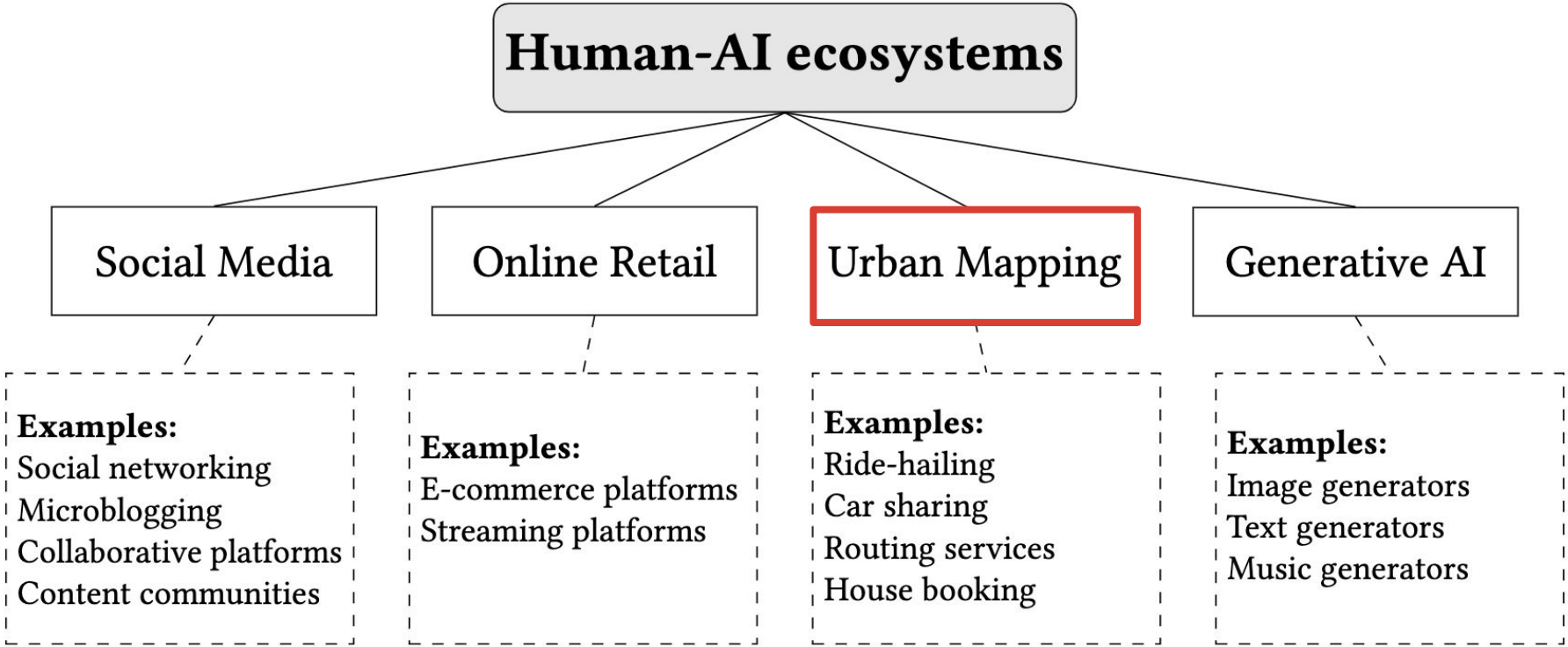
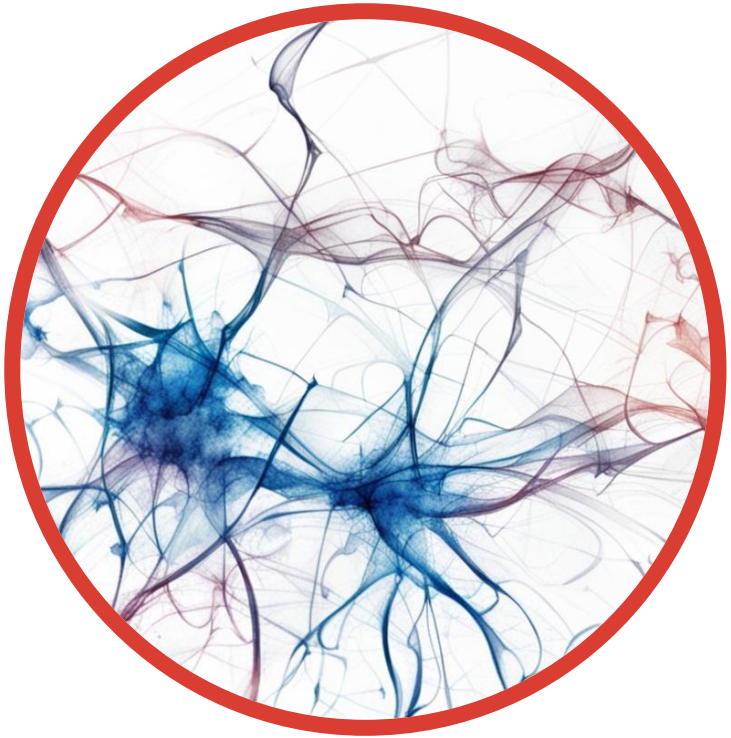

Human-AI ecosystems
Social Media
Online Retail
Urban Mapping
Generative AI
Examples:
Social networking
Microblogging
Collaborative platforms
Content communities
Examples:
E-commerce platforms
Streaming platforms
Examples:
Ride-hailing
Car sharing
Routing services
House booking
Examples:
Image generators
Text generators
Music generators

URBAN MAPPING

Travellers helped by smart *route recommenders* to reach their destinations

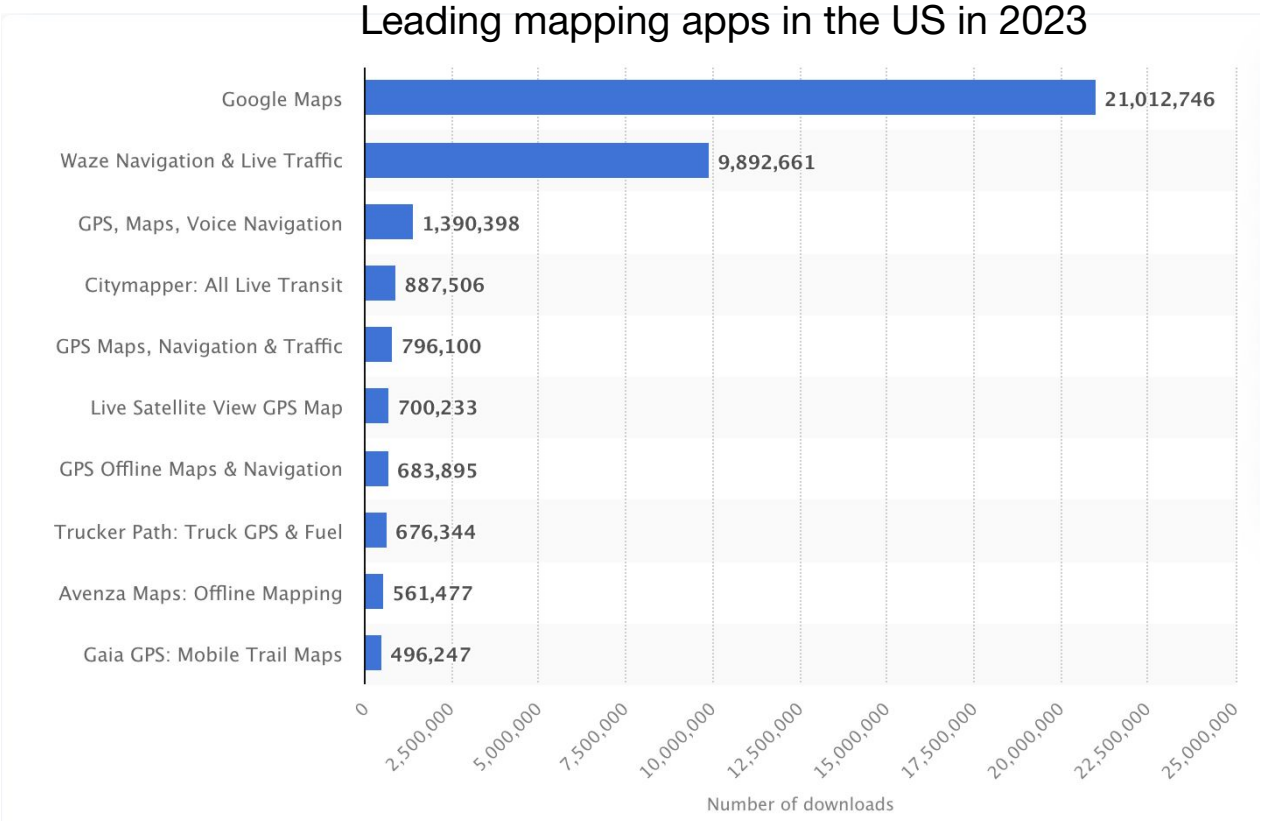
Outcomes: Navigation apps may create chaos if too many drivers are directed on the same route



Designated VLOPs

https://www.statista.com/statistics/865413/most-popular-us-mapping-apps-ranked-by-audience/

Google Maps



Discussion

What is the business model of navigation services?
What do they optimise for?

- **Advertising:** Businesses can list their ads on Google Maps, even creating profiles that allow their businesses to be found more easily.
- **Promoted pins**: display the company's logo instead of the standard pin.
- **APIs:** for navigation, tracking, and mapping, all of which it charges for.

The New York Times

Navigation Apps Are Turning Quiet Neighborhoods Into Traffic Nightmares

The corner of Fort Lee Road and Broad Avenue in Leonia, N.J. With traffic apps suggesting shortcuts for commuters through the borough, officials have decided to take a stand. Bryan Anselm for The New York Times

Il gigante e la viabilità

I sindaci dell'Alto Adige contro Google Maps: tutta colpa dei furbetti della coda

Con i 'percorsi alternativi', traffico da bollino nero e paesi intasati, sindaci contro Google, Kompatscher: "Serve un divieto di deviazione come all'estero"

15/10/2024

Autostrada del brennero con traffico

2024

Mail Online

Residents outrage after Waze app used to avoid traffic ends up sending Los Angeles drivers down once quiet 'hidden' street

TORONTO STAR

This tiny Toronto street is choked by traffic chaos. Residents are ‘fuming mad’ at being trapped by daily gridlock

Since Eglinton Crosstown LRT construction began in 2011, the street has been jammed by drivers, guided there by Google Maps or Waze.

KentOnline
News you can trust

Kent residents say councils call for car sat-navs to be banned in lorries won't help

The Standard

Map apps like Waze 'turning quiet London streets into polluted rat runs'

The Telegraph

Britain’s new road rage: how traffic rules are tearing our neighbourhoods apart

The Guardian

'Rat-running' increases on residential UK streets as experts blame satnav apps

Motoring on minor roads doubled between 2009 and 2019, regional figures reveal

- **Traffic jam by GPS: A systematic analysis of the negative social externalities of large-scale navigation technologies**, PLoS One 2024
- **In WAZE we trust? GPS-based navigation application users’ behavior and patterns of dependency**, PLoS One 2022

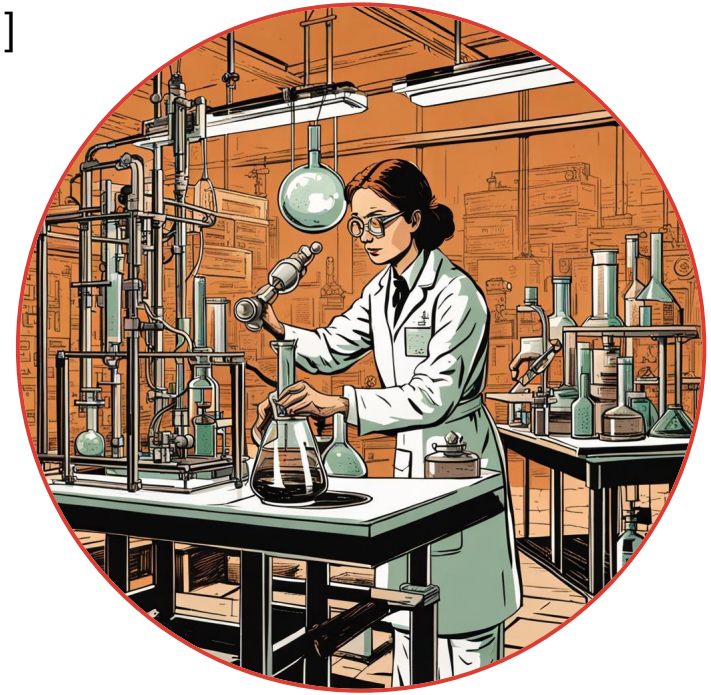
What is the aggregate impact of navigation services on the urban environment?

