OAK RIDGE National Laboratory

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Using Synthetic Populations to Model Travel Burdens Among U.S. Veterans Health Administration Patients

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U.S. DEPARTMENT OF ENERGY

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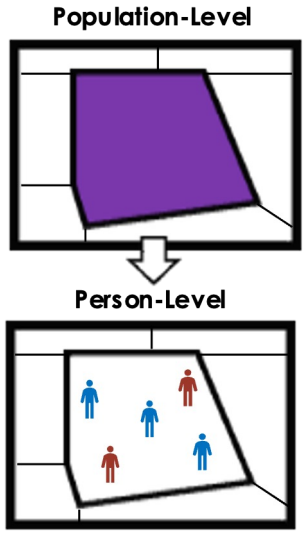
Motivation

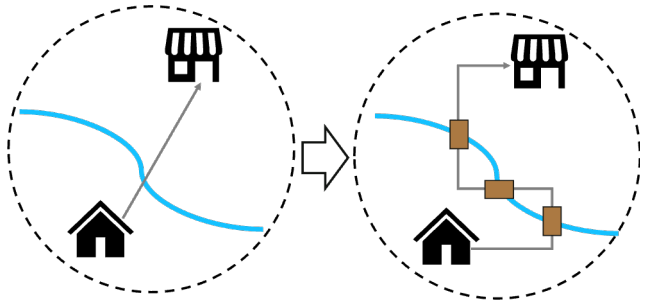
Population Heterogeneity

- Population subgroups exhibit variability in travel behavior via lifestyle (e.g., demographic, economic) characteristics
- How do cross-sectional characteristics of VHA patient populations (e.g., demographic, economic, mobility) affect access to points of care?



Real-World Resource Access

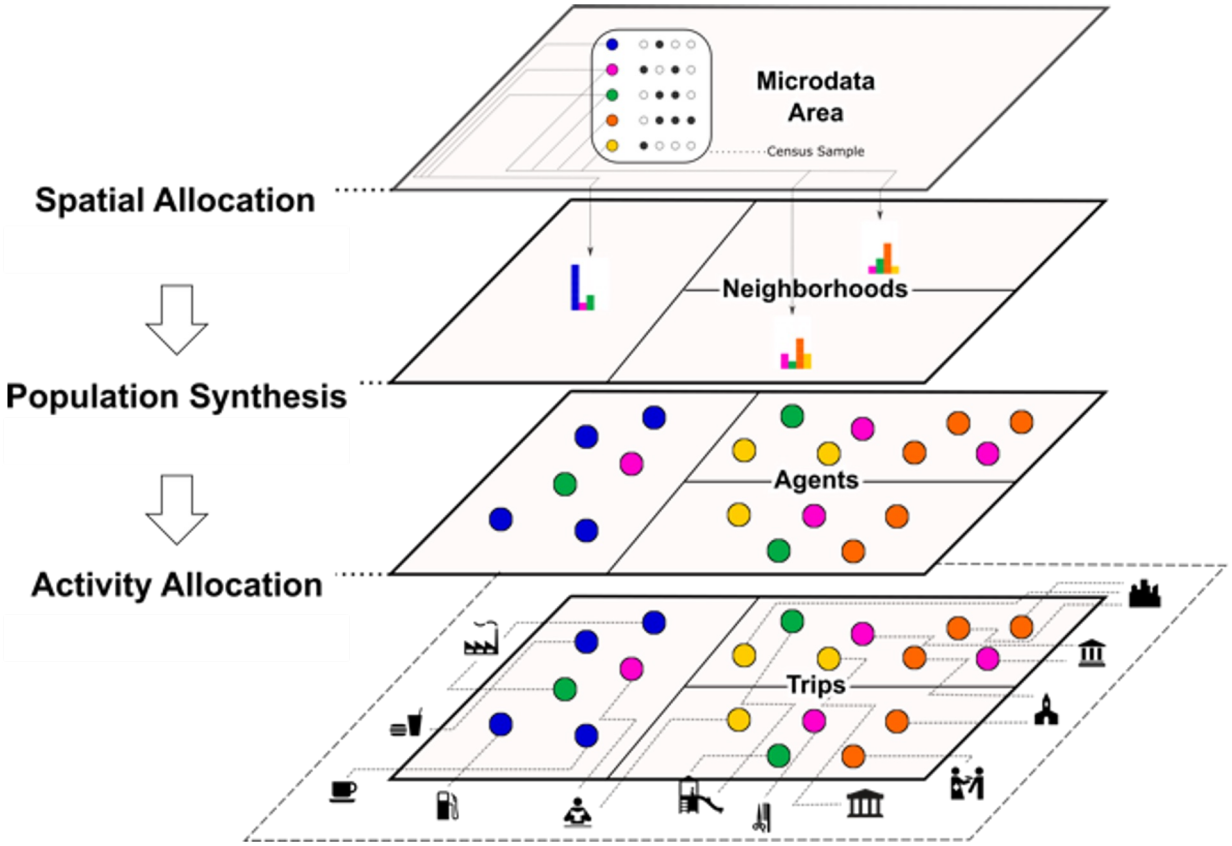
- Residential location + transportation networks affect access to points of care
- Network-based impedance affects access (modality, physical barriers, traffic/weather)



Synthetic populations, realistic virtual representations of people/households, allow us to address these challenges through large-scale “what if?” scenarios.

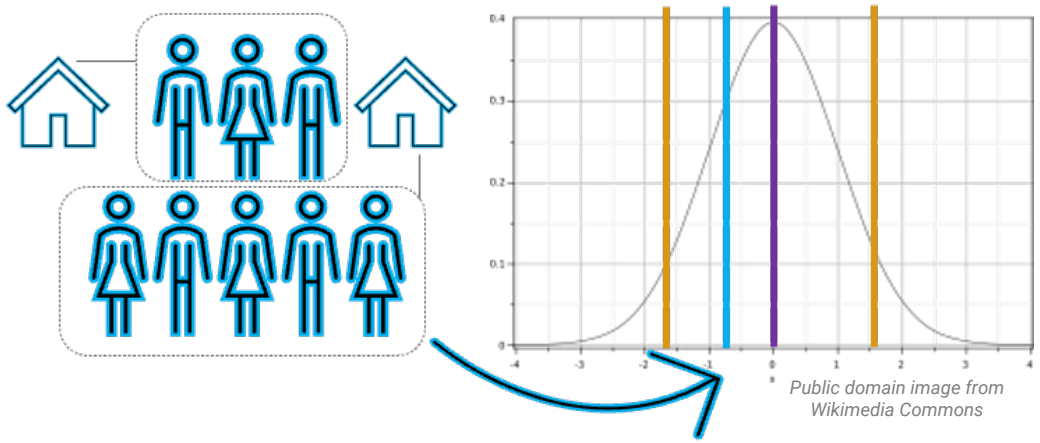
UrbanPop: High-Fidelity Synthetic Populations for the United States

