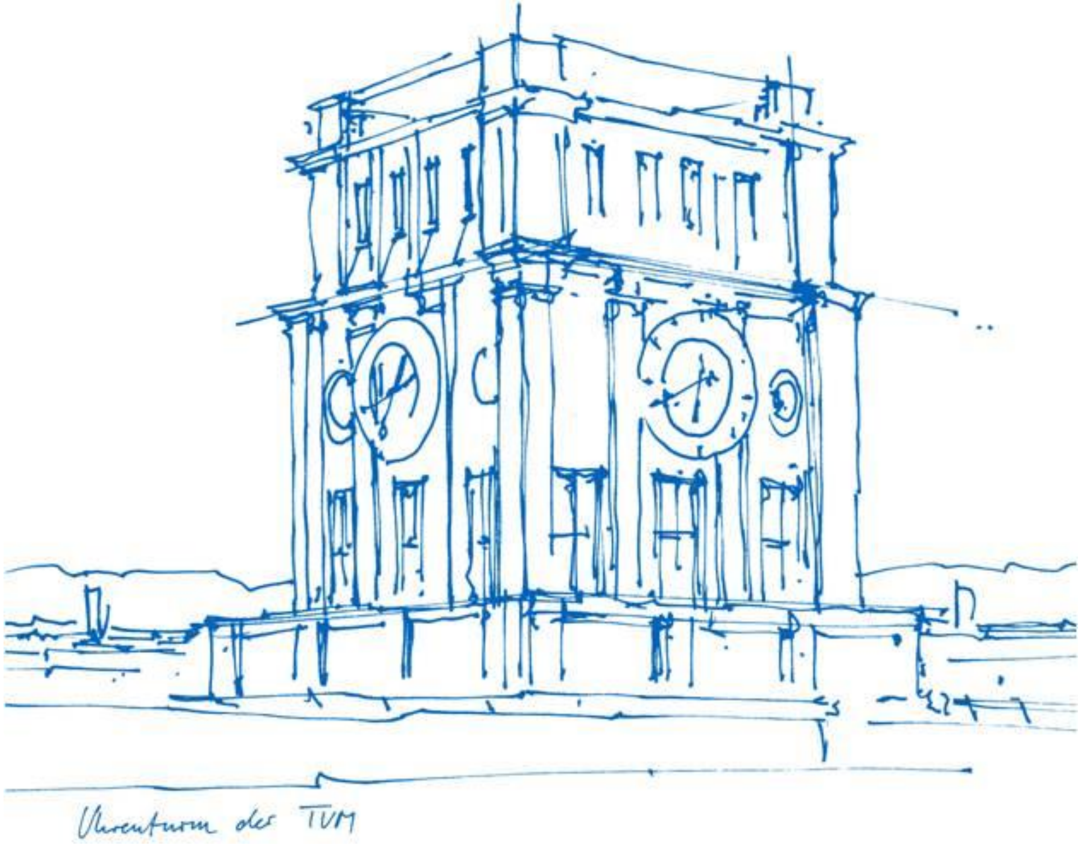
Advances in Pedestrian Travel Demand Modeling

Innovation of Data, Modeling Approaches and Outcomes

Doctoral defense, 13 March 2023

Qin Zhang



Examination Committee

Chairman: Prof. Dr.-Ing. Constantinos Antoniou

Examinator: Prof. Dr.-Ing. Rolf Moeckel

Prof. Dr. Kelly J. Clifton

Motivation

Walking (as transport)

- offers significant positive health benefits:
  - ➢ Improve cardio fitness
  - ➢ Reduce obesity
  - ➢ Control Diabetes
  - ➢ Increase lung capacity
  - ➢ Boost muscle power
  - ➢ Reduce stress

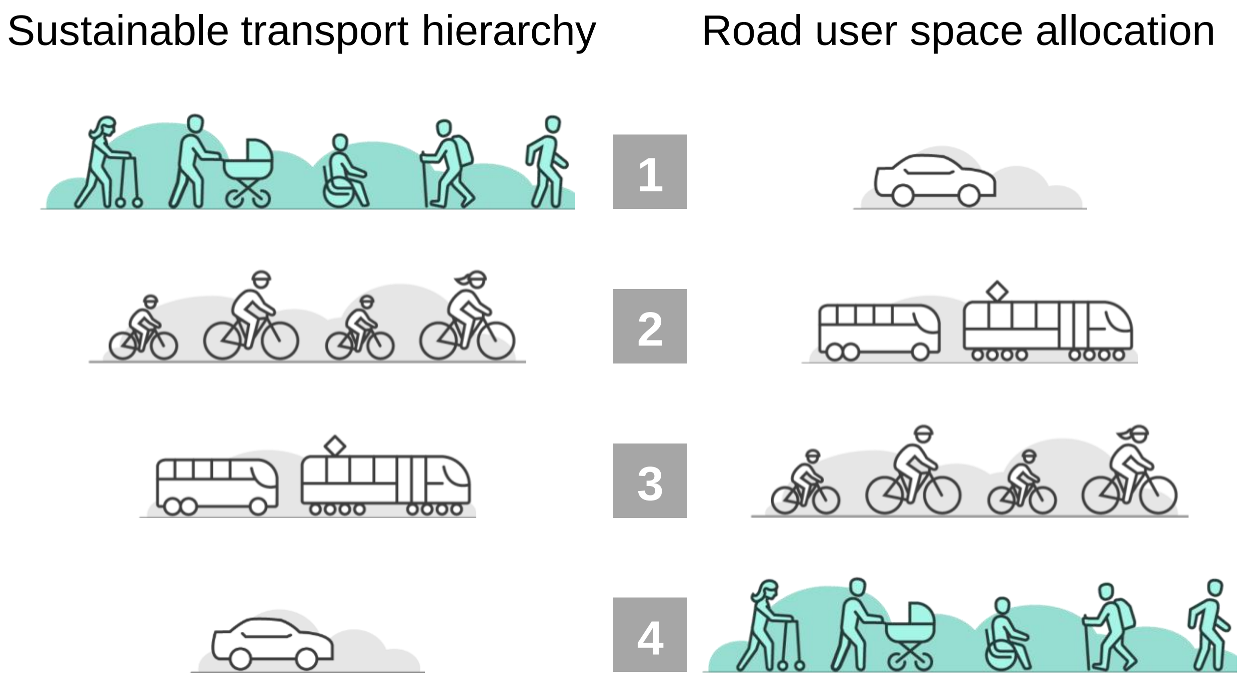
1 IN 4 adults is not active enough.

Walking for **30 minutes** on **most days** reduces mortality risk by at least **10%.**

Source: WHO 2022, Cycling and walking can help reduce physical inactivity and air pollution, save lives and mitigate climate change

Walking (as transport)

- is the most sustainable transport
  - ➢ Reduces energy consumption
  - ➢ Mitigates climate change
  - ➢ Reduces air pollutant



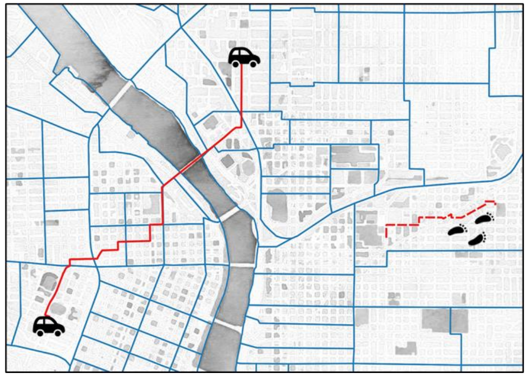
However, transport planning and decision-making have often overlooked walking.

Research Gap

Traditional travel demand models…

- have been more focused on motorized vehicles, and less on pedestrian.

Spatial resolution (TAZ)



Planning horizon (one day)

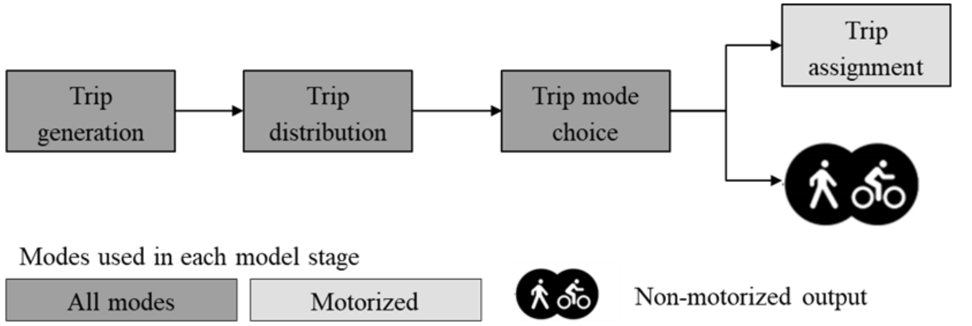
One-day travel survey → Modeled walking time/distance of a typical day x 7 → Health assessment

Travel behavior determinants

Individual/household attributes, (car/transit) accessibility

Pedestrian built environment (e.g. slope, park)

Modeling framework



Research Roadmap

Research goal

Improve pedestrian representation in travel demand models
to better assess travel outcomes and evaluate policies and scenarios

Research objectives

- Model accuracy
- Model sensitivity
- Model transferability
- Model efficiency

Research gaps

- Built environment measures
- Modeling Approach
- Pedestrian Data
- Travel behavior variability

Approaches

- 1) Enhance MoPeD 1.0 and
  2) integrate MoPeD with MITO
- 3) Collect longitudinal dataset & explore pedestrian travel behavior variability

What you may get from this thesis?

