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Measuring Social Vulnerability in Transit Deserts of United States Metro Areas

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Measuring Social Vulnerability in Transit Deserts of United States Metro Areas

Abstract

This study was aimed at identifying areas in the US that need both transit improvements and anti-displacement protection. First, rather than focusing on transit-dependent populations, we developed a new method of accounting for overall transportation demand among independent residents in comparison with public transit supply. Next, we analyzed transit deserts in metro areas using the social vulnerability index. Results indicated that living in transit deserts across 200 metro areas today are approximately 24.6 million people, of which about 19% live below the poverty line. Additionally, residents of transit deserts exhibit, on average, a social vulnerability that is approximately 21% higher than citywide averages.

Keywords

GIS, Transit deserts, social vulnerability, US metro areas

Acknowledgements

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1. Introduction

Today, most American metro areas are adequately covered by transit networks and systems, but many regions continue to see less development, with residents, especially low-income households, having low access to transportation services. Such areas are designated as “transit deserts,” which is a concept first introduced by Jiao and Dillivan (2013). Since 2013, the metric for transit deserts has been refined and applied to a growing number of cities in the US and China (Jiao and Dillivan 2013; Jiao 2017; Jiao 2019; Jiao and Cai 2020; Bates et al. 2017; Dawkins and Moeckel 2016) to identify areas that need both transit improvements. The transit desert method, derived from the supply-and-demand logic of the “food desert,” compares an area’s population of transportation-dependent residents to its supply of public transit infrastructure (Clark et al. 2002; Whelan et al. 2002; Wrigley 1993; Wrigley et al. 2002; Jiao et al. 2012). In earlier research by Jiao et al. 2012, transportation demand was defined by the number of non-institutionalized residents without access to a car. In this updated study, however, we aimed to expand this definition to cover all groups who may benefit from transit services, especially those burdened by car ownership. Instead of focusing on transit-dependent populations, this research considered overall transportation demand from independent residents-independent residents are those classified by the US Census as those not living in "institutional group quarters" (prisons, long term care facilities) in comparison with public transit supply. We then analyzed transit desert populations using the social vulnerability index (SVI), a nation-wide ranking of vulnerability published by the Centers for Disease Control and Prevention (Flanagan et al. 2011). Furthermore, whereas earlier transit desert research examined 52 major US cities at most, we expanded this scope to include 200 metro areas with transit systems across the United States, encompassing an estimated 224 million residents, or about 70% of the total US population (323 million).

2. Methods and Data

The transit desert index is a measurement of the difference between transportation demand and transit supply in each US Census tract, normalized within metropolitan or micropolitan statistical areas (MSAs) using z-scores. The transit desert index was calculated for 200 metro areas in the US using the following formula:

$$Transit\ Desert\ Index = Transportation\ Demand\ (z-score) - Transit\ Supply\ (z-score) \quad (1)$$

Transit deserts refer to census tracts with a significant transit desert index of 1 or greater. Conversely, “transit oases” are census tracts with a significant transit desert index of –1 or less. Raw transportation demand values per census tract were calculated as the population of residents aged 12 years (12 years old is generally the age when kids start to take the bus by themselves) and older minus the population of institutionalized residents divided by the area of the tract. The transportation demand in each census tract was calculated on the basis of the demographic data from the 2018 Five-Year American Community Survey. The computation can be written thus:

$$Transportation\ Demand\ (raw\ score)\ =\ (Pop - PopINS)/A \quad (2)$$

where
Transportation Demand= All groups who may benefit from transit services, especially those burdened by car ownership
Pop = Number of residents aged 12 years and older