- Powered by US Census Bureau's **American Community Survey (ACS)** and **Public Use Microdata Sample (PUMS)**
  - Hundreds of available socio-demographic, economic, housing, and mobility attributes
- **Population** characteristics realistically match ACS neighborhood profiles **anywhere in the United States**
- **Cross-sectional representations of individuals** at **high spatial resolution** for modeling access to **healthcare**, **nutrition**, and other **essential services**



Residential Synthetic Population Baseline

Population Synthesis



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Simulate virtual households/people from the ACS PUMS whose **aggregate characteristics** (e.g., sex/age, poverty, housing) fit **90% Margins of Error** on **neighborhood population statistics** from the ACS Summary File (SF).

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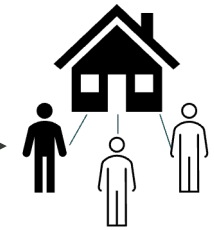
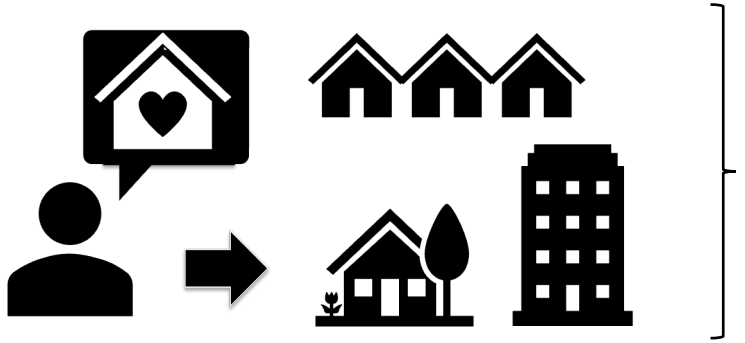
SERIAL	PERNUM	PERWT	Age	Sex	Race/Ethnicity	Poverty Status	Speaks English	Household Type
3859631	1	8	30-34	Male	Black or African-American alone	In Poverty	Yes	Nonfamily Household
3859646	**1**	**45**	**80-84**	**Female**	**White alone**	**In Poverty**	**No**	**Living Alone**
3859889	1	17	18-19	Female	White alone	Not In Poverty	Yes	Family Household
3859889	2	20	22-24	Male	White alone	Not In Poverty	Yes	Family Household
3859973	1	13	60-61	Female	White alone	In Poverty	Yes	Family Household
3859973	2	15	22-24	Female	White alone	In Poverty	No	Family Household

Questionnaire and Person Number | Sample Weight | Questionnaire Responses



Each synthetic household and its individual members can by attributed by PUMS characteristics via record linkage on household/person ID.

Residential Downscaling



FEMA USA Structures Dataset

Synthetic households “select” a residential location within their neighborhood via their linked dwelling type.

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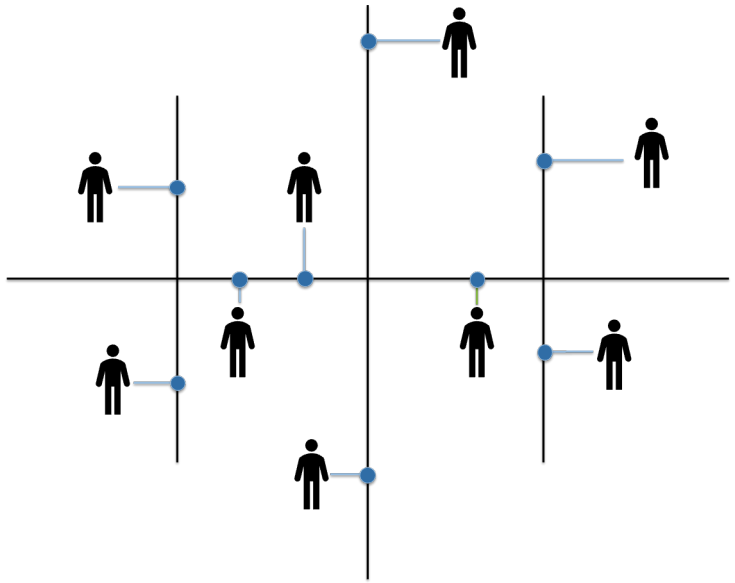
Adapted from: Tuccillo, J., & Gaboardi, J. (2024). Examining Food Access Disparities using Spatial Microsimulation. Population Association of America 2024 Annual Meeting (PAA), Columbus, Ohio. Zenodo. https://doi.org/10.5281/zenodo.11060895

Modeling Access to VA Points of Care

Synthetic Patient Selection

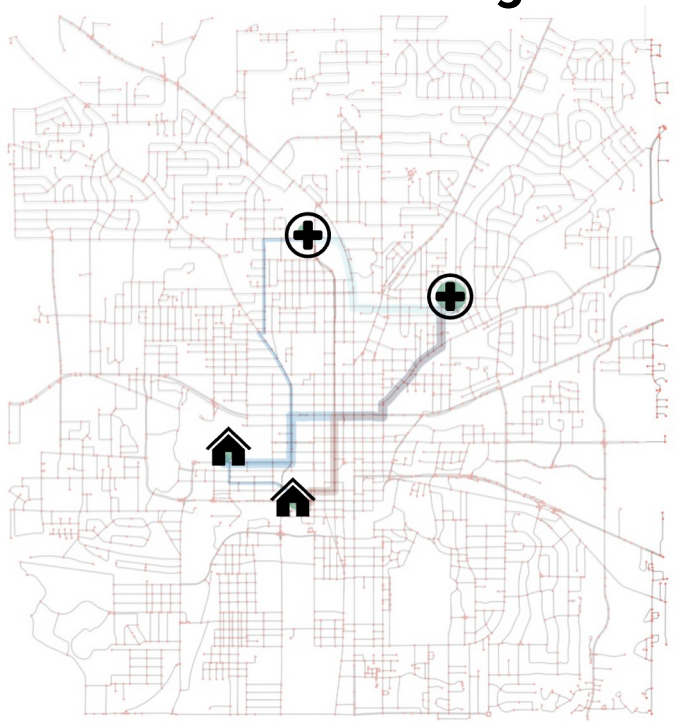
Select VHA patients via PUMS record linkage

Network Partitioning



Patients begin trips at nearest entry points to transportation network (vs. intersections).

