Automated Mobility-on-Demand, Accessibility and Residential Relocation: a simulation-based analysis

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Feb 16 2022

Outline

- Motivation
- Objectives
- Methods
- Application
- Results
- Conclusions

Motivations

Automated Vehicles (AVs) – mobility's next 'big thing'?

1st prototype of Autonomous Buggy

2010

Autonomous Car @One-North pilot

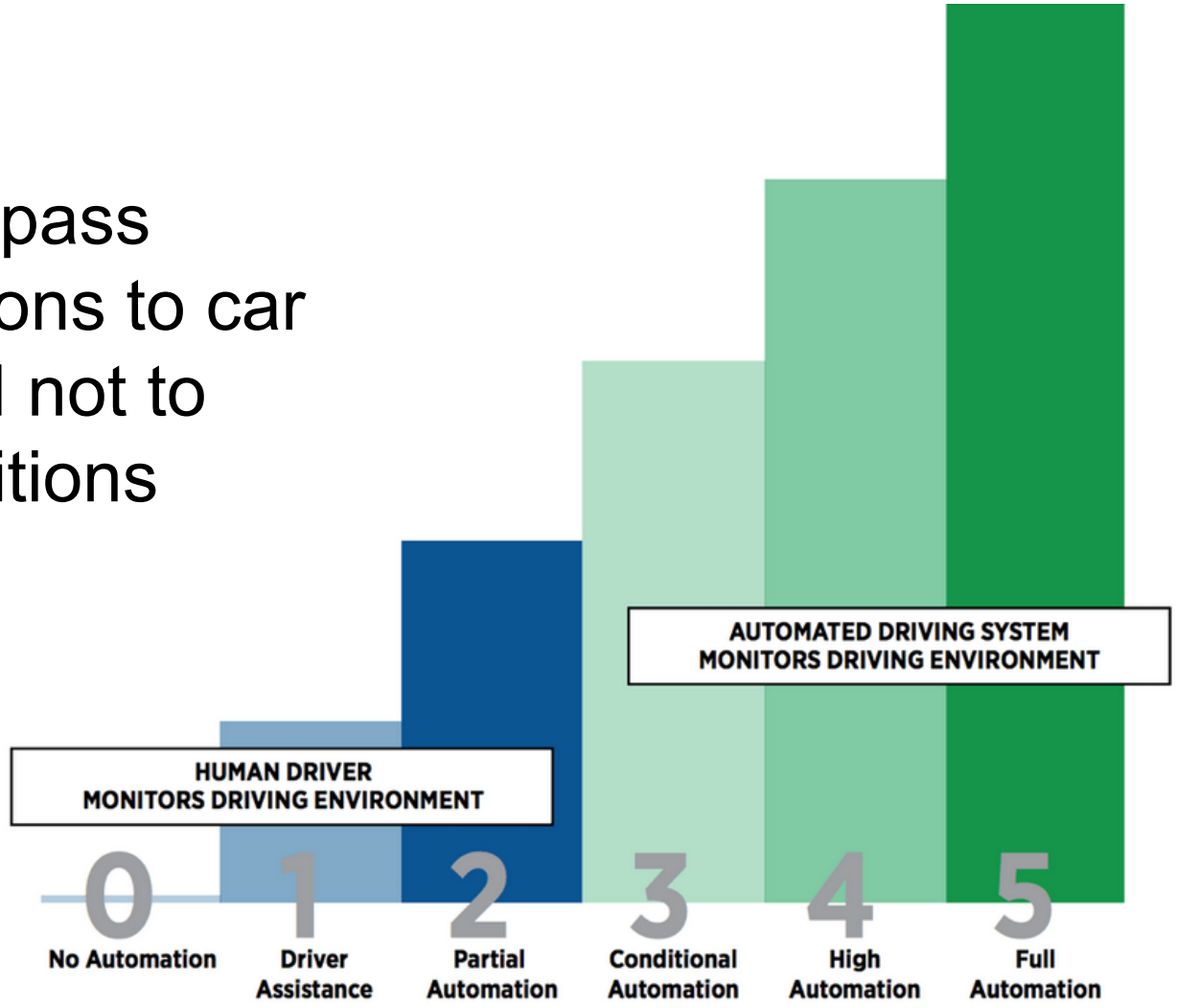
2015

Delphi acquires nuTonomy (Spin-off)

2017

Levels of Automation

1. E.g. Cruise Control
2. Tesla's autopilot
3. Driver required, can pass 'safety-critical' functions to car
4. Can be programmed not to drive in certain conditions
5. Full automation



SAE, Int'l

Automation – when…?

AVs and the Automakers (plans circa 2017)

Automaker	Key partnerships	Date
GM	Cruise Automation and Lyft	Nothing specific
Ford	Argo AI	Level 4 2021
Honda	Cruise (GM)	Highways by 2020
Toyota		Highways by 2020
Renault-Nissan	Microsoft	Urban by 2020
Volvo	Uber	Highway by 2021
Hyundai		Highway 2020; urban 2030
Daimler	Bosch, Uber; Trucks	4 and 5 by Early 2020s
Fiat-Chrysler		Unclear
BMW	Intel, Mobileye	4 or 5 by 2021
Tesla		Opaque….

https://www.techemergence.com/self-driving-car-timeline-themselves-top-11-automakers/, Company press releases, etc.

Automation – when…?

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‘Self-Driving’ Cars Begin to Emerge from a Cloud of Hype

Developers try to overcome a multitude of technical challenges before vehicles drive on their own

By: Steven E. Shladover

September 25, 2021 |

At the time, virtually every major motor vehicle manufacturer and high-tech company predicted widespread deployment of automated driving systems (ADS) by 2020,

Automation – when…?

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‘Self-Driving’ Cars Begin to Emerge from a Cloud of Hype

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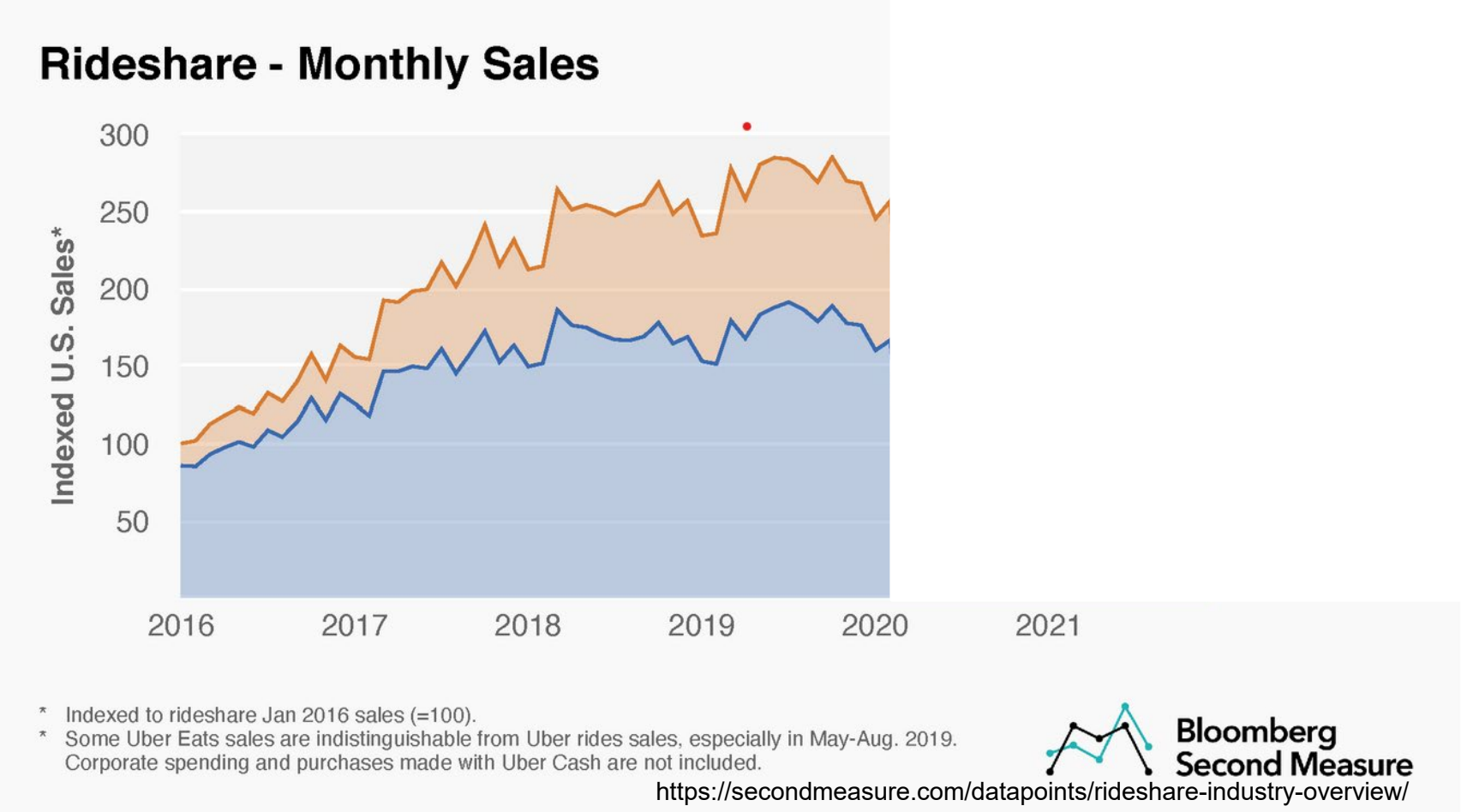
- The technology will initially be implemented for specialized uses such as local package delivery, long-haul trucking on motorways, urban transit services on fixed routes and, in more limited locations, for urban and suburban automated passenger ride hailing.

Mobility-on-Demand

Uber lyft Grab 滴滴 滴滴一下 美好出行



https://secondmeasure.com/datapoints/rideshare-industry-overview/

Mobility-on-Demand

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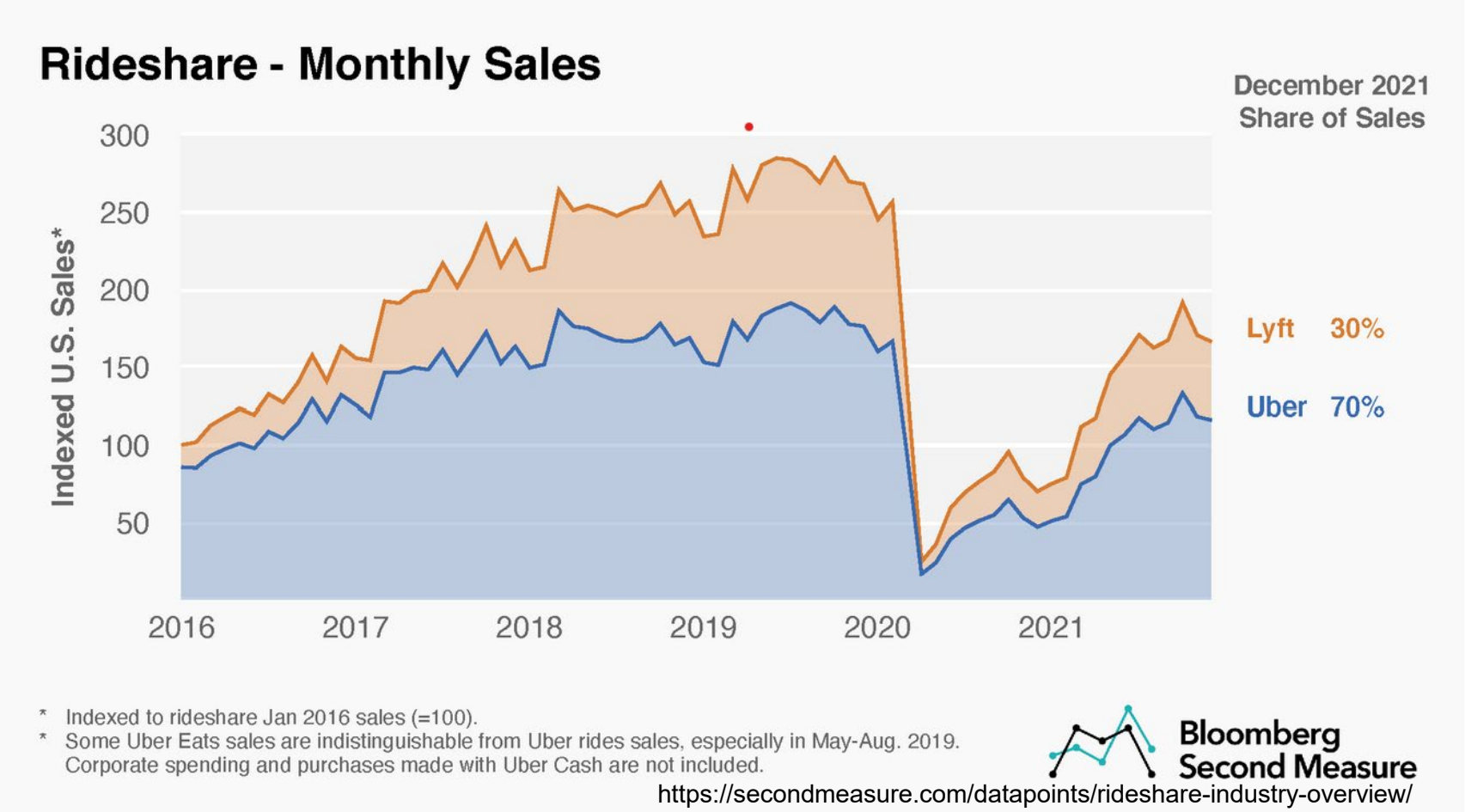


https://secondmeasure.com/datapoints/rideshare-industry-overview/

Automated Mobility-on-Demand (AMoD)

- Convergence of automation and sharing (shared AV or SAV)
- *Potential* benefits: efficiency, reliability, safety, affordability, accessibility…

Waymo's driverless taxi service can now be accessed on Google Maps

Kirsten Korosec

@kirstenkorosec / 2:00 PM EDT • June 3, 2021

Comment

https://techcrunch.com/2021/06/03/waymos-driverless-taxi-service-can-now-be-accessed-on-google-maps/

