OAK RIDGE National Laboratory

Bridging population, activity spaces, and social interactivity with the Likeness software stack

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Breakout Session 2: Advanced Methods and Models Using ACS Data
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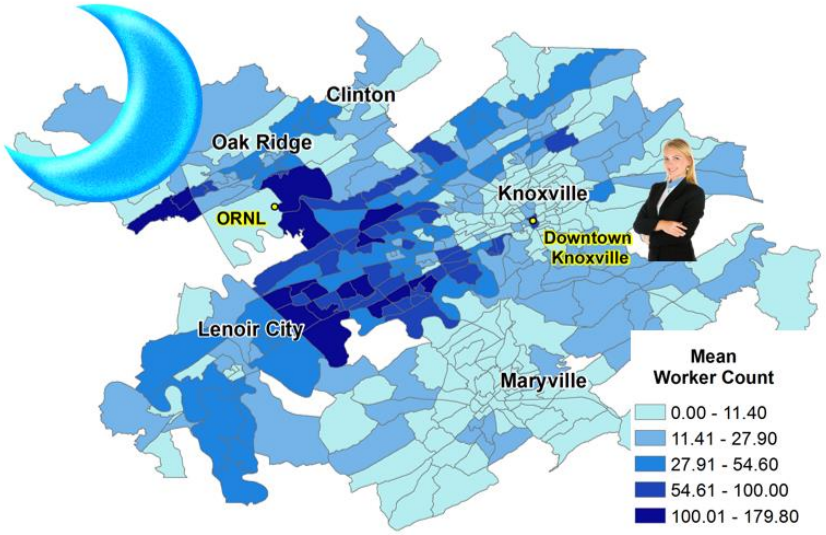
U.S. DEPARTMENT OF ENERGY

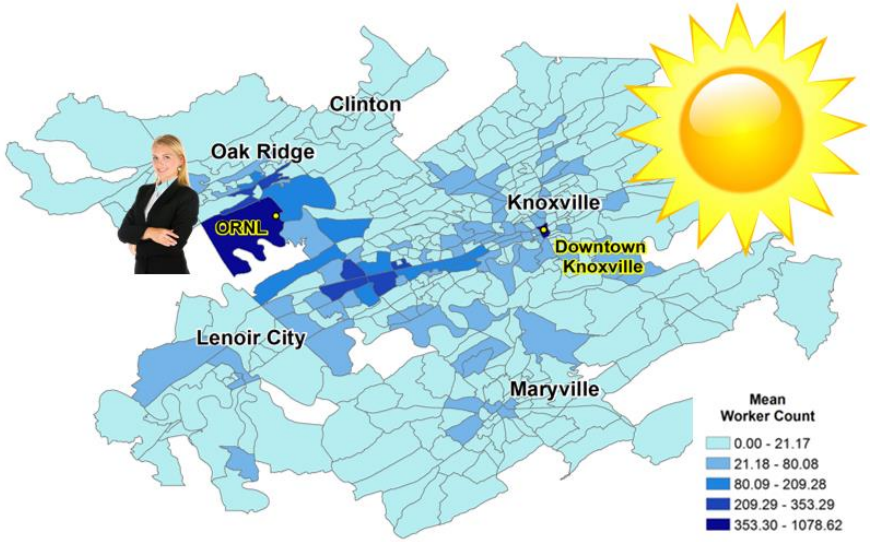
The UrbanPop Spatial Microsimulation Framework

- **Capabilities**
  - Coupled individual-neighborhood profiles (*how people live*)
  - Daytime/Nighttime dynamics (*how people move*)
  - Agent Generation -> patterns of Life/Social contacts (*how people [inter]act*)

- Based on the **American Community Survey (ACS)** and **Public-Use Microdata Sample (PUMS)**

- **Available for any location in the United States** 2016 – 2019





Tuccillo et. al 2023 [1]

Adapted from Stewart et. al (2015) [2]

UrbanPop History

2015: UP begins as an ORNL LDRD to develop a synthetic population for the United States and simulate commutes with Pitney Bowes.

2017-2018: Specific applications of UP are developed (transportation, energy).

2018: UP "goes public", swapping Pitney Bowes for LODES.

2020: UP contributes to National Virtual Biotechnology Laboratory (NVBL) COVID-19 situational awareness effort.

2021: UPgrading to 2019 ACS/2018 LODES; development of new school travel model.

2022-2023: Development of **Likeness**, extending methods to real-world transportation networks, points of interest (POIs).

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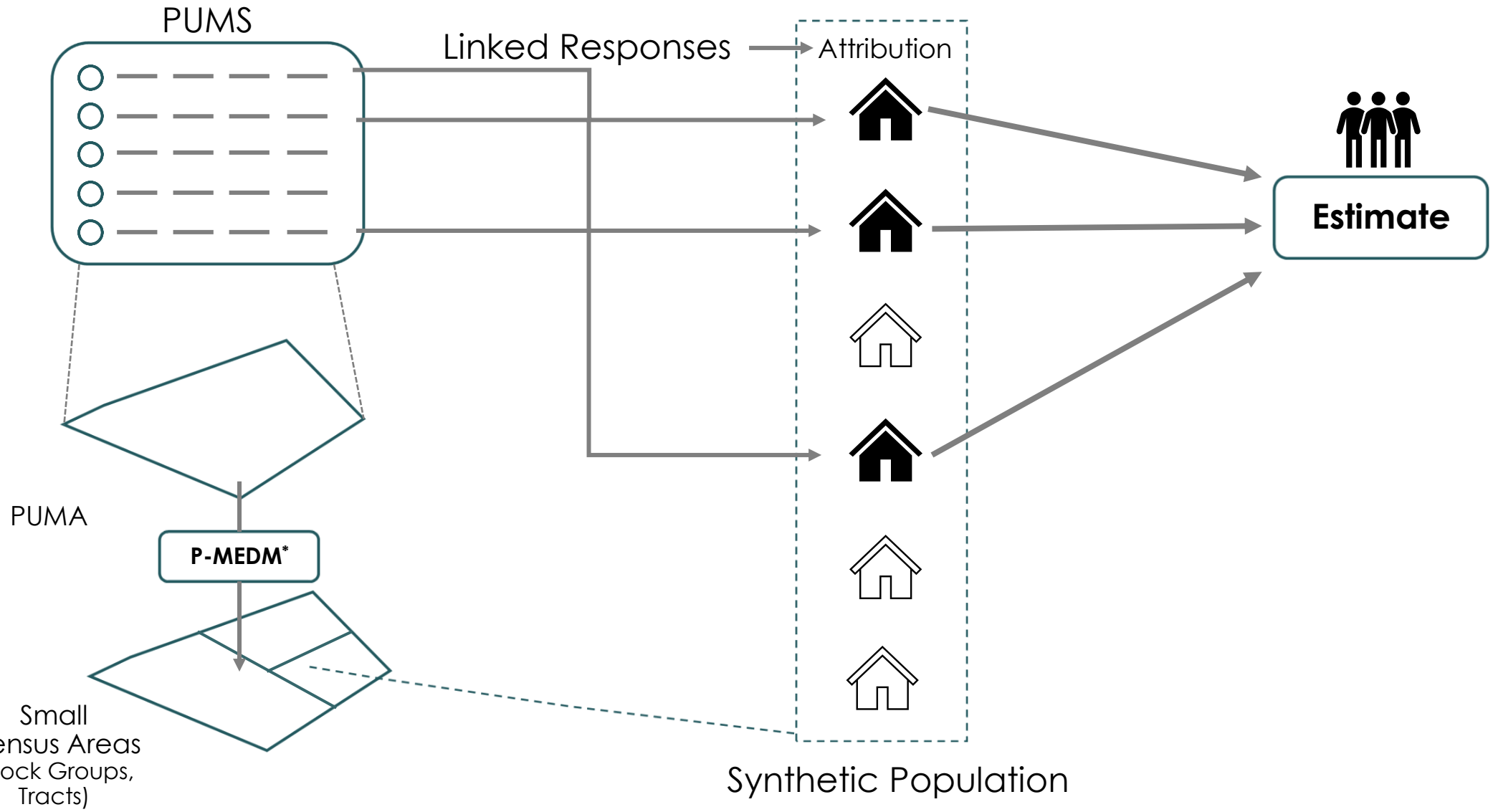
UrbanPop Core Workflow

