The mode less travelled:
quantifying transport flexibility using agent-based models

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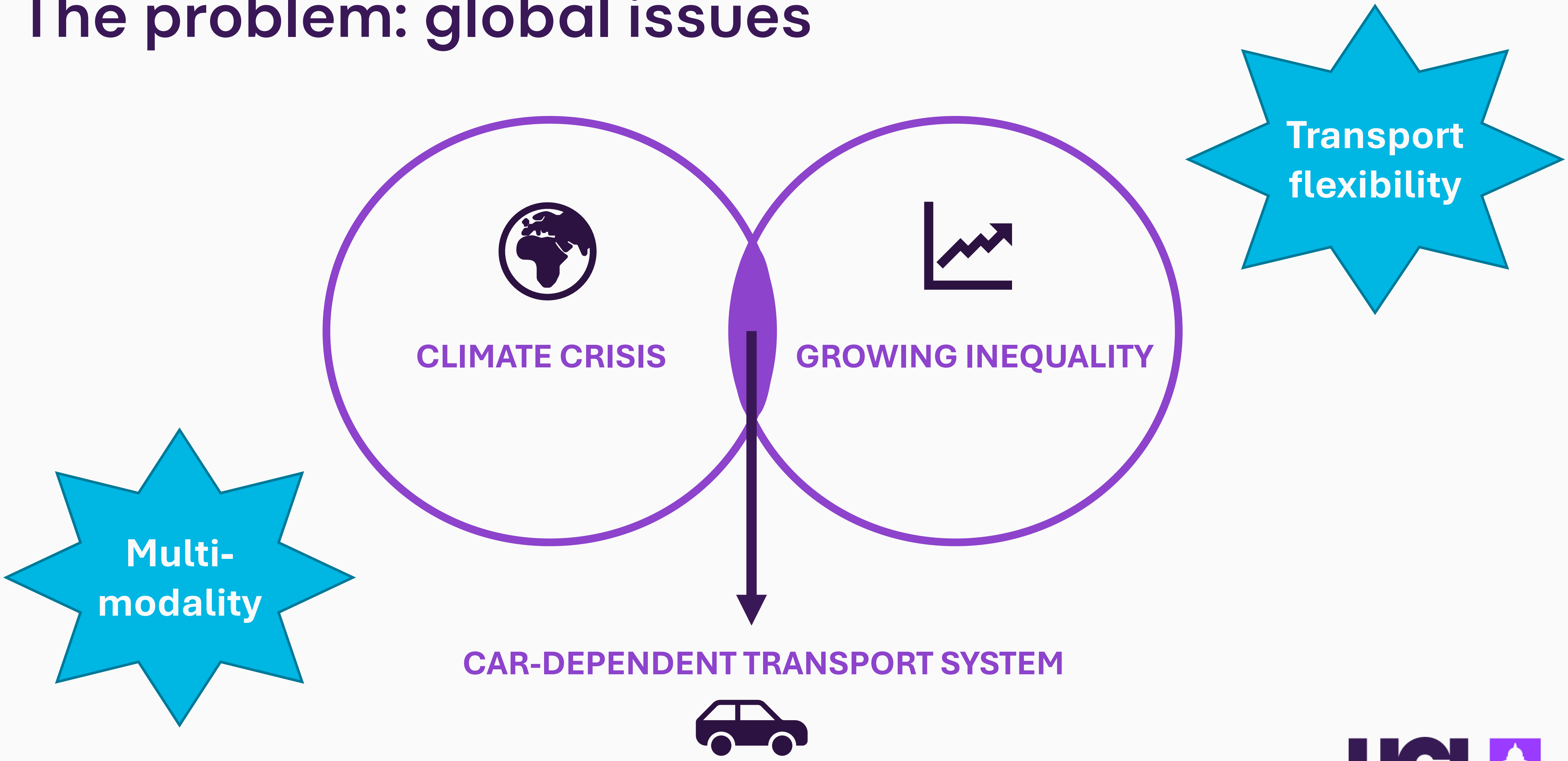
The problem: global issues



The concept: flexibility

Flexibility is an individual's ability to change their travel plans and still achieve their daily goals to the same standard

i.e., how much does changing travel plans affect your day?

Mode

Time

Route

Destination

Another problem: measurement vs reality

TRANSPORT PROVISION

"There is a bus stop right outside my house"

REALISABLE OPPORTUNITY

"The bus doesn't go where I need to go though"

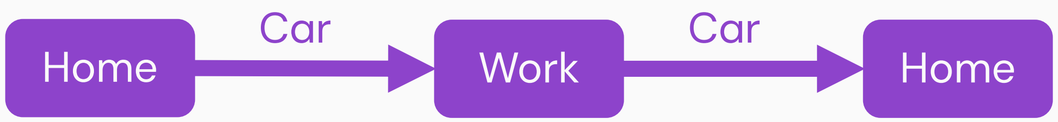
The gap is real, and is distributed unevenly across geographies and socio-demographic groups

The concept: simulation of alternatives

Agent-based simulation provides a unique perspective on not only what an agent **did** but also what they **could have done instead**

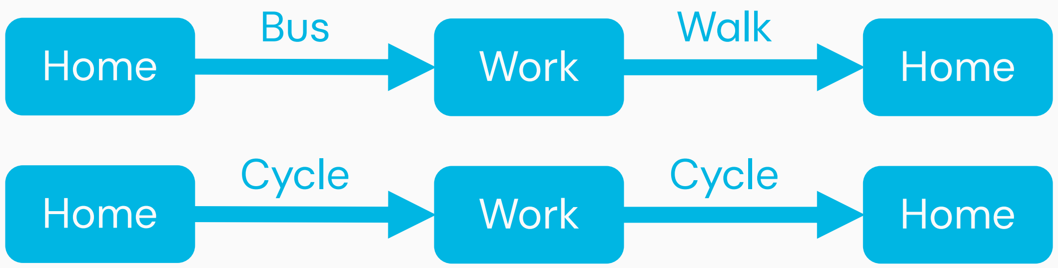
The alternatives are 'experienced' in a realistic **congested** and **dynamic** network

