

Accounting for intra-household joint travel in agent-based transport simulations

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01 Introduction

- Car **driver** trips generate negative externalities: congestion, CO₂ emissions, local pollution, noise
- Raising **vehicle occupancy** removes driver kilometres while everyone still travels the same distance

Driver (79.0 M km)

Passenger (21.6 M km)

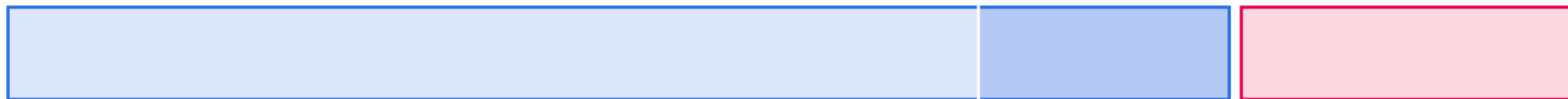


Daily kilometres travelled by car in Île-de-France, 2020. Source: IDF Mobilités-OMNIL-DRIEAT.

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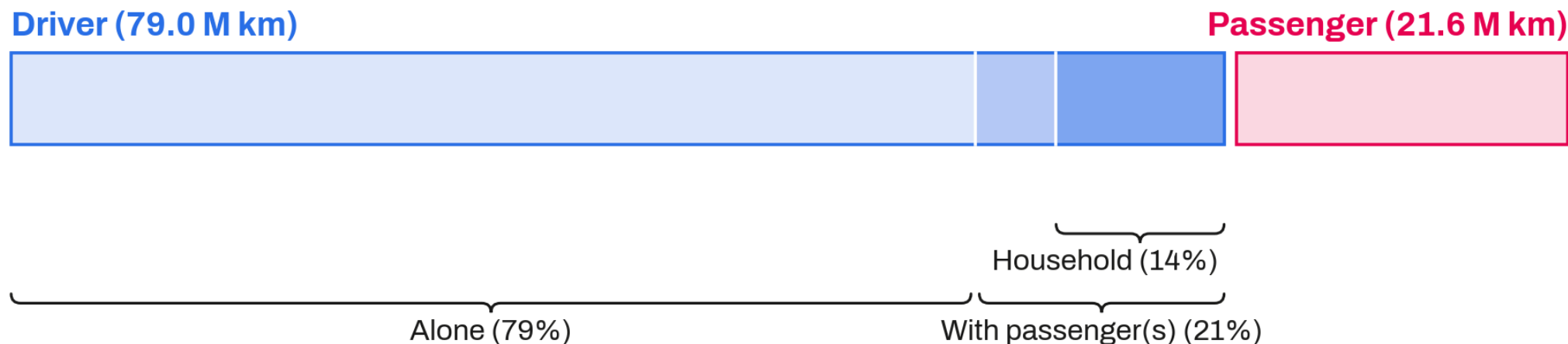


Alone (79%)

With passenger(s) (21%)