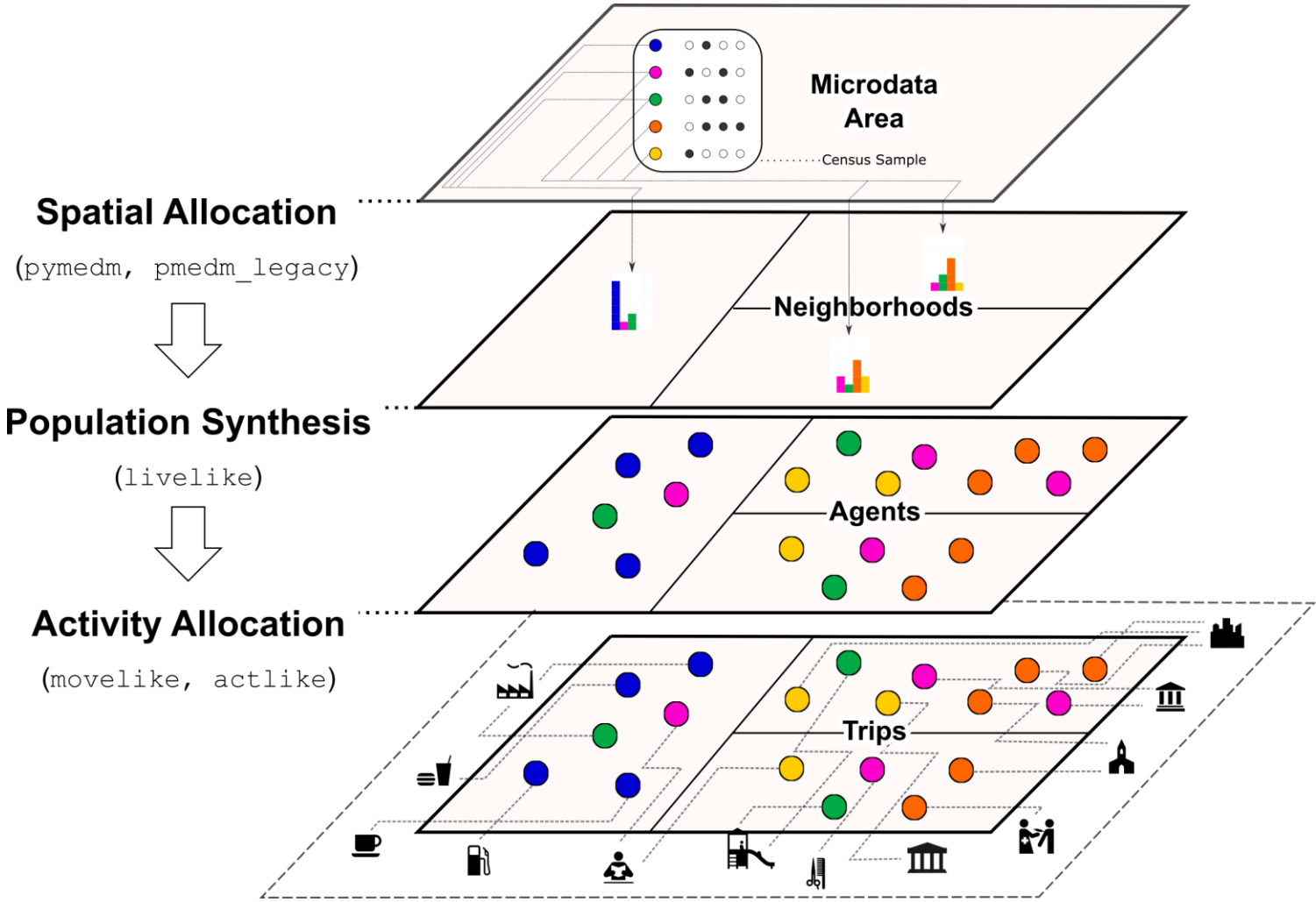


*Nagle et. al 2015 [3]

The Likeness Toolkit

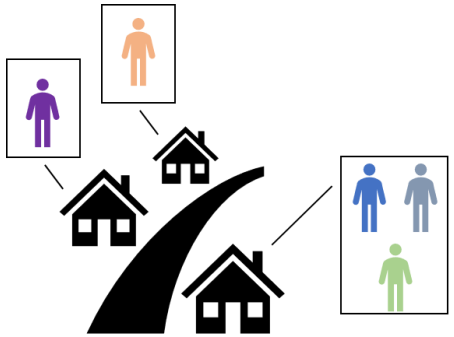
- **UrbanPop's core capabilities in a Python software stack**
  - Synthetic Population Generation
  - Small-Area Estimates for neighborhood characterization

- **Enhancements**
  - Travel along real-world transportation networks from OSM
  - POI-based destinations for a variety of activity types (work/school, social, recreation, errands, health…)



Tuccillo and Gaboardi (2022a) [4]

Likeness ecosystem



Problem Formulation

- **ACS SF 5-Year API** Geographic Constraints
- **Census Microdata API** Individual Constraints
- **TIGER WMS** Custom Geographies