Travel Routing



Evaluate network-based impedance between patient home locations and all available points of care

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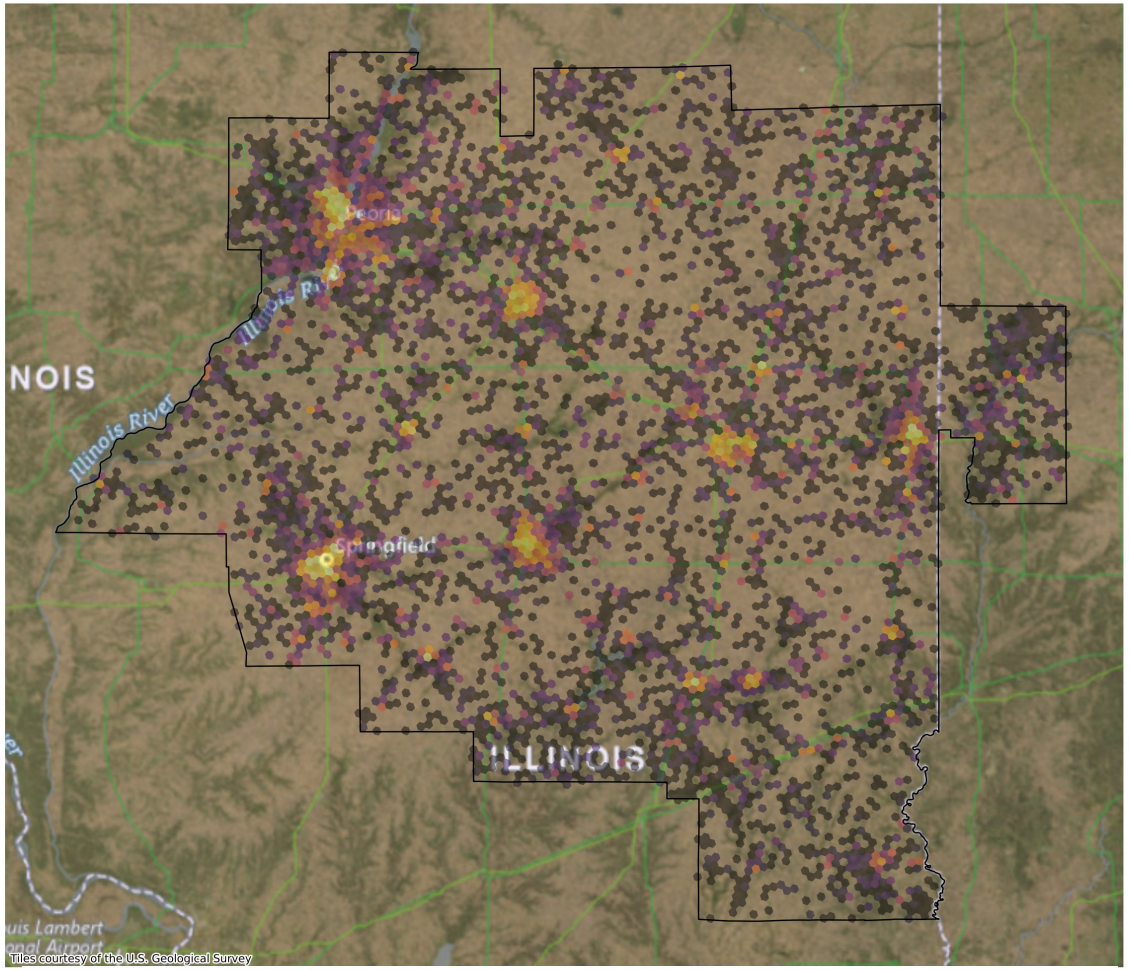
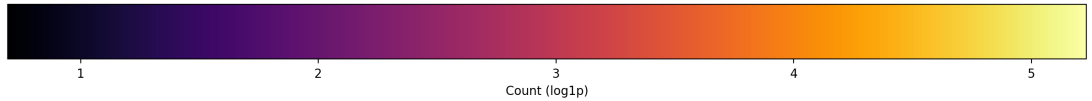
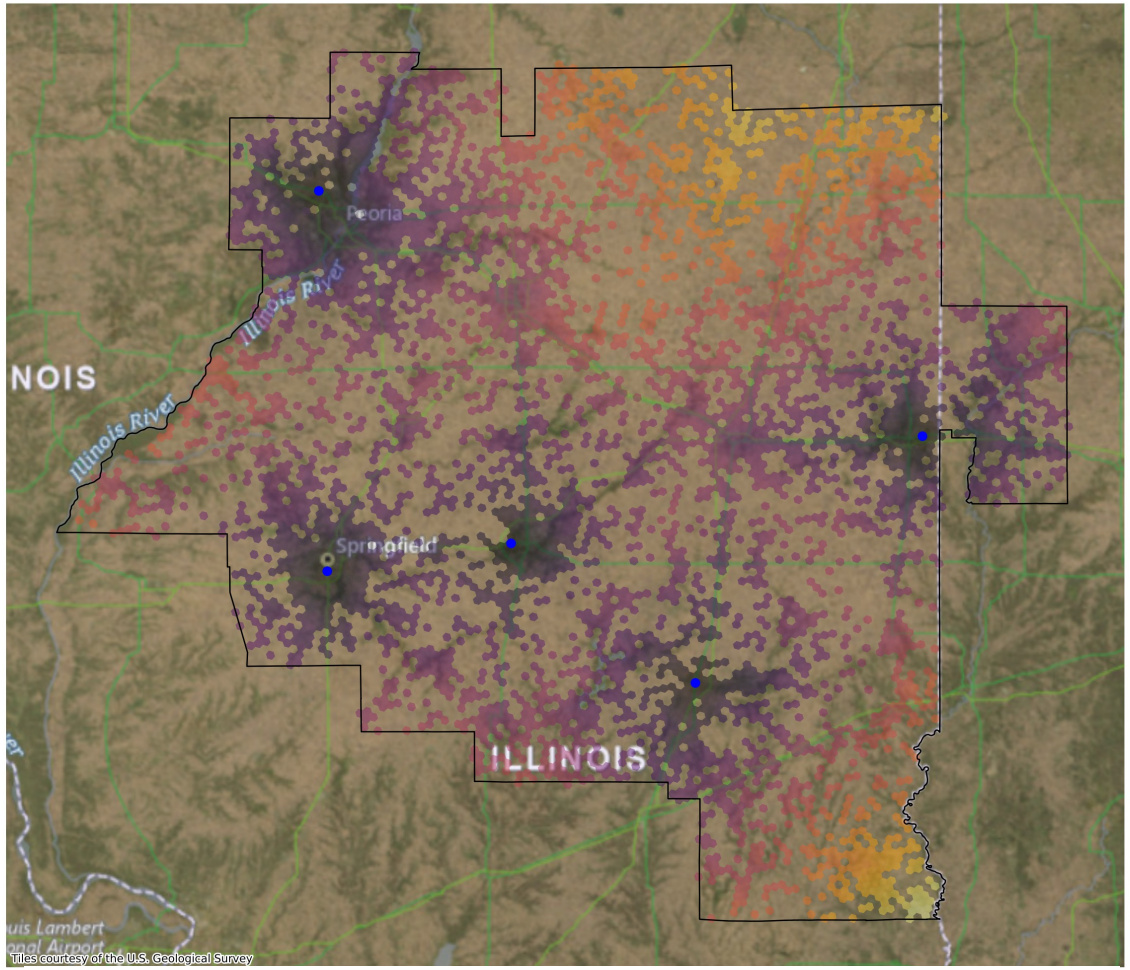
Synthetic Patient Mobility