What you may get from this thesis…

Everyone can gain access to the open-source pedestrian planning tool that can be transferred to your contexts and applied to various policies and scenarios.

If you are …

a transportation modeler

- You can contemplate the critical modeling issues raised in this thesis
- You can gain some ideas for the next generation of pedestrian travel demand model

a transportation analyst

- You can gain insights on travel behavior variability
- You can learn the potentials and limitations of using longitudinal GPS data

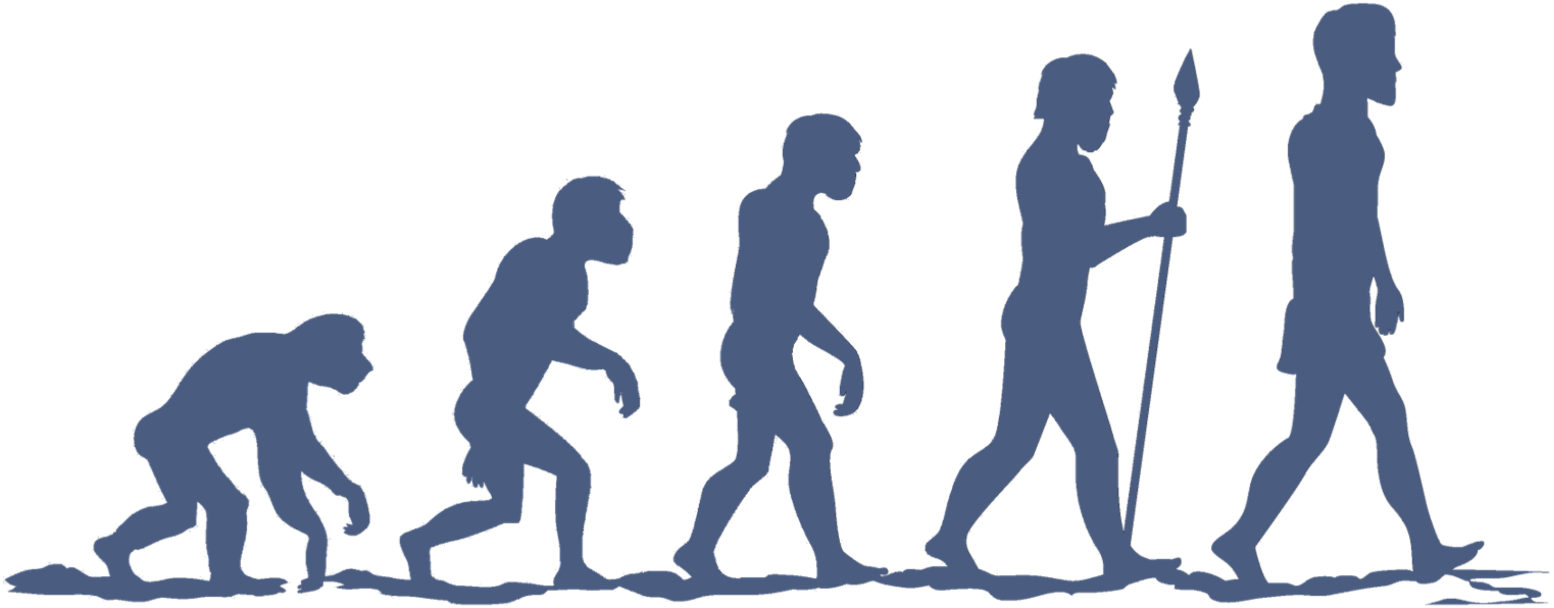
a general researcher

- You can grasp the up-to-date development of pedestrian travel demand model
- You may find out the potentials of linking it to your research field (e.g., health)

Towards MoPeD 2.0*

Advancing Pedestrian Demand Modelling

*MoPeD – Model of Pedestrian Demand is a regional pedestrian travel demand estimation model.



Zhang, Q., Moeckel, R., & Clifton, K. (2022). Assessing pedestrian impacts of future land use and transportation scenarios. Journal of Transport and Land Use, 15(1), 547–566. https://doi.org/10.5198/jtlu.2022.2117

MoPeD 1.0 → MoPeD 2.0

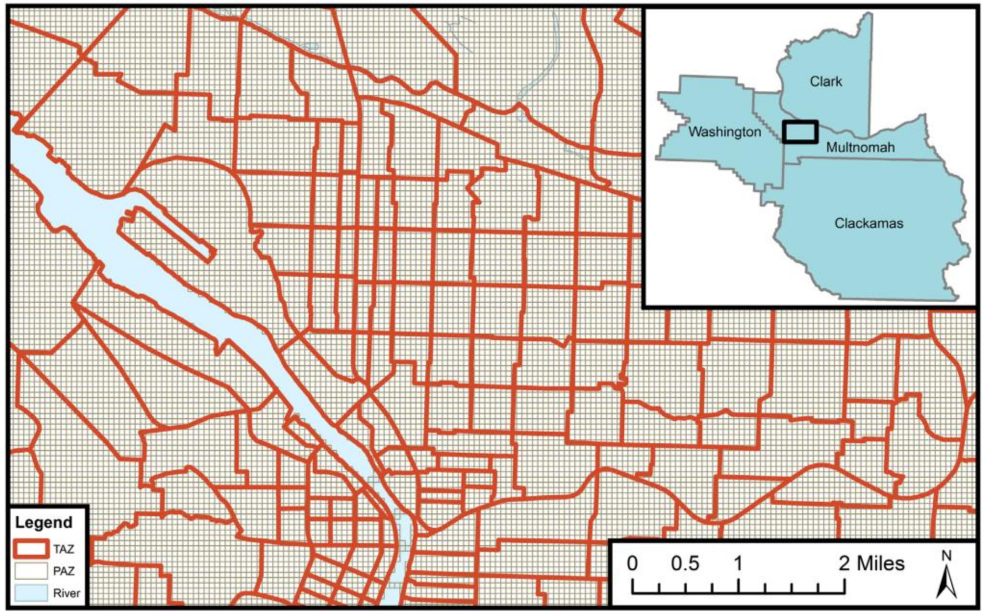
Operational and more efficient run time at urban scale

More transferable Pedestrian Index of the Environment

More accurate two-stage walk destination choice models

Complete modeling process including route choice

PAZs and TAZs in Part of the Portland, Oregon, Region



Pedestrian Analysis Zone (PAZ): 80 x 80 m grid cells

Portland metropolitan area ~ 2,000,000 PAZs

Run time: 4.5 minutes

MoPeD 1.0 → MoPeD 2.0

MoPeD – Model of Pedestrian Demand is a regional pedestrian travel demand estimation model.

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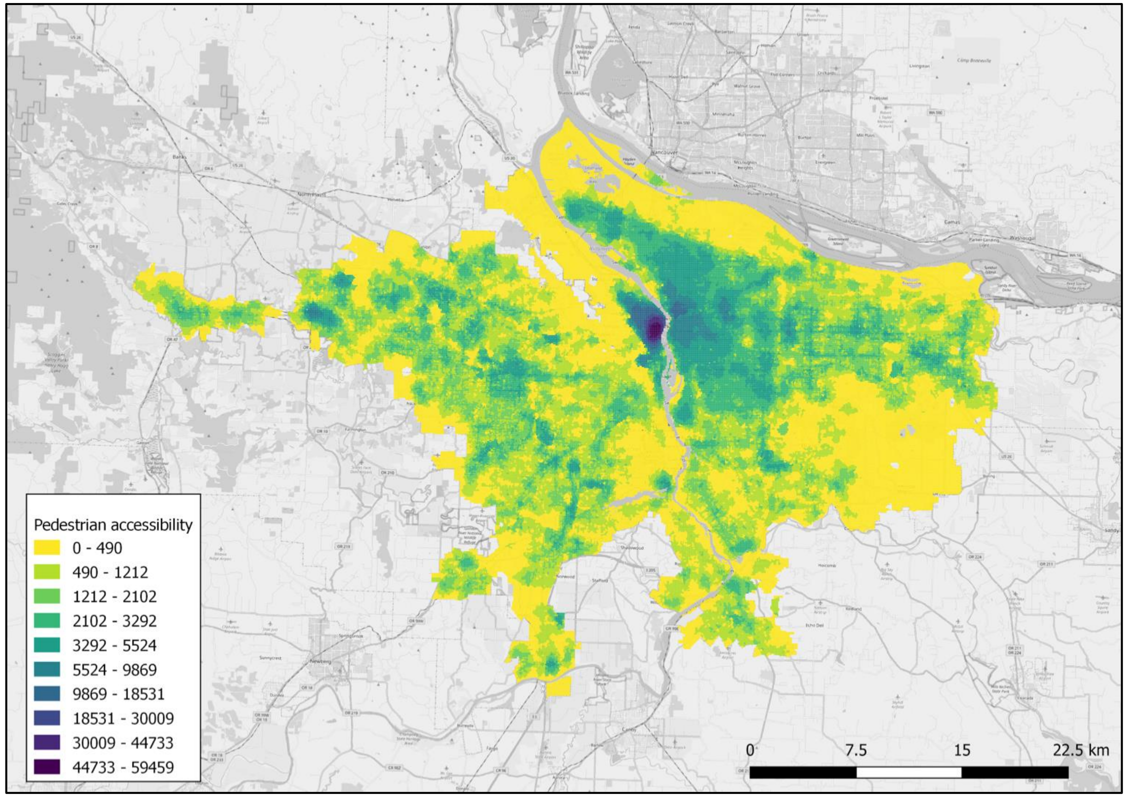