livelike Population Synthesis

pymedm Spatial Allocation

likeness-vitals Utilities

movelike Travel Routing

actlike Activity Allocation

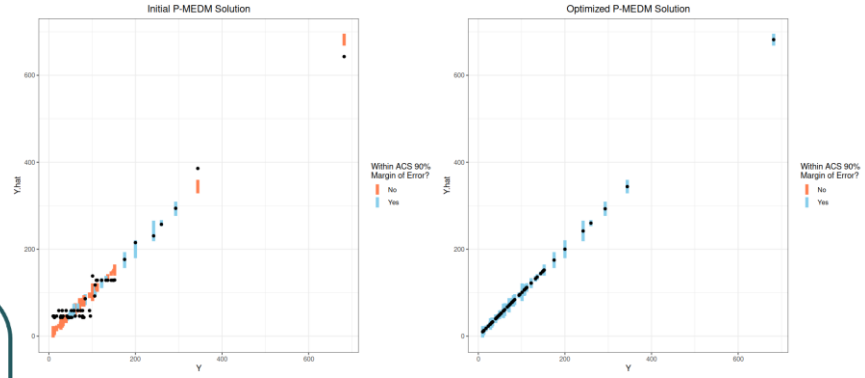
1 2 3 4

Agent Generation

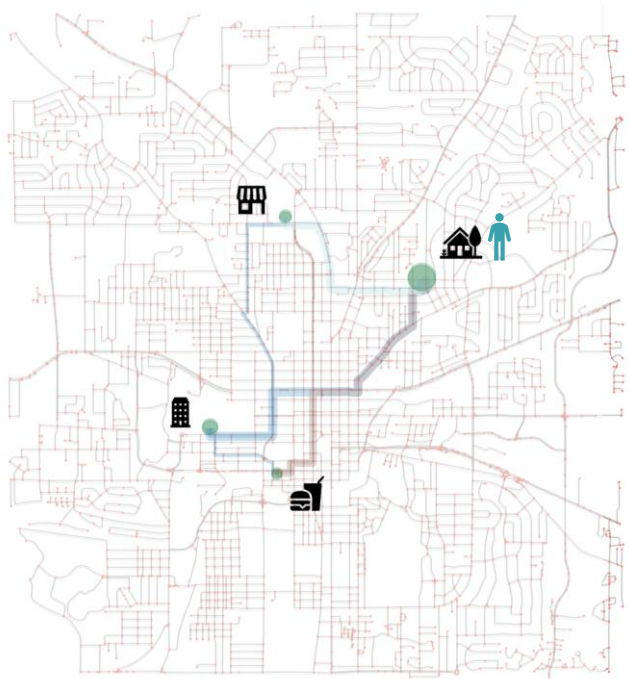
- **TIGER WMS/FEMA USA Structures** Residential Locations

Activity Model*

- **OpenStreetMap (via OSMNX), GTFS, pandana** Networks/Routes
- **COIN, PuLP, MIP** Transportation Problem



Tuccillo and Spielman 2022 [5]



***Activity Model attribution**
Boeing (2017) [6], Foti et al. (2012) [7], Lougee-Heimer (2003) [8], Forrest et al. (2023) [9], Mitchell et al. (2001) [10], Toffolo and Santos (2019) [11]

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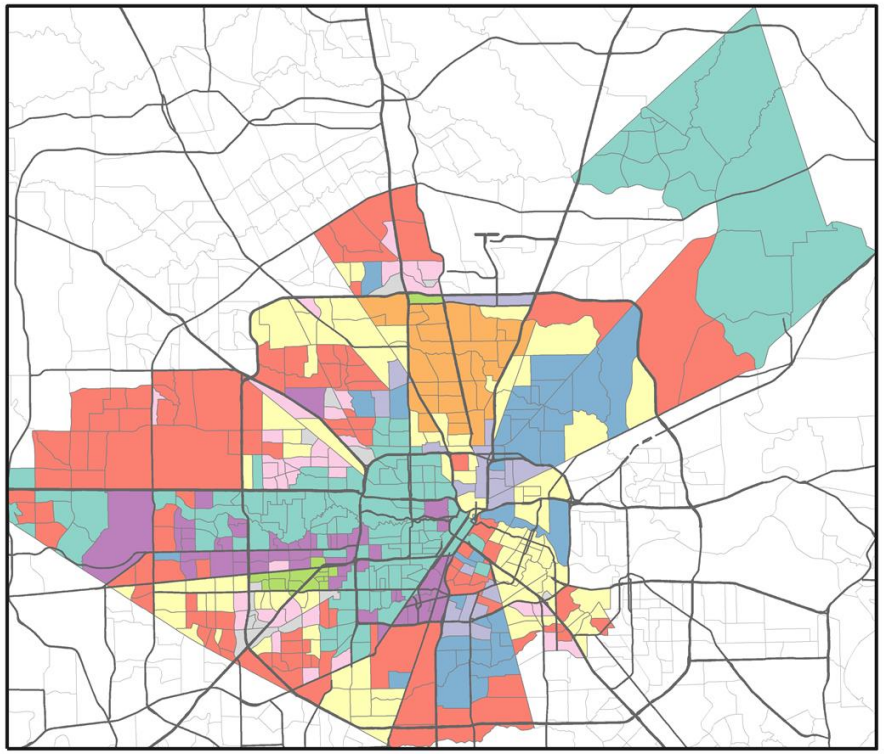
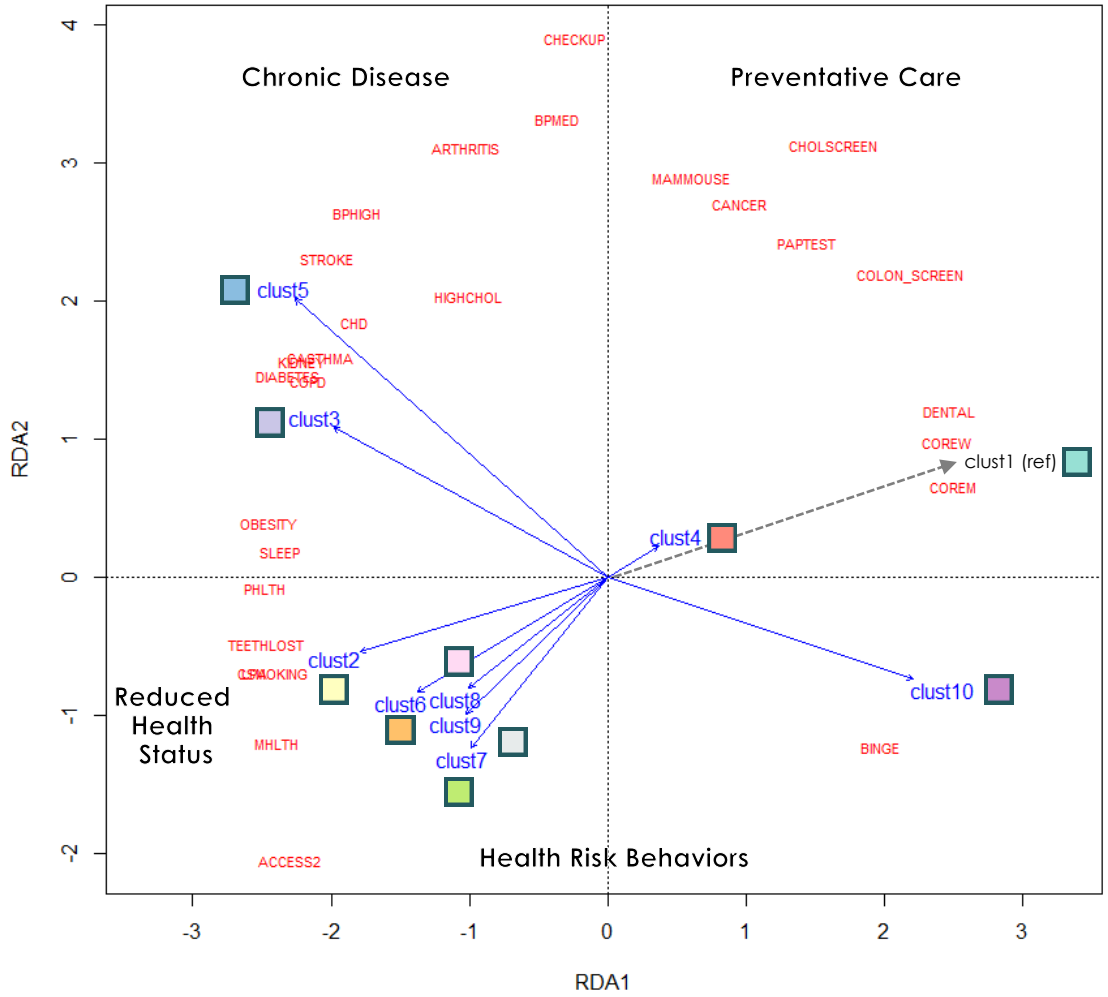
Case Study 1: Neighborhood riskscapes, health, and power outages

