajectory starting from n-th assignment at time step t in k-th episode. Update value network by minimizing $\sum_{k,t,n}(\tilde{V}_\psi^t(\tilde{s}_n^{t,(k)}) - \hat{V}_n^{t,(k)}(\tilde{s}_n^{t,(k)}))^2$.

Estimate advantage functions by

$$\hat{A}_{\theta_{j-1}}(\tilde{s}_n^{t,(k)}, \tilde{a}_n^{t,(k)}, c_n^{t,(k)}) := \begin{cases} r^t(\tilde{a}_n^{t,(k)}, c_n^{t,(k)}) + \tilde{V}_\psi(\tilde{s}_{n+1}^{t,(k)}) - \tilde{V}_\psi(\tilde{s}_n^{t,(k)}), & \text{If } n < N, \\ r^t(\tilde{a}_n^{t,(k)}, c_n^{t,(k)}) + \tilde{V}_\psi(\tilde{s}_1^{t+1,(k)}) - \tilde{V}_\psi(\tilde{s}_n^{t,(k)}), & \text{If } n = N. \end{cases}$$

Obtain the updated policy network $\tilde{\pi}_{\theta_j}$ by maximizing surrogate objective function

$$\hat{L}(\theta_j, \theta_{j-1}) := \frac{1}{K} \sum_{k,t,n} \min\left(\frac{\tilde{\pi}_{\theta_j}(\tilde{a}_n^{t,(k)} | \tilde{s}_n^{t,(k)}, c_n^{t,(k)})}{\tilde{\pi}_{\theta_{j-1}}(\tilde{a}_n^{t,(k)} | \tilde{s}_n^{t,(k)}, c_n^{t,(k)})} \hat{A}_{\theta_{j-1}}(\tilde{s}_n^{t,(k)}, \tilde{a}_n^{t,(k)}, c_n^{t,(k)}), \right.$$
$$\left. \text{clip}\left(\frac{\tilde{\pi}_{\theta_j}(\tilde{a}_n^{t,(k)} | \tilde{s}_n^{t,(k)}, c_n^{t,(k)})}{\tilde{\pi}_{\theta_{j-1}}(\tilde{a}_n^{t,(k)} | \tilde{s}_n^{t,(k)}, c_n^{t,(k)})}, 1-\epsilon, 1+\epsilon \right) \hat{A}_{\theta_{j-1}}(\tilde{s}_n^{t,(k)}, \tilde{a}_n^{t,(k)}, c_n^{t,(k)}) \right).$$

end

return *policy* $\tilde{\pi}_{\theta_J}$

	Revenue/$\bar{R}$	Revenue
Atomic-PPO	91%	\$390K
Power of d	71%	\$310K
Fluid policy	43%	\$185K

Table 1 – *Revenue comparison.*

	Setup	Revenue
Benchmark	75 kW & 130 miles	\$390K
Slow Chargers	15 kW & 130 miles	\$335K
Double Range	75 kW & 260 miles	\$390K

Table 2 – *Change of charging rates and range.*

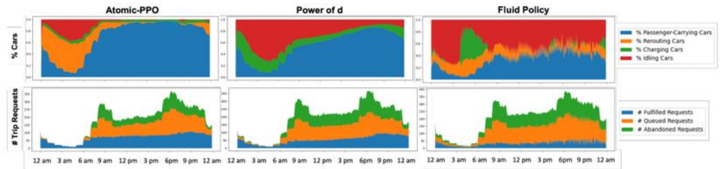


Figure 1 – *Policy evaluation. (First row) Fleet status; (Second row) Trip fulfillment status.*

Fair Courier Assignment and Dynamic Food Pricing via Multi-Agent Reinforcement Learning with Communication

Reinforcement Learning

Yang Deng, Andy Chow, and Zhili Zhou (City University of Hong Kong)

- This paper addresses a gap in food delivery service research, which often focuses on delivery efficiency but overlooks **courier fairness**.
- Introduce a **hierarchical multi-agent framework** to optimize both pricing and courier selection at the upper level using **Differentiated Inter Agent Learning** (DIAL, Foerster et al. (2016)) for **centralized decision-making**, and tackle the routing problem at the lower level through **decentralized execution** methods.
- This system emphasizes a human-centric approach by providing equitable work opportunities for couriers with different capabilities.

Keywords

Food delivery; Markov decision process; Multi-agent Reinforcement learning; Agent communication.

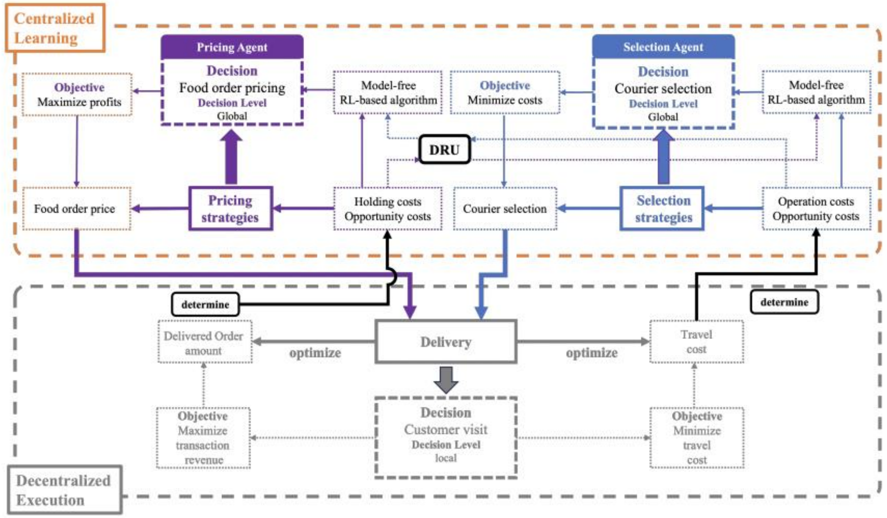
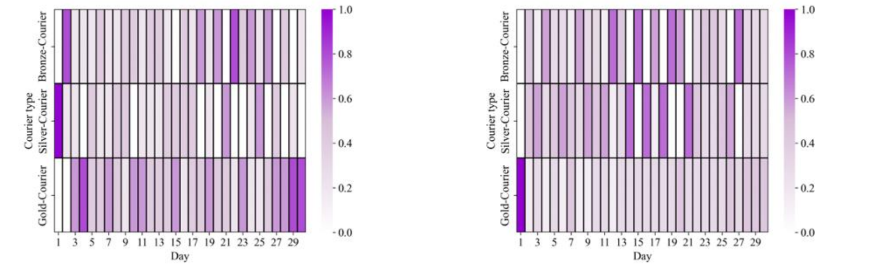


Figure 1 – *The structure of the proposed solution approach*



(a) *Courier assignment distribution without agent communication*

(b) *Courier assignment distribution with agent communication*

Figure 3 – *Heatmap comparison of courier assignment distribution with and without communication*

Non-myopic Matching and Rebalancing in Large-Scale On-Demand Ride-Pooling Systems Using Simulation-Informed Reinforcement Learning

Farnoosh Namdarpour and Joseph Y. J. Chow

- Formulates the ride-pooling vehicle matching and rebalancing problem using reinforcement learning (RL).
- Model-based simulation-informed approach for real-time decision making in large-scale systems.
- RL optimizes vehicle dispatch and repositioning decisions over time.
- Proves the effectiveness of centralized fleet dispatch over individual vehicle agents in improving system efficiency.
- The offline learning phase captures spatiotemporal patterns of supply and demand from historical data.
- Online RL policies use learned value functions to make real-time matching and rebalancing decisions.

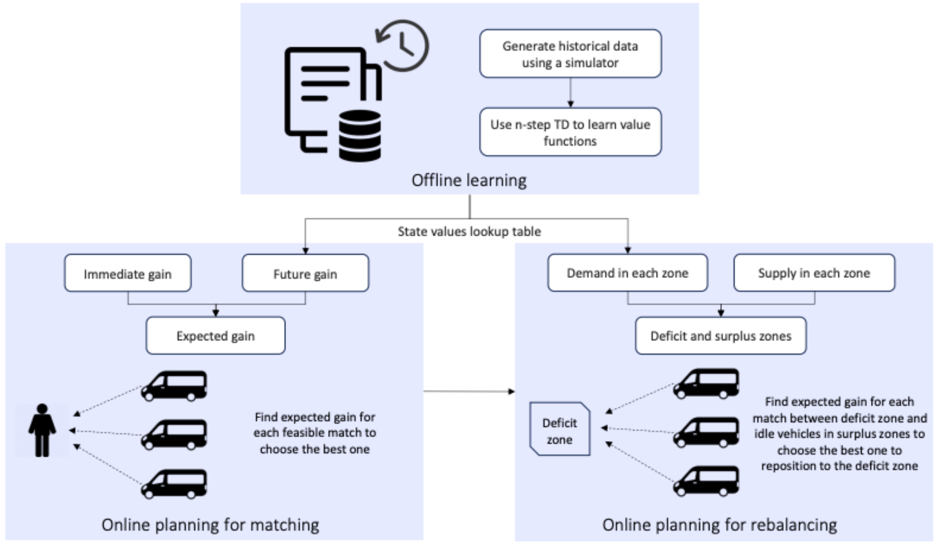


Figure 1 – *Proposed framework.*

Keywords

ride-pooling, ride-sharing, reinforcement learning, fleet dispatch, vehicle rebalancing

RouteFinder: Towards Foundation Models for Vehicle Routing Problems

Federico Berto*, Chuanbo Hua*, Nayeli Gast Zepeda*, Andr é Hottung, Niels Wouda, Leon Lan, Junyoung Park, Kevin Tierney, Jinkyoo Park

- Design a transformer-based model with global attribute embeddings to enhance the
- Representation of VRP variants and improve the model’s ability to generalize across tasks
- Introduce two reinforcement learning techniques: Mixed Batch Training and Multi-Variant Reward Normalization, to stabilize training across multiple VRP variants.
- Evaluate RouteFinder on **24 VRP variants** and demonstrate that it achieves competitive results, outperforming existing multi-task learning models for VRP
- RouteFinder variants achieve state-of-the-art results among learning methods. The out-of-distribution generalization is better compared to models trained on single variants, even multi-task approaches.

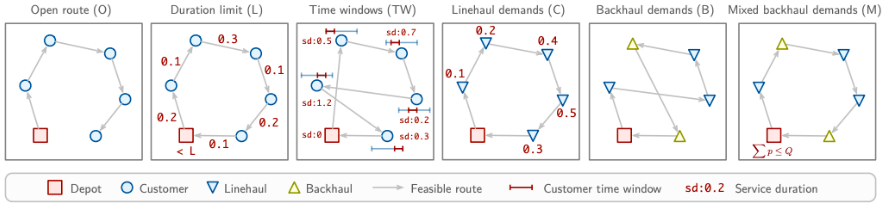


Figure 1 – *VRP variants we consider with respective attributes.*

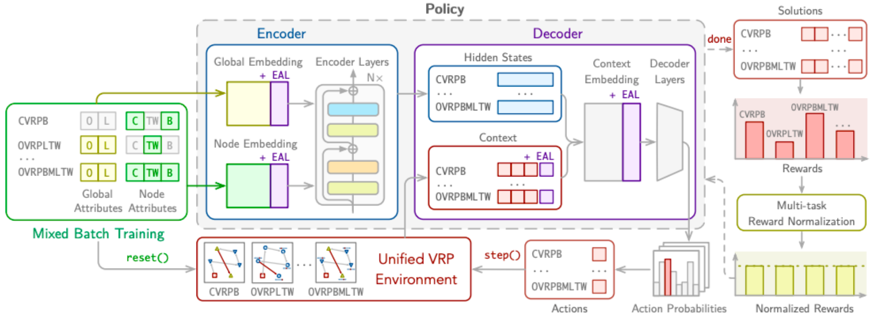


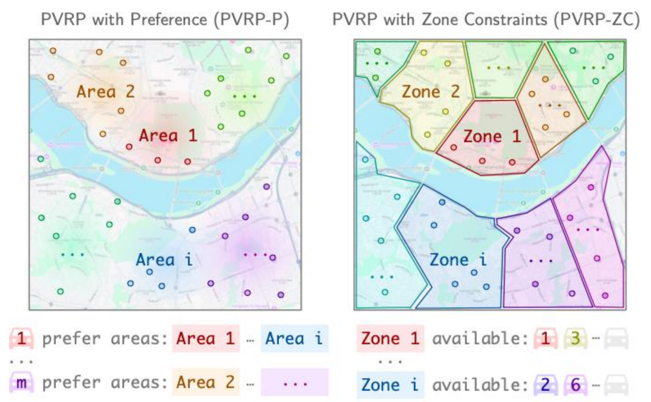
Figure 2 – *Overview of RouteFinder.*

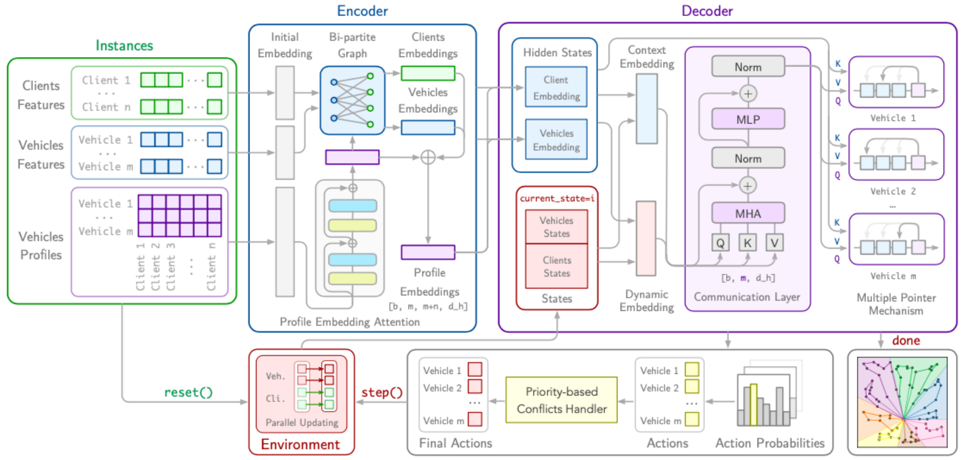
Keywords

foundation models, vehicle routing problem, reinforcement learning, neural combinatorial optimization

CAMP: Collaborative Attention Model with Profiles for Vehicle Routing Problems

Chuanbo Hua *, Federico Berto *, Jiwoo Son * , Seunghyun Kang ,
Changhyun Kwon , Jinkyoo Park





- Introduce the Profiled Vehicle Routing Problem (PVRP), a generalization of HCVRP that incorporates vehicle profiles with client-specific preferences and operational constraints
- Propose CAMP, a novel multi-agent reinforcement learning approach for PVRP that integrates vehicle and client profiles into an attention-based encoder-decoder framework for collaborative decision-making.
- Introduce a specialized attention-based communication architecture that processes profiled client representations per vehicle and enables cooperative decisions through a parallel pointer mechanism.
- Evaluate CAMP on multiple PVRP variants including PVRP with Preferences (PVRPP) and PVRP with Zone Constraints (PVRP-ZC), demonstrating competitive performance against both classical methods and neural multi-agent models

Keywords

neural combinatorial optimization, vehicle routing problems, reinforcement learning, attention network

Learning destroy operators for vehicle routing problems with deep neural networks

Andr é Hottung, Paula Wong-Chung, and Kevin Tierney

- Introduces a learning-based large neighborhood search (LNS) framework using a deep neural network (DNN) trained via reinforcement learning (RL).
- The DNN is used to perform the destroy operation, improving the traditional LNS or ruin-and-recreate methods.
- The approach alternates between destroy and repair phases, with the DNN guiding the complex destroy procedure.
- A simple greedy insertion algorithm is used for the repair phase to efficiently reinsert removed customers at locally optimal positions.
- Demonstrates superior performance over SISRs, HGS, and PyVRP in most scenarios, especially for larger problem sizes (500 and 1000 customers).