How to study this phenomenon?

Pedreschi et al., Human-AI Coevolution, 2025

Ideally, with an **empirical controlled** study [1] (if you own a platform!):

- assign vehicles *randomly* to either the control group or the treatment group
- monitor and record vehicles' behavior during the journey



similar to experiments in social media: e.g., Algorithmic amplification of politics on Twitter, 2022, 10.1073/pnas.2025334119

How to study this phenomenon?

Pedreschi et al., Human-AI Coevolution, 2025

Limitations related to privacy and access [1]:

- algorithms and data are proprietary
  - APIs available on a fee
- data about routes followed by users are not available for privacy reasons

D.R. Cox, Planning of experiments, 1958

How to study this phenomenon?

Pedreschi et al., Human-AI Coevolution, 2025

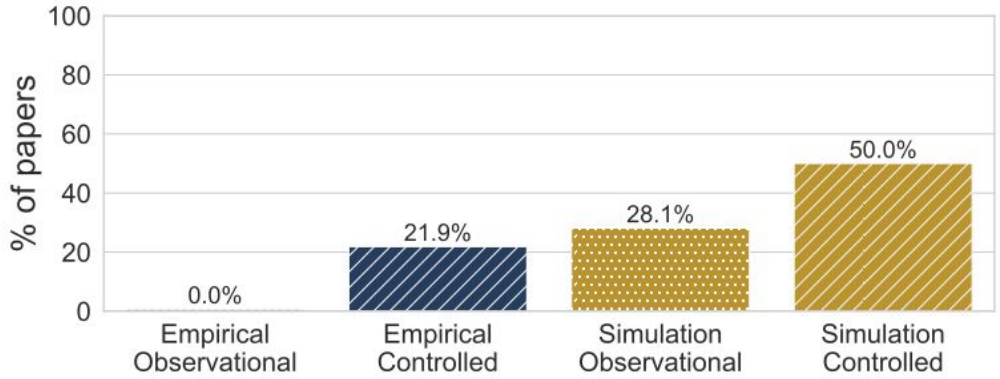
Limitations related to causal claims [1, 2]:

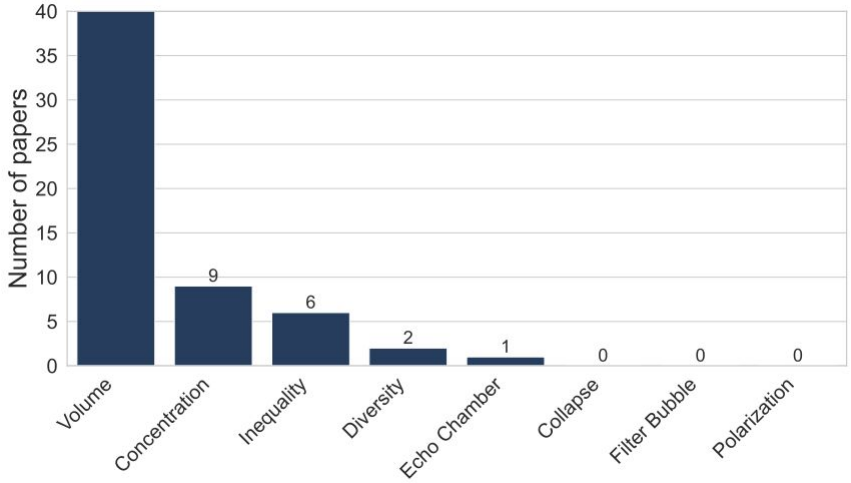
- *interactions between vehicles* in the two groups and the other vehicles
- bias introduced by *exogenous factors* (e.g., storms, strikes, accidents)
- experiments are not replicable under same conditions

D.R. Cox, Planning of experiments, 1958

Experiments and outcomes

L. Pappalardo et al. A survey on the impact of AI-based recommenders on human behaviours, 2024, https://doi.org/10.48550/arXiv.2407.01630



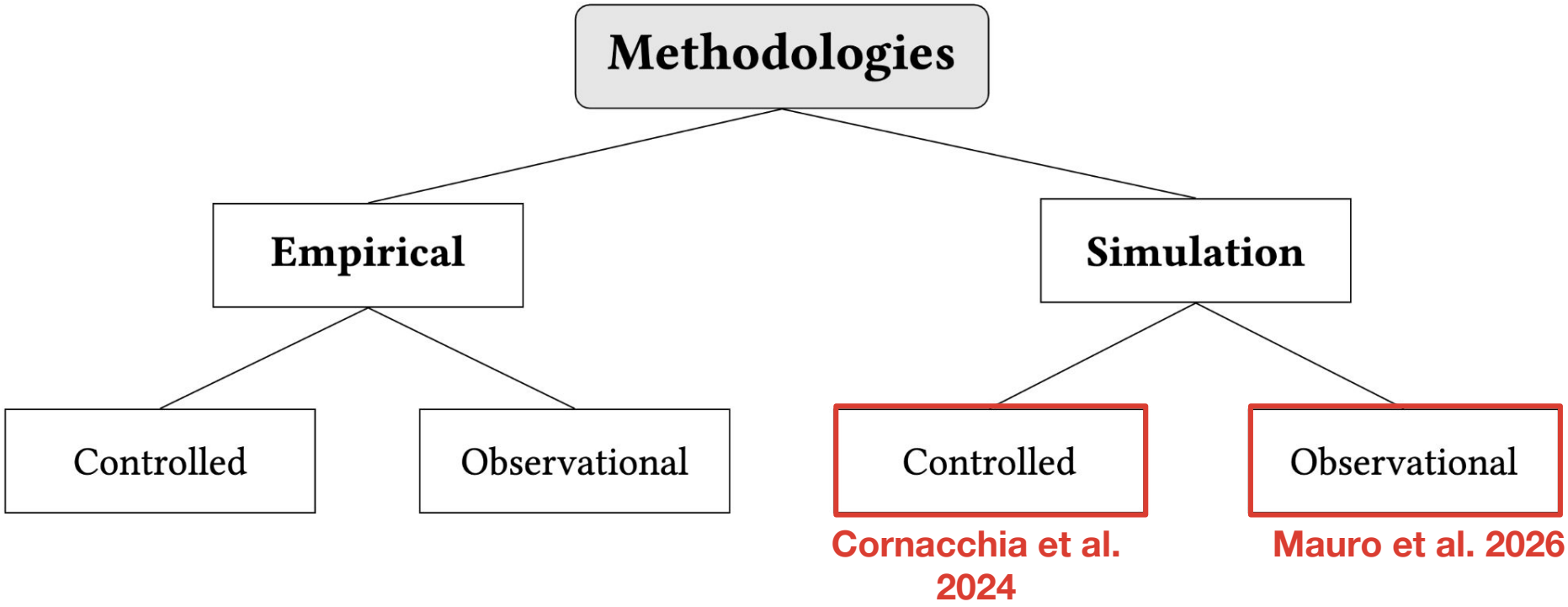


Urban Mapping		Empirical		Simulation	
		Observational	Controlled	Observational	Controlled
Individual	**Filter Bubble**				
	Radicalisation				
Model	**Collapse**				
Systemic	**Concentration**	[55, 70, 115]		[35, 50, 86]	[36, 136, 156]
	Echo Chamber	[89]			
	Inequality	[48, 165]		[1, 21, 86]	[31]
	Polarization				
Individual Item Systemic	**Diversity**			systemic [37]	systemic [38]
	Volume	individual: [84, 104, 144, 146, 165], item: [70, 84, 104], systemic: [84, 115]		individual: [90, 107–110, 123], item: [2, 7, 37, 61, 108–110, 123, 170], systemic: [2, 7, 15, 35–37, 50, 53, 54, 90, 121, 152]	individual: [3, 12, 31, 136, 158], systemic: [3, 12, 36, 38, 136, 156, 158, 170]

Selected studies:

- [36] Cornacchia et al. 2024

Examples on Urban Mapping



Navigation services amplify concentration of traffic and emissions in our cities

Cornacchia et al., Arxiv 2024

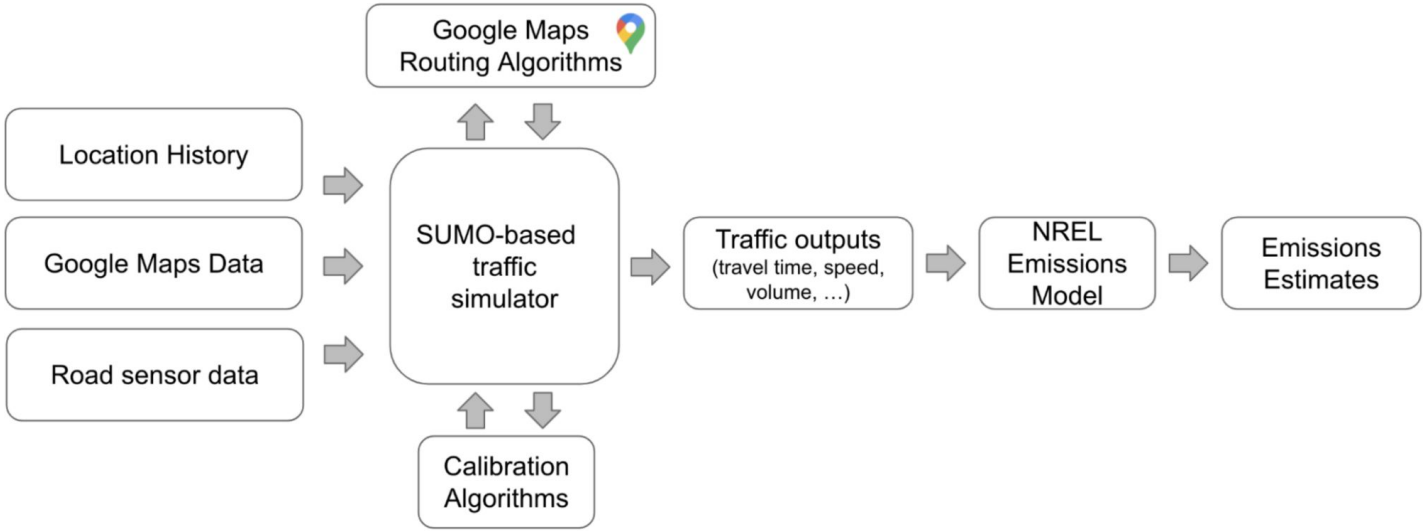
Type:	**Simulation controlled**
VLOP:	**Google Maps**
Outcomes:	**concentration (increase)**

Impact of Google Maps

Simulation study

Quantifying the sustainability impact of Google Maps: A case study of Salt Lake City, 2021, arXiv:2111.03426

- Arora et al. investigate the impact of GM' real-time navigation on travel time and CO2 emissions in Salt Lake City

