Ride-pooling meets network science

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2019-2022: PostDoc @ TU Delft working in Critical MaaS team of prof. Oded Cats

- shared rides (this talk)
- agent based model MaasSim

PhD: Modelling Rerouting Phenomena in DTA (with prof. Guido Gentile, Rome)

previously:

- R&D software developer (PTV SISTeMA)
- transport modeller (models for Kraków, Warsaw and more)
- data scientist (NorthGravity)

CRITICAL MAAS
lab Smart Public Transport

Background

Introduction

Shared ride:

1. two or more travellers can be matched into a shared a ride and travel in the same ride-hailing vehicle.
2. vehicle picks them up from origins and drops-them off at their destinations,
3. both pickup and travel times deviate from the desired or minimal ones,
4. this inconvenience needs to be compensated with a lower fare compared to an individual ride,
5. service provider can now:
   - better utilise its capacity
   - charge several users for a ride
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Method

Problem statement

Match trips to attractive shared-rides.

1. Identify attractive shared rides (subsets of sequentially visited trips' origins and destinations).
2. Optimally match trips to shared rides

Problem - complexity

	degree:	1	2	3	4	5	6	7
search space:	theoretical	3.00×10^{3}	3.60×10^{7}	6.47×10^{11}	1.55×10^{16}	4.65×10^{20}	1.67×10^{25}	7.01×10^{29}
	explored	3000	8997000	1807	226	123	24	0
	attractive	3000	5270	243	130	76	8	0

Solution

1. define attractive shared-ride
2. identify pairwise shareable trips and build shareability graph (directed, multigraph)
3. explore the graph gradually exploiting rides of increasing degree
4. optimally assign trips to rides.

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Attractive shared-rides

Attractive shared-ride

Shared-ride is attractive if and only if detour and delay are compensated with lower fares for all sharing travellers.

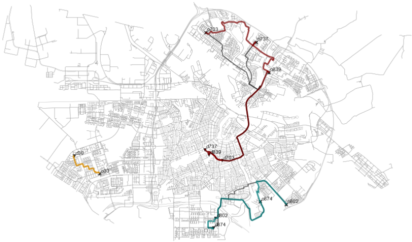
Utilities

non shared ride: $U_i^{ns} = \lambda^{ns} l_i + \beta^t t_i + \varepsilon$, where:

- λl_i distance-based fare
- β^t value-of-time
- t_i non-shared travel time
- ε random term

shared-ride: $U_{i,r}^s = \lambda^s l_i + \beta^t \beta^s (\hat{t}_i + |\hat{t}_i^p - t_i^p|) + \varepsilon$, where:

- β^s willingness-to-share
- $\hat{t}_i + \beta^d(\hat{t}_i^p - t_i^p)$ detoured and delayed shared time



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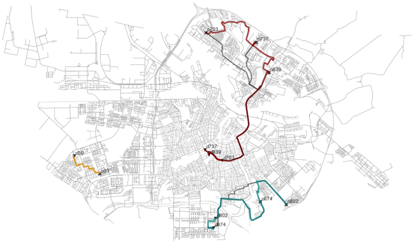

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Shared rides is attractive if

$$U_i^s > U_i^{ns}$$

$$U_{i,r} = U_{i,r}^s - U_i^{ns} =$$

$$\lambda l_i + \beta^t (t_i - \beta^s (\hat{t}_i + |\hat{t}_i^p - t_i^p|)) + \varepsilon > 0$$

interplay between:

- λ discount
- $\hat{t}_i + \beta^d (\hat{t}_i^p - t_i^p)$ detour and delay
- β^s willingness-to-share
- β^t value-of-time

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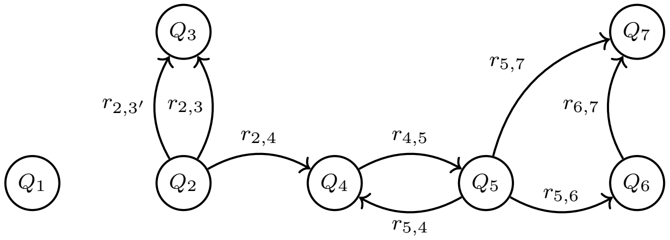
Shareability graph

topology

Shareability directed multigraph:

1. nodes are trips Q,
2. directed edges are pairwise shareable rides $r_{i,j}$,
3. two kinds of edges: FIFO and LIFO (denoted $r_{i,j'}$)



Trip-ride assignment

optimally matching trips to shared-rides

Problem: Determine set of rides

1. such that each trip is assigned to exactly one ride
2. yielding minimal costs:

$$\min \quad C_R(x_r) = \sum_{r \in \mathbb{R}} c_r x_r \tag{1a}$$

$$\text{subject to} \quad \sum_{i \in \mathbb{Q}} I_{i,r} x_r = 1, \tag{1b}$$

$$x_r \in \{0, 1\}. \tag{1c}$$

Trip-ride incidence

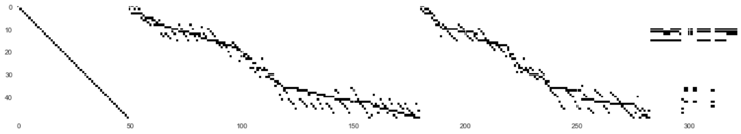


Fig. Trip-ride incidence matrix $I_{m,r}$ for 50 trips and 320 rides, rows denote trips and columns denote rides of increasing degree (number of trips per ride). Starting with diagonal part of single rides, followed with FIFO pairwise shared rides, LIFO pairwise shared rides and finally triplets.

Method summary

Method:

1. explicitly considering only attractive shared-rides,
2. exact search, no heuristics,
3. hierarchical, yet complete search,
4. applicable to real-size demand sets.