Pedestrian Index of the Environment (PIE) = Activity density (employment and population) that can be reached within an 800-meters network distance

MoPeD 1.0 → MoPeD 2.0

MoPeD – <u>Mo</u>del of <u>Pe</u>destrian <u>D</u>emand is a regional pedestrian travel demand estimation model.

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More accurate two-stage walk destination choice models

Complete modeling process including route choice

Two-stage walk destination choice model
(Home-based shop as an example)

SuperPAZ choice model - HBS	θ	Sg.	PAZ choice model - HBS	θ	Sg.
Distance (km)			OriginPAZ	0.62	0.13
x Child (Yes)	-2.18	***	Distance (km)	-2.12	***
x Child (No)	-1.77	***	Retail (ln)	0.82	***
Network density	0.05	0.21	Service (ln)	0.19	***
Retail (ln)	0.98	***	Household (ln)	-0.17	***
Industrial job share	-1.31	**	Industrial job share	n.s.	
Slope (mean)	-0.39	***	Park(acre)	-0.65	0.28
Crossing Motorway	-0.28	0.15			
Park (Yes)	n.s.				
Pseudo R^2:	0.53		pseudo R^2:	0.22	

MoPeD 1.0 → MoPeD 2.0

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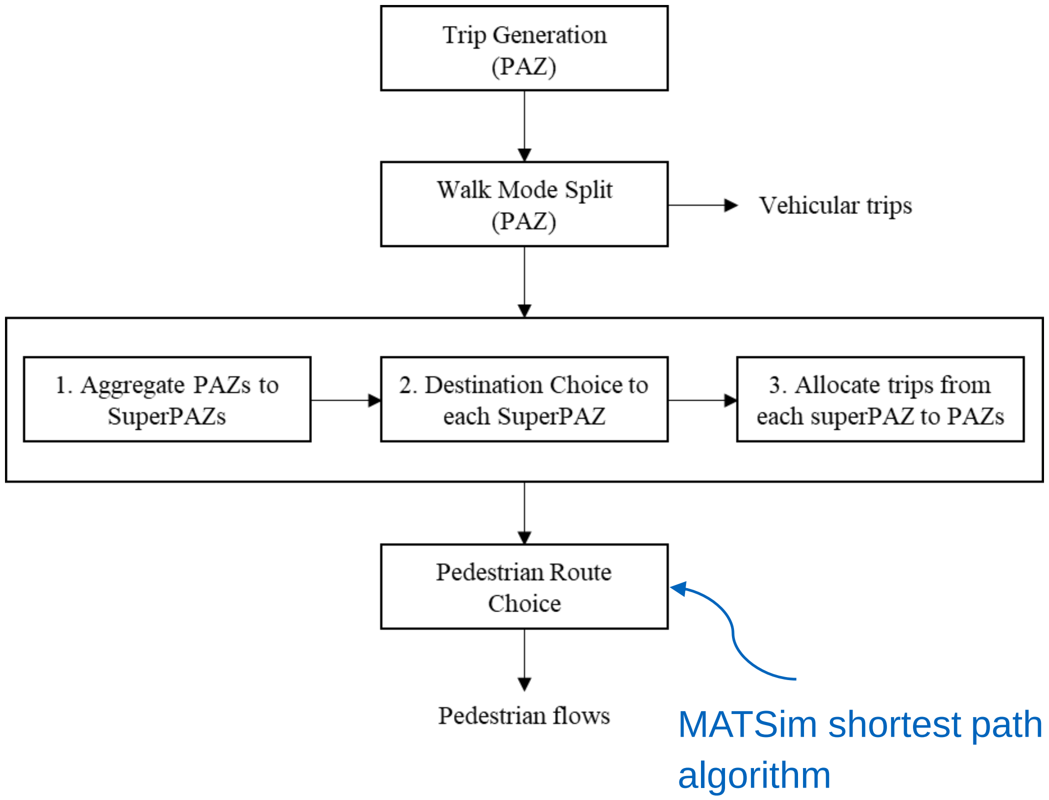
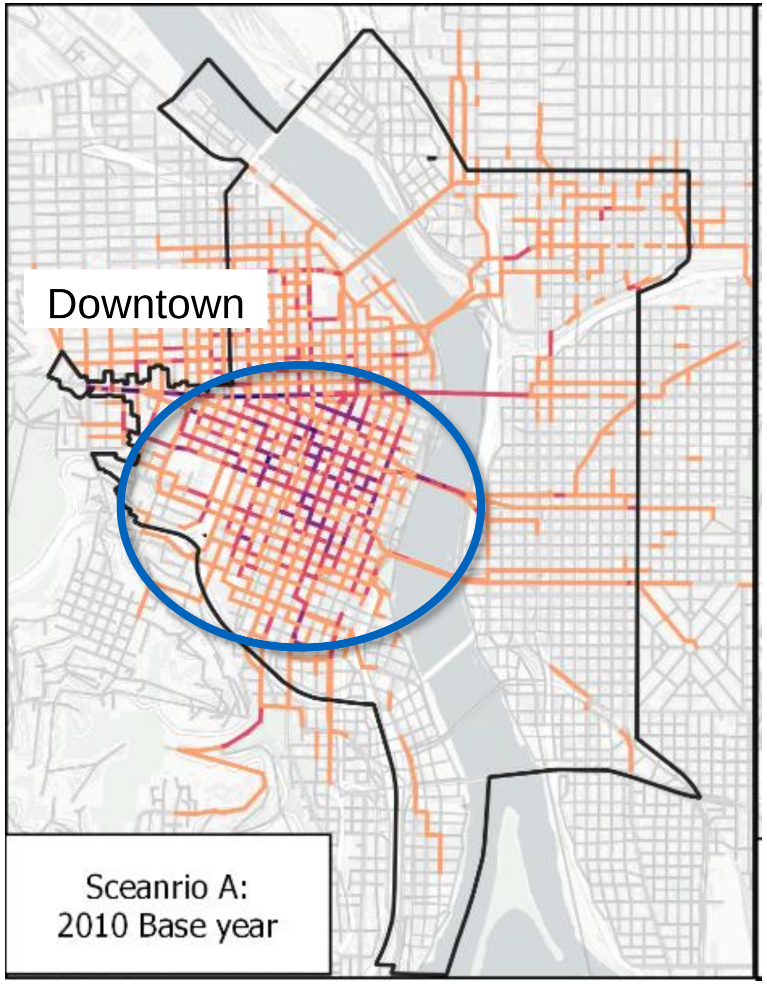
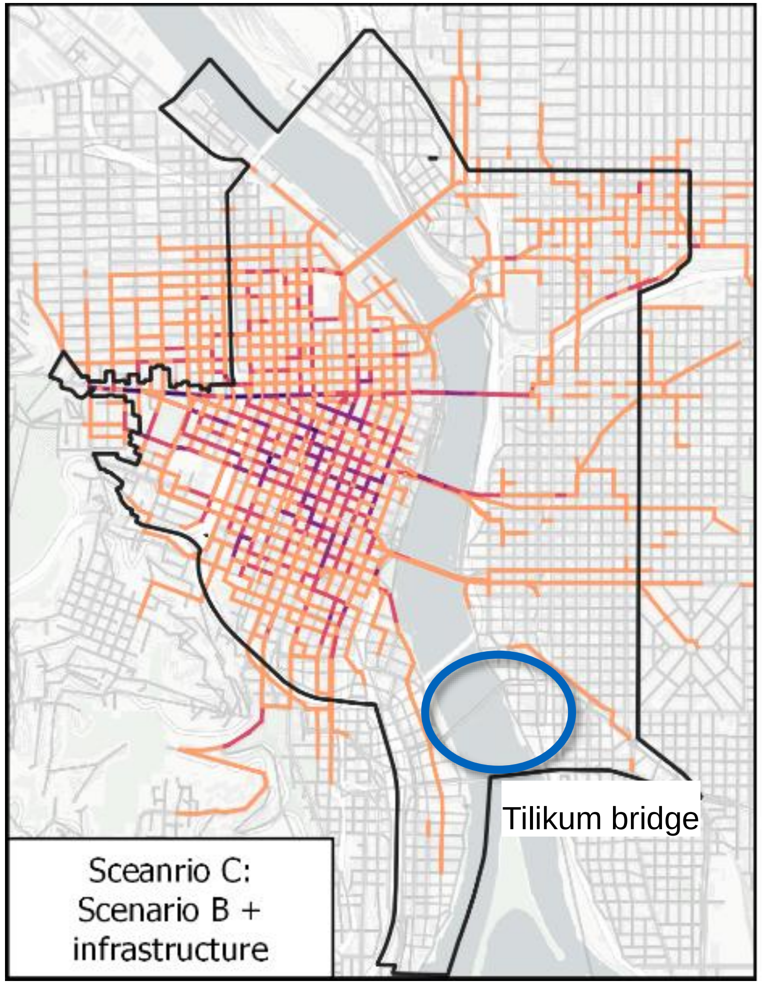