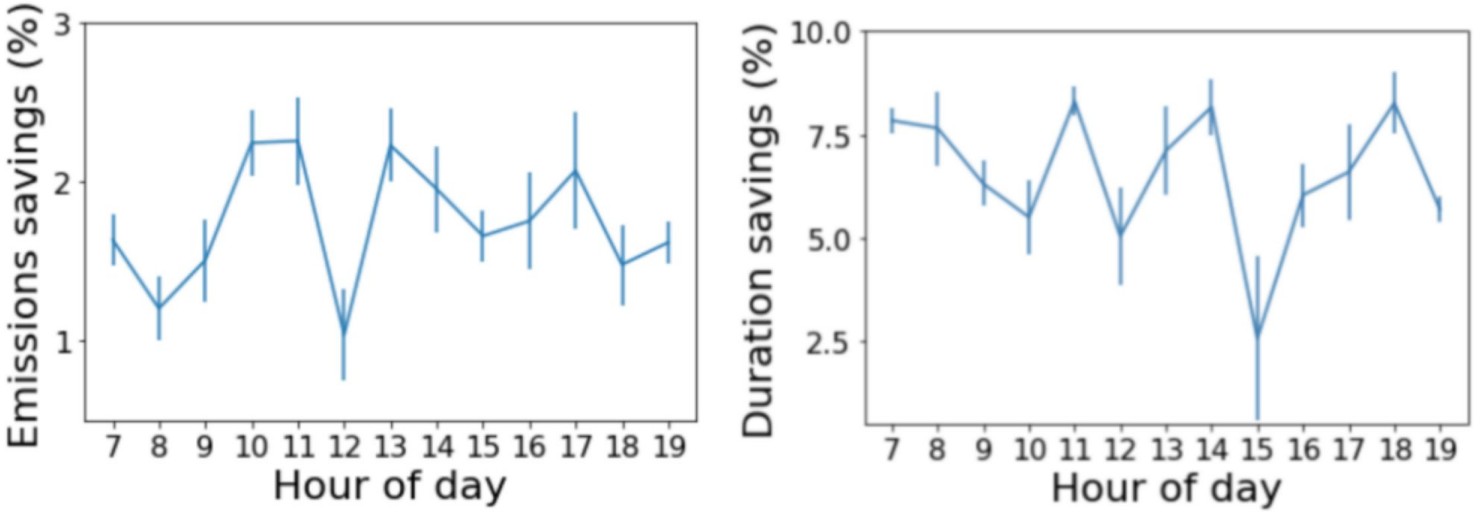


Impact of Google Maps

Simulation study

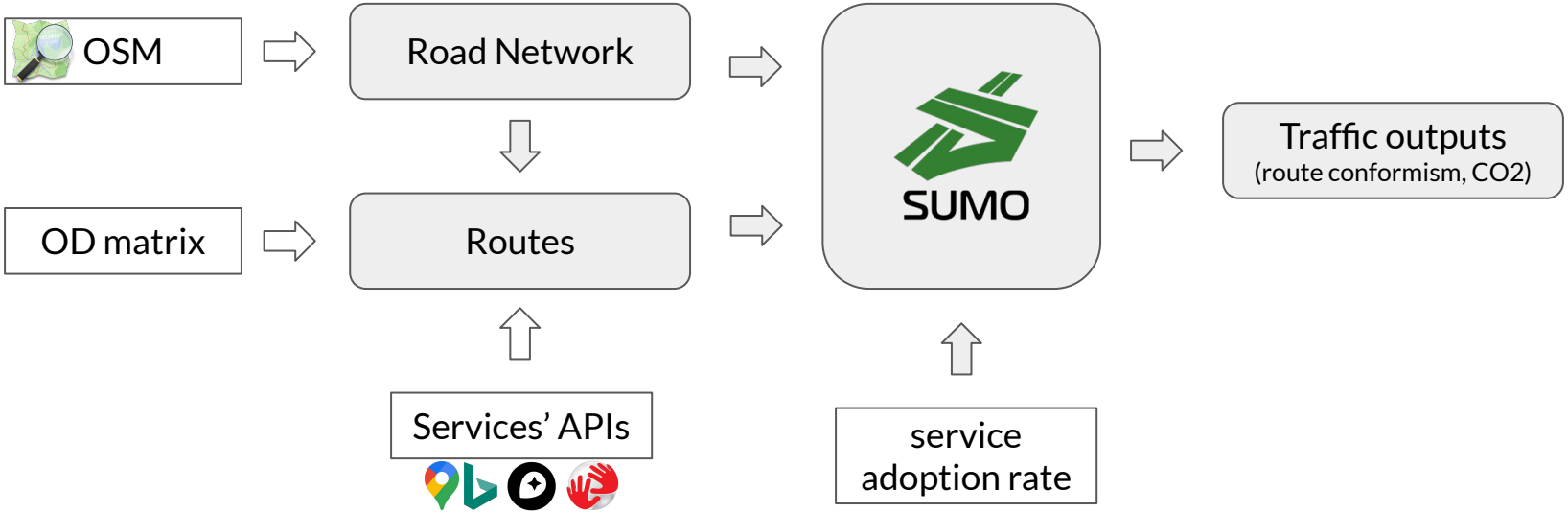
Quantifying the sustainability impact of Google Maps: A case study of Salt Lake City, 2021, arXiv:2111.03426

- GM users reduce CO2 emissions by 1.7% and travel time by 6.5%
- The reduction of 3.4% (CO2) and 12.5% (travel time) for users whose routes differ from their original plans



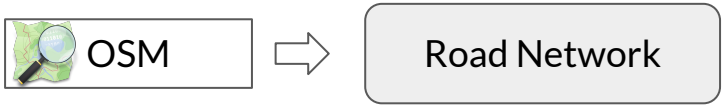
An Open Simulation Framework

How routing strategies impact urban emissions, 2022, 10.1145/3557915.356097



Simulation Framework

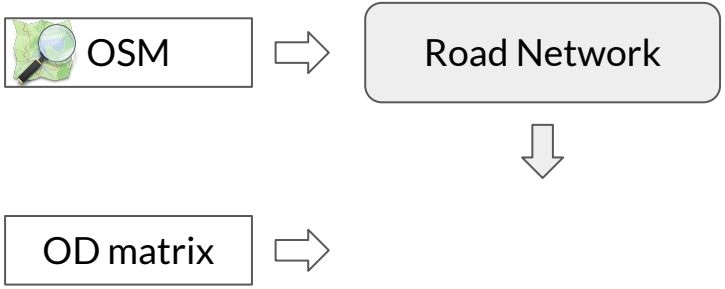
How routing strategies impact urban emissions, 2022, 10.1145/3557915.356097