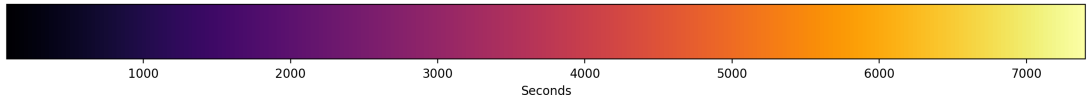
Synthetic VHA Patients





Mean Least Cost Travel Time to VA Outpatient Clinic





VISN 12-f: Central Illinois

Uber H3 Level 7 Grid

Initial Patient Mobility Analysis

Study Design

One 2019 VISN market per 9 US Census Divisions in Continental United States

- **Synthetic population** → ACS 2015-2019 5-Year Estimates
- **VHA patients** → VA outpatient clinic visits for 2019 via CDW

Area of Interest (AOI) definitions:

- Core market only
- Core market + edge counties

In total, *N* = 18 AOIs

Analysis

Measure time-based impedance between synthetic patient home location and VA outpatient clinic location on OpenStreetMap (OSM) drive network

- Outpatient clinic locations from VAST

Compare patient trip summary statistics across AOIs:

- Least-cost path (lowest travel time) to any clinic in AOI
- Mean travel time to all clinics in AOI

Validation

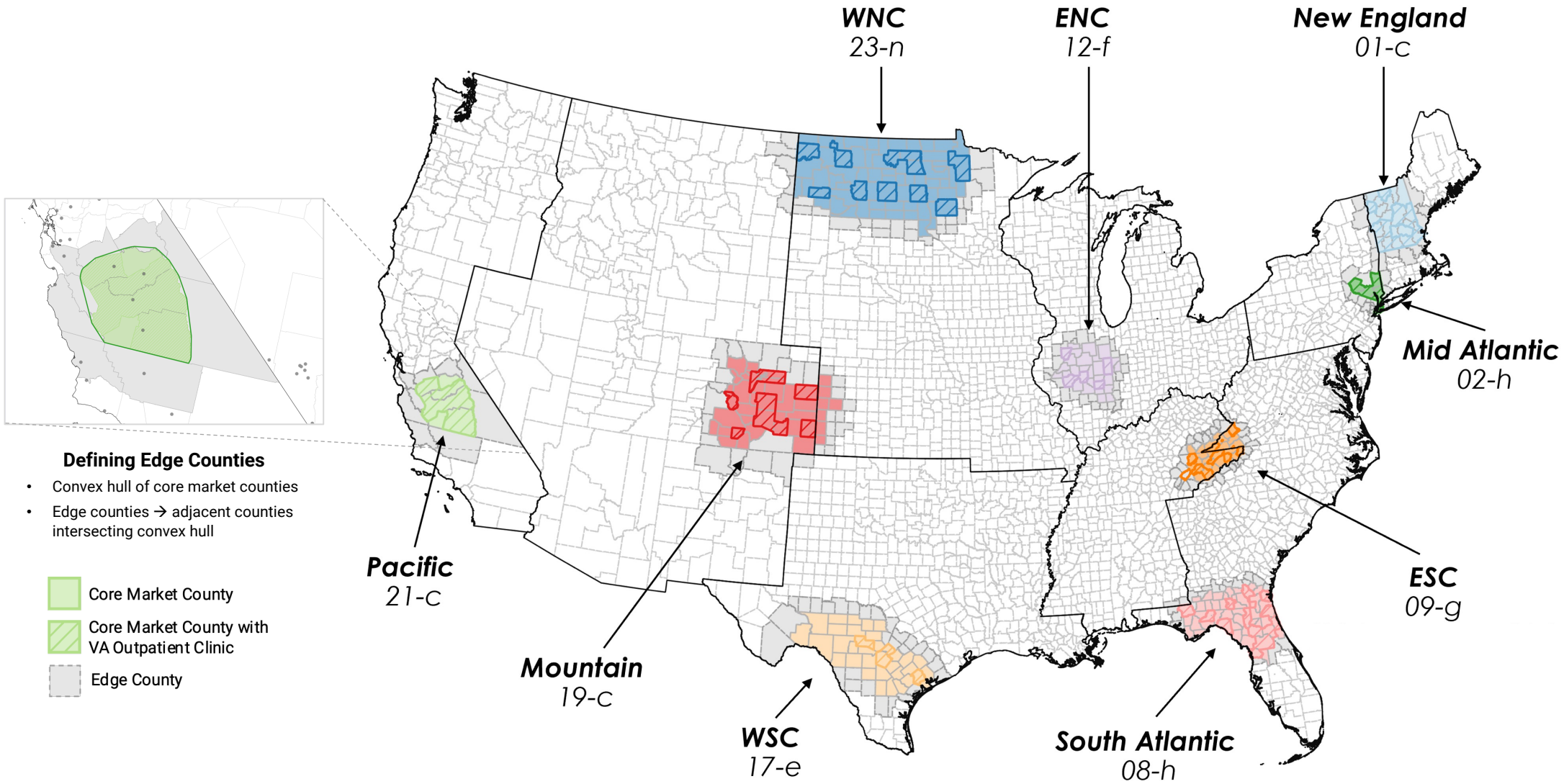
Neighborhood demographics → compare aggregate synthetic population characteristics to ACS Summary File 90% Margins of Error