Selected plan: realized choice



~ observed behaviour e.g., NTS

Unselected plans: potential, unrealized choices



~ stated preference in surveys – unreliable

MATSim in a nutshell

1 → 2 → 3 → 4

1. Synthetic population

Population with demographics, activity plans, and activity locations derived from National Travel Survey and UK Census data

2. Network simulation

Agents complete activity plans in shared, congested network. Network includes real road and rail provision, PT services, and vehicle fleet

3. Innovation and scoring

Some agents "innovate" by randomly mutating their plans. All attempted plans are scored by utility (according to distance, duration, etc)

4. Repeated iterations

Simulation iterated hundreds of times to reach equilibrium where no agent can improve given the rest of the network

At equilibrium, all agents have a **selected plan** (what they did) and a set of **unselected alternative plans** (what they could have done). All plans have been **experienced** and **scored** in the shared network

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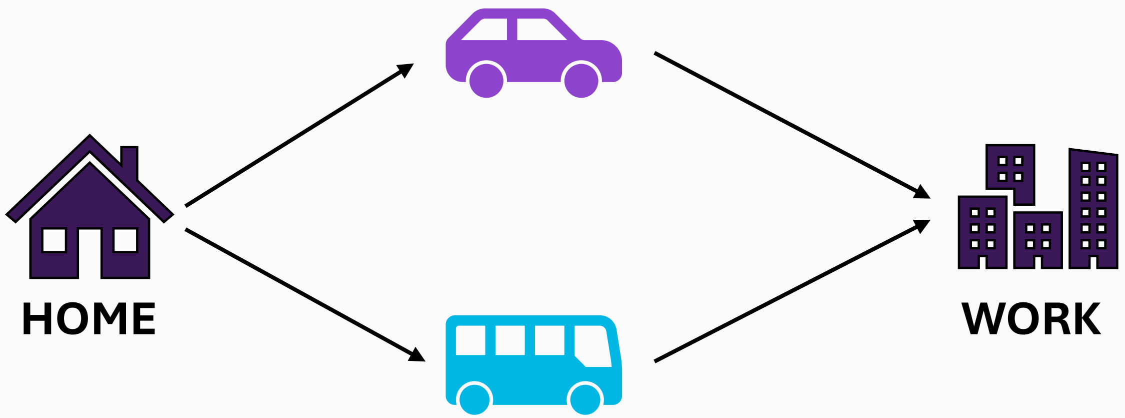

Selected plan: travel by car
U = 150

Unselected plan: travel by bus
U = 30

LOW FLEXIBILITY
HIGH COST OF MODE SWITCH

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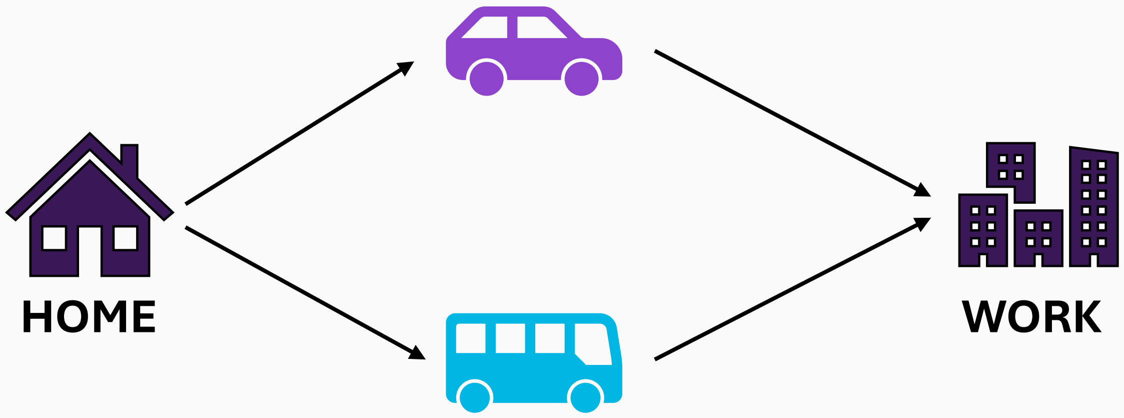


Selected plan: travel by car
U = 150

Unselected plan: travel by bus
U = 145

HIGH FLEXIBILITY
LOW COST OF MODE SWITCH

Flexibility from MATSim outputs

Compare the selected plan (highest-scoring plan) to the best alternative that invokes a mode shift

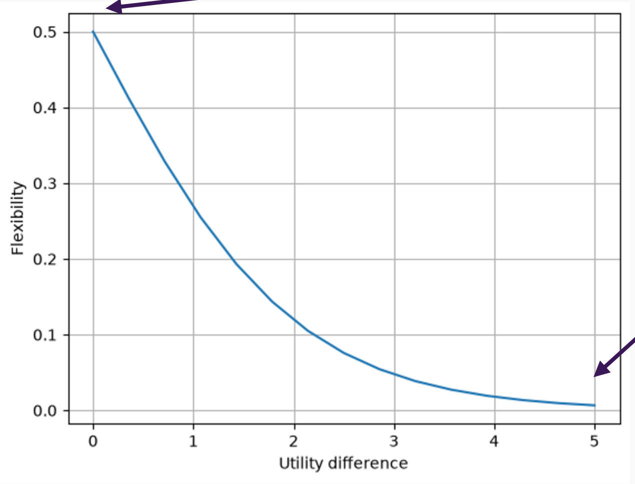
Transform the difference in utility using a **logistic function**