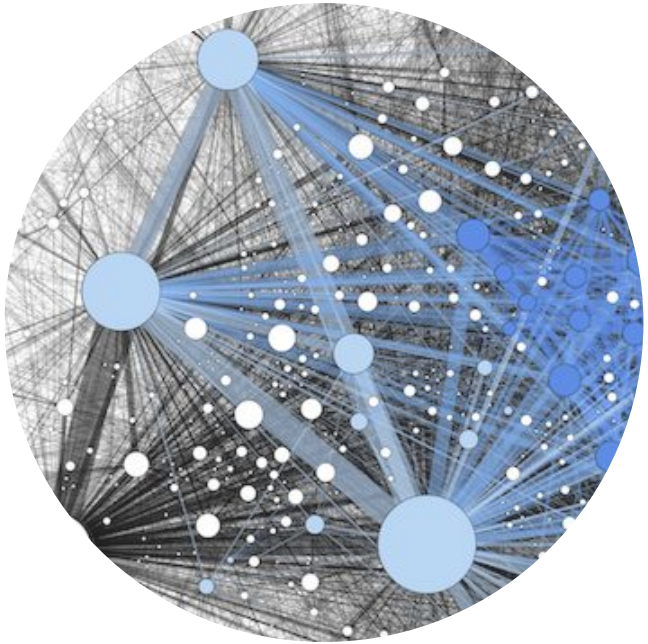


Download city’s road network from OSM

Simulation Framework

How routing strategies impact urban emissions, 2022, 10.1145/3557915.356097

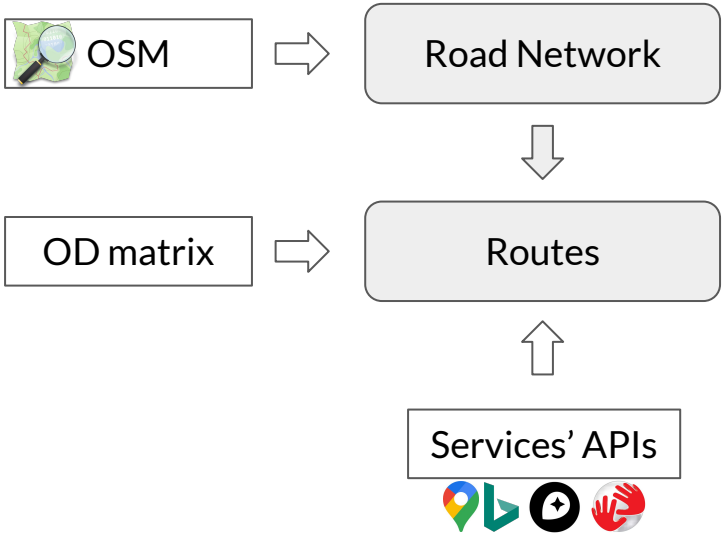


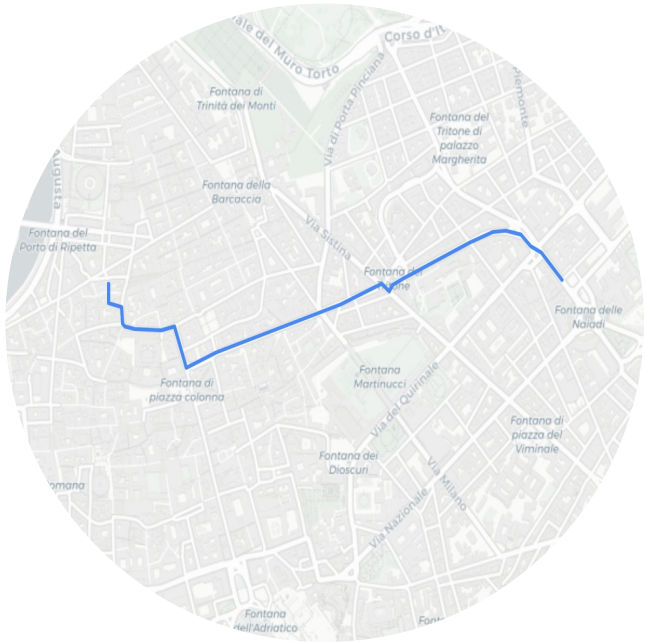


Extract *N* O-D pairs based on edge weights

Simulation Framework

How routing strategies impact urban emissions, 2022, 10.1145/3557915.356097





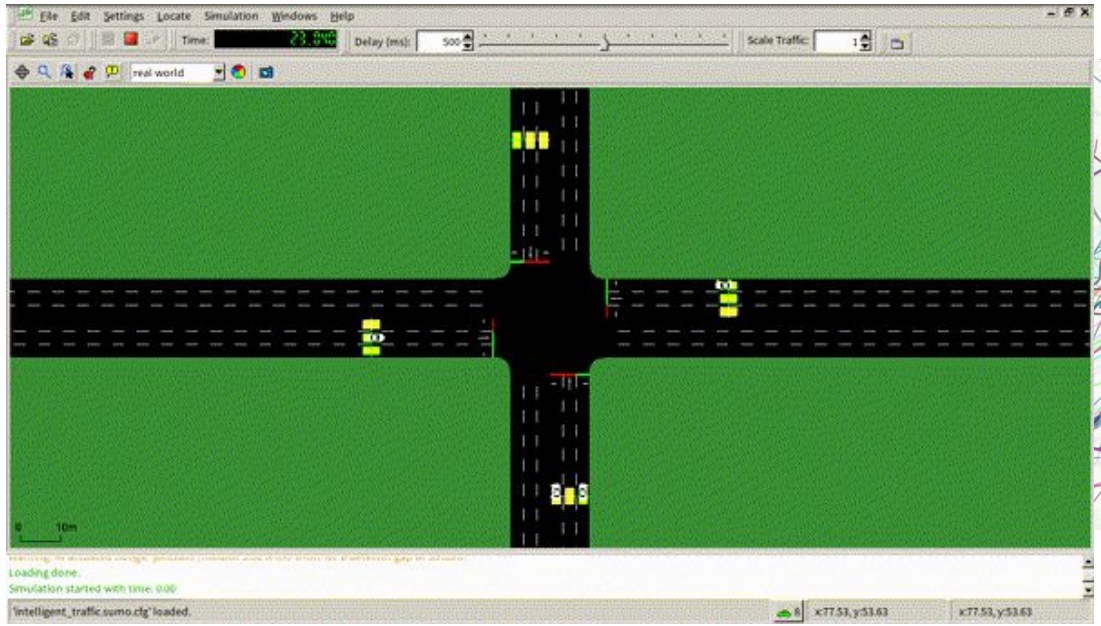
Create N routes using APIs

Simulation Framework

How routing strategies impact urban emissions, 2022, 10.1145/3557915.356097

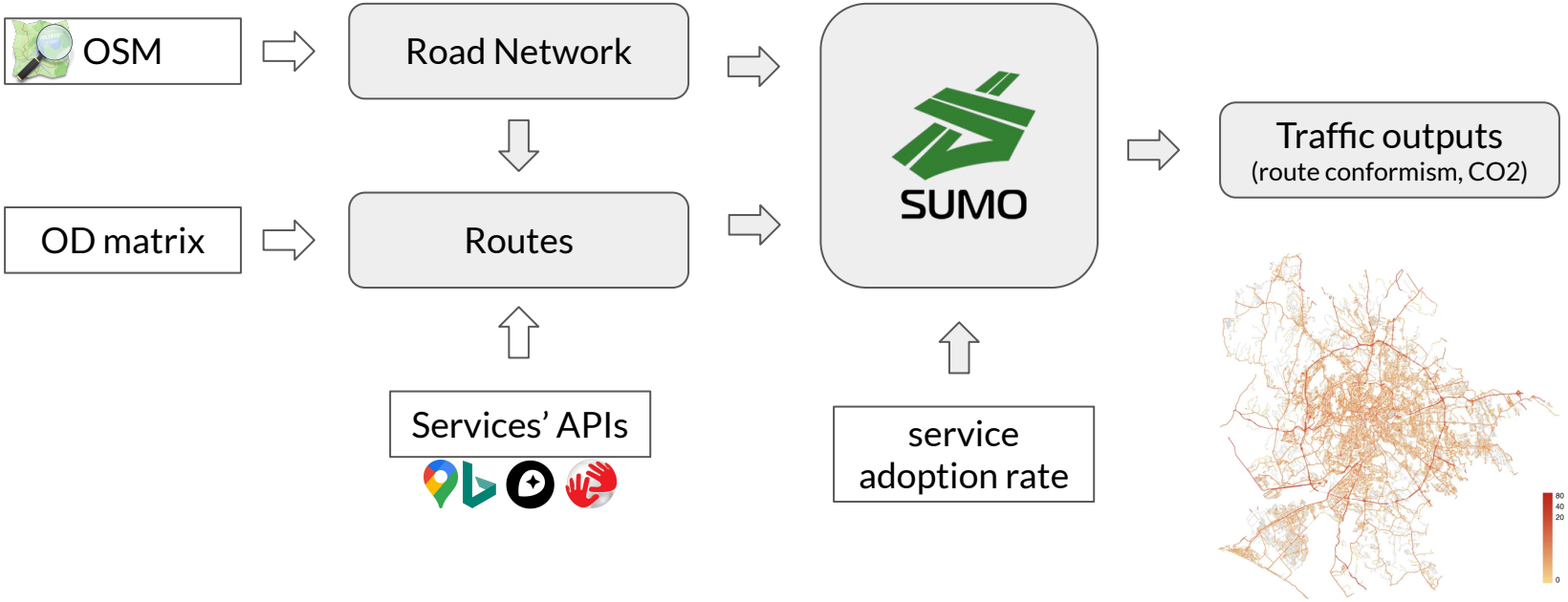
OSM

OD matrix



Simulation Framework

How routing strategies impact urban emissions, 2022, 10.1145/3557915.356097



Limitations of the framework

Navigation services amplify concentration of traffic and emissions in our cities, arXiv:2407.20004v1, 2024

Limited simulation capacity

- imperfection of road network
- limited number of vehicles

Violation of SUTVA:

- vehicles in the two groups encounters each other
- peer effects reduce observable differences
  - reported statistics underestimate true causal effects

Experimental Setup

Vary the adoption rate $r \in [0, 10, \ldots, 100]$

- $r\%$ of vehicles randomly assigned* to the treatment group
  - they follow the suggestion based on APIs

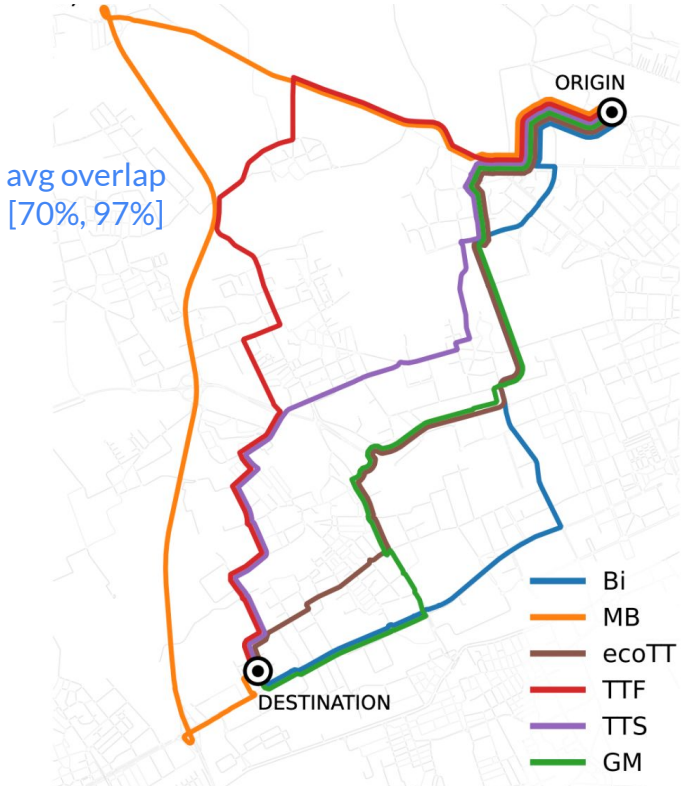
- $(100 - r)\%$ assigned to the control group
  - they follow a *noisy* fastest route
  - to account for the imperfections of human drivers [4]

* experiment repeated 10 times for statistical robustness

Cognitive aspects of traffic simulations in virtual environments. 2012, 10.11128/sne.22.tn.10127

Experimental Setup

At today, Waze and AppleMaps do not provide public APIs.



- **Uniform distribution of departure time (in 1h)**

Bing Maps

TOMTOM SHORT

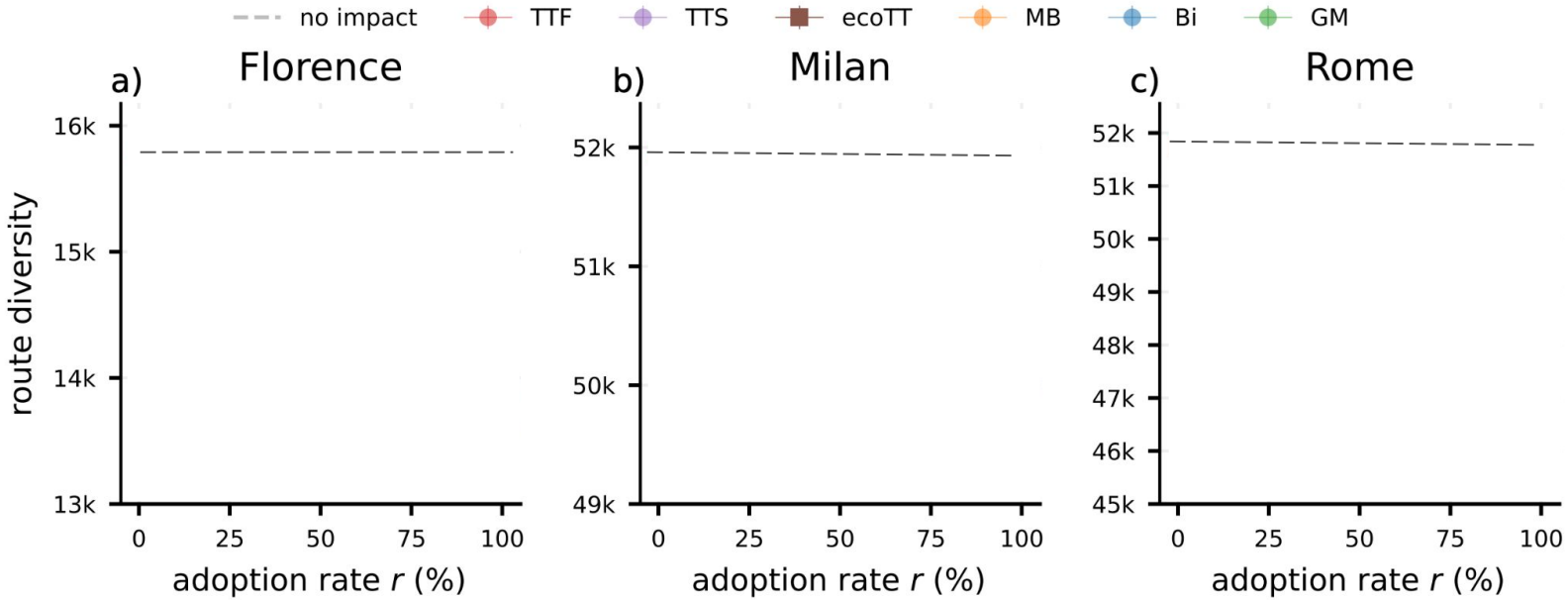
TOMTOM

mapbox

TOMTOM FASTEST

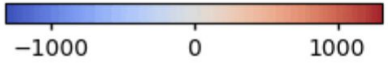
Results: route diversity

* Results are consistent with traffic loads



- Low adoption rate (0-20%): route diversity slightly increases (<1%)
- High adoption rate: strong diversity reduction (up to 15%)

0% adoption rate



$r = 0\%$

$r = 100\%$

51,967 travelled edges

49,848 travelled edges

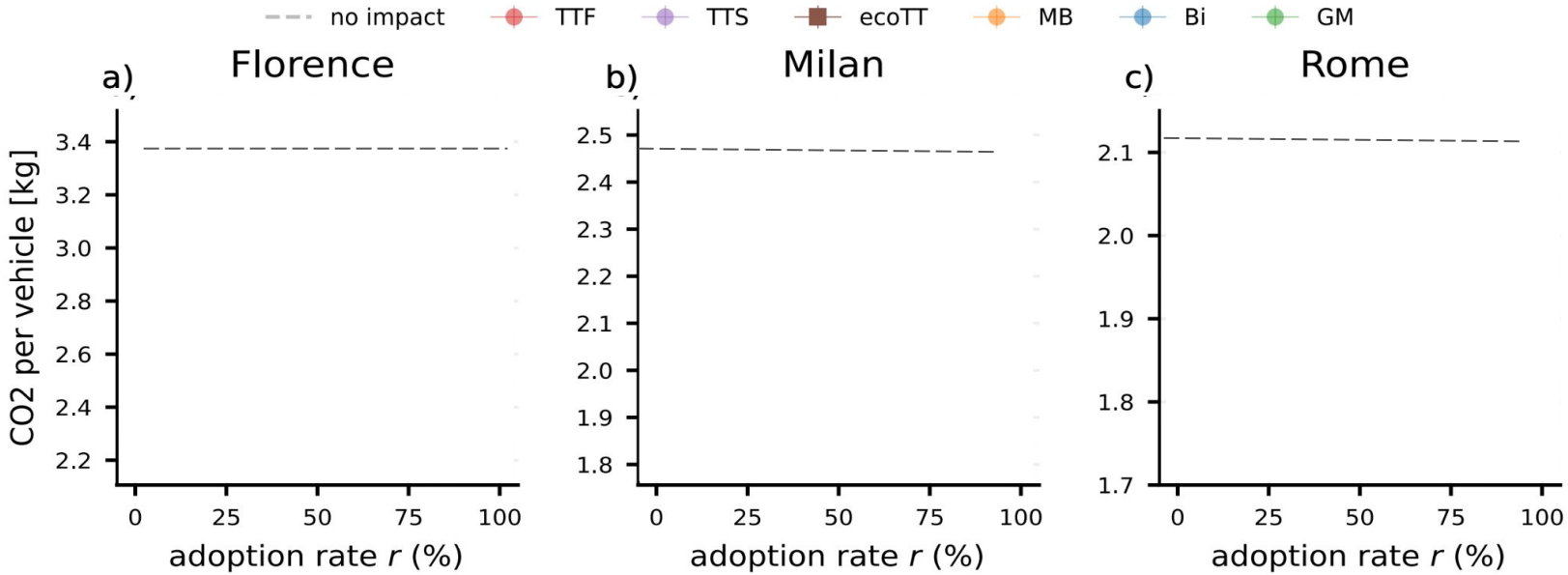
500 1500

number of routes (n)

