

WHAT MAKES ACCESS RESILIENT? NEW PERSPECTIVES ON CRITICAL AND ESSENTIAL SERVICE ACCESS

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Edwardson School of Industrial Engineering

Framing the Problem: Disasters and Critical and Essential Service Access

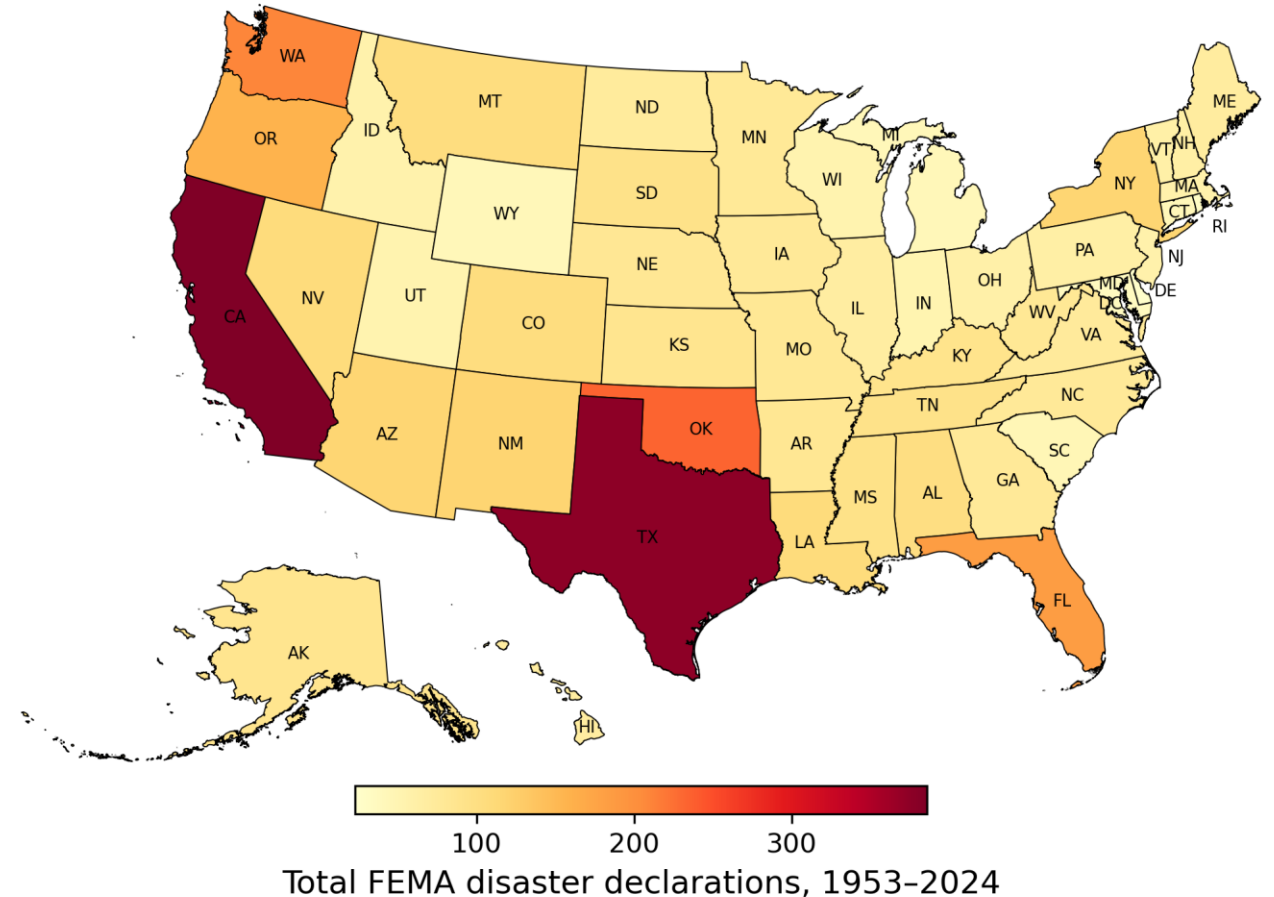
There have been 4844 federally declared disasters between 1956 and 2024.

(Federal Emergency Management Agency, 2026)

Critical and essential services (CES) are vital for community well-being and resilience in the face of natural hazards.

(Logan & Guikema, 2020; Tariverdi et al., 2023)

Equitable access to CES promotes several United Nations Sustainable Development Goals, mainly access to health and education, and the reduction of inequities. (United Nations, 2015)



Why consider critical and essential service access for resiliency?

Workshops with four communities in Louisiana:

- To elicit local and traditional knowledge about how extreme weather events and non-structural mitigation actions affect residents' lives and influence household decisions.

What did we find?

Worsening access to critical and essential services after repeated disasters and population decline is one of the major concerns for residents.



Photo: The Water Institute

Motivation

Residents with fewer resources and lower adaptive capacity often face poorer access to essential services.

(Hong et al., 2021; Larson et al., 2009; Wei & Mukherjee, 2023; Weiss et al., 2020)

Underserved populations tend to bear the greatest burdens during and after disasters.

(Coleman et al., 2024; Cutter & Finch, 2008; Drake et al., 2023; Esmalian et al., 2022; Flanagan et al., 2011; Hong et al., 2021; Shao et al., 2020; Tate et al., 2021)

Communities already experiencing population decline before feel more inclined to leave after a disaster.

(Cross, 2014)

The loss of even a single essential service may serve as a tipping point, compelling residents to relocate permanently. (Contreras et al., 2017; Bittle, 2023)

What about Arkansas?

Arkansas seeks funding as rural hospitals cut services, face financial strain



George "Clay" Mitchell

Fort Smith Southwest Times Record

Nov. 11, 2025, 4:07 a.m. CT

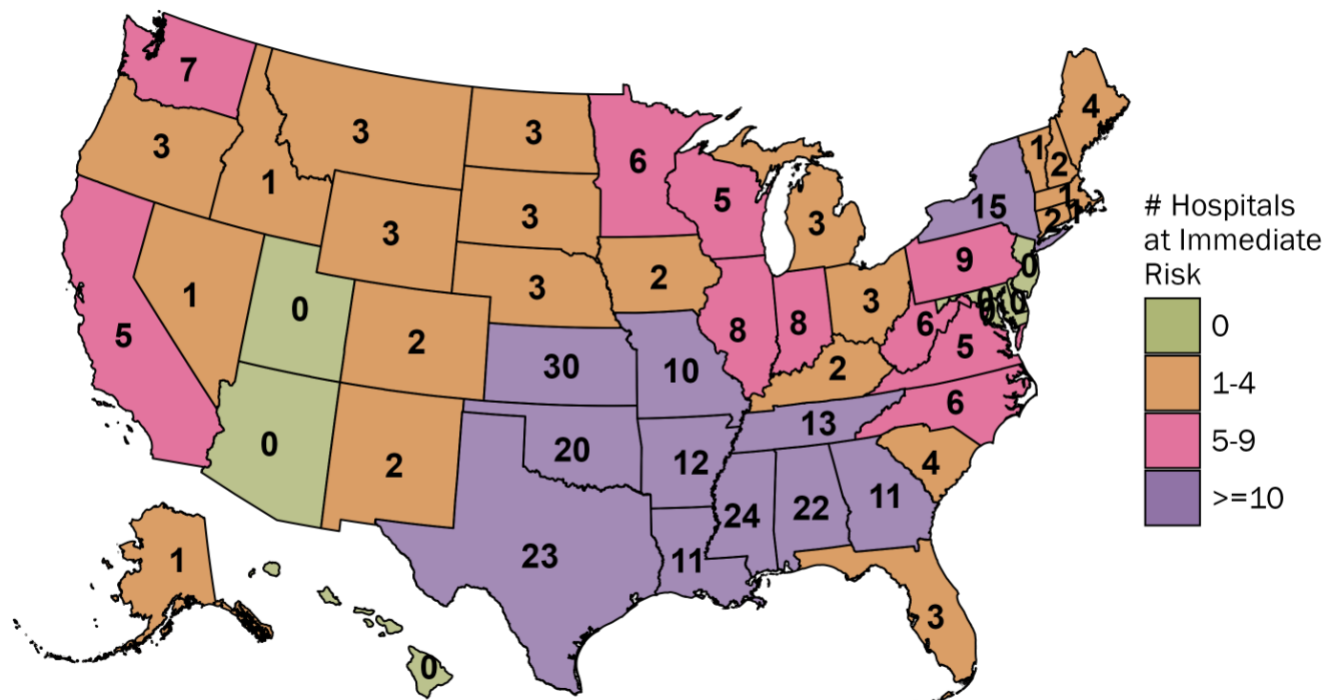
Report: 11 Rural Hospitals at 'Immediate Risk of Closure' in Arkansas

Red River Radio | By [Jeff Ferrell](#), [Nathan Treece](#)

Published July 15, 2025 at 11:05 AM CDT



Rural Hospitals at Immediate Risk of Closing



Source: [Center for Health Care Quality and Payment Reform \(CHQPR\)](#)

AMERICAN AMBULANCE ASSOCIATION

Arkansas EMS In Crisis!

Rising Wages		Fuel	Medical Supplies
13%↑	22%↑	35%↑	12%↑
EMT	Paramedic		

Source: [American Ambulance Association](#)

NORTHWEST ARKANSAS NEWS

Lincoln Fire Department faces crisis after sudden budget cuts

by: [Phoebe Cramer](#), [Jordan Moeller](#)
Posted: Apr 9, 2026 / 09:46 AM CDT
Updated: Apr 9, 2026 / 06:17 PM CDT

Source: [KNWA FOX24](#)

What does fragile access to critical and essential services mean?

Fragile Access to Critical and Essential Services



Traditional Accessibility

Can people reach a service?

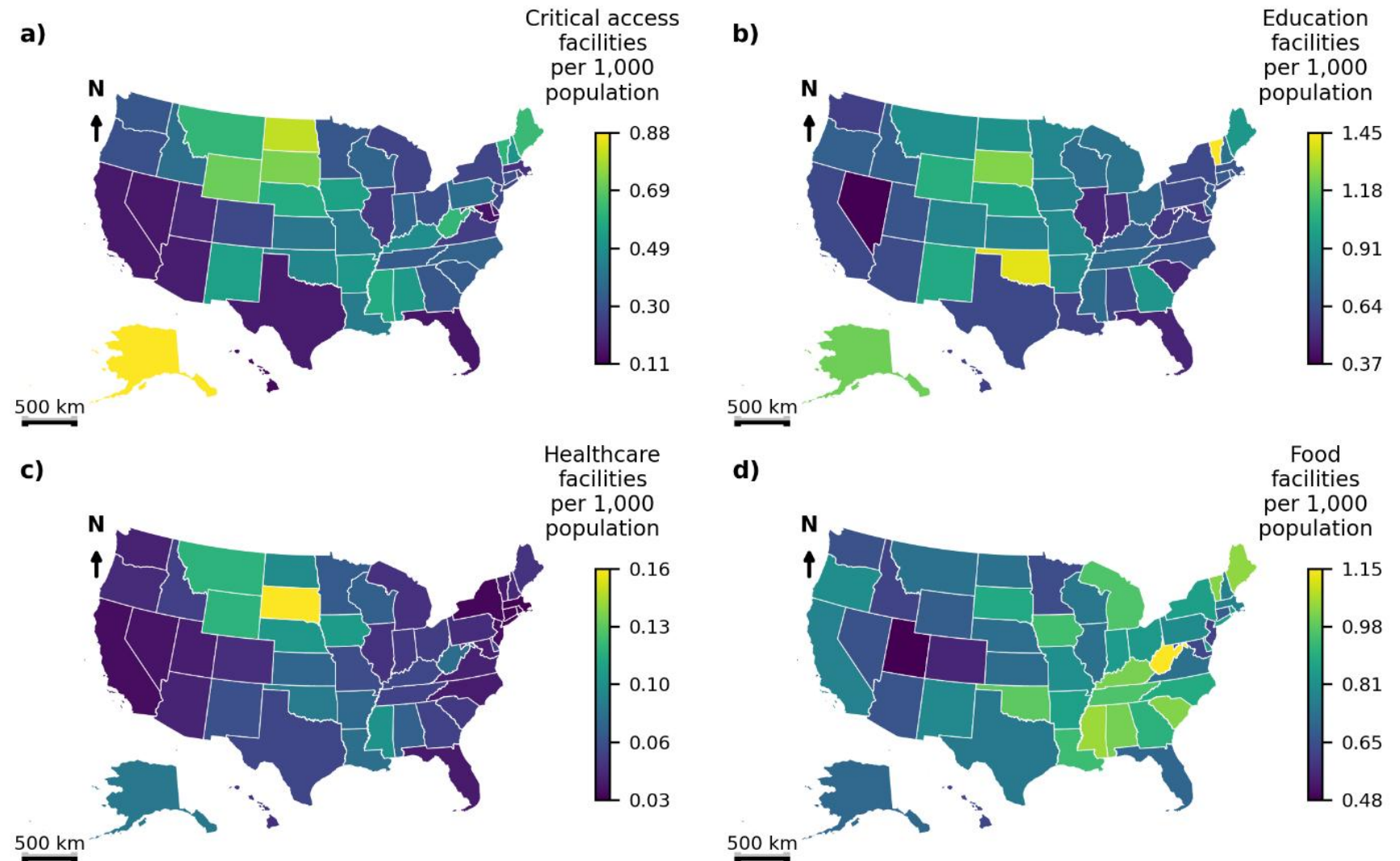


Access Fragility

How convenient are alternatives if a household's best option is shut down?