- Demographic, social, economic, housing, and mobility characteristics + Veteran status

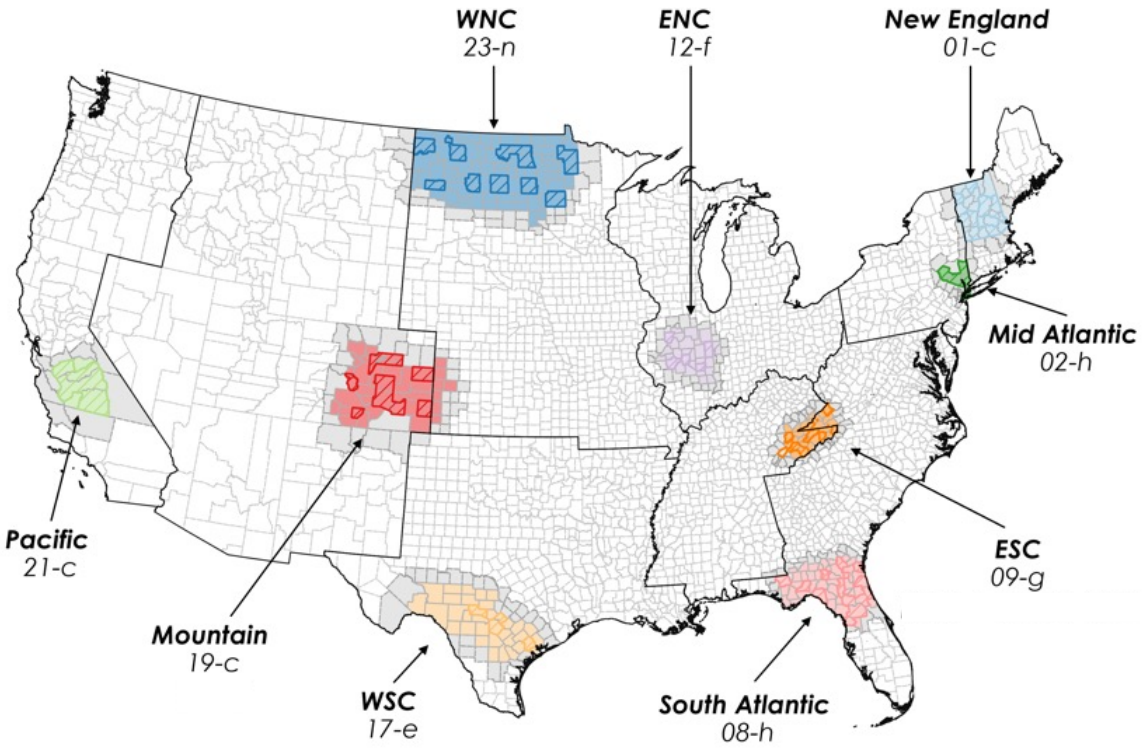
Mobility → compare synthetic vs. observed (VAST) origin-destination matrices

- Home ZIP → Outpatient clinic ZIP
- Exclude trips outside area of interest
- Canonical Correlation Analysis (CCA)