Harris County, TX 2019



Social Vulnerability Profiles by Individual Vulnerability Theme

	7	6	9	3	8	2	5	4	10	1	Avg. Prop.
Few SV Indicators	13%	15%	17%	25%	26%	29%	38%	55%	60%	**87%**	**49%**
Independent Living Sensitivity	2%	7%	3%	14%	5%	10%	**16%**	9%	4%	4%	**7%**
Poverty/Density/Limited Mobility	49%	**51%**	43%	26%	34%	38%	18%	17%	12%	3%	**23%**
Communication Sensitivity/Unemployment	**28%**	22%	27%	16%	22%	16%	14%	12%	14%	4%	**14%**
Single Caregiver Relationships	8%	5%	11%	**19%**	12%	6%	13%	8%	9%	2%	**7%**



Redundancy Analysis (RDA) on CDC PLACES 2019

$R^2 = 0.65$ (pr(F) < 0.001)

Kahl et. al (2022) [12]

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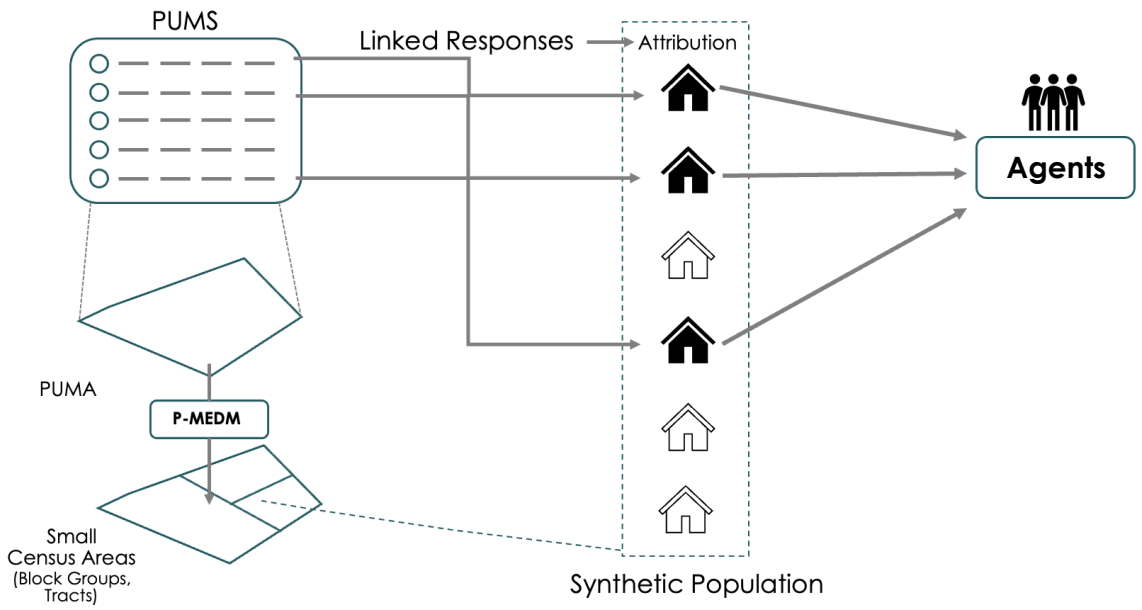
Generating Household/Agent Locations

Spatial Allocation

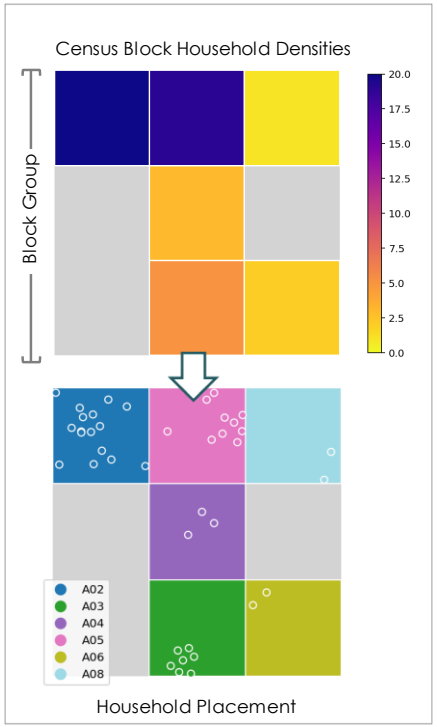
Core Workflow



Downscaling

Working Approach

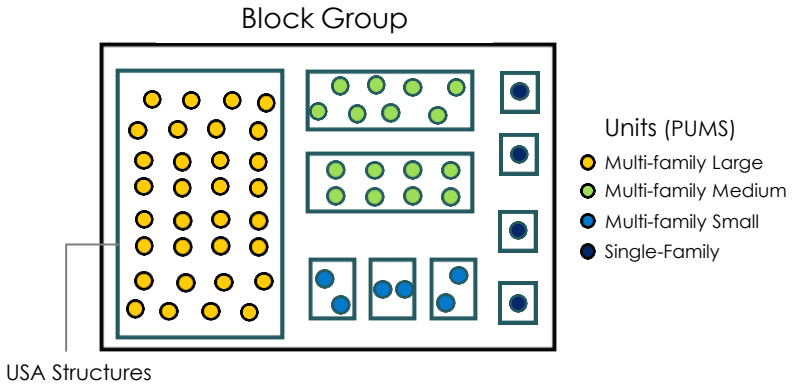
- Weighted random allocation of households to census blocks based on 2010 Decennial Census household density
- Variable-size binpacking problem
- Clustered placement of household points within blocks