This gives the **binary logit choice probability** between these two plans in a head-to-head comparison

$$F = \frac{1}{1 + \exp(\mu \cdot \Delta U)}$$

$\Delta U = U(selected) - U(alternative)$

$\mu = 1$ for consistency with MATSim



Perfect flexibility
Zero cost to mode switch

Near-zero flexibility
Mode switch cost asymptotically large

Case study: car dependence in the East of England

Data: BERTIE (Behaviour and Transport: Impact and Equity)

- Developed by Transport East and Arup
- 10% representative synthetic population
- Activity and agent-based MATSim model of East of England

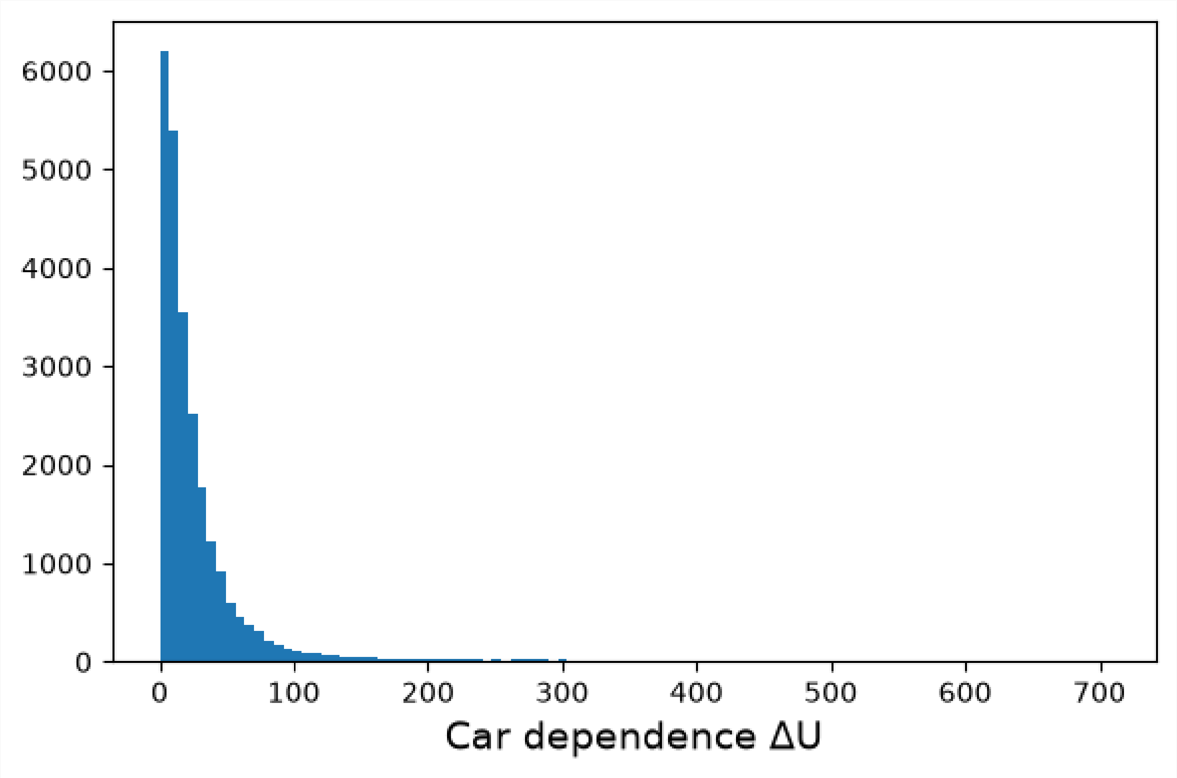
TRANSPORTEAST ARUP

RQ: To what extant can agents who travel by car reduce their car use?

- Select agents with car in selected plan **(57%)**
- Identify best alternative plan that reduces car use (by distance)
- Compare utilities and transform to find **F**
- Weight **F** by proportion of car reduction
- Validate results against DfT Connectivity (the "*national measure of connectivity*")