MoPeD 2.0: Portland application

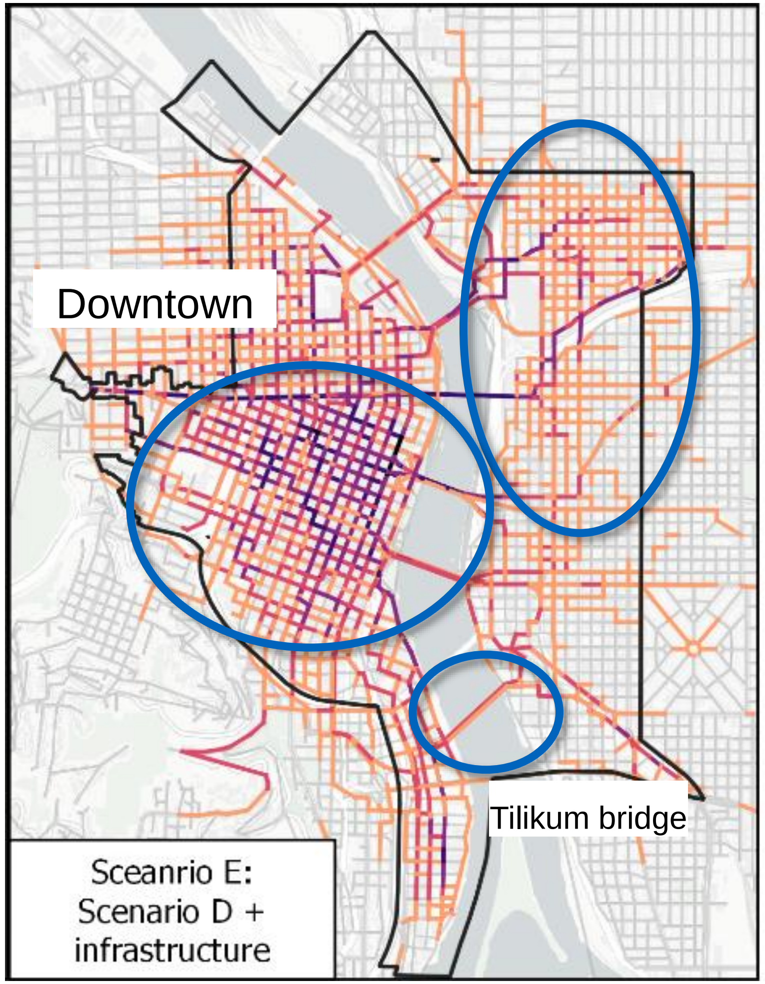
Base 2010



Average growth 2035 + bridges + links



Massive growth 2035 + bridges + links



MoPeD 2.0 Meets MITO*

A Hybrid Agent Based Model For Pedestrian Travel

*MITO - Microscopic Transportation Orchestrator is an agent-based travel demand model

Zhang, Q., Moeckel, R. & Clifton, K.J. MoPeD meets MITO: a hybrid modeling framework for pedestrian travel demand. Transportation (2023).
https://doi.org/10.1007/s11116-022-10365-x

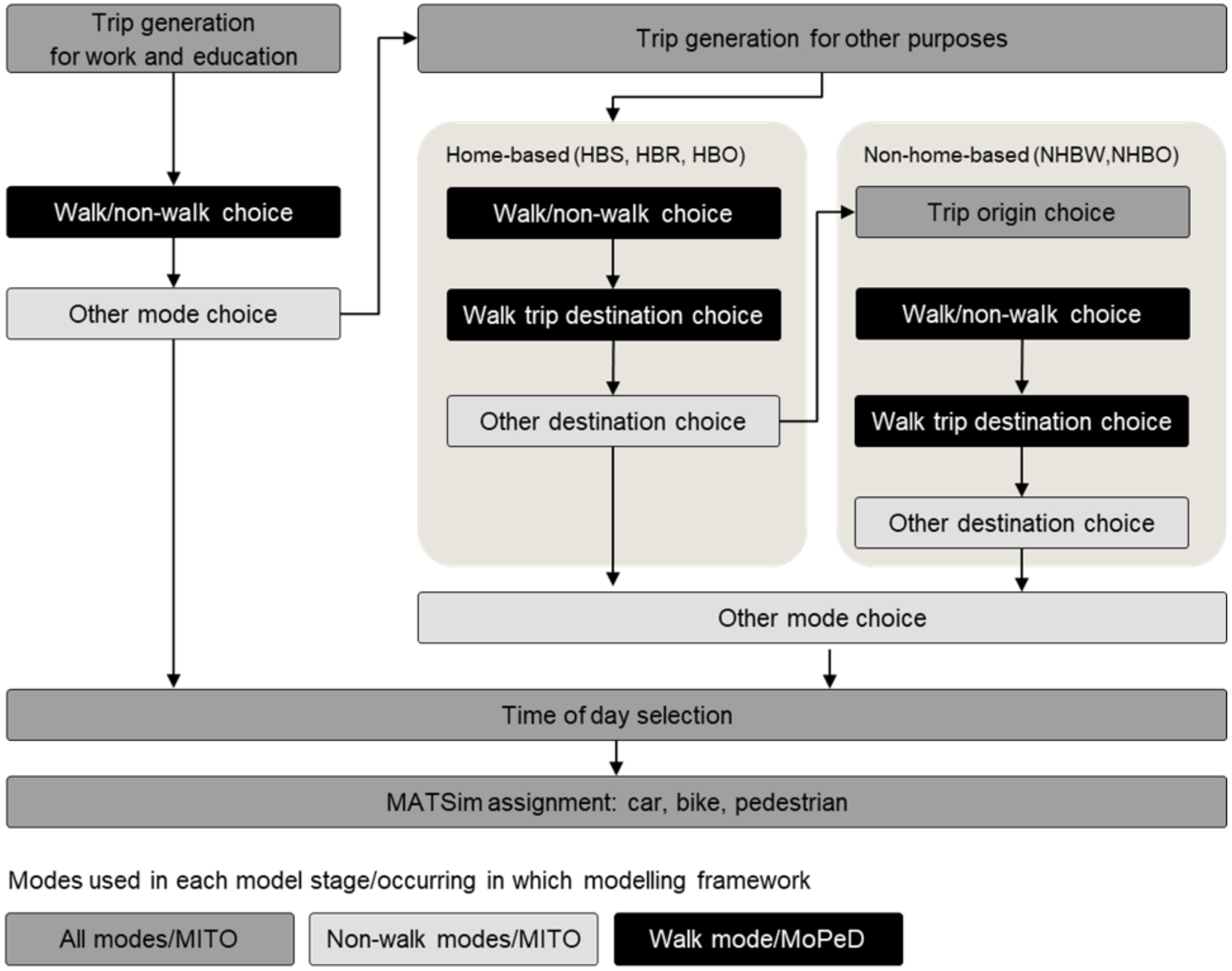
The Hybrid Model

Benefits from MoPeD 2.0:

- Fine spatial resolution
- Pedestrian built environment
- Pedestrian behavior models

Benefits from MITO:

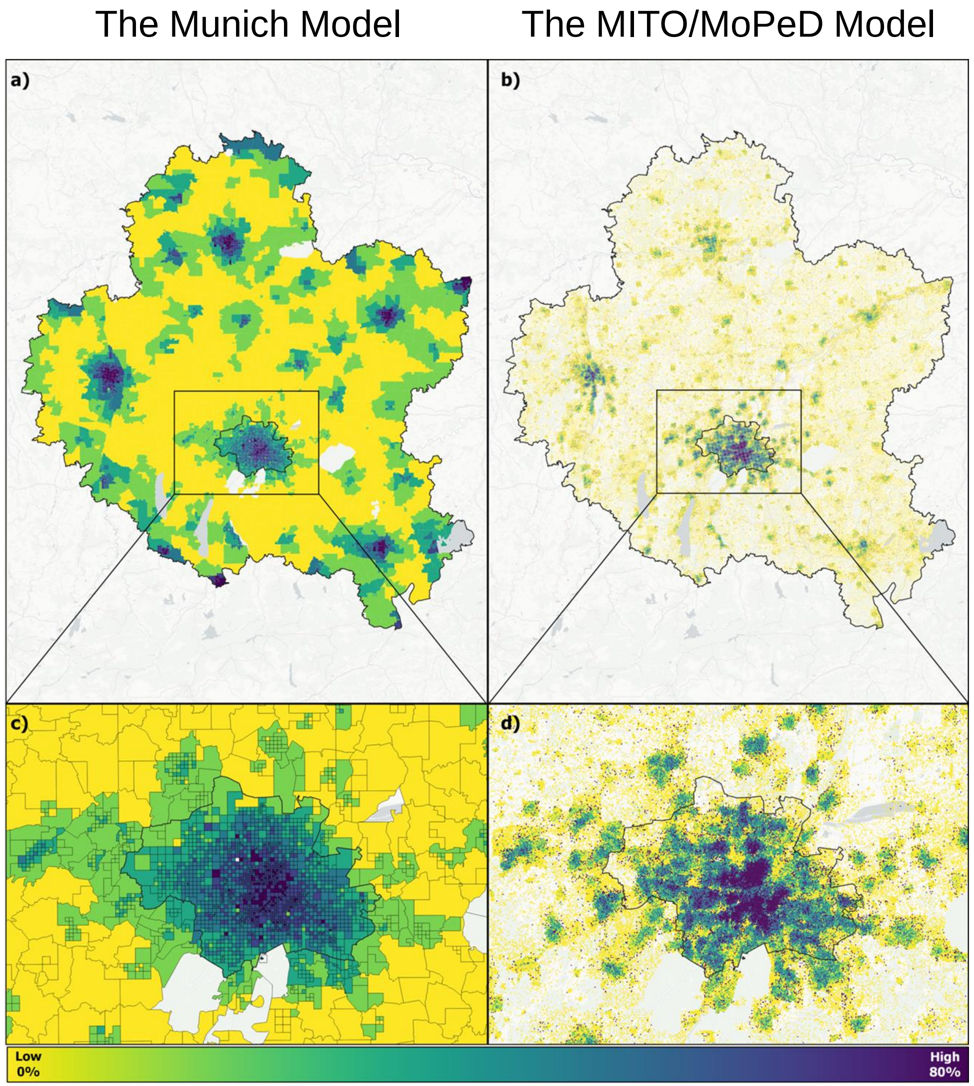
- Agent-based environment
- Behavior models of other modes



The Hybrid Model: Munich application

The hybrid model can better estimate pedestrian demand than the existing Munich Model.

1. More precise walk trip spatial distribution
2. Better capturing short distance trips
3. Better picture of pedestrian flows on network links



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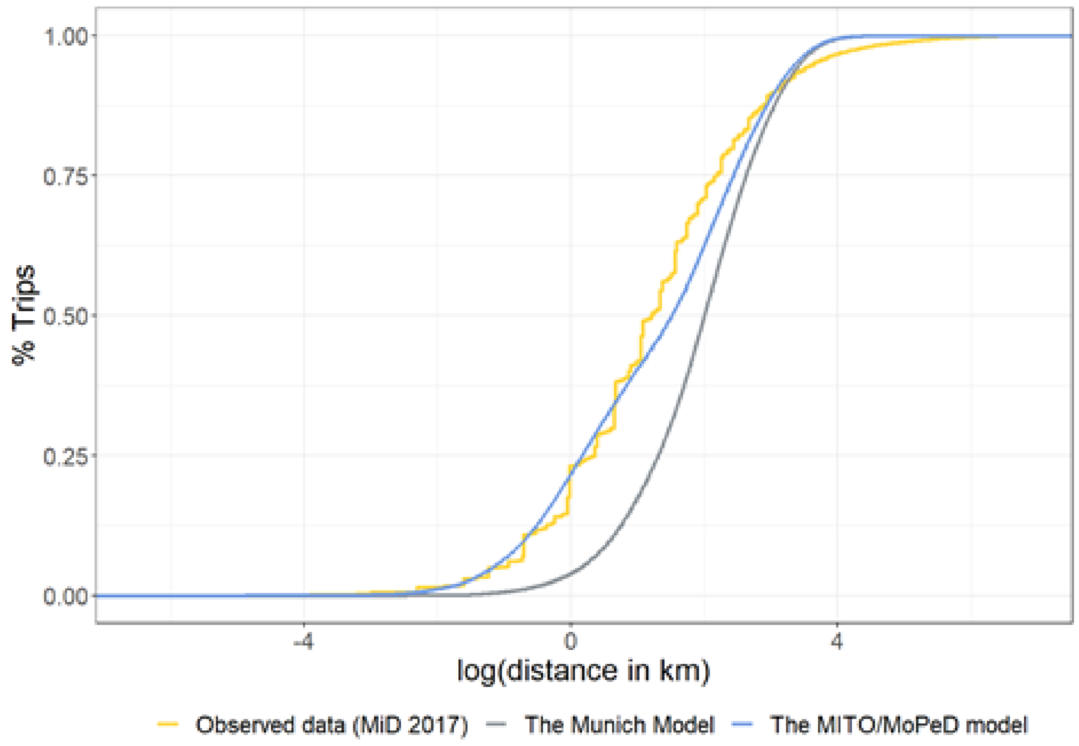

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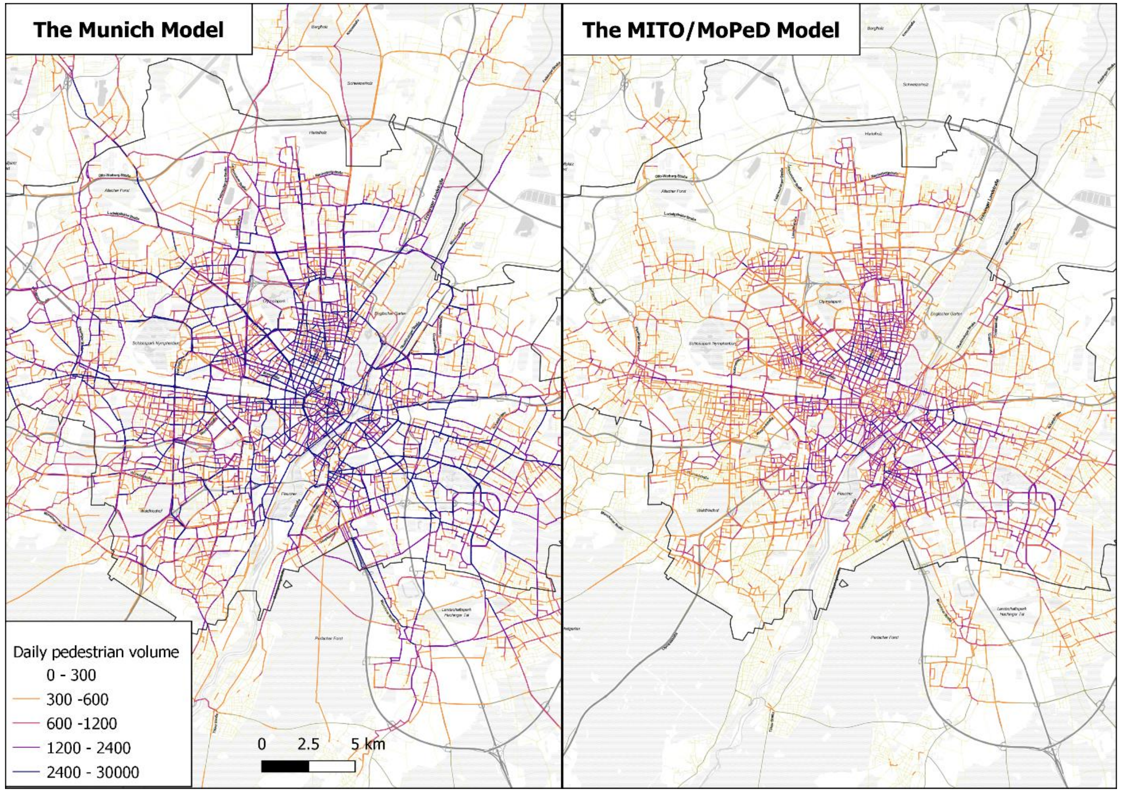
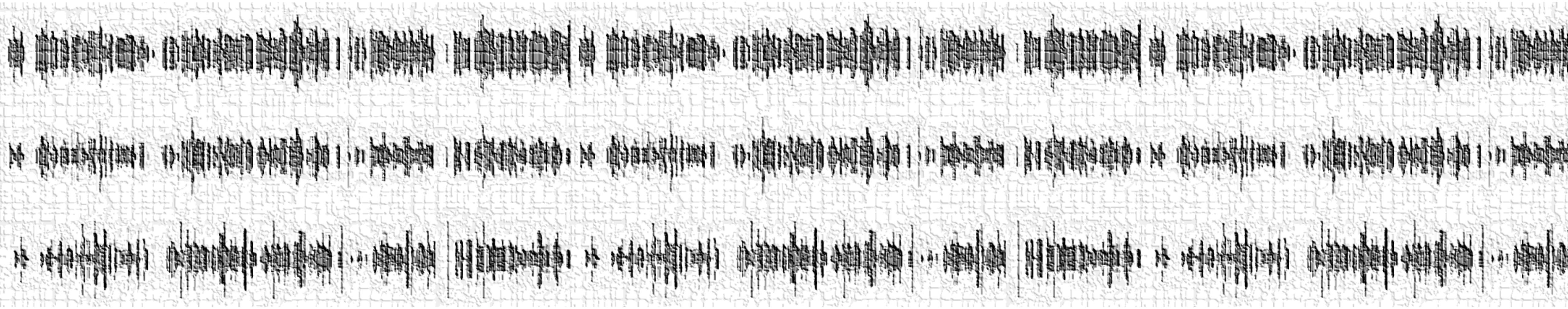