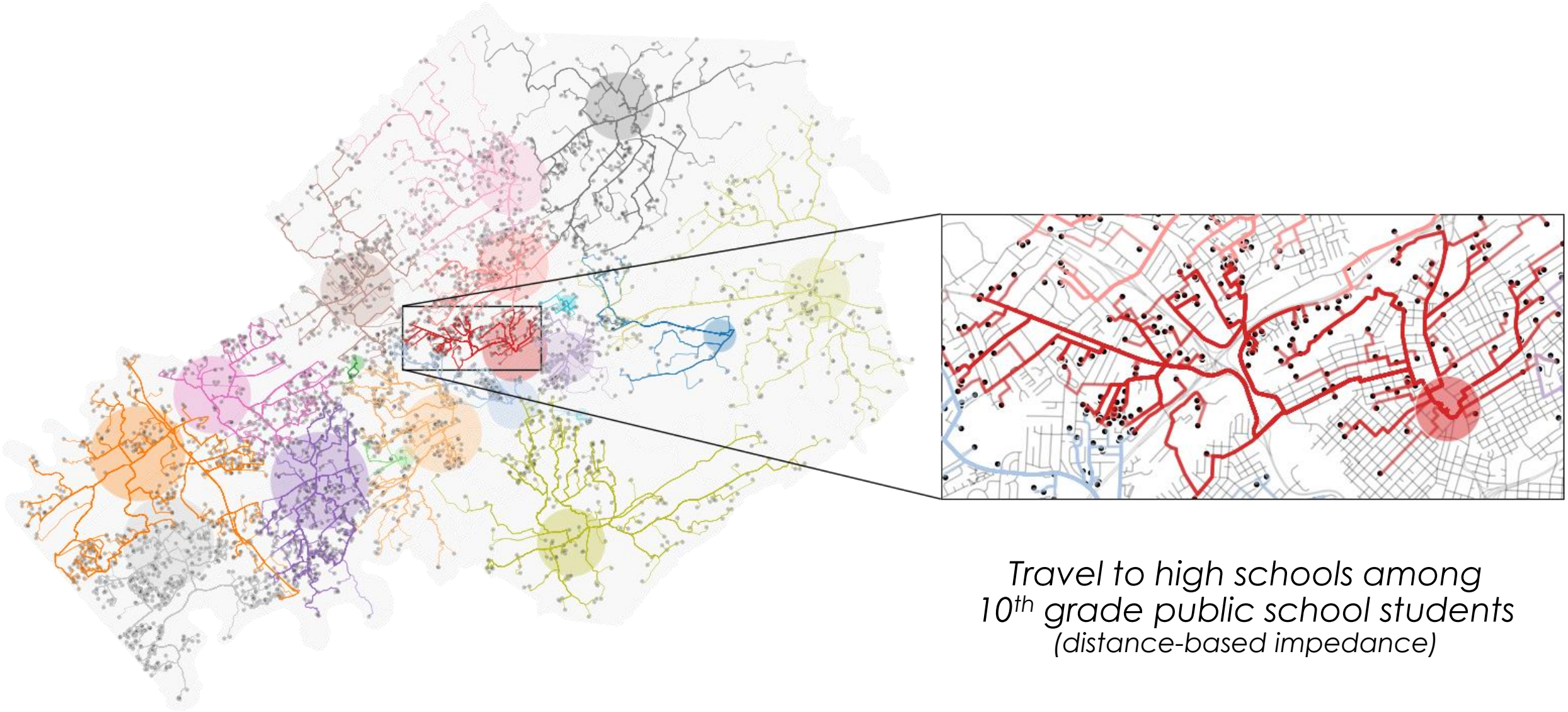
Downscaling

In Development

- Downscaling resolved to USA Structures
- Weighted random assignment of building IDs to synthetic households scored on similarity in unit counts between household (PUMS) and local USA Structures



Case Study 2: K-12 Public Schools in Knox County, TN



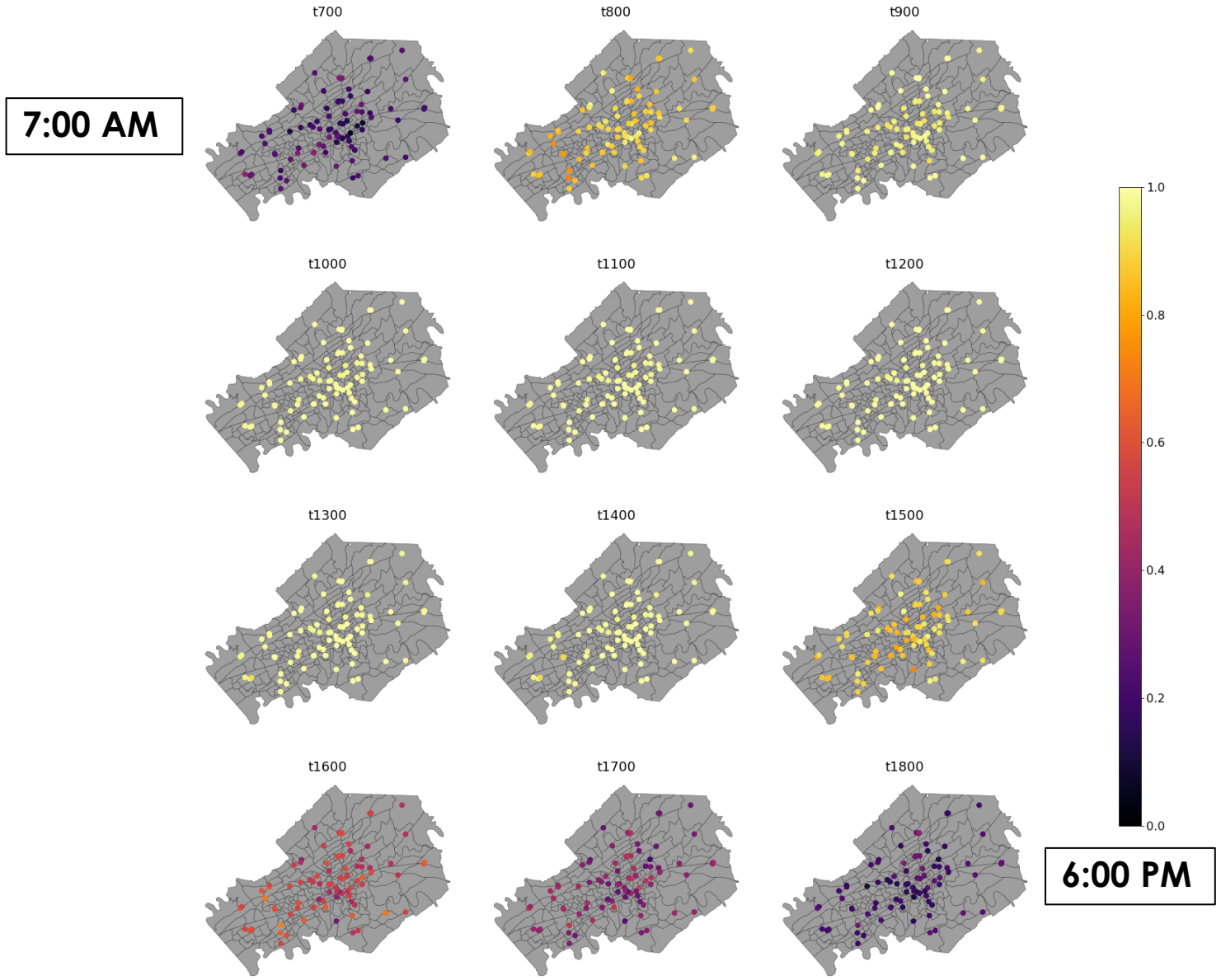
Travel to high schools among
10th grade public school students
(distance-based impedance)

Tuccillo and Gaboardi (2022a) [13]