−1000 0 1000

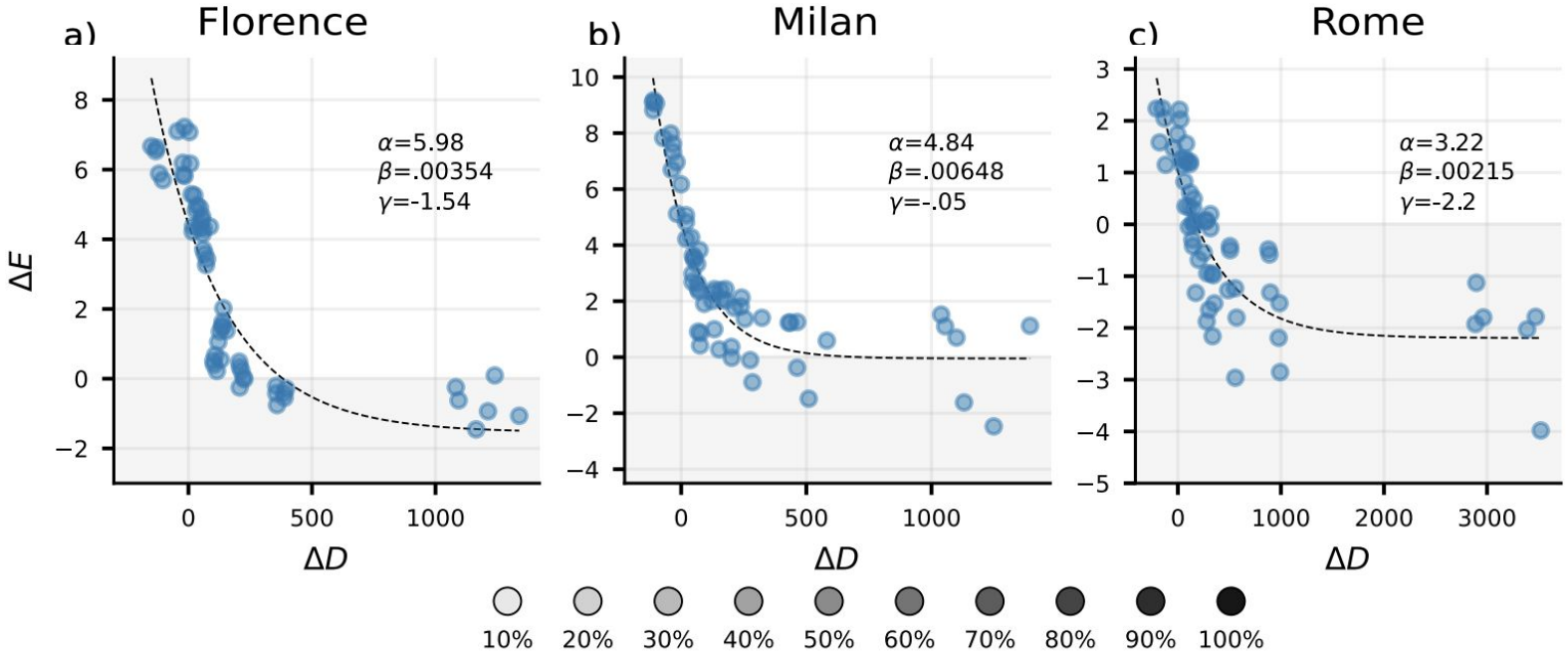
difference in n

Results: CO2 emissions



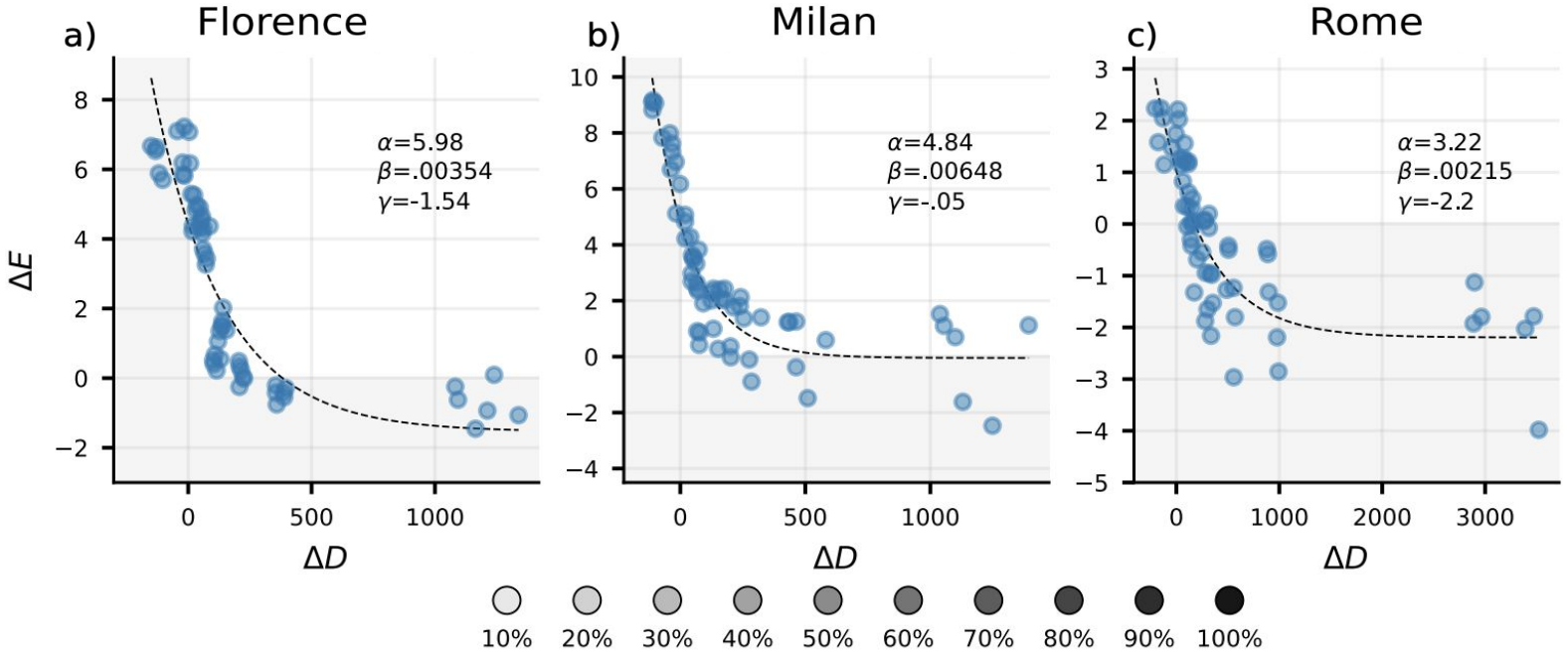
- Low traffic loads: services are beneficial, reducing CO2 emissions
- High traffic loads: with high adoption rates, the benefits plateau or event revert

Results: marginal change



- At low adoption rates, slight increases in route diversity lead to substantial reductions in CO2 emissions

Results: marginal change



- As high adoption rates, small D reductions result in moderate E reductions
- As ΔDr further increases, ΔEr decreases, indicating a diminishing return effect

In summary

[11] Navigation services amplify concentration of traffic and emissions in our cities, arXiv:2407.20004v1

Navigation services **amplify** concentration of traffic

Navigation services may:

- exacerbate exposure inequality
- interfere with existing policies
- impact the economic and social fabric of neighbourhoods

0% adoption rate

Discussion

What additional factors, beyond diversity and CO2, could be explored in this analysis?

Discussion

How can we mitigate the detrimental effects of navigation services?

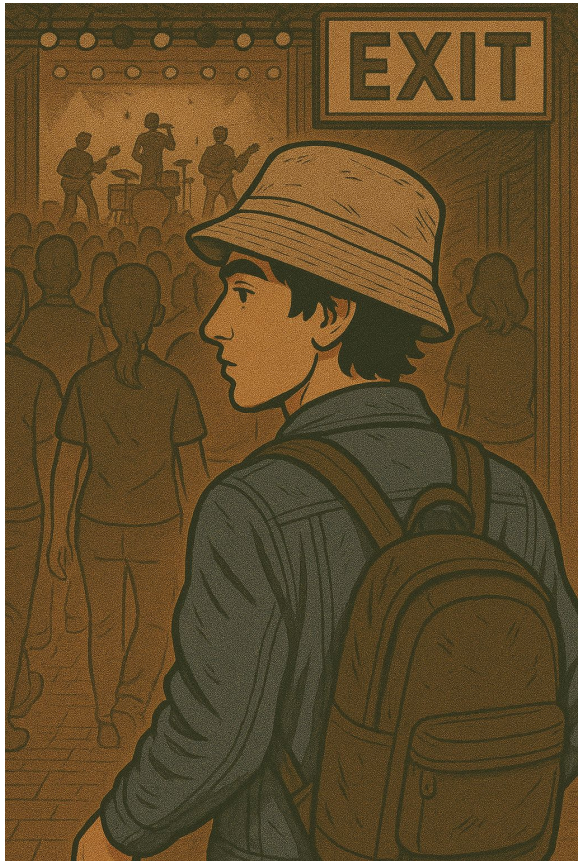
The urban impact of AI: modelling feedback loops in location-based recommender systems

Cornacchia et al., Arxiv 2024

Type:	**Simulation observational**
VLOP:	**Google Maps**
Outcomes:	**concentration**

Venue Selection

“The gig is over,
I need to eat something”



Venue Selection

"..The gig is over, I need to eat something"

Return

Venue Selection

"..The gig is over, I need to eat something"

Return

Explore

Venue Selection

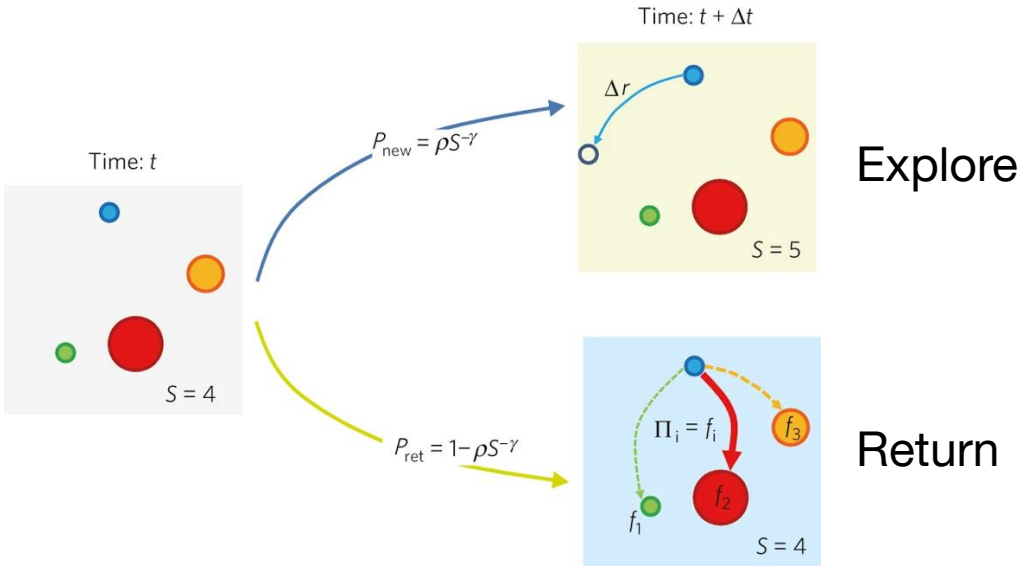
"..The gig is over, I need to eat something"