AVs, SAVs & AMOD: potential impacts (vehicle miles traveled, vmt)

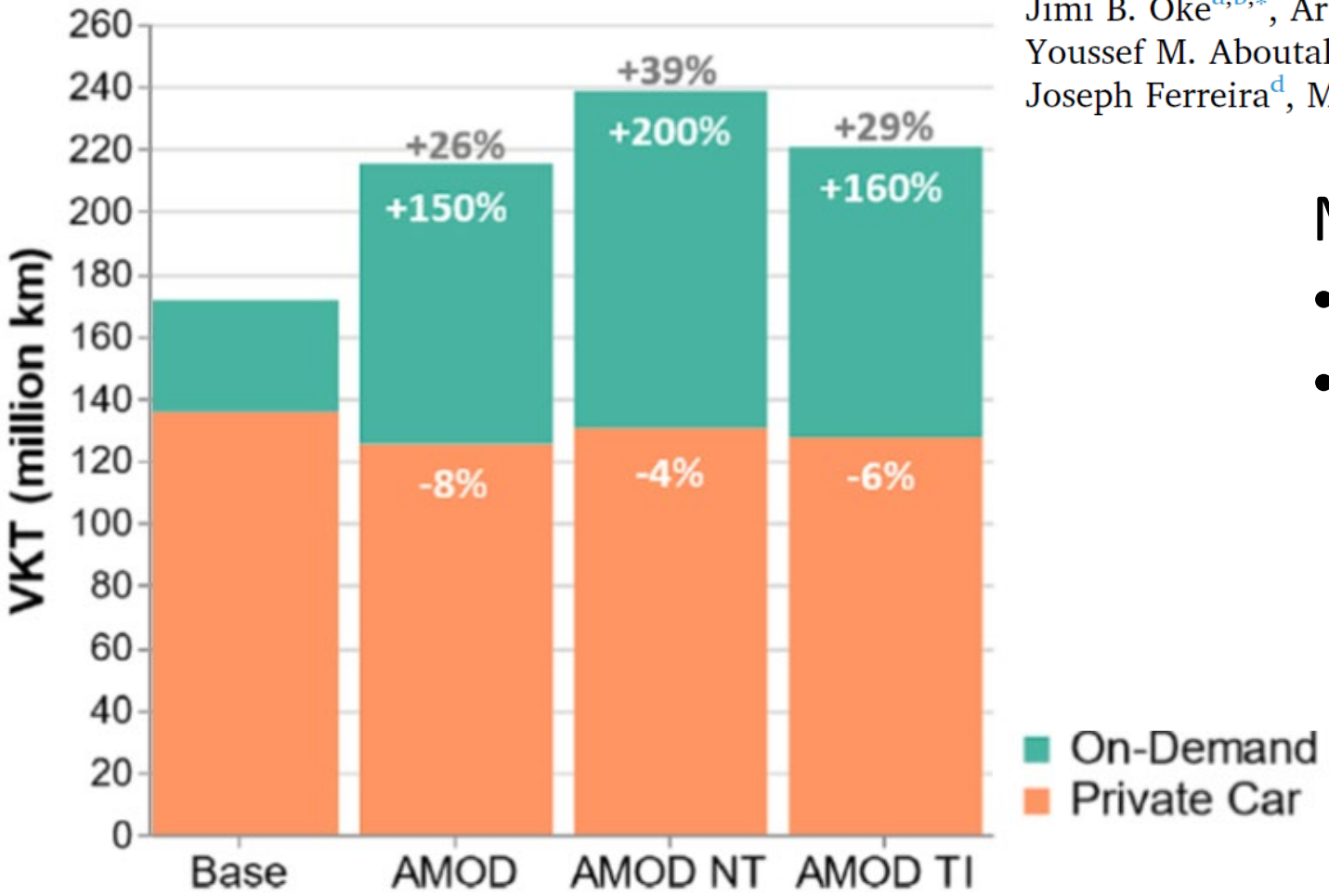
Influencing Factor	Total VMT: Increases VMT	Total VMT: Decreases VMT
Rebound effect	X	
Car-sharing and reduced vehicle ownership		X
Driverless taxis	X	
Greater sprawl	X	
Substitute for intracity or intercity public transportation	X	

RAND, 2016

AVs, SAVs & AMOD: potential impacts

Evaluating the systemic effects of automated mobility-on-demand services via large-scale agent-based simulation of auto-dependent prototype cities

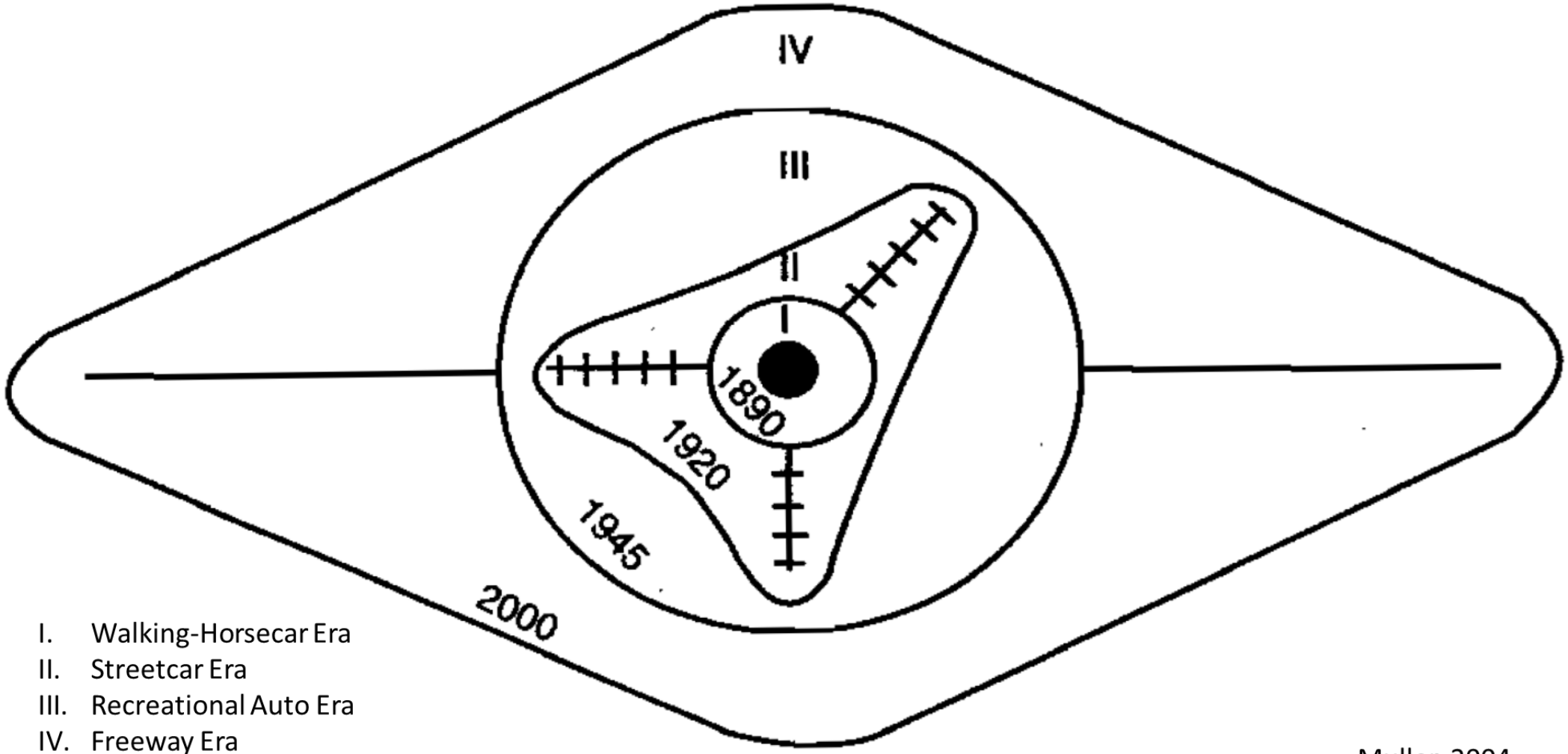
Jimi B. Oke[a,b,*], Arun Prakash Akkinepally[b], Siyu Chen[b], Yifei Xie[b], Youssef M. Aboutaleb[b], Carlos Lima Azevedo[c], P. Christopher Zegras[d], Joseph Ferreira[d], Moshe Ben-Akiva[a]



Metro Area "like Boston":

- AMOD increases VKT
- AMOD w/ transit integration (AMOD TI) → (slightly) better outcomes (VKT and congestion).

AVs, SAVs & AMOD: potential *longer term* impacts

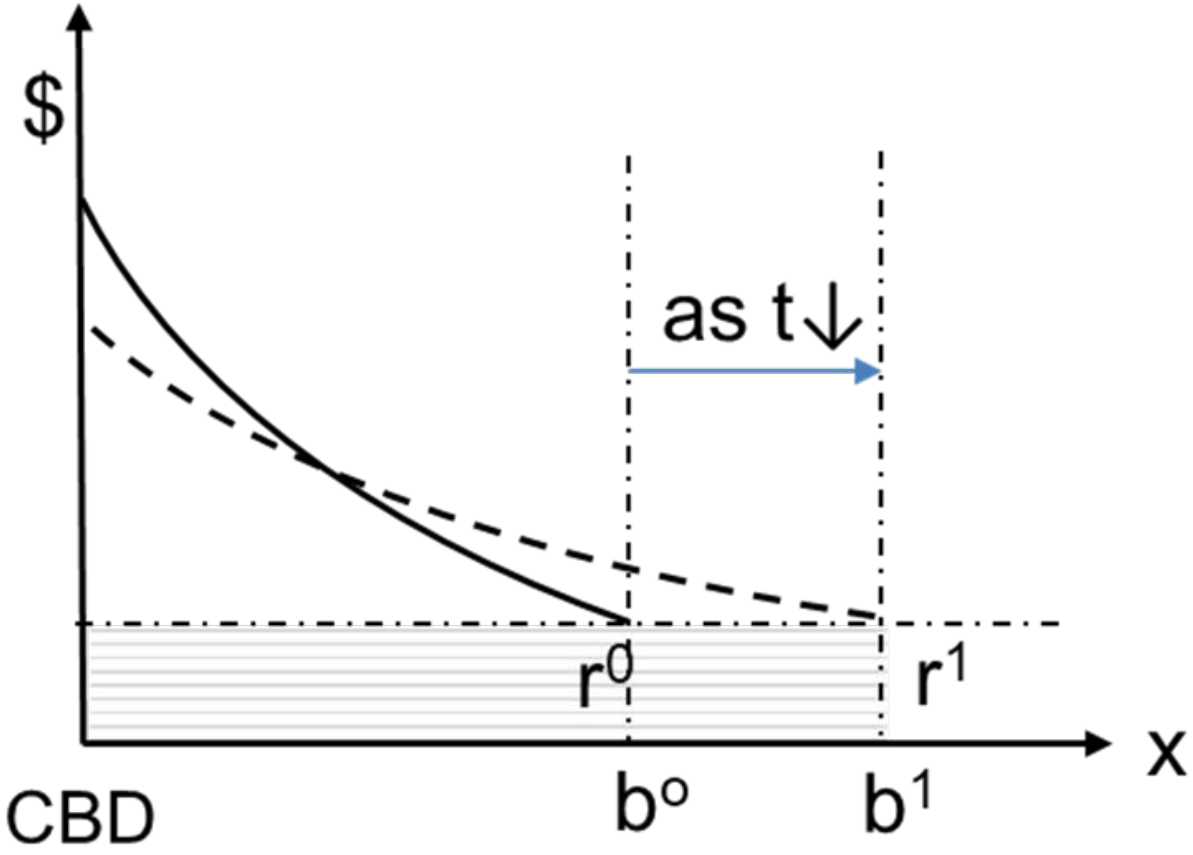


I. Walking-Horsecar Era
II. Streetcar Era
III. Recreational Auto Era
IV. Freeway Era
V. Post-2000?

Muller, 2004

AVs & Traditional Urban Economic Theory

Automation and urban development



Should we expect anything different?

AVs, SAVs & AMOD: potential *longer term* impacts

- Value of time and generalized costs of travel
  - Congestion *may* decrease
  - Tolerance for congestion **will** increase
  - → expansionary
- Parking
  - Policy (and sharing) matters
- Infrastructure, Urban & Building Design
  - Smaller footprints? Need for less “room for error”
  - SAVs+EVs: seamless interfaces between public/private spaces
- AVs Demand for density and the future of agglomeration economies
  - Centripetal <> Centrifugal?
  - Many other things matter here: ‘future of work’, post-pandemia, etc.