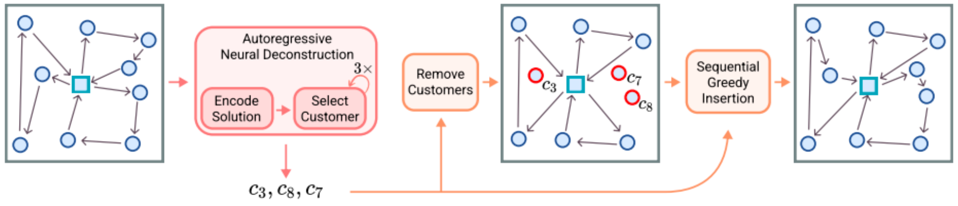


Figure 1 – *Large neighborhood search with a learned destroy operator.*

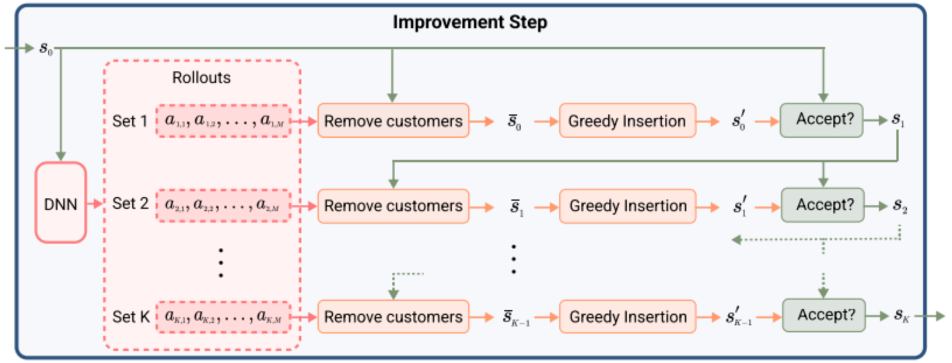


Figure 2 – *GPU-accelerated improvement step.*

Keywords

neural combinatorial optimization, vehicle routing problems, large neighborhood search, reinforcement learning

Assessing the Resilience of Rebalancing Strategies for Ride-hailing Services in Multi-modal Transportation System

Resilience

Euntak Lee[a] , Rim Slama[a] , and Ludovic Leclercq[a]

Univ Gustave Eiffel, ENTPE, LICIT-ECO7, F-69675, Lyon, France

- Develops rebalancing strategies for RH mobility services in multi-modal transportation systems, as an extension of the work Lee & Leclercq (2025).
- The study highlights how ride-hailing (RH) services can strengthen the resilience of multimodal transportation systems by offering flexible, adaptive mobility during disruptions, particularly as first- and last-mile solutions that complement public transit.
- It emphasizes the role of demand predictability in designing effective RH strategies, showing that adaptability to fluctuating or uncertain demand is crucial for ensuring continued service quality and modal integration during system shocks.

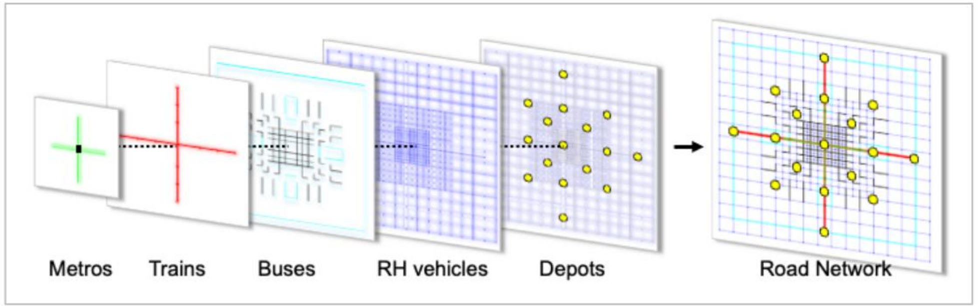


Figure 1 – *Multi-modal road network with different transportation layers*

Keywords

Ride-hailing services, Rebalancing strategy, Multi-modal transportation, Resilience

Development of network generation model with the properties of real road networks by machine learning

Resilience

Takumi Mori[a] , Hiroe Ando[b], , Ryuji Kakimoto[b]

a Kumamoto University, Graduate School of Science and Technology, Japan
b Kumamoto University, Center for Water Cycle, Marine Environment and Disaster Management, Japan

- Develop a road network generation model that uses machine learning to represent networks as matrices, making them suitable for network science analysis.
- The framework enables researchers to test growth dynamics and robustness core aspects of network science on synthetic yet realistic road networks, thereby improving the generalizability and validity of findings in transportation network modeling.
- Bridging Network Science with Realistic Road Network Modeling

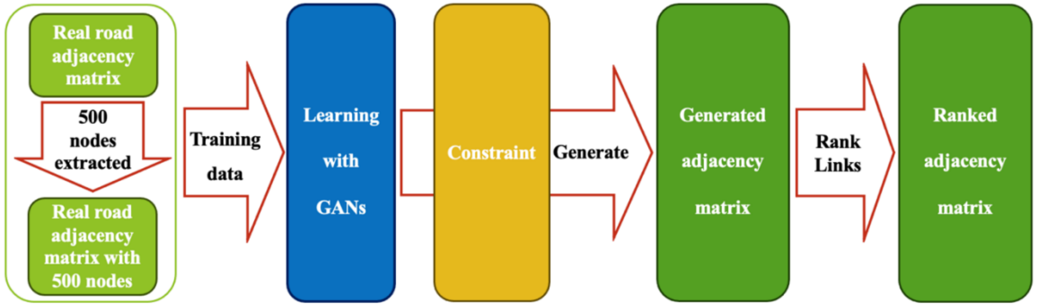


Figure 1 – *Network generation flow*

Keywords

network generation, road network, cluster analysis, machine learning, GAN

Resilience of Railway Stations: Impacts of Strategic Infrastructure Modifications

Resilience

Md Tabish Haque, Jan Eisold, Nikola Bešinović

a Kumamoto University, Graduate School of Science and Technology, Japan
b Kumamoto University, Center for Water Cycle, Marine Environment and Disaster Management, Japan

- The study shifts attention from broad, network-wide changes to the impact of small-scale infrastructure modifications near station areas, providing new insights into how targeted interventions can enhance rail system resilience.
- Bridging the Gap Between Vulnerability and Practical Resilience Planning
- The study is motivated by real-world challenges that infrastructure managers face, offering a decision-support perspective on how to prioritize limited resources for resilience improvement, particularly in budget-constrained environments.

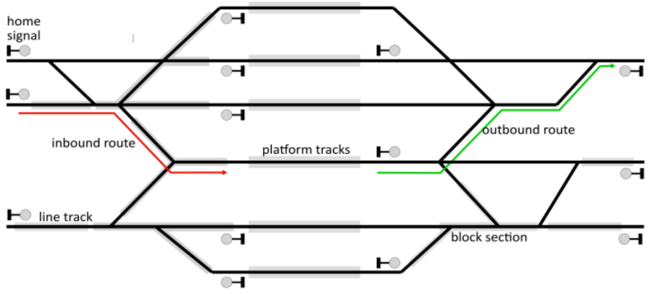


Figure 1 – *A schematic of station area and elements used in developing a mesoscopic model*

Keywords

resilience, capacity management, railway, disruptions, infrastructure enhancement

Robust Outbound Load Planning with Volume Splitting for Parcel Carriers

Ritesh Ojha (Amazon) and Alan Erera (Georgia Institute of Technology)

- Studies a hub-level load-planning subproblem that lets commodity volumes split across primary and alternate lanes, reducing trailer needs.
- Formulates a two-stage robust optimisation (ROLPP) and solves it via column-and-constraint generation, reformulating the bilinear adversary as a MILP.
- Adds heuristic scenario generation plus a mountain-climbing warm-start to speed the MILP subproblem inside the CCG loop.
- Medium-sized US-terminal tests return robust plans in seconds with optimality gaps below 0.1 % and iterate fewer than 15 times.
- Demonstrates that integrated routing and robust load sizing effectively hedge daily demand surges in parcel middle-mile networks.

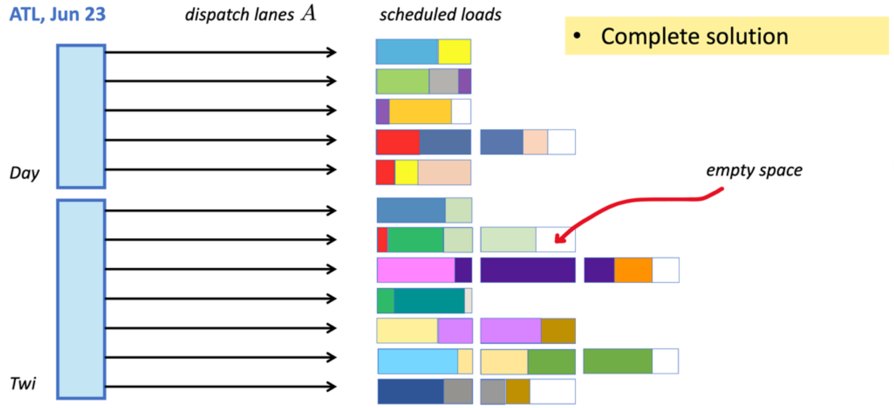
Keywords

Load Planning, column-and-constraint generation (CCG),

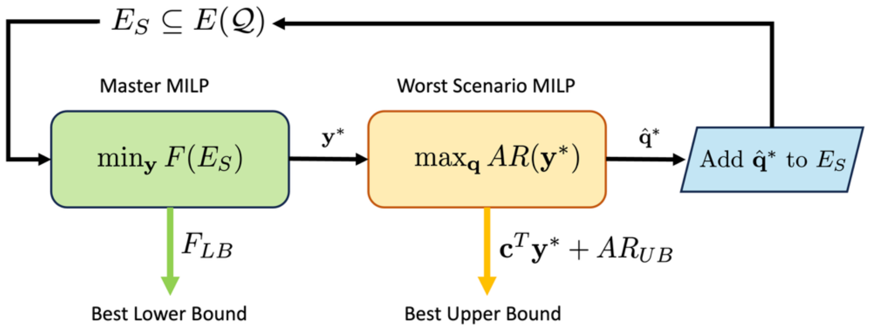
Splitting flow volumes

Robust optimization

Example: Atlanta hub on June 23



Column-and-constraint generation (CCG)

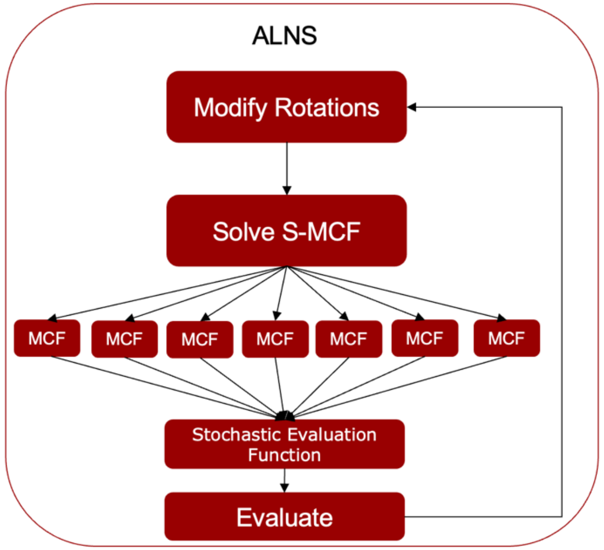


A Consensus-Fixing Heuristic for Liner Shipping Network Design with Stochastic Demands

Robust optimization

Mikkel Lassen Johansen, David Pisinger, and Stefan Røpke (Technical University of Denmark)

- Frames the liner-shipping network design problem (LSNDP) as a two-stage stochastic program that designs rotations first, then routes containers after demand is revealed.
- Proposes a highly parallel “consensus-fixing” metaheuristic that alternates Adaptive Large-Neighborhood Search (ALNS) for routes with column generation for flows, while scenarios vote to fix arc decisions.
- Introduces a polarity score to identify the first-stage variable that most divides the scenarios, fixing it to the cheaper value each iteration.
- Extends consensus fixing beyond binary ‘visit’ choices to complex arc–speed–vessel options, showing general applicability to stochastic optimization.
- Computational tests on up to 96 LINER-LIB scenarios cut average and worst-case costs with only a 30 % runtime increase when moving from 1 to 24 scenarios.



Keywords

liner-shipping network design problem, “consensus-fixing” metaheuristic , column generation

Optimising Skip Schedules for Construction & Demolition Waste under Uncertainty

Robust optimization

Ze Wang, Zhiqi Shao, Michael G.H. Bell, D. Glenn Geers, and Junbin Gao (The University of Sydney)

- Skip: a large container for bricks, wood, and similar heavy waste (LDOCE)
- Models multi-day delivery/collection of skips as a distributionally robust MILP that captures empty-delivery, full-collection and combined tasks, plus vehicle and depot limits.
- Handles travel-time uncertainty with a P-VaR(Value-at-Risk)–based adjustment inside a moment-based ambiguity set, yielding worst-case travel times used in scheduling constraints.
- Introduces chance-constraints so regional daily driving stays under a limit D with probability ≥ 1 − ε across all distributions in the ambiguity.
- Results confirm the framework's ability to balance cost and service reliability for skip logistics facing stochastic travel conditions.

Keywords

Skip schedule, Value-at-Risk, chance-constraints, waste management

Robust Planning of Bus-Fleet Electrification and Charging Deployment

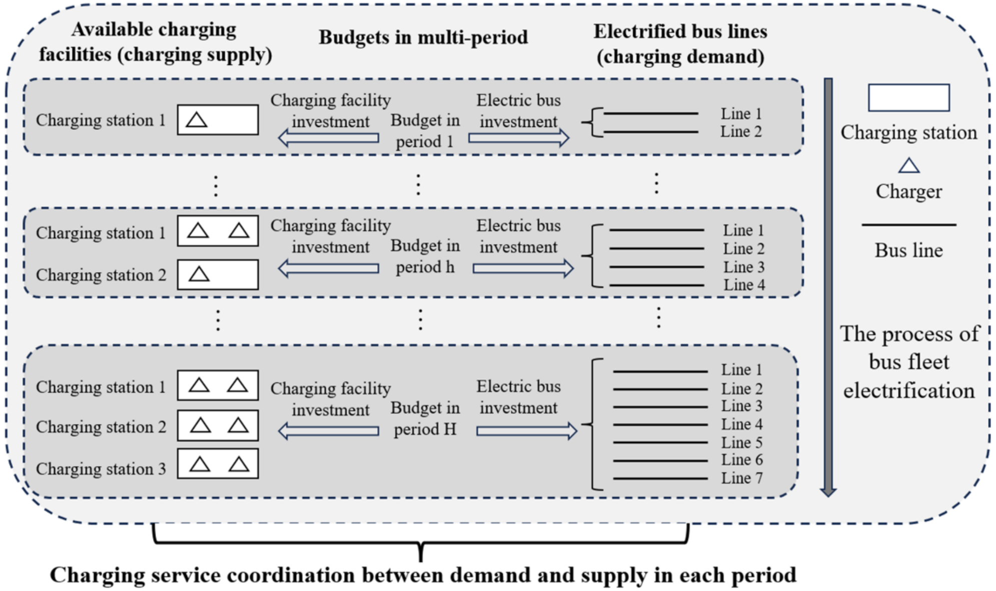
Robust optimization

Yihan Gao and Wei Liu (The Hong Kong Polytechnic University)

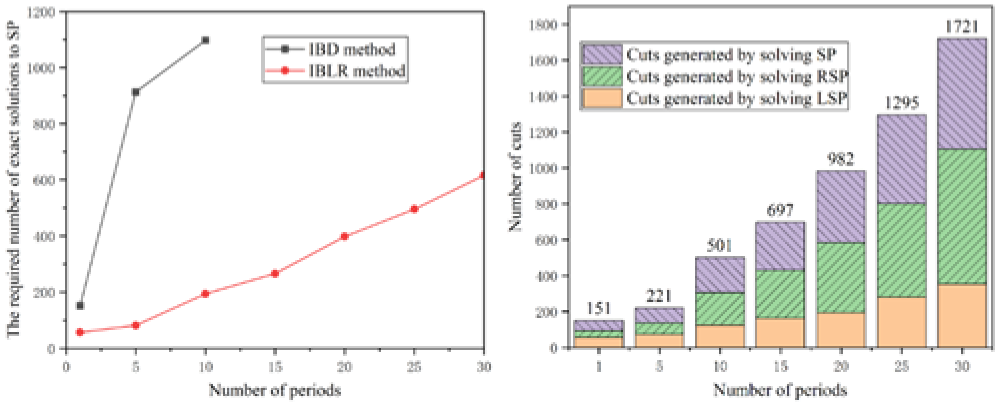
- Integrates phased diesel-to-electric bus replacement with charging-station siting/sizing over a multi-period horizon, under uncertain service frequency and charging demand.
- Uses budget-uncertainty sets in a mixed-integer model that minimises investment, operating emissions and salvage costs.
- Solves the model with an Integer-Benders framework strengthened by Lagrangian-relaxation lower bounds for the subproblem.
- Lagrangian cuts speed convergence, trimming subproblem solves and closing gaps that standard Benders cannot within 24 h.
- Robust solutions synchronise bus purchases with charger roll-outs, satisfy budgets each period and keep service levels, offering a practical roadmap for zero-emission fleets.