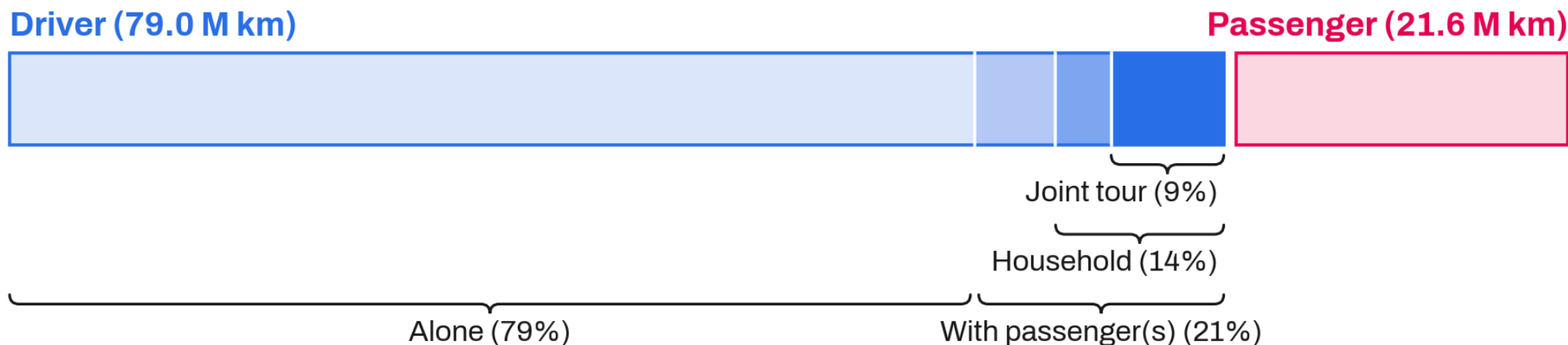
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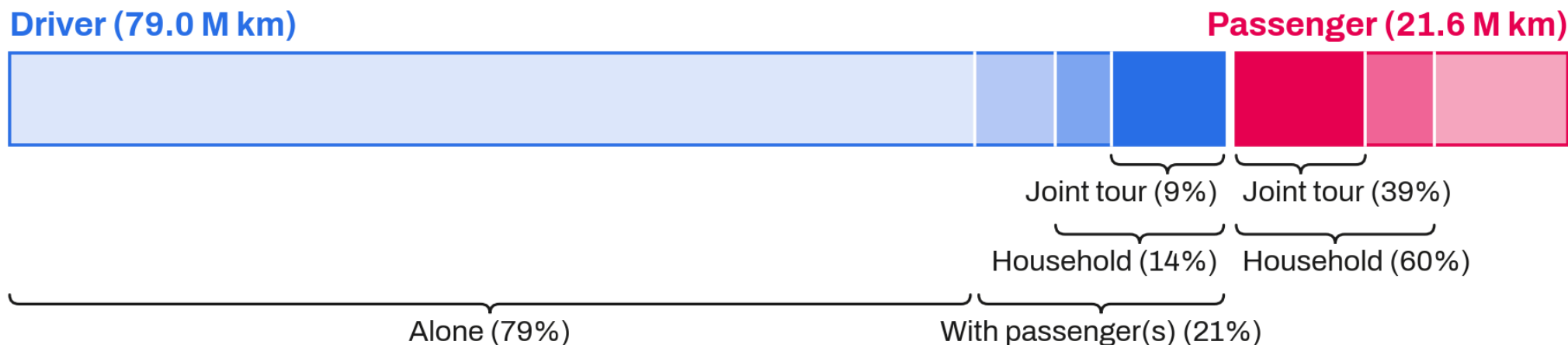
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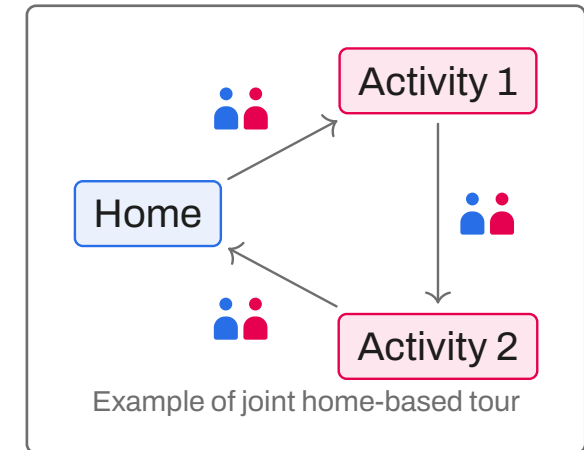
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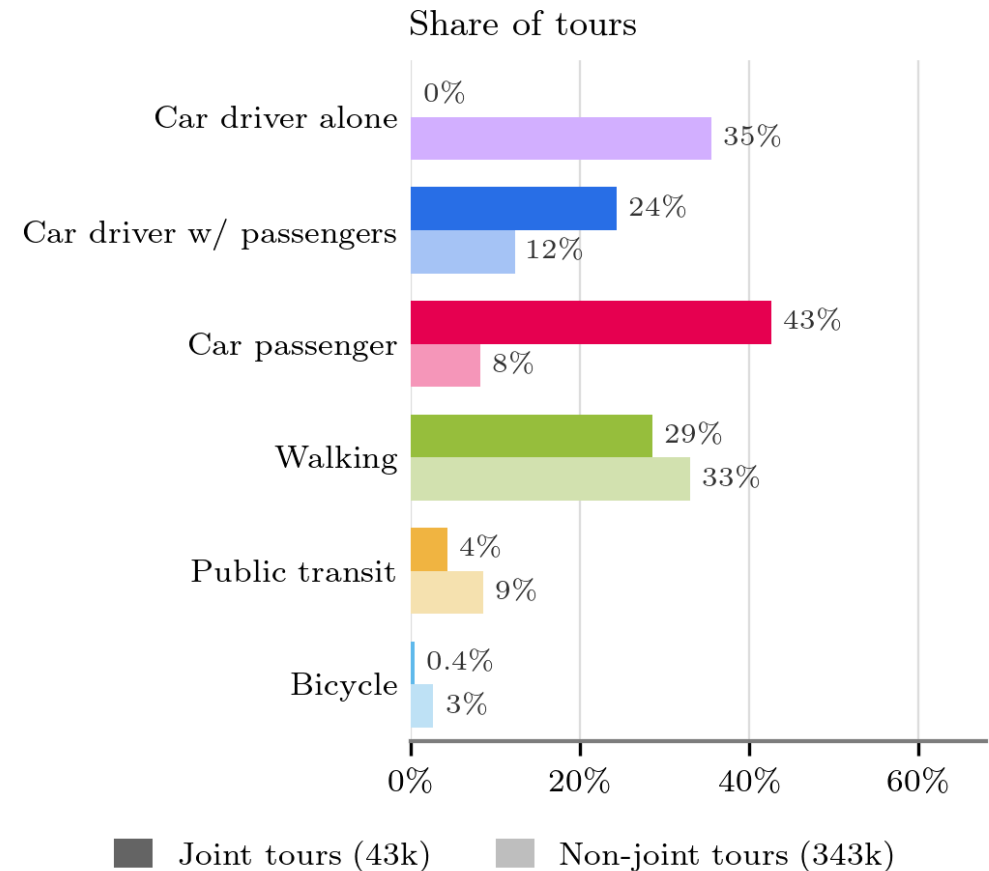
Daily kilometres travelled by car in Île-de-France, 2020. Source: IDF Mobilités-OMNIL-DRIEAT.

- Intra-household **joint home-based tour**: household members leave home together, share one or more activities, and return home together
 - a family shopping trip, dinner as a couple, the park with young children
- About **1 home-based tour in 9** is joint in the Paris household travel survey



Joint tours follow their own mode choice logic

- Their own logic: fuel and tolls are shared but transit fares are not, the walking pace is set by the slowest traveller, and driving alone is not an option
- **Two thirds** of joint tours are made by ridesharing, against **one in five** non-joint tours
- Agent-based simulations still treat them like solo tours → biased preference parameters
- Telling the **forms of ridesharing** apart is what makes it possible to know how to raise vehicle occupancy, and to predict what a policy promoting ridesharing really achieves



Mode shares of joint and non-joint tours in the Clermont-Ferrand household travel survey (weighted), each tour type summing to 100 %.

Econometrics: mode choice of joint travel

Household members travelling together choose their mode differently

Dissanayake & Morikawa (2010); Ho & Mulley (2015); Picard et al. (2018)

→ Behavioural insight, not parameters a simulator can use

Activity-based models: joint activities

Generate and schedule the activities household members share

Gliebe & Koppelman (2002); Bradley & Vovsha (2005); Dubernet & Axhausen (2015); Rezvany et al. (2023)

→ Need a full household activity model: most simulators run on individual activity chains