Pop_{INS} = Number of institutionalized residents
A = Census tract area

Transit supply values per census tract were calculated by combining various raw transit supply values into a single z-score for each tract. In past transit desert studies, transit supply values were computed with consideration for transit stops, frequency of service, sidewalks, bike routes, low-speed roads, and street intersections. Given limited nationwide data sources, however, we considered only three parameters, namely, transit stops, intersections, and points of interest (POIs). Transit stop data were obtained from the General Transit Feed Specification dataset available from Transitland (https://transit.land/). Street intersections and POIs were derived from the US Census TIGER/Line road data and SafeGraph, respectively. Each parameter was first divided by the area covered by each census tract, after which it was normalized into separate z-scores before these scores were combined into a single transit supply z-score per tract. The raw transit supply formula used is presented below:

$$Transportation\ Supply\ (raw\ score)\ =\ S(z-score)\ +\ I(z-score)\ +\ P(z-score) \quad (3)$$

where
S = Number of transit route stops per area of census tract
I = Number of intersections per area of census tract
P = Number of points of interest per area of census tract

3. Results

By mapping the transit desert index for 200 MSAs in the US, we identified that 24.6 million residents (11% of the study area's population) live in a transit desert. Geographically, in general, this methodology yields transit oasis tracts within urban cores and transit desert tracts in suburban areas, matching expectations regarding urban transit system networks. This essential pattern varies relative to each city's physical size, density, and demographic characteristics. Figures 1,2, and 3 illustrate examples featuring a large city (New York, NY), a medium-sized city (Austin, TX), and a small city (Fresno, CA). For data that cover patterns for the entire US, please refer to a complete map at https://sites.utexas.edu/uil/transit-deserts. Our analysis showed considerable demographic differences between residents of MSA tracts as a whole and those living in transit deserts within these tracts. Some MSAs have fewer percentages of vulnerable populations within their transit deserts, whereas others have highly vulnerable people in their transit deserts. These areas warrant more attention from transport authorities and decision makers in the development of new public investment projects. Overall, whereas the average SVI within MSAs is 0.48, that within transit deserts is 0.58—a difference translating to a 21% increase (Table 1). In the cities of Philadelphia, Grand Rapids, Providence, Baltimore, Boston, Denver, Salt Lake City, and Minneapolis, the increase is over 50%, whereas in the MSAs of San Antonio, Las Vegas, Raleigh, St. Louis, and Birmingham, the SVI decreases by more than 10% (Table 2). Furthermore, the poverty rate within MSAs is 12.8% on average, but that within transit deserts is 18.5%. The MSAs in Philadelphia, Providence, Minneapolis, Milwaukee, and San Diego have the highest discrepancies in poverty rate, each over 10 percentage points, while in St. Louis, Fresno, Raleigh, San Antonio, Las Vegas, Riverside, Birmingham, and El Paso, the discrepancy drops to 4 percentage points (Table 3).