The distribution of CES facilities is heterogeneous

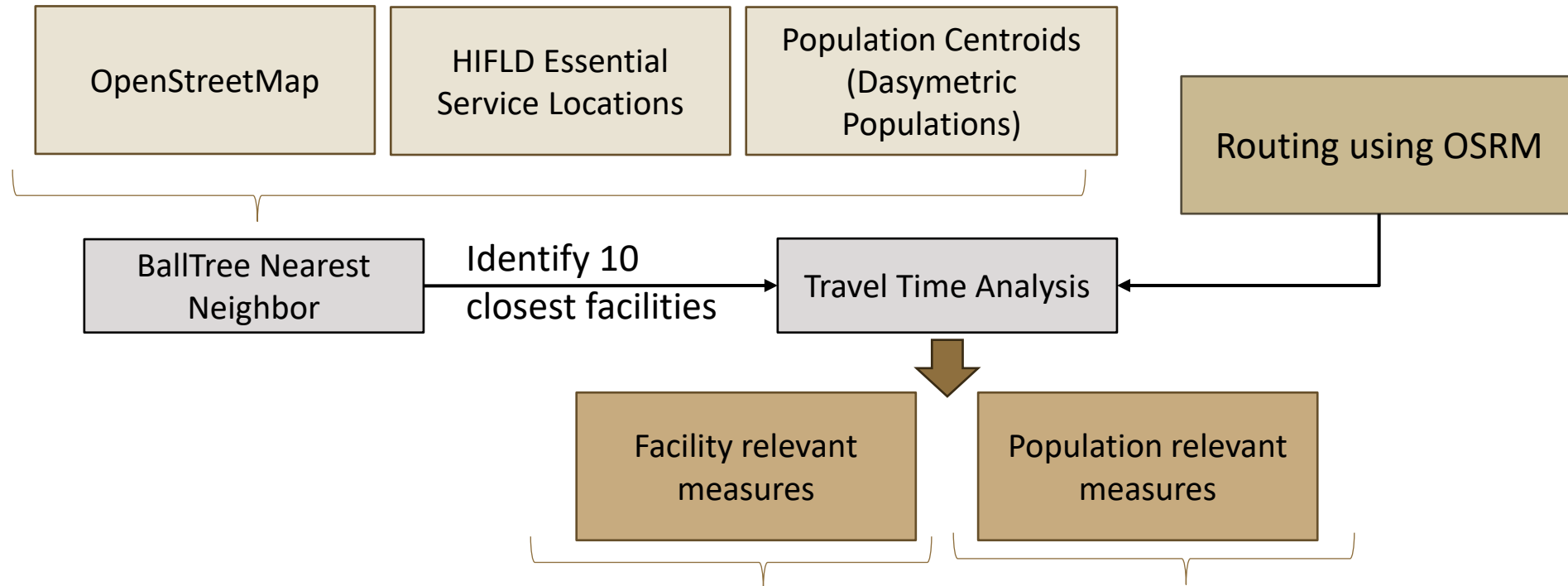
1. Emergency Medical Services (EMS)
2. Fire Stations
3. Daycares
4. Public Primary Schools
5. Public High Schools
6. Dialysis Centers
7. Hospitals, Rural Health Clinics
8. Trauma Hospitals
9. Grocery Stores



Research Questions

1. How can measures of accessibility to critical and essential services be modified to capture access fragility in communities?
2. How does access fragility vary across geographic contexts in the United States?
3. How do decision-maker priorities shape what is considered critical, and how can robust solutions be identified under preference heterogeneity?

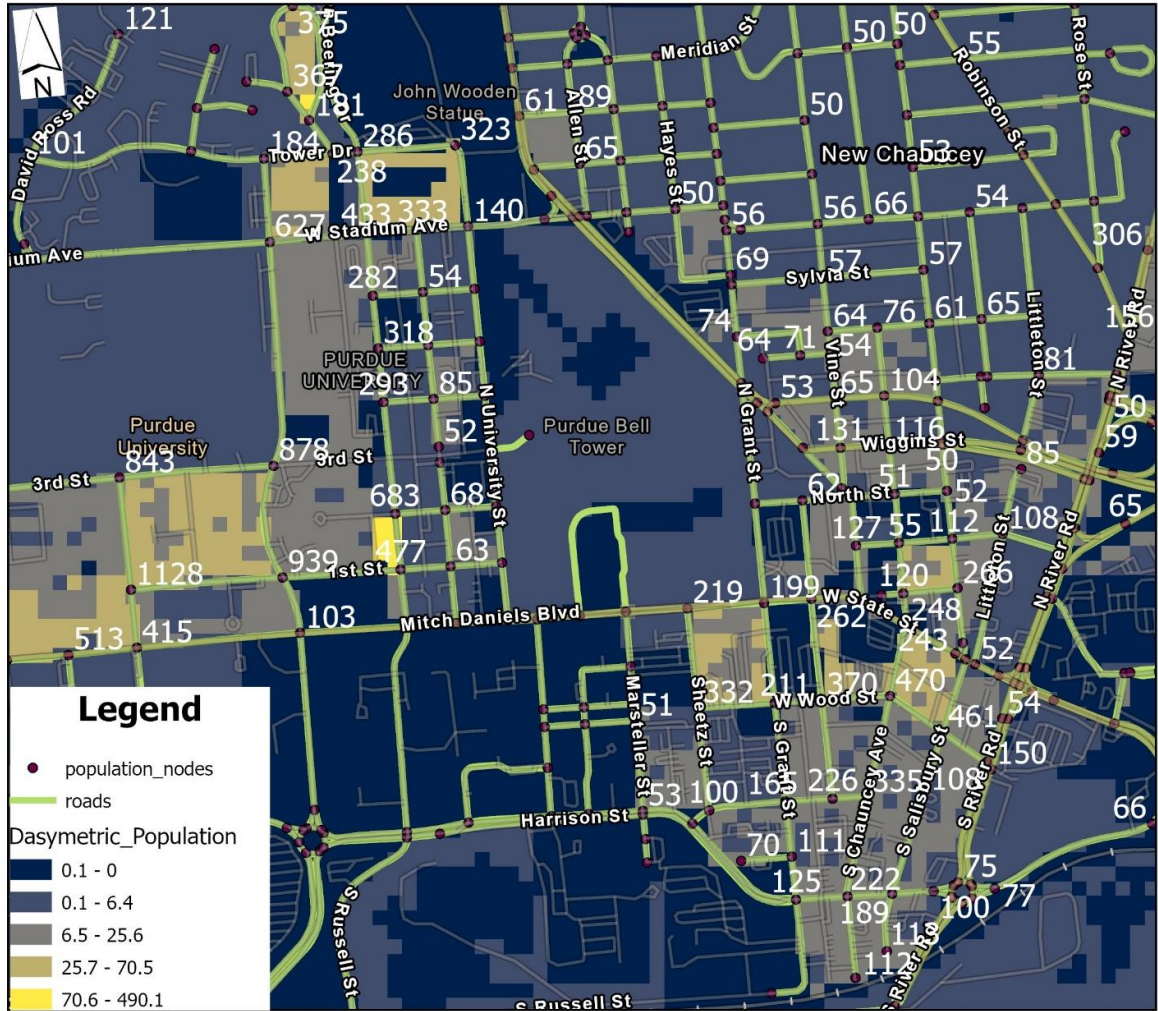
How can measures of accessibility to critical and essential services be modified to capture access fragility in communities?



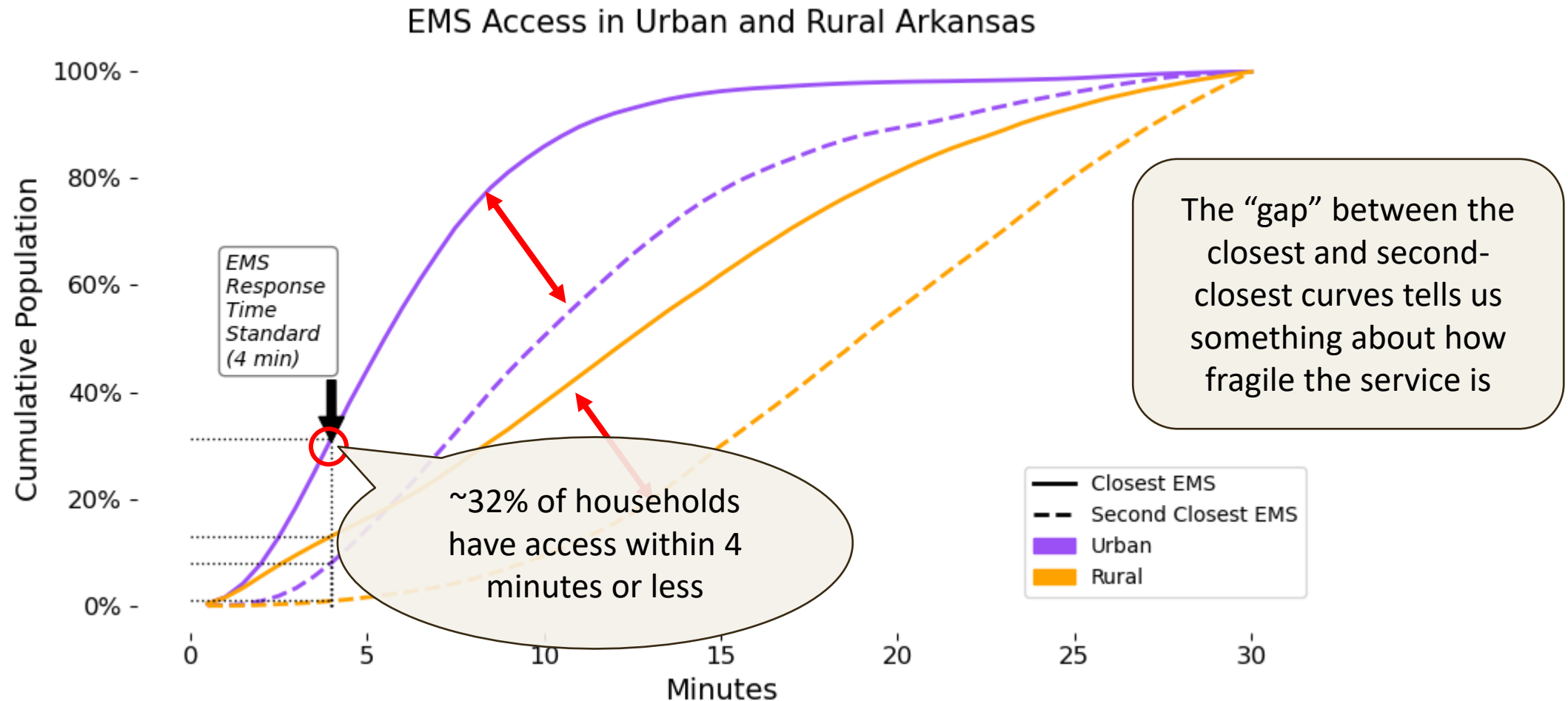
- Total population served as primary provider
- Primary population percentage with no other alternative under the critical time threshold
- Weighted average of marginal travel time for the primary population with no other alternative under the critical time threshold

- Travel time to the closest facility
- The marginal difference between the first- and second-closest travel times
- The number of facilities accessible within the critical time threshold