Policy evaluation: ridesharing incentives

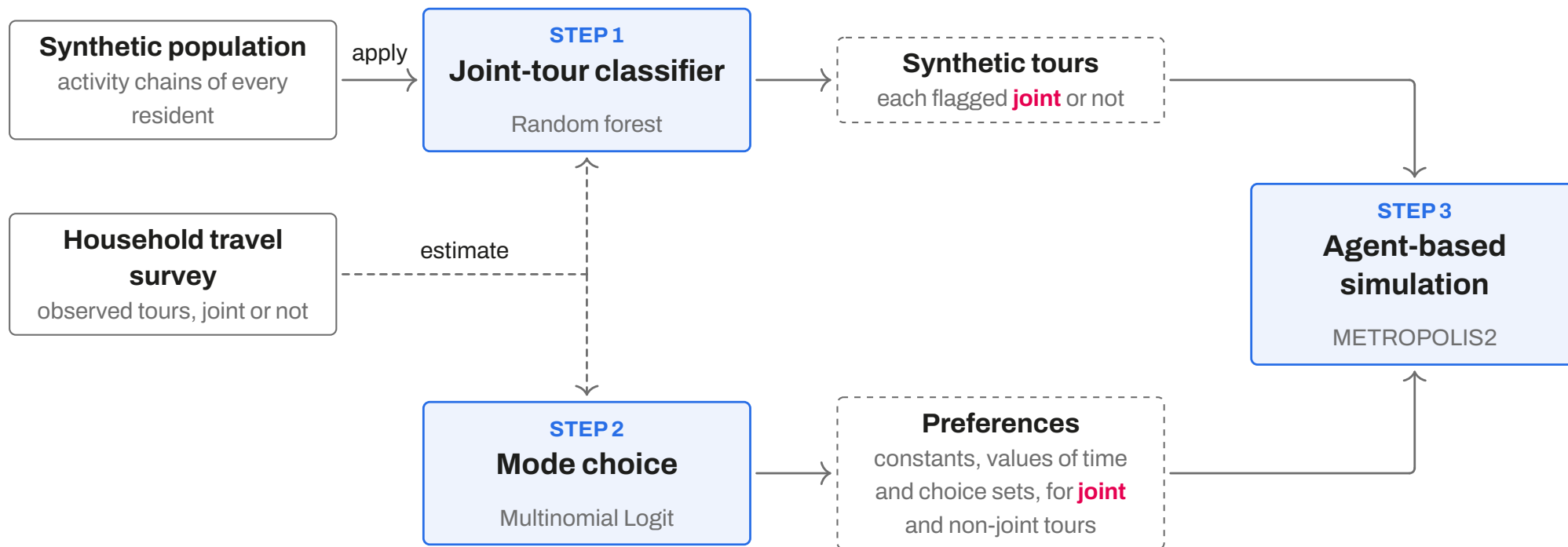
Incentives and HOV lanes to raise vehicle occupancy

Brownstone & Golob (1992); Le Goff et al. (2022)

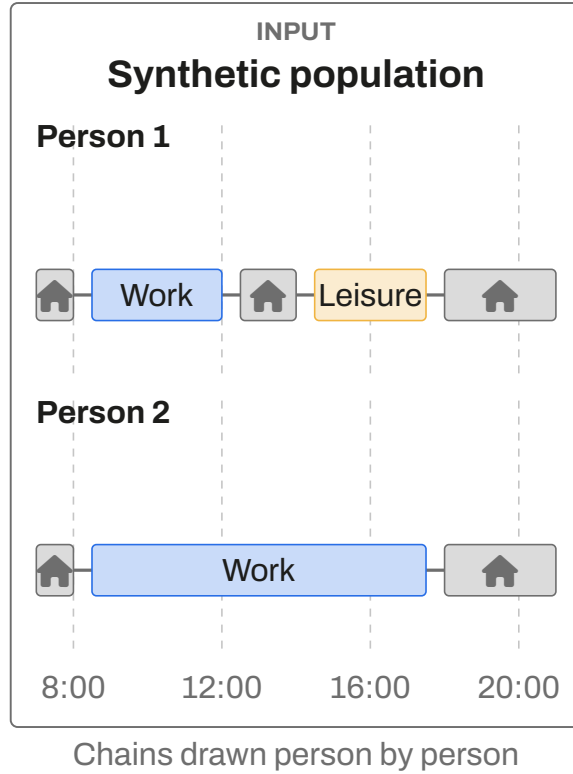
→ Focus on commuters: joint household tours are left out

- **Question:** how can agent-based simulations account for joint tours, and does it change policy predictions?
- **Method:**
 1. classify tours as joint
 2. estimate mode preferences for joint and non-joint tours, with specific choice sets
 3. run an agent-based simulation
 4. simulate and evaluate a **€1 ridesharing subsidy**
- **Illustration:** Clermont-Ferrand (France)
- **Finding:**
 - a joint-blind model **over-estimates the drop in car vehicle-kilometres** by 40 %

