Ride-sharing with Inflexible Drivers in the Paris Metropolitan Area

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Outline

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Motivations

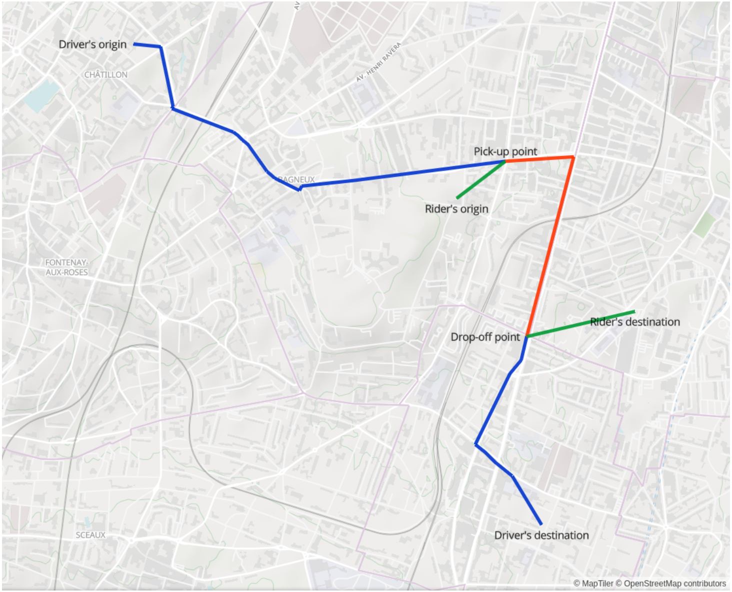
- **Low vehicle occupancy**, especially for commuting trips (1.05 persons per vehicle on average for commuting trips in Île-de-France, EGT, 2010)
- Increasing vehicle occupancy would decrease **congestion** and **pollution**
- The French government is **subsidizing ridesharing drivers** (up to 100 euros for new drivers)
- What would be the impact of a large-scale development of ridesharing?

Ridesharing Scheme

We propose the following ridesharing scheme:

- Drivers keep their chosen route and departure time (**no detour** and **same schedule**)
- Drivers can be compensated by **state subsidies** for the (small) inconvenience cost of having someone in their car
- Riders **walk** from origin to a **pick-up point** and from a **drop-off point** to destination
- The trip is **free-of-charge** for the riders
- The **matching** between drivers and riders is centralized

Example


Driver's origin
CHÂTILLON
AV. HENRI RAVERA
Pick-up point
BAGNEUX
Rider's origin
FONTENAY-AUX-ROSES
Rider's destination
Drop-off point
Driver's destination
SCEAUX
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Results

We propose a methodology to evaluate the impact of such a ridesharing scheme, with an application to the **Île-de-France** region using the transport simulator **METROPOLIS**.

Results with 30 % of people willing to participate in the scheme:

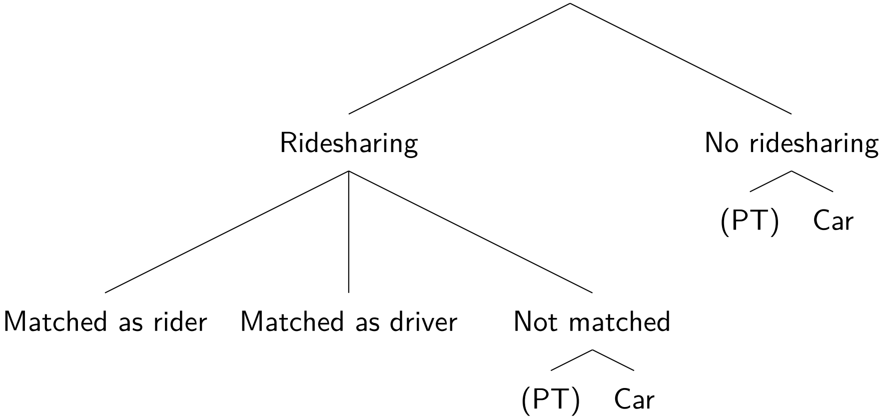
- **Ridesharing share:** 3.3 %
- Average **walking time** (for riders): 4 minutes and 53 seconds
- Variation of **mileage:** decrease of 204 000 vehicle-kilometers (2.2 %)