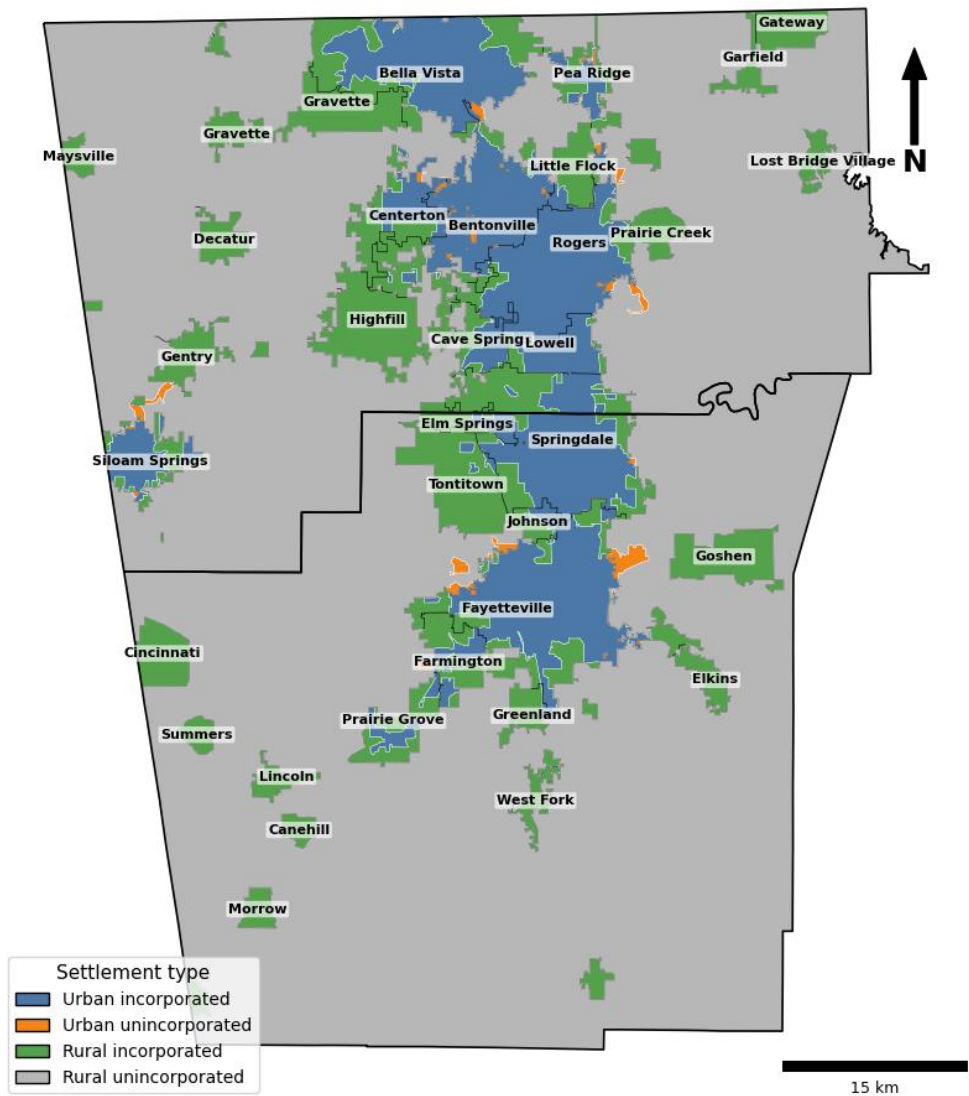
Coarse centroids obscure fine-scale accessibility differences



Urban and Rural Arkansas Have Stark Differences in Access



Spatial analysis framework, population density-relevant comparisons



Census Region	Urban Incorporated Population (Percentage)	Urban Unincorporated Population (Percentage)	Rural Incorporated Population (Percentage)	Rural Unincorporated Population (Percentage)
Northeast	28,963,004 (50.31%)	19,318,756 (33.56%)	939,881 (1.63%)	8,346,268 (14.50%)
Midwest	44,072,900 (63.91%)	7,020,657 (10.18%)	5,495,060 (7.97%)	12,373,507 (17.94%)
South	63,593,730 (50.45%)	31,528,364 (25.01%)	6,174,642 (4.90%)	24,759,203 (19.64%)
West	58,372,528 (74.30%)	11,200,108 (14.26%)	1,836,437 (2.34%)	7,150,190 (9.10%)

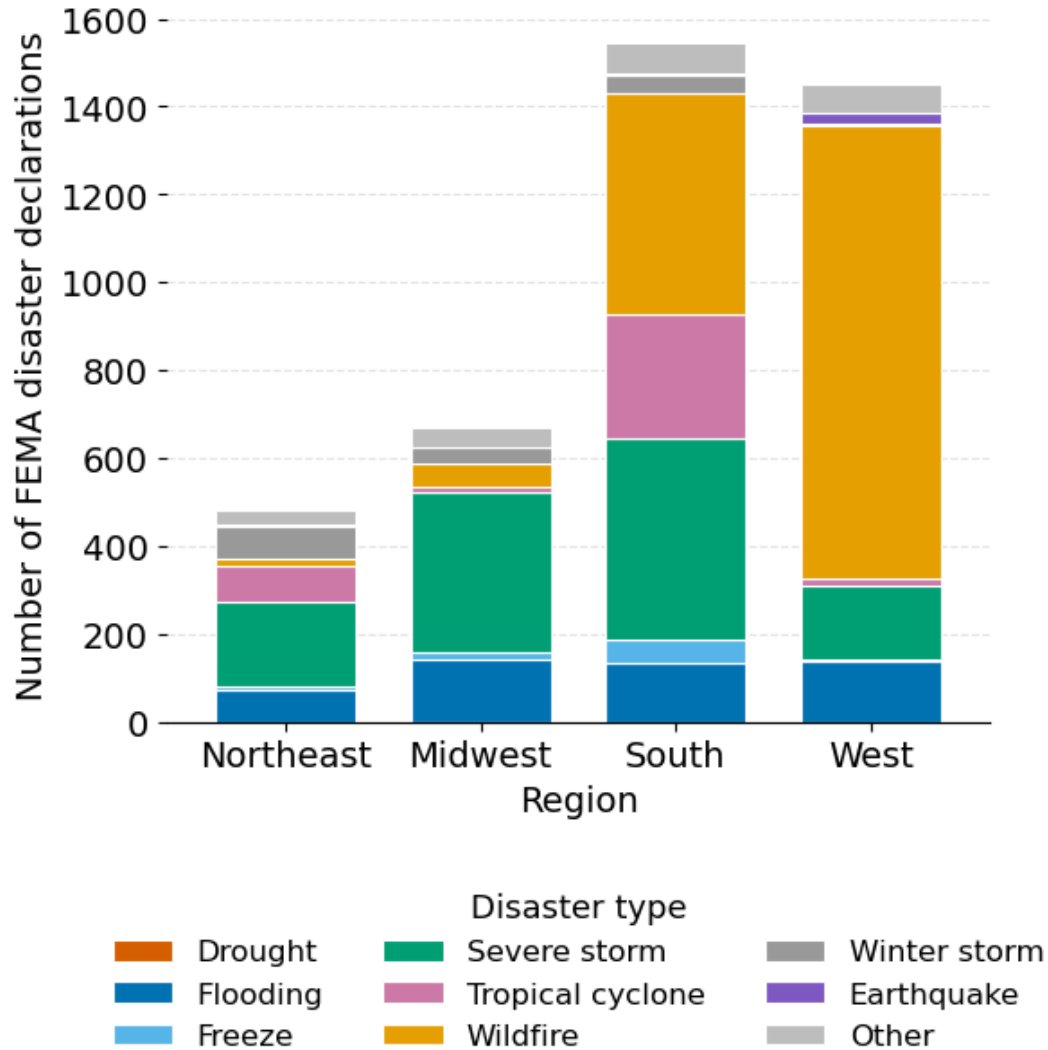
Overall State Rankings Averaged Across 3 Metrics and 8 Facilities, by Region Category – Top 10 by overall average

State	All Regions (Population)	Urban Incorporated (Population)	Urban Unincorporated (Population)	Rural Incorporated (Population)	Rural Unincorporated (Population)	Ranking of Average Across 4 Buckets (Population)
District_of_Columbia	1 (686,491)	1 (686,491)	NA (NA)	NA (NA)	NA (NA)	1 (686,491)
Rhode_Island	3 (1,094,958)	2 (567,846)	3 (432,476)	1 (1,032)	4 (93,604)	2 (1,094,958)
New_Jersey	4 (9,286,627)	6 (4,381,343)	1 (4,324,170)	5 (65,465)	1 (515,649)	3 (9,286,627)
New_York	5 (20,193,643)	3 (12,699,451)	4 (4,987,050)	8 (319,908)	8 (2,187,234)	4 (20,193,643)
Connecticut	7 (3,602,444)	4 (1,391,859)	8 (1,707,796)	2 (16,632)	3 (486,158)	5 (3,602,444)
Pennsylvania	17 (12,999,226)	8 (5,312,550)	6 (4,643,732)	11 (371,706)	7 (2,671,238)	6 (12,999,226)
California	2 (39,525,551)	7 (32,681,515)	5 (4,471,640)	15 (348,727)	18 (2,023,669)	7 (39,525,551)
Massachusetts	6 (7,021,262)	5 (3,755,913)	17 (2,660,770)	3 (52,909)	4 (551,671)	8 (7,021,262)
Maryland	11 (6,169,667)	12 (1,502,641)	8 (3,776,247)	25 (66,159)	11 (824,621)	9 (6,169,667)
Michigan	20 (10,075,252)	9 (4,774,424)	12 (2,662,008)	9 (339,399)	9 (2,299,422)	10 (10,075,252)

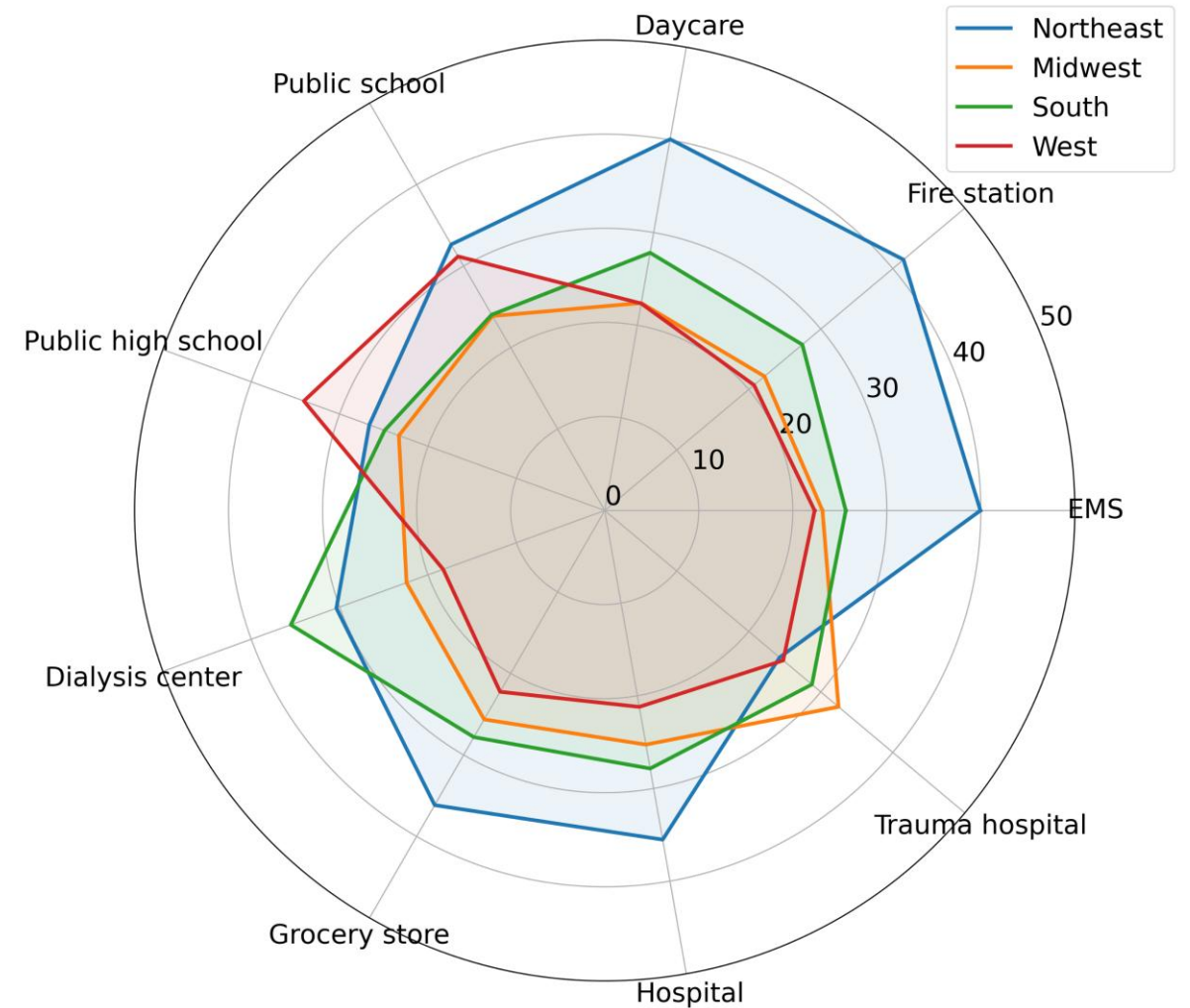
Overall State Rankings Averaged Across 3 Metrics and 8 Facilities, by Region Category – Bottom 10 by overall average