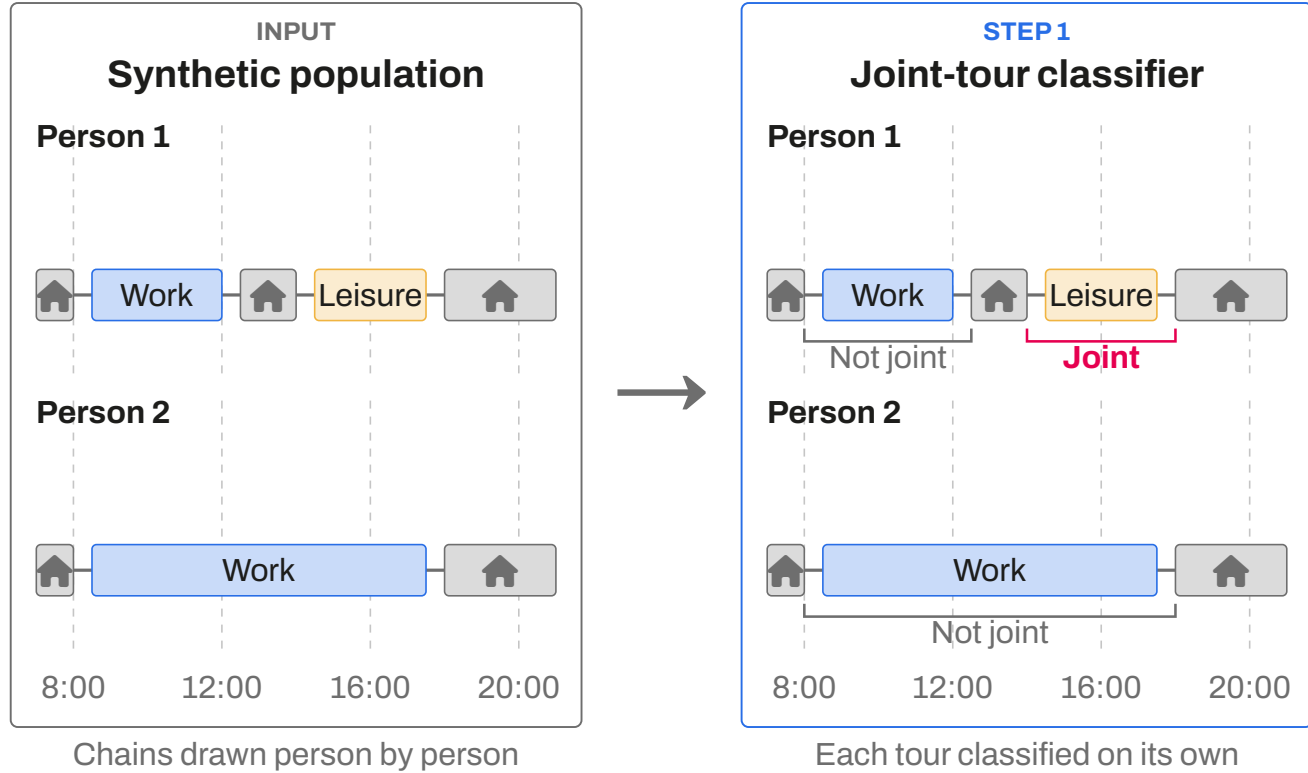
02 Modelling framework



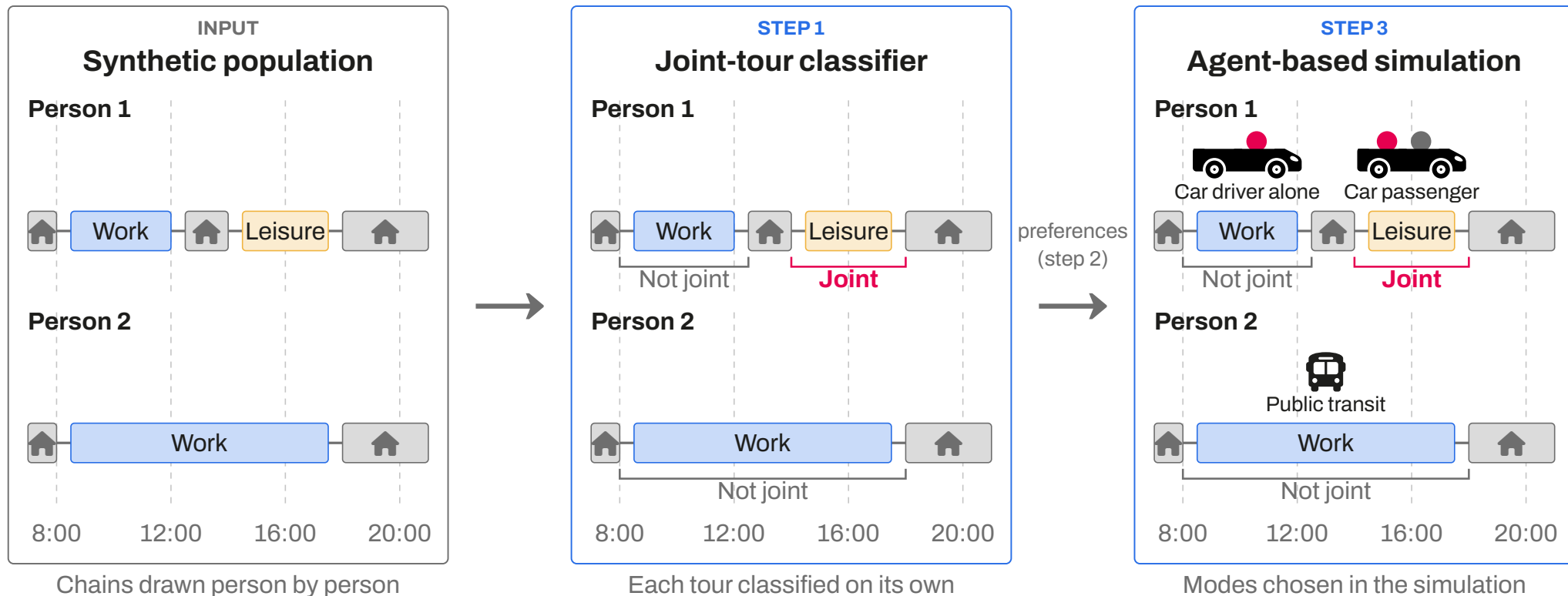
One household through the pipeline



One household through the pipeline



One household through the pipeline



- Nothing ties person 1's **joint** tour to person 2, who is at work all day
- Fine for aggregate results: a car passenger has no matching driver in the simulation, but the difficulty of finding one is captured by the car passenger constant

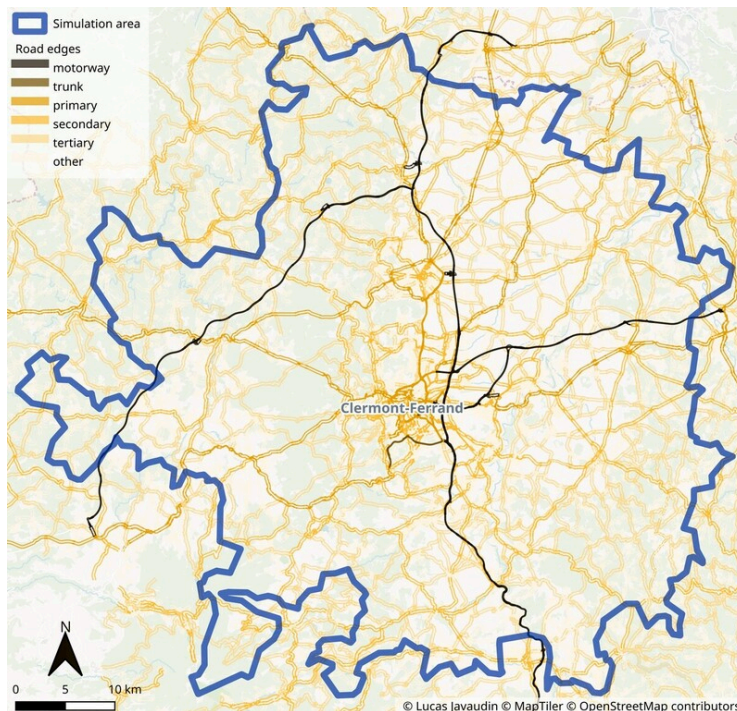
Illustration: Clermont-Ferrand

- Medium-size French city
- Household travel survey from 2023
- Eqasim synthetic population

