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Identifying transit deserts in major Texas cities where the supplies missed the demands

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Abstract: Coined by the author, the concept “transit desert” is developed from the now common concept of a “food desert,” which is an area where there is limited or no access to fresh food (Clark et al. 2002; Jiao et al. 2012; Whelan et al. 2002; Wrigley 1993; Wrigley et al. 2002). The food desert concept has received a lot of attention and influenced planning policies and practices. By applying the same idea to transit systems within urban areas, geographic areas can be identified where there is a lack of transit service. This involves identifying the transit dependent populations as a measure of transit demand, calculating the transit supply, and then subtracting the supply from the demand to measure the gap (Jiao & Dillivan 2013). In detail, transit dependent populations are those who might require transit service to get around more than other people. The transit supply is measured by aggregating a number of criteria that contribute to better transit access and measured within a designated geographic area. Transit deserts are defined as areas where the transit demand is significantly greater than the supply.

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1 Introduction

Coined by the author, the concept “transit desert” is developed from the now common concept of a “food desert” (Clarke et al., 2002; Jiao et al., 2012; Whelan et al., 2002; Wrigley, 1993; Wrigley et al., 2002). By applying the same idea to urban transit systems, geographic areas with high transit demand but low transit service are named as “transit deserts.” Locating transit deserts within cities involves identifying the transit dependent populations as a measure of transit demand, calculating the transit supply, and then subtracting the supply from the demand to measure the gap (Jiao and Dillivan, 2013). In detail, transit dependent populations are those who might require transit service to get around more than other people. The transit supply is measured by aggregating a number of criteria that contribute to better transit access within a designated geographic area. Transit deserts are defined as areas where the transit demand is significantly greater than the supply. Compared to previous transit planning methods based on complicated network modeling (Schöbel, 2011; Nayeem et al., 2014; Nikolić and Teodorović, 2013), this research presents a straightforward GIS method to quickly measure the transit demand and supply at the city block group level and professionally presents the results.

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1.1 Objective

The main objective of this research was to identify the transit gaps in urban areas of five major Texas cities (Austin, Dallas, Fort Worth, Houston, and San Antonio). Through a clearly defined quantitative analysis of transit supply and demand within the cities (Jiao and Dillivan, 2013), the author was able to highlight areas that might need more attention in regards to transportation access and planning. Using this method, transit agencies and local governments can identify urban neighborhoods in great need of transit service and be able to better locate limited transit resources to the most needed urban areas (Garrett and Taylor, 1999; Polzin et al., 2000).

1.2 Research methods

The transit gap analysis was conducted in five major cities of Texas (Austin, Dallas, Fort Worth, Houston, and San Antonio). For each city, transit gaps were measured as the difference between transit supply and demand at the **block group level**. The transit demand, or the transit dependent population, was calculated using the 2012 American Community Survey. These data were joined with GIS shapefiles from the U.S. Census to spatially display the demand data at the block group level. Transit supply was calculated with data collected directly from the involved municipalities and transit agencies.

A formula created by the U.S. Department of Transportation was used to calculate the transit dependent population at the block group level for each city (Steiss, 2006). **First, the household drivers are calculated by subtracting the persons living in group quarters from the population that is 16 years or older. Then, the transit dependent household population is calculated by subtracting the vehicles available from the household drivers and adjusted by the national level carpooling ratio** (McKenzie, 2015); see formulas (1), (2) and (3).

$$\text{Household drivers} = (\text{population age 16 and over}) - (\text{persons living in group quarters}) \quad (1)$$

$$\text{Transit-dependent household population} = (\text{household drivers}) - (\text{vehicles available}) * \text{national level carpooling ratio} \quad (2)$$

$$\text{Transit-dependent population} = (\text{transit-dependent household population}) + (\text{population ages 12–15}) + (\text{non-institutionalized population living in group quarters}) \quad (3)$$

Here group quarters and non-institutionalized populations living in group quarters were defined as “a place where people live or stay other than the usual house, apartment, or mobile home. There are institutional group quarters (nursing homes, mental hospitals or wards, hospitals or wards for chronically ill patients, hospices, and prison wards) and noninstitutional group quarters (college or university dormitories, military barracks, group homes, shelters, missions, and flophouses)” (U.S. Census Bureau, 2013).