Research Objectives

Knowledge gaps

- Little attention on AMoD impacts on accessibility, long-term mobility choices, and urban growth patterns
- Existing studies lack spatiotemporal & demographic granularity
- Realistic depiction of housing market behaviours is also missing: only consumer choices, no supply-side behaviours or bargaining processes

Research Questions

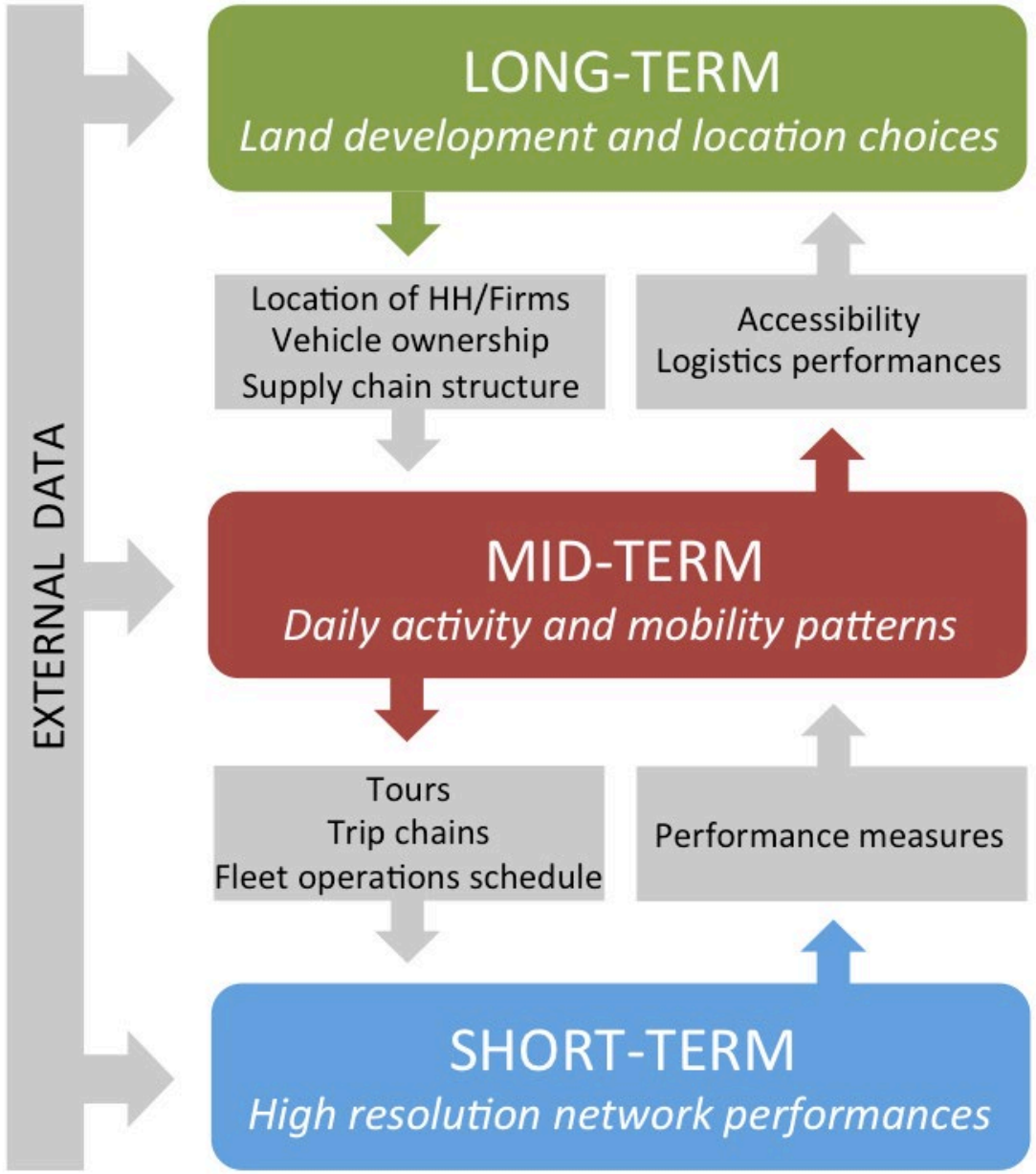
- What is the impact of AMOD on individuals' **accessibility** and how does the effect vary across socioeconomic groups?
- How might we expect **residential location patterns** to change under different AMOD scenarios?

Methods

Research Design

- Agent-based microsimulation
  - Modelling individual (heterogenous) long-term mobility decisions
- Scenario analysis
  - Comparative analysis of hypothetical future AMOD scenarios
- SimMobility
  - An integrated ***agent-*** and ***activity-based*** simulation platform

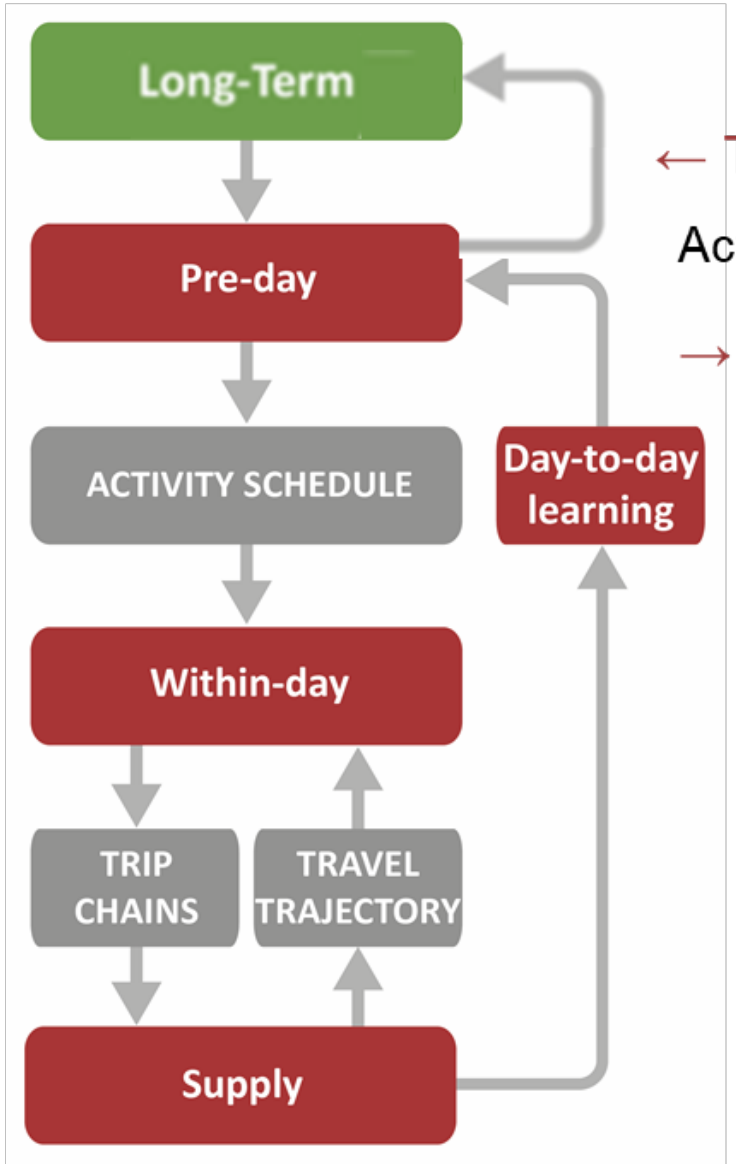
- **Microsimulation** (Agent-based) Integrated/ modular platform
- **Activity-Based** Persons and goods
- **Multiple** spatial-temporal **scales**
- **Dynamic** plan/action-transaction behavioral models
- **Multimodal** networks
- **Open-source**



SimMobility Mid-Term: Activity-based model

Integrates:

- Pre-day
- Within-day
- Supply



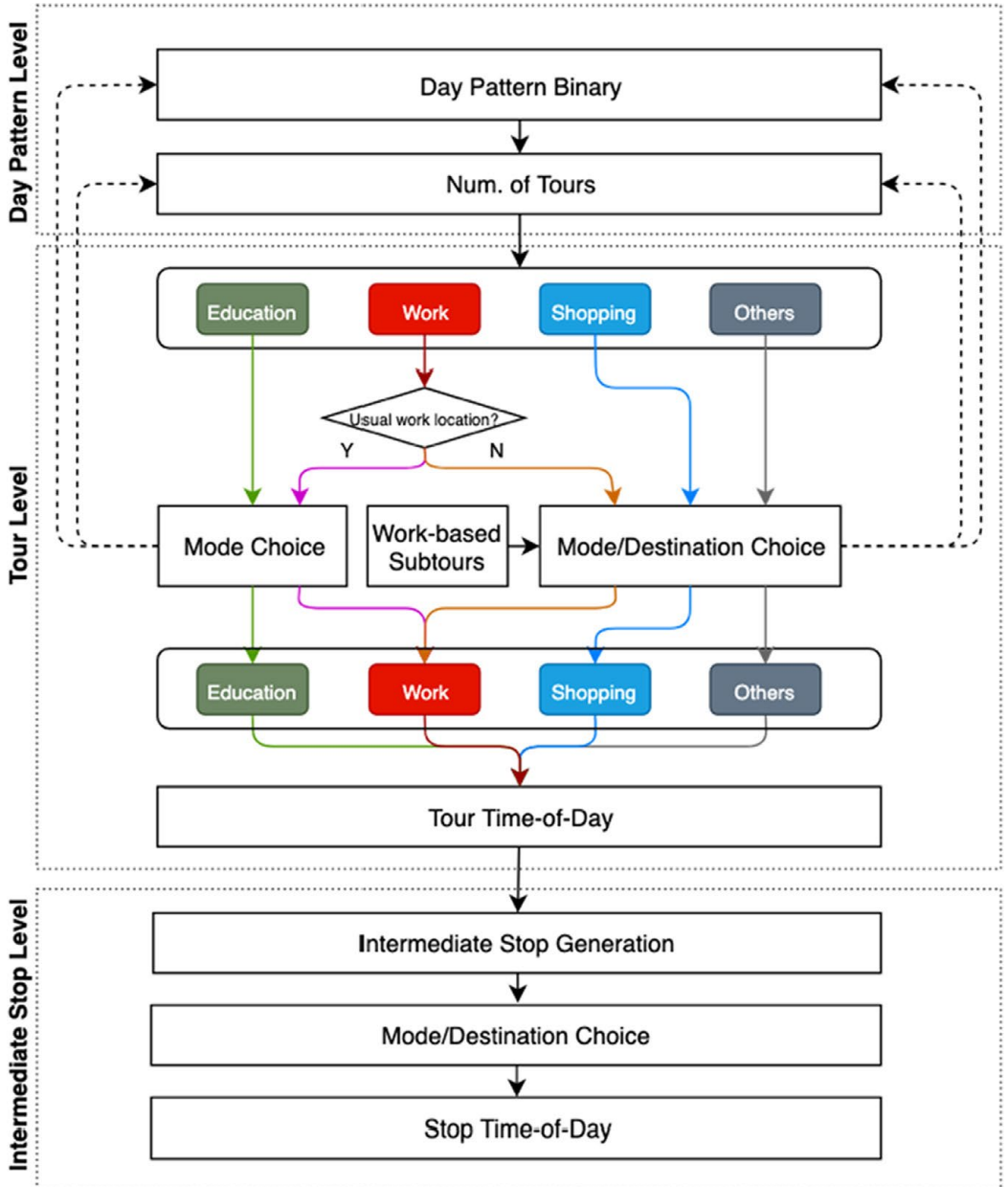
← Theoretically consistent link to Long-Term

Activity-Based Accessibility (ABA)

→ Economic Evaluation Criterion

Oh et al, 2020

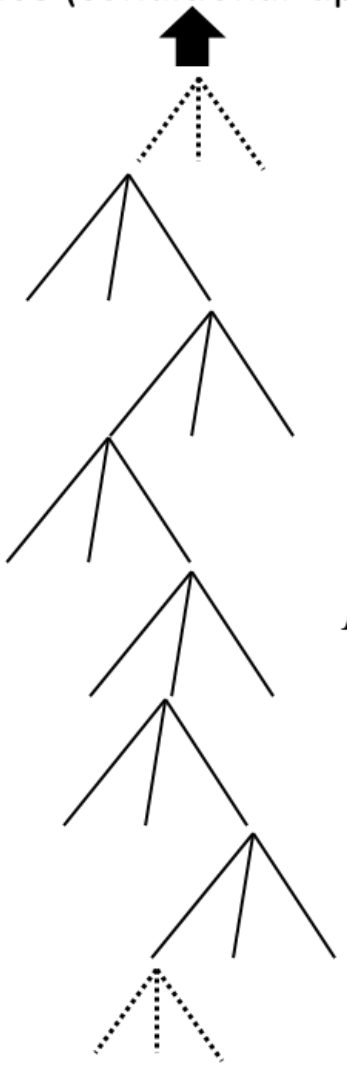
Activity-based Accessibility (ABA)



Oh et al, 2020

ABA:

Benefit ("Expected Maximum Utility") of the Day Pattern Choice (conditional upon given location)



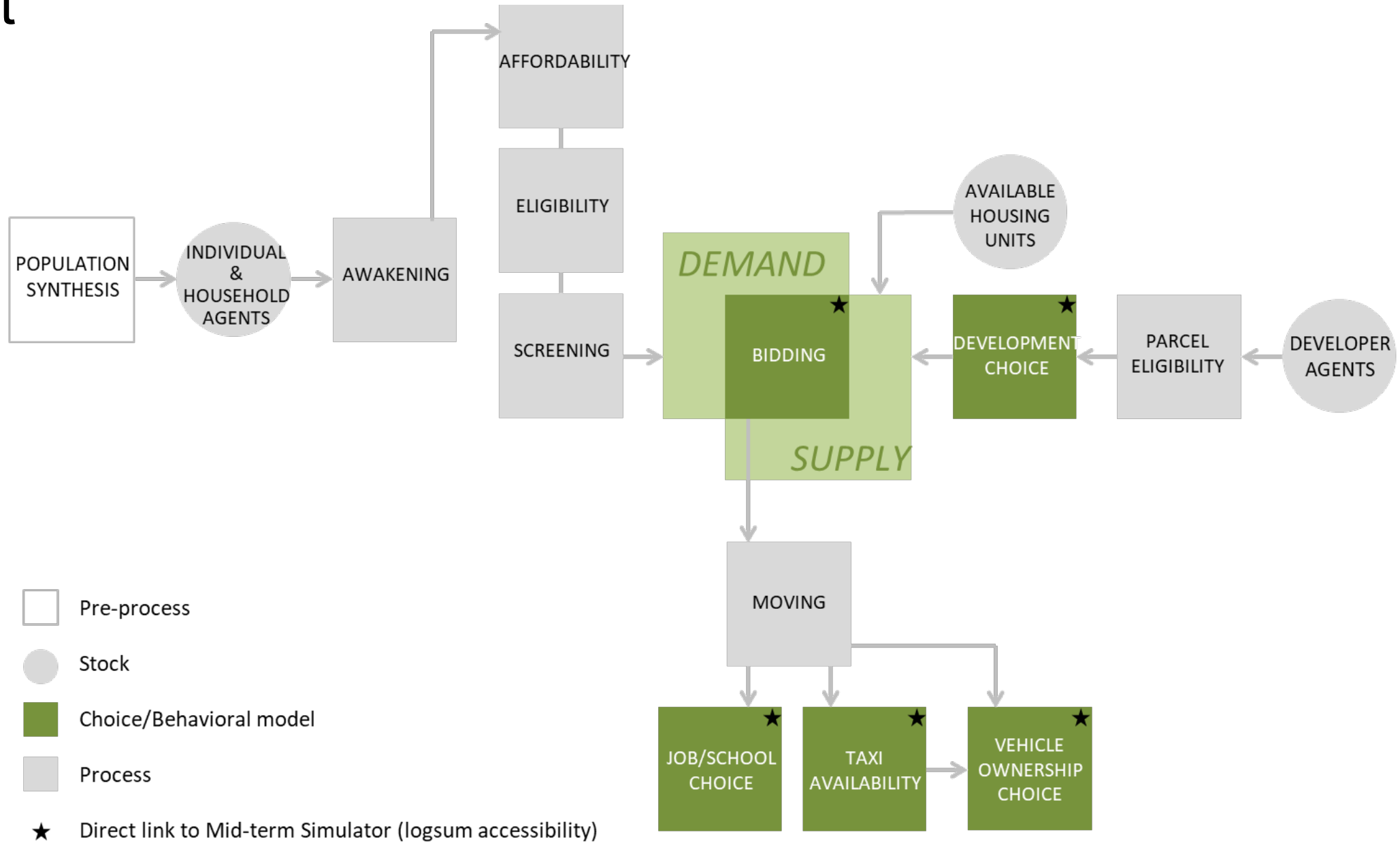
E.g.:

$$P_n(d) = \frac{e^{(V_d + V'_d)\mu^d}}{\sum_{d \in D_n} e^{(V_d + V'_d)\mu^d}}$$

$$V'_d = \frac{1}{\mu^m} \ln \sum_{m \in M_{nd}} e^{(V_m + V_{dm})\mu^m}$$

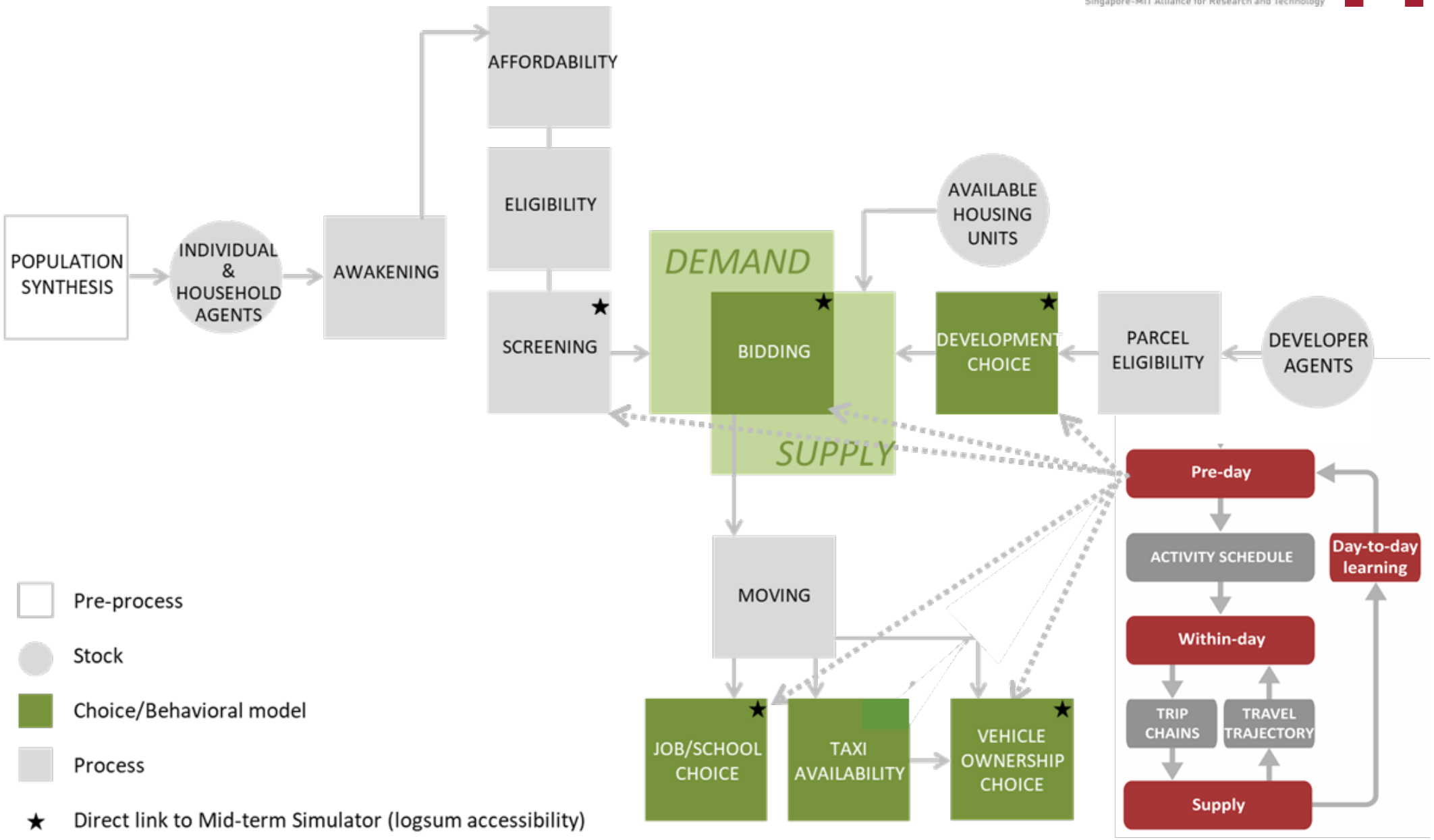
$$P_n(m \mid d) = \frac{e^{(V_m + V_{dm})\mu^m}}{\sum_{m \in M_{nd}} e^{(V_m + V_{dm})\mu^m}}$$

SimMobility Long-Term: Dynamic real-estate market



Zhu et al. 2018

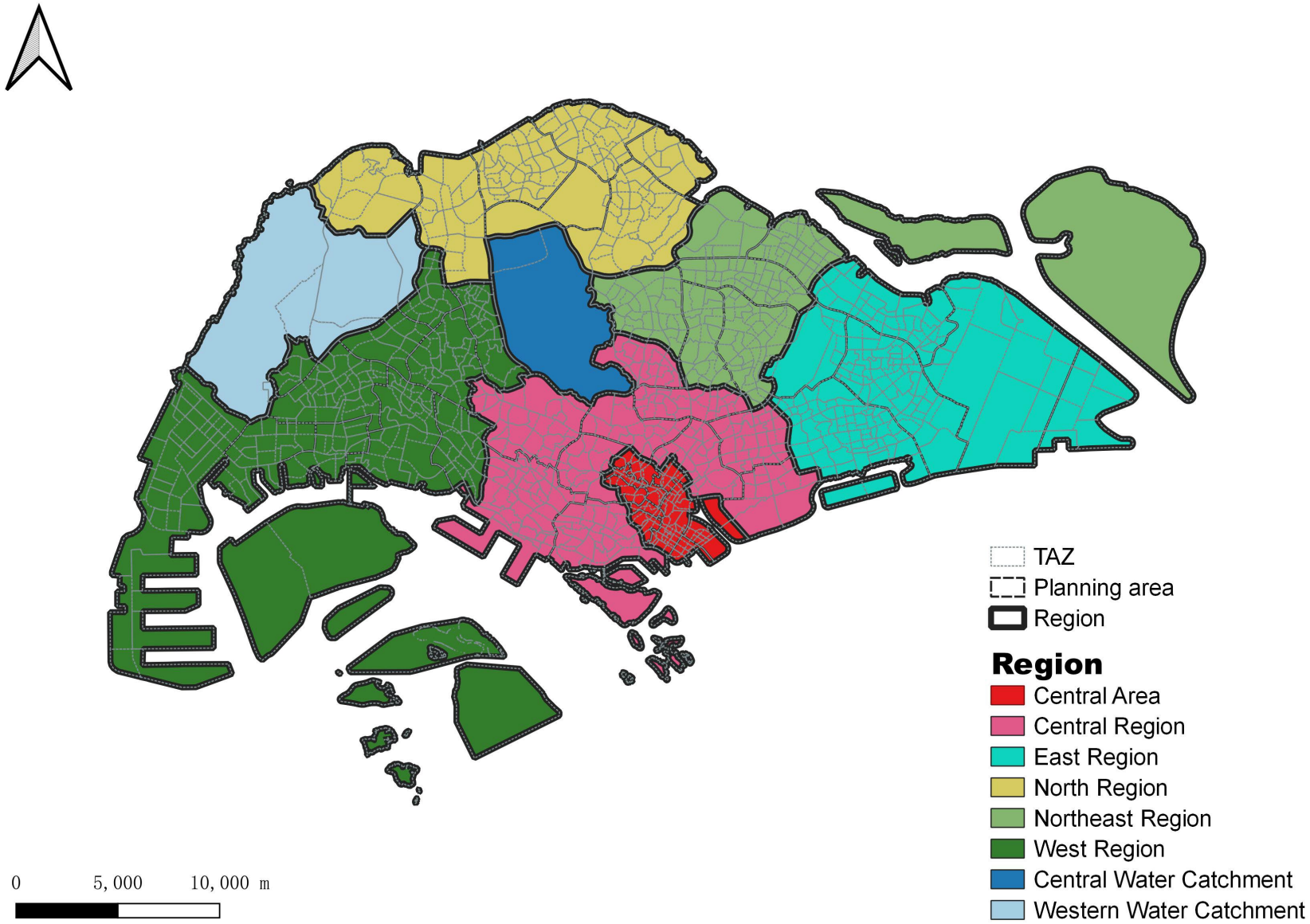
SimMobility Long-Term: ABA-links (to mid-term)



Zhu et al. 2018

Application

Study Area

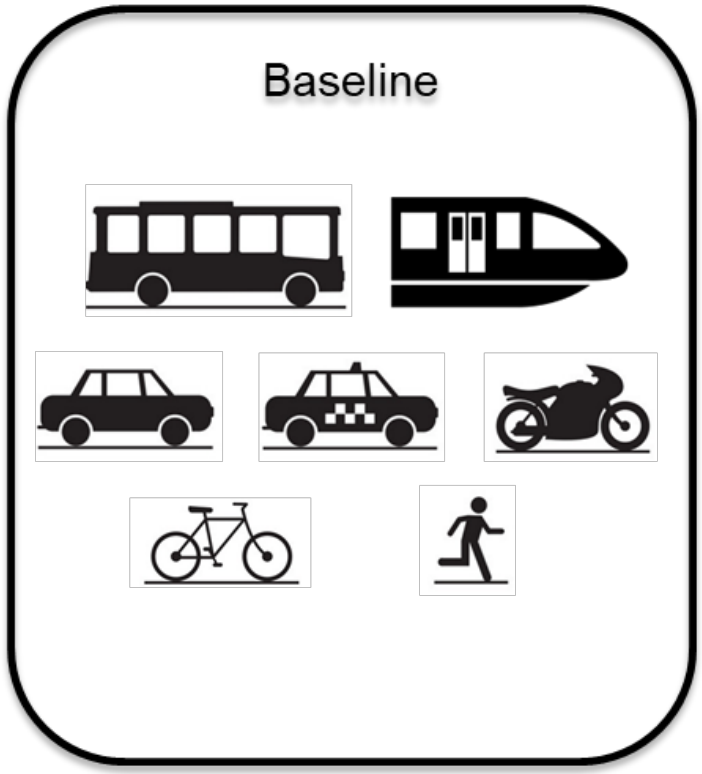


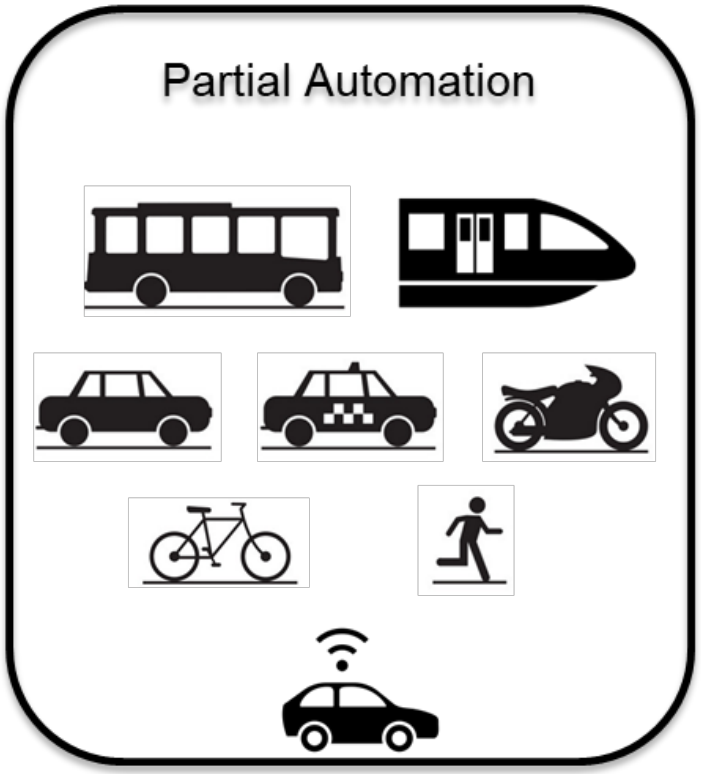
Source: Zhou et al., (2022)

Data

- ***Synthetic population*** (1.9 million households & 6.7 million individuals)
  - Based on Household Interview Travel Survey (HITS) data
  - Built environment: various sources
- Activity-based models (mid-term)
  - Estimated with HITS data
  - Calibrated with transit smartcard (EZLink) data & SP survey data on AMOD adoption
- Housing market models
  - Estimated with REALIS transaction data, HDB resale data & HITS data