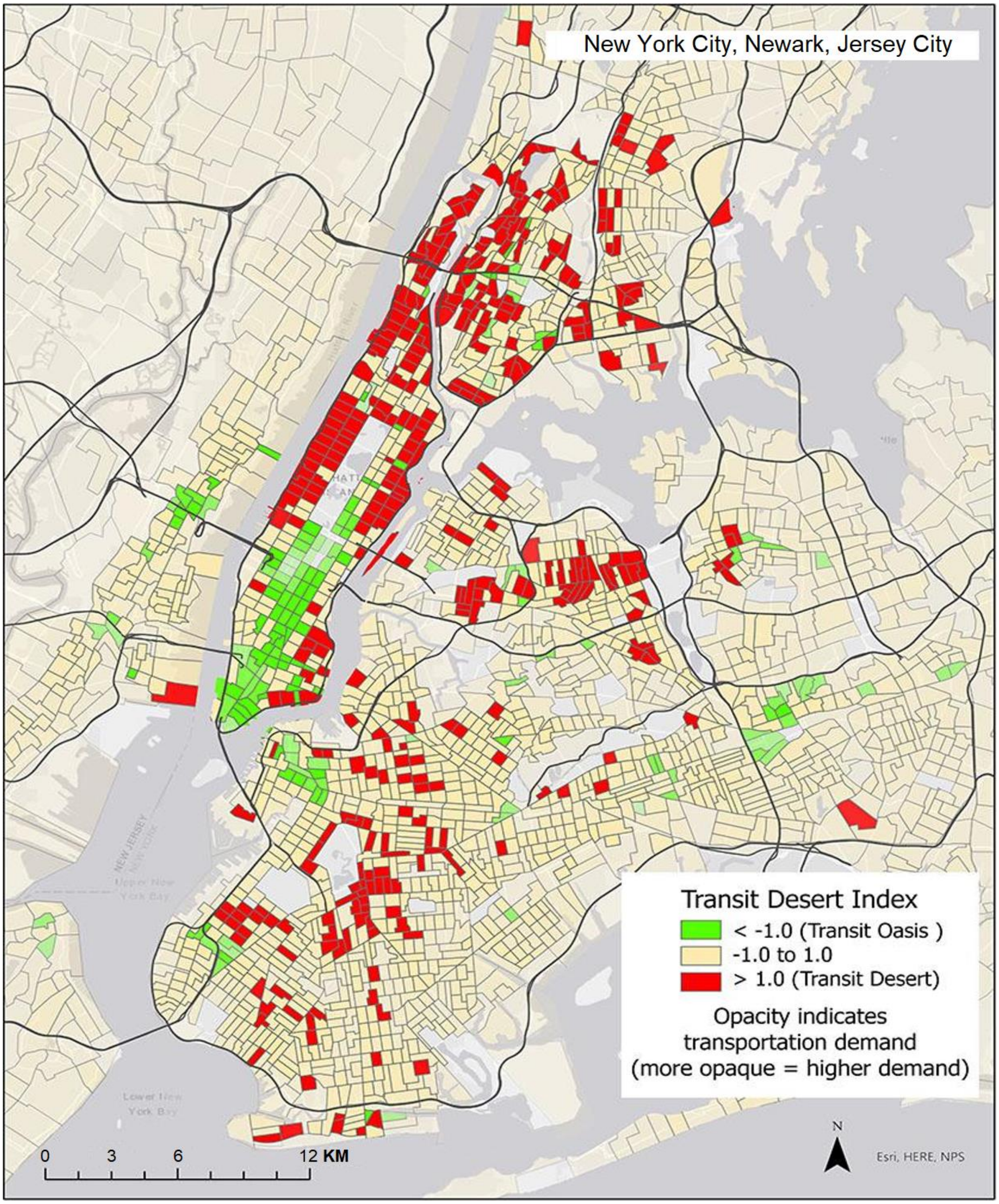

Figure 1. Map of Transit Deserts in New York City (New York), Newark (New Jersey), and Jersey City (New Jersey).