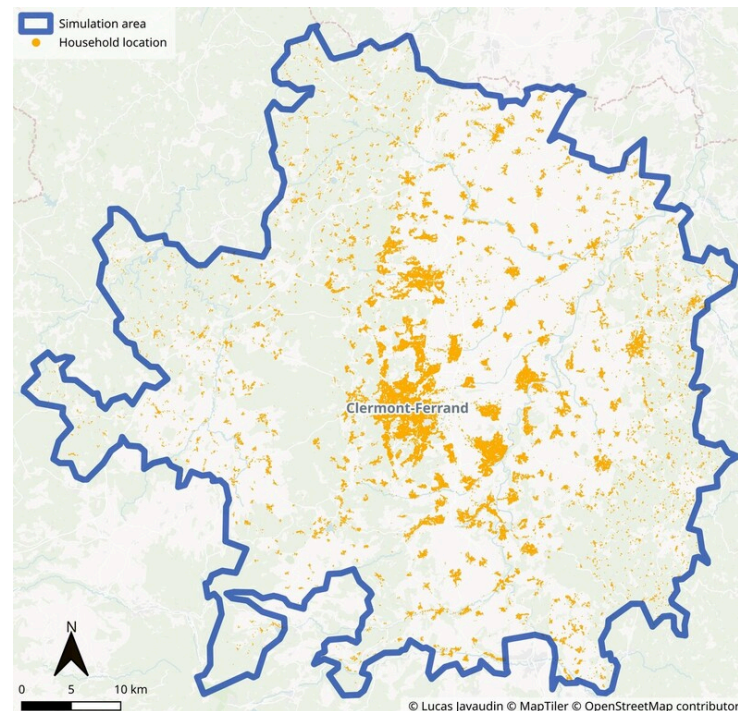
155 000
road edges
26 600
km of roads

264 000
households
643 000
tours

510 000
persons
1 573 000
trips



Road network

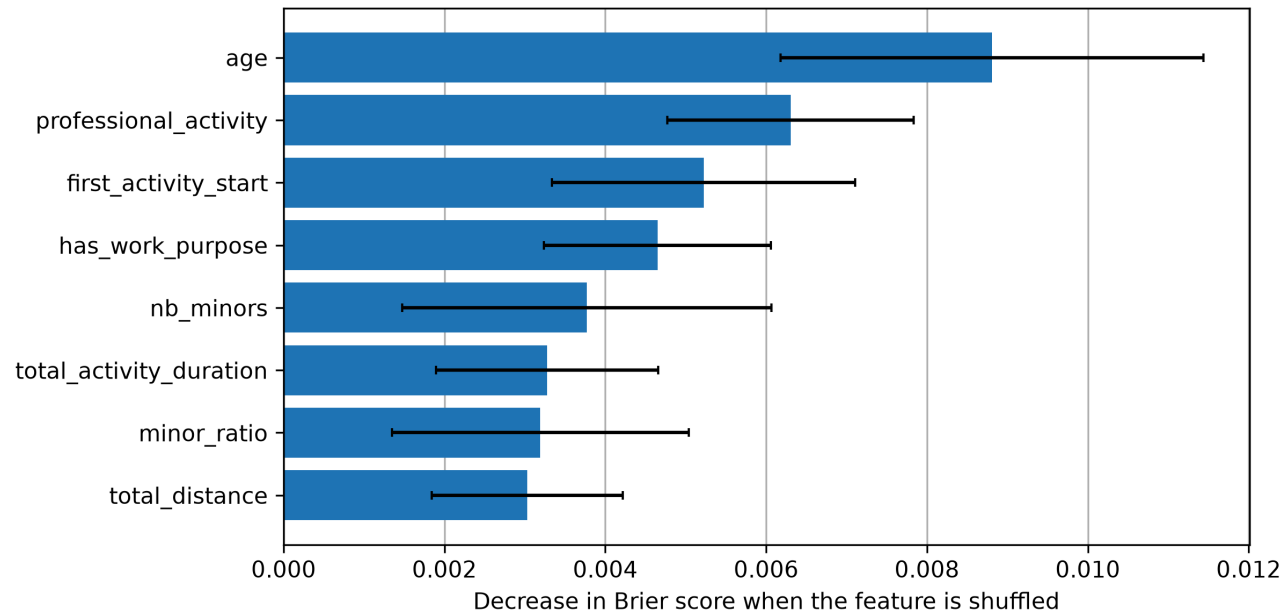


Household locations

- **Assumption**: whether a tour is joint is **inherent to the tour**, and mobility policies do not change it → predicted, not modelled as a choice
- Machine-learning classifier, trained on the survey's home-based tours
 - one-person households are left out: by construction, they cannot make a joint tour
- Applied to the synthetic population to classify tours as joint or not
- Classification is at the **individual** level: the model says a tour is joint, not which household members share it

Step 1 · Joint tour classification: results

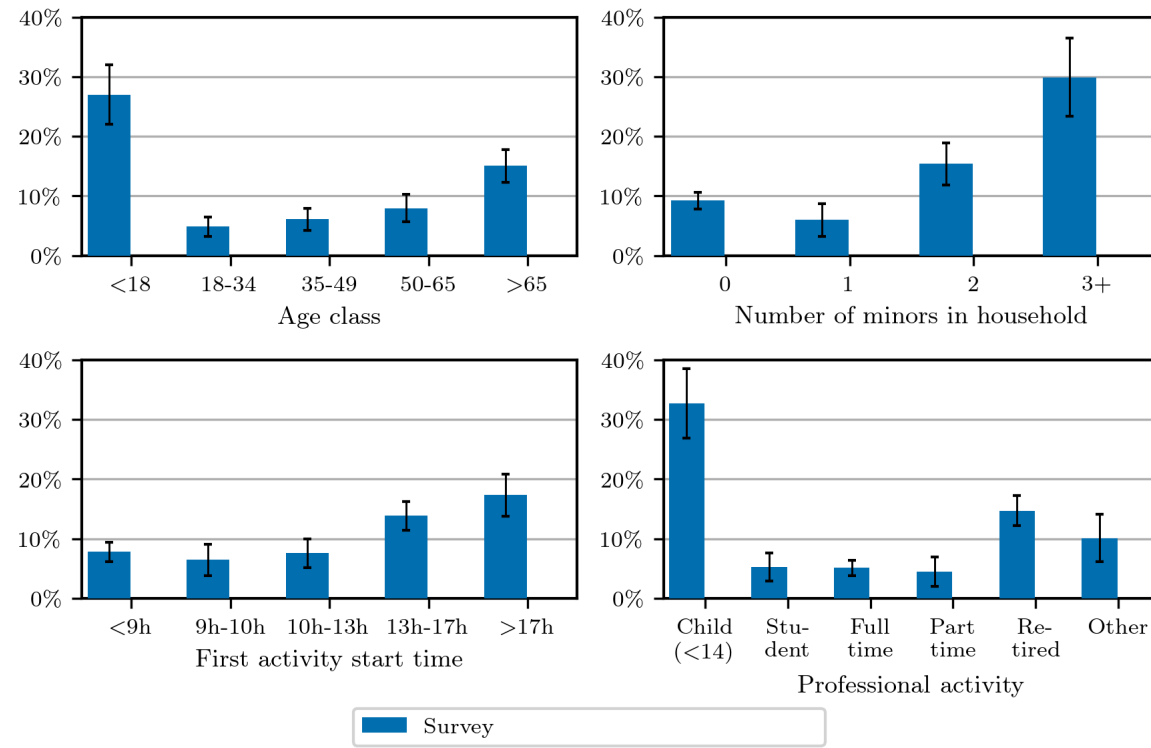
- Survey: 3479 households, 8543 home-based tours, 10.8 % of them joint
- Random forest on 27 features, five-fold cross-validation: Brier score 0.113, the best of the models tested
 - 0.120 for gradient boosting, 0.122 for k-nearest neighbours, 0.123 for a logit, 0.146 for a dummy classifier
- Which features predict joint tours: age, professional activity, when the tour starts, whether it serves work, and the minors in the household



Permutation importance (random forest, 20 shuffles), eight most important features.