Census data on vehicles available are not publicly available at the block group level. These data were collected at the census tract level and then proportionally estimated at the block group level based on the size of individual block groups and census tracts. In some block groups, there are more vehicles available than household drivers, thus resulting in a negative value for the transit dependent population. In these cases, the transit dependent population was adjusted to a value of zero, since it would be impossible to have a negative number of people. Once the transit dependent population was calculated for each block group, the value was divided by the acres of each block group to calculate the transit dependent population density per block group. Then Z-scores were calculated for each block group to standardize

the transit dependent population density in each city.

Transit supply in each city was measured using the following seven criteria (Estupiñán and Rodríguez, 2008; Pucher and Buehler, 2009)

1. Number of transit stops within each block group
2. Frequency of transit service within each block group (based on weekday service)
3. Number of transit routes within each block group
4. Total length of sidewalks (miles) in each block group
5. Total length of bike routes (miles) in each block group
6. Total length of low speed limit roads (miles) in each block group
7. Intersection density in each block group

These seven criteria were chosen because together they address both the physical presence of transit as well as the ability to access it. Numerous transit stops and frequent transit services are not effective if it is too difficult to access them. Geospatial data for each of the criteria were spatially joined in GIS with block group shapefiles in each city. Once each of the criteria was measured at the block group level, the value was divided by acres to get the density value and then a z-score value was calculated to standardize each criterion. The z-scores of seven criteria were aggregated to represent the level of transit supply for each block group. Finally, demand and supply Z scores were subtracted and a final numerical value was calculated for each block group to determine an excess or lack of supply (Hulchanski et al., 2010). Block groups with significantly less supply than demand were shown to have transit gaps and were identified as possible transit deserts (4).

$$\text{Transit Gap} = \text{Supply (Z score)} - \text{Demand (Z score)} \quad (4)$$

2 Results

Houston has the highest transit dependent population percentage (38.22%) followed by Dallas (26.19%), San Antonio (23.74%), and Fort Worth (22.46%). Austin is the only city that has less than 20% transit dependent population (14.70%) (Table 1).

Table 1: Transit and built environment characteristics of Texas cities

Measurements	Austin	Dallas	Fort Worth	Houston	San Antonio
Population [2013 estimate, July 2013]	885,400	1,257,676	792,727	2,195,914	1,409,019
Transit Dependent Population	130,146.56	329,386.94	178,058.99	839,284.33	334,529.53
Percent Transit Dependent	14.70%	26.19%	22.46%	38.22%	23.74%
Area [sq. mi.]	297.9	340.52	339.82	599.59	460.93
Density [pop/sq. mi.]	2,972.14	3,693.40	2,332.79	3,662.36	3,056.90
Routes	80 bus 1 rail	113 bus 6 rail	47 bus 1 rail	134 bus 1 rail	111 bus
Stops Within City Limits	2,620	7,653	1,977	9,182	6,810
Average Weekday Ridership	120,500 bus 2,500 rail	128,511 bus 103,789 rail	25,000 bus 8,000 rail	236,402 bus 42,652 rail	139,335 bus
Trips [24 hr, weekday]	144,158	350,969	56,832	528,367	559,984
Length, bike routes [mi]	623.81	320.59	310.21	505.69	238.19
Length, sidewalks [mi]	2,306.73	6,199.98	2,326.00	N/A	4,777.34
Length, low-speed roads [mi]	2,653.93	5,159.37	3,714.45	6,748.78	4,859.63
Intersections	19,357	65,823	26,217	61,686	47,242
Intersection density [intersections/area]	64.98	193.30	77.15	102.88	102.49