Keywords

Bus-Fleet Electrification, budget uncertainty, Integer-Benders framework



A multi-period plan of bus system electrification



(a) The required number of exact solutions to SP

(b) The number of cuts generated by the IBLR method

Fig. 7. The performance of algorithm(s) varies with the number of planning periods

Continuous-time optimal control for trajectory planning of autonomous vehicles under joint probabilistic constraints.

Ange Valli and Abdel Lisser (L2S, Université Paris-Saclay)

- Developed a joint chance-constrained optimal control model for reference trajectory planning as a **deterministic equivalent second-order conic-constrained optimal control problem**.
- Those **chance constraints** could consider physical parameters of height, depth, wind velocity, or strength of ocean currents to control different types of vehicles such as aircraft, spacecraft, or submarines, with respect to stochastic components.
- No requirement for relaxation or approximation of the constraints.
- The **joint probability** formulation can solve with a feasible solution.
- This model is robust to various types of scenarios with good performances.

$$
\begin{aligned}
\min_{\mathbf{u},\mathbf{z}} \quad & \int_0^T \mathbf{w}_g * D_t^2(x_t, y_t) + \mathbf{w}_v * (v_r - v_t)^2 + \mathbf{w}_a * a_t^2 \\
& + \mathbf{w}_\omega * \omega_t^2 + \mathbf{w}_j * \left(\frac{da_t}{dt}\right)^2 + \mathbf{w}_h * H(\theta_t)^2 \\
& + \mathbf{w}_p * P(x_t^{tgt}, y_t^{tgt}, x_t, y_t)\, dt & (5) \\
\text{s.t.} \quad & \frac{dz_t}{dt} = f(z_t, u_t), & (5a) \\
& L(x_t, y_t) \quad \leq \quad 0, & (5b) \\
& |v_t| \leq v_{max}, & (5c) \\
& |\omega_t| \leq \omega_{max}, & (5d) \\
& |a_t| \leq a_{max}, & (5e) \\
& \left|\frac{da_t}{dt}\right| \leq j_{max}, & (5f) \\
& K(x_t^{tgt}, y_t^{tgt}, x_t, y_t) \geq d_{min} & (5g) \\
& x_t^{tgt}, y_t^{tgt}, x_t, y_t, v_t \in \mathbb{R}^+ \\
& a_t \in \mathbb{R} \quad \theta_t, \omega_t \in [-\pi, \pi]
\end{aligned}
$$

Keywords

Autonomous vehicles, Trajectory planning, Joint probabilistic constraints, Continuous time optimal control

Dynamic management of shared autonomous electric vehicles and charging bays considering battery swapping queue delays

Mengjie Li, Haoning Xi, Chi Xie (Tongji University, The University of Newcastle)

- This paper aims to optimize the operational decisions of a **SAEV (Shared autonomous electric vehicles)** system with **battery swapping**.
- Propose a network model based on **two time-electricity-expanded networks**, Battery-related network and Vehicle-related network.
- Formulate the dynamic management problem of SAEVs and CBs as an **MIP** model (Mixed-integer linear programming model)
- Customize an exact solution method**, B&P algorithm**, significantly improving the computational efficiency.

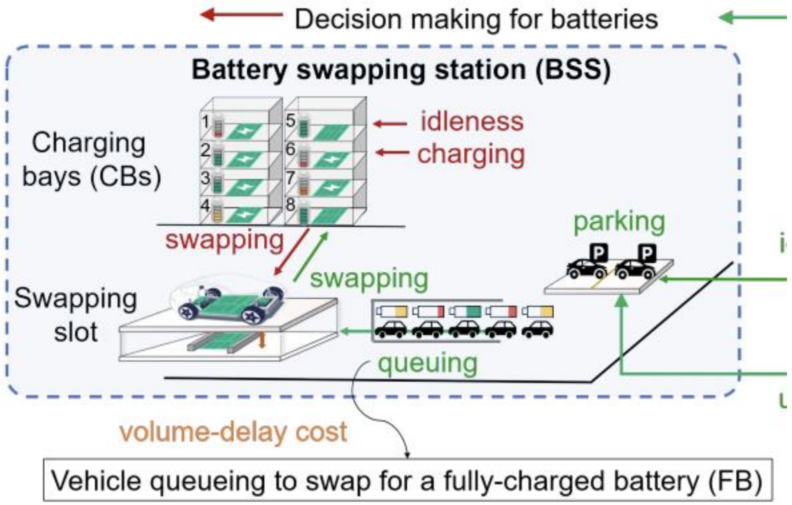


Figure 1 – *Illustration of the operational decisions for the SAEV system at given time of day*

Keywords

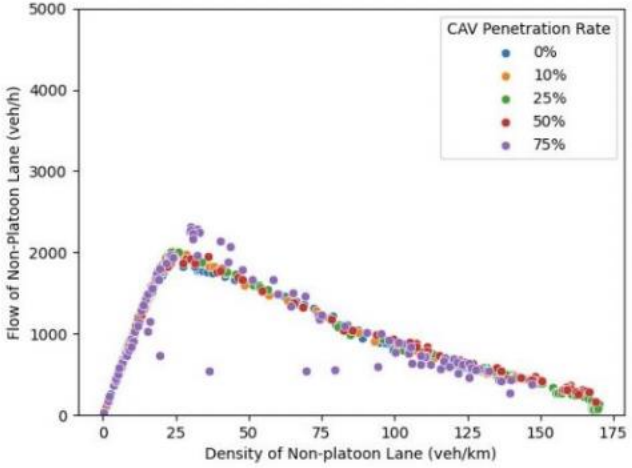
Shared autonomous electric vehicles (SAEVs), Vehicle relocation, Battery swapping, Branch-and-price algorithm (B&P), Queue delays

Lane Management Strategies to Enhance Traffic Performance in Mixed Traffic Environments with Platoons of Connected Autonomous Vehicles

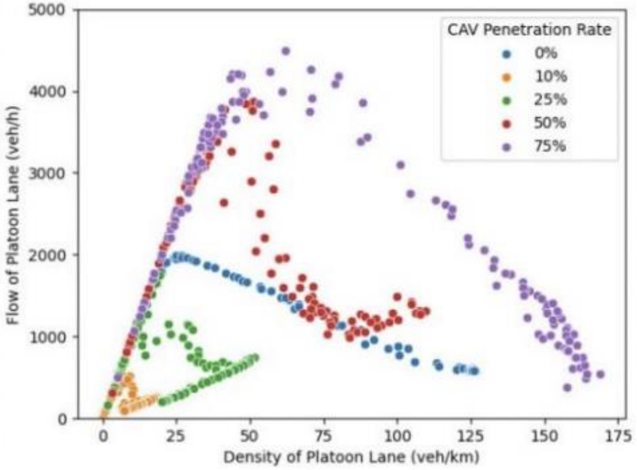
Shared and Autonomous Vehicles

S. N. Moode, F. Soriguera, M. Sala, M. Martínez-Díaz (UPC BarcelonaTech, Aimsun)

- This study investigates how innovative **lane management strategies** with novel CAV Platoon-based car following algorithm can enhance traffic performance in mixed-traffic settings.
- Outline a three-phase process for **CAV platooning**: (i) platoon formation, (ii) platoon driving, and (iii) platoon splitting
- Several platoon management **scenarios** are defined: (i) dedicated platoon lane, (ii) mixed platoon lane, (iii) mixed double platoon lane.
- Two traffic management **strategies** at the vehicular level are implemented: (i) Platooning lane speed limits, (ii) Platoon lane desirability.
- The dedicated lane approach is inefficient, particularly at low CAV penetration rates. Exploring alternative strategies like mixed platoon lanes and double mixed platoon lanes could be beneficial.



(a) Non-platooning lane



(b) Dedicated platooning lane

Keywords

CAV Platoons, Traffic flow, Management strategies, Mixed traffic, Simulation

ONLINE STOCHASTIC OPTIMIZATION FOR REAL-TIME TRANSFER SYNCHRONIZATION IN PUBLIC TRANSIT NETWORKS

Stochastic Programming

Laura Kolcheva, Antoine Legrain, and Martin Trépanier (Polytechnique Montréal)

- Develops an arc-flow model that embeds hold, skip-stop and speed-up controls to cut passenger travel time in real time.
- Adapts two rolling-horizon Online Stochastic Optimization (OSO) algorithms—Consensus and Regret—that sample demand/delay scenarios at every stop.
- Gains are largest on medium-frequency lines where Regret nears the perfect-information upper bound.
- Each re-optimization finishes in < 10 s, proving feasibility for city-scale deployment.
- Over-activating all three tactics can slightly hurt performance, highlighting the need for balanced control.

Keywords

transfer, arc-flow model, rolling-horizon

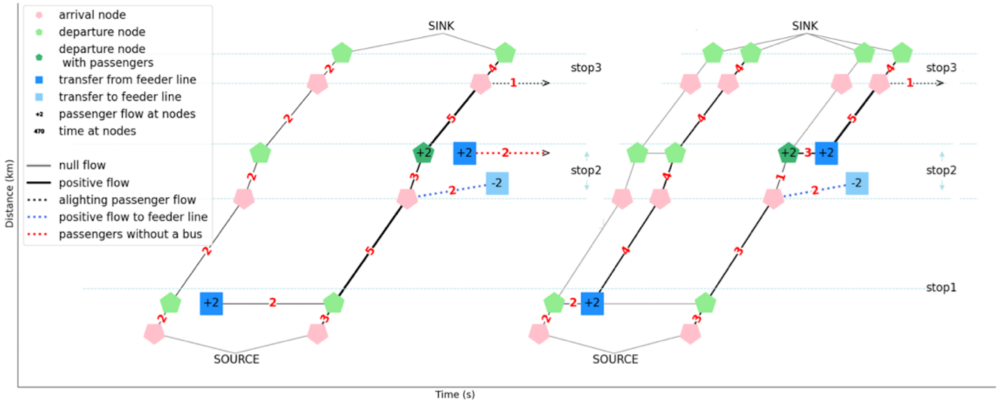
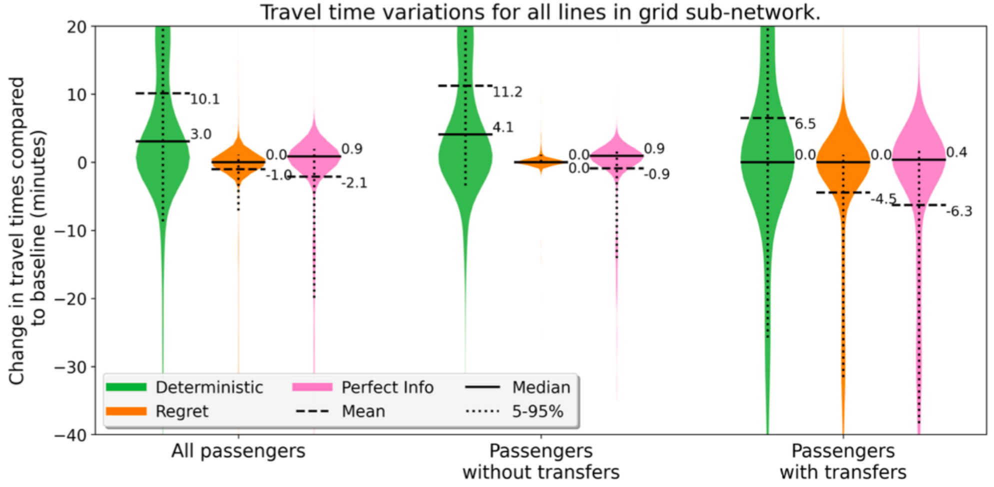


Figure 1 – *Graph for the arc-flow model demonstrating the construction of hold tactics. Left: no tactics, right: with hold tactics.*



Pricing carsharing services under decision-dependent demand uncertainty: A two-stage stochastic programming approach

Jiali Deng and Giovanni Pantuso (University of Copenhagen)

- Presents a two-stage stochastic MIP where prices directly shape demand.
- Encodes price-dependent demand via a probability space (Ω, F, μ_X) and embeds it in the objective $E_{(P_x)}$[profit].
- Proposes a distribution-specific L-shaped algorithm (D-LS) with dual cuts to handle thousands of price scenarios. Provides analytical dual solutions for integer recourse problems.
- D-LS lifts the solved-instance rate from 23.8 % to 70.4 % and keeps average gaps at 1.06 % across up to 3125 distributions.
- Small instances run 60 × faster than Gurobi (14 s vs 844 s), highlighting computational advantages.
- Results show that ignoring price-demand feedback risks both profit loss and intractable models.

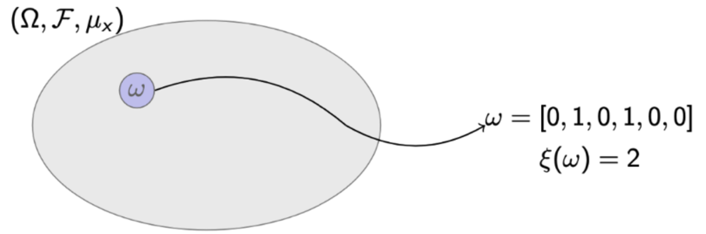


Figure 1 – *Illustration on probability space $(\Omega, \mathcal{F}, \mu_x)$ of possible carsharing choice outcomes.*

Keywords

pricing carsharing, distribution-specific L-shaped algorithm, dual cuts

Optimizing ride-hailing with a mix of on-demand and pre-booked customers under distributional shift

Stochastic Programming

Breno Serrano, Alexandre Jacquillat (MIT), Stefan Minner, and Maximilian Schiffer (Technische Universität München)

- Frames a two-stage stochastic model: accept/reject pre-bookings up front, then route vehicles for stochastic on-demand trips.
- Implements a sample-average approximation (SAA) plus a K-disjoint-path heuristic to keep large instances tractable. K-disjoint-path heuristic solves the approximate subproblem where customer pick-up times are fixed and the linking constraints are removed.
- NYC Yellow-Cab study: SAA solutions always out-earn a pure on-demand baseline, even when spatial demand shifts strongly.
- Mixed-service design boosts operator profit across all shift levels, illustrating the value of selective pre-booking.
- Model guides pricing, fleet sizing and acceptance policies when demand patterns differ for pre-booked vs on-demand riders.

Figure 1 – *Out-of-sample performance of the SAA model*

Keywords

on-demand and pre-booked, sample-average approximation, K-disjoint-path heuristic

Stochastic Optimization under Supply Uncertainty for Multimodal Trip Planning Based on Demand Prediction

Stochastic Programming

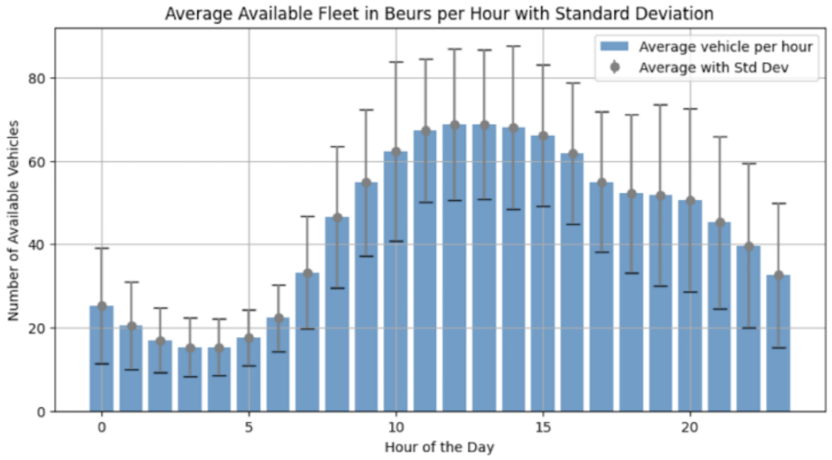
Yimeng Zhang, Jingyi Cheng, Oded Cats, Shadi Sharif Azadeh (Delft University of Technology)

- Couples a transformer-based demand predictor for e-scooters with a chance-constrained optimizer that guarantees high vehicle availability.
- Chance constraint enforces ≥ (1-α) probability that supply meets demand before recommending a micromobility-PT route.
- Real-time heuristic matches passengers to scooters and public transport while updating fleet states.
- Rotterdam case yields 0 false positives/negatives and serves 80–100 % of passengers, versus 20–60 % under a noisy-prediction baseline.
- Performance stays robust across fleets of 2–10 scooters and varying request volumes, outperforming idealized and noisy benchmarks.
- Demonstrates how MaaS platforms can blend prediction and stochastic optimization to deliver reliable micromobility-public-transport integration.