Step 1 · Joint tour classification: validation

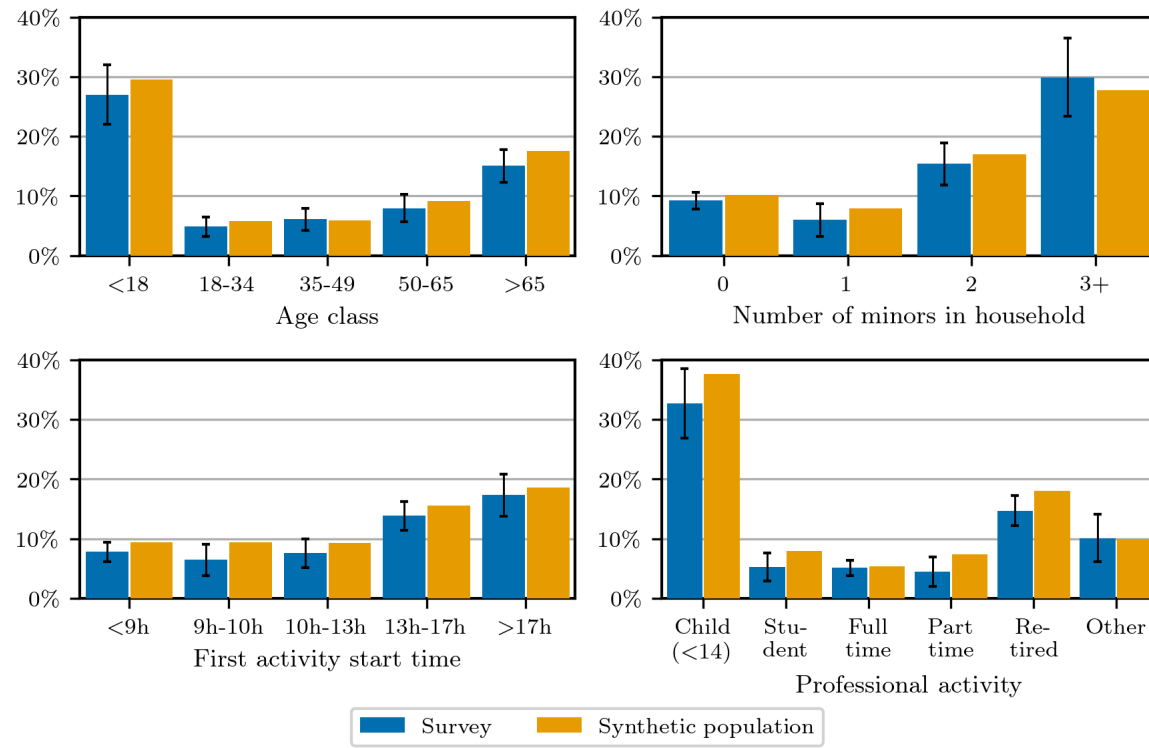
- Joint touring concentrates on **children**, **large households**, **retired** travellers and tours starting **after midday**



Share of tours that are joint in the survey (95 % CI).

Step 1 · Joint tour classification: validation

- Joint touring concentrates on **children**, **large households**, **retired** travellers and tours starting **after midday**
- The classified synthetic population **reproduces the survey well**, class by class



Share of tours that are joint. Survey (95 % CI) against the classified synthetic population.

- Multinomial logit at the **tour** level, since travellers rarely mix modes within a tour
- Six alternatives: bicycle, car driver alone, car driver with passengers, car passenger, public transit, and walking as the reference
- Utilities are converted to euros by setting the average value of time for car drivers alone to 15 €/h
- Two versions, both estimated on all tours: a **baseline**, and one where **joint tour** enters as a dummy that shifts each mode's constant

Step 2 · Mode choice: estimation results

	 Car driver alone	 Car driver w/ passengers	 Car passenger	 Walking	 Public transit	 Bicycle
	Joint- blind	Joint- blind	Joint- blind	Joint- blind	Joint- blind	Joint- blind
Constant	-8.85	-15.26	-28.85	—	-28.60	-32.73
Woman	-0.90 [†]	3.63	2.61	—	5.22	-12.21
Leisure purpose	-27.97	-31.64	-11.56	—	-30.28	-11.49
Shopping purpose	-11.66	-16.97	-7.41	—	-18.36	-11.30
Travel time (€/h)	-8.76	-7.78	-49.90	-27.46	-4.47	-39.18
Woman × travel time (€/h)	-12.31	-18.77	11.03	-0.10 [†]	-1.32	-0.75 [†]

Coefficients in euros, travel-time terms in euros per hour. A dash marks a coefficient that is not estimated; walking is the reference alternative. [†] not significant at the 5 % level. Joint-blind: sample size 8992, $\rho^2 = 0.281$.