Scenarios





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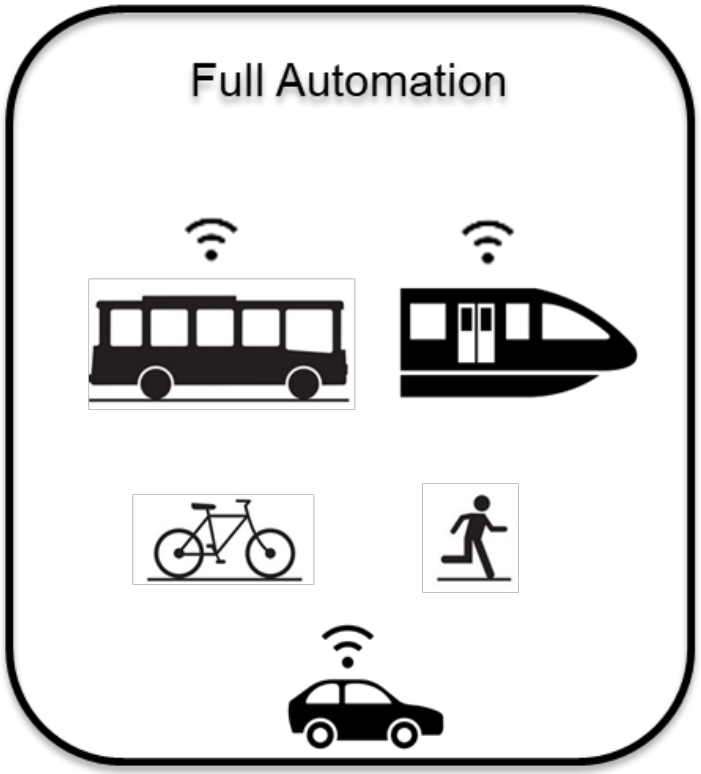


(FA)

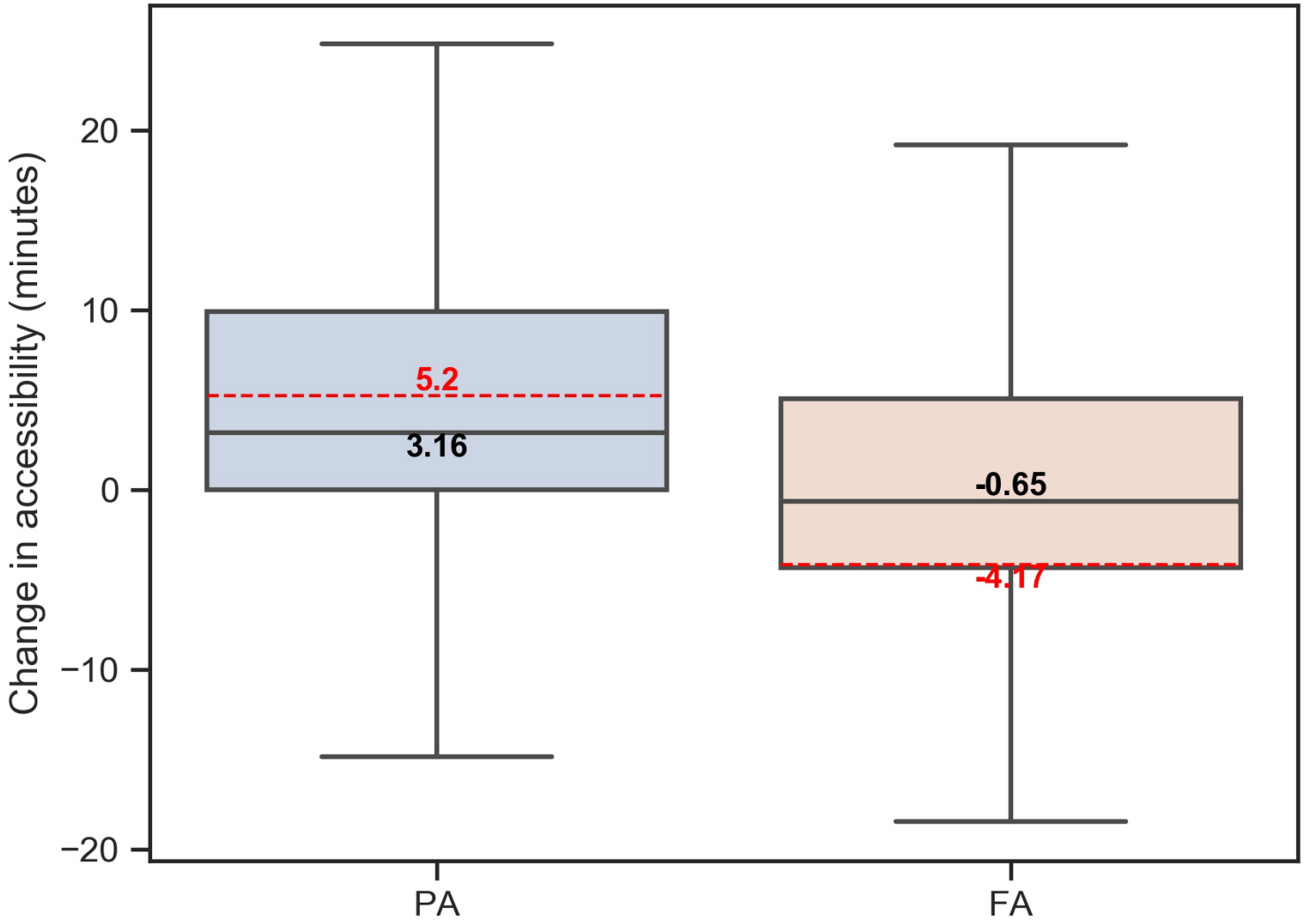
Other simulation specifications

- Housing market simulation: 10 repeated ***one-year*** runs of daily market dynamics for each scenario
- AMoD pricing: 75% of conventional taxis & additional 30% *off* for shared rides
    - Additional modifications to utility function based on SP survey (Seshadri et al, 2019)
- AMoD level-of-service & fleet size (4-, 6-seaters): updated/optimized through feedback loops between mid-term & long-term modules

Results

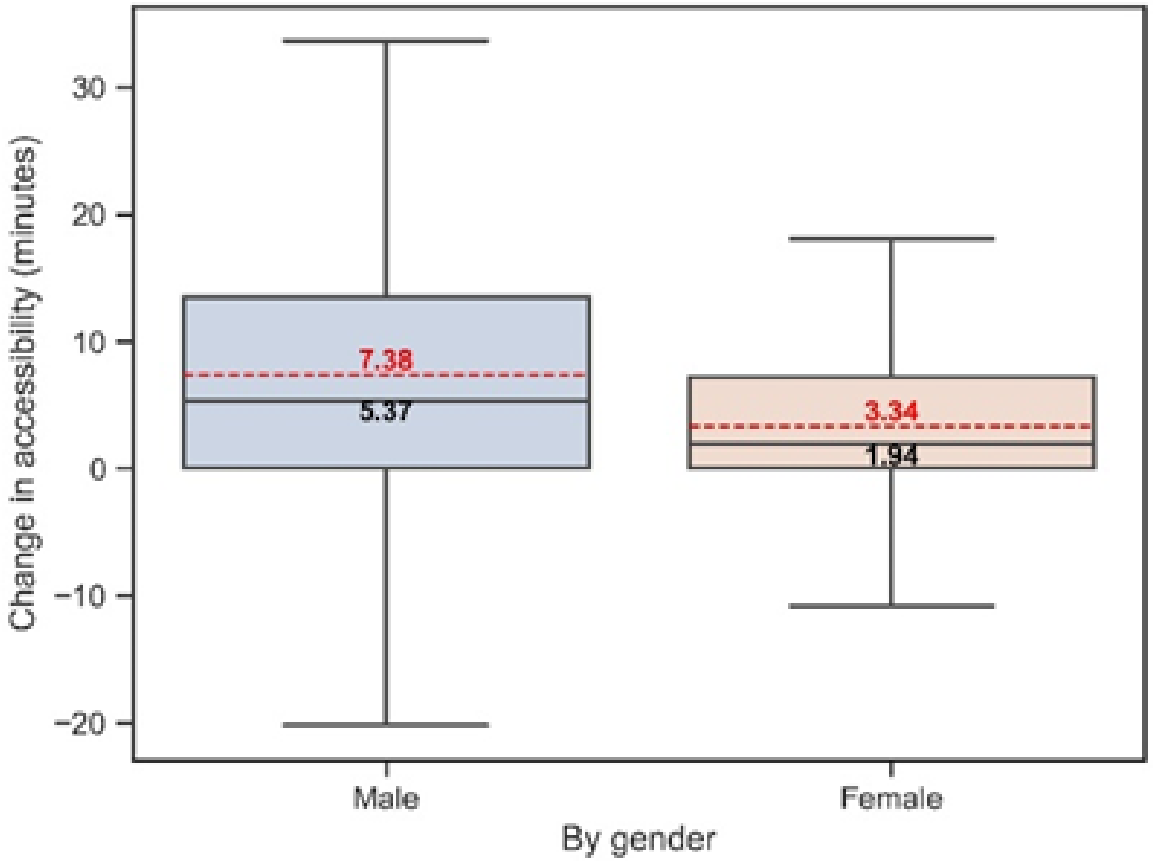
Accessibility Impacts (Overall)

Compared to Baseline



Source: Zhou et al., (2022)

Accessibility Impacts (Gender)



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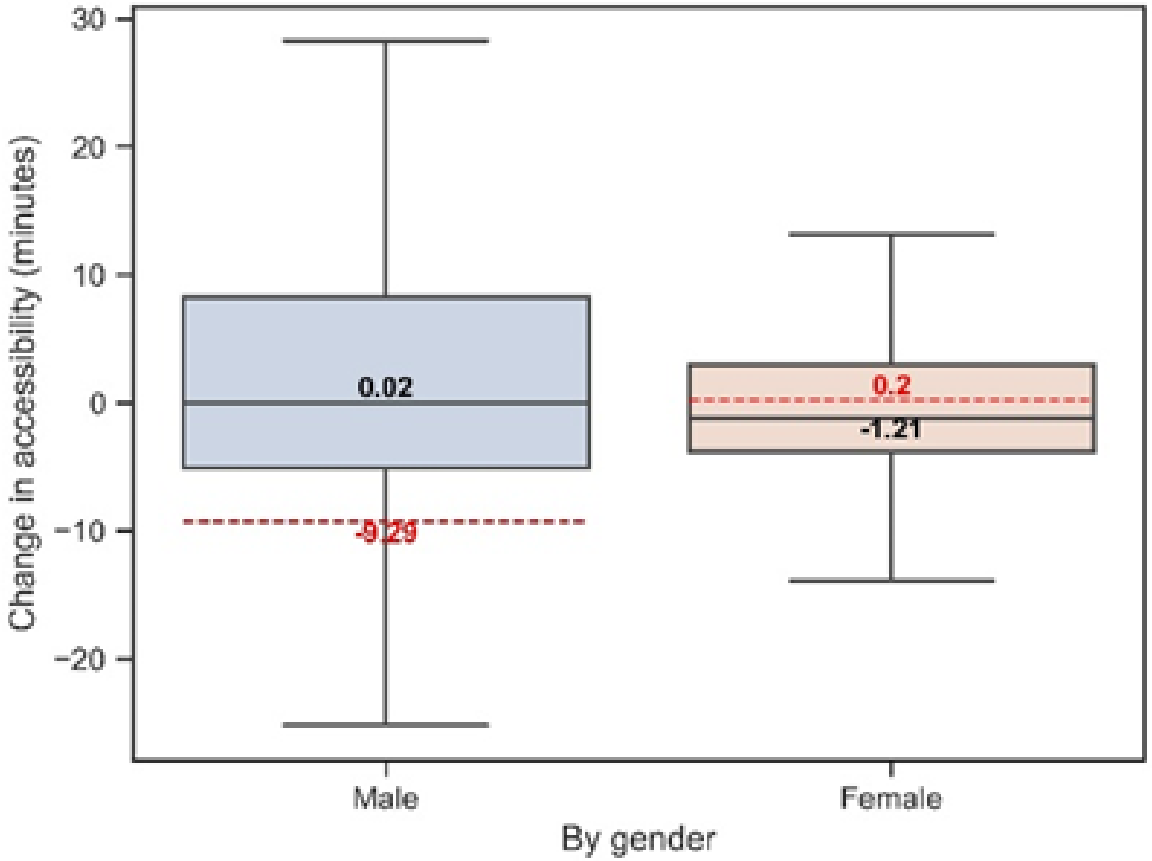

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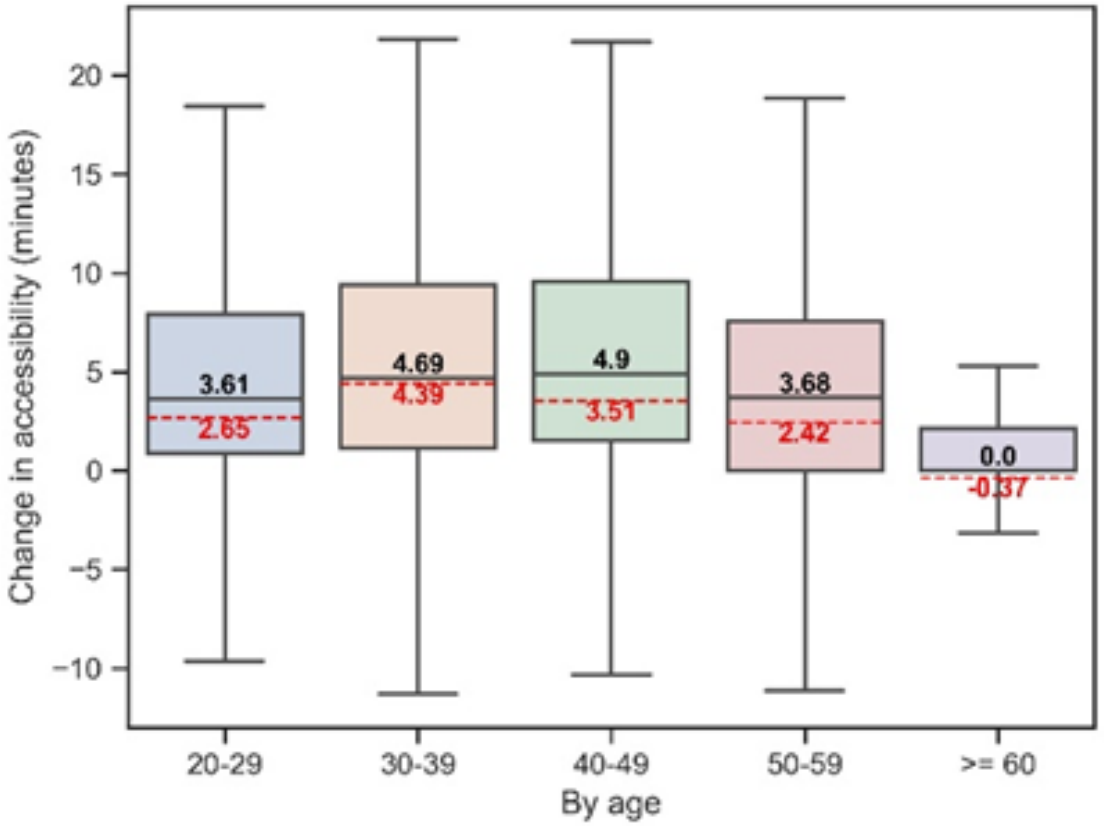
Source: Zhou et al., (2022)