Keywords

multimodal transport, chance-constrained,

(a) *Heatmap of Pickup Demand*



(b) *Mean and Variability of Available Fleet Size*

A naturalistic experiment on individual activity, mobility and emotional patterns

Carlos Lima Azevedo, Marta Conceicao, Sonja Haustein, Paulo Morgado and Bruno Miranda

- Proposes the eMOTIONAL Daily Patterns framework using wearable devices and smartphones to collect detailed data on emotions, psychophysiological markers and daily activities.
- The framework includes three stages: **screening and pre-survey, naturalistic experiment, and post-survey/choice experiment**.
- The screening survey ensures participant suitability and collects demographic and health-related factors that could influence emotional states.
- In the naturalistic experiment, participants wear a medical wristband and use a mobile app to track travel, activities, emotional states, and physiological data.
- The post-survey assesses stress impacts and includes a choice experiment based on reinforcement learning to understand decision-making processes and emotional regulation.
- Initial statistical results show **significant links between daily mobility, activity features, and emotions**, supporting existing lab findings on stress, relaxation, and emotional responses across activities.

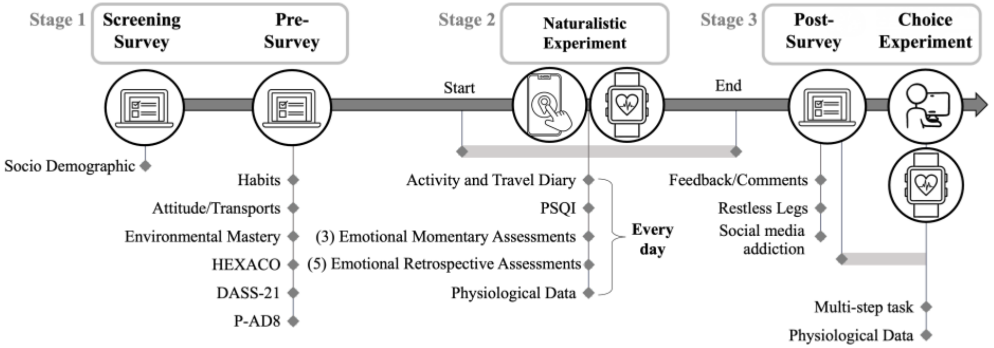
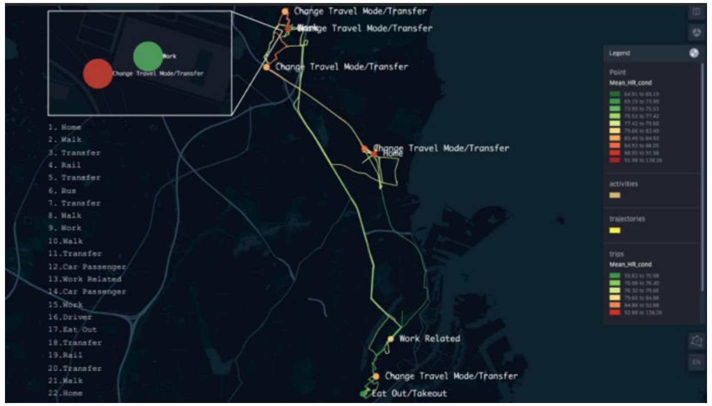


Figure 1 – *eMOTIONAL Daily Patterns' Data collection framework*



Keywords

emotions, activity patterns, travel patterns, well-being, bio-sensing, surveys

Striking a Balance: Co-Training Framework for Enhancing Survey Accuracy While Reducing Respondent Burden in Travel Data Collection

AlOlabi Reem, Makoto Chikaraishi

- Proposes a novel co-training framework to improve transportation mode detection in travel surveys with scarce labeled data.
- Integrates semi-supervised learning to **minimize manual labeling** while enhancing model accuracy using both labeled and unlabeled GPS data.
- Co-training method uses two classifiers with distinct data views: one focused on speed features, the other on GIS, weather, and socio-economic data.
- The framework iteratively exchanges high-confidence pseudo-labels between classifiers to improve predictions, enhancing accuracy without requiring additional labeled data.
- Tested on travel data from Hiroshima, Japan, the framework demonstrates superior performance compared to standard supervised models, offering a scalable and low-burden solution for transportation research.

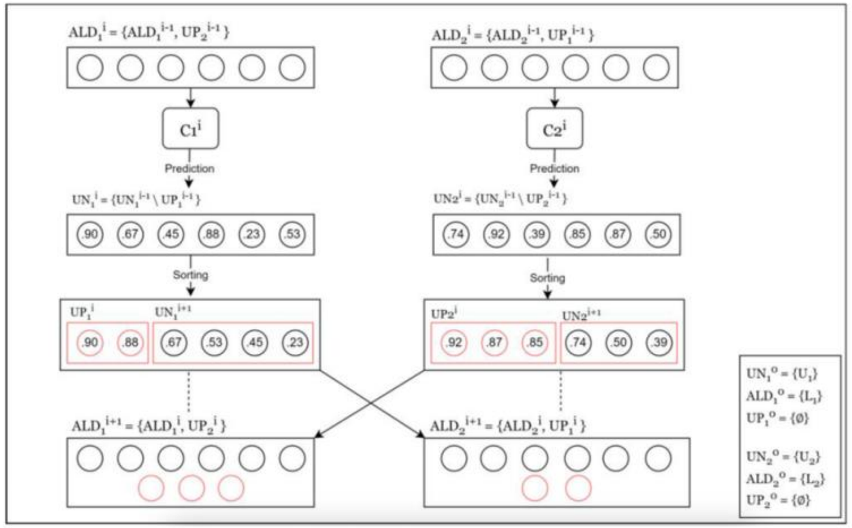


Figure 2: Co-Training Process for Semi-Supervised Learning

Keywords

Co-training, Semi-supervised learning, Travel mode detection, Respondent burden, Data accuracy

Incentive Scheme for Low-carbon Travel Based on the Public-private Partnership and Personal Trip Carbon Accounts

Yingtian ZHANG, Gege JIANG (Sun Yat-Sen University), and Guanqun SHI (Huazhong University of Science and Technology)

- Transit subsidy policy to induce travel mode shifts to low-carbon travel under Public-Private Partnership (PPP) scheme.
- Builds a three-player analytical model (government, private sector, heterogeneous travelers) and derives the Wardrop user-equilibrium flow with elastic demand and value-of-time heterogeneity.
- Demonstrates a triple-win outcome: PPP-PTCAs lowers social cost, maximises private-sector profit, and offers the largest carbon-credit benefit to tr compared with government-only or private-only schemes.

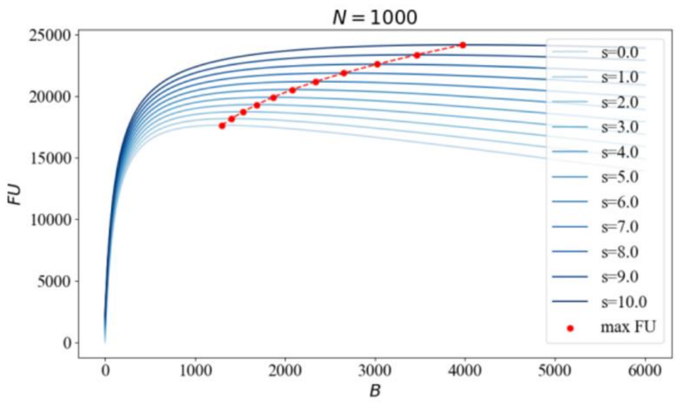


Fig.8. The impact of unit subsidy s on the low-carbon rewards and the utility of the private sector.

Keywords

Public-Private Partnership, three-player, Wardrop user-equilibrium

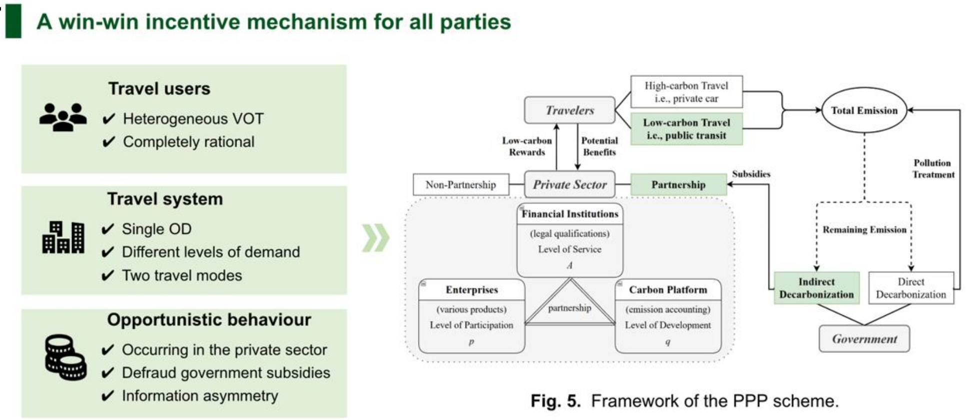


Fig. 5. Framework of the PPP scheme.

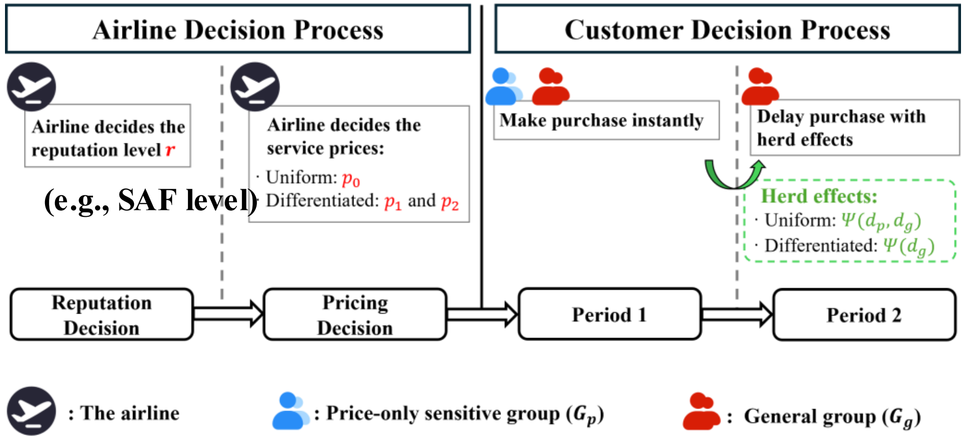
Optimal Pricing and Reputation Investment for Sustainable Aviation Fuel with Herd Effects and Heterogeneous Customers

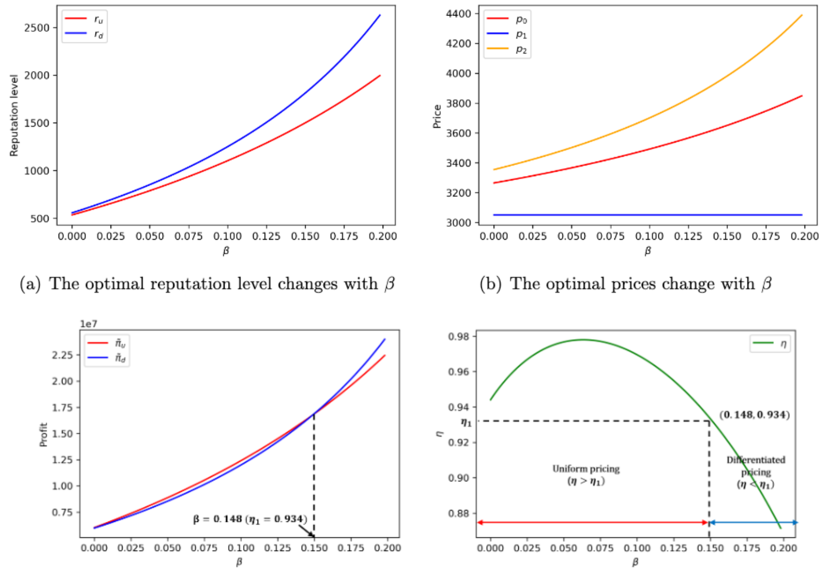
Jinshu Cai[a], Yanyan Ding[b], and Sisi Jian[a] ([a]The Hong Kong University of Science and Technology, [b]The Hong Kong Polytechnic University)

- Game between carriers and heterogeneous customers over environmental reputation
- Builds a two-stage model: invest in SAF reputation first, set ticket prices second.
- Solved by the backward induction method.
- The integrated efficiency indicator $\eta (= z_1 / z_2)$ is used to analyze the interplay between various market factors and the optimal pricing strategy.
- Finds herd effects raise optimal reputation spending and can favour uniform pricing.

Keywords

heterogeneity, backward induction method, herd effect





(a) The optimal reputation level changes with β

(b) The optimal prices change with β

(c) The optimal profits change with β

(d) η change with β

Refrigerated Container Loading Problem (R-CLP) Models for Managing Arrangement of Smart Containers

Sustainable Transport Planning

Zara Safira Ramadhani, Ahmad Rusdiansyah, Ratna Sari Dewi, and Fadila Isnaini
(Institut Teknologi Sepuluh Nopember)

- The assignment problem of packing cargoes into reefer involves aligning the required optimal temperatures of products with the internal temperature distribution within reefers to reduce product quality deterioration.
- The goal of this problem is to reduce the overall cost while ensuring with quality requirements.
- Aims at implementing R-CLP models to manage PI(Physical Internet)-boxes equipped with IoT sensors for temperature and humidity monitoring.
- Temperature distribution inside the reefer is simulated using Computational Fluid Dynamic (CFD).
- The optimal storage temperature can be determined using the average of the optimal temperatures of the stored products.

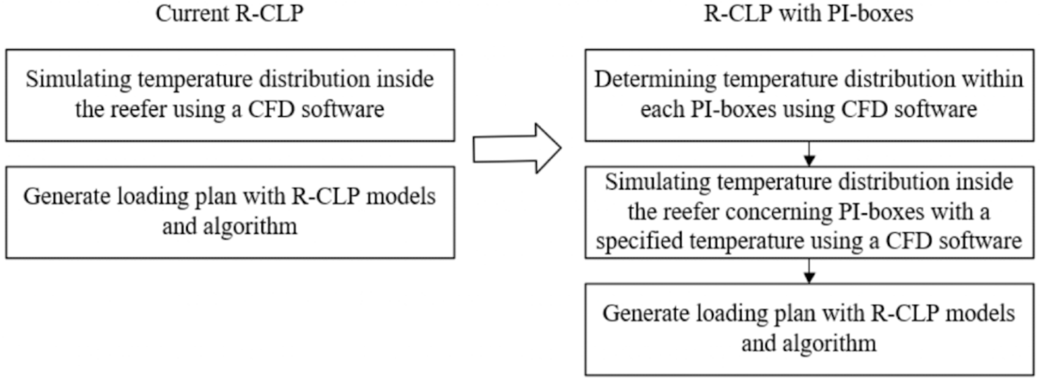
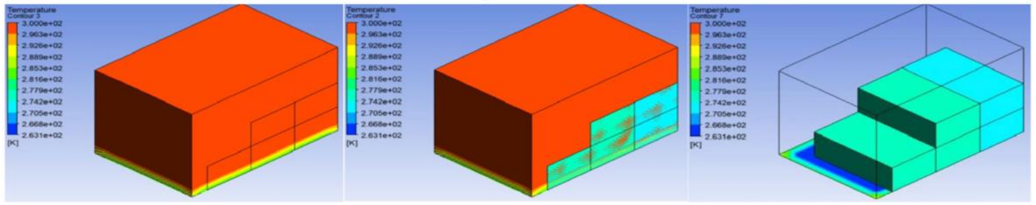


Figure 1. Differentiation of current R-CLP and R-CLP with PI-boxes



(a) Temperature distribution inside refrigerated containers
(b) Temperature distribution inside containers and PI-boxes
(c) Temperature distribution inside PI-boxes

Keywords

Refrigerated Container Loading Problem (R-CLP), Physical Internet (PI), Computational Fluid Dynamic (CFD)

Nonlinear and Ready-to-depart Based Bus Holding Control

Weihua GU, Li ZHEN, Minyu SHEN , and Le ZHANG (Hong Kong Polytechnic University)

- Analyze linear holding controls and their **nonlinear adaptations**
- Pareto-optimal holds for schedule deviation and holding delay
- Pareto-optimal holds for headway variation and holding delay
- Propose a **ready-to-depart (RTD)** based hold that uses information known at the RTD time (door closing time) right before hold is executed
- The findings benefit transit operators, as the nonlinear RTD-based traditional holding addresses critiques of prolonged slacks and delays and is straightforward to implement.