Case Study 2: K-12 Public Schools in Knox County, TN

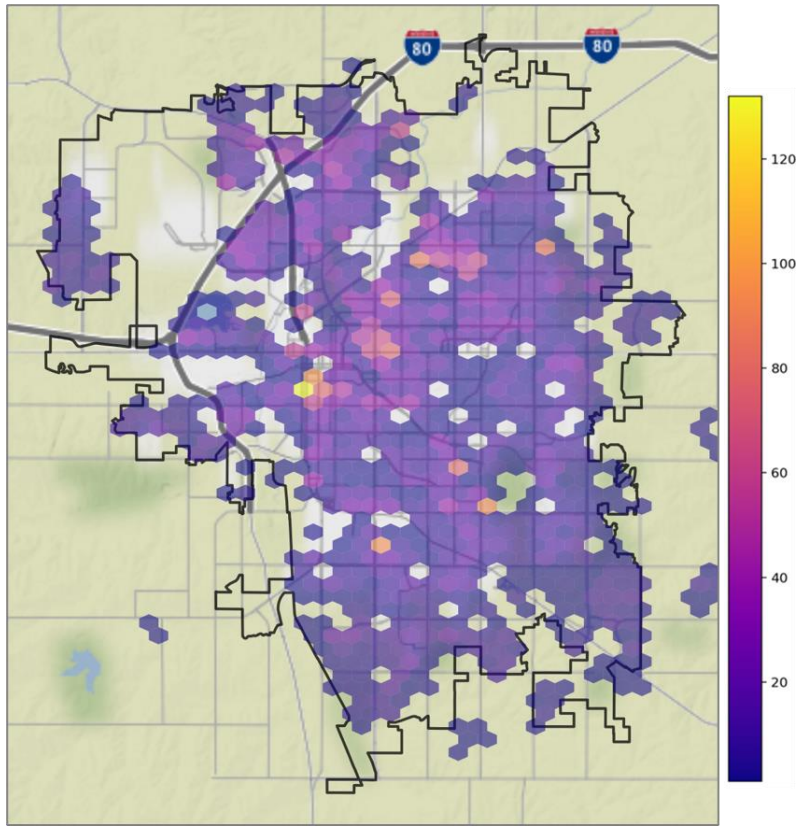
- **Educator arrivals**
  - PUMS time of arrival at work (`JWAP`)
- **Educator departures**
  - PUMS `JWAP` + (`WKHP` / 5)

    where `WKHP` represents the number of hours worked per week

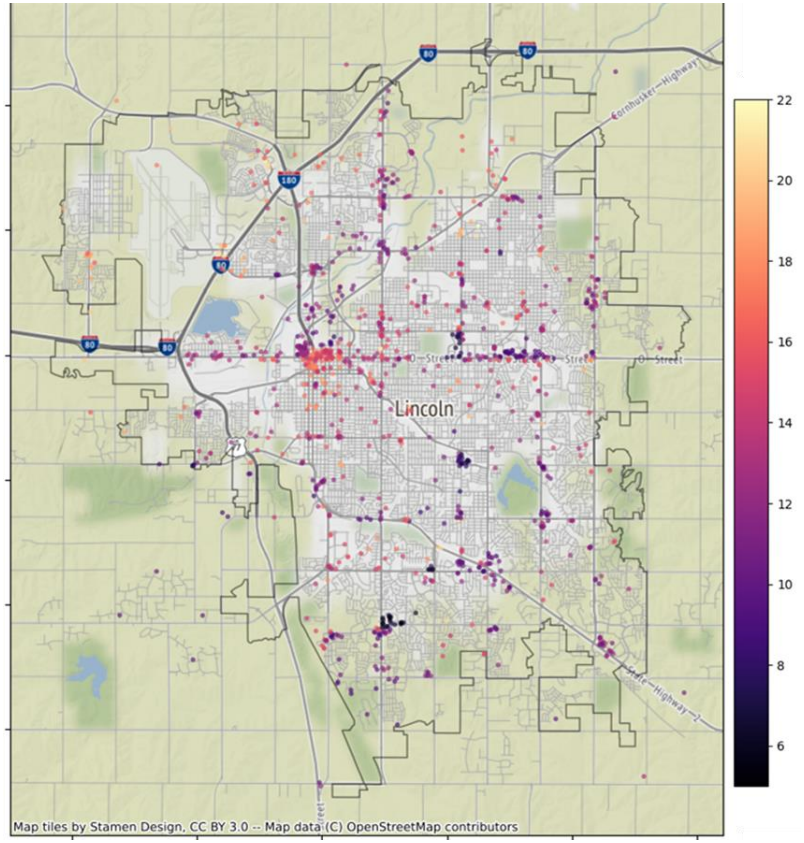


Tuccillo and Gaboardi (2022a) [13]

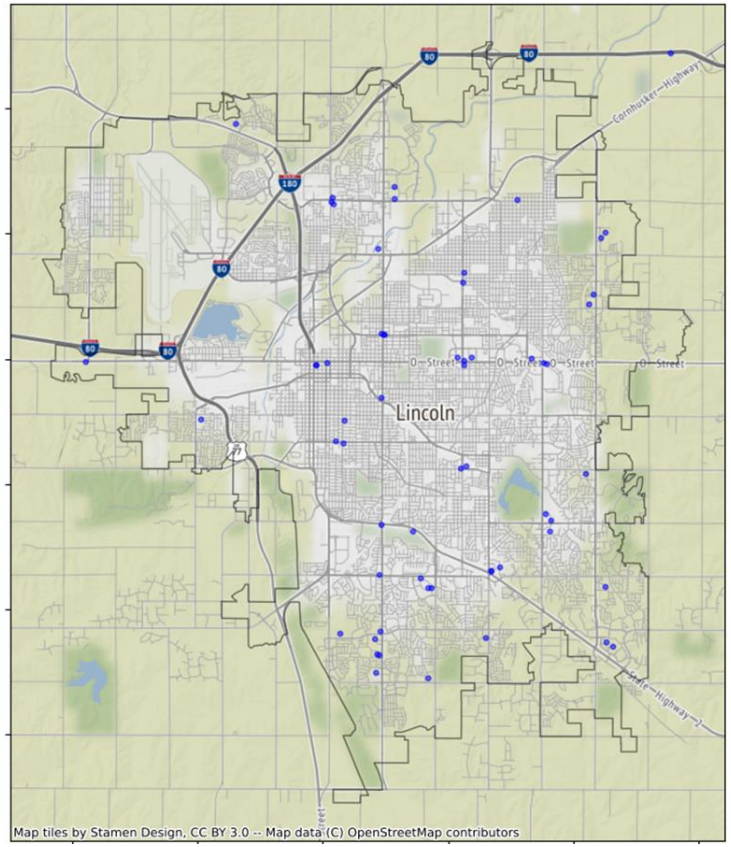
Case Study 3: Essential Activities



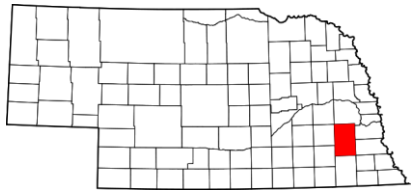
Synthetic Population
Food Service Workers