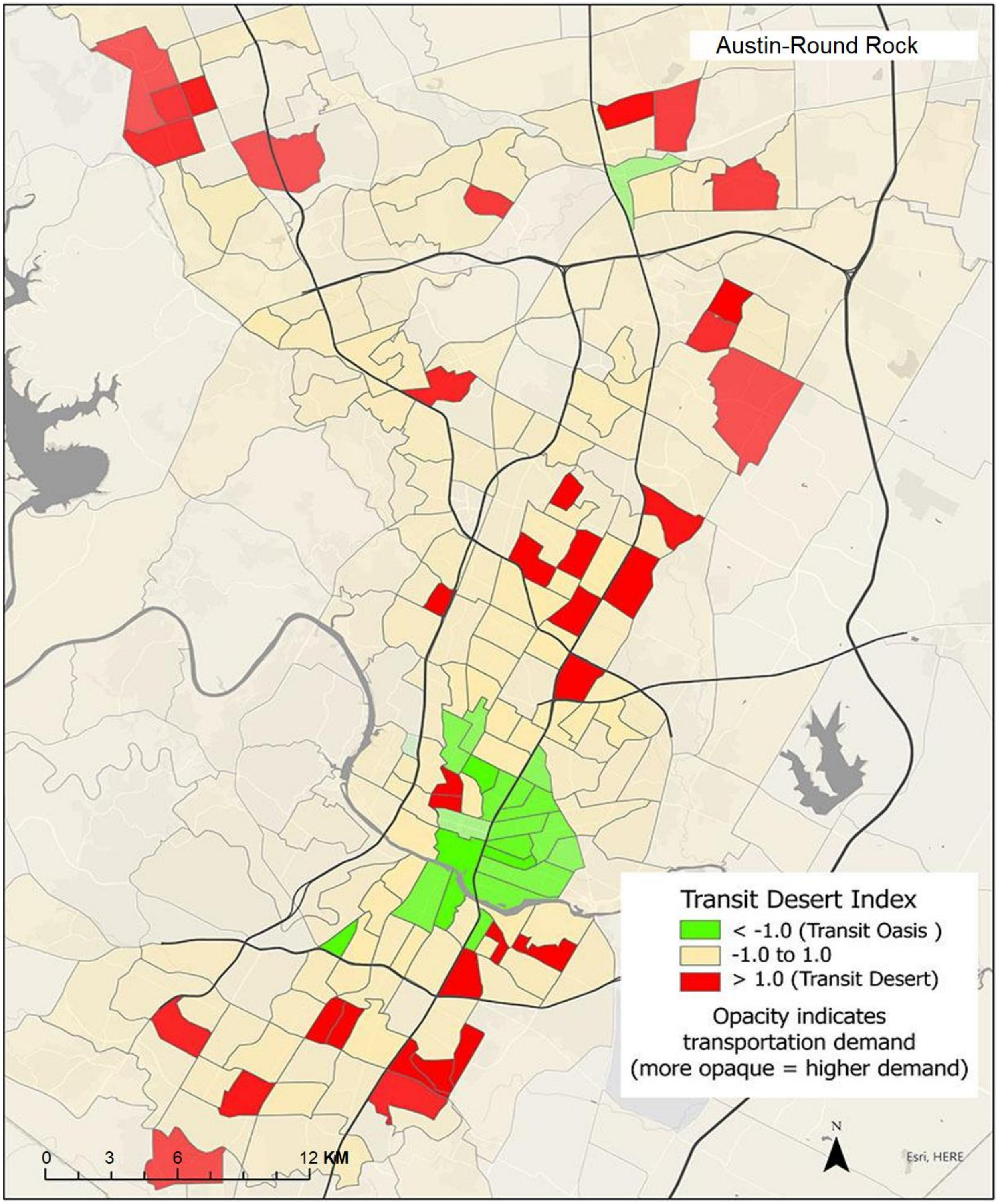

Figure 2. Map of Transit Deserts in Austin-Round Rock (Texas).