Houston also operates the largest transit system among these five cities. With one rail line, 134 bus routes, and 9,182 stops, Metropolitan Transit Authority of Harris County (METRO) spreads the service across 600 square miles, which includes 2.2 million residents. METRO has an average weekday ridership of 280,000, from which 84% are bus riders and 16% are rail riders. The city also has the longest low-speed roads (6,748 miles) and the second-longest bike lanes (506 miles) after Austin (624 miles). Dallas has the second largest transit system with 6 rail lines, 113 bus routes, and 7,653 stops within the municipal boundary. On average, it has 230,000 weekday riders, from which 53% are bus and 47% are rail riders. It also has the longest sidewalks (6,200 miles) and the second-longest of low-speed roads (5,159 miles) among the five cities. Austin and Fort Worth have comparable populations (885,400 vs. 792,777), geographic areas (298 square miles vs. 340 square miles), and similar amounts of sidewalks, low-speed roads, and intersection densities. However, Austin has twice the amount of bike lanes than Fort Worth (624 miles vs. 310 miles). Both systems are made up of bus lines and a single commuter rail line, but the ridership and the number of trips made within a 24-hour period are drastically different (144,148 vs. 56,832). Austin's average weekday transit ridership is almost four times higher than that of Fort Worth (123,000 vs. 33,000), which suggests Austin residents are more likely to use public transit services than their counterparts in Fort Worth. San Antonio is the only city that does not have rail service out of these five cities, although it has the second largest population (1,409,019), the second largest transit dependent population (334,529), and the highest number of trips made within a 24-hour period.

Table 2: Largest transit gaps in Texas cities

Largest Gaps		
Austin	Neighborhood	Gap
1	West Campus (25th Street)	-12.90
2	West Campus (22nd Street)	-5.87
3	West Campus (27th Street)	-5.58
4	Pleasant Valley (East Riverside Drive)	-4.84
5	West Campus (26th Street and Shoal Creek)	-4.78
Dallas	Neighborhood	Gap
1	Dallas North Tollway & President George Bush Turnpike	-8.59
2	I635 & Walnut Hill Lane	-8.32
3	Dallas North Tollway & Lemmon Avenue	-6.02
4	Royal Lane & Skillman Street	-5.73
5	Old East Dallas (Bennet Avenue)	-5.59
Fort Worth	Neighborhood	Gap
1	TCU	-11.63
2	Ridgemoor (Ridgemoor & I30)	-6.91
3	Western Hills (Between Cherry Lane & Las Vegas Trail)	-5.87
4	I30 (Between Oakland Hills Drive & Country Club Lane)	-5.60
5	South Hills (Crowley Road & Altamesa Boulevard)	-4.92
Houston	Neighborhood	Gap
1	Sharpstown (Westpark Tollway & I65)	-12.55
2	Chinatown (Westpark Tollway & Sam Houston Parkway)	-10.37
3	I45 & I610	-8.86
4	Gulfton (I69 & Westpark Tollway)	-8.82
5	I45 & I610	-7.86
San Antonio	Neighborhood	Gap
1	Braun's Farm	-6.44
2	I10 & Wurzbach Road	-6.10
3	Hausman Road & Babcock Road	-5.51
4	I410 & I10	-4.59
5	Wurzbach Road & Evers Road	-3.65

Table 2 shows the top five neighborhoods in each city have the highest levels of transit demand. There is no clear spatial pattern of their spatial distribution. Some block groups are located near downtown (e.g., old East Dallas) or near large universities (e.g., UT-Austin, TCU) (Balsas, 2003) and some are in the newly developed suburban areas (e.g., Sharpstown and Chinatown in Houston, Ridgemar Hall in Fort Worth). Table 3 shows the block groups with the smallest transit gaps within each city. Most of these block groups are located in the downtown areas, where transit demands are relatively well satisfied. Maps of demand, supply, and gaps for each city are shown in Figures 1 through 5; the greater gaps are identified by the darkness of the color. These maps show that Austin and Fort Worth have the fewest transit desert areas, followed by Dallas. However, Houston and San Antonio have more urban areas where the local transit demands are not met by the supplies.