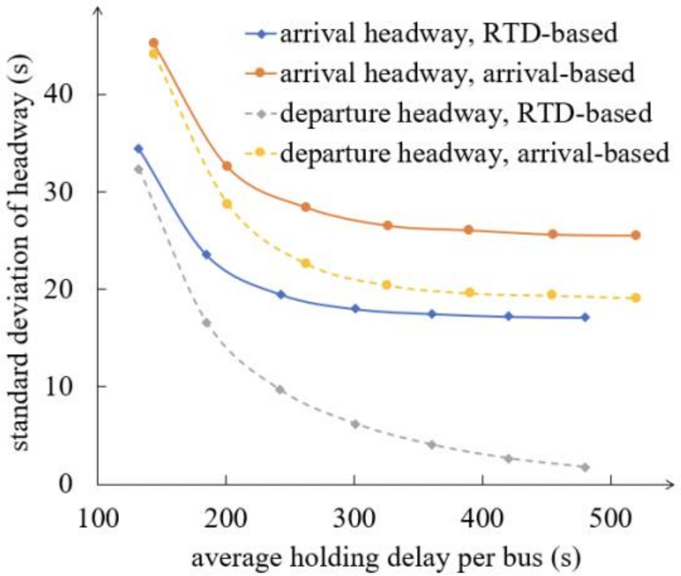


Figure 3 – Benefits of RTD-based control

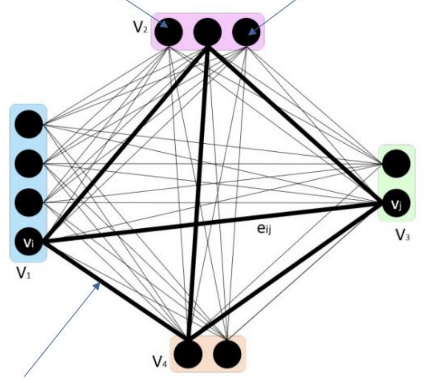
Keywords

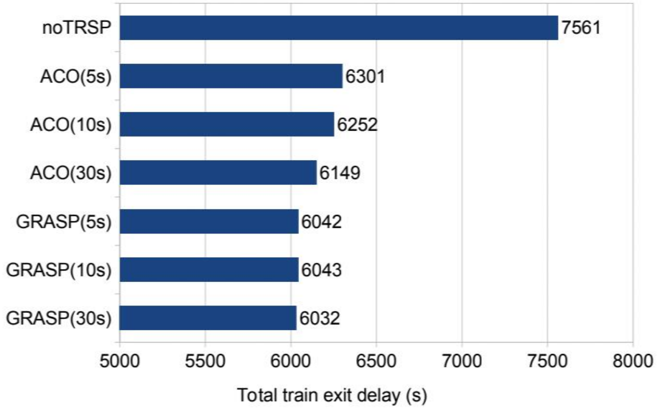
bus bunching, bus holding, nonlinear control, Pareto optimal control

A GRASP-based solution for real-time train route selection in disturbed railway traffic

Bianca Pascariu, Paola Pellegrini (Univertsité Gustave Eiffel, France)

- the **Train Routing Selection Problem (TRSP)**, a combinatorial problem focused on selecting the best set of routes for each train.
- Model the problem using the undirected k-partite graph G = (V, E)
- Propose a **Greedy Randomized Adaptive Search Procedure (GRASP).**
- GRASP involves two main phases: a **construction phase** to build feasible cliques and a **local search phase** to refine them.
- GRASP repeats this iterative process until a computation time limit is reached, then selects the p best cliques as the final solution





Keywords

Train routing, Real-time rail traffic management, Greedy randomized adaptive search procedure

A Logic-Based Benders Decomposition Approach for Cyclic Microscopic Timetabling

Florian Fuchsa , Bernardo Martin-Iradia , Francesco Corma (ETH Zürich, Switzerland)

- Leverages **decomposition** techniques to achieve microscopically feasible timetables at a large scale.
- Present the **Cyclic-MRTP (C-MRTP)** model, which integrates the temporal and spatial periodicity of train operations while considering infrastructure usage and conflict avoidance.
- Present an **LBBD** method, where the CMRTP is split into a master optimization problem, and a feasibility sub-problem comprising the full C-MRTP comprised without the objective function.
- Numerical results demonstrate that the proposed LBBD-AGG approach is computationally efficient for large-scale, complex timetabling instances.

$$\min \sum_{a=(i,j)\in\mathcal{A}^{\mathrm{COM}}} (t_j - t_i) \tag{1a}$$

subject to:

$$\sum_{w\in\rho(n)^+} x_w = 1, \quad \forall l \in \mathcal{L}, n \in \mathcal{N}_l^{\mathrm{Source}}, \tag{1b}$$

$$\sum_{w\in\rho(n)^+} x_w = \sum_{w\in\rho(n)^-} x_w, \quad \forall l \in \mathcal{L}, n \in \mathcal{N}_l \setminus (\mathcal{N}_l^{\mathrm{Source}} \cup \mathcal{N}_l^{\mathrm{Sink}}), \tag{1c}$$

$$lb_a \cdot x_{w(a)} \le t_j - t_i \le ub_a \cdot x_{w(a)} + M \cdot (1 - x_{w(a)}), \quad \forall a = (i,j) \in \mathcal{A}^{\mathrm{ITI}}, \tag{1d}$$

$$lb_a \le t_j - t_i \le ub_a, \quad \forall a = (i,j) \in \mathcal{A}^{\mathrm{COM}}, \tag{1e}$$

$$z_p \ge \sum_{w\in\mathcal{W}_p} x_w - |\mathcal{W}_p| + 1, \quad \forall p \in \mathcal{P}, \tag{1f}$$

$$y_{pp'} + y_{p'p} \le 1, \quad \forall \{p,p'\} \in \mathcal{K}, \tag{1g}$$

$$y_{pp'} + y_{p'p} \ge z_p + z_{p'} - 1, \quad \forall \{p,p'\} \in \mathcal{K}, \tag{1h}$$

$$t_{p'}^{\mathrm{entry}} - t_p^{\mathrm{exit}} + \delta \ge M(y_{pp'} - 1), \quad \forall \{p,p'\} \in \mathcal{K}, \tag{1i}$$

$$t_p^{\mathrm{entry}} - t_{p'}^{\mathrm{exit}} + \delta \ge M(y_{p'p} - 1), \quad \forall \{p,p'\} \in \mathcal{K}, \tag{1j}$$

$$t_{e^{(k)}} = t_{e^{(0)}} + kT, \quad l \in \mathcal{L}, \forall e \in \mathcal{E}_l : (e^{(0)}, e^{(k)}) \in \mathcal{A}^{\mathrm{PER}}, \quad \forall k \in \{0,1,\ldots,\hat{k}-1\}, \tag{1k}$$

$$x_w^{(k)} = x_w^{(0)}, \quad \forall l \in \mathcal{L}, w \in \mathcal{W}_l, \quad \forall k \in \{1,\ldots,\hat{k}-1\}, \tag{1l}$$

$$t_e \in \mathbb{R}^+, \quad \forall l \in \mathcal{L}, e \in \mathcal{E}_l, \tag{1m}$$

$$y_{pp'}, y_{p'p} \in \{0,1\}, \quad \forall \{p,p'\} \in \mathcal{K}, \tag{1n}$$

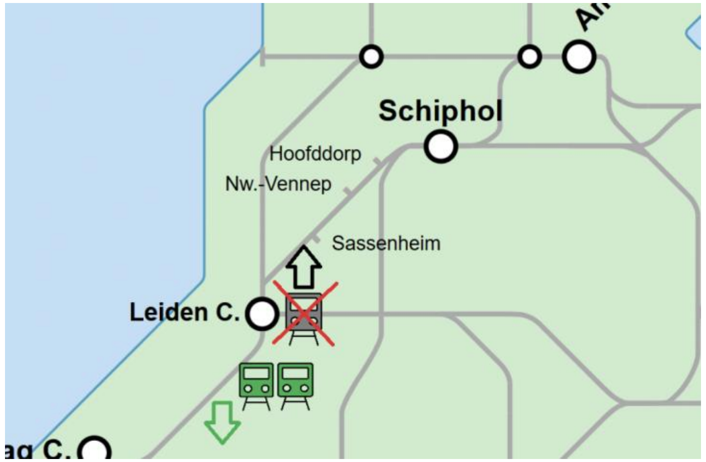
$$x_w \in \{0,1\}, \quad \forall l \in \mathcal{L}, w \in \mathcal{W}_l. \tag{1o}$$

Keywords

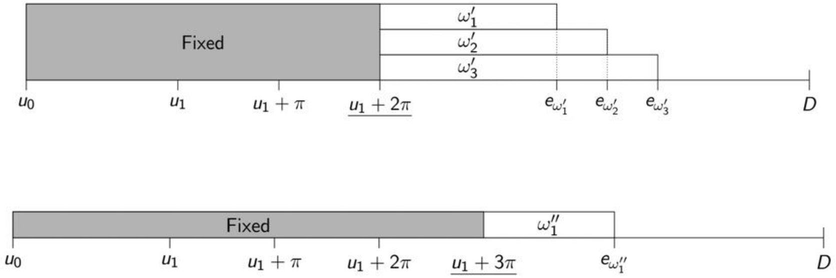
Railway timetabling, Microscopic model, Logic-based Benders decomposition, PESP

Iterative Two-Stage Stochastic Programming Approach for Real-Time Rolling Stock Rescheduling Under Uncertainty

Jia Hui Zhu, Twan Dollevoet, Dennis Huisman (Erasmus University Rotterdam)



- An updated **rolling stock** schedule should be created with each information update.
- To account for the **uncertainty** in the accuracy and completeness of the information updates, define a set of possible disruption scenarios.
- Model the problem as **a two-stage optimization problem (TSOP)**, this paper defines a recovery algorithm R.
- A **Benders Decomposition** approach in line with seems fruitful. Benders master problem and subproblems are constructed for each disruption scenario.



Keywords

Rolling Stock Rescheduling, Railway Optimization, Stochastic Programming

An adaptive large neighbourhood search with MILP and heuristic repair operators for bus timetabling

Timetabling 2

Robin Gaborit[a], Evelien van der Hurk[a] , Otto Anker Nielsen[a] , Yu Jiang[a,b] ,
a - Department of Technology, Management and Economics, Technical University of Denmark, Denmark
b - Lancaster University Management School, Lancaster University, United Kingdom

- integrating MILP and heuristic repair operators for the ALNS,
- identifying a common pitfall when setting the weights of operators with different computation times,
- devising a formula called the inverse-square rule to correct i

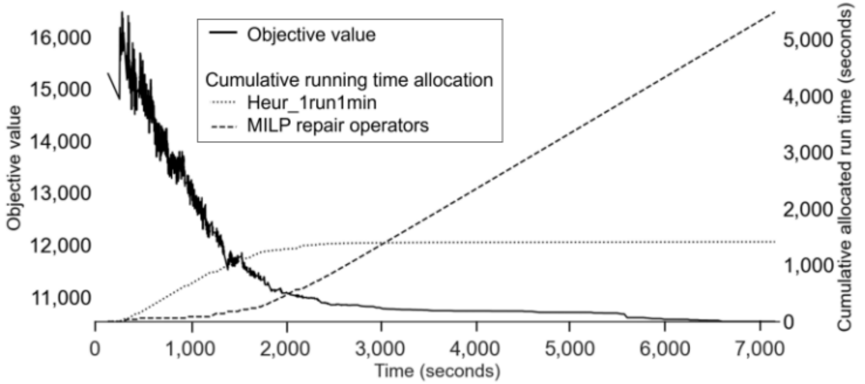


Figure 1 – *Illustration of the changes in operator selection*

Keywords

Metaheuristic, Bus timetabling, ALNS, Matheuristic, Operator selection

Data-Driven Train Timetabling with Contextual Information

Timetabling 2

Jiateng Yin[1] , Hanxiao Fan1 , D'Ariano Andrea[2] , Lixing Yang[2]
1. Beijing Jiaotong University, Beijing, China
2. Rome Tre University, Roma, Italy

- proposes a data-driven approach for DTP considering contextual information
- Transform the model into a bi-level programming model and further into a large-scale single-level MILP.
- testing our approach on the real-world data of Beijing metro and comparing the approach with traditional stochastic programming approaches, involving sample-average-approximation (SAA) and robust optimization (RO)

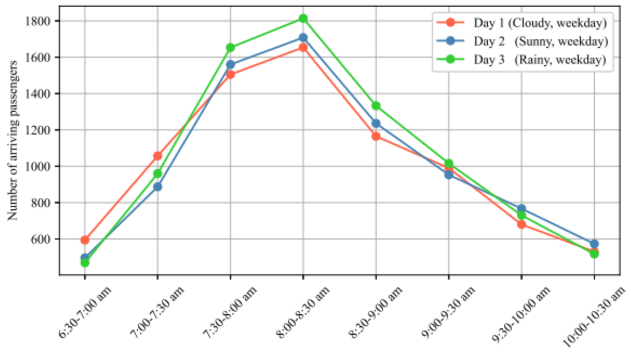


Figure 1 – *Number of arriving passengers at Sihui station, Beijing metro (Aug. 8-10, 2023)*

Keywords

Train timetabling; demand-driven; predict-then-optimize; urban rail systems

Modeling and Optimising Infrastructure Upgrade Deployment in Railway Networks Operating Cyclic Timetables

Timetabling 2

Pedro José Correia Duarte[1] , Lucas P. Veelenturf[2] , Dennis Huisman[1,3]
1 - Econometric institute, Erasmus Center for Optimization in Public Transport Erasmus University Rotterdam, the Netherlands
2 - Department of Technology and Operations Management, Rotterdam School of Management Erasmus University Rotterdam, the Netherlands
3 - Digitalization of Operations, Netherlands Railways Utrecht, the Netherlands

- introduce the RIUDP as a new problem focused on planning the phased deployment of infrastructure upgrades in a railway network.
- present an exact Mixed Integer Linear Programming (MILP) formulation for the RIUDP.
- propose two solution methods aimed at selecting cost-effective infrastructure upgrades.
- illustrate the importance of infrastructure upgrade choice over multiple periods on a case study focused on the deployment of European Railway Traffic Management Systems (ERTMS) on the Dutch Railway Network

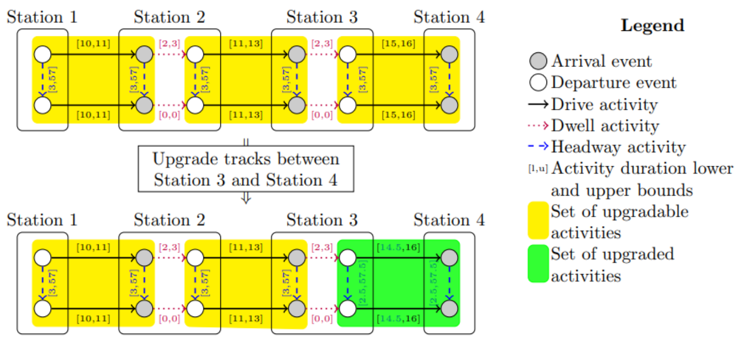


Figure 1 – *Example of infrastructure upgrade effects on activity duration bounds in a simple event-activity network.*

Keywords

Multi-period Railway Network Design; Infrastructure Upgrade Deployment; Mixed Integer Linear Programming; PESP

Passenger Based Intermodal Connection Optimization of the Italian Passenger Railway Network

Timetabling 2

Boris Grimm[1] , Ralf Borndörfer[1] , Andrea Fraioli[2] , Giovanni Luca Giacco[3] , Federico Marinucci[2]
1 Zuse Institute Berlin, Berlin, Germany,
2 IVU Traffic Technologies Italia S.r.l., Rome, Italy
3 Industrial Planning Management, Trenitalia, Rome, Italy

- In Giacco & Dell'Olmo (2022) an optimization model for the resulting Connection Optimization Problem is investigated for roughly 10,000 daily trains and 2,000 stations in Italy. Computational results indicate potential for increasing the number of connections between 5% for ±1 minute shifts up to 15% for ±8 minute shifts.
- the model is further enhanced by additional constraints to improve the model's accuracy and consider passenger flows given by an OD matrix.
- discuss the impact of the extensions of the enhanced model. The Connection Optimization Problem considered here shows some significant similarities to timetabling and line planning problems which is a very well-studied field in railway optimization

Keywords

Connection Optimization, Mixed Integer Programming, Railway Scheduling

A Multi-objective User Equilibrium of Time Loss in Congestion and Time Surplus

J. Y. T. Wang[a,b] , R. P. Batley [b] , M. Ehrgott[c] , P. Boriwan[d] . T. Phoka[e]

a - School of Civil Engineering, University of Leeds, Leeds, UK
b - Institute for Transport Studies, University of Leeds, Leeds, UK
c - Department of Management Science, Lancaster University, Lancaster, UK
d - Department of Mathematics, Khon Kaen University, Khon Kaen, Thailand
e - Department of Computer Science and Information Technology, Naresuan University,

- Introducing the Multi-objective User Equilibrium (MUE) model as a novel route choice framework that incorporates time surplus as a behavioral objective alongside travel time and cost.
- Exploring the theoretical and practical implications of the MUE framework on CVTT multipliers, proposing that a more accurate representation of congestion effects on user behavior may require moving beyond traditional linear GC functions.
- Integrating indifference curves to capture user preferences and path-switching behavior.