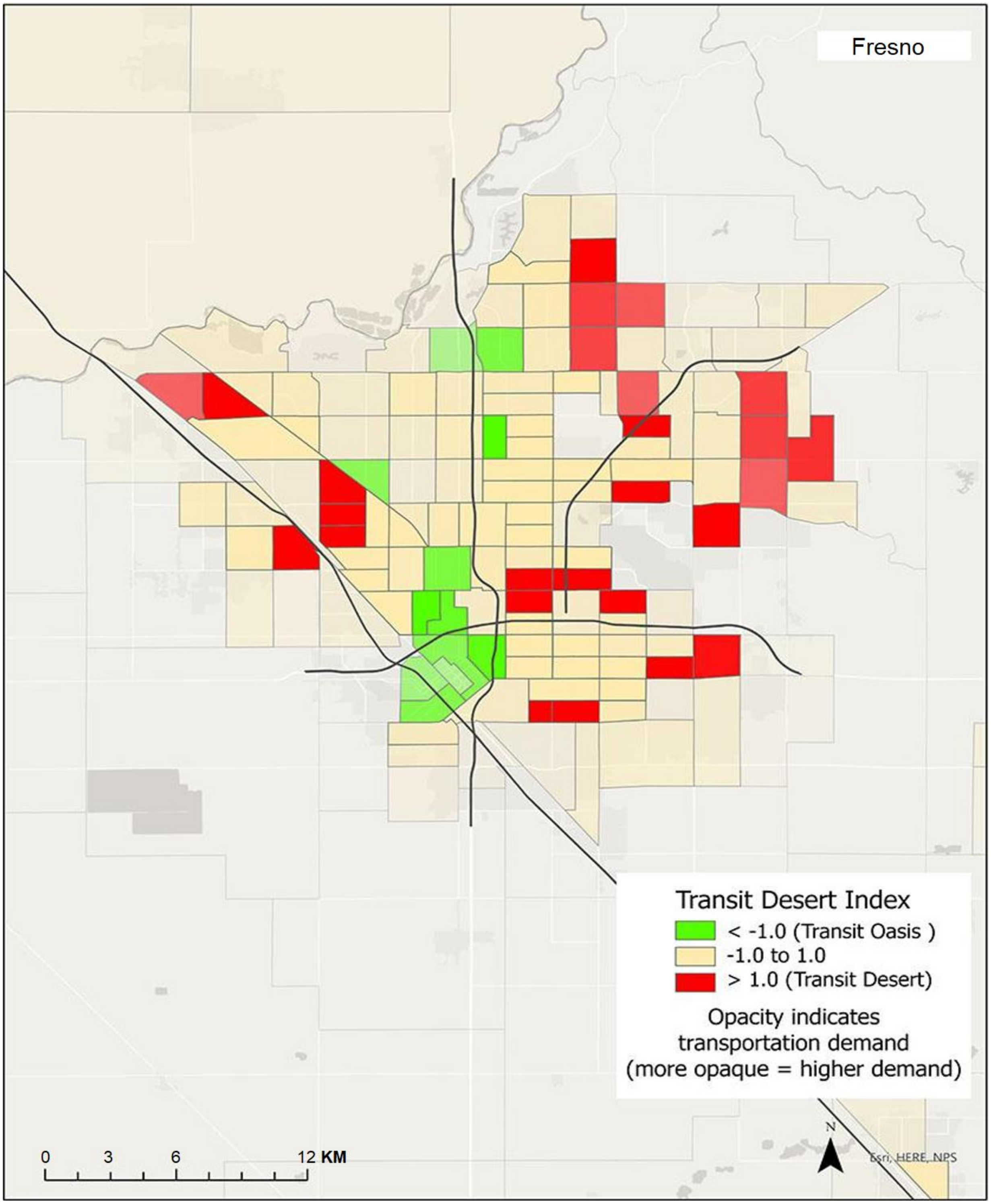

Figure 3. Map of Transit Deserts in Fresno (California).

4. Conclusions

In this study we identified the areas in the US that need both transit improvements by accounting for independent residents. Moreover, we analyzed transit deserts in metro areas using the social vulnerability index. Results indicated that the poverty rate within MSAs is 12.8% on average, but that within transit deserts is 18.5%. Additionally, residents of transit deserts exhibit, on average, a social vulnerability that is approximately 21% higher than citywide averages.

Table 1. Summary of all 200 MSAs in study, with demographic population estimates and rates citywide and within transit desert tracts.

Variables	Estimate	Rate	Percentage point difference
Population estimate, 2014-2018 ACS	224,005,891		
Estimate within Transit Deserts	24,646,079	11.0%	
Social Vulnerability Index (SVI), mean	0.480 (mean)		
Mean SVI within Transit Deserts	0.581 (mean)		21% (percent change)
Minority (all persons except white, non-Hispanic) estimate, 2014-2018 ACS	97,775,904	43.6%	
Estimate within TDs	14,317,439	58.1%	14.4%
Persons below poverty estimate, 2014-2018 ACS	28,657,930	12.8%	
Estimate within Transit Deserts	4,551,688	18.5%	5.7%
Persons (age 5+) who speak English "less than well" estimate, 2014-2018 ACS	11,326,206	5.1%	
Estimate within Transit Deserts	2,163,914	8.8%	3.7%
Persons (age 25+) with no high school diploma estimate, 2014-2018 ACS	18,032,828	8.1%	
Estimate within Transit Deserts	2,672,246	10.8%	2.8%
Households with no vehicle available estimate, 2014-2018 ACS	7,911,400	3.5%	
Estimate within Transit Deserts	1,584,618	6.4%	2.9%
Civilian (age 16+) unemployed estimate, 2014-2018 ACS	6,707,060	3.0%	
Estimate within Transit Deserts	882,604	3.6%	0.6%
Single parent household with children under 18 estimate,	7,276,558	3.2%	

2014-2018 ACS			
Estimate within Transit Deserts	1,012,939	4.1%	0.9%
Civilian noninstitutionalized population with a disability estimate, 2014-2018 ACS	25,240,208	11.3%	
Estimate within Transit Deserts	2,783,871	11.3%	0.0%

Table 2. Summary of top MSAs by transit desert population with CDC SVI estimates and transit desert rates per MSA.