Google Timeline

A Novel Longitudinal Dataset For Exploring Pedestrian Behavior

Individual Travel "Cardiogram" – Daily travel metrics over years
(Top to bottom: daily trips, daily walk trips, daily walk time)

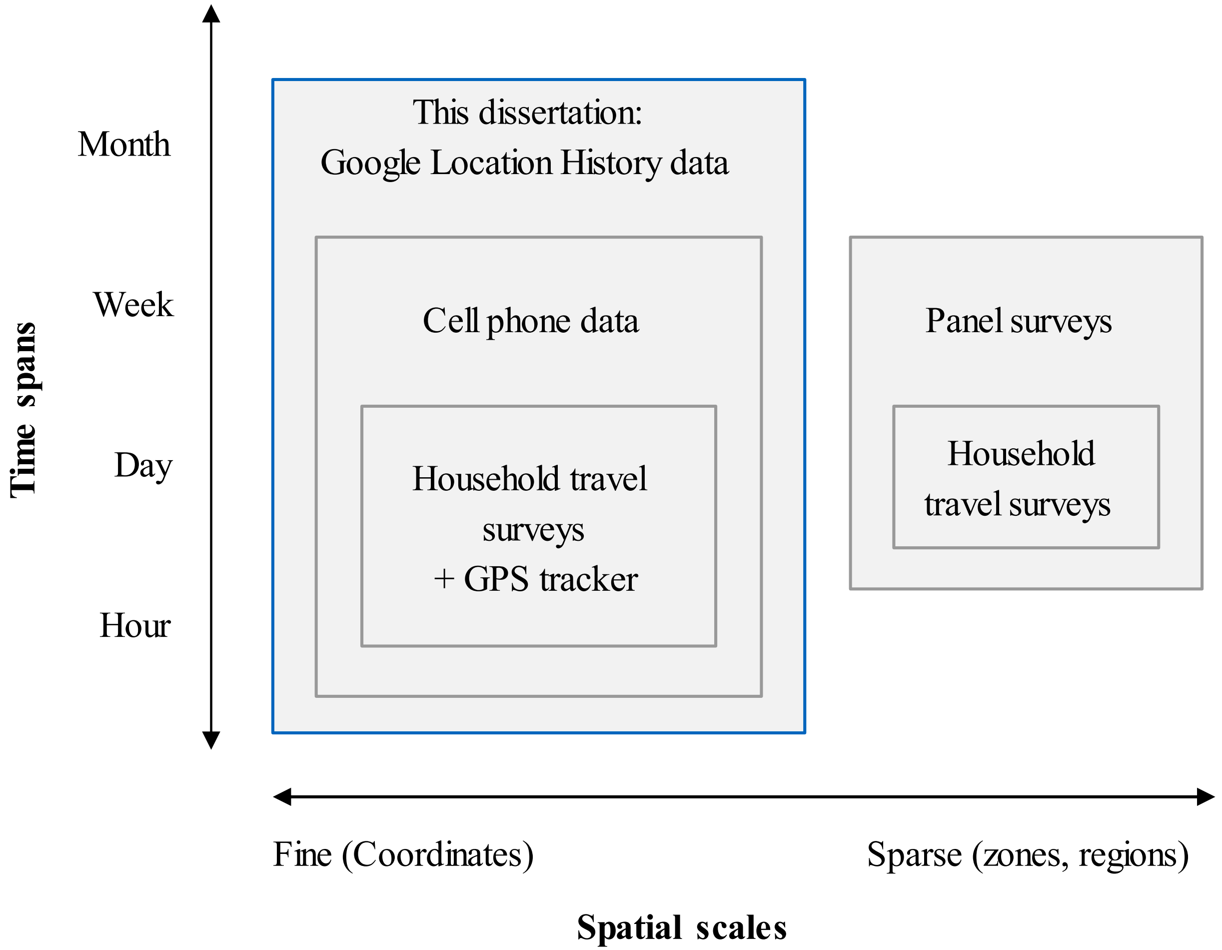


Zhang, Q, Moeckel, R & Clifton, K, Defining Travel Routines and Disruptions using Machine Learning Approaches. IATBR conference 2022
Zhang, Q, Moeckel, R & Clifton, K, Exploring Intrapersonal Travel Behavior Variability in Various Temporal Scales using Google Location History Data. 2023 TRB Annual Meeting

Google Location History data (GLH)

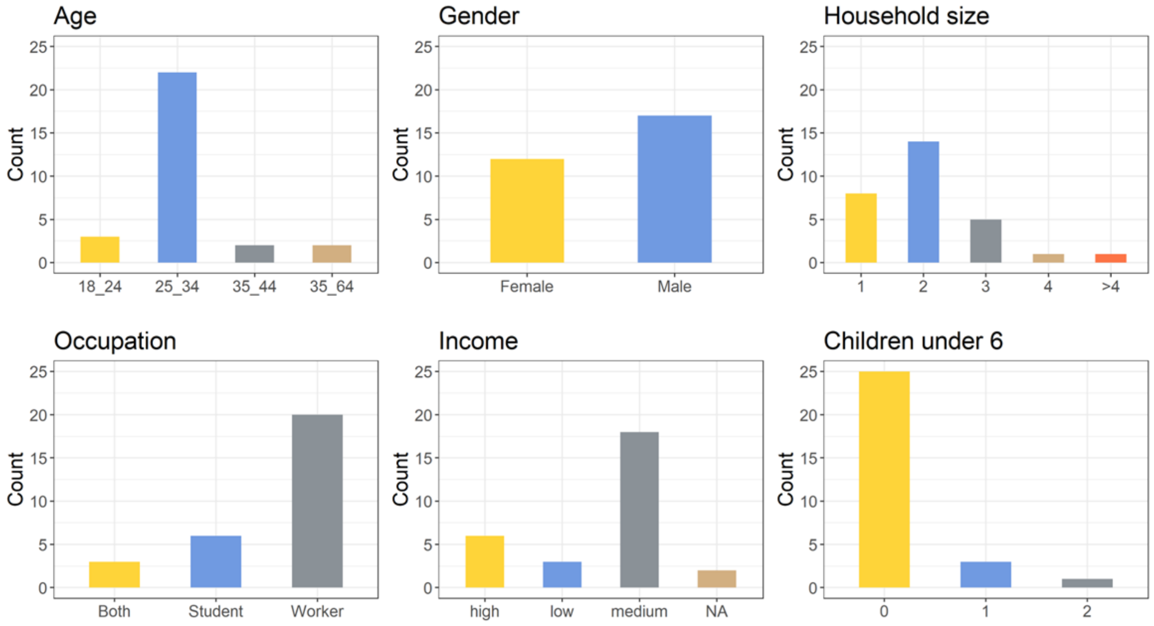
Benefits of Google timeline data:

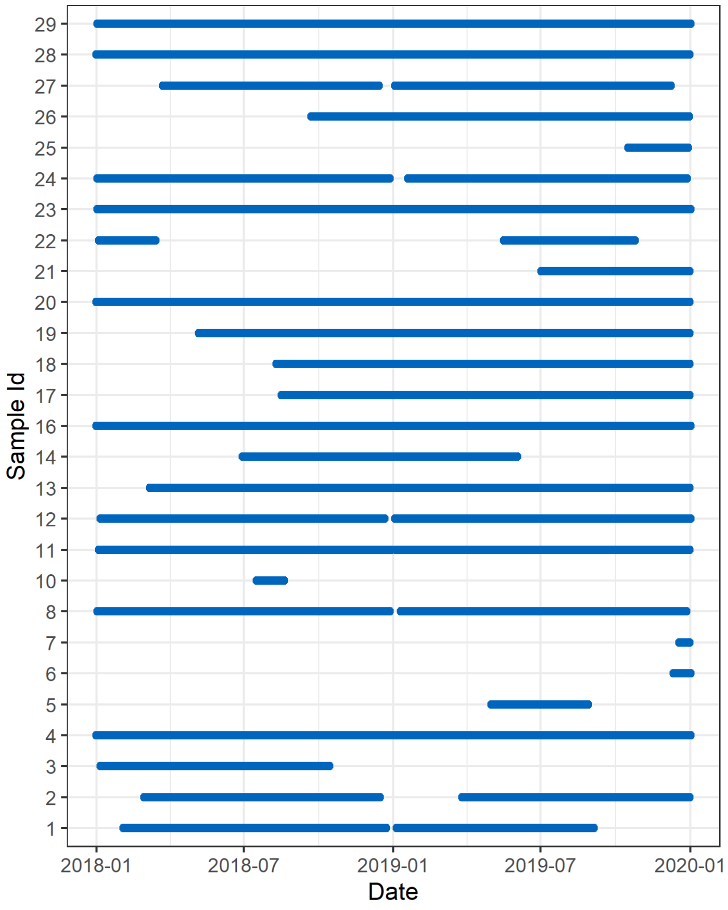
- Fine temporal and spatial scale
- Long periods of time
- Broad spatial coverage
- Little burden for the participant



27 individuals with 1,668 weeks

- University-centric respondents
- Mean number of days recorded is 481
- 42,744 trips and 12,999 person-days recorded





SAMPLEID	NUMBER OF DAYS RECORDED
29	726
28	730
27	606
26	465
25	74
24	704
23	730
22	232
21	183
20	727
19	600
18	507
17	501
16	731
14	335
13	663
12	714
11	722
10	34
8	712
7	13
6	21
5	119
4	731
3	282
2	570
1	567

Analysis of travel behavior variability

- Variability across different temporal scales:

Day-to-day > week-to-week > month-to-month

- Variability across different travel metrics:

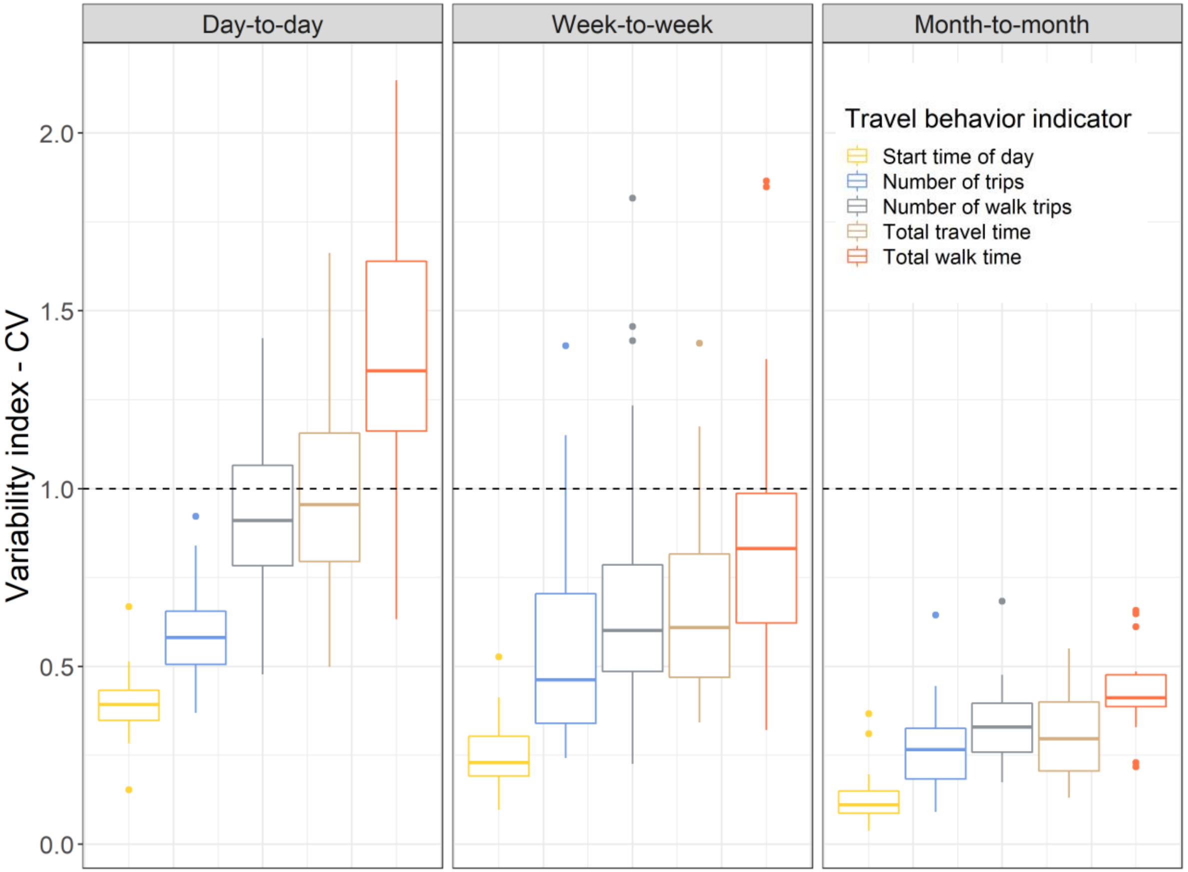
Time budget > trip counts > start time of day

→ A traditional one-day survey is not adequate to capture complex travel patterns.

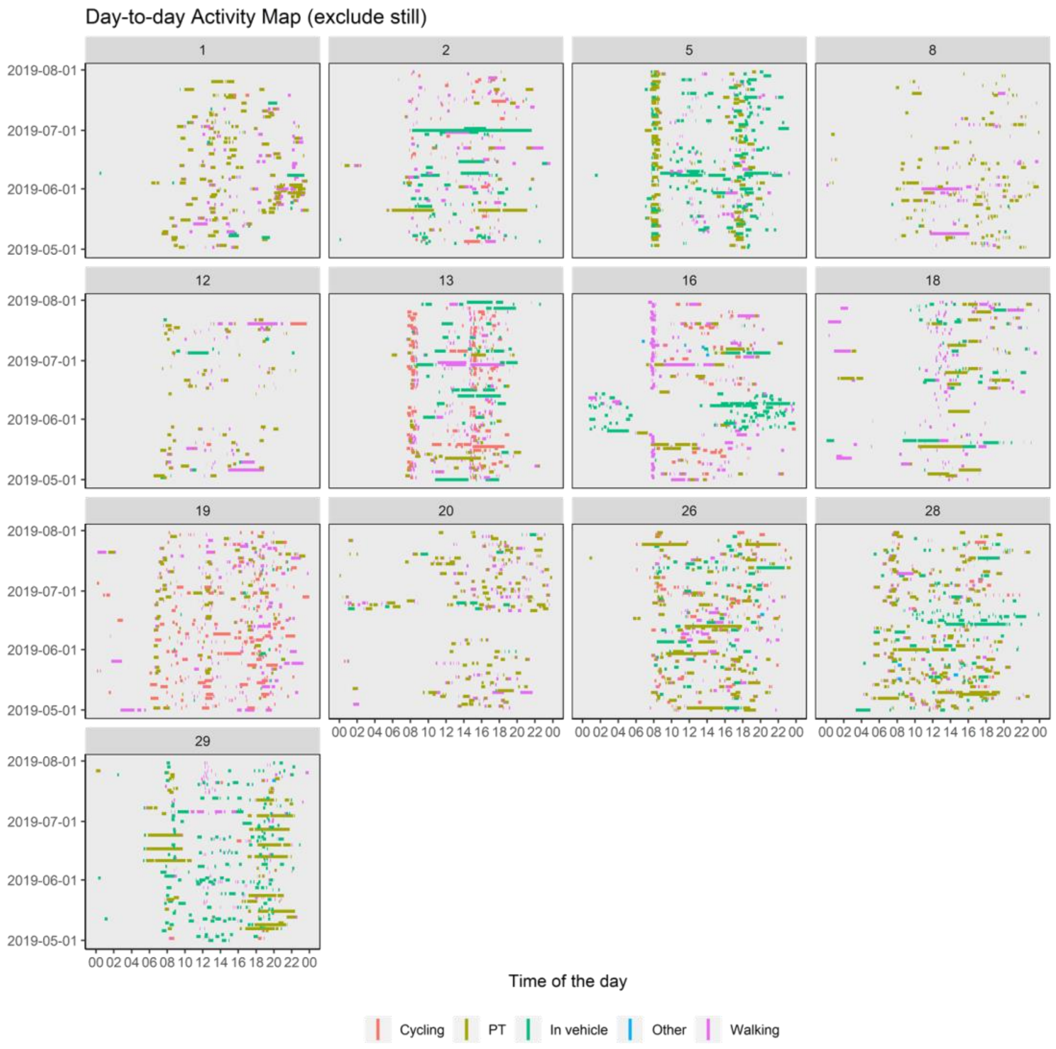
→ Patterns may exist over week or month time periods

→ One week maybe is sufficient to capture routine travel behavior in surveys or other data collection efforts.