Job Locations
Workers per Establishment



COVID-19 Healthcare Services
Vaccination and Testing Centers

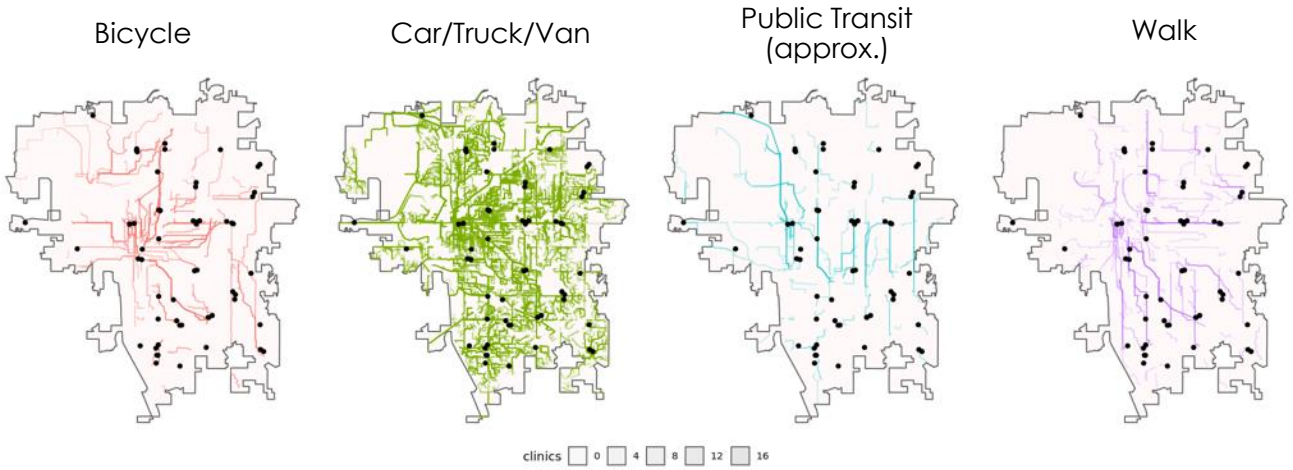


Public domain image from Wikimedia Commons
https://commons.wikimedia.org/wiki/File:Map_of_Nebraska_highlighting_Lancaster_County.svg

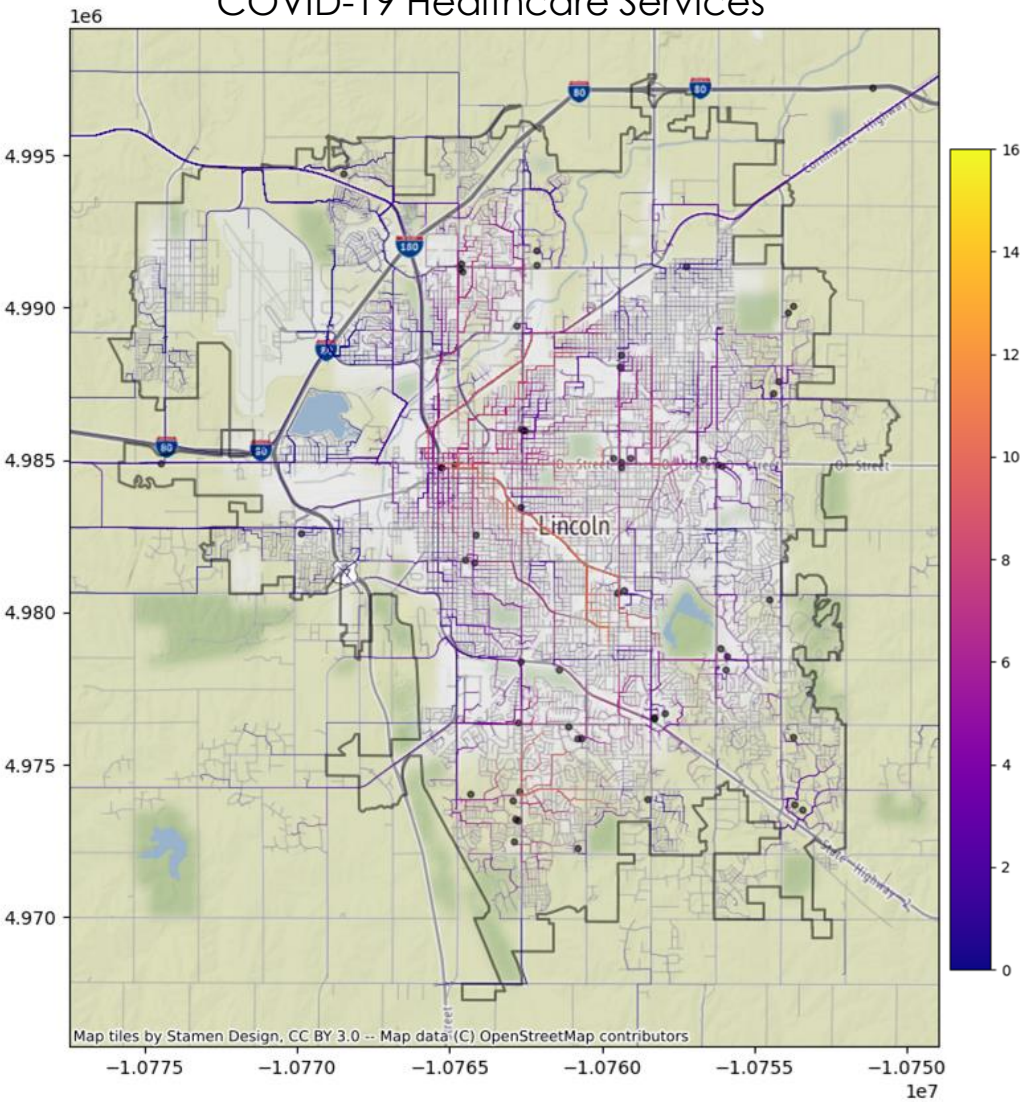
Tuccillo and Gaboardi (2022b) [13]

Case Study 3: Essential Activities

- Greatest access to COVID-19 healthcare services for commutes into downtown core, along major commercial corridors
- Access decreases with urban intensity, particularly in W/NW, SE Lincoln