Step 2 · Mode choice: estimation results

	 Car driver alone		 Car driver w/ passengers		 Car passenger		 Walking		 Public transit		 Bicycle	
	Joint- blind	Joint- aware	Joint- blind	Joint- aware	Joint- blind	Joint- aware	Joint- blind	Joint- aware	Joint- blind	Joint- aware	Joint- blind	Joint- aware
Constant	-8.85	-9.58	-15.26	-17.65	-28.85	-36.42	—	—	-28.60	-28.64	-32.73	-31.34
Woman	-0.90 [†]	-1.26	3.63	4.36	2.61	4.67	—	—	5.22	5.34	-12.21	-12.77
Leisure purpose	-27.97	-26.35	-31.64	-32.39	-11.56	-12.74	—	—	-30.28	-29.80	-11.49	-10.98
Shopping purpose	-11.66	-9.59	-16.97	-17.82	-7.41	-8.33	—	—	-18.36	-16.77	-11.30	-10.66
Joint tour		—		15.66		28.01		—		-9.52		-24.93
Travel time (€/h)	-8.76	-9.50	-7.78	-7.32	-49.90	-46.14	-27.46	-27.86	-4.47	-4.91	-39.18	-42.60
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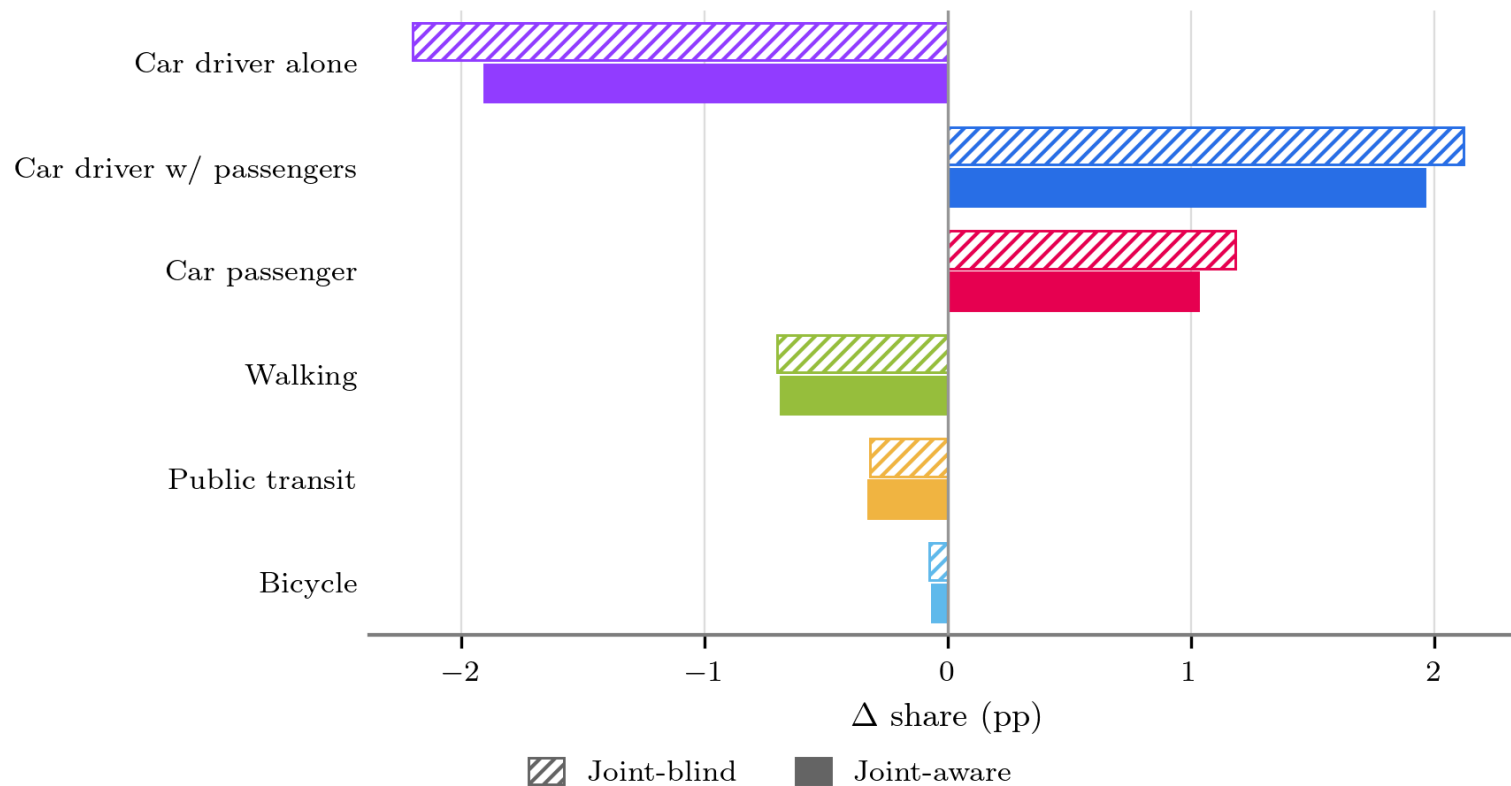
- Agent-based simulation of the whole day (departure time, mode, and route), with congestion resolved by day-to-day learning until equilibrium
- Every agent's preferences come straight from the logit estimates: an alternative-specific constant and a value of time for each mode
- A tour flagged as **joint** differs in two ways:
 - **preferences**: the constants of the joint-tour model apply
 - **choice set**: “car driver alone” is infeasible, since the tour is shared by construction
- Non-joint tours keep the standard preferences and the full choice set

03 Policy experiment

- The subsidy adds €1 to the utility constant of the two ridesharing alternatives: **car driver with passengers** and **car passenger**
- The same policy is simulated twice, on the same tours:
 - **joint-blind**: every tour is treated as a standard tour, with the baseline preferences and the full choice set
 - **joint-aware**: the tours classified as joint take the joint-tour constants and cannot drive alone
- Comparing the two runs isolates what accounting for joint travel changes in the predicted mode shift and car vehicle-kilometres