UCL

Results: flexibility distribution



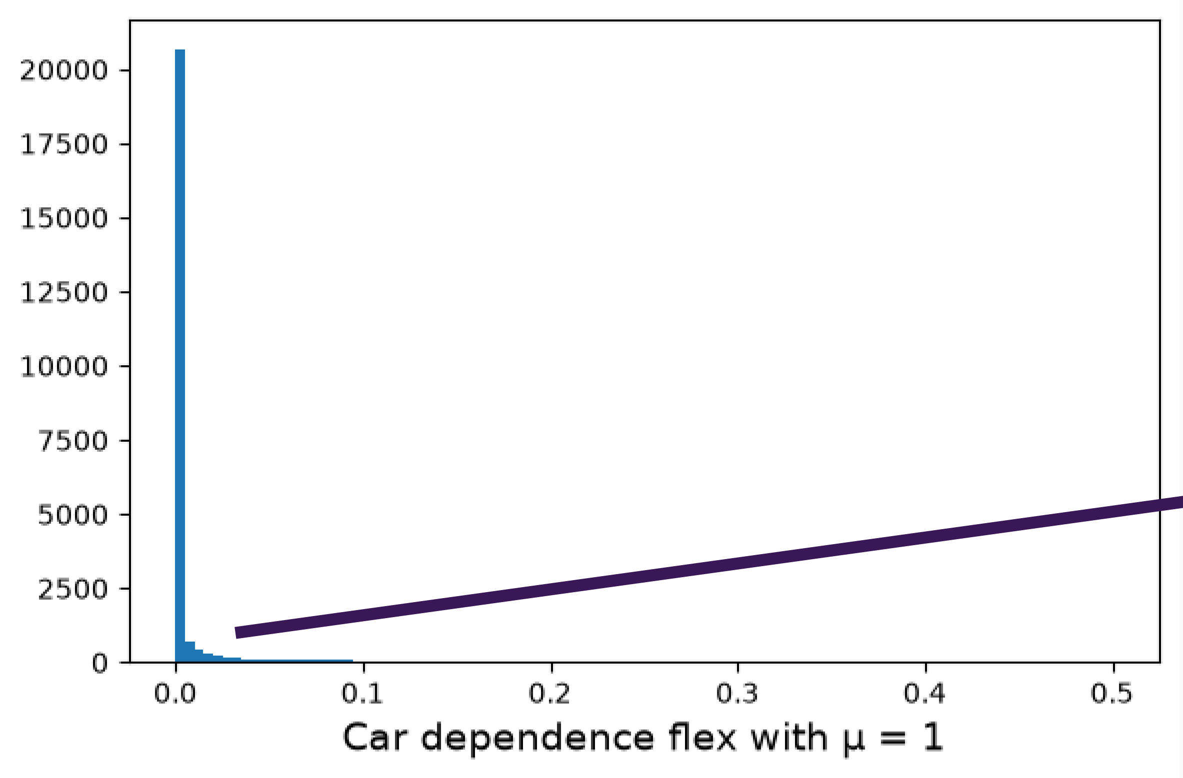
34% agents have **ΔU < 10 utils**

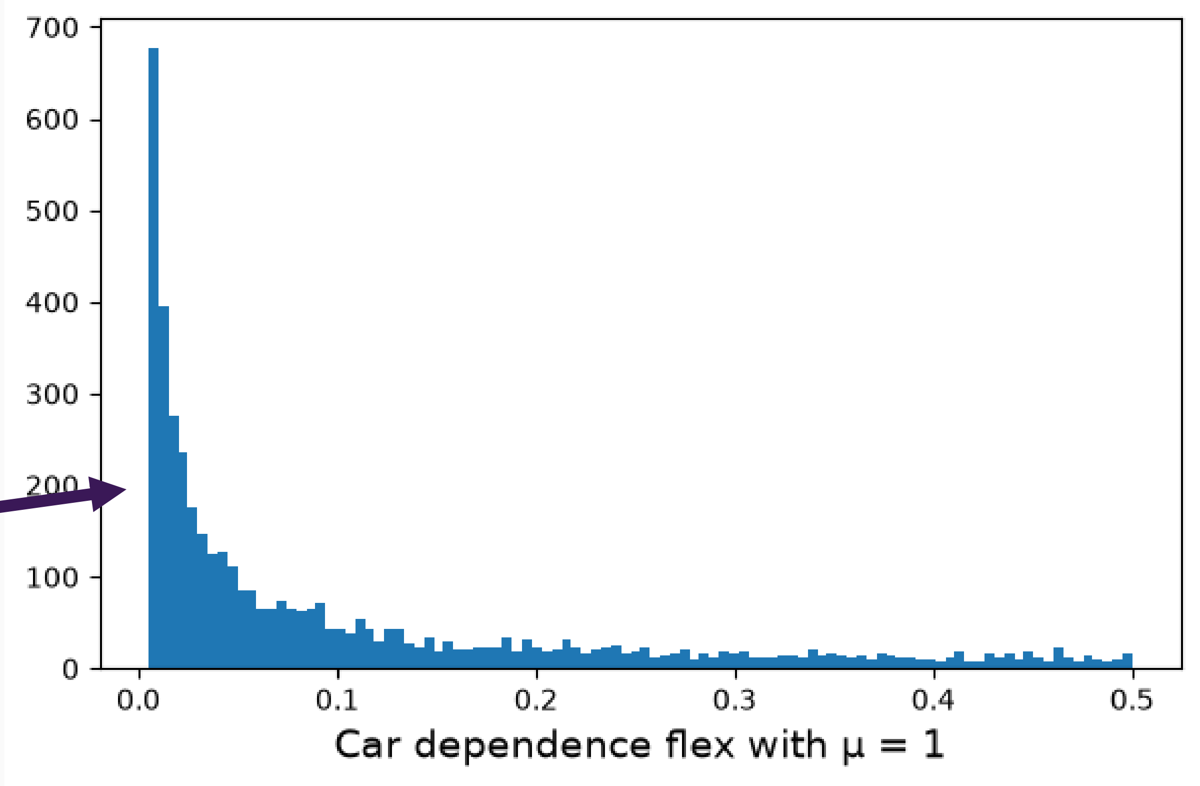
- Many agents have a decent car-reducing alternative