Return

Explore

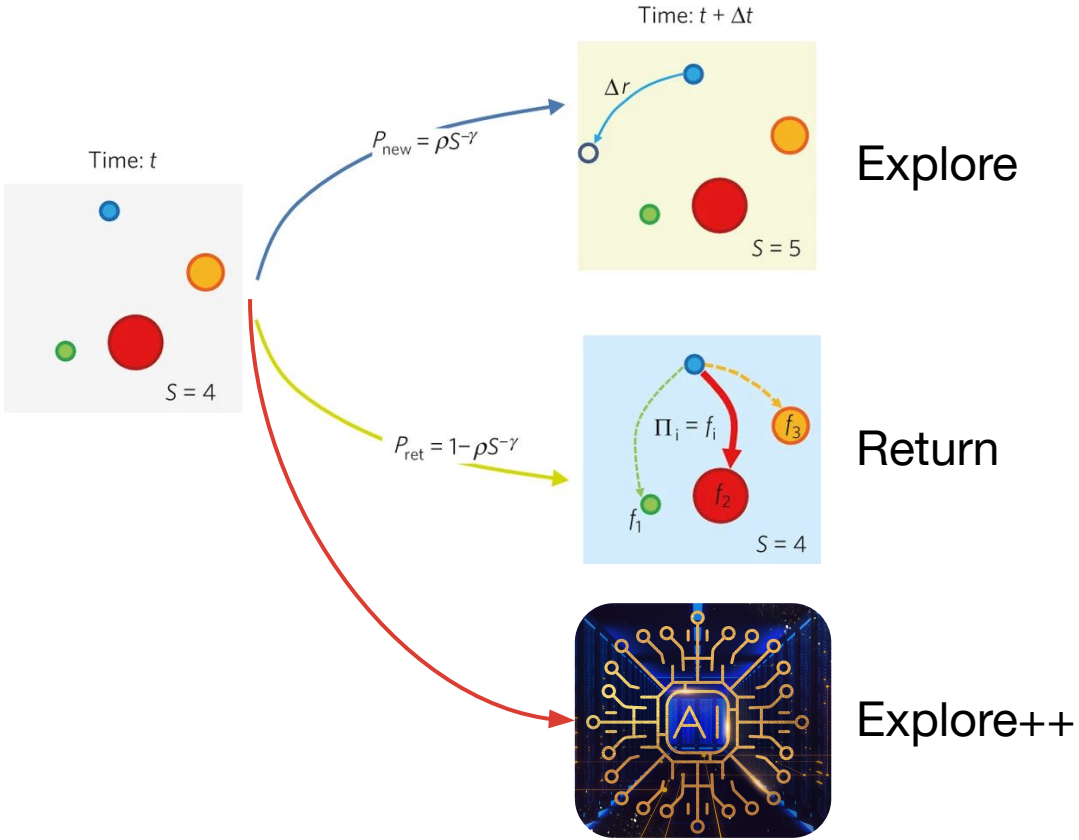
Explore++

Let’s start from the basis…



Song, C., Koren, T., Wang, P., & Barabási, A. L. (2010). **Modelling the scaling properties of human mobility**. *Nature physics*, *6*(10), 818-823.

.. and account for the new mode



Mauro, G., Minici, M., & Pappalardo, L. (2025). The Urban Impact of AI: Modeling Feedback Loops in Next-Venue Recommendation. *arXiv preprint*

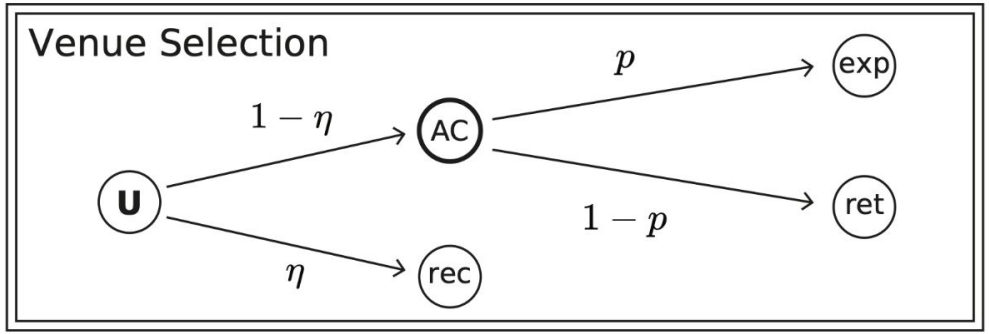
Mobility agenda

Category matters

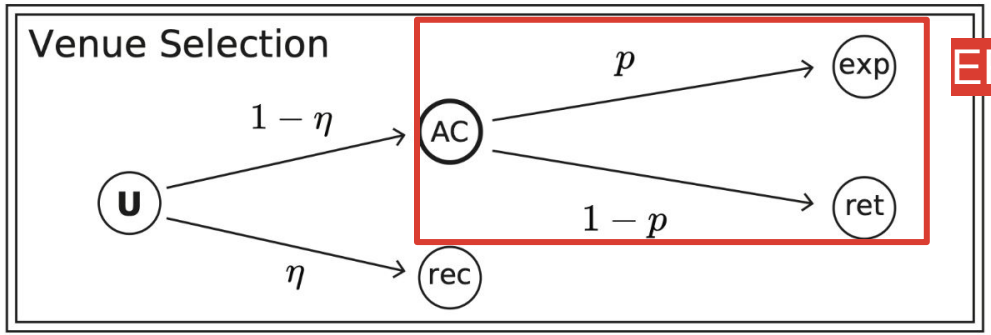
- **Category*** of visited places
- Retained from data
  - **Foursquare** visits in NYC and TKY

*https://docs.foursquare.com/data-products/docs/categories

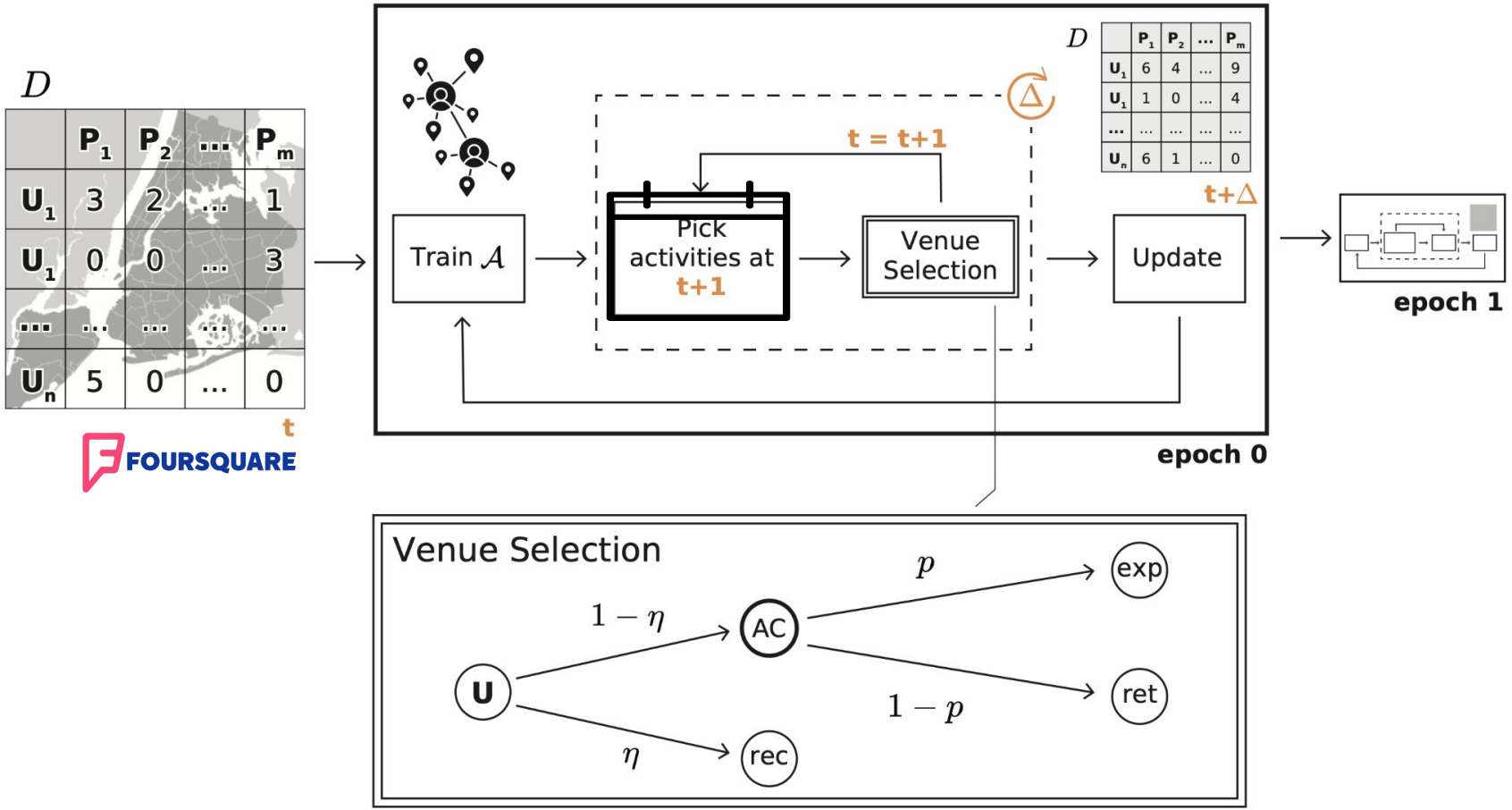
AI vs EPR



AI vs EPR



AI vs EPR.. in the loop



Exploration phase

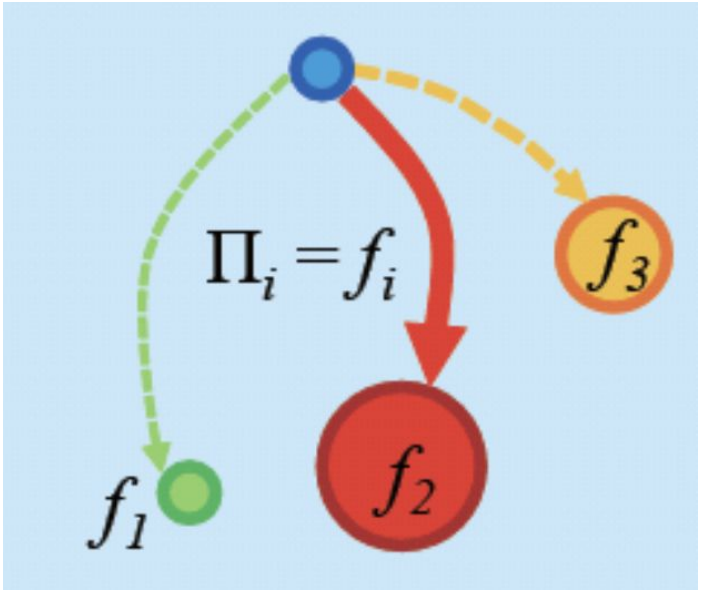
An individual explores a **zone** looking for a type of venue

- **Pick** a **radius** from jump distribution
- Select **correct** category
- Choose the venue by **relevance**

Return Phase

Choose among the **visited** venues of the category

- **proportionally** to the nr of times it visited

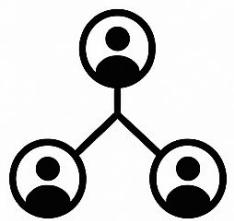


Song, C., Koren, T., Wang, P., & Barabási, A. L. (2010). Modelling the scaling properties of human mobility. *Nature physics*, *6*(10), 818-823.