Accessibility Impacts (Age)



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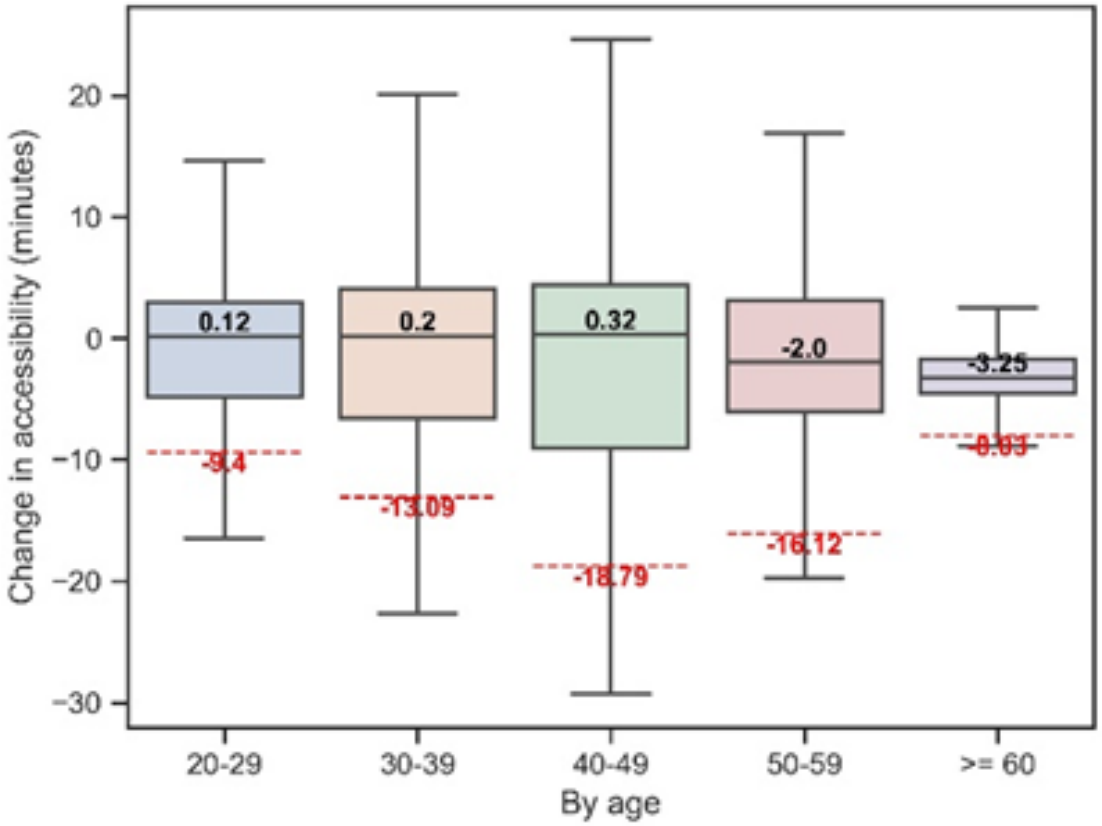

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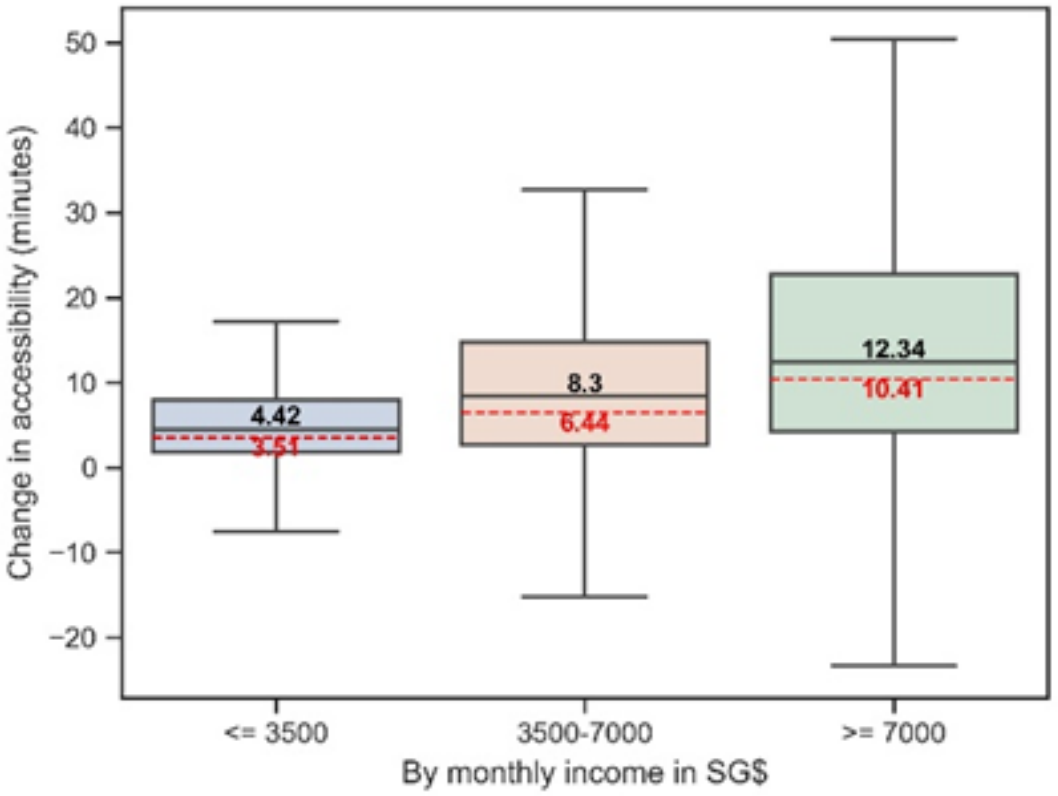
Source: Zhou et al., (20 22)

Accessibility Impacts (Income)



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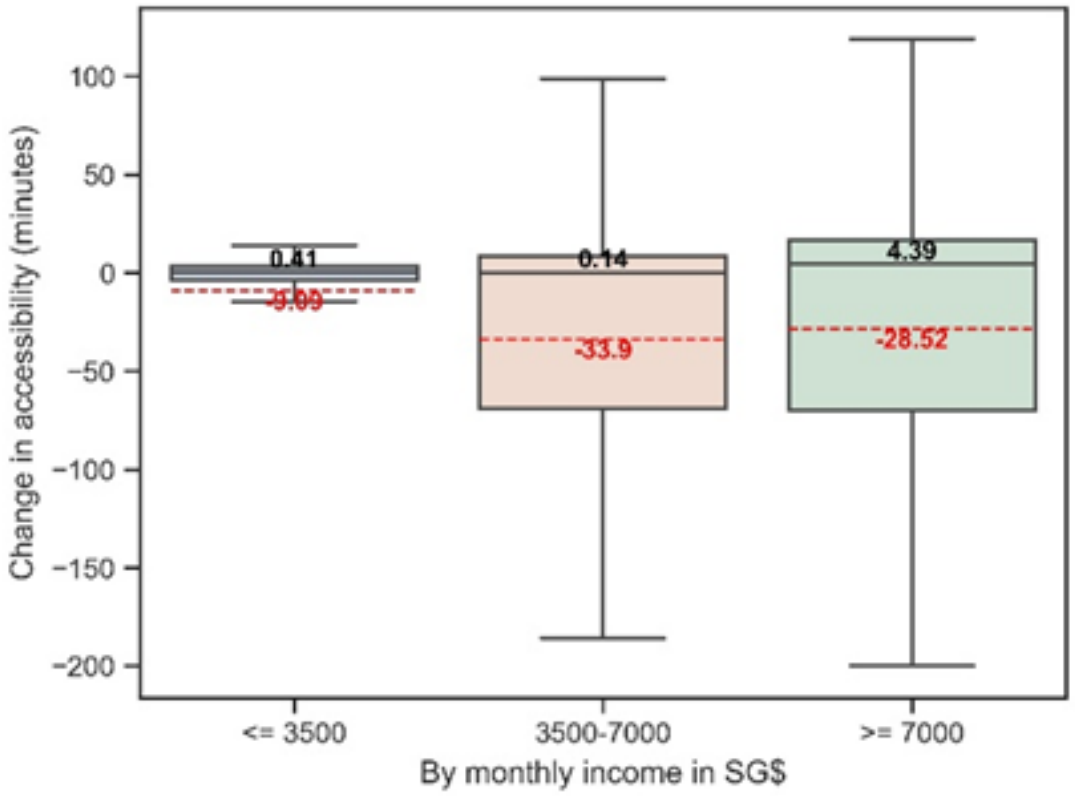

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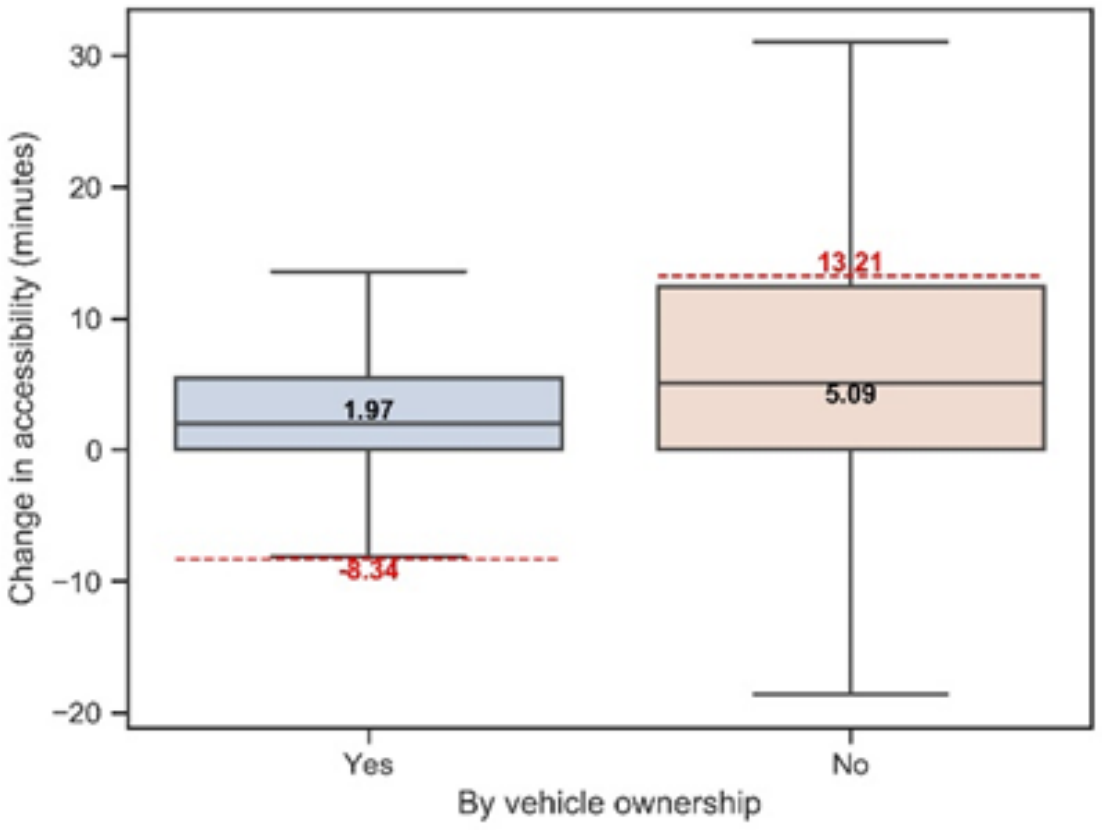
Source: Zhou et al., (2022)

Accessibility Impacts (car owners)