State	All Regions (Population)	Urban Incorporated (Population)	Urban Unincorporated (Population)	Rural Incorporated (Population)	Rural Unincorporated (Population)	Ranking of Average Across 4 Buckets (Population)
Iowa	35 (3,189,722)	43 (1,961,246)	28 (44,147)	33 (603,337)	27 (580,992)	42 (3,189,722)
Alaska	43 (728,944)	32 (385,518)	46 (86,561)	48 (108,558)	45 (148,307)	43 (728,944)
South_Dakota	47 (886,319)	38 (477,687)	32 (24,846)	32 (155,214)	47 (228,572)	44 (886,319)
New_Mexico	38 (2,116,572)	39 (1,343,887)	42 (224,721)	42 (86,509)	41 (461,455)	45 (2,116,572)
Arkansas	42 (3,010,129)	45 (1,573,765)	48 (87,685)	35 (436,562)	37 (912,118)	46 (3,010,129)
Wyoming	46 (576,327)	42 (328,082)	26 (26,410)	46 (70,240)	48 (151,595)	47 (576,327)
Vermont	51 (642,194)	47 (124,170)	48 (103,343)	38 (30,021)	43 (384,660)	48 (642,194)
Kansas	40 (2,936,097)	49 (2,038,887)	50 (73,026)	43 (400,373)	40 (423,811)	49 (2,936,097)
North_Dakota	48 (779,149)	46 (465,491)	47 (7,866)	49 (136,618)	50 (169,174)	50 (779,149)
Montana	50 (1,083,961)	50 (483,418)	45 (94,435)	45 (104,911)	49 (401,198)	51 (1,083,961)

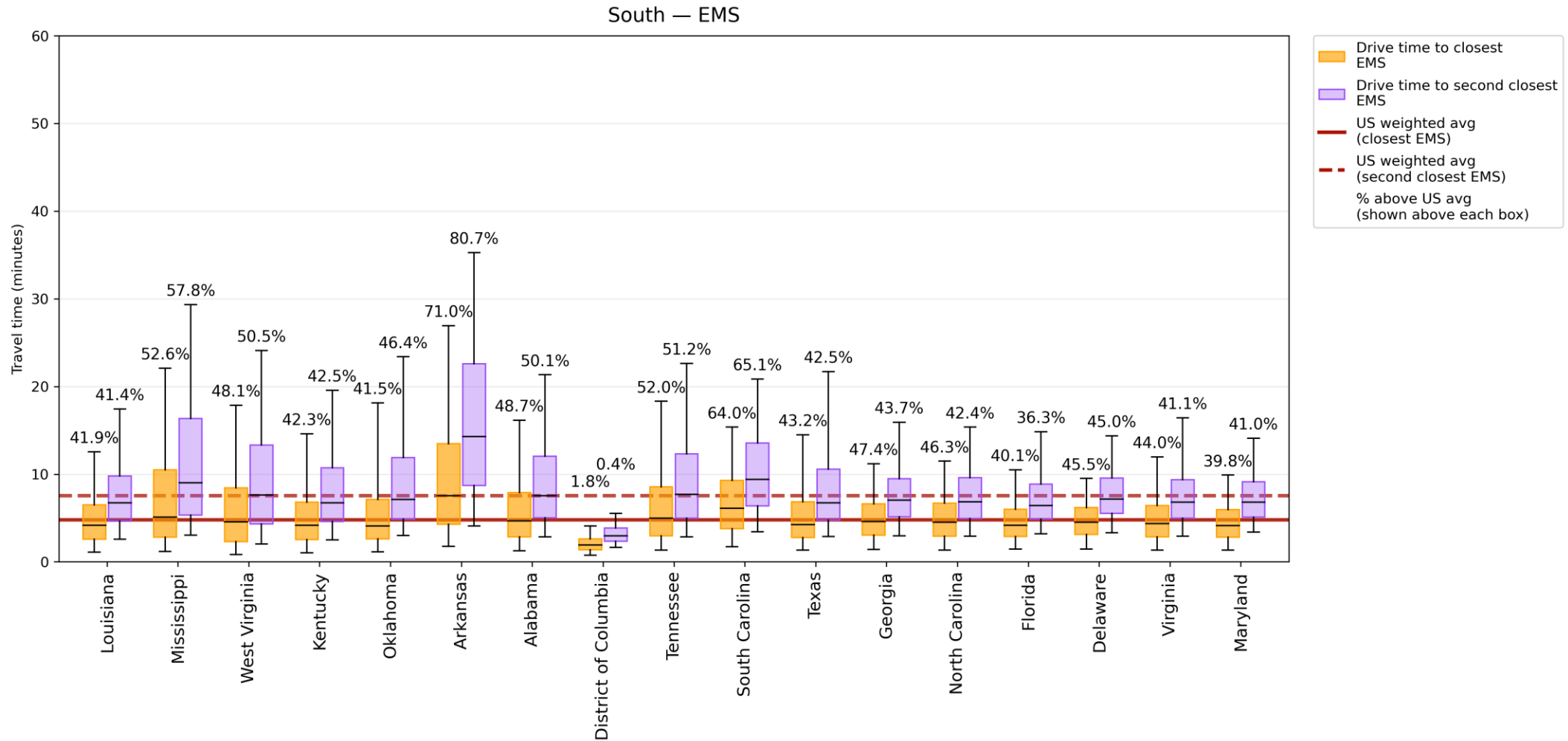
FEMA Disaster Declarations by Region and Disaster Type, 1953-2024



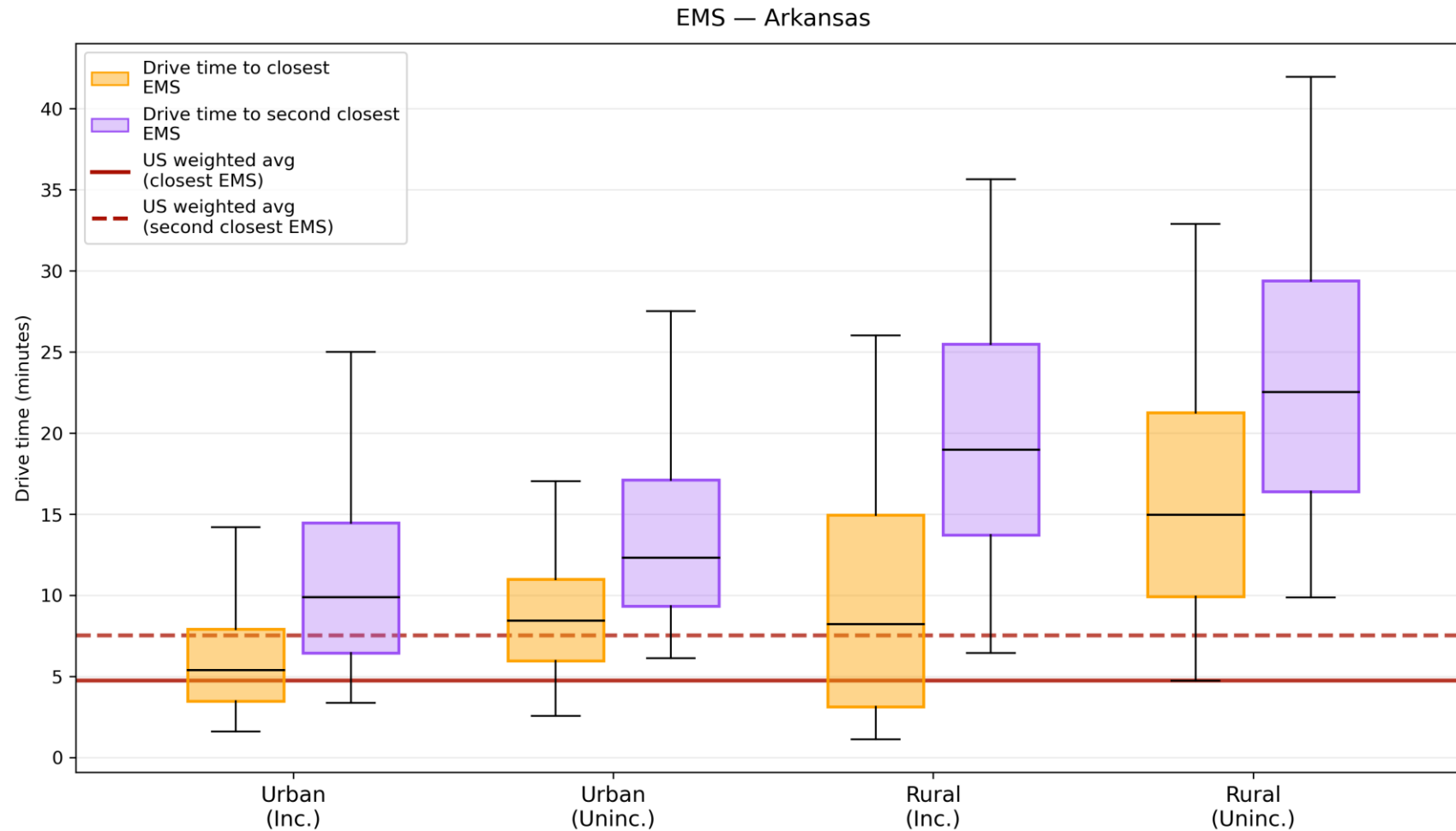
Average service-specific ranking by Census region. Higher values indicate better and more robust essential service access



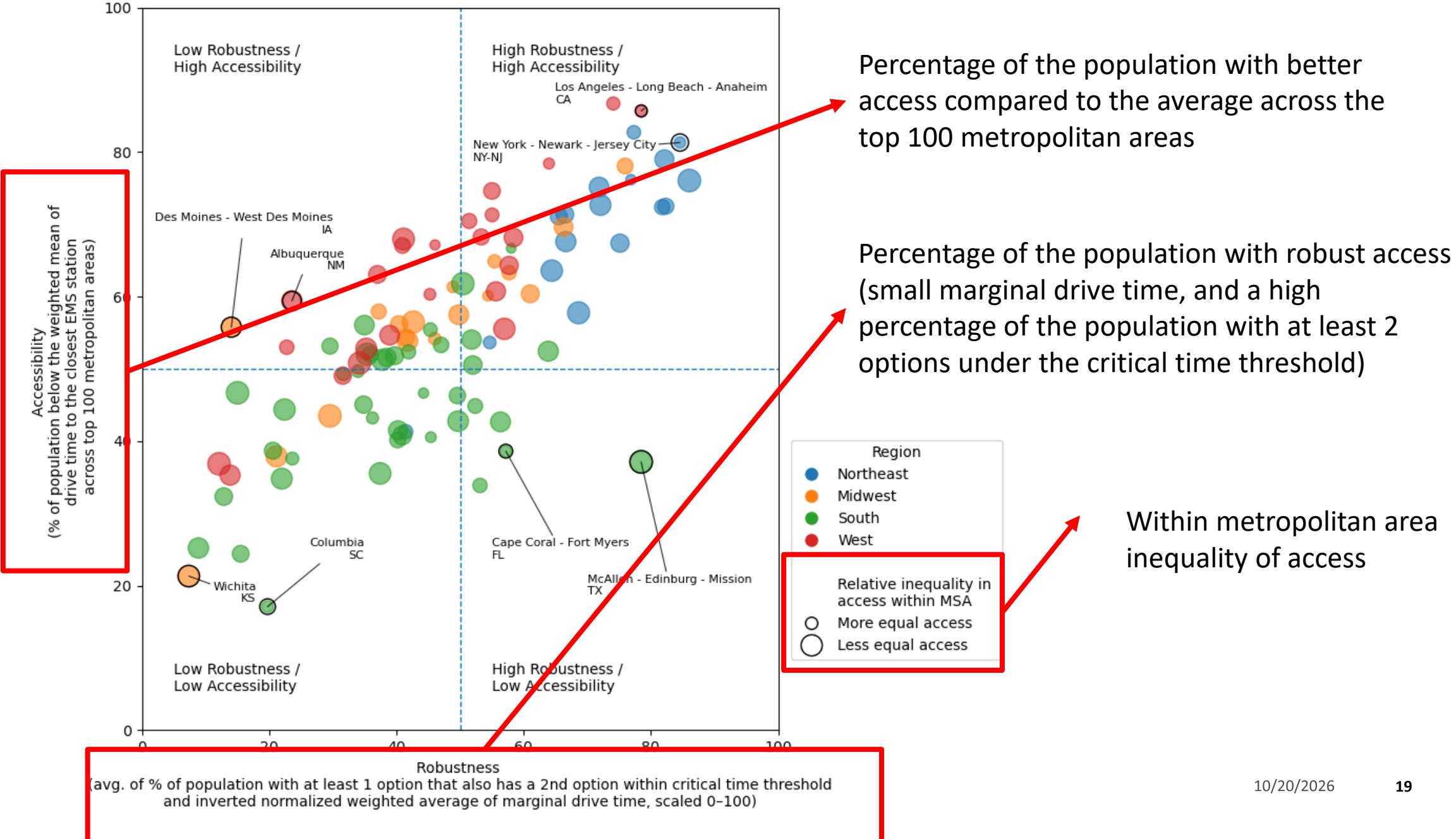
EMS Access By Region – Graphs ordered by highest percentage in population in poverty to lower from left to right