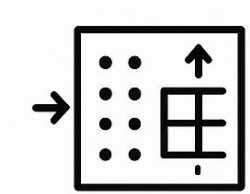
Next-venue Recommender

- **Ask** the **RS**
    - Top k venues of the same **category** returned
        - i.e. I open GMaps and ask for restaurants
- Based on the **last training** set

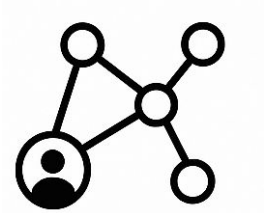
Many Recommenders



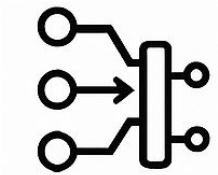
UserKNN



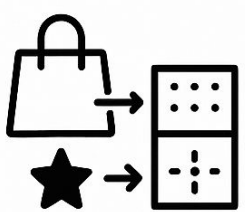
MATRIX FACTORIZATION



Light Graph Convolutional Network

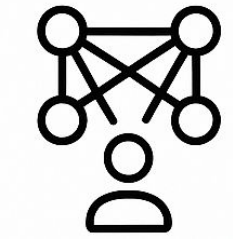


NEURAL MF



ItemKNN

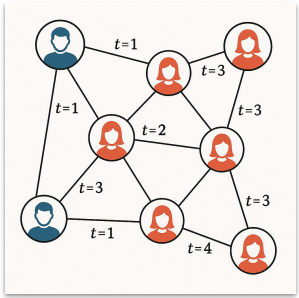
PGN



MULTIVAE

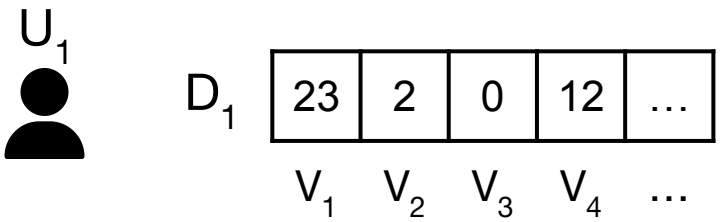
Idea

- Not only look at classical RS literature metrics
  - HitRate@k, Accuracy@k etc.
- Look at the Complex System
  - Colocation Networks
  - Mobility patterns
- Impact of adoption rate η



Measuring visits inequality

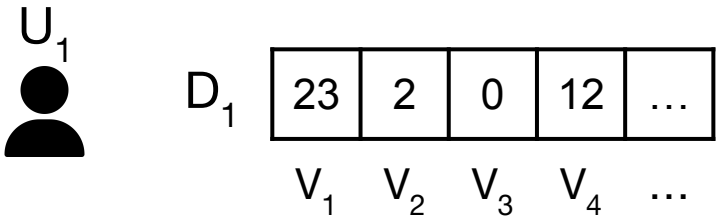
Individual Level



Collective Level

Measuring visits inequality

Individual Level

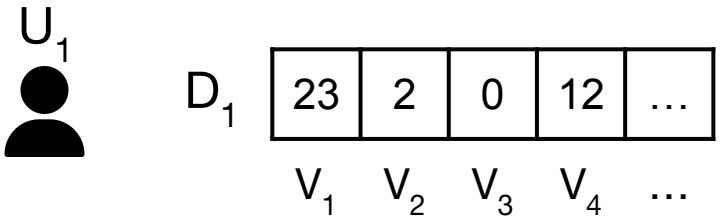


$$G_{U_1} = \text{Gini}(D_1)$$

Collective Level

Measuring visits inequality

Individual Level

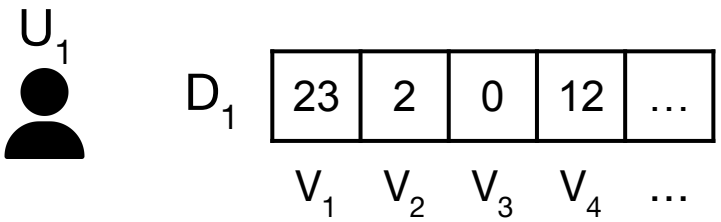


$$G = \frac{1}{n}\left(n + 1 - 2\,\frac{\Sigma_{i=1}^{n}\,(n+1-i)y_i}{\Sigma_{i=1}^{n} y_i}\right)$$