Table 3: Smallest transit gaps in Texas cities

Smallest Gaps		
Austin	Neighborhood	Gap
	1 Downtown	2.09
	2 North Campus	2.04
	3 UT Campus (Northeast)	1.65
	4 Heritage (Between Lamar and Guadalupe)	1.59
	5 North Downtown & Capitol	1.55
Dallas	Neighborhood	Gap
	1 Downtown	7.16
	2 Downtown (East)	5.18
	3 Downtown (North)	4.19
	4 Downtown (West)	3.77
	5 Oak Lawn (North Hall Street)	3.61
Fort Worth	Neighborhood	Gap
	1 Downtown	3.72
	2 Downtown (Panther Island)	3.63
	3 Boca Raton Boulevard & Country Club Lane	2.36
	4 Medical district (Rosedale & Hemphill)	2.25
	5 Arlington Heights (Camp Bowie & Hulen)	2.15
Houston	Neighborhood	Gap
	1 Downtown on Buffalo Bayou	7.52
	2 Downtown (I45 and Eastex Freeway)	7.06
	3 Midtown	4.02
	4 Northeast Downtown	3.52
	5 Midtown (Houston Community College)	3.24
San Antonio	Neighborhood	Gap
	1 Downtown (West Riverwalk)	7.67
	2 Downtown (East Riverwalk)	3.89
	3 Midtown (San Antonio College)	2.60
	4 Fredericksburg Road & I10	2.56
	5 Midtown (San Pedro Park)	2.44

3 Discussion

Transit deserts were identified in all these five cities. Spatially, these transit desert areas were located in different parts of the city. Austin and Fort Worth have significantly fewer transit deserts than Houston and San Antonio (Figures 1–5). In terms of transit supply, most of these cities have a high concentration of transit service in or near the city center with decreasing services as distance from the center increases (Daganzo, 2010). The areas with high concentrations of supply often extend along major corridors. Transit demand was often scattered sporadically throughout each of the cities. The only consistency for

transit dependent populations was that they were not located in the central part of the city or downtown. It is not clear whether or not, and to what extent, the supply has an effect on the demand. One way of addressing this problem would be to include more socioeconomic measures to adjust for transit dependent populations (Giuliano, 2005). Further, all five cities have significantly higher proportion of transit demand populations than the transit mode market shares, which indicates that the transit dependent population living outside of a transit system's service area might have to depend on cars and operate them even when it is not economically feasible, purely out of necessity. Local governments need to pay special attentions to these population groups, who are transit dependent but forced to drive, and make sure their transit demands are satisfied within cities.