Keywords

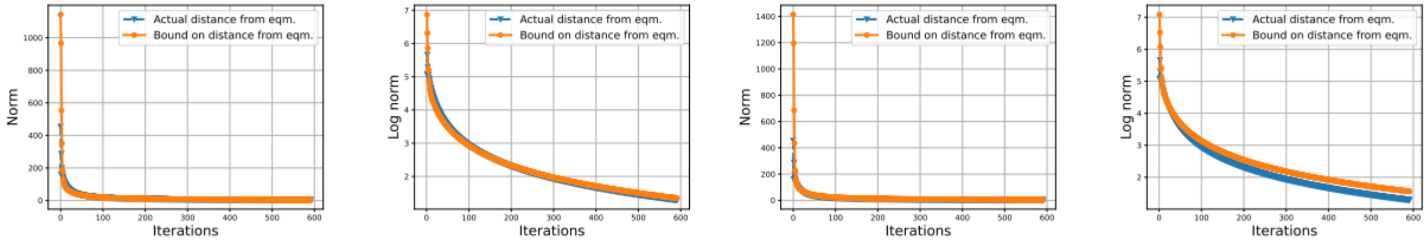
Route choice, Traffic assignment, Equilibrium problem, Multi-objective user equilibrium

Error bounds for stochastic user equilibrium traffic assignment

Debojjal Bagchi[a], Stephen D. Boyles[a]

a - The University of Texas at Austin, USA

- Deriving explicit upper bounds on the distance between a feasible traffic flow solution and the stochastic user equilibrium (SUE) solution, addressing a critical gap in how well gap functions reflect actual proximity to equilibrium.
- It advances beyond traditional gap metrics (e.g., average travel time vs. shortest path time), which are widely used but do not directly quantify how close current flows are to equilibrium flows, by offering a more mathematically grounded evaluation.



$r = 0.01$ *(actual scale)* $r = 0.01$ *(log scale)* $r = 0.2$ *(actual scale)* $r = 0.2$ *(log scale)*

Figure 1 – *Bound in the Sioux Falls network OD pair* $(8, 11)$ *for two different values of* r

Keywords

Stochastic user equilibrium, network design, bilevel traffic assignment

Multimodal stochastic user equilibrium of a tradable credit scheme considering vehicle capacity and passenger waiting time

Debojjal Bagchi[a], Stephen D. Boyles[a]

a - The University of Texas at Austin, USA

- Recognizing that restricting driving can reduce the utility of excluded users, the model explicitly addresses equity concerns by offering accessible and dynamic transit alternatives, thereby reducing the risk of welfare loss due to limited mobility options.
- Capturing how credit incentives and mode shifts affect network-wide traffic performance, enabling a comprehensive evaluation of flow efficiency, modal balance, and transit optimization under the tradable credit scheme.
- The study innovatively combines tradable driving credits originally designed to reduce road usage, with Autonomous Shuttles (AS) as a flexible alternative mode of transportation.

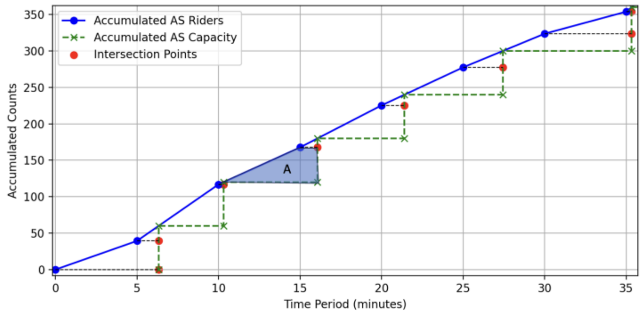


Figure 1 – *Accumulated arrival and bus service curves illustrating passenger waiting times.*

Keywords

Point queue model, Tradable credit scheme, Stochastic user equilibrium, Trip-based MFD, Traffic dynamics

Budget-constrained user equilibrium: A quasi-variational inequality approach

Yuzhen Feng, Wei Liu (The Hong Kong Polytechnic University)

- Proposes a novel formulation of **budget-constrained user equilibrium using a Quasi-Variational Inequality (QVI) framework**.
- Incorporates flow-dependent resource consumption, addressing scenarios like energy limits or congestion impacts.
- Develops an Augmented Lagrangian Method (ALM)-like algorithm to efficiently solve the QVI problem.
- Demonstrates algorithmic convergence and effectiveness through numerical experiments with 10 user types and 20 facilities.
- Offers theoretical foundations and practical algorithms for facility planning and congestion management in energy/time-constrained systems.

Keywords

User equilibrium, budget constraint, quasi-variational inequality,

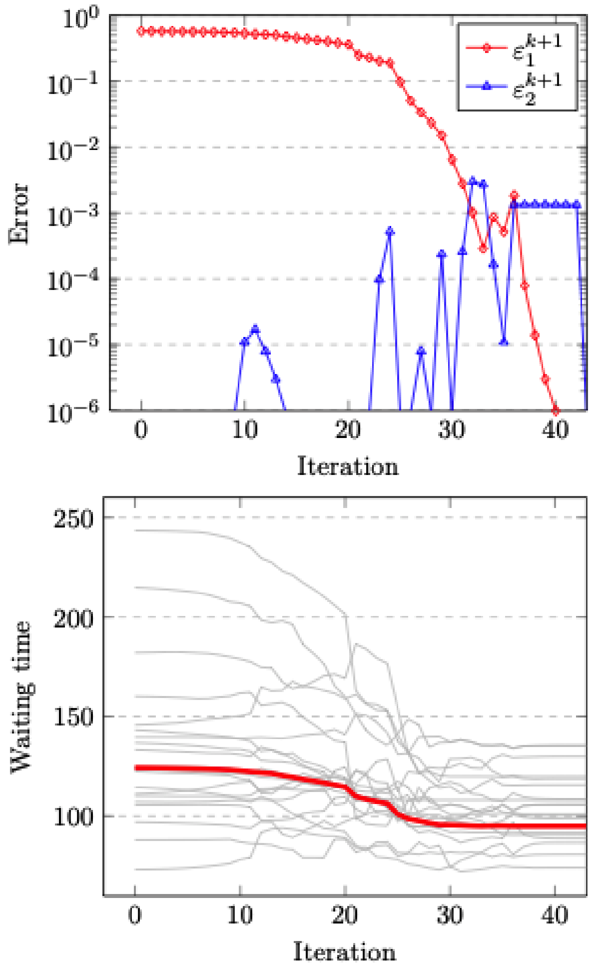


Figure 1 – *Error measures and queue waiting time*

Complex dynamics in transportation networks in the context of assignment

J.P. Lebacque (UGE University Gustave Eiffel),
M.M. Khoshyaran (Economics Traffic Clinic Paris)

- Studies medium-term dynamics of dynamic traffic assignment (DTA) and conditions for network equilibrium formation.
- Uses the GSOM model (macroscopic, conservation law + behavioral law) to model traffic flows and user choices.
- Demonstrates **existence of multiple equilibria, periodic dynamics, and persistent instabilities** under different learning schemes.
- Shows how route and departure time choices based on predictive and instantaneous costs can lead to complex, sometimes chaotic, dynamics.
- Highlights the critical role of learning strategies and traveler information systems in determining stability and performance of transportation networks.

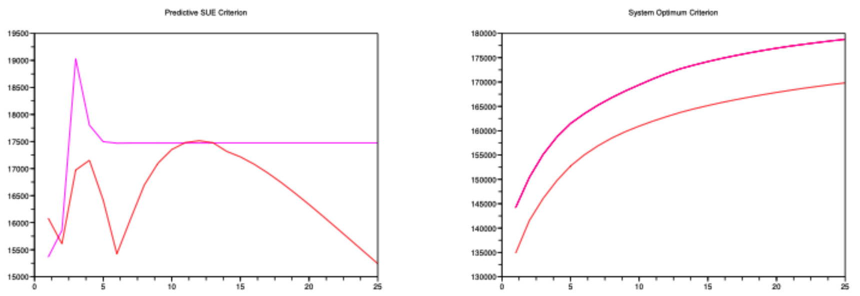


Figure 1 – *Comparison of system dynamics estimated i) with PTC,φ learning (purple) and ii) without PTC learning (in red). Horizontal axis: τ iteration (day) index*

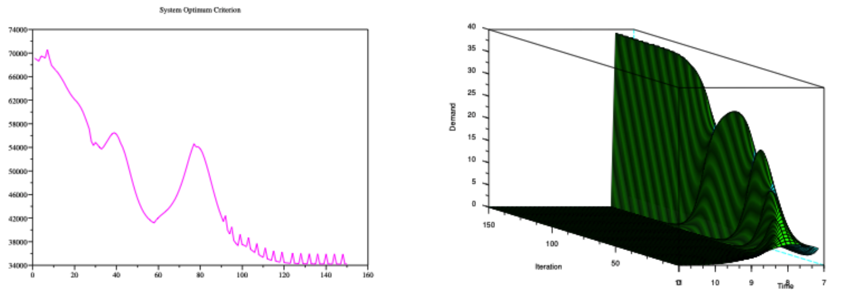


Figure 2 – *Emergence of a period 4 solution with constant smoothing coefficients. Left: SO as a function of τ, right departure time distribution*

Keywords

Dynamic traffic assignment, complex dynamics, GSOM model,

A spatiotemporal knowledge graph-based method for identifying individual activity locations from mobile phone data

Travel Behavior Analysis

Jian Li, Tian Gan, Weifeng Li, Yuhang Liu

- Proposes a spatiotemporal knowledge graph (STKG)–based method for identifying individual activity locations from mobile phone data.
- Constructs the STKG by encoding stays, time slots, and grid cells into RDF-style triples to capture mobility traces.
- Combines spatial and temporal graphs via Hadamard product to form the STG.
- Applies Fast Unfolding community detection to extract dense activity clusters.
- Achieves +10 % more clusters within 1 km and 10–20 % lower time-variance (Shanghai case study).

Figure 1 – *Research framework*

Keywords:

Human mobility, Mobile phone data, Activity location, Spatiotemporal knowledge graph, Community detection

Grasp the Amount and Service Level of Directionally Predominant Traffic

Makoto Okumura , Yuri Sawamurab , Hiromichi Yamaguchic

- Develops an indirect estimation method for directionally predominant traffic using hourly population estimates from 500 m meshes (Docomo MSS data).
- Constructs zonal cumulative diagrams to derive one-dimensional flow volumes and travel times between zones.
- Introduces two stay-time division schemes (minimum vs. maximum) to separate pure travel time from destination dwell time.
- Calculates average travel speed by dividing total travel distance by total travel time.
- Quantifies temporal trends in volunteer traffic: total movement volume, average travel distance, travel time, and speed during morning and evening peaks.

Keywords:

Traffic Measurement, Directionally Predominant Traffic, Mobile Statistics Data, 2024 Noto Earthquake

About the authors:

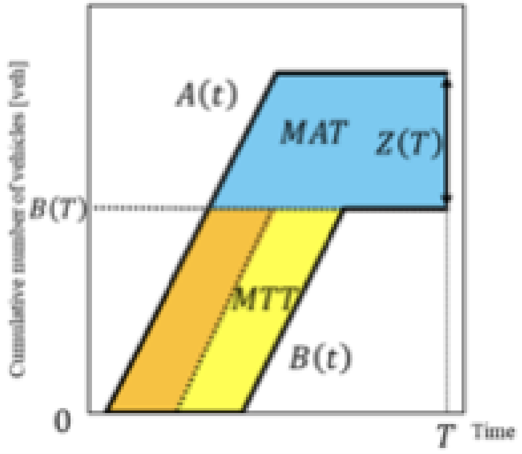


Figure 1 – *Minimum division to the time after arrival: when vehicles heading further arrive earlier.*

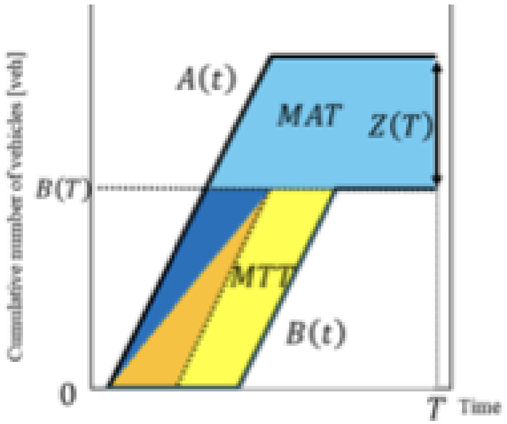


Figure 2 – *Maximum division to the time after arrival: when arrival rate to any zone is constant along time.*

A Unified Approach to Evaluation and Routing in Public Transport Systems

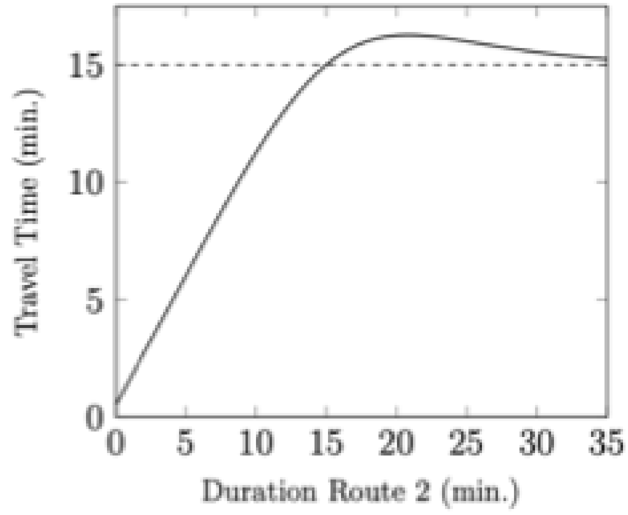
Rolf N. van Lieshout1 Kevin Dalmeijer2

Travel Behavior Analysis

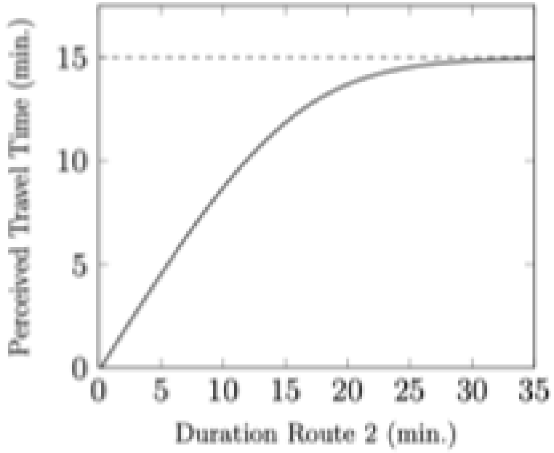
- Formalizes route-choice and service-quality evaluation across three supply models: route sets, periodic timetables, and line plans.
- Defines two key properties-monotonicity (service improvements never worsen the measure) and consistency (the chosen routing minimizes the measure)-and shows average travel time under logit violates both.
- Introduces **perceived travel time,** derived from the Random Utility Model, which restores monotonicity and consistency under logit routing.
- Extends to periodic timetables (with uniform arrivals) to derive two consistent, monotonic metrics: average travel time (shortest-path routing) and average perceived travel time (logit routing), along with efficient computation algorithms.

Keywords:

Passenger Mobility, Choice Modeling, Line Planning, Transit Network Design, Timetabling.