5% agents have **ΔU > 100 utils**

- Some agents have only very poor car-reducing alternatives

Results: flexibility distribution

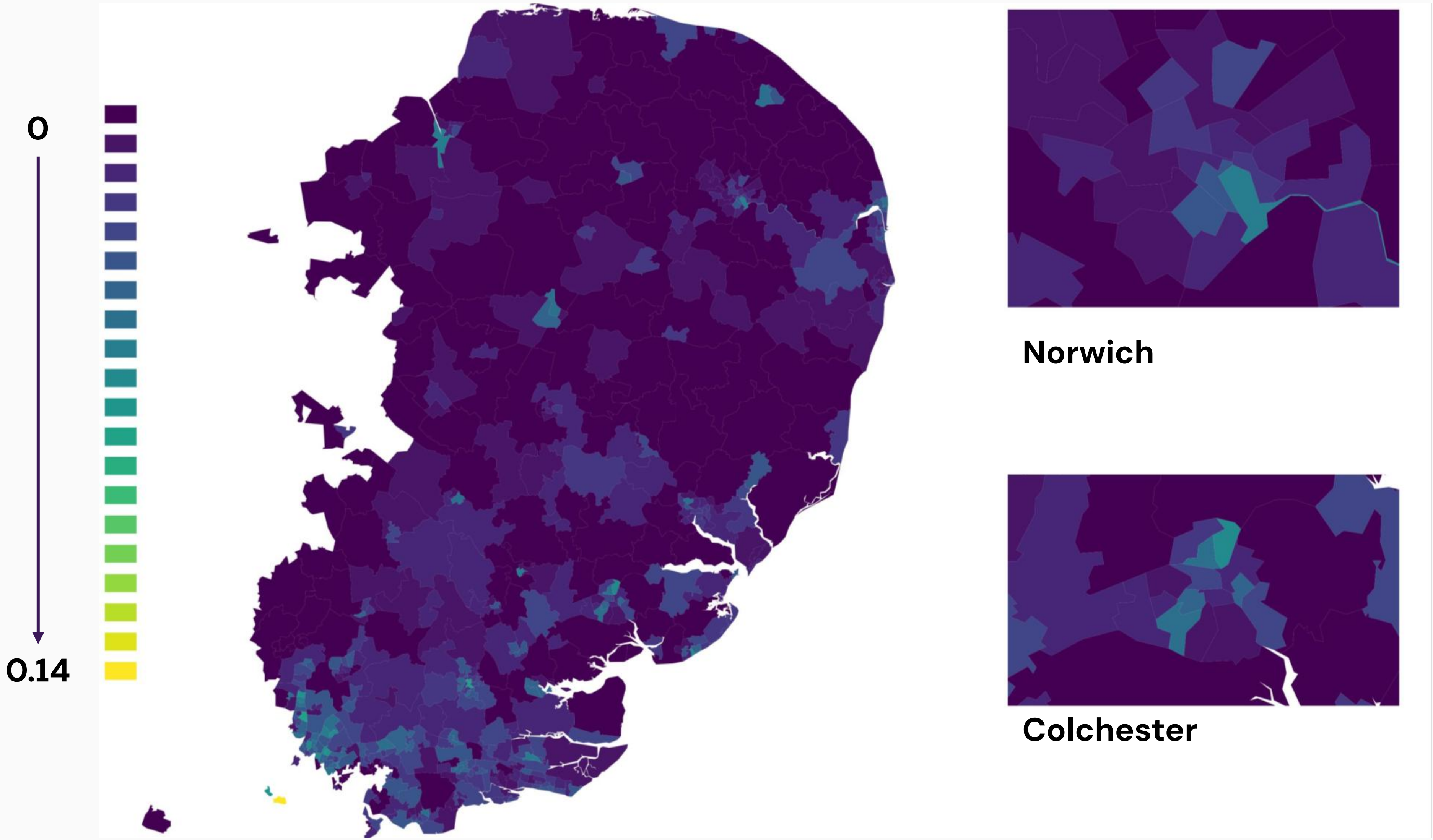




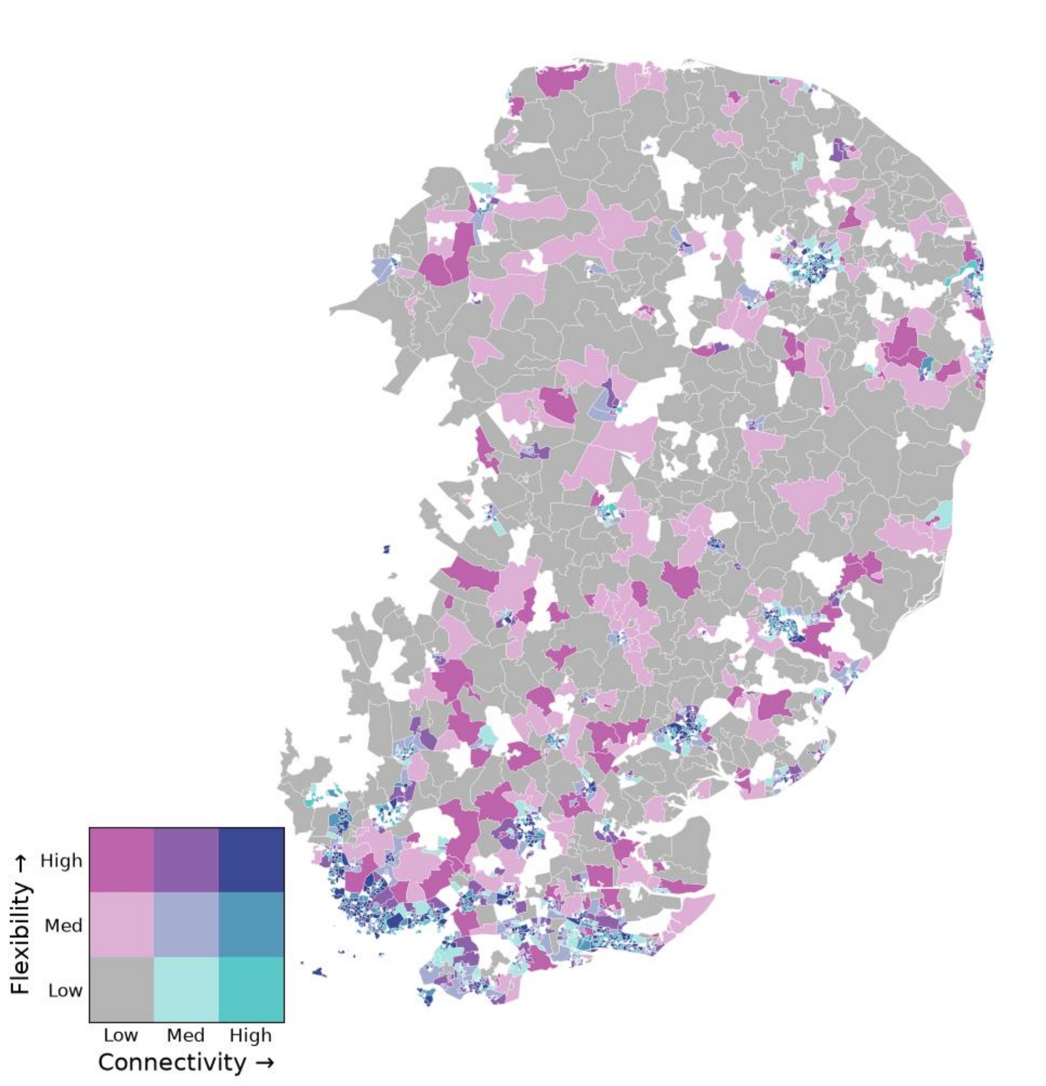
94% agents have **F < 0.05** at **μ = 1**
0.2% agents have **F > 0.45** at **μ = 1**