Figure 1: Transit deserts analysis in Austin, Texas

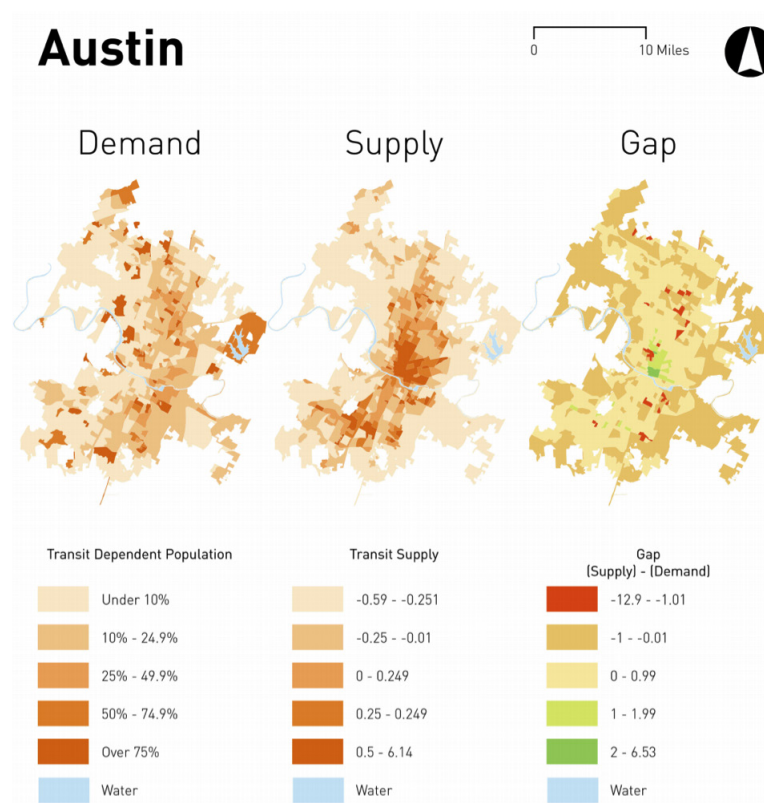


Figure 2: Transit deserts analysis in Dallas, Texas

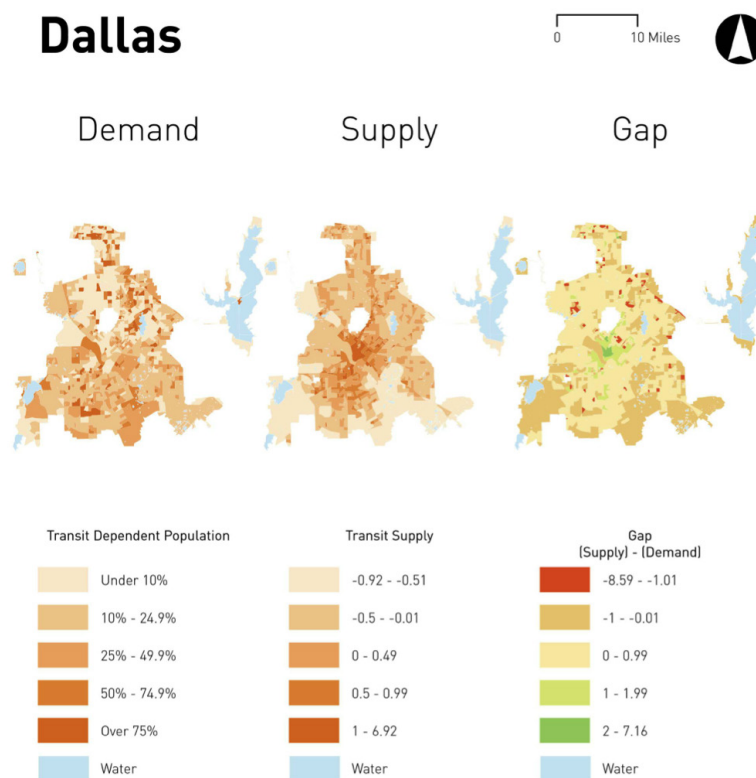