Outline

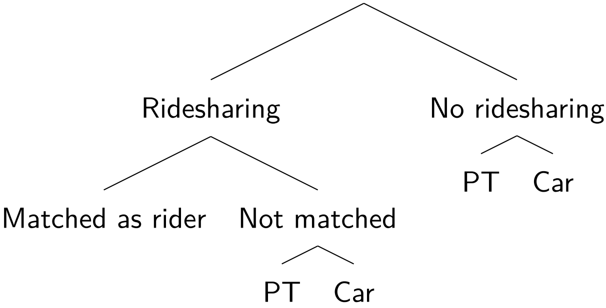
Four-Step Procedure

1. We run a simulation of **METROPOLIS without ridesharing** to identify the routes and departure times chosen
2. We compute the **ridesharing costs** for any pair of agents participating in the ridesharing scheme
3. We find the **optimal matching** (Linear programming algorithm)
4. We run a new simulation of **METROPOLIS, excluding the riders**, to get aggregate results (e.g., congestion level, mileage, mode shares)

Choices for former car drivers



Choices for former public-transit users



METROPOLIS

- **Mesoscopic dynamic transport simulator**
- **Mode choice** between car and public transit (nested Logit model)
- **Departure-time choice** (continuous Logit model)
- **Route choice** (deterministic, minimum travel time)
- Choices are based on the **generalized travel cost**

Generalized Travel Cost

The generalized travel cost by car includes **in-vehicle cost** and **schedule-delay cost** (α-β-γ model):

$$Cost_{\text{car}} = \underbrace{\alpha_{\text{car}} \cdot tt_{\text{iv}}}_{\text{In-vehicle cost}} + \underbrace{\beta \cdot [t^* - t_a]^+ + \gamma \cdot [t_a - t^*]^+}_{\text{Schedule-delay cost}}$$

- tt_{iv}: travel time (in-vehicle)
- t_a: arrival time
- t^*: desired arrival time
- α_{car}: value of time in the car
- β: penalty for early arrivals
- γ: penalty for late arrivals
- $[x]^+ = \max(0, x)$

Ridesharing Cost

The generalized travel cost for riders also includes **walking cost**:

$$Cost_{\text{RS}} = \underbrace{\alpha_{\text{car}} \cdot tt_{\text{iv}}}_{\text{In-vehicle cost}} + \underbrace{\alpha_{\text{walk}} \cdot tt_{\text{walk}}}_{\text{Walking cost}} + \underbrace{\beta \cdot [t^* - t_a]^+ + \gamma \cdot [t_a - t^*]^+}_{\text{Schedule-delay cost}}$$

- tt_{walk}: walking time (from origin to pick-up and from drop-off to destination)
- α_{walk}: walking value of time

Optimal Matching

The optimal matching is obtained by solving the following **linear programming problem:**

$$
\begin{cases}
\min\limits_{x_i, x_{i,j}} & \sum_i \left[x_i \cdot Cost_{NoRider}(i) + \sum_j x_{j,i} \cdot Cost_{Rider}(i,j) \right] \\
\text{s.t.} & x_i + \sum_j x_{j,i} = 1, \quad \forall i \\
& \sum_j x_{i,j} \leq x_i, \quad \forall i \\
& x_i \in \{0,1\}, \quad \forall i \\
& x_{j,i} \in \{0,1\}, \quad \forall (i,j)
\end{cases}
$$

- $Cost_{NoRider}(i)$: travel cost of i when not a rider (car or public transit)
- $Cost_{Rider}(i,j)$: ridesharing cost of i when matched with driver j
- $x_i = 1$ if i travels by car or public transit (0 otherwise)
- $x_{j,i} = 1$ if j is a driver for i (0 otherwise)

Outline

1. Introduction
2. Methodology
3. Application to Île-de-France
4. Conclusion

Data

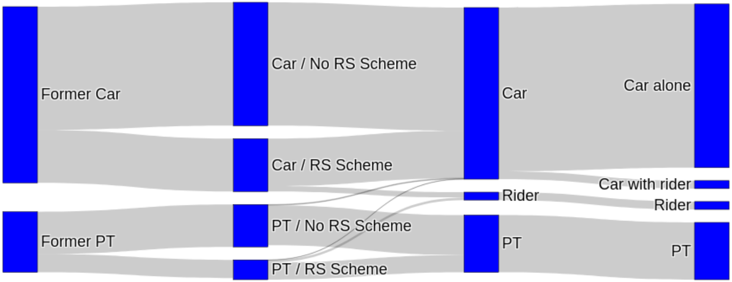
- **Morning peak-period**
- Network: 43 857 links, 18 584 intersections and 1360 OD zones
- Demand: 934 042 trips by car or public-transit (commute and non-commute)
- Calibration of METROPOLIS from Saifuzzaman et al., 2012 (EGT 2001)