Home-Work Trajectories by Number of COVID-19 Healthcare Services

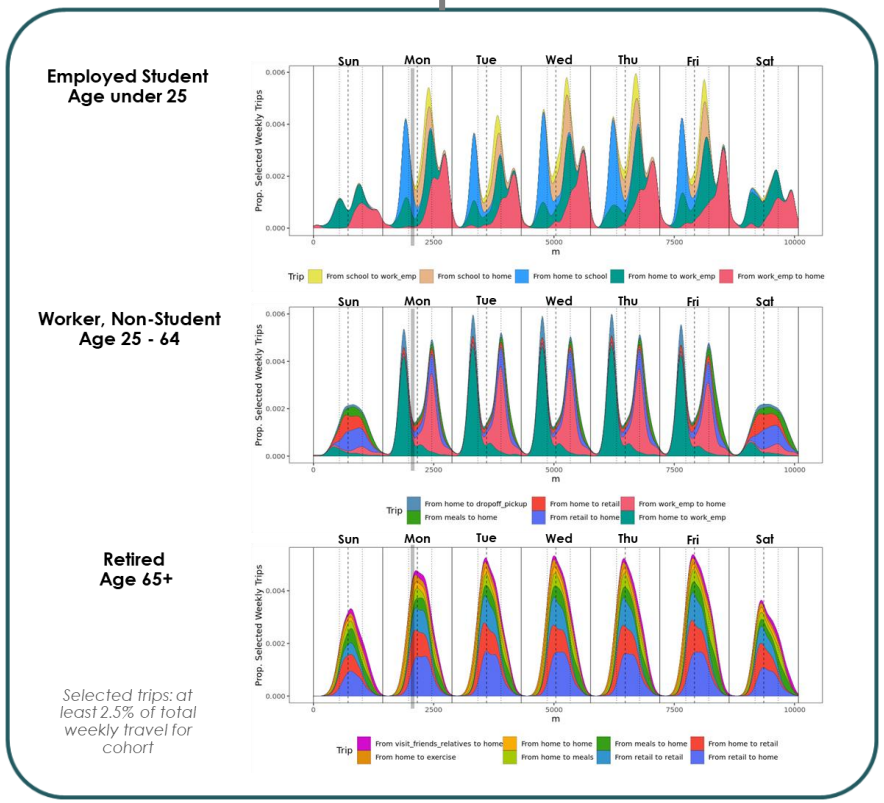


COVID-19 Healthcare Service

UTM Zone 14N

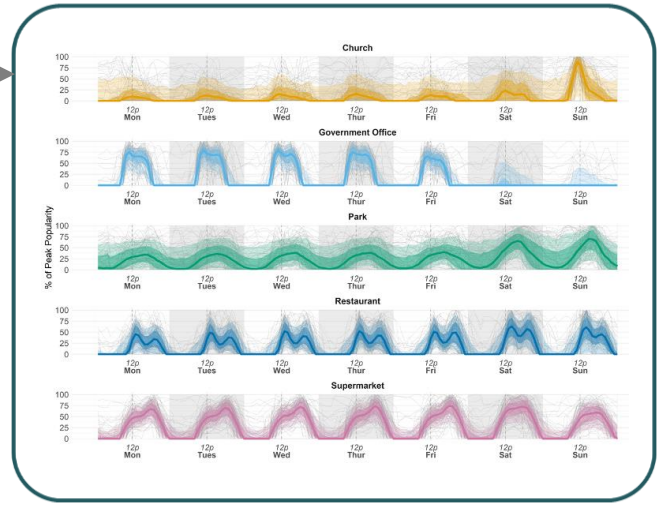
Tuccillo and Gaboardi (2022b) [13]

Up Next: Toward 24-Hour Synthetic Populations



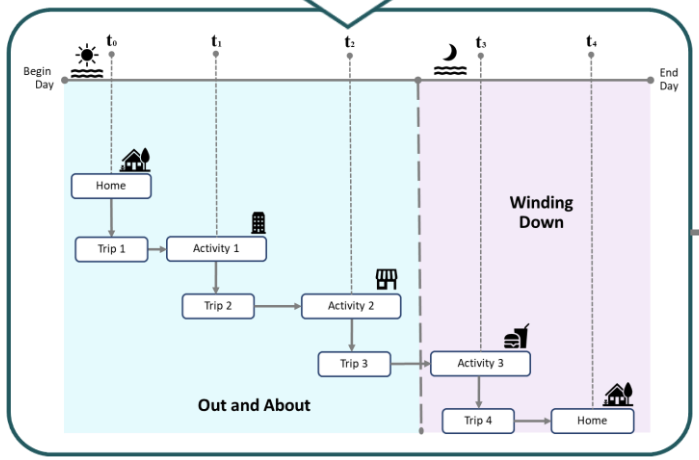
Time-Use and Travel Surveys

Tuccillo and Gaboardi (2023) [15]



POI Popularity Curves

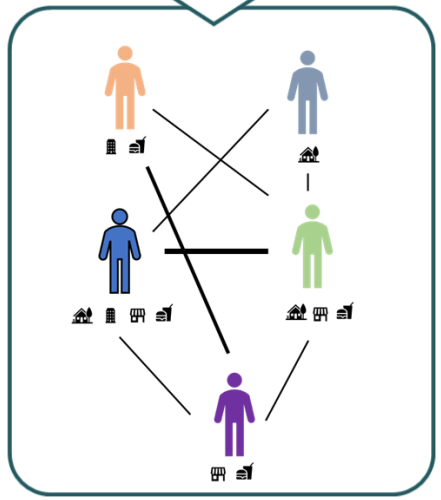
Thakur et. al (2015) [14]



Activity Scheduling

Tuccillo and Gaboardi (2023) [15]

Activity Modeling



Social Contact Networks

Thank you!

Questions?

References

1. Tuccillo, J., Stewart, R., Rose, A., Trombley, N., Moehl, J., Nagle, N., and Bhaduri, B. L. (2023). UrbanPop: A spatial microsimulation framework for exploring demographic influences on human dynamics. *Applied Geography*, 151, 102844.
2. Stewart, R., Aziz, H., Morton, A., Park, H. , Duchscherer, S., Piburn, J., Maness, M., and Nagle, N. N. (2015). Population as a Service: Simulating the American population for modeling urban dynamics. Poster presentation*, Oak Ridge National Laboratory (ORNL)*, Oak Ridge, TN (United States).
3. Nagle, N. N., Buttenfield, B. P., Leyk, S., and Spielman, S. E. (2014). Dasymetric modeling and uncertainty. *Annals of the Association of American Geographers* 104 (1), 80–95.
4. Tuccillo, J. V. and Gaboardi, J. D. (2022a). Likeness: a toolkit for connecting the social fabric of place to human dynamics. In Agarwal, M., Calloway, C., Niederhut, D., and Shupe, D. (Eds.), *Proceedings of the 21st Python in Science Conference*, pp. 125 – 135.
5. Tuccillo, J. V., and Spielman, S. E. (2022). A method for measuring coupled individual and social vulnerability to environmental hazards. *Annals of the American Association of Geographers*, 112(6), 1702-1725.
6. Boeing, G. (2017). OSMnx: New methods for acquiring, constructing, analyzing, and visualizing complex street networks. *Computers, Environment and Urban Systems*, 65, 126-139.
7. Foti, F., Waddell, P., and Luxen, D. (2012, April). A generalized computational framework for accessibility: from the pedestrian to the metropolitan scale. In *Proceedings of the 4th TRB conference on innovations in travel modeling*. Transportation research board (pp. 1-14).
8. Lougee-Heimer, R. (2003, January). The Common Optimization INterface for Operations Research. *IBM Journal of Research and Development*, 47(1):57-66.
9. Forrest, J. et al. (2023). coin-or/Cbc. Zenodo. https://doi.org/10.5281/zenodo.7843975
10. Mitchell, S., O'Sullivan, M., and Dunning, I. (2001). PuLP: a linear programming toolkit for python. *The University of Auckland*, Auckland, New Zealand, 65.
11. Toffolo, T. A. M. and Santos, H. G. (2019). PYTHON-MIP. https://www.python-mip.com/
12. Kahl, A., Tuccillo, J. V., Luke, N., Tran, L., Bhaduri, B. L., and Dumas M. (2022, July). Coupling vulnerability metrics to assess the impacts of large-scale winter storms. *Natural Hazards Workshop Researchers Meeting 2022*.
13. Tuccillo, J. V. and Gaboardi, J. D. (2022b, November). Examining COVID-19 Vaccine Access Profiles through Spatial Microsimulation and Activity Allocation. *69th Annual North American Meetings of the Regional Science Association International*, Montreal, Quebec, Canada.
14. Thakur, G. S., Bhaduri, B. L., Piburn, J. O., Sims, K. M., Stewart, R. N., and Urban, M. L. (2015). PlanetSense: a real-time streaming and spatio-temporal analytics platform for gathering geo-spatial intelligence from open source data. In *Proceedings of the 23rd SIGSPATIAL International Conference on Advances in Geographic Information Systems*, pp. 1–4.
15. Tuccillo, J. V. and Gaboardi, J. D. (2023). Demographic characterization of human dynamics models with time-use and travel surveys. *American Association of Geographers 2023 Annual Meeting* (AAG), Denver, Colorado, United States. Zenodo. https://doi.org/10.5281/zenodo.7853705

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