Figure 3: Transit deserts analysis in Fort Worth, Texas

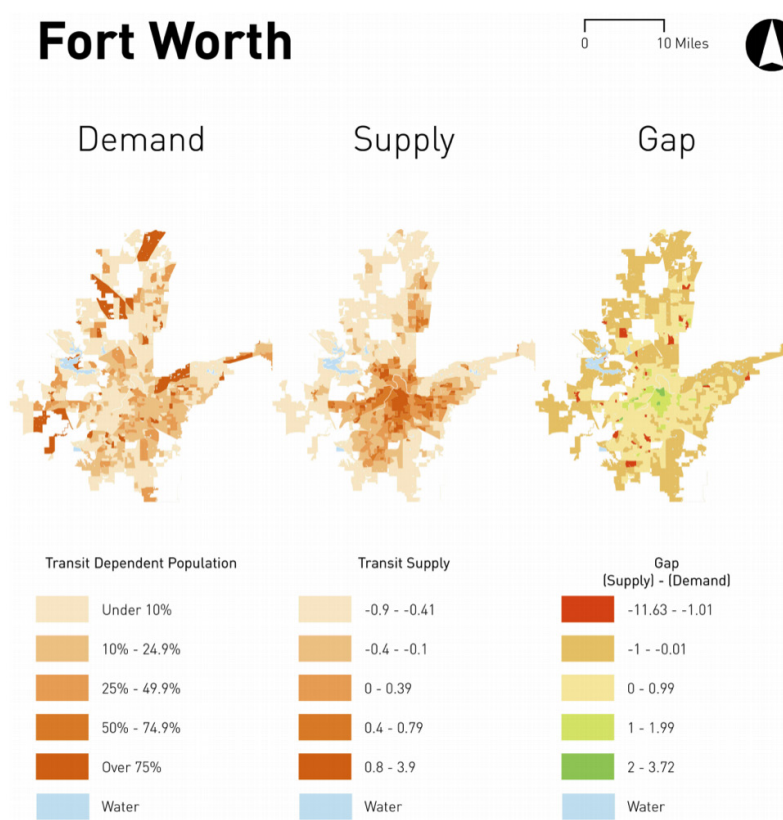
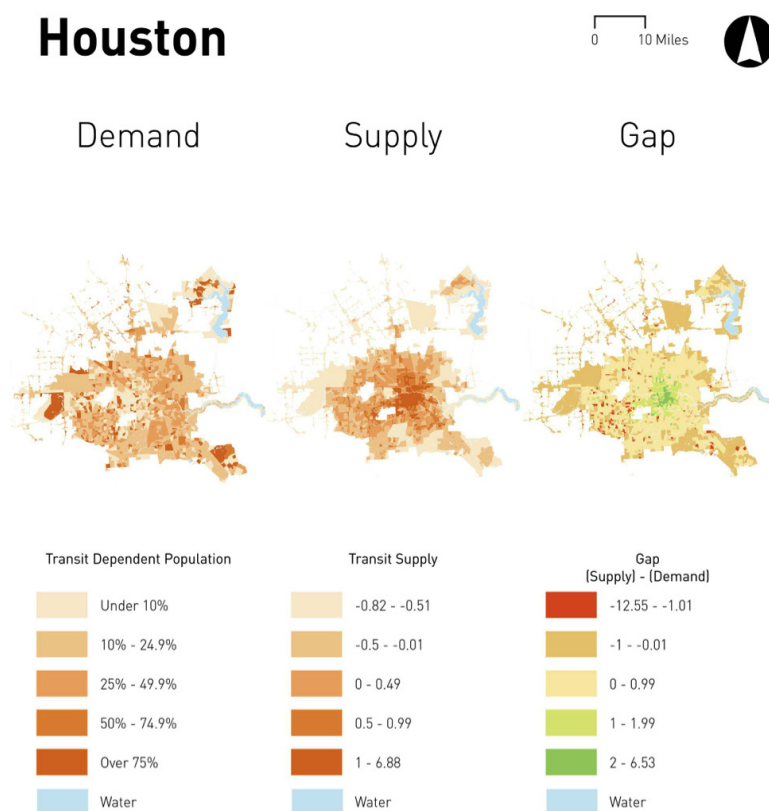
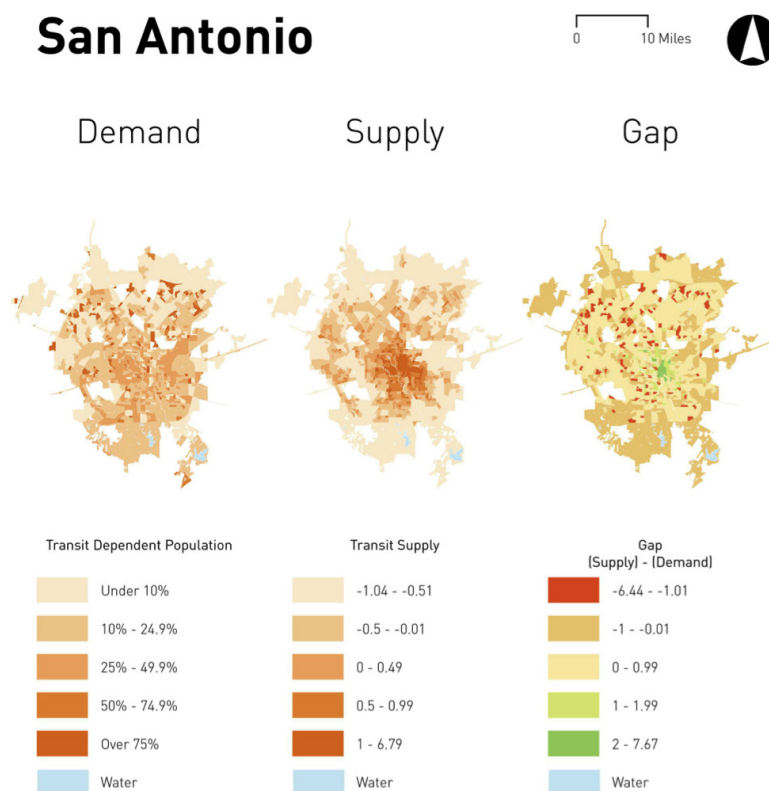