Selected VISN Markets by US Census Division



VA Outpatient Clinic Access by VISN Market

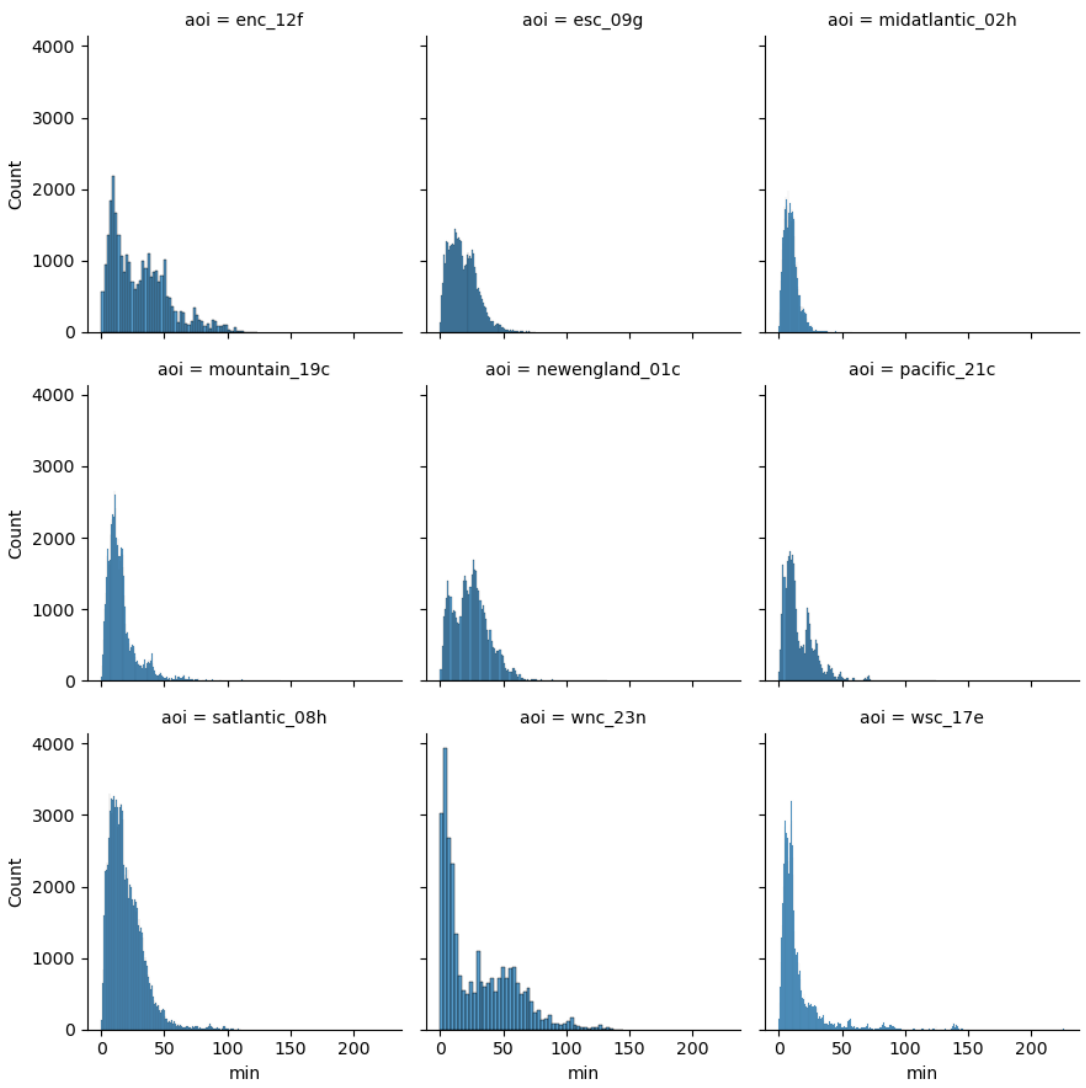


	Mean Least-Cost (Core Market)	Mean Least-Cost (Core Market + Edges)	Grand Mean (Core Market)	Grand Mean (Core Market + Edges)
Mid-Atlantic (02-h)	**9.6**	**9.1**	55.5	**59.1**
WSC (17-e)	15.7	15.5	**43.4**	70.9
Mountain (19-c)	16.0	15.6	95.7	119.7
Pacific (21-C)	16.1	17.6	53.0	112.3
ESC (09-g)	18.5	13.3	87.2	109.1
South Atlantic (08-h)	19.5	18.9	101.1	122.1
New England (01-c)	24.7	23.7	110.6	126.5
WNC (23-n)	29.8	**29.7**	**184.1**	**202.5**
ENC (12-f)	**30.8**	27.3	82.8	113.0

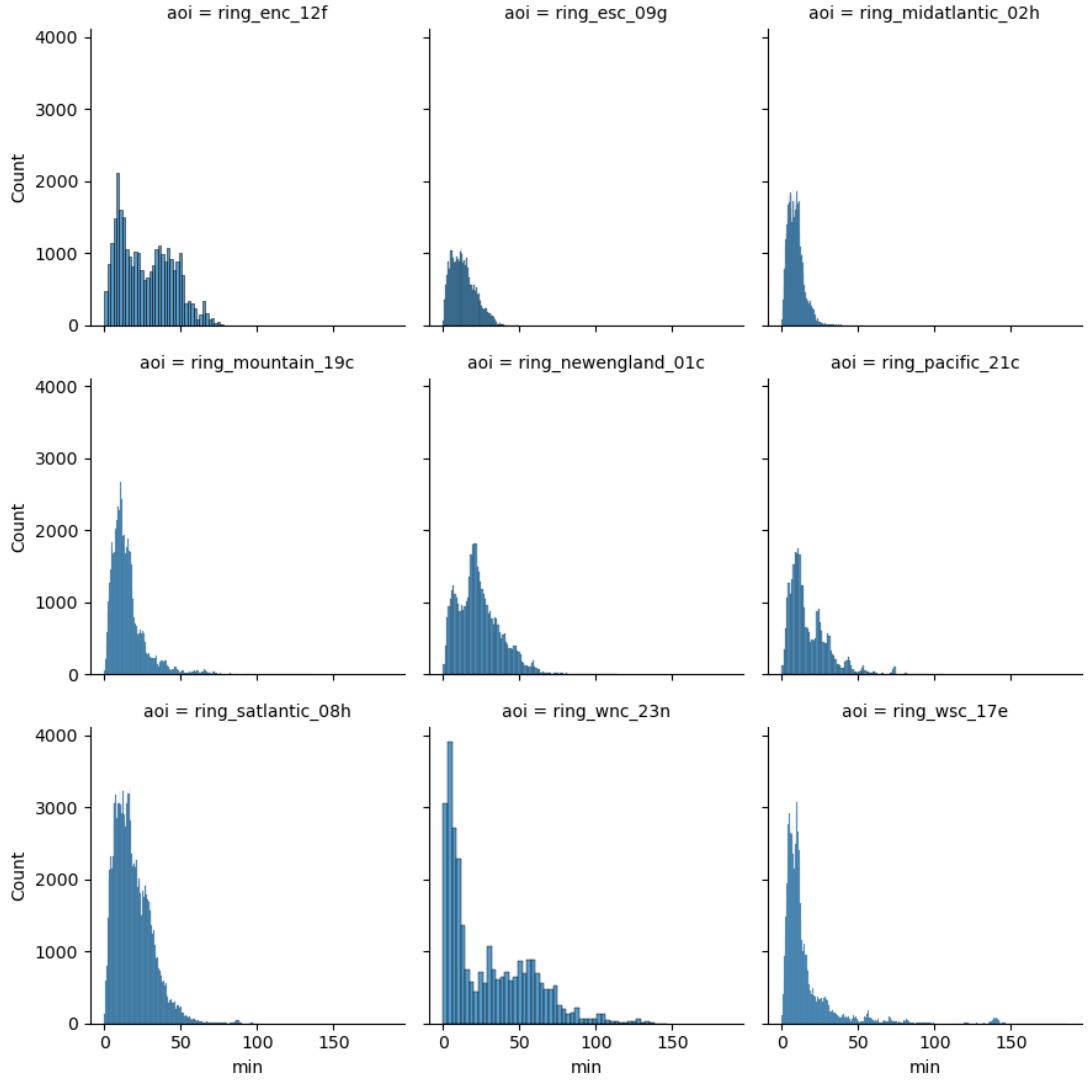
Mean travel time estimates, in minutes, for least-cost paths (selected VA outpatient clinic) and to all outpatient clinics in the area of interest ("grand mean").