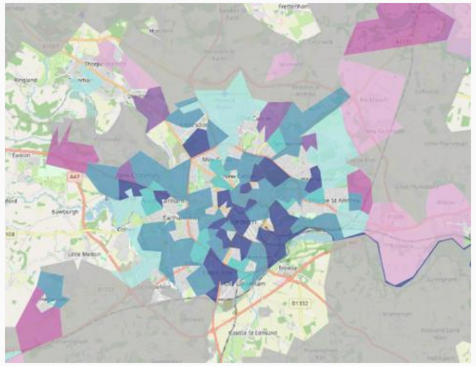
- Choice of μ influences shape of distribution

Results: geographical distribution

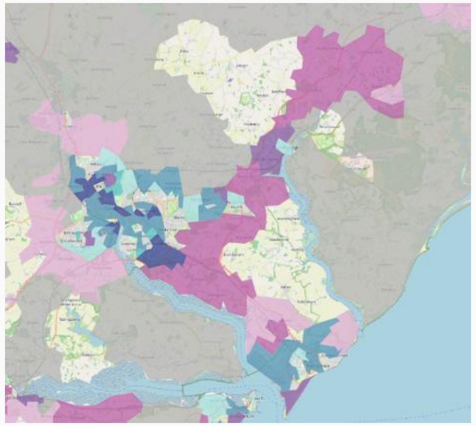


Results: comparison to connectivity





Norwich



Ipswich + Woodbridge

Resourceful mobility (high flex, low conn)

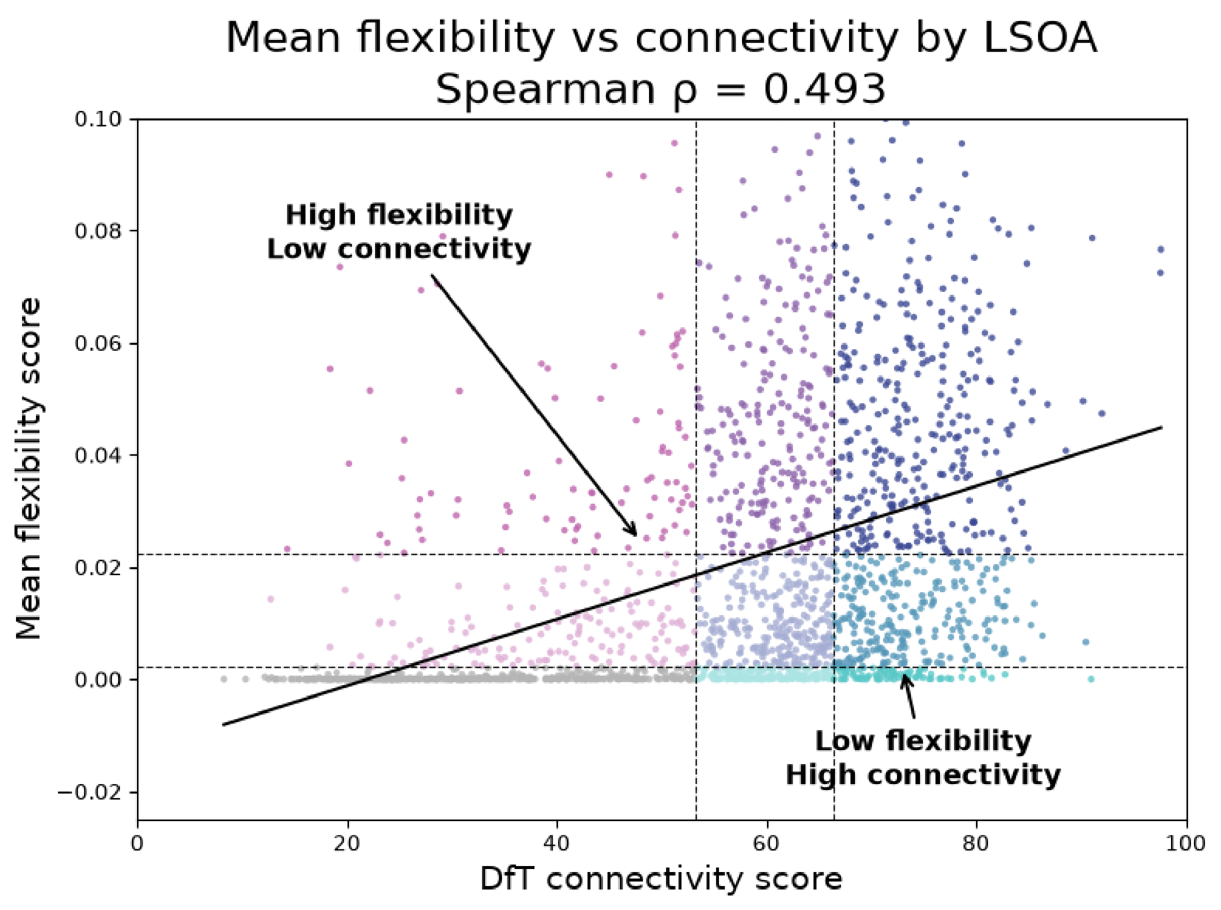
Mostly periphery of urban centres

Unrealized provision (low flex, high conn)