MSA	Pop. overall	Pop. in transit deserts	% in transit deserts	Avg. SVI citywide	Avg. SVI in transit deserts	Percent change
New York-Newark-Jersey City, NY-NJ-PA	**19,985,920**	**2,338,369**	**11.7%**	**0.512**	**0.767**	**49.6%**
Los Angeles-Long Beach-Anaheim, CA	13,255,322	1,192,969	9.0%	0.600	0.823	37.1%
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	6,069,448	822,489	13.6%	0.421	0.733	74.2%
Chicago-Naperville-Elgin, IL-IN-WI	9,512,367	808,469	8.5%	0.473	0.652	37.7%
Houston-The Woodlands-Sugar Land, TX	6,779,101	759,910	11.2%	0.575	0.660	14.8%
Riverside-San Bernardino-Ontario, CA	4,522,279	706,947	15.6%	0.659	0.622	-5.7%
Detroit-Warren-Dearborn, MI	4,314,800	605,671	14.0%	0.460	0.533	16.0%
Phoenix-Mesa-Scottsdale, AZ	4,673,634	603,676	12.9%	0.489	0.681	39.2%
Miami-Fort Lauderdale-West Palm Beach, FL	6,068,257	505,311	8.3%	0.577	0.669	16.0%
Dallas-Fort Worth-Arlington, TX	7,255,028	493,034	6.8%	0.486	0.600	23.4%
San Francisco-Oakland-Hayward, CA	4,632,169	466,661	10.1%	0.441	0.517	17.2%
Washington-Arlington-Alexandria, DC-VA-MD-WV	6,132,725	459,204	7.5%	0.347	0.500	44.1%
St. Louis, MO-IL	2,805,551	433,910	15.5%	0.399	0.328	-17.7%
San Diego-Carlsbad, CA	3,302,833	430,126	13.0%	0.506	0.687	35.7%
Atlanta-Sandy Springs-Roswell, GA	5,779,463	419,816	7.3%	0.457	0.551	20.6%
Boston-Cambridge-Newton, MA-NH	4,788,014	394,840	8.2%	0.368	0.592	60.8%
Tampa-St. Petersburg-Clearwater, FL	3,019,634	368,211	12.2%	0.523	0.590	12.8%
Portland-Vancouver-Hillsboro, OR-WA	2,417,931	336,768	13.9%	0.442	0.588	33.1%
Las Vegas-Henderson-Paradise, NV	2,151,941	316,255	14.7%	0.552	0.474	-14.0%
San Antonio-New Braunfels, TX	2,426,196	313,428	12.9%	0.596	0.520	-12.7%
Orlando-Kissimmee-Sanford, FL	2,450,261	311,335	12.7%	0.526	0.616	17.2%
Baltimore-Columbia-Towson, MD	2,793,244	292,514	10.5%	0.399	0.652	63.4%
Pittsburgh, PA	2,339,928	277,433	11.9%	0.366	0.449	22.9%
Minneapolis-St. Paul-Bloomington, MN-WI	3,557,528	262,507	7.4%	0.354	0.541	52.7%
Cleveland-Elyria, OH	2,051,431	256,672	12.5%	0.477	0.557	16.9%
Seattle-Tacoma-Bellevue, WA	3,809,717	247,490	6.5%	0.414	0.400	-3.3%
Kansas City, MO-KS	2,106,632	243,706	11.6%	0.407	0.385	-5.5%