(b) *Travel Time as function of l_2.*



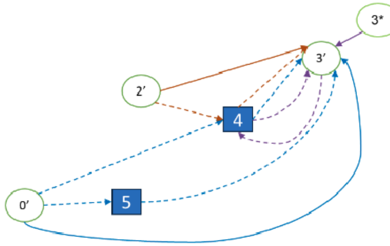
(c) *Perceived Travel Time as function of l_2.*

A scalable three-sided electric Mobility-as-a-Service assignment game model with charging activity

Two-Sided Markets

Hai Yang, Joseph Chow

- **Link-based assignment game model** for electric eMaaS, **incorporating travelers, operators, and energy providers** into a unified framework.
- Introduces the **Perturbed Utility Route Choice** model to handle stochastic link-level flows without enumerating paths, improving computational scalability.
- Models eMaaS as a **three-sided Stackelberg game**, with operators and energy providers setting prices and capacities while travelers choose routes stochastically (multi-leader multi-follower game).
- Incorporates **time intervals** into the modeling, connecting operational decisions for traveler flows with charging and rebalancing operations between intervals.
- Quadratic programming to solve traveler-operator matching and operator-energy provider matching, enabling application to large-scale networks.



Path	Flow	Time
(0', 3', 0*)	79.09	0.42
(0', 4, 3', 0*)	42.92	0.5
(0', 5, 3', 0*)	42.92	0.5
(2', 3', 2*)	34.19	0.17
(2', 4, 3', 2*)	35.40	0.25
(3', 4, 3'', 3*)	60	0.17
(3*, 3')	37.36	0

Keywords

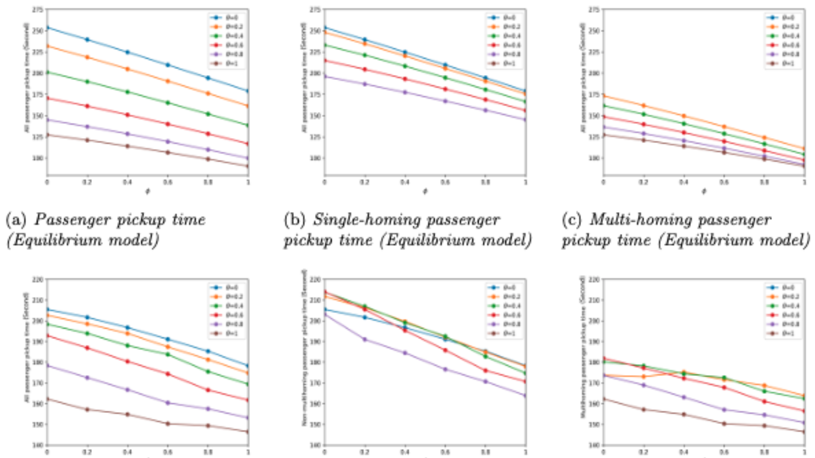
Electric Mobility-as-a-Service, Perturbed utility route choice, multimodal network assignment, Mobility-on-demand

On the Joint Effects of Supply and Demand Multi-homing in the e-hailing Market

Two-Sided Markets

Guipeng Jiao, Yue Yang, Mohsen Ramezani

- Investigates **multi-homing behavior** of passengers and drivers in two-sided e-hailing markets, where users simultaneously access multiple platforms.
- Develops both an **equilibrium model and a dynamic simulation model** to analyze the impacts of multi-homing.
- Models matching rates using a Cobb-Douglas function, capturing network effects and how multi-homing influences platform performance metrics.
- Increased multi-homing **reduces average passenger pickup times**, benefiting both single- and multi-homing passengers.
- Highlights that single-homing passengers can also benefit indirectly from the presence of multi-homers, due to better system-wide efficiency.



(a) *Passenger pickup time (Equilibrium model)*
(b) *Single-homing passenger pickup time (Equilibrium model)*
(c) *Multi-homing passenger pickup time (Equilibrium model)*
(d) *Passenger pickup time (Simulation model)*
(e) *Single-homing passenger pickup time (Simulation model)*
(f) *Multi-homing passenger pickup time (Simulation model)*

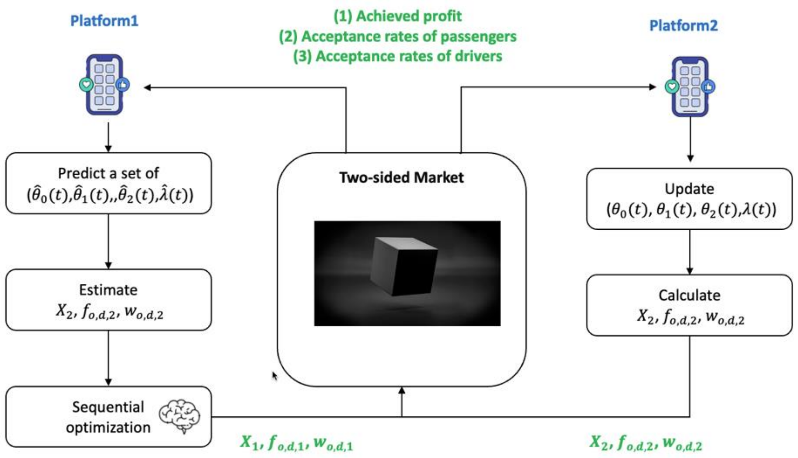
Keywords

Mobility on-demand, Ride-sourcing, Two-sided market

The intraday competition in a duopoly ride-hailing market

Yue Yang, Mohsen Ramezani

- Analyzes **intraday competitive strategies** between two ride-hailing platforms in a duopoly, where passengers and drivers multi-home across platforms.
- Formulates the platform competition as a **repeated game**, considering perfect information, limited information, and dynamic competitor strategies.
- Models passenger and driver choices via **discrete choice models**, incorporating preferences over fare, wage, pickup time, and travel time.
- Uses bandit algorithms like **UCB and DUCBDT (Discounted UCB with Dynamic Tuning)** to adapt to incomplete or changing market conditions.
- Shows through simulations that **adaptive strategies significantly improve profit and matching rates**, even under dynamic competitive environments.



Keywords

Inter-platform competition, Two-sided market, Multi-homing, Two-player games

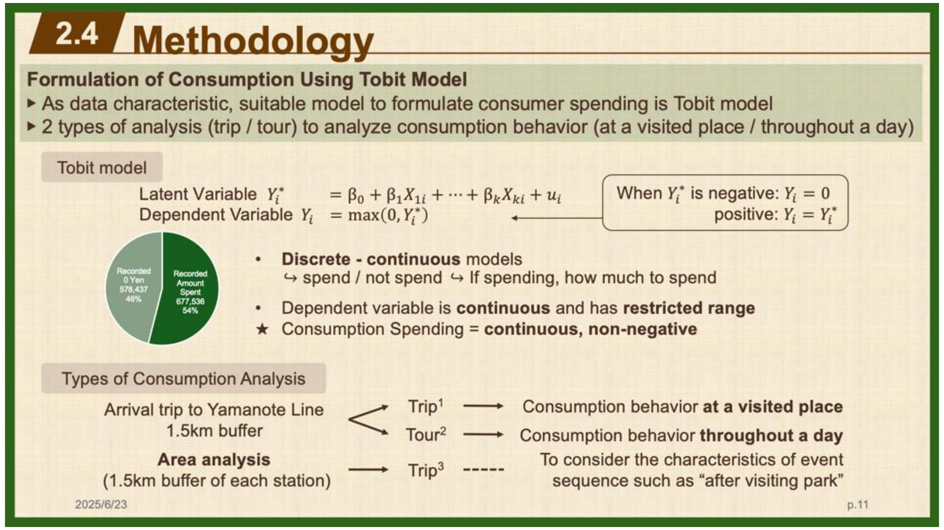
A Study on the Tour and Consumption Behavior at Station Areas in Considering the Green Coverage

Anju Kawazu and Kuniaki Sasaki (Waseda University)

- Integrates the 2018 Tokyo Person-Trip survey with GIS-extracted green-coverage inside a 1.5 km buffer of every Yamanote-line station.
- Tobit models show evening travel, park proximity, and moderate greenery (10–30 %) significantly raise spending.
- Travellers exposed to greenery make more trips (3.8 vs 2.7) and spend about ¥1,500 extra per day.
- Spending also grows with age, small groups (1-3 people), and a higher number of trips per tour.
- Comparing nine station areas confirms greenery boosts consumption everywhere, but coverage above 35 % lowers it—likely due to reduced retail density.

Keywords

Green Coverage, Person-Trip survey, Tobit model



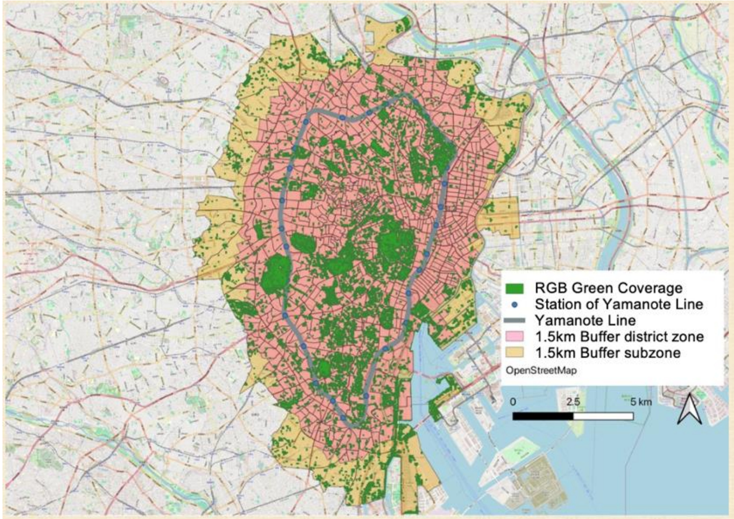


Figure 1 – *Study Area (1.5km Buffer of Yamanote Line)*

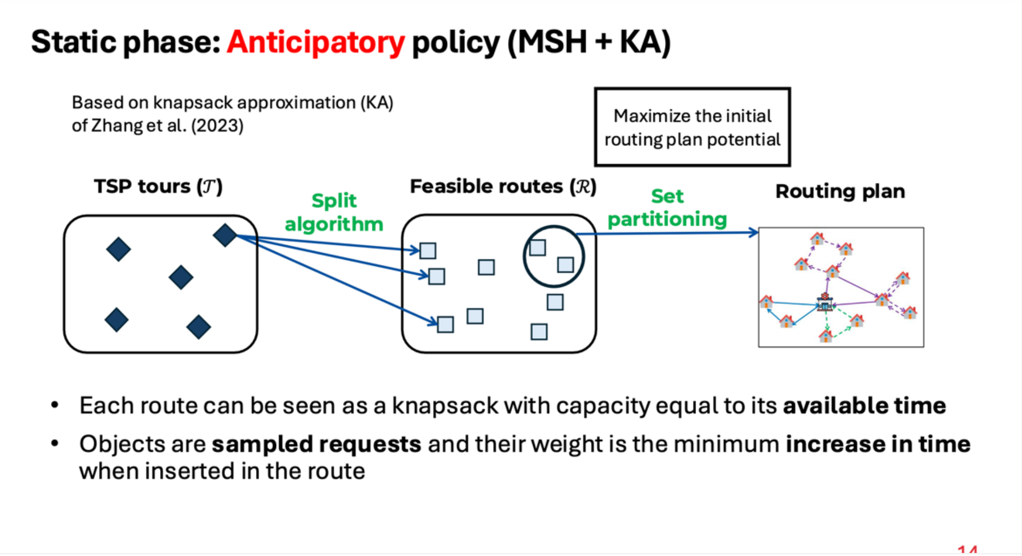
The Dynamic Park-and-loop Routing Problem

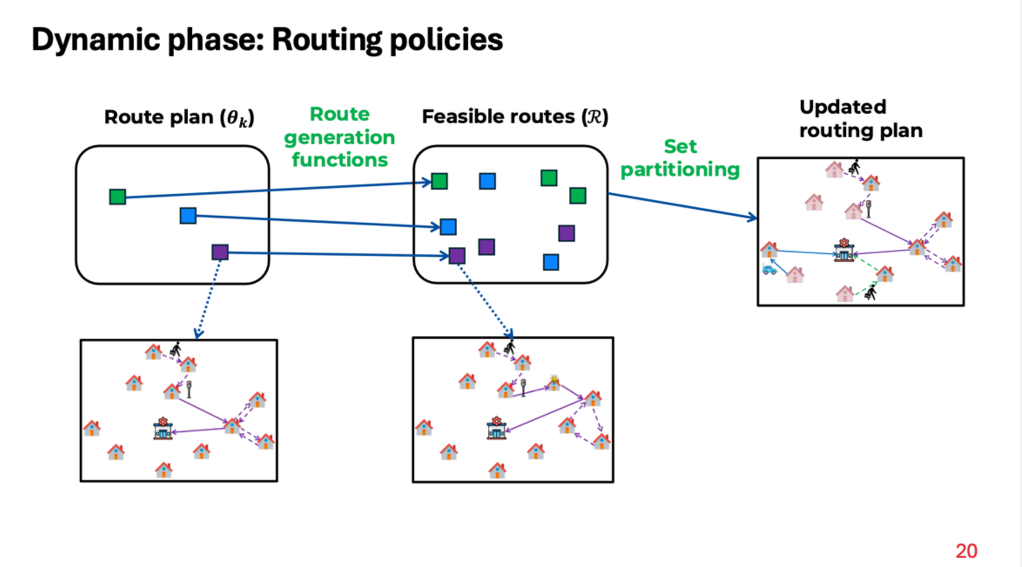
Jean-François Cordeau, Nicolas Cabrera, and Jorge Mendoza
(HEC Montréal)

- Defines Dynamic Park-and-Loop Routing Problem (DPLRP), letting utility crews park a van and walk “loops” to serve **both scheduled and on-demand jobs**.
- Casts the task sequence as an offline–acceptance–online decision process that updates routes whenever new requests arrive. This process is represented as a Markov Decision Process.
- Static Phase: Builds on a multi-space sampling heuristic (MSH). Also based on (multi) knapsack approximation (KA) with Anticipatory policy.
- Dynamic Phase: best-insertion vs split-based samplers plus myopic and anticipatory assemblers give flexible re-routing.
- Derives a complete-information upper bound; the best policy attains most of this limit, confirming near-optimal performance.

Keywords

Dynamic Park-and-Loop Routing Problem, Markov Decision Process, multi-space sampling heuristic, knapsack approximation





A Model-Based Approach to Vacant Vehicle Routing of a Ride-Sourcing Fleet in Transportation Networks

Vehicle Routing Problem 1

Guocheng Jiang, Song Gao (University of Massachusetts Amherst)

- Formulates the ride-sourcing vehicle repositioning problem using the **infinite-horizon semi-Markov decision process (SMDP)**.
- Model-based analytical approach for the long-term matching equilibrium.
- SMDP represents **the holding time before each transition**.
- Proves **the existence and uniqueness** of a stationary distribution for the SMDP with endogenous state-transition probabilities
- The endogenous transition prob is calculated using the fixed-point algorithm.
- A parametrized, closed-form reward function enables the finding of optimal parameters, thereby maximizing the average reward.