Low flexibility, high connectivity

Mostly within urban centres

Results: comparison to connectivity



LSOAs in upper-left and lower-right quadrants show **decoupling**:

Resourceful mobility (3% of LSOAs)
High flexibility, low connectivity
Less deprived, lower PT stop density, higher car ownership, semi-urban

Unrealized provision (6% of LSOAs)
Low flexibility, high connectivity
More deprived, higher PT stop density, lower car ownership, highly urban

Spatial lag model shows strong neighbourhood effects at play

Spearman's $\rho = 0.5$
Moderate relationship but with much variance unexplained

Extension: trip-level car dependence

Apply the methodology to a given trip in the day e.g., the **commute or school drop-off**

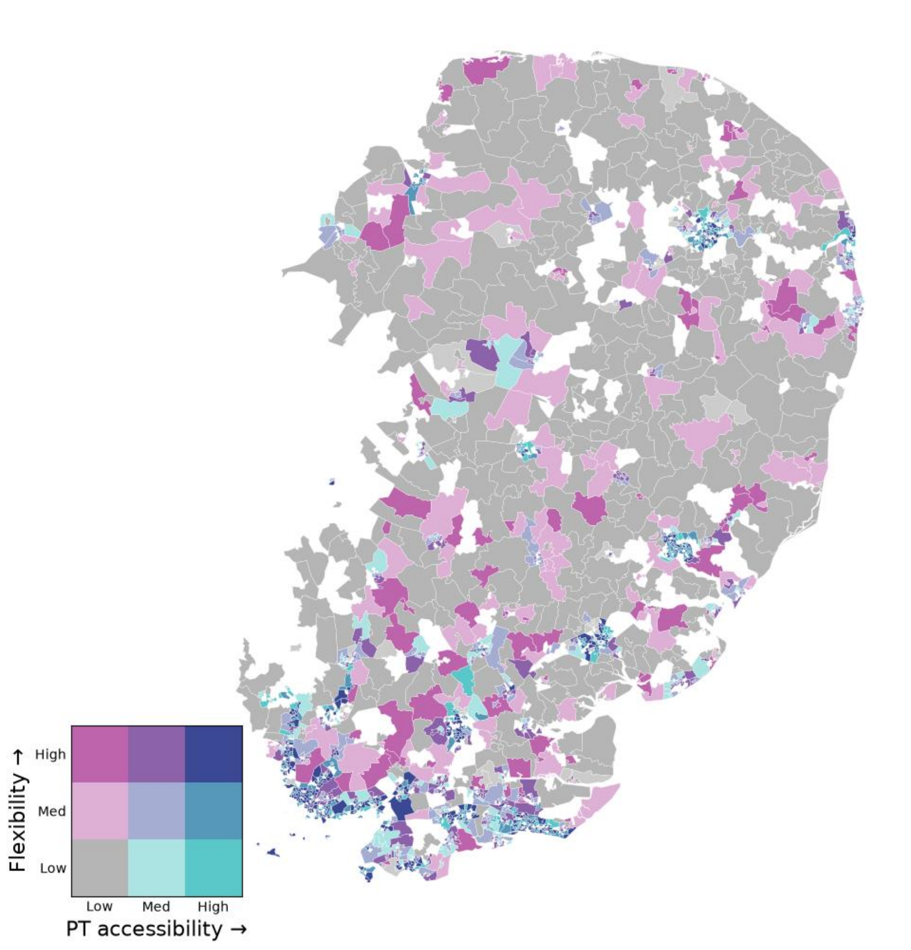
For agents who travel to work (or school dropoff) by car in their selected plan, compare the utility of this trip against alternative plans where car is not used

Include additional term to flexibility transform to account for **downstream scheduling effects**