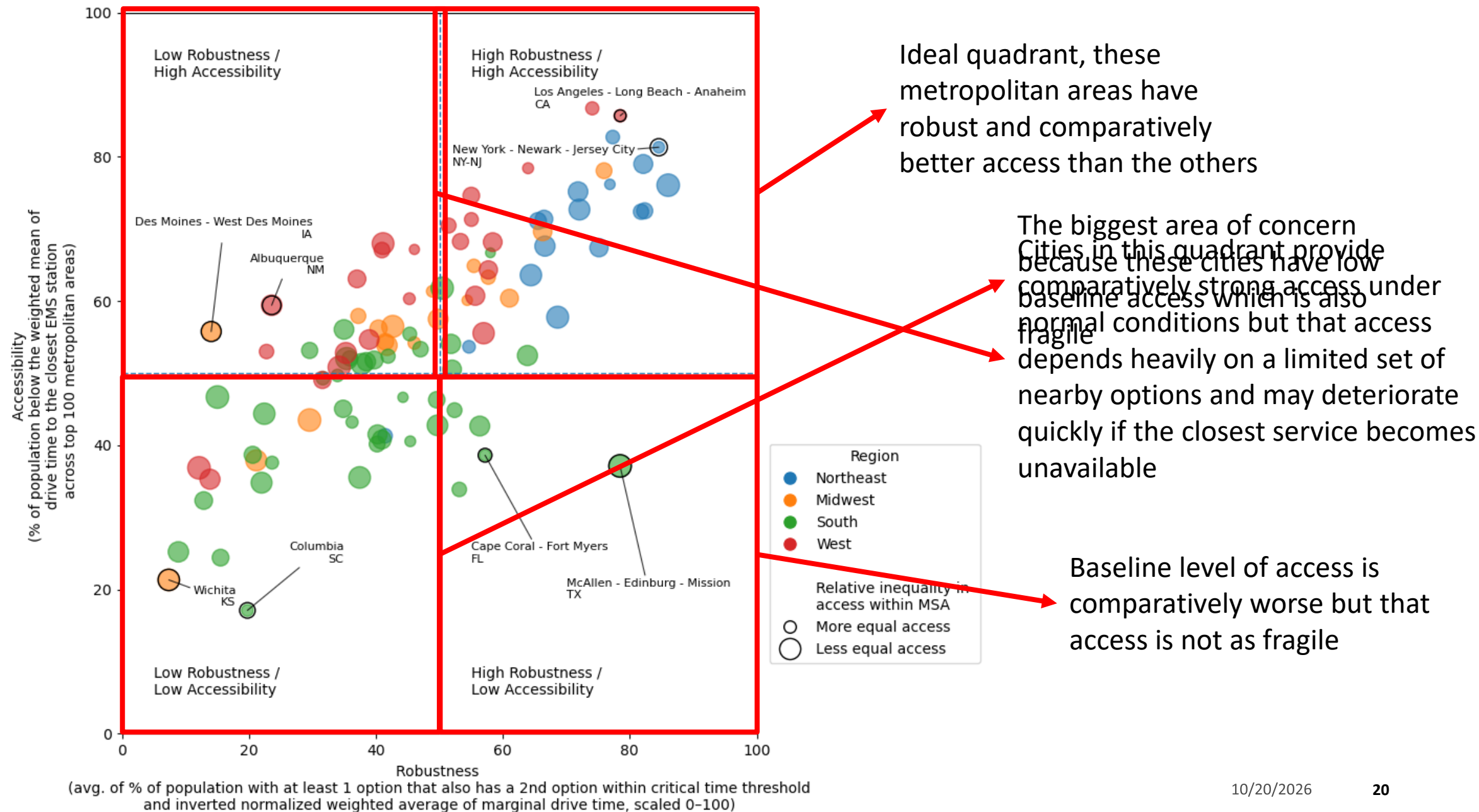
EMS Access of States with Largest Percentage of Population above the National Average



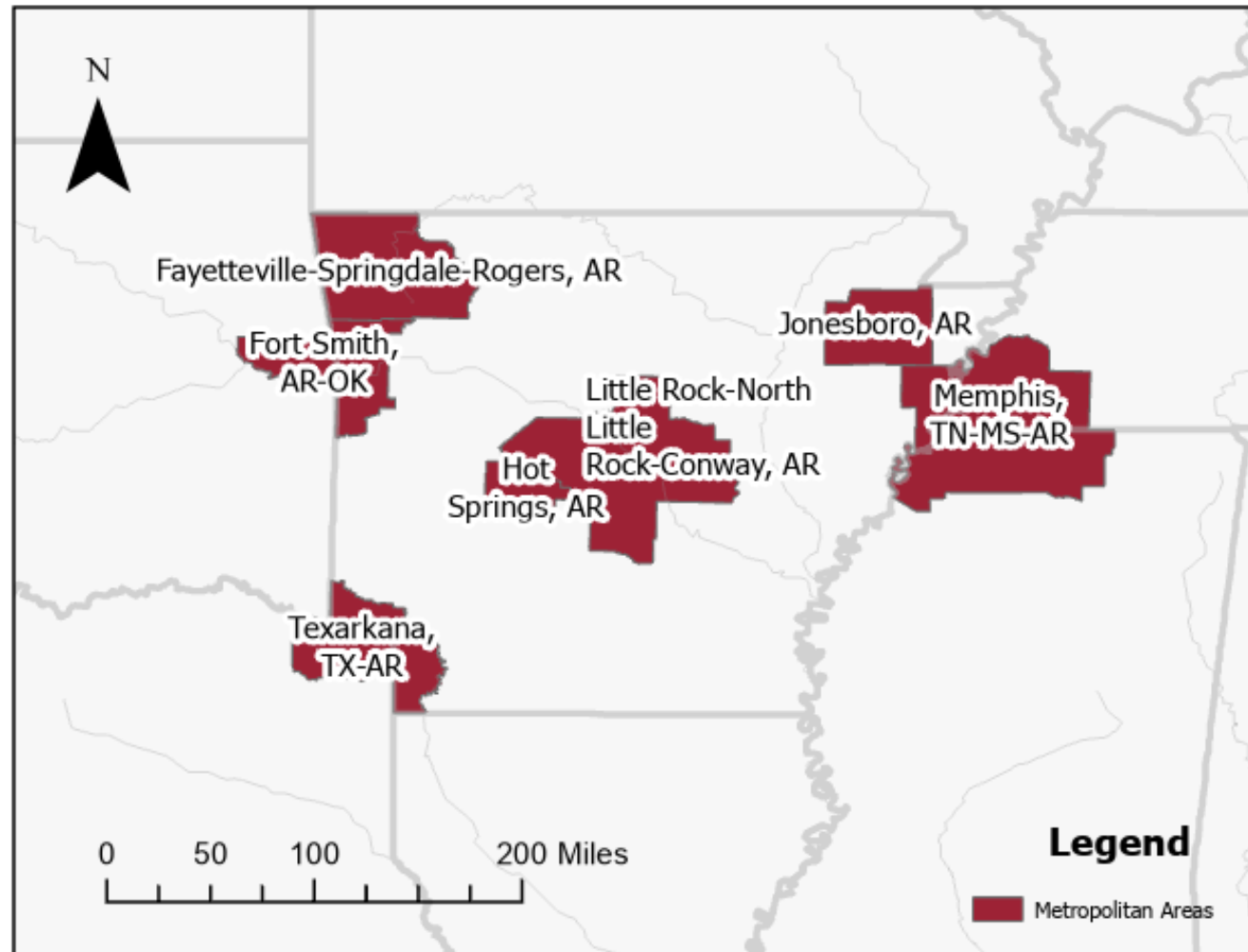
Emergency Medical Service Access Across Top 100 Most Populated Metropolitan Areas



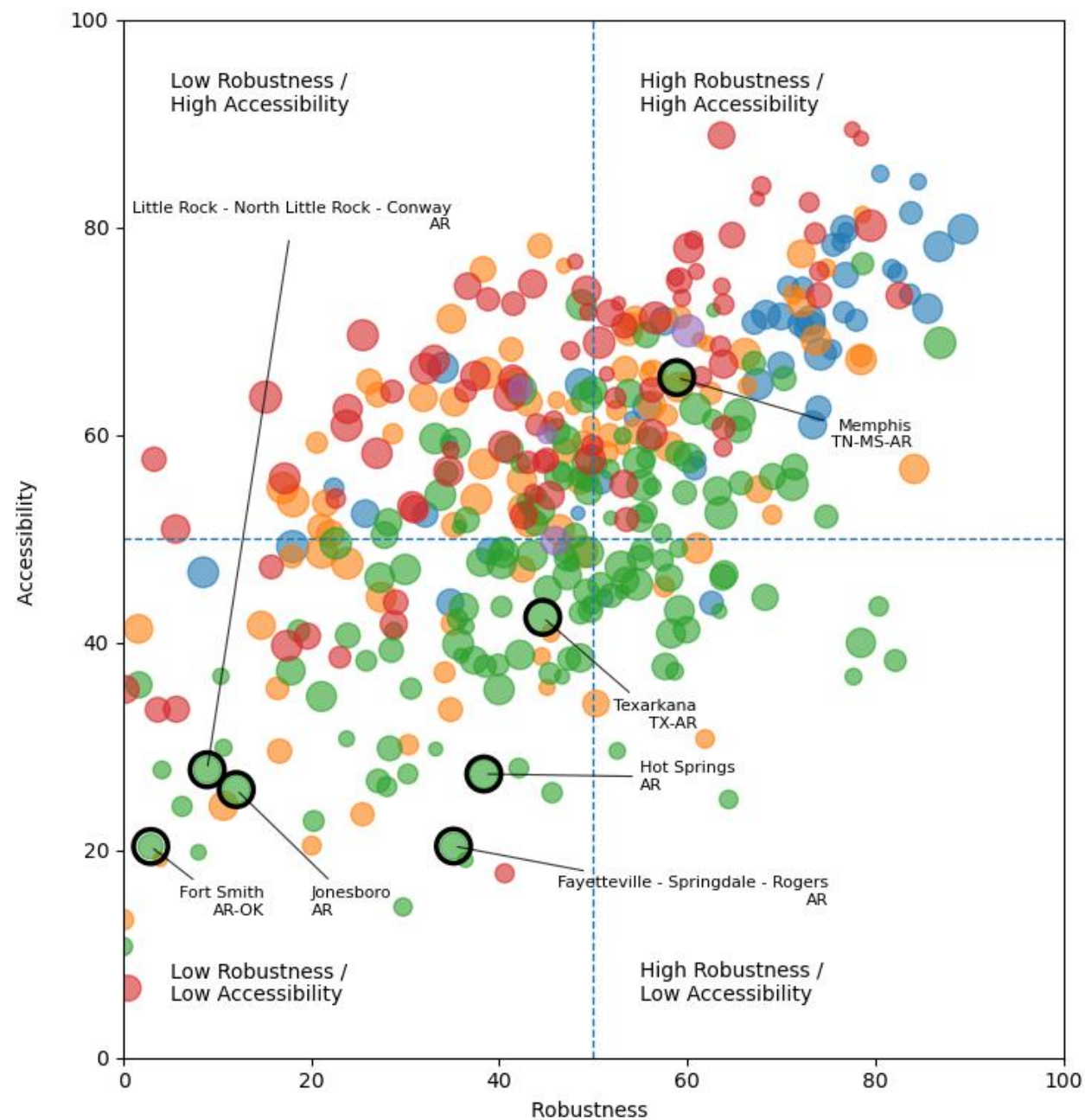
Emergency Medical Service Access Across Top 100 Most Populated Metropolitan Areas