VA Outpatient Clinic Access by VISN Market

Travel Time along Least-Cost Paths



Core Market Only



Core Market + Edge Counties

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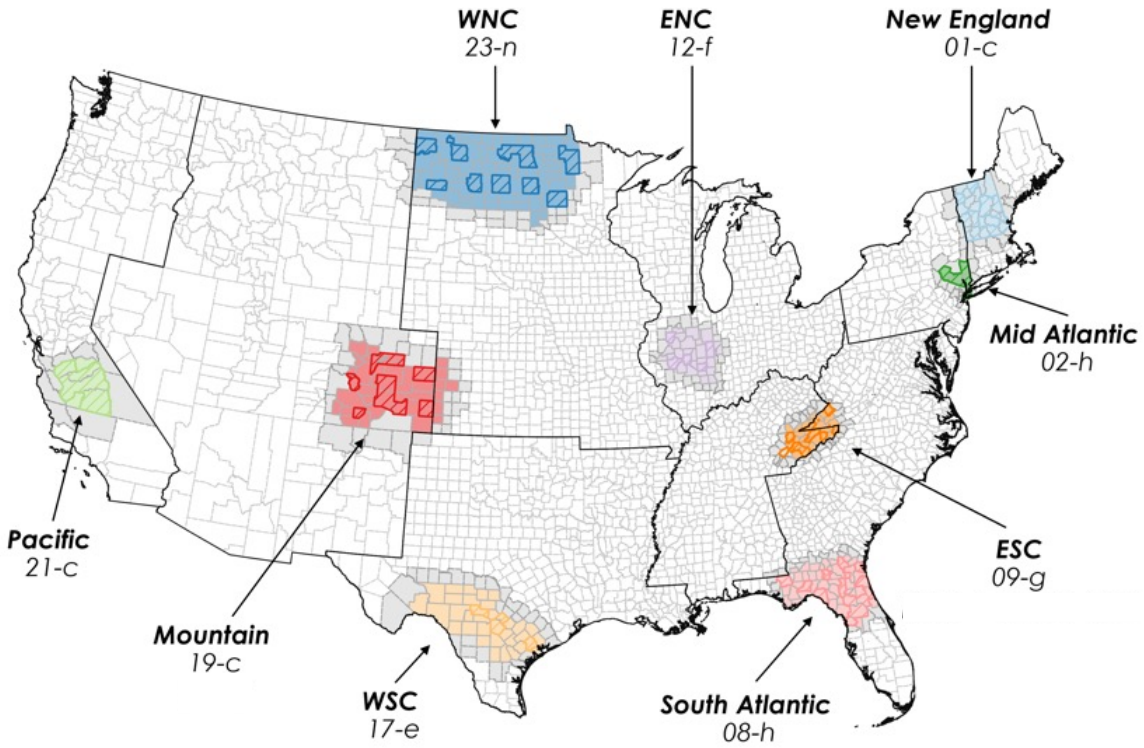
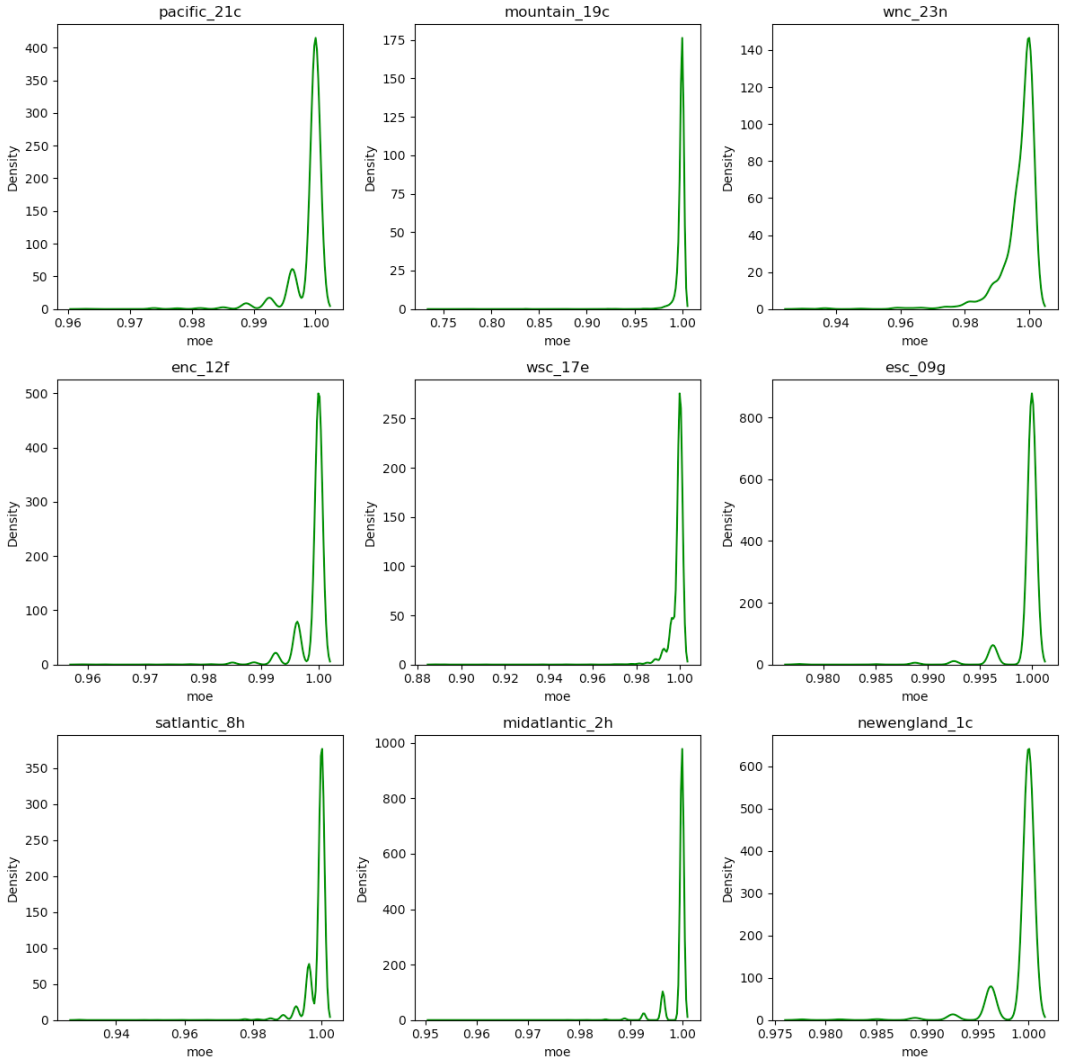
Validation: Neighborhood Demographics





Percentage of block group-level constraints conforming to ACS SF 90% Margins of Error

Validation: VHA Patient Mobility

- **Origin-Destination (O-D) matrices:** Home ZIP → Outpatient ZIP
  - **Observed patients** → CDW home address ZIP
  - **Synthetic patients** → georeference by ZCTA5, assign to outpatient clinic with lowest travel cost
- Compare O-D matrices with **Canonical Correlation Analysis (CCA)**
  - CCA R^2: relative strength of association between synthetic/observed in terms of visits to outpatient clinics