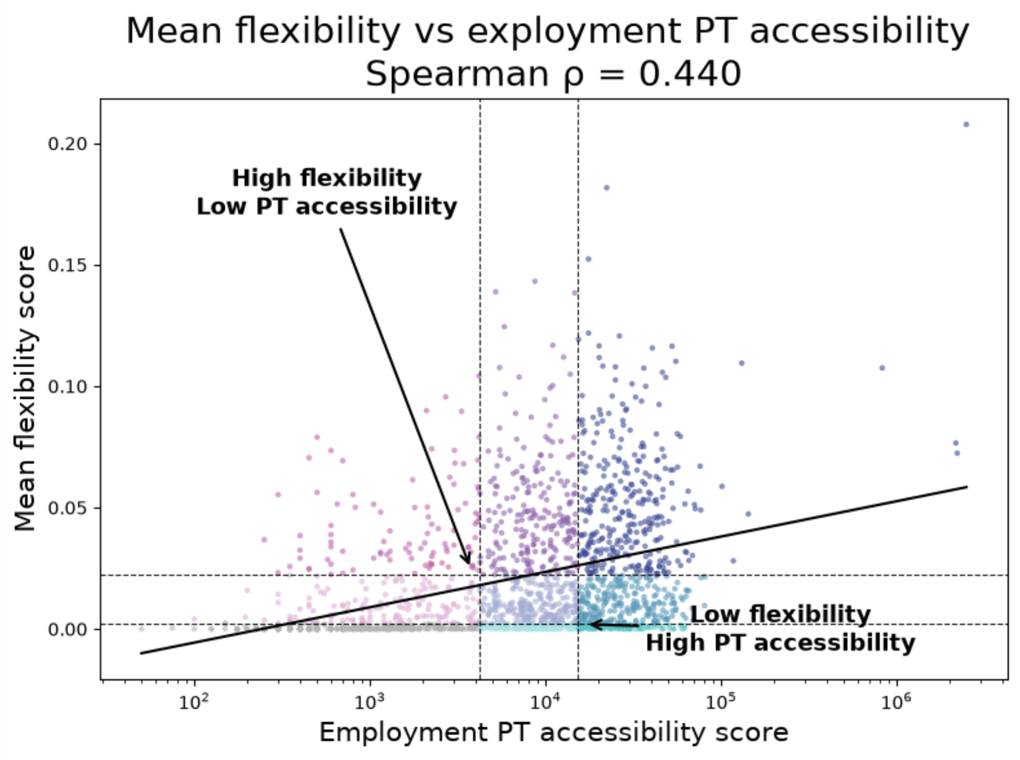
$$\boldsymbol{F} = \frac{\mathbf{1}}{\mathbf{1} + \mathbf{exp}(\boldsymbol{\mu} \cdot (\Delta \boldsymbol{U}_{\boldsymbol{trip}} + \Delta \boldsymbol{U}_{\boldsymbol{activity}}))}$$

We can find which agents are able to reduce car across the day, but not for essential trips

Extension: trip-level car dependence



Comparison to employment public transport accessibility indicators (30 minutes)



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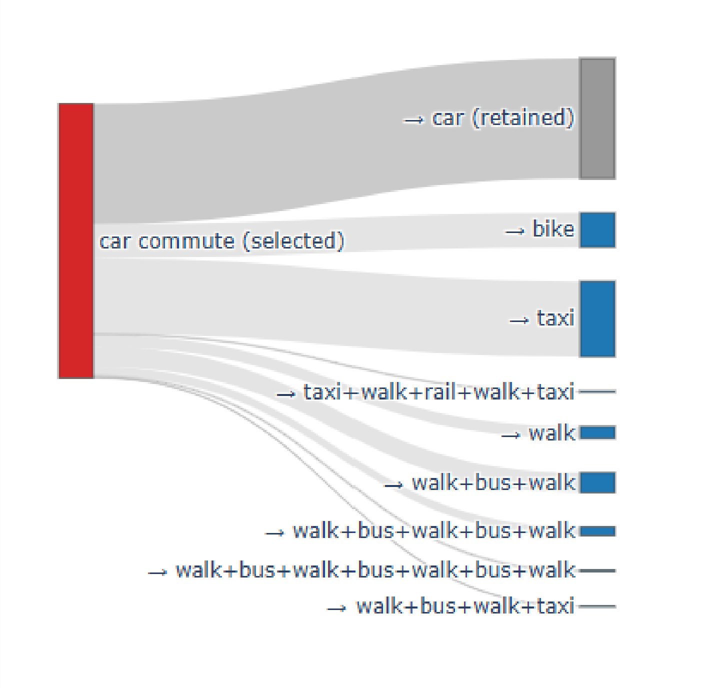

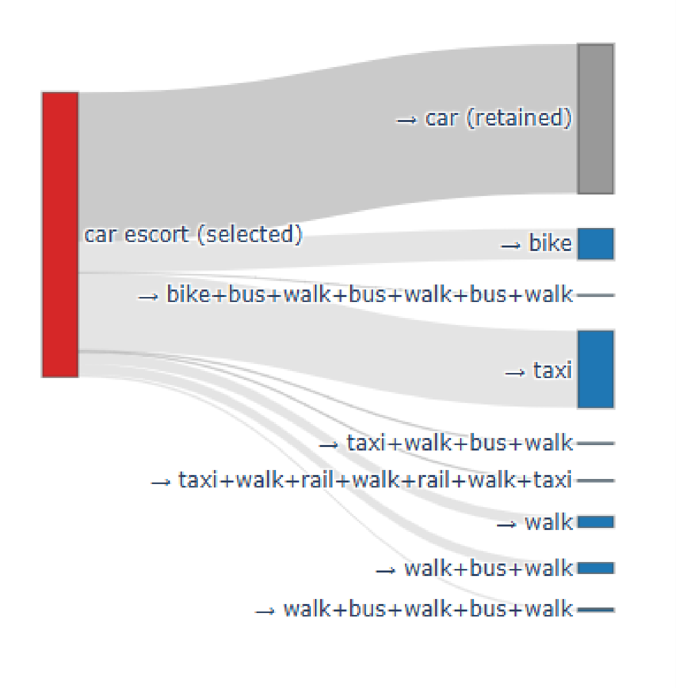

Commute

42% of agents retain car in best day-level car-reducing alternative

School drop-off

49% of agents retain car in best day-level car-reducing alternative

Next steps

- Modal elimination (100% car reduction)
- Network-level modal resilience
- Disaster scenario testing including route flexibility
- Modelling of outcome distributions to understand relationships between demographics, geography, and flexibility more robustly
- Policy scenario testing for efficacy of interventions to improve flexibility

Conclusions

- Examining unselected simulated travel plans can generate a novel quantified description of modal flexibility
- Flexibility can be assessed across an entire day or for a specific trip purpose
- Flexibility is not the same as connectivity – provision does not always translate into usefulness
- It's not just rural areas that experience low car-reducing flexibility; many urban areas suffer despite high connectivity

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Thank you!

Any questions?

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