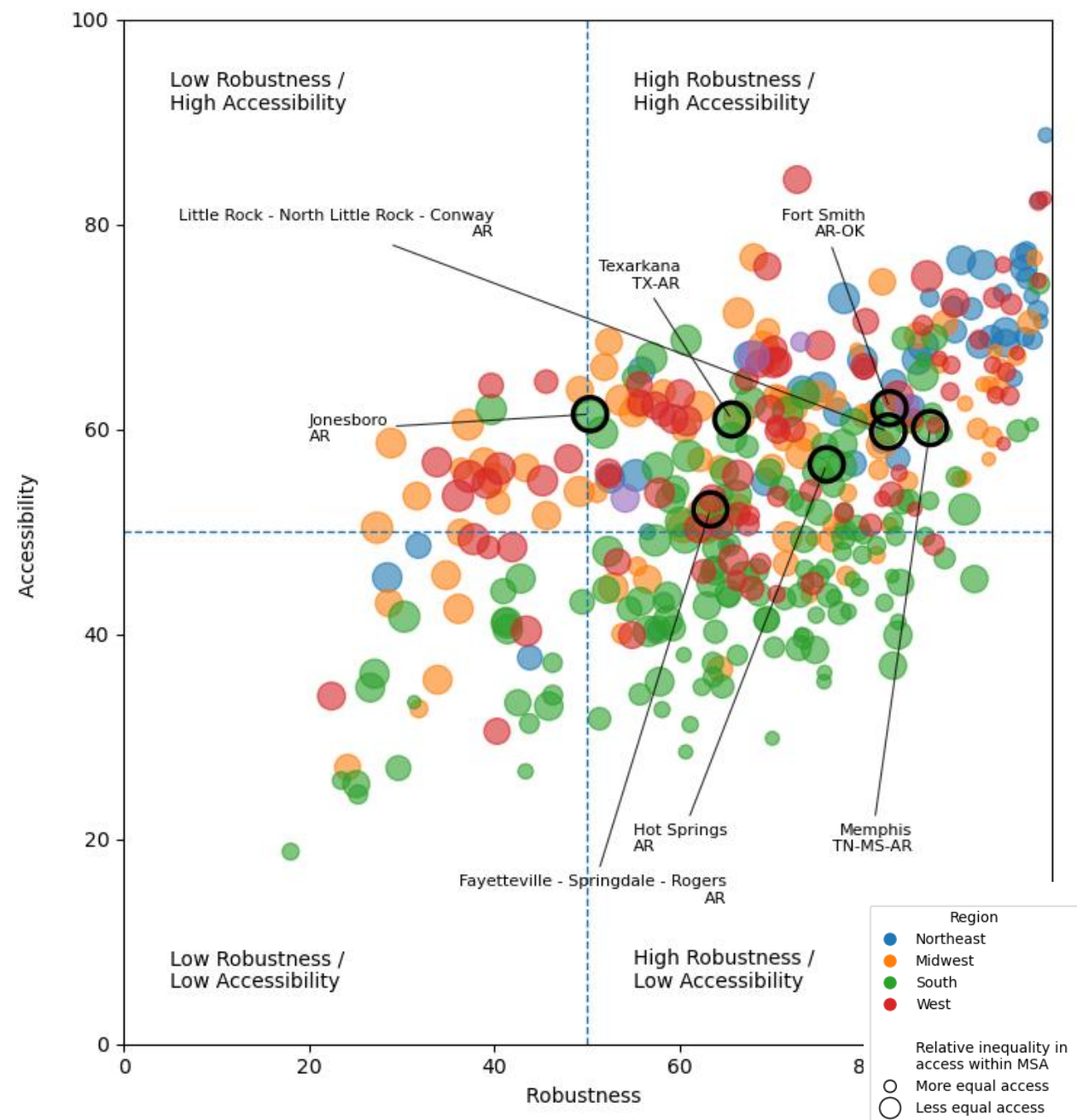
Metropolitan areas in Arkansas



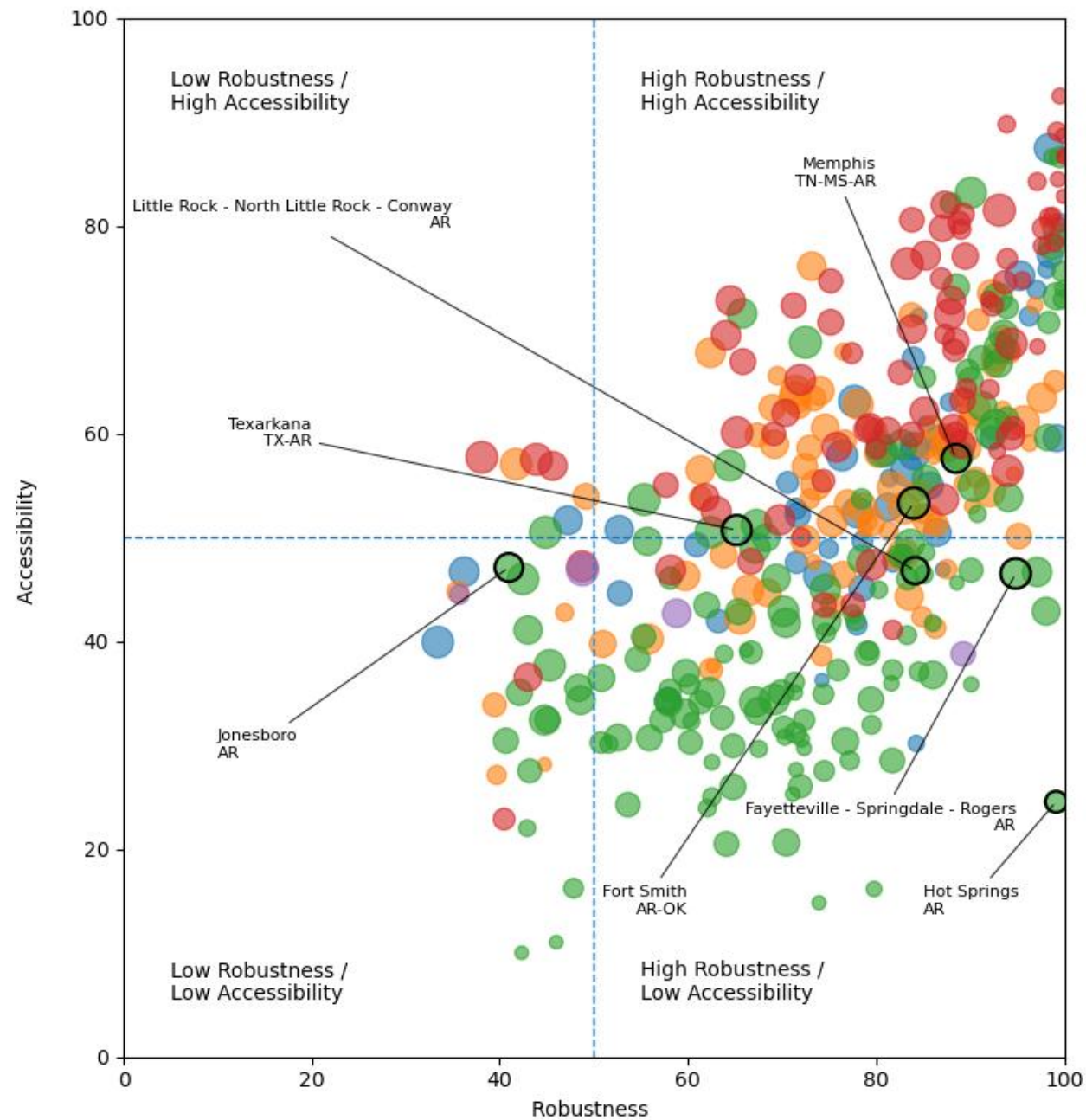
Emergency Medical Services



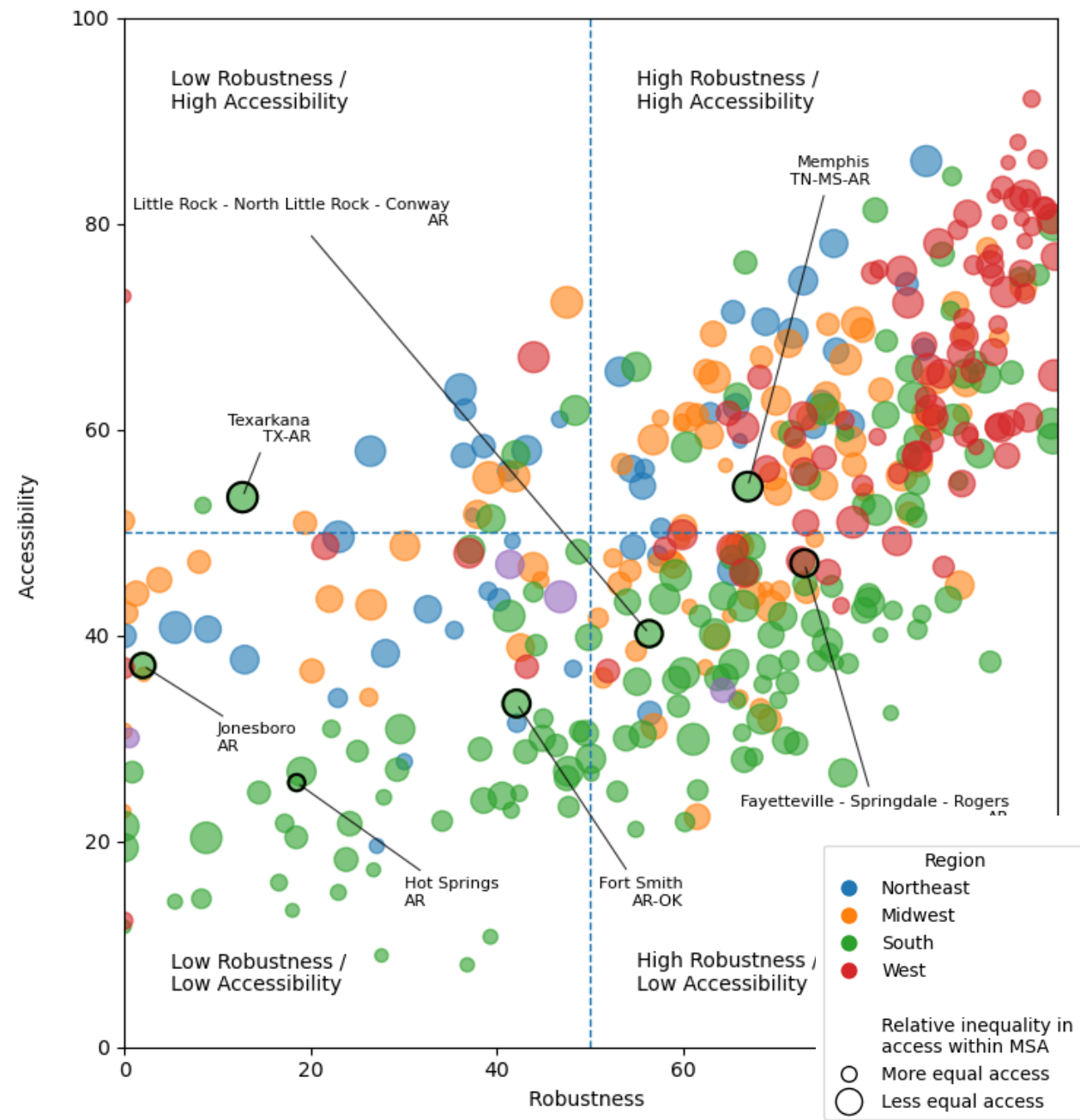
Fire Stations



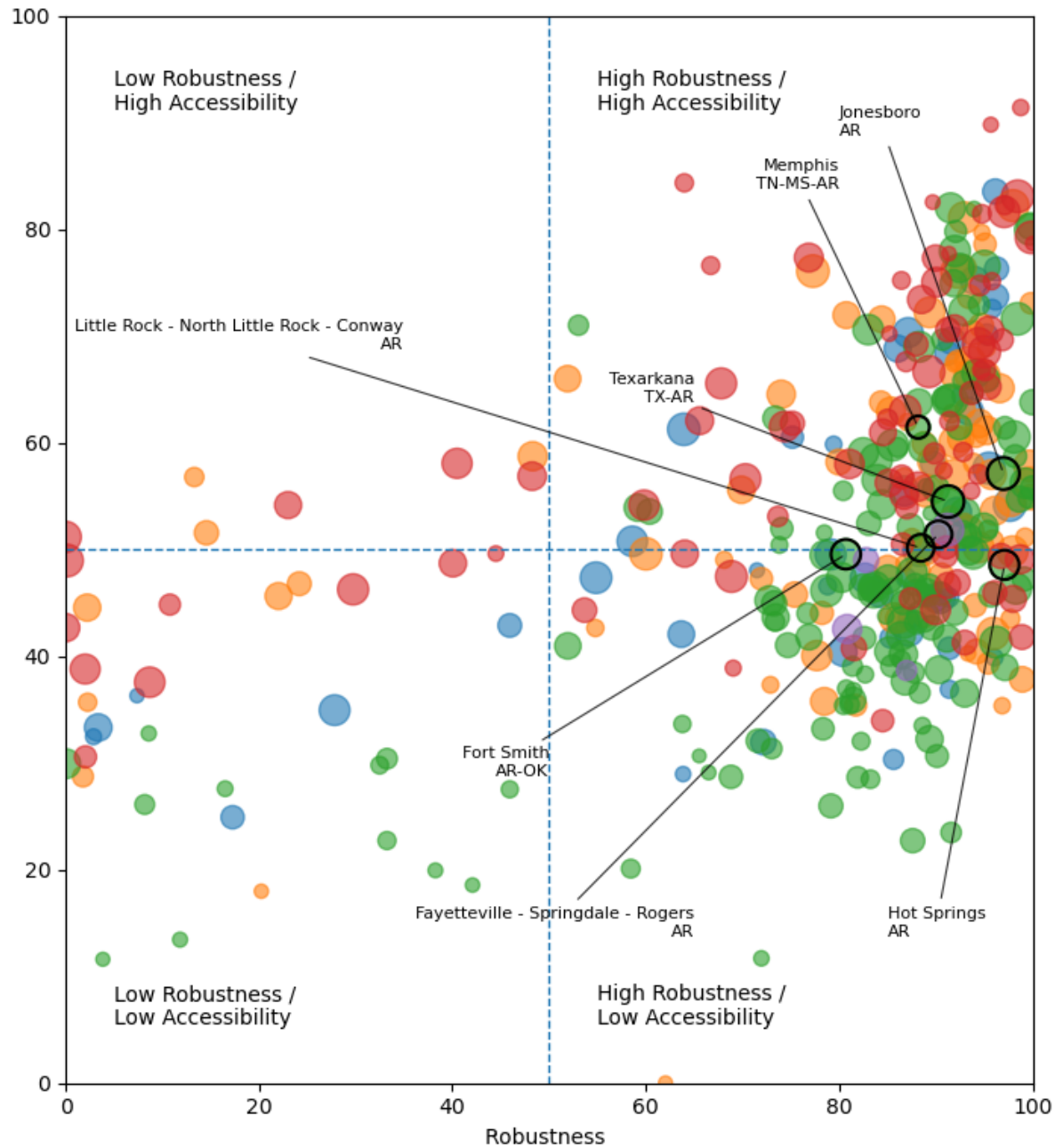
Public Schools



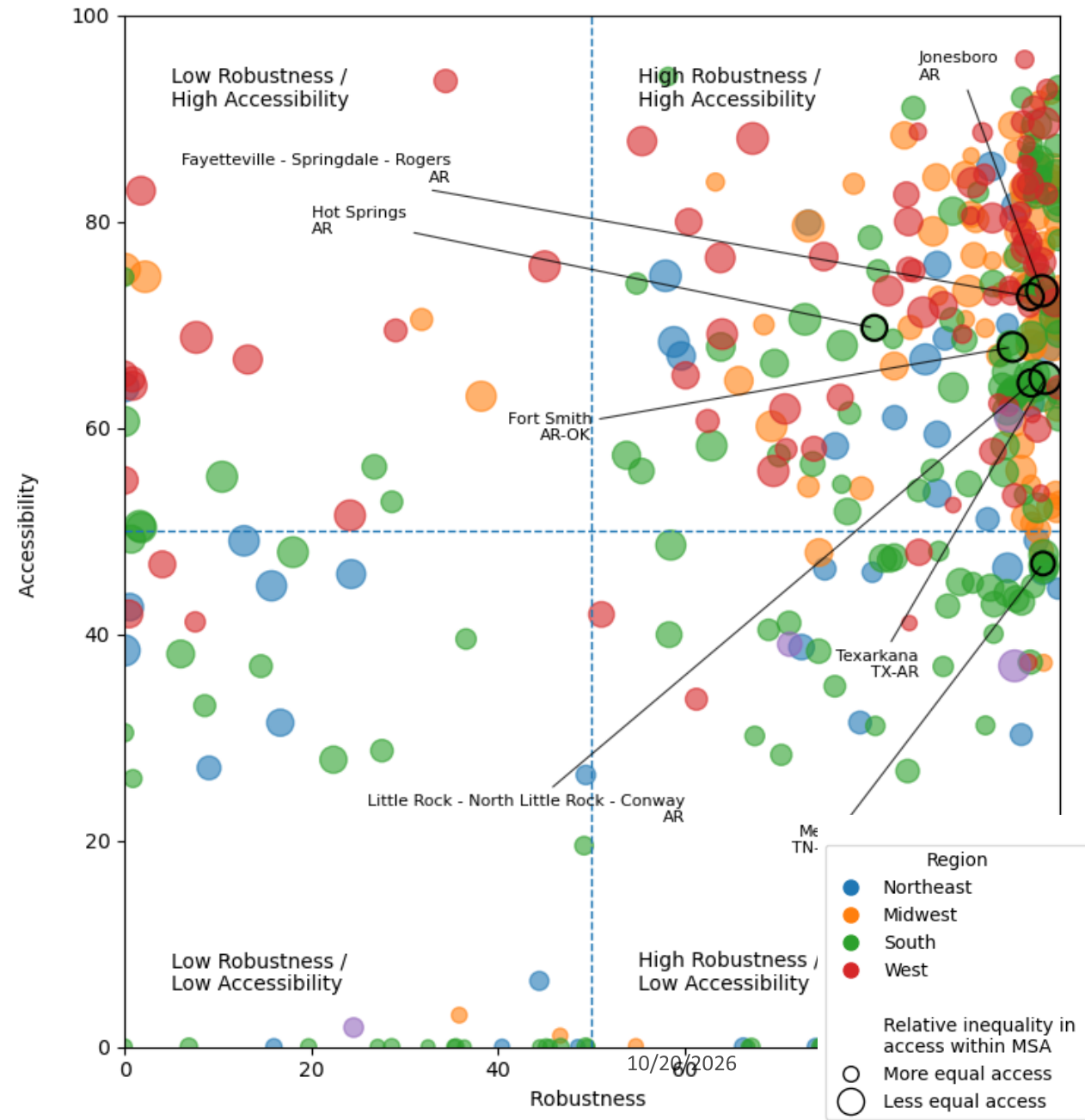