Figure 4: Transit deserts analysis in Houston, Texas**Figure 5:** Transit deserts analysis in San Antonio, Texas

There was no clear grouping of transit deserts identified in Austin. The neighborhoods around the University of Texas at Austin were categorized as transit deserts although these neighborhoods do have a high transit supply compared to the rest of city. The population density and a high concentration of students in these neighborhoods could contribute to the situation. Similar to Austin, Fort Worth also has very few transit deserts identified. Most of the city's transit demand is fairly well served. There are a few block groups with greater demand than supply within the city. Most of these neighborhoods are located in the suburban or rural parts of the city. This may be caused by the lack of adequate sidewalks or bike lanes. In the case of Dallas, the majority of the city is well served with public transit. It has fewer dark colored block groups than other cities. Its 6 rail lines, 119 bus routes, and 7,653 stops are well spread throughout the city. However, there are some transit deserts located near downtown Dallas (e.g., Old East Dallas) and in the northern part of the city. This may be because of the lacking of transit and infrastructure investment in these outskirt areas due to the fast development.

Compared to Austin, Dallas, Fort Worth, Houston and San Antonio have much more transit deserts identified. In the case of Houston, there is a high concentration of transit deserts in the southern part of the city (e.g., Sharpstown and Chinatown), where the median household incomes are lower compared to the rest of the city. San Antonio has the most transit dependent populations but is the only city without rail service. The whole city is relatively under served by transit and has the highest number of transit deserts among the five cities. All these signals indicated a much higher demand for transit services compared to the rest of the four cities.

As a summary, all five cities have higher proportions of transit dependent populations than the transit market shares, which indicates a potential high demand for transit services. Compared to Houston and San Antonio, transit demands are fairly met in Austin, Dallas and Fort Worth. Although there is a fair amount of transit deserts identified in Houston, San Antonio has the strongest demand for transit infrastructure among major Texas cities. Local governance, politics and taxation regimes play major roles in distributing public transportation investments for transit development and improvement. For example, Austin gets its transit funding through a one-cent sales tax, while Fort Worth transit funding comes through only a half-cent sales tax (Hegar, 2016). Thus, in order to remove possible transit deserts, planners need to work with local government officials to develop more transit friendly policies and channel in more investments. This research filled some existing gaps in city level transit optimization by presenting an efficient and approachable method to measure transit demand and supply and transit needs within cities (Klier and Haase, 2015).

4 Conclusions and limitations

This research demonstrated an effective method to easily quantify transit demand and supply within cities and visually highlights the urban areas where the transit needs are far greater than the transit services. This information can help transportation planners to better plan urban transit systems to serve those who need it most. In an age where transit systems often operate on very limited financial resources, it is extremely important that these systems operate and function as efficiently as possible, serving not only a high number of people, but also highly dependent people, resulting in a more socially just transit system.

While this study has its limitations and can be improved from the following perspectives (e.g., including more socioeconomic and built environment variables for transit demand and supply measures, quantifying transit dependent populations by block group populations, rather than by block group size), it should be noted that the concept of a transit desert and methods used for measuring them are relatively new. This paper might not provide a definitive way of addressing the transit desert problem, but it does act as a step in the right direction. By providing a clear and concise method for measuring transit deserts, this can act as a foundation for future research in the field. The straightforward methods make this research accessible to academics, and most importantly, to the cities and transit agencies that will actually benefit from this research and have the ability to implement changes based on the findings.

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