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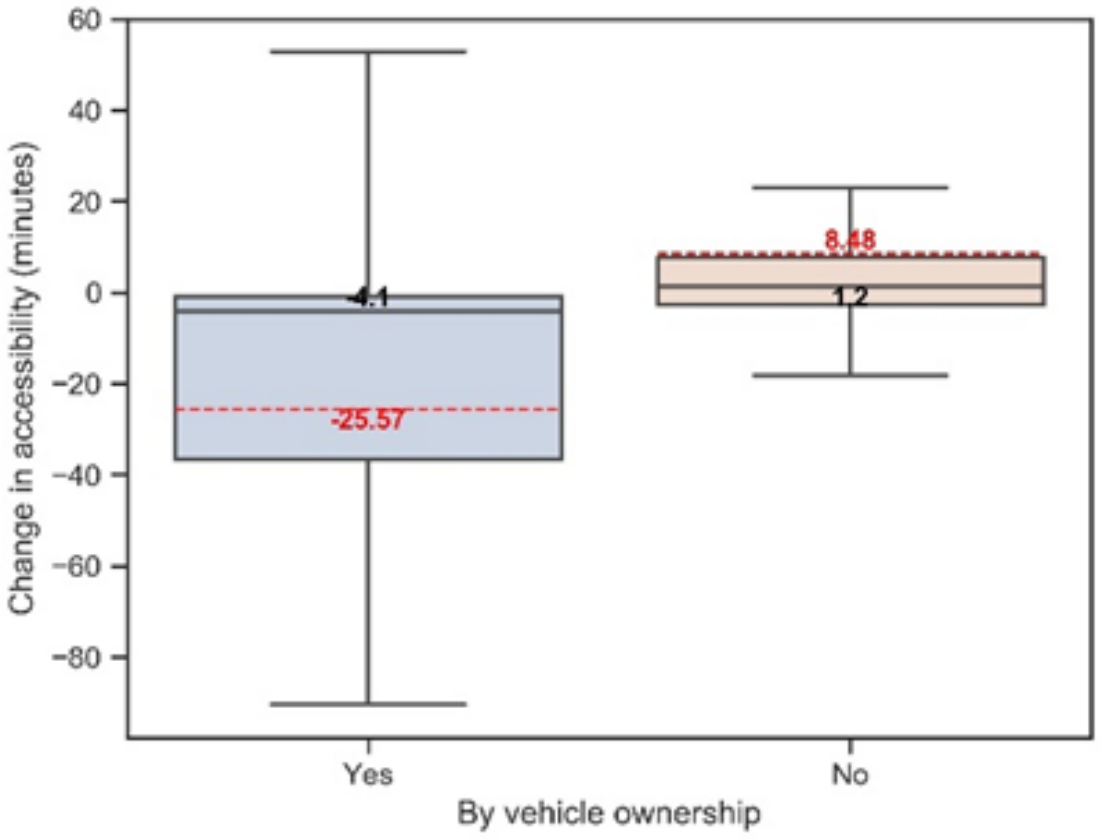

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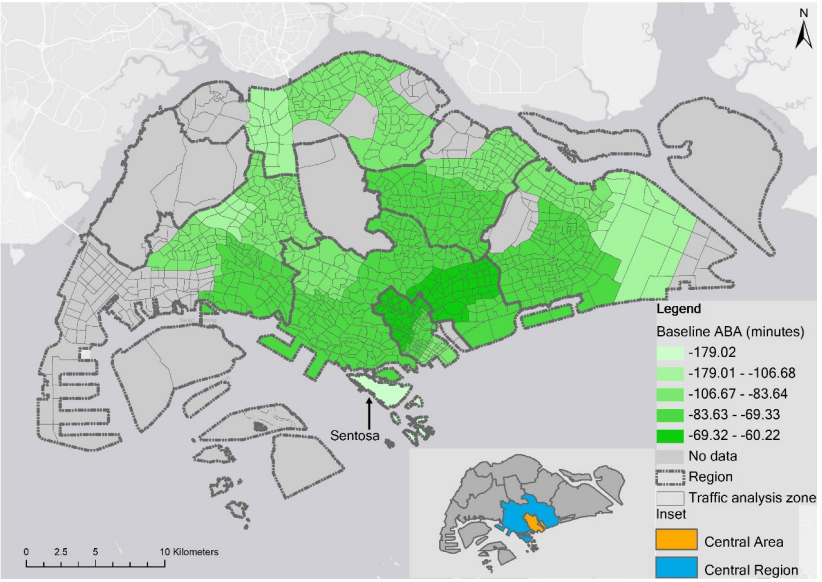
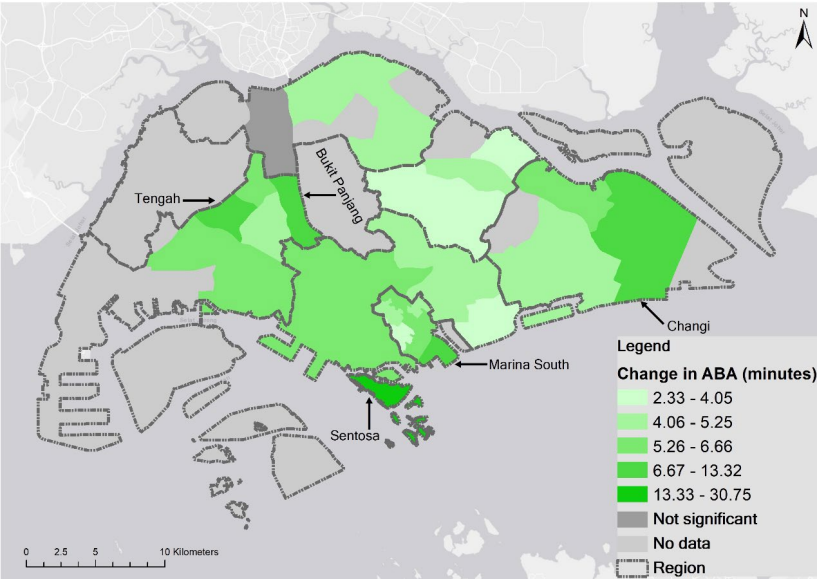
Source: Zhou et al., (20 22)

Accessibility Impacts (across space)

Zone-averaged ABA by residence



Baseline



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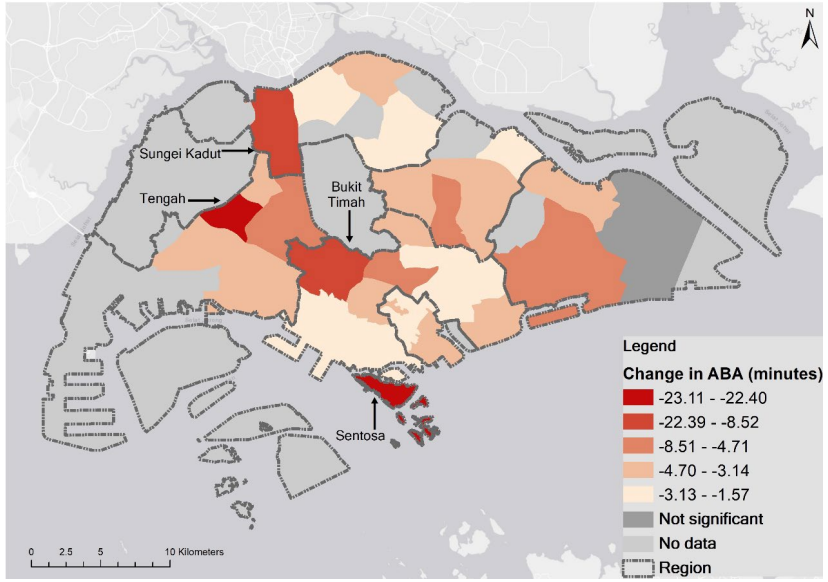

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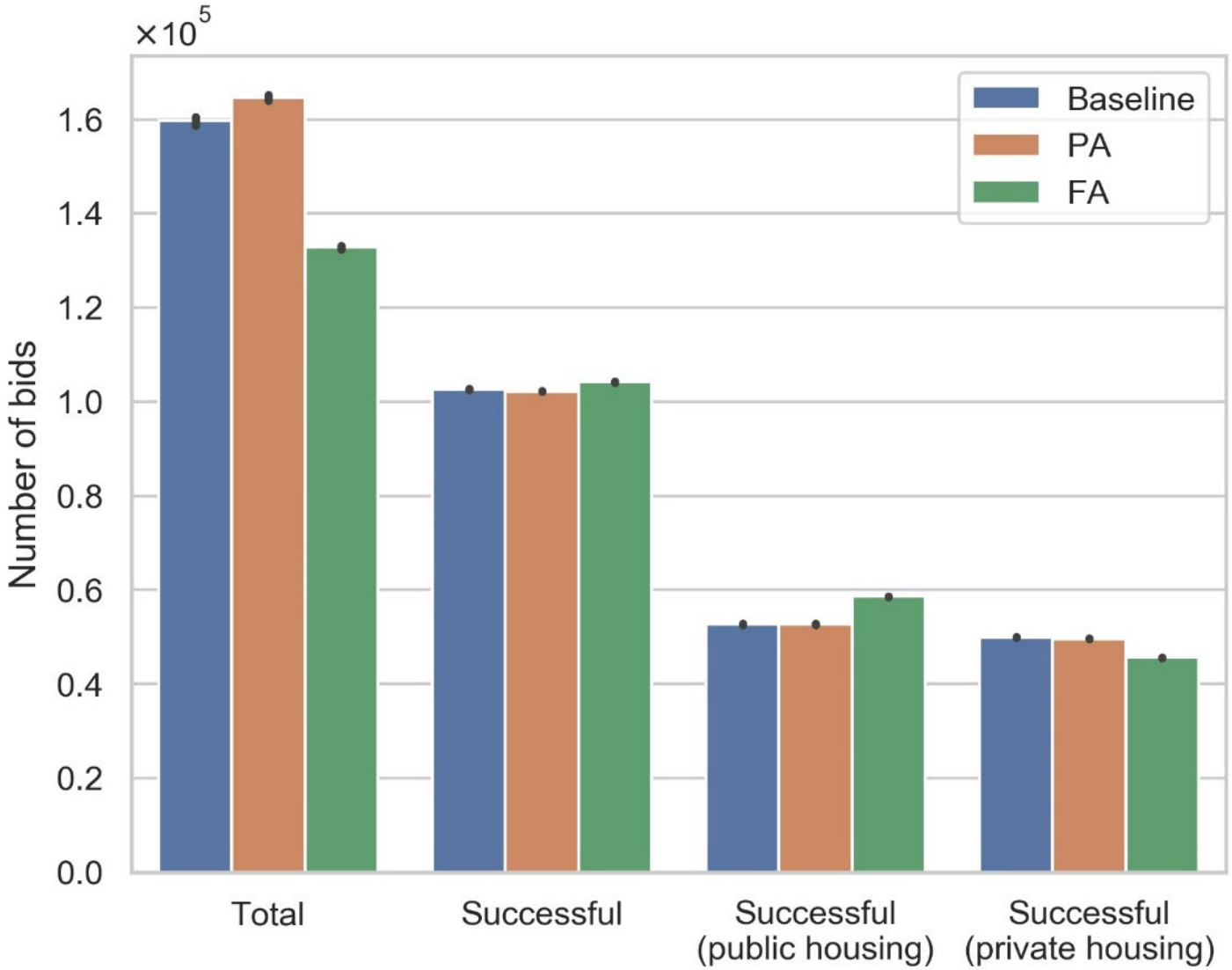
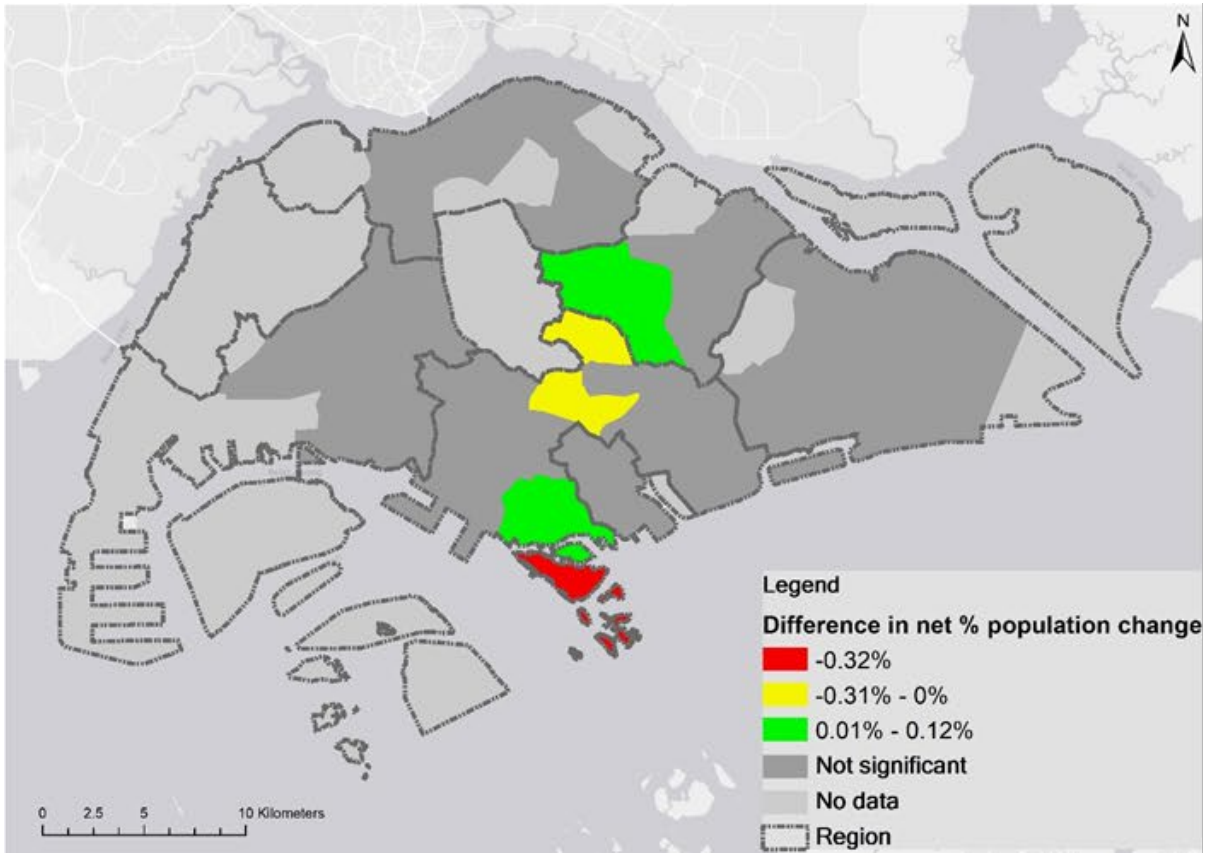
Source: Zhou et al., (2022)