Public High Schools



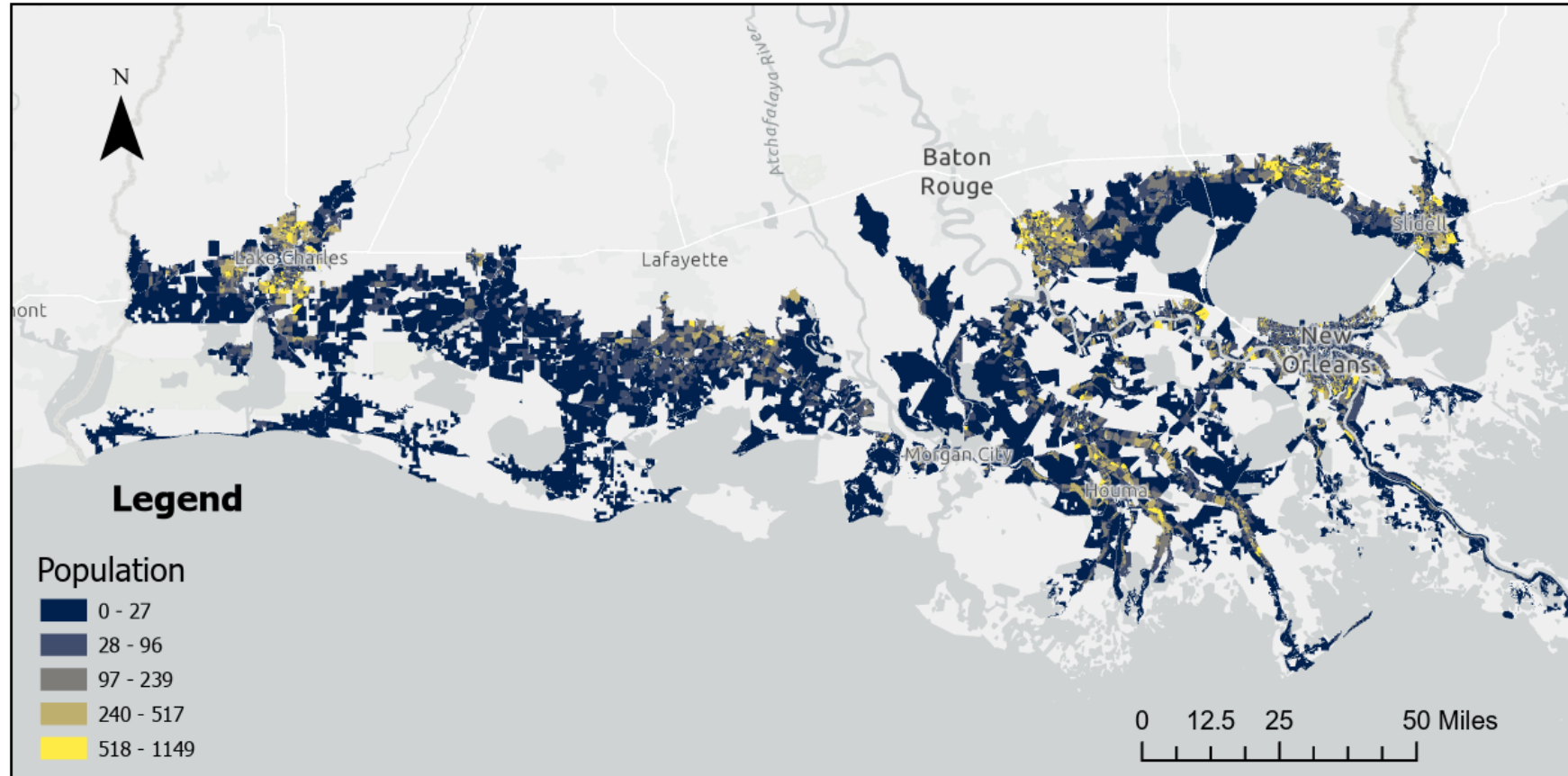
Hospitals



Trauma Hospitals



Robustness analysis empirical setting



Empirical Setting Communities in Louisiana - Communities with population in Coastal Louisiana Risk Assessment (CLARA)

What makes an asset more or less critical to a community?