Austin-Round Rock, TX	**2,058,351**	**239,444**	**11.6%**	**0.393**	**0.552**	**40.6%**
Sacramento--Roseville--Arden-Arcade, CA	2,289,377	238,580	10.4%	0.507	0.680	34.0%
Indianapolis-Carmel-Anderson, IN	2,007,497	237,352	11.8%	0.468	0.642	37.3%
Denver-Aurora-Lakewood, CO	2,859,706	231,610	8.1%	0.320	0.510	59.4%
San Jose-Sunnyvale-Santa Clara, CA	1,981,616	231,578	11.7%	0.436	0.653	49.8%
Cincinnati, OH-KY-IN	2,168,825	222,352	10.3%	0.412	0.536	30.1%
Charlotte-Concord-Gastonia, NC-SC	2,473,125	198,638	8.0%	0.470	0.594	26.4%
Louisville/Jefferson County, KY-IN	1,285,270	197,456	15.4%	0.440	0.485	10.0%
Virginia Beach-Norfolk-Newport News, VA-NC	1,722,001	196,994	11.4%	0.422	0.427	1.0%
Nashville-Davidson--Murfreesboro--Franklin, TN	1,864,138	192,745	10.3%	0.412	0.594	44.0%
Raleigh, NC	1,302,632	187,209	14.4%	0.385	0.329	-14.3%
Tulsa, OK	985,233	179,085	18.2%	0.527	0.501	-4.8%
Providence-Warwick, RI-MA	1,615,516	178,155	11.0%	0.464	0.771	66.2%
Birmingham-Hoover, AL	1,147,054	162,058	14.1%	0.514	0.376	-26.8%
Milwaukee-Waukesha-West Allis, WI	1,562,954	153,712	9.8%	0.453	0.633	39.7%
Salt Lake City, UT	1,192,970	153,070	12.8%	0.361	0.568	57.3%
Jacksonville, FL	1,475,386	152,651	10.3%	0.498	0.485	-2.6%
Grand Rapids-Wyoming, MI	1,050,440	149,987	14.3%	0.418	0.711	70.0%
Fresno, CA	**978,130**	**149,473**	**15.3%**	**0.754**	**0.713**	**-5.4%**
Oklahoma City, OK	1,369,755	148,028	10.8%	0.487	0.585	20.1%
New Orleans-Metairie, LA	1,262,255	147,273	11.7%	0.532	0.519	-2.5%
El Paso, TX	843,517	141,252	16.7%	0.762	0.706	-7.3%

Table 3. Summary of top MSAs by transit desert population with poverty and minority estimates per MSA.

MSA	Minority overall	Minority in transit deserts	% point diff.	Poverty overall	Poverty in transit deserts	% point diff.
New York-Newark-Jersey City, NY-NJ-PA	**10,618,032**	**1,749,978**	**21.71%**	**2,624,963**	**539,547**	**9.94%**
Los Angeles-Long Beach-Anaheim, CA	9,302,244	1,036,913	16.74%	1,948,988	284,790	9.17%
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	2,296,873	610,283	36.36%	748,266	218,441	14.23%
Chicago-Naperville-Elgin, IL-IN-WI	4,459,242	551,839	21.38%	1,166,199	151,313	6.46%
Houston-The Woodlands-Sugar Land, TX	4,296,001	604,378	16.16%	951,874	130,985	3.20%
Riverside-San Bernardino-Ontario, CA	3,042,395	544,872	9.80%	705,092	93,845	-2.32%
Detroit-Warren-Dearborn, MI	1,443,165	234,431	5.26%	645,356	120,961	5.01%
Phoenix-Mesa-Scottsdale, AZ	2,064,889	378,422	18.50%	674,355	130,491	7.19%
Miami-Fort Lauderdale-West Palm Beach, FL	4,195,350	433,217	16.60%	920,561	94,135	3.46%
Dallas-Fort Worth-Arlington, TX	3,850,979	355,876	19.10%	903,397	91,150	6.04%