Collective Level

Measuring visits inequality

Individual Level



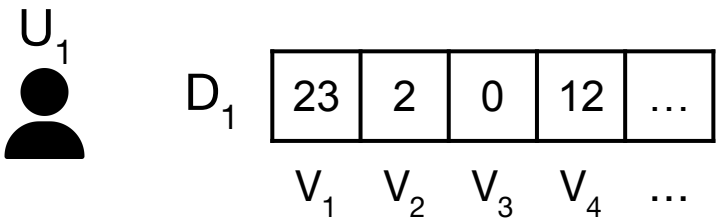
$$G_{U_1} = \text{Gini}(D_1)$$

$$\bar{G} = \sum_{i=1}^{n} G_{U_i}$$

Collective Level

Measuring visits inequality

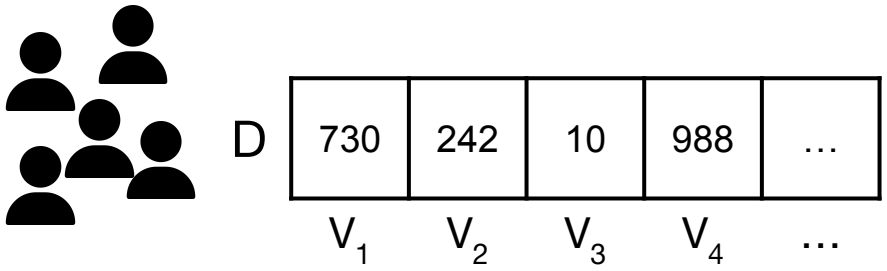
Individual Level



$$G_{U_1} = \text{Gini}(D_1)$$

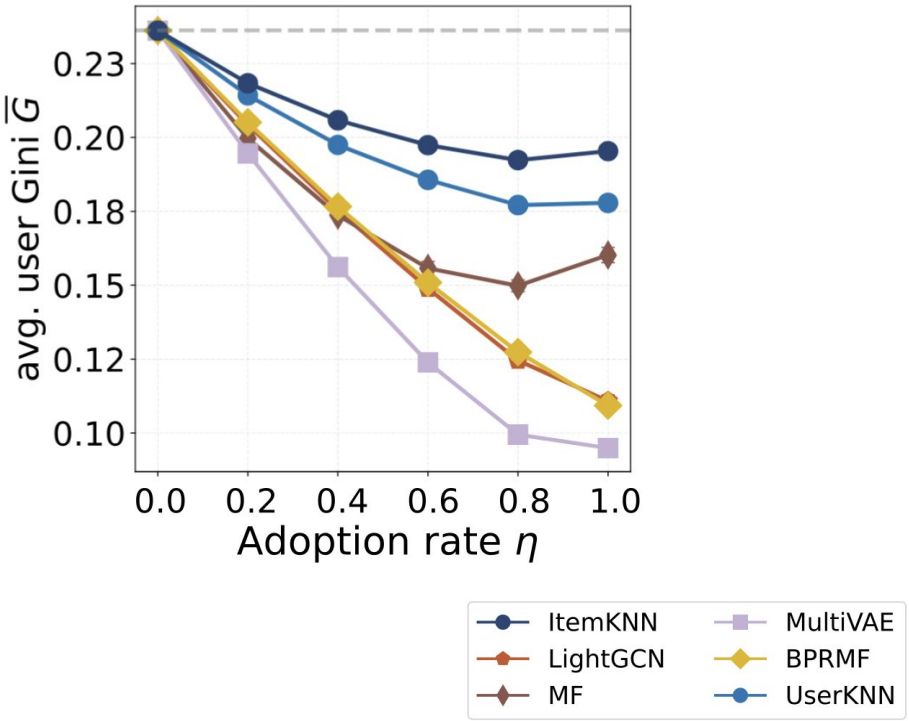
$$\bar{G} = \sum_{i=1}^{n} G_{U_i}$$

Collective Level



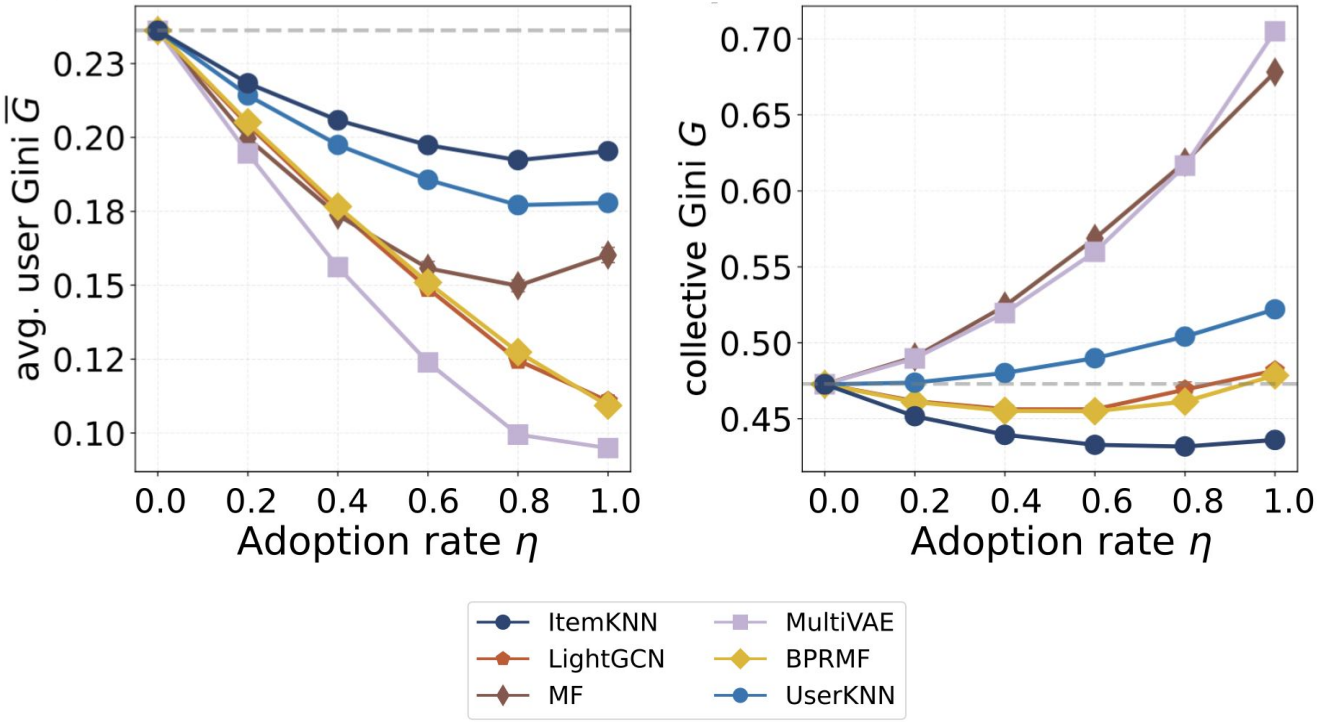
$$G = \text{Gini}(D)$$

Visitation Layer

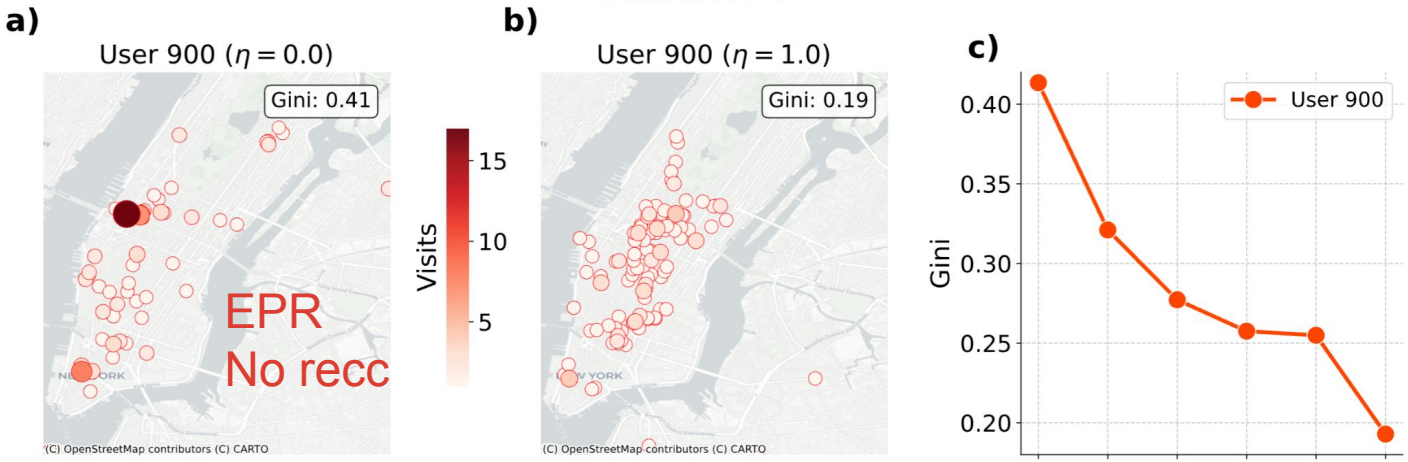


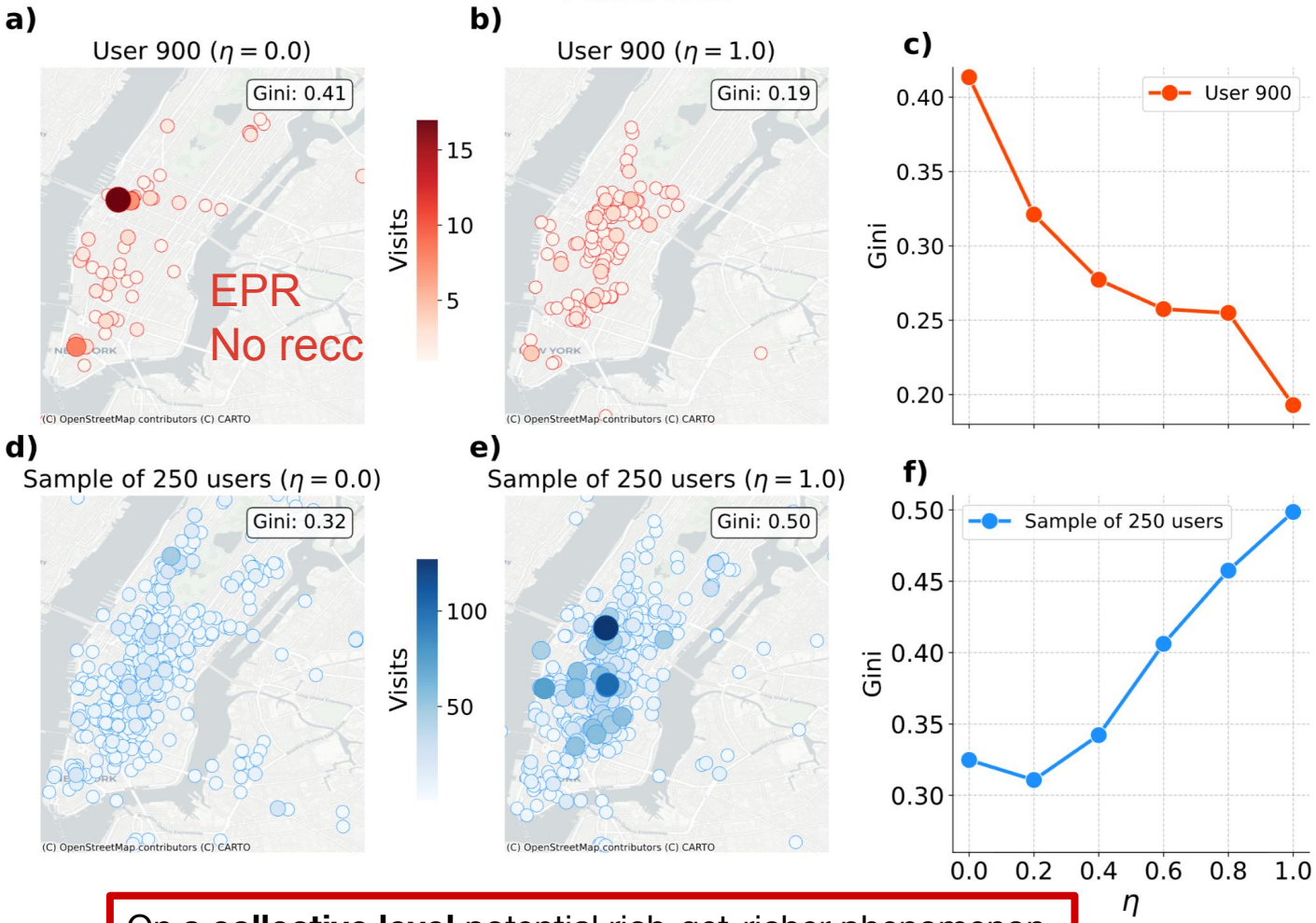
- The feedback loop **boosts individual diversity**
- On a **collective** level the distribution is more **unequal**. Potential rich-get-richer

Visitation Laver

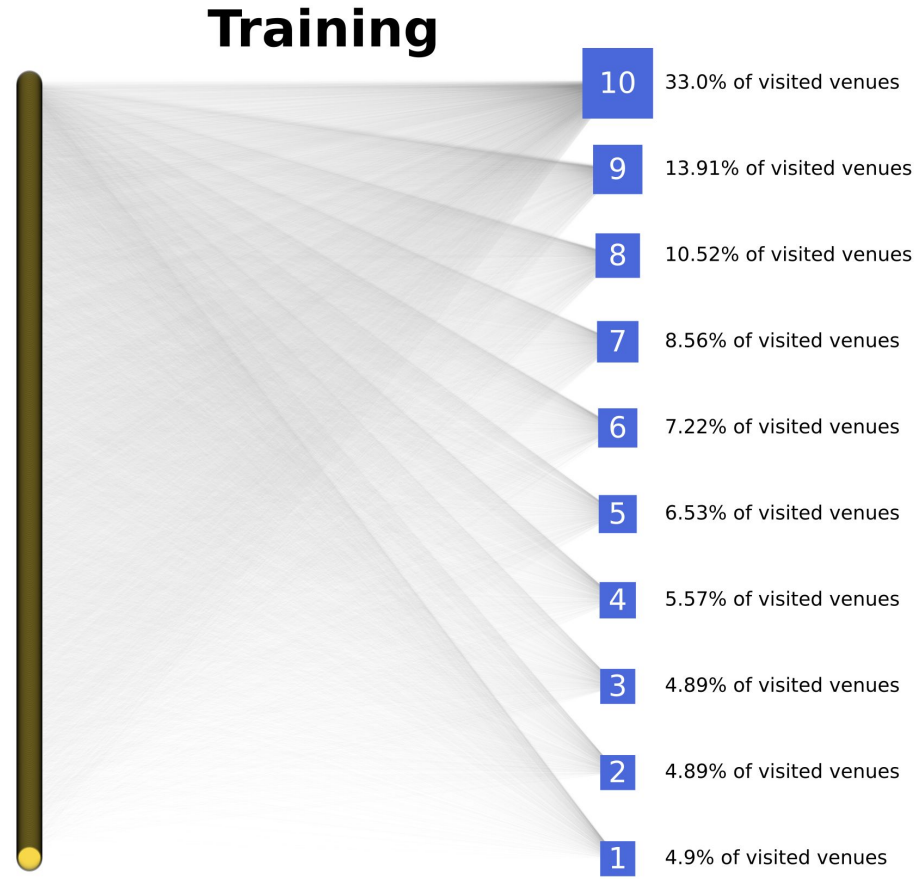


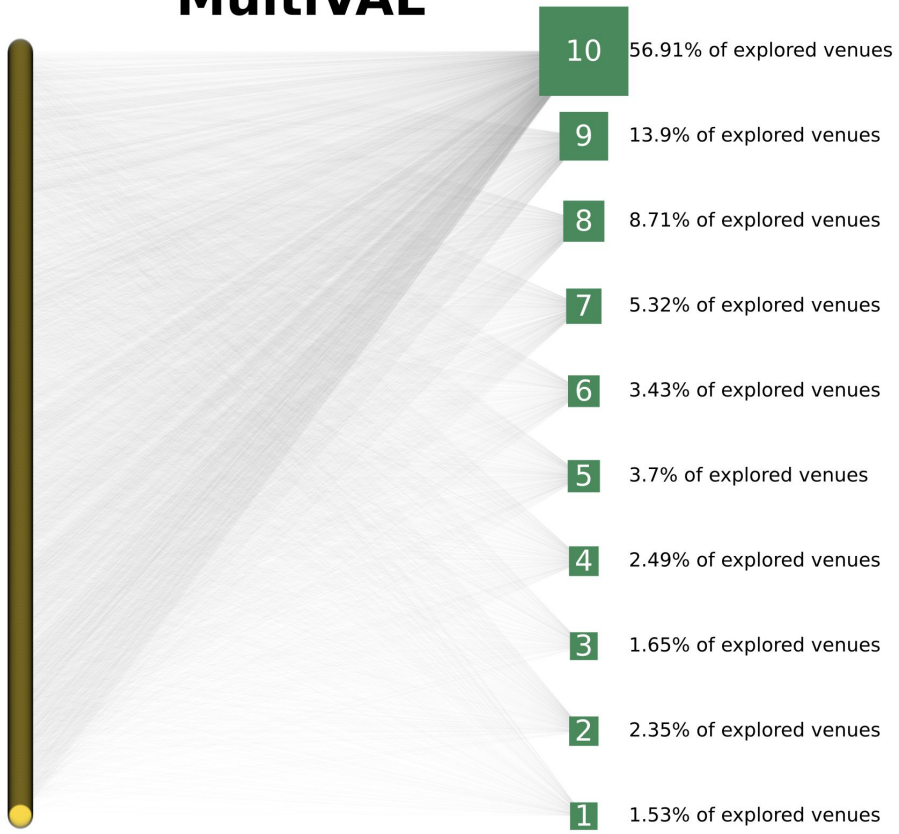
- The feedback loop **boosts individual diversity**
- On a **collective** level the distribution is more **unequal**.


MultiVAE
a)
User 900 ($\eta = 0.0$)
Gini: 0.41
EPR
No recc
(C) OpenStreetMap contributors (C) CARTO
Visits
15
10
5
b)
User 900 ($\eta = 1.0$)
Gini: 0.19
(C) OpenStreetMap contributors (C) CARTO
c)
User 900
Gini
0.40
0.35
0.30
0.25
0.20



On a **collective level** potential rich-get-richer phenomenon


Training
10
33.0% of visited venues
9
13.91% of visited venues
8
10.52% of visited venues
7
8.56% of visited venues
6
7.22% of visited venues
5
6.53% of visited venues
4
5.57% of visited venues
3
4.89% of visited venues
2
4.89% of visited venues
1
4.9% of visited venues


MultiVAE
10
56.91% of explored venues
9
13.9% of explored venues
8
8.71% of explored venues
7
5.32% of explored venues
6
3.43% of explored venues
5
3.7% of explored venues
4
2.49% of explored venues
3
1.65% of explored venues
2
2.35% of explored venues
1
1.53% of explored venues

Discussion

What other aspects can we investigate?

References

Articles (useful for the project):

- Arora et al., **Quantifying the sustainability impact of Google Maps: A case study of Salt Lake City**, ArXiv 2021, https://arxiv.org/abs/2111.03426
- Cornacchia et al., **Navigation services amplify concentration of traffic and emissions in our cities**, ArXiv 2024, https://arxiv.org/abs/2407.20004
- Mauro et al., The urban impact of AI: modelling feedback loops in location-based recommender systems, Machine Learning 115: 19, 2026
- L. Pappalardo et al. **A survey on the impact of AI-based recommenders on human behaviours: methodologies, outcomes and future directions**, 2024, https://doi.org/10.48550/arXiv.2407.01630
    - Section 5 Urban Mapping Ecosystem

Books, articles, podcasts

To learn more:

- Pappalardo et al., Future direction in Human Mobility Science, Nature Comp. Science, 2023
- Dahmani and Bohbot, Habitual use of GPS negatively impacts spatial memory during self-guided navigation, Scientific Reports, 2020
- Schade et al., Traffic jam by GPS: A systematic analysis of the negative social externalities of large-scale navigation technologies, PLoS One 2024
- “An artist used 99 phones to fake a Google Maps traffic jam”, https://www.wired.com/story/99-phones-fake-google-maps-traffic-jam/

Intellectually stimulating:

- Greg Milner, “Pinpoint: How GPS is Changing Technology, Culture, and Our Minds Paperback”, W. W. Norton & Company, 2017
- Roger Elwood, “Future City”, Paperback, 1973