Assumptions

- A **fixed share of people are willing to participate in the ridesharing scheme** (as either a driver or a rider): 10 %, 20 %, 30 % and 40 % scenarios are tested
- The walking distance between an origin / destination and an intersection is the **euclidian distance**
- Walking speed is set to **4 km/h**

Mode Shifts

Mode shifts in the 30 % scenario:



Detailed results

Aggregate Results

Scenario	Ref.	10 %	20 %	30 %	40 %
Shares					
Transit modal share	25.5 %	25.3 %	24.8 %	24.3 %	23.9 %
Car modal share	74.5 %	73.9 %	73.2 %	72.4 %	71.5 %
Ridesharing modal share	0.0 %	0.9 %	2.1 %	3.3 %	4.6 %
Surplus					
Total generalized cost (euros)	—	−72 763	−187 686	−305 683	−427 401
CO_2 emissions reduction (tons of CO_2)	—	11.387	21.809	39.372	57.900
Road network					
Congestion	22.1 %	21.7 %	21.4 %	20.6 %	19.8 %
Car VKT (10^3 km)	10 799	10 740	10 686	10 595	10 499

Drivers' Results

Scenario	Ref.	10 %	20 %	30 %	40 %
Mean travel time	15' 32''	15' 31''	15' 32''	15' 27''	15' 22''
Mean schedule-delay cost (euros)	2.67	2.67	2.67	2.67	2.65
Mean travel cost (euros)	6.03	6.02	6.02	6.00	5.97
Share of time spent with a passenger (for ridesharing drivers only)	—	51.5 %	56.1 %	58.0 %	59.8 %

Riders' Results

Scenario	**Ref.**	10 %	20 %	30 %	40 %
Mean OD distance (meters)	—	5491	5972	6205	6425
Mean walking distance (meters)	—	383	347	325	310
Mean car travel time	—	7' 21"	8' 00"	8' 20"	8' 38"
Mean travel time	—	13' 06"	13' 12"	13' 13"	13' 17"
Mean travel cost (euros)	—	3.26	3.24	3.22	3.22
Riders at their best match	—	76.7 %	69.3 %	65.0 %	62.2 %

Multiple Passengers: Aggregate Results

Passengers per driver	1	2	3
Shares			
Transit modal share	24.3 %	24.1 %	24.0 %
Car modal share	72.4 %	71.9 %	71.8 %
Ridesharing modal share	3.3 %	4.0 %	4.2 %
Surplus			
Total generalized cost (euros)	−305 683	−368 724	−393 185
CO2 emissions reduction (tons of CO2)	39.372	51.145	50.373
Road network			
Congestion	20.6 %	20.1 %	19.6 %
Car VKT (10^3 km)	10 595	10 534	10 538

Note: Assuming 30 % of participation in the ridesharing scheme

Outline

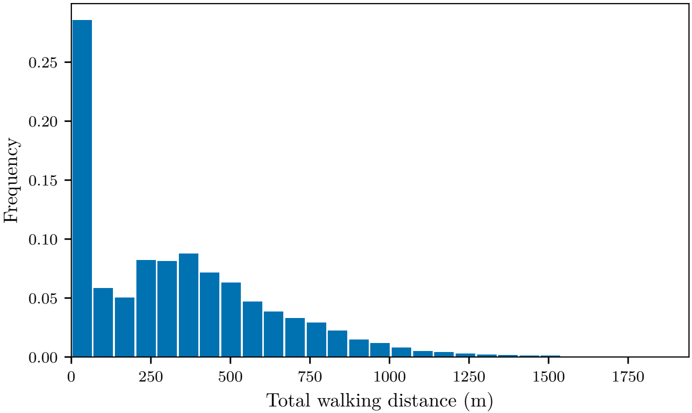
Concluding remarks:

- Ridesharing is an **effective tool to reduce congestion and CO2 emissions**
- Because of **network effects**, state intervention through **subsidies** might be needed to start-up a shift to ridesharing

Future works:

- Allowing drivers to make a **detour**
- Optimal matching minimizing both **individual and social costs** (e.g., CO2 emissions)
- Considering **morning and evening commute** together

Walking Distance



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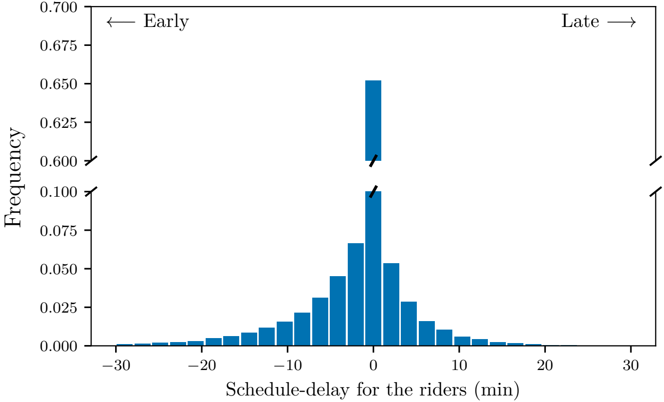
Riders' Schedule-Delay



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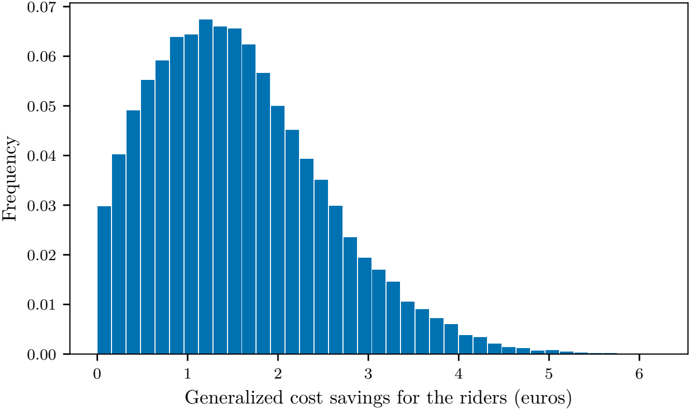
Generalized Cost Savings



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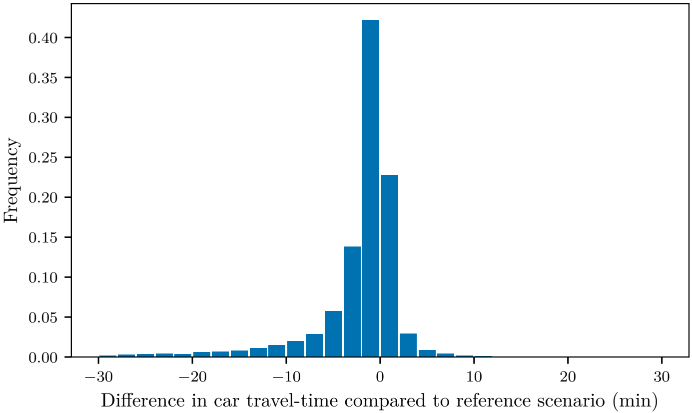
Car Travel-Time Variation



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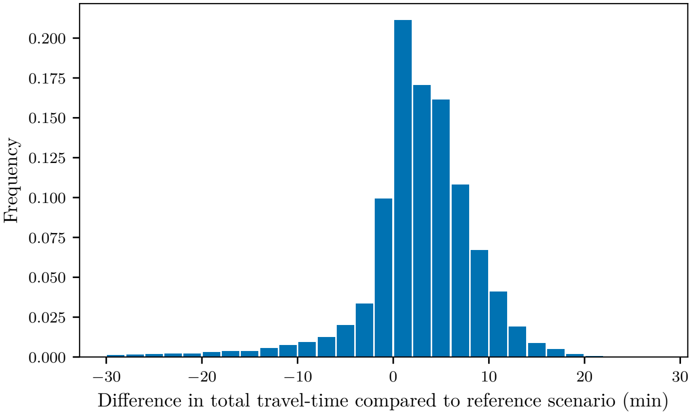
Total Travel-Time Variation



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