Results: overall mode shifts with €1 ridesharing subsidy

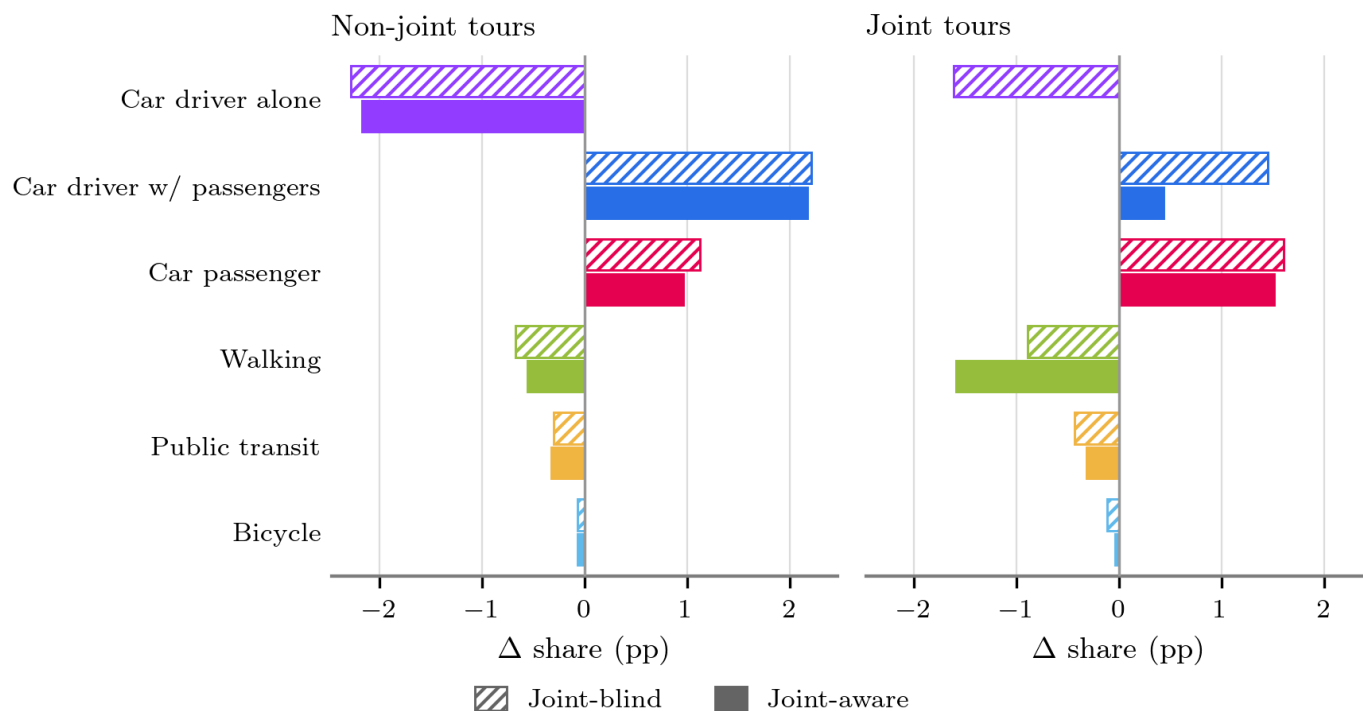
Both models predict a shift from **driving alone** (−2.2 and −1.9 pp) to **ridesharing** (+3.3 and +3.0 pp, as driver or passenger)



Change in mode shares under the €1 subsidy, in percentage points, all tours.

Results: mode shifts with €1 ridesharing subsidy

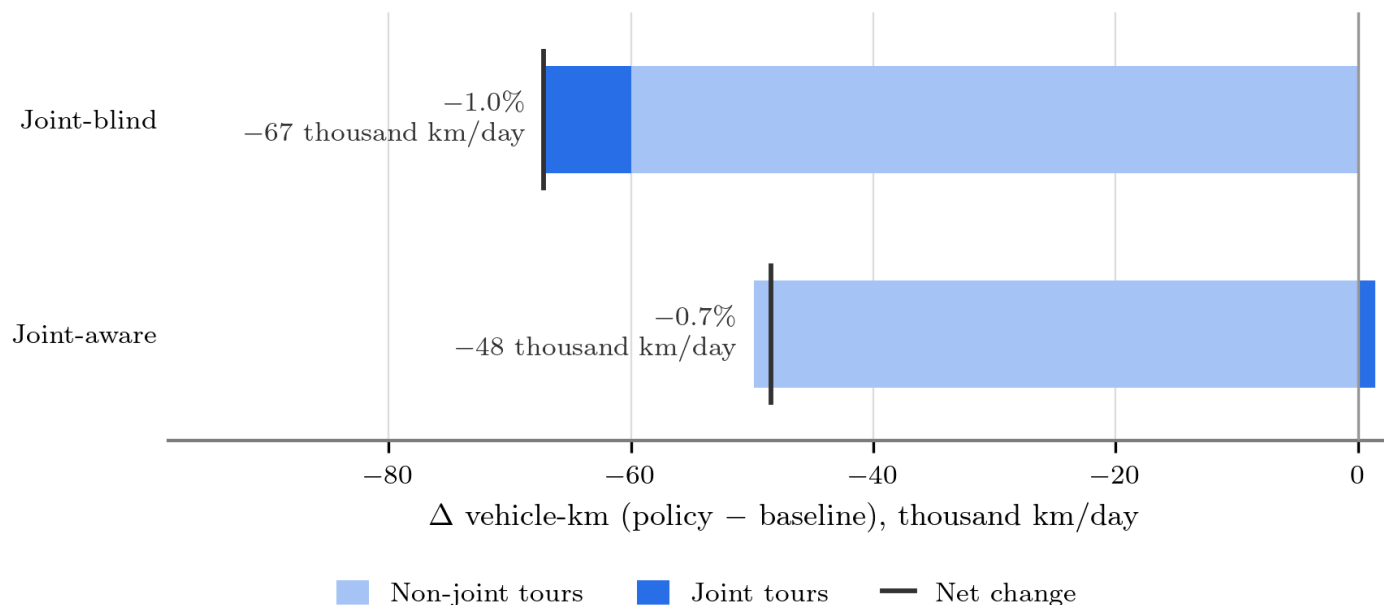
- **Non-joint tours**: both runs agree → the subsidy moves travellers from **driving alone** to **ridesharing**
- **Joint tours** in the **joint-blind** model: similar shifts than for non-joint tours
- **Joint tours** in the **joint-aware** model: shift from **walking** and **public transit** to **ridesharing**



Change in mode shares under the €1 subsidy, in percentage points, by tour type.

Results: car vehicle-kilometres with €1 ridesharing subsidy

- The **joint-blind** model **over-estimates the drop** in car vehicle-kilometres by 40 %: **-1.0 %** against **-0.7 %**
- **Non-joint tours**: the joint-blind model over-estimates how easily travellers switch to ridesharing, since its ridesharing constants absorb the joint tours' taste for it
- **Joint tours**: car vehicle-kilometres even rise slightly in the joint-aware model, since the new rideshares replace walking and transit trips, not solo drives



Change in daily car vehicle-kilometres under the €1 subsidy, split between non-joint and joint tours.

04 Conclusion

Takeaways

- Joint tours are a **distinct segment**: 11 % of home-based tours, two thirds of them by car, mostly as a passenger
- Integration into **agent-based simulations**: ML classifier and mode choice MNL, estimated on a travel survey (no household activity model needed)
- Ignoring joint tours **over-estimates the drop in car vehicle-kilometres** from a ridesharing subsidy: -1.0% predicted vs -0.7%

Future work

- Other shared trips: **escorting** and pick-ups on the way, rides with **friends or neighbours**, formal ridesharing
- **Balance drivers and passengers**, e.g. with a tension indicator, so passengers cannot outgrow drivers
- Other policies: **HOV lanes**, family transit fares

Thank you!



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