San Francisco-Oakland-Hayward, CA	2,784,222	308,317	5.96%	434,756	62,276	3.96%
Washington-Arlington-Alexandria, DC-VA-MD-WV	3,320,087	302,268	11.69%	484,913	60,113	5.18%
St. Louis, MO-IL	733,372	122,493	2.09%	327,664	49,909	-0.18%
San Diego-Carlsbad, CA	1,787,453	305,670	16.95%	403,190	97,323	10.42%
Atlanta-Sandy Springs-Roswell, GA	3,025,833	295,895	18.13%	741,832	77,471	5.62%
Boston-Cambridge-Newton, MA-NH	1,396,119	219,139	26.34%	454,491	70,614	8.39%
Tampa-St. Petersburg-Clearwater, FL	1,104,095	169,167	9.38%	423,436	63,003	3.09%
Portland-Vancouver-Hillsboro, OR-WA	636,196	125,753	11.03%	272,393	53,200	4.53%
Las Vegas-Henderson-Paradise, NV	1,214,263	189,582	3.52%	301,320	39,195	-1.61%
San Antonio-New Braunfels, TX	1,602,631	229,072	7.03%	355,670	43,305	-0.84%
Orlando-Kissimmee-Sanford, FL	1,283,731	216,066	17.01%	354,691	58,073	4.18%
Baltimore-Columbia-Towson, MD	1,200,041	209,400	28.62%	283,441	51,515	7.46%
Pittsburgh, PA	337,159	60,530	7.41%	261,614	42,821	4.25%
Minneapolis-St. Paul-Bloomington, MN-WI	851,775	120,842	22.09%	314,597	54,682	11.99%
Cleveland-Elyria, OH	612,871	99,215	8.78%	296,937	50,506	5.20%
Seattle-Tacoma-Bellevue, WA	1,369,902	98,475	3.83%	360,506	35,771	4.99%
Kansas City, MO-KS	573,609	79,637	5.45%	227,093	30,292	1.65%
Austin-Round Rock, TX	**979,607**	**148,157**	**14.28%**	**234,467**	**40,963**	**5.72%**
Sacramento--Roseville--Arden-Arcade, CA	1,082,238	164,179	21.54%	323,222	43,513	4.12%
Indianapolis-Carmel-Anderson, IN	545,745	110,820	19.50%	259,224	49,102	7.77%
Denver-Aurora-Lakewood, CO	1,020,615	129,134	20.07%	266,357	36,406	6.40%
San Jose-Sunnyvale-Santa Clara, CA	1,344,924	196,355	16.92%	155,309	28,313	4.39%
Cincinnati, OH-KY-IN	441,321	57,039	5.30%	270,070	46,838	8.61%
Charlotte-Concord-Gastonia, NC-SC	950,244	131,086	27.57%	309,454	34,148	4.68%
Louisville/Jefferson County, KY-IN	302,011	71,835	12.88%	164,616	28,520	1.64%
Virginia Beach-Norfolk-Newport News, VA-NC	767,289	100,228	6.32%	193,120	23,753	0.84%
Nashville-Davidson--Murfreesboro--Franklin, TN	511,331	97,189	22.99%	226,647	34,167	5.57%
Raleigh, NC	499,709	88,886	9.12%	134,183	18,648	-0.34%
Tulsa, OK	340,948	72,320	5.78%	140,823	25,955	0.20%
Providence-Warwick, RI-MA	389,934	101,082	32.60%	195,494	43,283	12.19%
Birmingham-Hoover, AL	416,312	71,422	7.78%	170,174	18,842	-3.21%
Milwaukee-Waukesha-West Allis, WI	519,874	88,279	24.17%	214,761	37,190	10.45%
Salt Lake City, UT	331,070	64,320	14.27%	112,424	22,775	5.45%
Jacksonville, FL	539,967	69,823	9.14%	193,080	20,160	0.12%
Grand Rapids-Wyoming, MI	221,178	66,605	23.35%	117,665	29,543	8.50%
Fresno, CA	**686,675**	**102,534**	**-1.61%**	**232,067**	**34,982**	**-0.32%**
Oklahoma City, OK	484,427	69,649	11.69%	192,773	28,755	5.35%

New Orleans-Metairie, LA	609,538	85,457	9.74%	217,167	27,403	1.40%
El Paso, TX	740,660	127,651	2.56%	176,609	24,139	-3.85%

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