

Pick-Up Drop-Off (PUDO) location network design for on-demand ride-pooling with walking legs

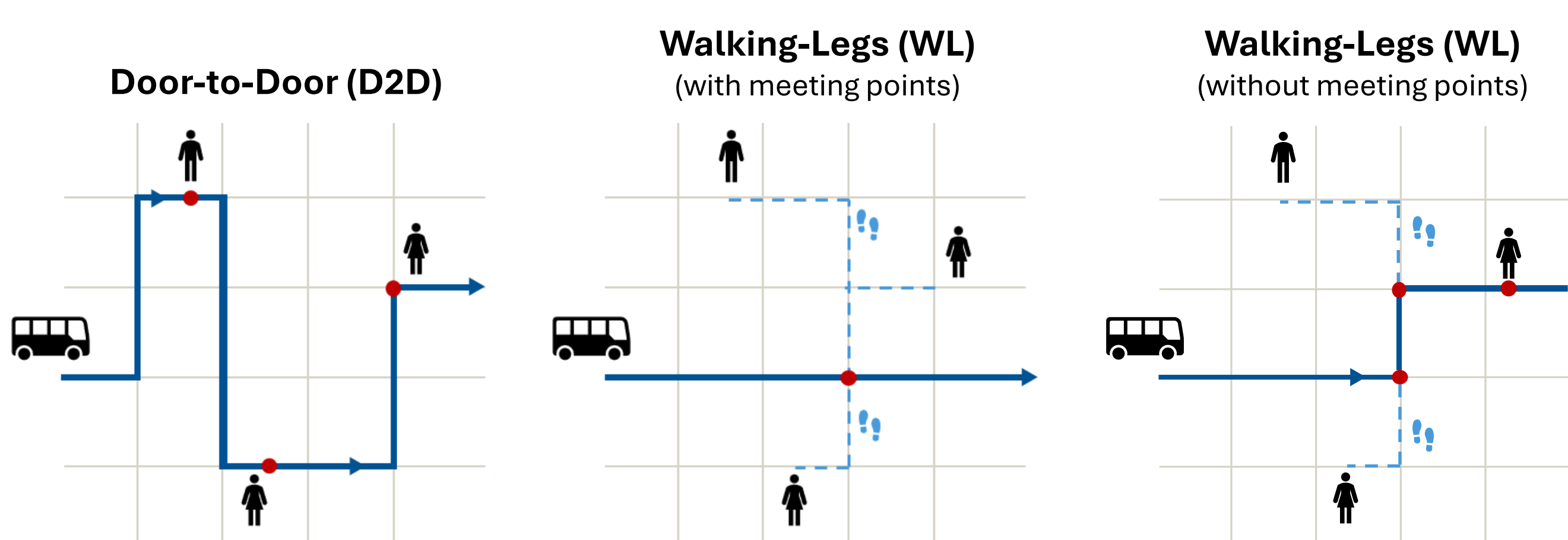
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Background

Mobility-on-Demand (MoD) Ride-Pooling services:

- Users request a ride between two points via a smartphone app
- They are served by an unscheduled fleet
- Multiple requests can be combined simultaneously in a vehicle

Different strategies regarding PUDO location:



Walking Legs (WL) without meeting points:

- Passengers may be asked to walk to/from a nearby PUDO location
- PUDO locations can be static (pre-defined) or dynamic (flexible)
- **Benefits** compared to D2D services [1,2,3,4]:
 - Decrease in:
 - vehicle detours
 - vehicle-km-travelled (VKT)
 - energy consumption and emissions
 - noise immisions
 - operational costs
 - Increase in vehicle utilization and n. of served requests
 - Possible to equip stops with infrastructure (e.g., shelter, lighting, ...)
- **Drawbacks:**
 - Travel time and/or waiting time may slightly increase
 - Walking increases disutility for users

Motivation & Problem Description

Despite its benefits, WL services present important **challenges** [5]:

- Each request can have multiple candidate PUDO locations
- This increases the solution space for the request-vehicle assignment
- Exact algorithms only feasible for very small instances
- **Trade-off:**
 - ↑ candidates per request: better quality of the solution
 - ↓ candidates per request: reduced computational complexity

Previous research tackled this problem by:

- Solving sub-problems sequentially (1. assignment, 2. PUDO location)
- Reducing the n. of candidate stops (in a random or simplified way)

Core Idea of this Research

Design framework that strategically:

- identifies areas where WL may be less effective
- optimizes number and placement of PUDO locations within a city

Resulting network is:

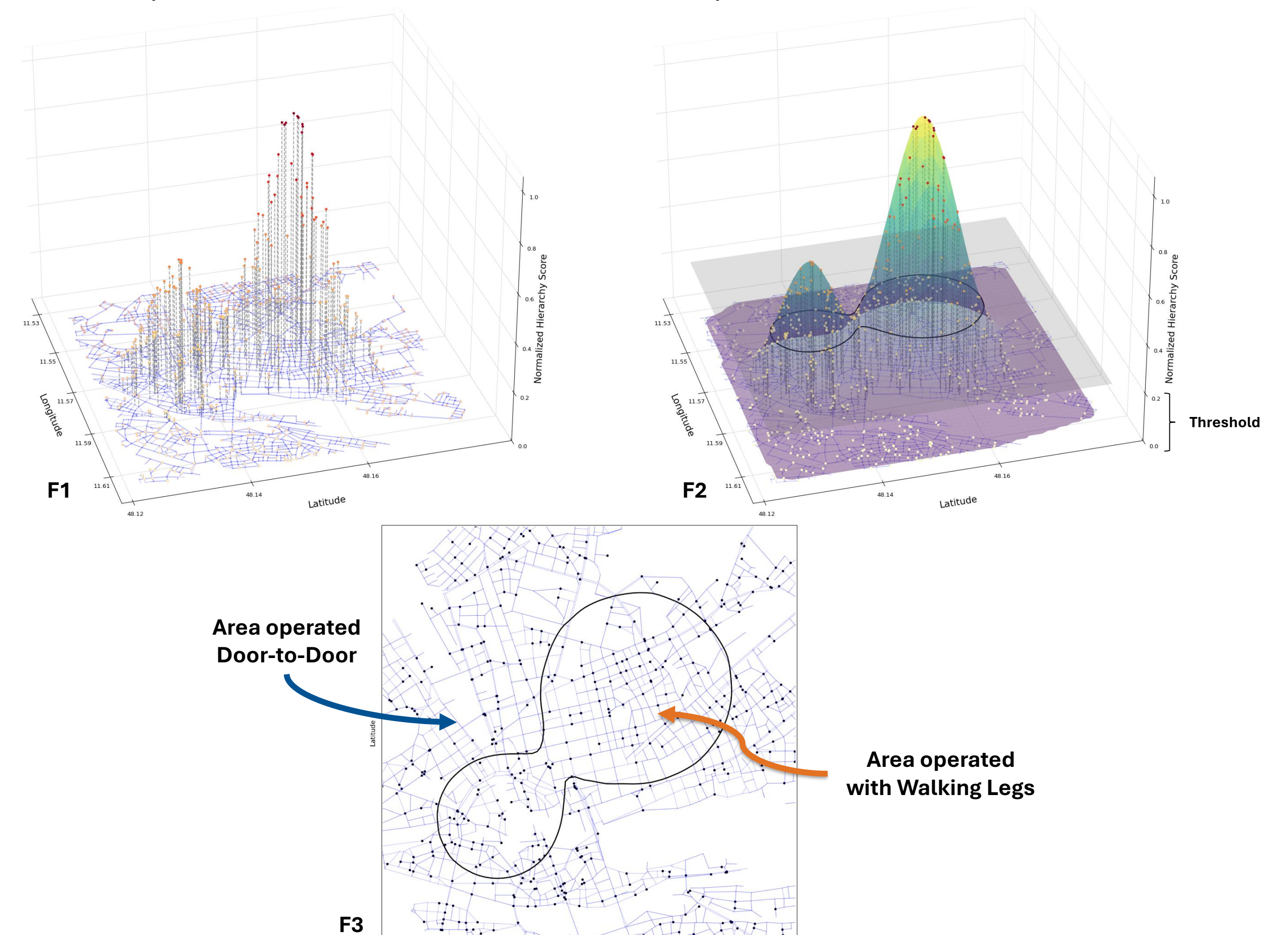
- less dense, supporting faster computations
- maintains good spatial availability & enhances trip-sharing potential

Methodology

Our approach builds on the *simulation-based* “*hierarchy score*” concept, inspired by Fielbaum and Alonso-Mora [6].

Seven-step process:

1. Simulate the operation of a MOD provider serving large, representative demands, using open-source simulation framework *Fleetpy*
2. Define an initial set of candidate locations (e.g., all urban intersections and/or *Points of Interest* decided by the planner)
3. Calculate a *hierarchy score* for each candidate location (the number of MOD vehicles flowing through it) [F1]
4. Spatial aggregation and smoothing of the hierarchy score [F2]
5. Selection of regions suitable for services with WL or D2D, based on a *hierarchy score* threshold [F2-F3]
6. In WL-regions, optimize subset of stops that maximizes total hierarchy scores while minimizing candidates, s.t. spatial availability constraints
7. Use of resulting PUDO-network with existing request-assignment algorithms (both exact and heuristics-based)



Hierarchy scores and candidates shown in these figures are synthetic (randomly drawn, not the result of a simulation)

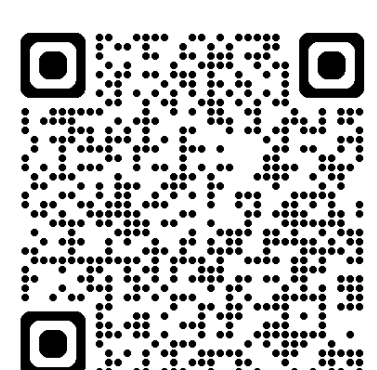
Future Steps

Evaluation of the results based on:

- KPIs for the operator (VKT, operational costs, % of served requests, ...)
- Level-of-Service to passengers (in-vehicle, waiting and walking times)
- Computation time

We will conduct a sensitivity analysis on different:

- Aggregation and smoothing methods
- Hierarchy-threshold values
- City structures (Munich, Manhattan, Chicago)
- Demand levels



[1] Sarma et al (2023) On-demand Ride-pooling with Walking Legs: Decomposition Approach for Dynamic Matching and Virtual Stops Selection.
[2] Engelhardt and Bogenberger (2021): Benefits of Flexible Boarding Locations in On-Demand Ride-Pooling Systems
[3] Zwick et al. (2021): Agent-based simulation of city-wide autonomous ride-pooling and the impact on traffic noise

[4] Fielbaum et al. (2021): On-demand ridesharing with optimized pick-up and drop-off walking locations.
[5] Wang et al. (2022): On Optimizing Shared-ride Mobility Services with Walking Legs.
[6] Fielbaum and Alonso-Mora (2024): Design of mixed fixed-flexible bus public transport networks by tracking the paths of on-demand vehicles