Housing Market Summary

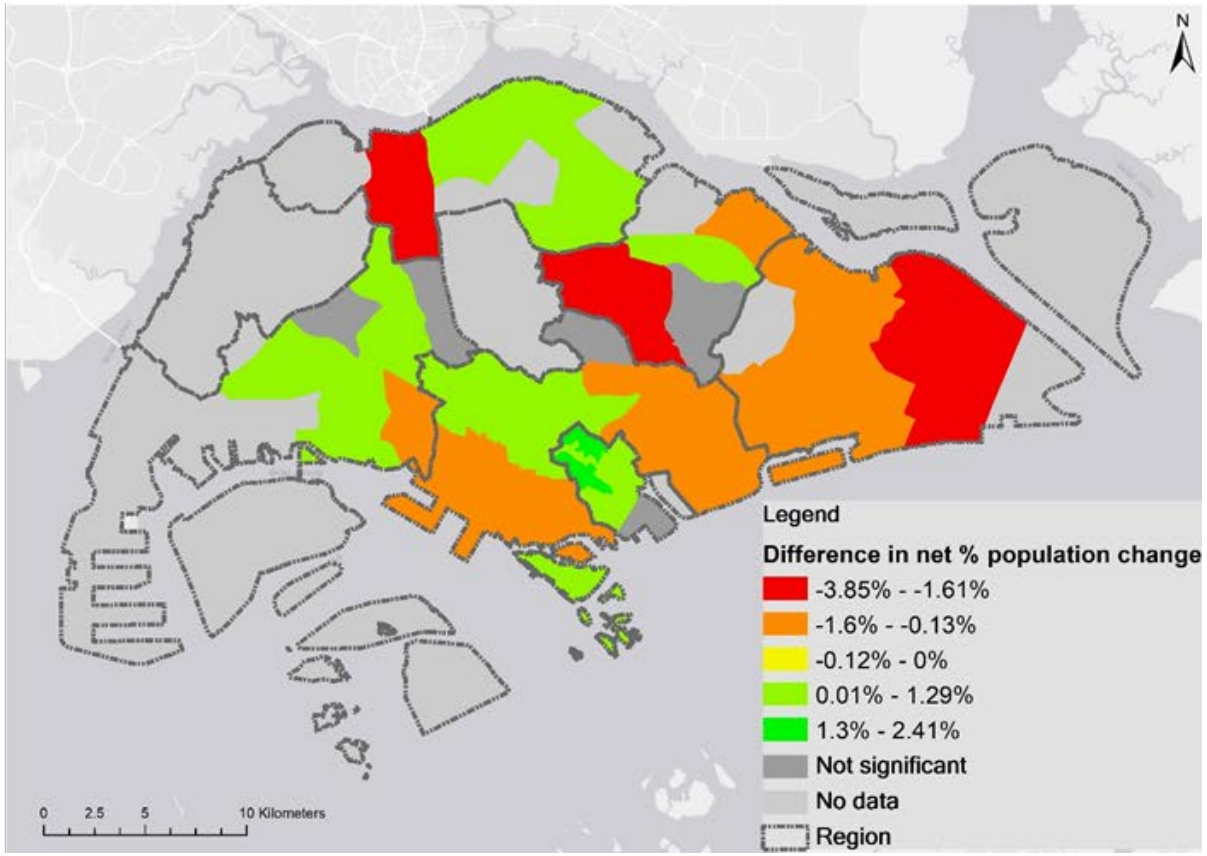


Source: Zhou et al., (2022)

Residential Relocation (% difference in total population change by zone, relative to baseline)



Partial Automation

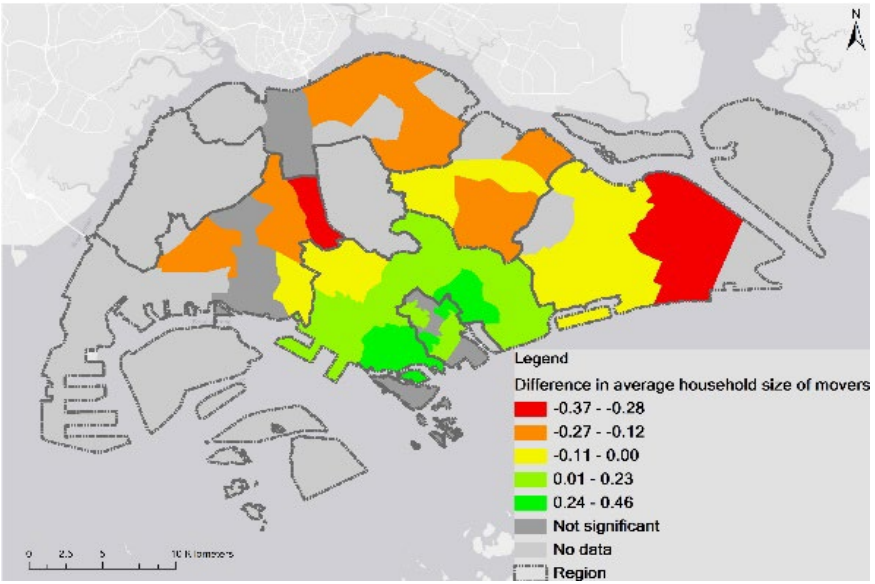


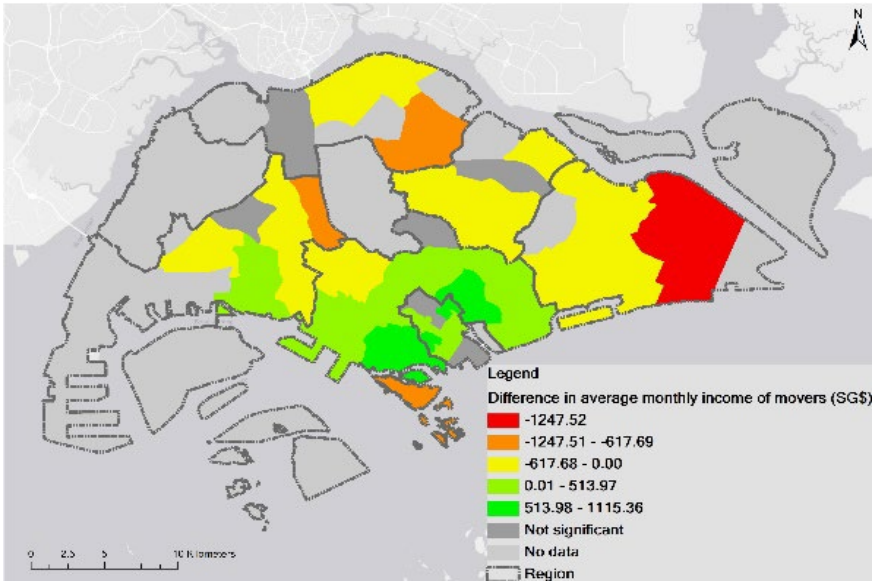
Full Automation

Source: Zhou et al., (2022)

Residential Relocation (by HH Types, % difference in FA relative to baseline)

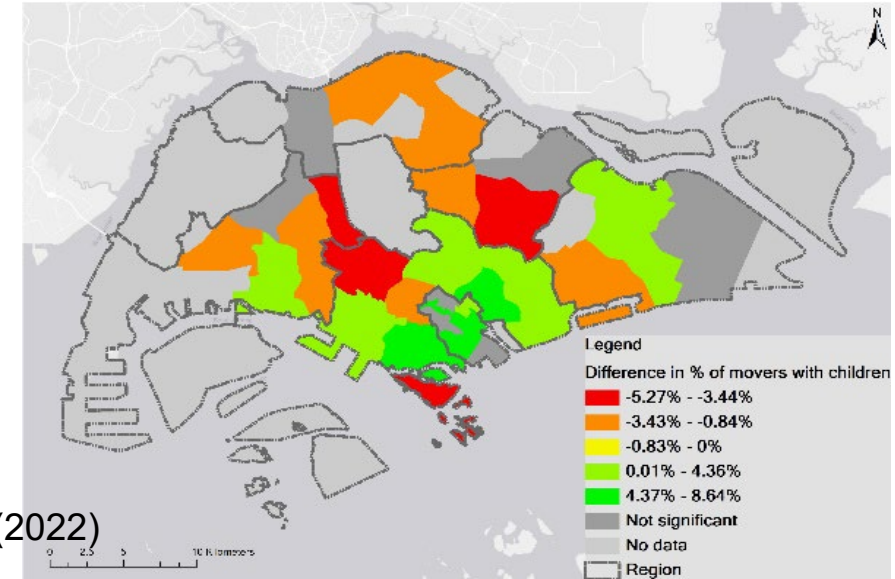
Average household size

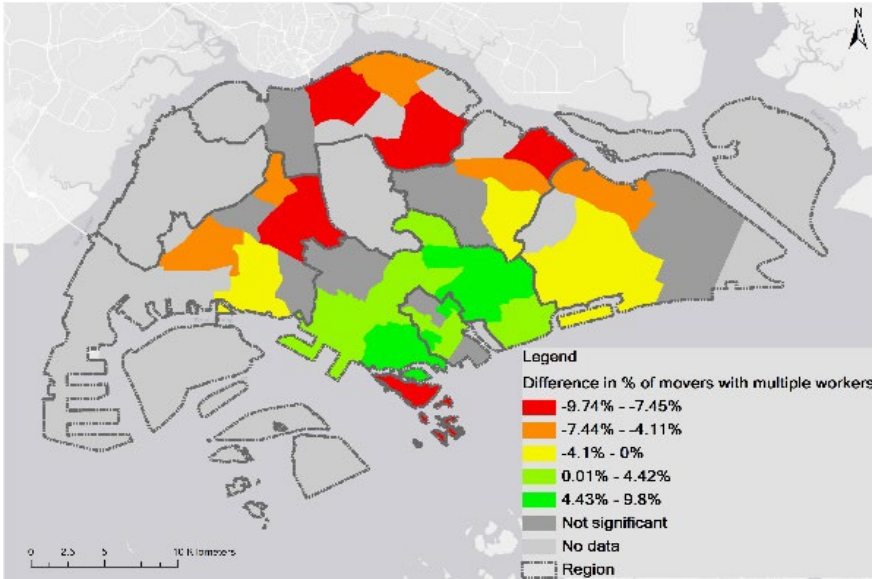




Average household income

% of movers with children





% of movers with multiple workers

Source: Zhou et al., (2022)

Conclusions

Key Findings

Full substitution of private cars with AMoD: measurably distinct influences on individual accessibility

- Mostly ***more privileged*** groups experience larger accessibility impacts
- Full Automation: City center more attractive

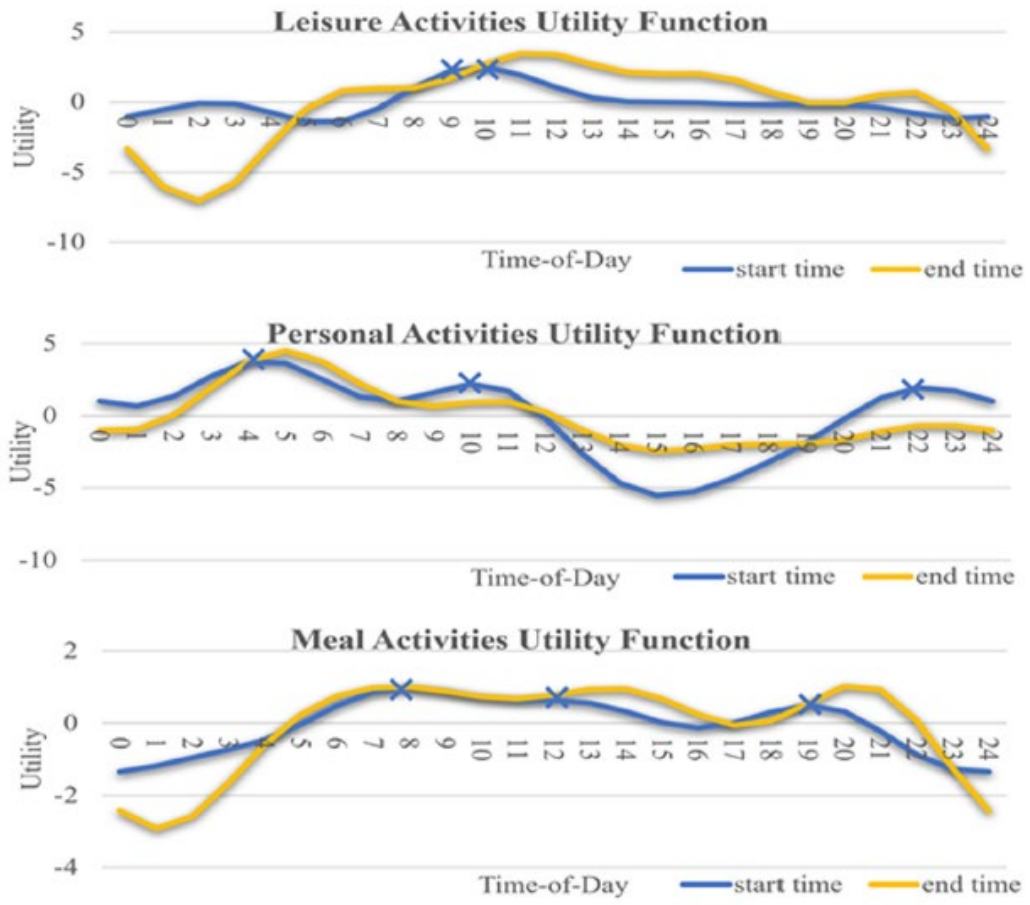
  - especially for larger & richer households with kids

Discussion

- AMoD service (under our hypothetical design)
  - not yet able to fill private mobility's shoes w.r.t. accessibility
- Full Automation (AMoD with private mode ban)
  - *reduces social inequality* in accessibility (what would happen w/just private ban?)
- *Induced Sprawl?*
  - Little evidence in either scenario (unique to Singapore?)
- Central areas (with better transit & denser amenities): more attractive
  - Possible *gentrification* effects in Full Automation

Future Research

- AMoD impacts on weekly (and longer) activity patterns



Hermawan et al, 2022

Future Research

- AMoD impacts on weekly (and longer) activity patterns
- Varying taste parameters across different scenarios
- Intra-household dynamics (Accessibility) and residential decisions
- Sensitivity analysis of pricing & fleet size
- Broader examination of longer term impacts (job and school location changes, new development (residential and commercial), & (maybe) demographic changes
- Extensions to broader impacts – carbon, local AQ, accidents…

Acknowledgements

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