Strong Association

Home \ Clinic	A	B	C
1	10	12	6
2	30	8	1
3	13	9	20
4	5	25	16

Observed

Home \ Clinic	A	B	C
1	11	15	8
2	22	6	3
3	10	10	17
4	6	20	19

Synthetic

Weak Association

Home \ Clinic	A	B	C
1	10	12	6
2	30	8	1
3	13	9	20
4	5	25	16

Observed

Home \ Clinic	A	B	C
1	30	8	25
2	3	32	15
3	4	19	6
4	25	3	2

Synthetic

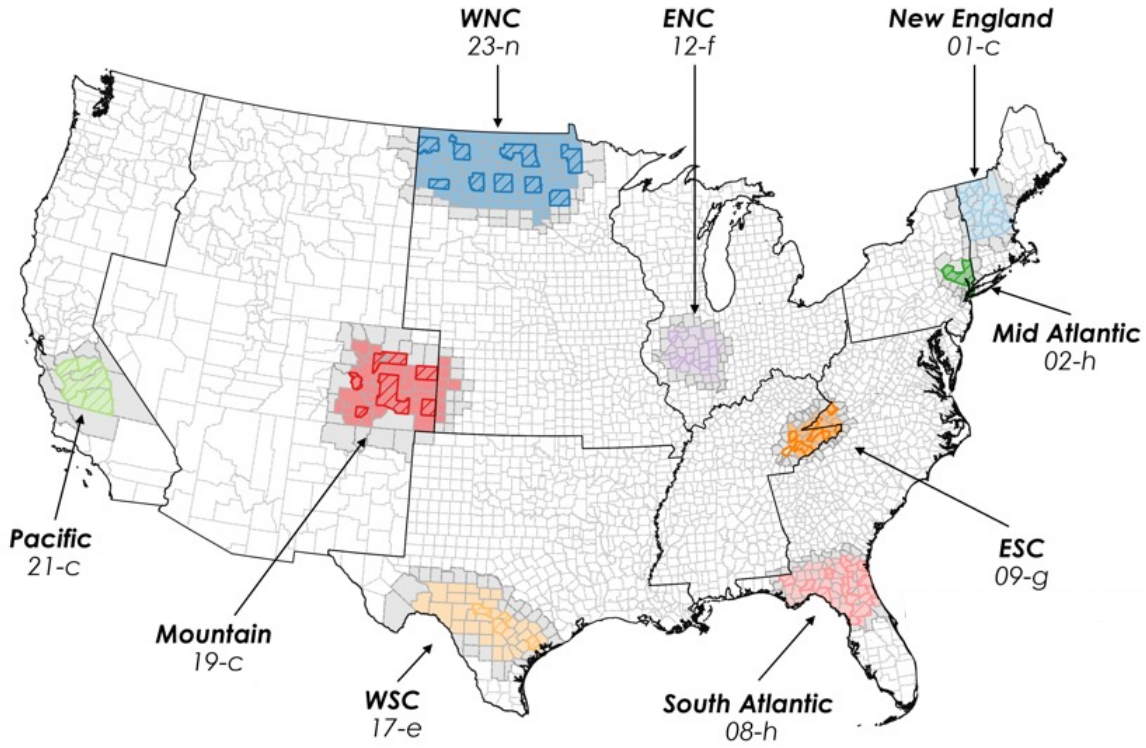
Validation: VHA Patient Mobility

Market-Only

Census Division	Origin ZIPs	Destination ZIPs	Observed Trips outside Market %	CCA Adj. R^2	p(Pillai)
Pacific	136	4	8.9	0.878	< 0.0001
Mountain	328	12	5.3	0.758	0
WNC	533	11	11.3	0.856	0
ENC	387	5	18.5	0.869	0
WSC	242	9	5.3	0.648	0
ESC	259	12	7.2	0.768	0
S Atlantic	330	16	10.3	0.745	0
Mid Atlantic	424	18	3.5	0.668	0
New England	496	13	9.9	0.793	0

Core Market + Edge Counties

Census Division	Origin ZIPs	Destination ZIPs	Observed Trips outside Market %	CCA Adj. R^2	p(Pillai)
Pacific	136	5	8.6	0.805	< 0.0001
Mountain	328	15	4.8	0.761	0
WNC	533	14	10.6	0.690	0
ENC	387	11	15.2	0.621	0
WSC	242	13	4.3	0.561	< 0.0001
ESC	259	12	7.2	0.766	0
S Atlantic	330	26	6.9	0.718	0
Mid Atlantic	424	24	3.5	0.583	0
New England	496	20	9.4	0.692	0



Change in CCA R^2:

Core-Edges vs. Market-Only

Census Division	$\Delta(R^2)$ (vs. Market-Only)
Pacific	-0.073
Mountain	0.004
WNC	-0.165
ENC	-0.247
WSC	-0.087
ESC	-0.002
S Atlantic	-0.028
Mid Atlantic	-0.085
New England	-0.101

Summary of Findings

VA Outpatient Clinic Access

VISN markets with **large urban centers → reduced travel time**

- **Mid Atlantic (02-h):** New York City metro
- **West South Central (17-e):** San Antonio metro

Mixed urban/rural VISN markets with **small-midsize urban centers → increased travel time**

- **West North Central (23-n):** North Dakota/Northeast Minnesota
- **East North Central (12-f):** Central Illinois

Neighborhood Demographics

Synthetic populations overall closely recreate block group-level ACS SF estimates

Some deficiencies for block groups with large group quarters/military populations

VHA Patient Mobility

Overall strong association between synthetic, observed patient flows

- …but a **weaker association** for VISN markets with **large urban centers** (Mid Atlantic/02-h; West South Central/17-e)

Market-Only AOIs tend to better represent observed patient mobility than Core-Edges AOIs

Outlook

In Progress

Modernizing synthetic populations to ACS 2019 – 2023 5-Year Estimates

Improving selection of synthetic VHA patients

- ➢ Constrain P-MEDM on health insurance coverage (PUMS: HINSx / ACS: B27010)

Adding indicator for telehealth access to complement physical access

- ➢ Constrain P-MEDM on internet access (PUMS: ACCESSINET / ACS: B28002)

Examining relationship between **low access to points of care** and **urbanicity**

- GHS-SMOD: very low-density rural → dense urban core

On the Horizon

Large-scale comparative analysis of VHA patient access across VISN markets in United States

- By urbanicity, median age, physical/telehealth access, etc.

Expanding travel modalities

- Walk/bike infrastructure, public transit

Synthetic population ensembles for uncertainty quantification

Thank you!

Questions?

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Try our tools on GitHub!
https://github.com/likeness-pop/livelike