Planners may have different views on what is most important

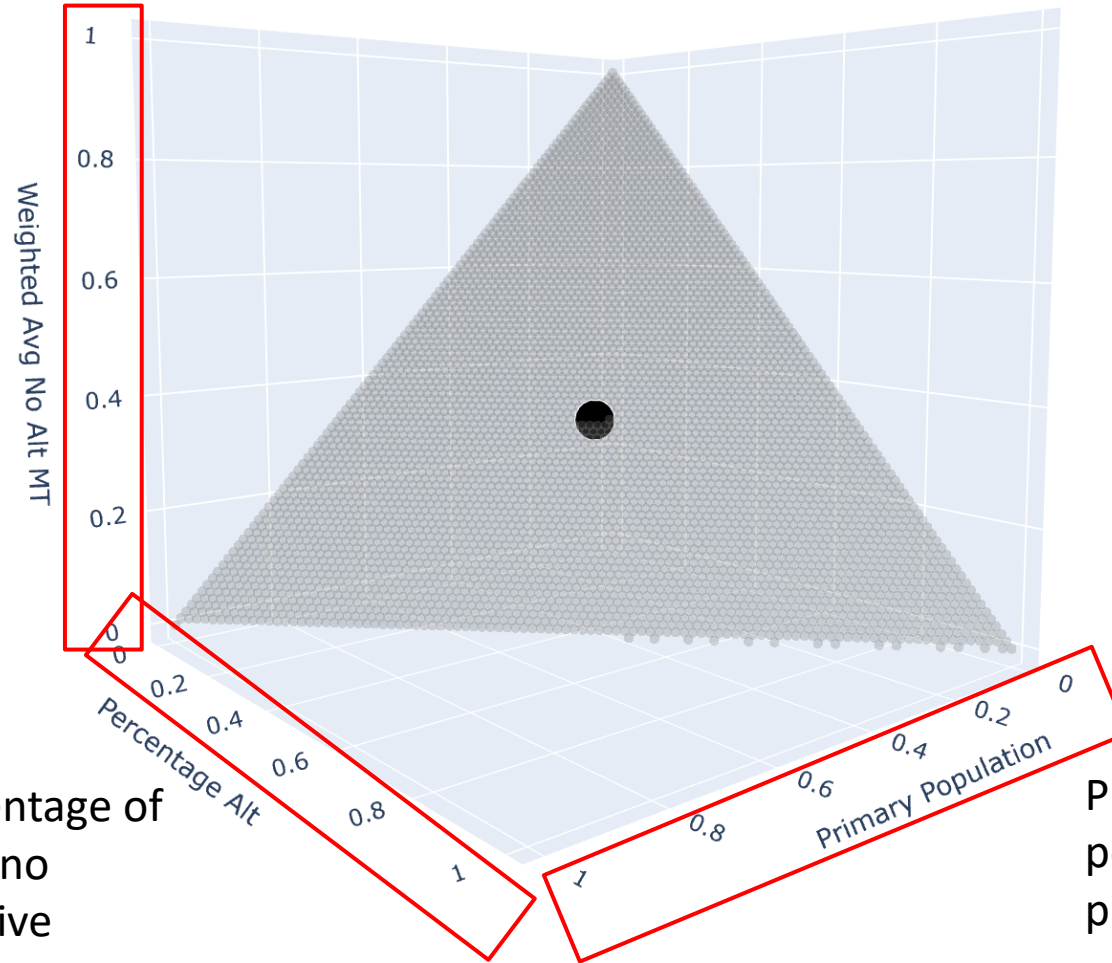
- How many people are served by this facility?
- How many of those people have no suitable alternative?
- For those with no suitable alternative, just how bad is the next best option?
- Total population served as primary provider
- Percentage of primary population with no other alternative within a critical time threshold for service
- Weighted average of marginal travel time for the primary population with no other alternative under the critical time threshold

Robustness analysis helps us answer this question

- Normalize all three measures
- Create a large combination space of priority weights
- $Criticality = w_1 * P + w_2 * A + w_3 * M$
- w_1, w_2, w_3 : Weights assigned to each variable, which must sum to 1 ($w_1 + w_2 + w_3 = 1$)
- P : Primary population served by the facility
- A : Primary population percentage without an alternative
- M : Weighted average of marginal travel time for primary population with no other alternative under critical time threshold
- Rank all facilities within their type between 1-5 based on their criticality score (higher = more critical)
 - We care about rank stability of facilities in determining criticality → facilities that constantly appear in top 5 are critical

How robust are rankings of criticality to different priorities?

Priority on marginal travel time for primary population with no suitable alternative



Priority on percentage of population with no suitable alternative

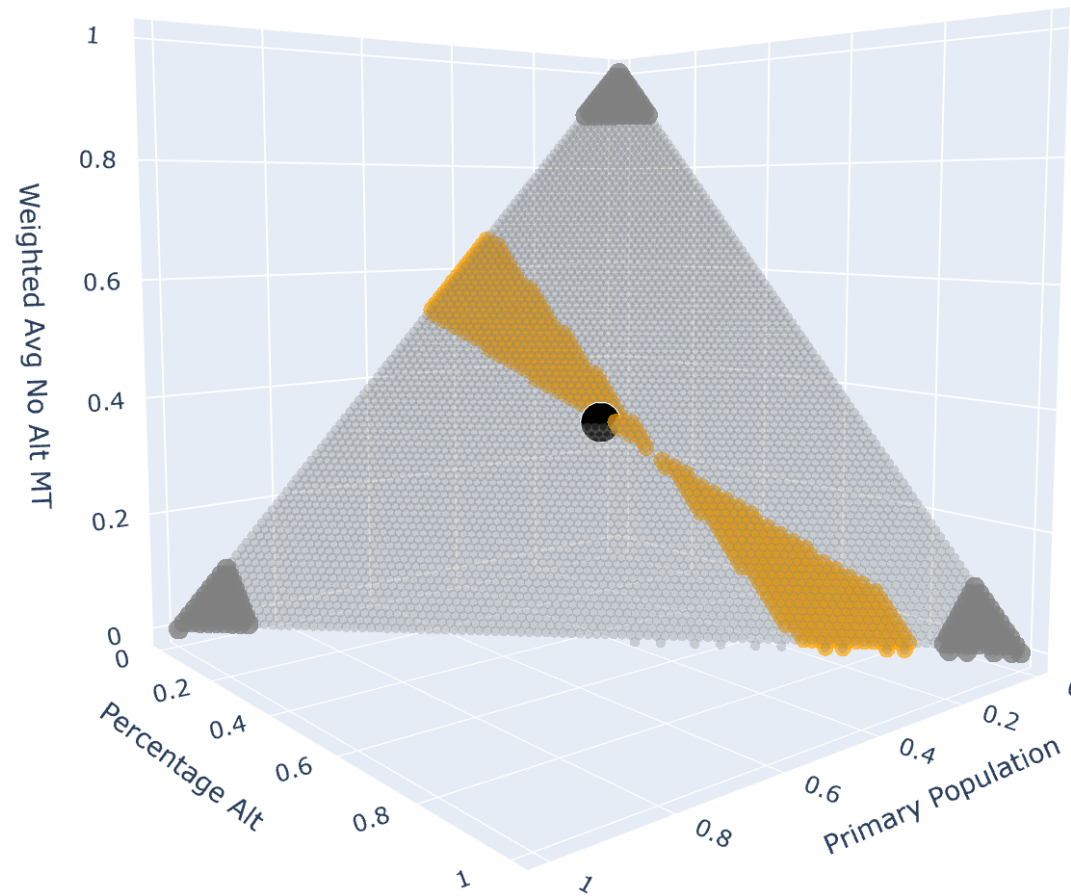
Priority on total population served as primary provider

How robust are rankings of criticality to different priorities?

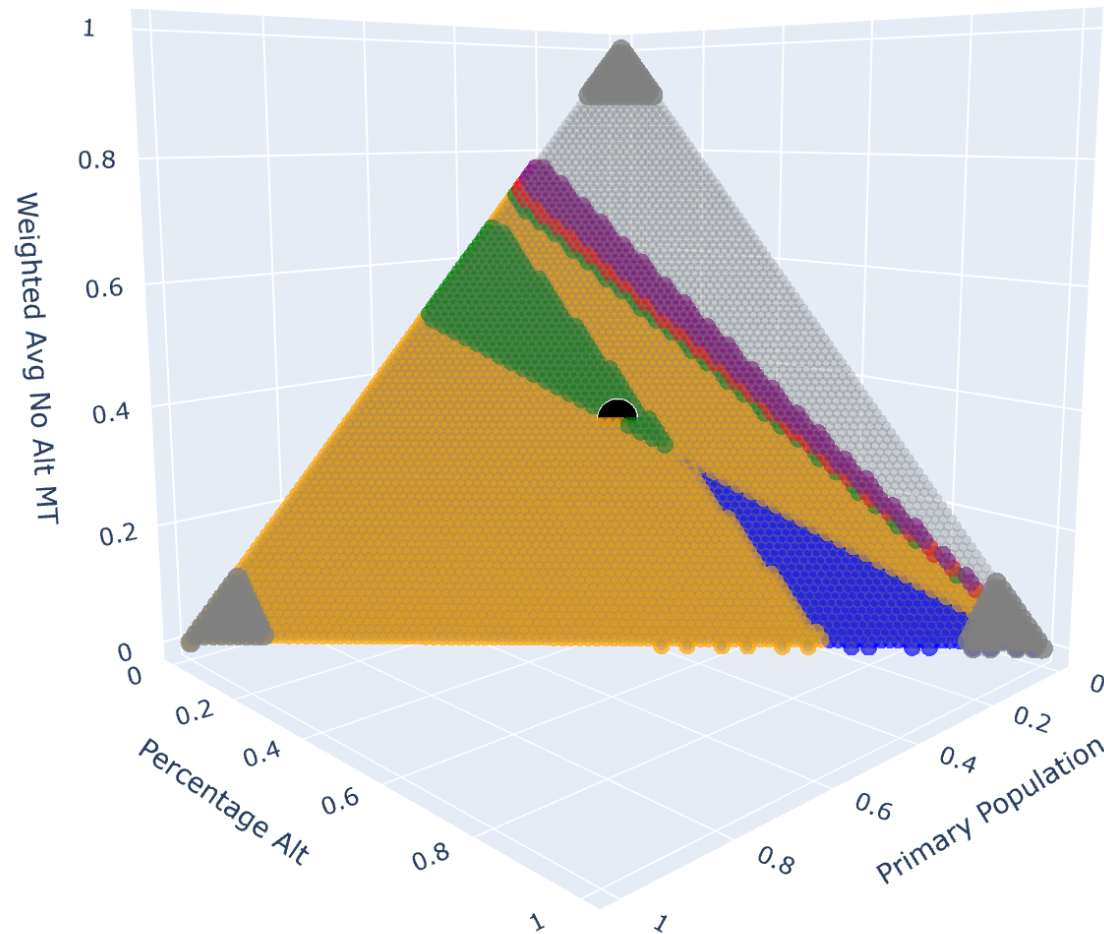
Row Rank	Facility Name	Primary Population	Percentage without Alternative	Weighted Avg Marginal Time (No Alt)	Rank 1%	Rank 2%	Rank 3%	Rank 4%	Rank 5%	Total Percentage	Equal Weight Rank
1	NEW ORLEANS LAKEFRONT AIRPORT AIRCRAFT RESCUE ...	103195	100.00	5.53	6.67	55.88	8.56	1.83	3.79	76.72	3.0
2	PLAQUEMINES PARISH AMBULANCE DEPARTMENT - WOOD...	374	100.00	32.39	50.28	2.17	4.89	13.05	4.47	74.87	2.0
3	NEW ORLEANS EMERGENCY MEDICAL SERVICES	125109	94.19	2.67	43.03	11.20	10.53	1.35	1.37	67.48	1.0
4	EASTBANK CONSOLIDATED FIRE DEPARTMENT STATION 17	92471	97.70	3.17	0.00	0.58	42.81	18.02	1.03	62.44	4.0
5	CAMERON PARISH EMERGENCY MEDICAL SERVICES - GR...	312	100.00	16.50	0.00	30.10	4.21	4.55	13.11	51.97	NaN

This shows, percentage of combination space each facility appears in each rank within its facility type. For instance, New Orleans Emergency Medical Services is ranked 2 most critical among all schools 11.2% of the weight combination space.

How robust are rankings of criticality to different priorities?



Some assets may be critical over a wide range of preferences



- Rank 1
- Rank 2
- Rank 3
- Rank 4
- Rank 5
- All Weight Combinations
- Equal Weights Point
- Extreme Scenarios

Example: New Orleans Lakefront Airport Rescue and Fire Station

Policy Implications

Northeastern states have better baseline access that is also less fragile compared to other states.

Arkansas metropolitan areas have comparatively worse and less robust EMS and public high school access.

Preferred actions may be fairly robust to divergent priorities

In other words, even if we disagree on what is most important, we may agree on the right course of action.

Limitations

1. Drive time calculations use ideal road conditions: no traffic, no inundation, no closures considered.
2. While drive time measures are at the population node level, aggregating those results to larger areas can mask differences within the geographic area of the unit.
3. There are no considerations about the quality of the service each facility provides, so the closer options might not be the most feasible option.

Evaluating critical and essential service access vulnerabilities

LETTER • OPEN ACCESS

Evaluating critical and essential service access vulnerabilities

Utkuhan Genc^{*}, David R Johnson, Jordan R Fischbach, Audrey Grismore, Allison Haertling, Scott Hemmerling and Patrick Kane

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THANK YOU!

Questions?

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