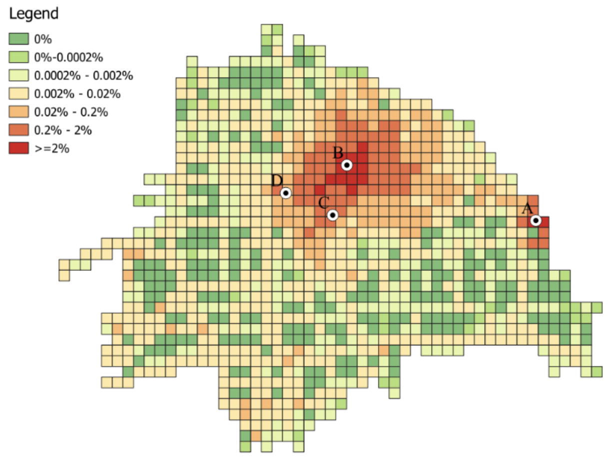


Figure 1 – *Stationary Distribution of Vacant Vehicles with Fleet Size 10000 (7:30am-9:30am)*

stationary distribution

$$\phi_s(\vartheta) = \frac{\mu_s(\vartheta)\mathbb{E}[t_s(\vartheta)]}{\sum_u \mu_u(\vartheta)\mathbb{E}[t_u(\vartheta)]} = \frac{\mu_s(\vartheta)(\tau_s+m_s(\vartheta)\omega_s(\vartheta))}{\sum_u \mu_u(\vartheta)(\tau_u+m_u(\vartheta)\omega_u(\vartheta))}$$

Keywords

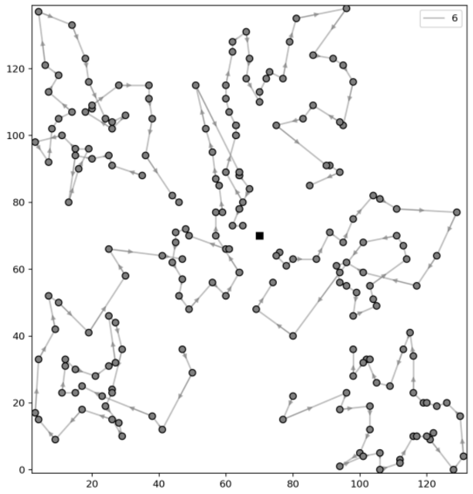
Semi-Markov Decision Process, Matching, Vehicle repositioning,

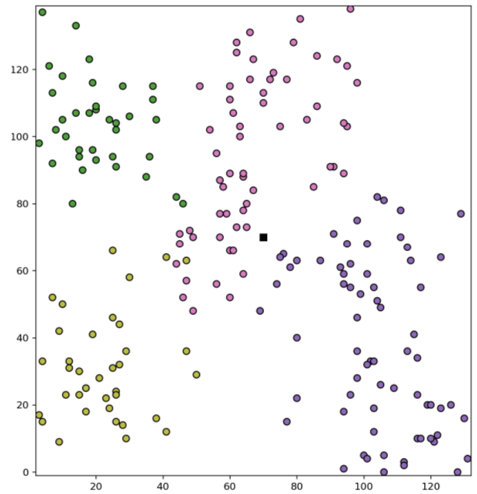
Decomposition and Set Covering Strategies for Large-Scale Heterogeneous Vehicle Routing Problems

Vehicle Routing Problem 1

Christoph Kerscher, Stefan Minner, Fabien Lehuédé, Guillaume Massonnet

- A matheuristic framework combining **decomposition, metaheuristics, and set covering to solve large-scale heterogeneous VRP with time windows.**
- **Fuzzy c-medoids clustering** for customer- and route-based decomposition, enabling overlapping subproblems and better route diversity in densely populated areas.
- Integrates existing metaheuristics (e.g., PyVRP) to solve subproblems and constructs a **set covering problem (SCP)** to select the optimal combination of routes.
- Achieves **high scalability**, solving instances with over 800 customers in under 10 minutes while finding 42 new best-known solutions across benchmark datasets.
- Maintains **solution quality stable** even as problem size increases, with mean optimality gaps around 2–3% compared to existing best-known solutions.





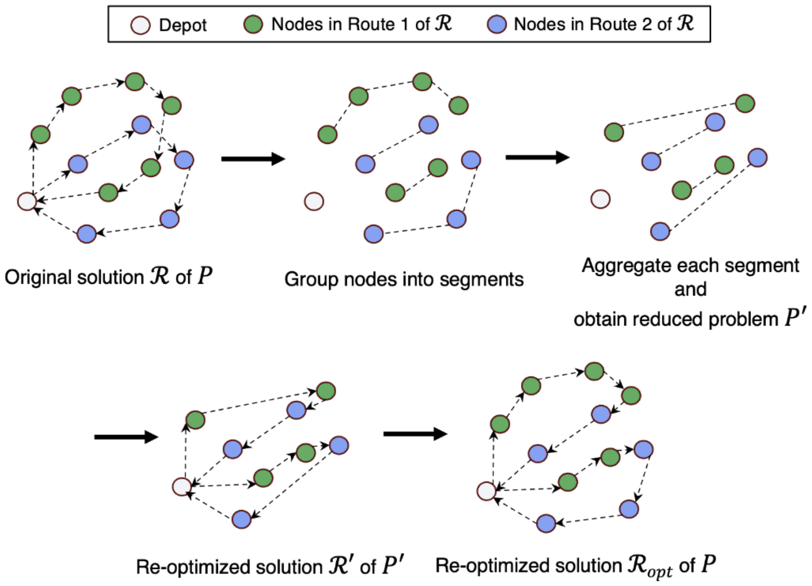
Keywords

Heterogeneous vehicle routing, Matheuristic, Set covering, Decomposition

Learning to Segment for Capacitated Vehicle Routing Problems

Wenbin Ouyang, Sirui Li, Yining Ma, Cathy Wu

- **L2Seg**, a novel machine learning framework that predicts stable segments in VRP solutions to reduce redundant search and accelerate iterative optimization.
- Introduces a generic **First-Segment-Then-Aggregate (FSTA)** technique that partitions stable segments into hypernodes, reducing problem size while preserving solution quality.
- Designs a specialized **graph neural network (GNN) and transformer architecture** to estimate edge re-optimization probabilities at different search stages.
- Demonstrates that L2Seg accelerates state-of-the-art VRP solvers (e.g., LKH-3, LNS, L2D) by up to **32%** and also improves solution quality on CVRP instances with up to 5,000 customers.



Keywords

Vehicle Routing, Machine Learning, Neural Combinatorial Optimization

Inverse Optimization for Dynamic Vehicle Routing

Pedro Zattoni Scroccaro , Peyman Mohajerin Esfahani , and Bilge Atasoy
(Delft University of Technology, The Netherlands)

- In **Inverse Optimization (IO)** problems, our goal is to model the behavior of an expert agent, which given an exogenous signal, returns a response action.
- IO learns a dispatching policy from data given a **dynamic vehicle routing problem with time windows (DVRPTW)** where requests appear in the system dynamically.
- The training of the IO approach is handled through a training algorithm given in Algorithm 2: **Stochastic first-order algorithm.**
- The proposed approach is promising to tackle dynamic vehicle routing problems without relying on deep learning techniques which necessitate a thorough tuning of the involved parameters.

Keywords

inverse optimization, dynamic routing, prize-collecting VRP, dispatching policy

Algorithm 1 DVRPTW scenario

for $t = 1, \dots, T$ **do**
  Set of available customers: A_t
  Choose $x_t \subseteq A_t$ customers to dispatch
  New customers: w_{t+1}
  Update set of available customers: $A_{t+1} = (A_t \setminus x_t) \cup w_{t+1}$
end for
Total cost: $\sum_{t=1}^{T} c(x_t)$.

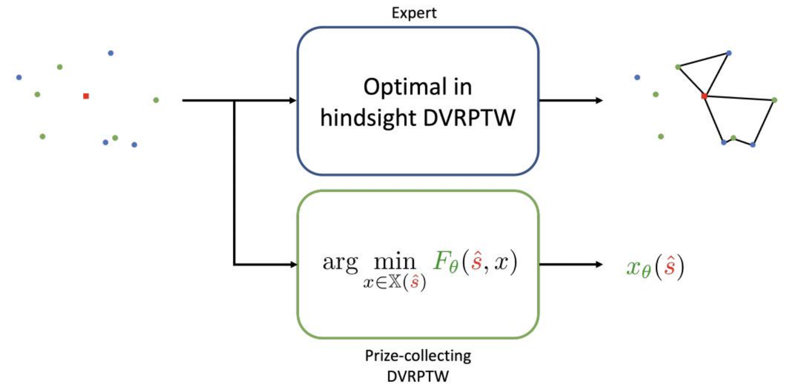


Figure 1 – *Illustration of the IO approach on dynamic VRP*

Algorithm 2 Stochastic first-order algorithm

Input: $\theta_1 \in \Theta$ and $\mathcal{D} = \{(A_t, x_t^\star)\}_{t=1}^{T}$.
for $k = 1, \dots, N$ **do**
  Sample example: $(A_k, x_k^\star)$
  $x_k \in \text{FOP}(\theta_k, A_k)$
  $g_k = \sum_{z_{ik} \in A_k \setminus x_k^\star} z_{ik} - \sum_{z_{ik} \in A_k \setminus x_k} z_{ik}$
  $\theta_{k+1} = \theta_k - \eta_k g_k$
end for

Quantile-based Sequential Learning and Optimization for Contextual Stochastic Vehicle Routing

Vehicle Routing Problem 2

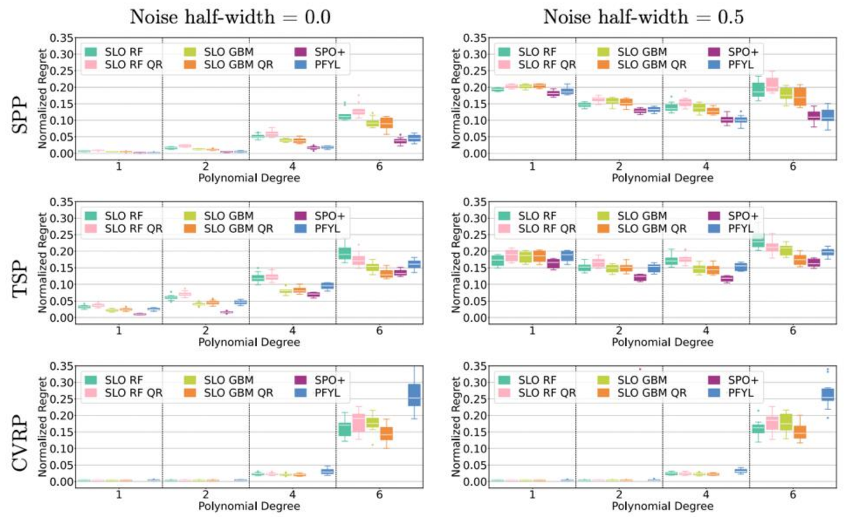
Nele Bertling , Michael Römer and Kevin Tierney (Bielefeld University, Germany)

- Propose a quantile-based **SLO(sequential learning and optimization)** approach that predicts a quantile instead of the expected values of the uncertain parameters in the first stage of the SLO method.
- Using PyEPO, implement and compare various SLO and ILO methods for the **capacitated vehicle routing problem (CVRP),** which to the best of our knowledge has not yet been done.
- The experimental results show, that the quantile-based SLO approach **generally outperforms** the classical expected value-based SLO approaches.

Keywords

contextual stochastic optimization problems, vehicle routing, sequential learning and optimization, integrated learning and optimization, quantile regression

Table 1 – *Experimental results for SPP, TSP and CVRP. For each problem, 10 experiments are conducted using a training dataset of 100 instances and evaluated with the normalized regret of the test datasets with 1000 instances. The uncertain costs (Eq. (3)) vary with different polynomial degrees and noise half-widths.*



Time-Dependent Vehicle Routing Problem in Subway-Assisted Delivery Systems

Vehicle Routing Problem 2

Yu Yao , Pengli Mo (Hohai University, Southeast University)

- Introduction of the **TDVRP-SA** that integrates urban ground transportation with subway networks to address the growing complexity of urban logistics.
- Development of a **branch-price-and-cut algorithm** to efficiently solve the TDVRP-SA and an innovative two-step technique employed to accelerate the algorithm.
- Execution of extensive computational experiments using extended Solomon benchmarks, demonstrating the **effectiveness of the subway-assisted delivery system** in reducing distribution costs and providing actionable insights for urban logistics planning.

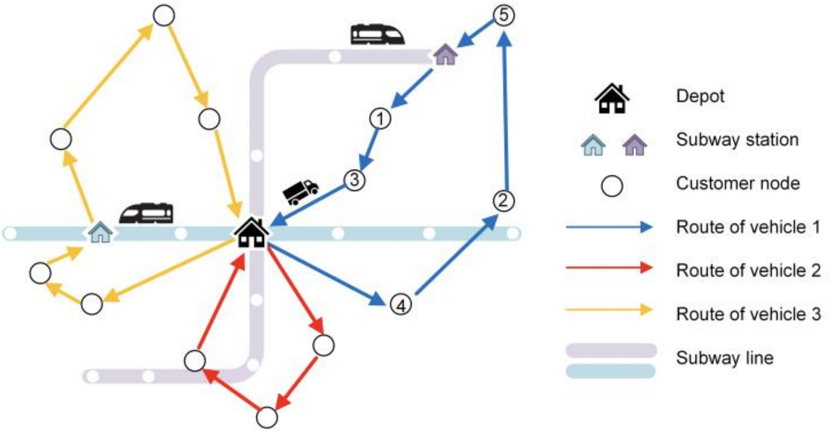
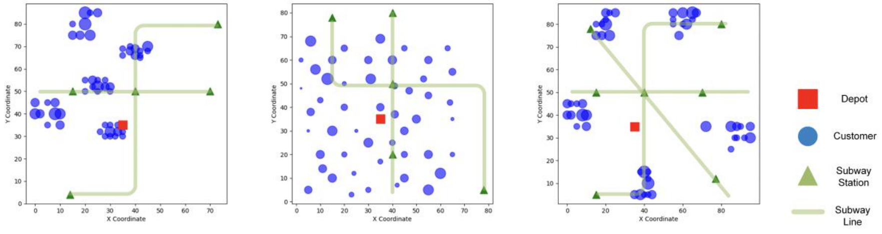


Figure 1 – *Illustration of TDVRP-SA*



(a) C101-50+I (b) R101-50+II (c) RC101-50+III

Figure 3 – *Illustrations of customer type and subway station layout combinations*

Keywords

Urban Logistics, Time-Dependent Vehicle Routing Problem, Subway-Assisted Delivery, Mixed-Integer Linear Programming

A deep attention model for solving vehicle routing problems with uncertain parking availability

Zhenjun Tian, Zhaoxia Guo, Feng Guo, Mouna Bamoumen, Jan Fransoo

- Introduces a **Time-Dependent VRP with uncertain parking availability.**
- Proposes the **AM-GA^{3}M model**, an **advanced attention-based NN** integrating Node-Type-Specific Attention and Residual Attention mechanisms.
- The Node-Type-Specific Attention improves differentiation between **customer nodes and parking nodes**, crucial due to their geographical proximity and feature similarity.
- Residual Attention mechanisms enhance **information propagation across network layers**, avoiding performance degradation in deep architectures.
- AM-GA^{3}M scales effectively, solving hundreds of thousands of instances.

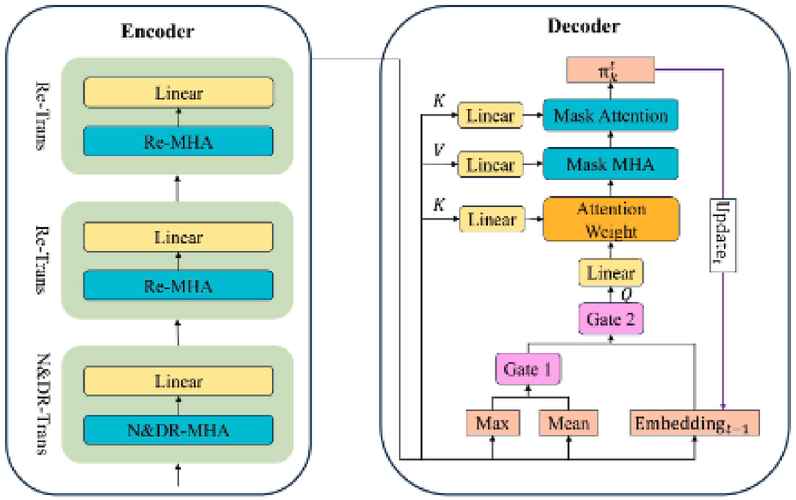


Figure 1 – *Architecture of the AM-GA^{3}M*

Keywords

Deep learning, Vechile routing, Parking availability

Fast Shapley Value approximation in routing problems through machine learning models

Vehicle Routing Problem 3

Pirmin Fontaine, Johannes Gückel

- Addresses the **computational intractability of exact Shapley Value calculations** in routing problems like TSP and CVRP, crucial for fair cost or CO_2 allocation.
- Proposes a **machine learning–based Shapley Value Approximator (MLSVA)** trained offline to rapidly estimate Shapley Values for new routing instances.
- Uses **instance- and customer-specific features** (e.g., distance to depot, marginal cost) as ML inputs, achieving high approximation accuracy with minimal computation.
- Achieves an average **MAPE of ~2.4% for TSP**, outperforming classical methods (e.g., depot-distance heuristics) and matching or exceeding the SHAPO state-of-the-art.
- Demonstrates that the model scales well to larger instances by using **heuristic labels** during training, enabling practical real-time applications.

Keywords

Costs allocation, Machine learning, Vehicle routing problem, Traveling salesman