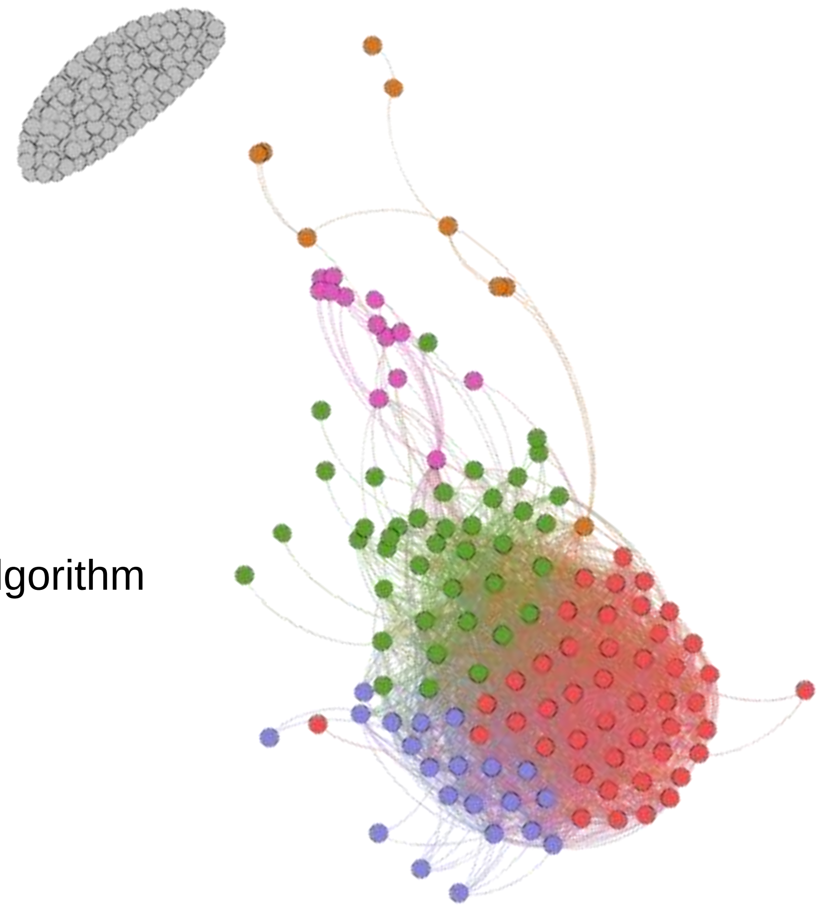
Figure: Intrapersonal variability index (CV) of different travel behavior indicators across different temporal scales



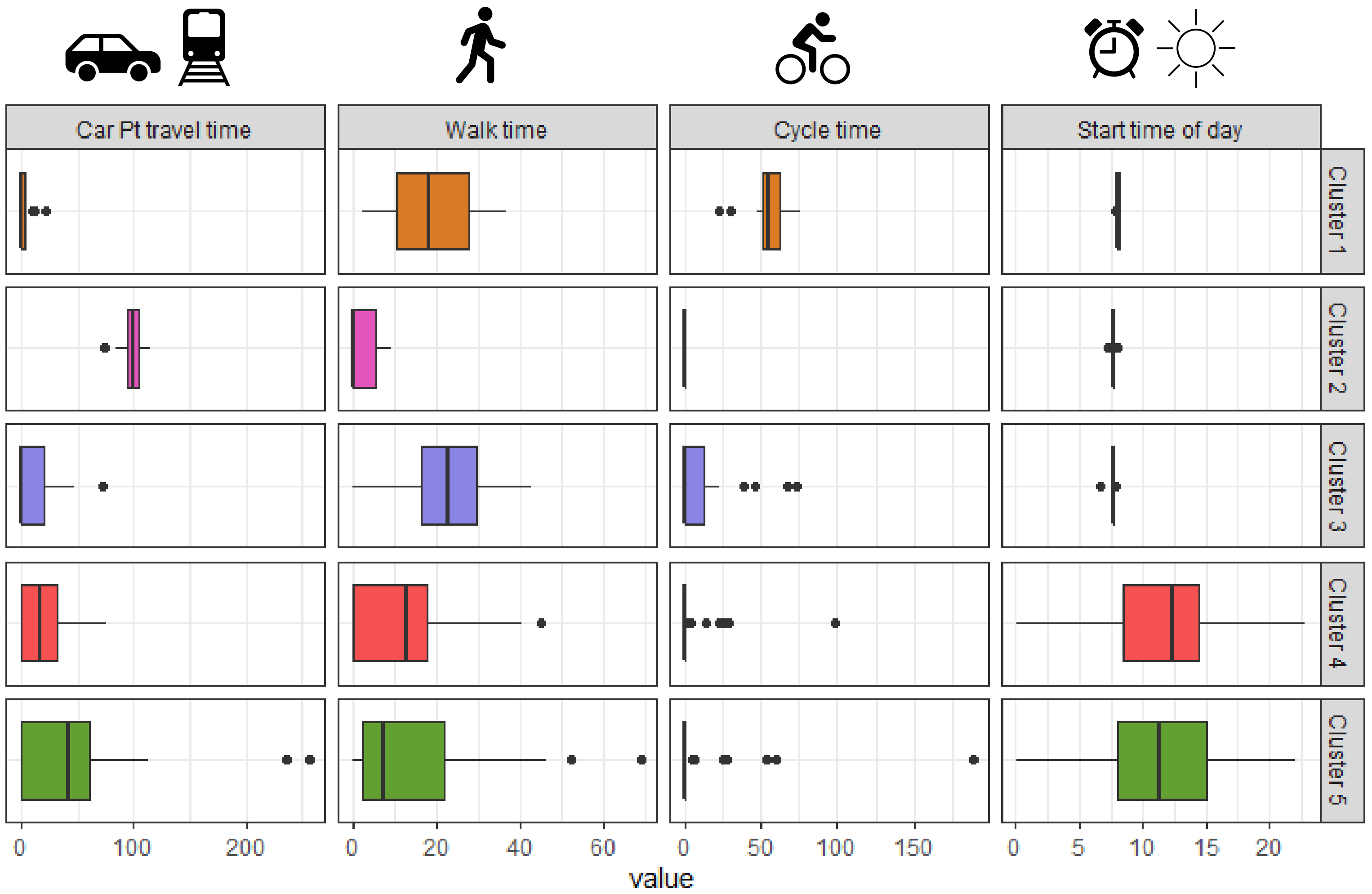
Analysis of travel behavior pattern



community detection algorithm



Analysis of travel behavior pattern



Travel pattern

An active day with early start

A non-active day with early start

An actively walking day with early start

A mix-mode (more walk) day with late start

A mix-mode (more carPT) day with late start

Analysis of travel behavior pattern

Travel pattern /Other pattern

An active day with early start
Weekday, Worker, no car access

A non-active day with early start
Weekday, Worker, no car access

An actively walking day with early start
Weekday, Worker, has car access

A mix-mode (more walk) day with late start
Student, Worker’s weekend, less rain

A mix-mode (more carPT) day with late start
Student, Worker’s weekend, more rain

Conclusion

Photo by Tammy Kaye Clifton, Tierra del Fuego, Chile

Contribution

What have been accomplished?

- A more efficient, transferable, accurate and sensitive pedestrian planning tool for urban areas with fine spatial resolution.
- Collected small sample size of Google timeline data with wide time periods over months
- Provided numerical evidence toward travel behavior variability
- Reveal the limitation of travel surveys for capturing pedestrian activities

What could be improved?

- Sensitive to the quality of street connectivity
- Investigate more factors to improve the goodness-of-fit of the PAZ-level destination choice model
- Larger dataset to draw more solid conclusion

Future work and recommendation

Better represent the quality of street connectivity	• Investigate micro-level built environment such as the design and pavement conditions of the pedestrian street
Link to health assessment tool	• Simulate broader walking activities (access walk, egress walk, walk as leisure, walk during occupation) • Energy consumption budget
Further fundamental research on travel behavior	• Pedestrian route choice behavior • To quantify how many days are enough to capture travel behavior pattern

The Next Generation of Pedestrian Travel Demand Models:

Move Towards Finer Spatial Attributes, Longer Planning Horizon and Broader Range of Pedestrian Activities

Thanks for your attention!

Qin Zhang

Doctoral defense, 13 March 2023