Attachment D
Transit Propensity Score for Census Tracts in Los Angeles County
Methodology

The concept of a Transit Propensity Score (TPS) is that there are physical, locational, and socio-economic factors that can potentially serve as a predictor of where transit service, if made available, could thrive. Most models, either regionally based or corridor based rely on the supply of transit service, its frequency, etc. as a key element to predict transit use. The Centers for Neighborhood Technology (AllTransit™), for example, provides a Transit, Jobs, Health, Equity, Bikeshare and Carshare, among other scores for each area or region selected. Their goal is to explore the social and economic impacts of Public Transit that is offered.[1] Alternatively, many cities have turned to the Census to collect data and compare the results of the socio-economic factors, journey to work, and other parameters that can be associated with transit use. Robert Bush, AICP of HDR presented a paper at the APTA Bus and Paratransit Conference held in Raleigh North Carolina on May 8, 2012. The principal question at the heart of the work was "Where should transit service be provided?"

Mr. Bush examined characteristics of transit riders using the following demographic factors:

1. Zero Vehicle housing units
2. Mobility limitations that prevented individuals from going outside the home
3. Employment disabilities
4. Minority populations
5. Recent immigrant populations with a tenure of less than 10 years
6. Low income households (Income less than or equal to $15,000
7. Females

All these factors were found to be relevant when controlling for income. Certain factors were rejected because of a lack of available data at the census block group level. These rejected variables included younger and older workers. Education played a significant role in defining a category of commuters that were found to have higher income but primarily related to rail travel. Finally, the team did not use categories of individuals who were primarily renters and non-licensed drivers because the variables could not be controlled for income. The resultant model, added an 8th factor to the above list – population density.

Ultimately, the research came down to two major factors – population and employment density. Figure 1 displays the results of the research and displays the linkage between the two highest ranking factors – population and employment density and the transit service supportive of that ratio. The study also provided a table which displayed the relationships between Mode and Density. Shown in Exhibit 1.

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[1] CNT has created a robust, one of a kind database consisting of stop, route and frequency information for 824 transit agencies in regions with populations greater than 100,000 as well as a large number of smaller regions and agencies. Metropolitan areas as defined by the U.S. Office of Management and Budget with 2013 populations greater than 100,000 were chosen, and the transit agencies serving these areas were compiled from the 2013 National Transit Database as well as the American Public Transportation Agency. Based on their website, CNT has collected data from 824 Transit Agencies, covers 661,966 stop locations, and 13,099 routes.

Figure 1: Employment and Population Supportiveness by Mode

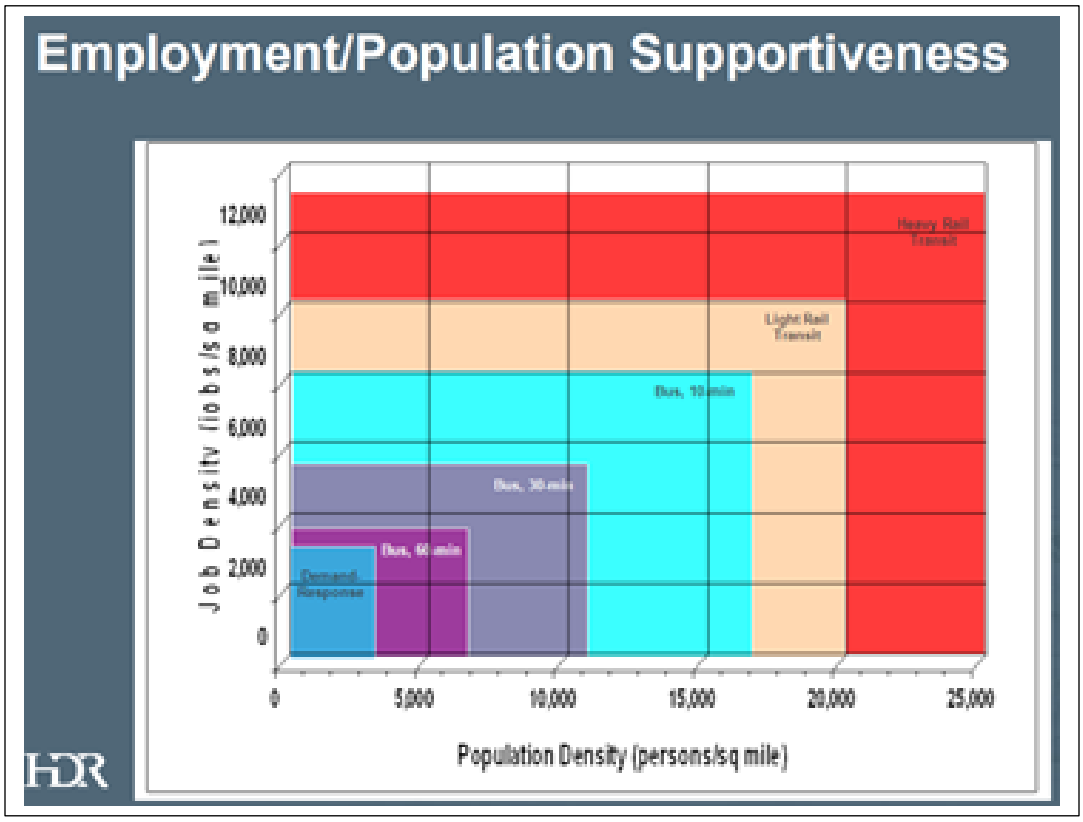
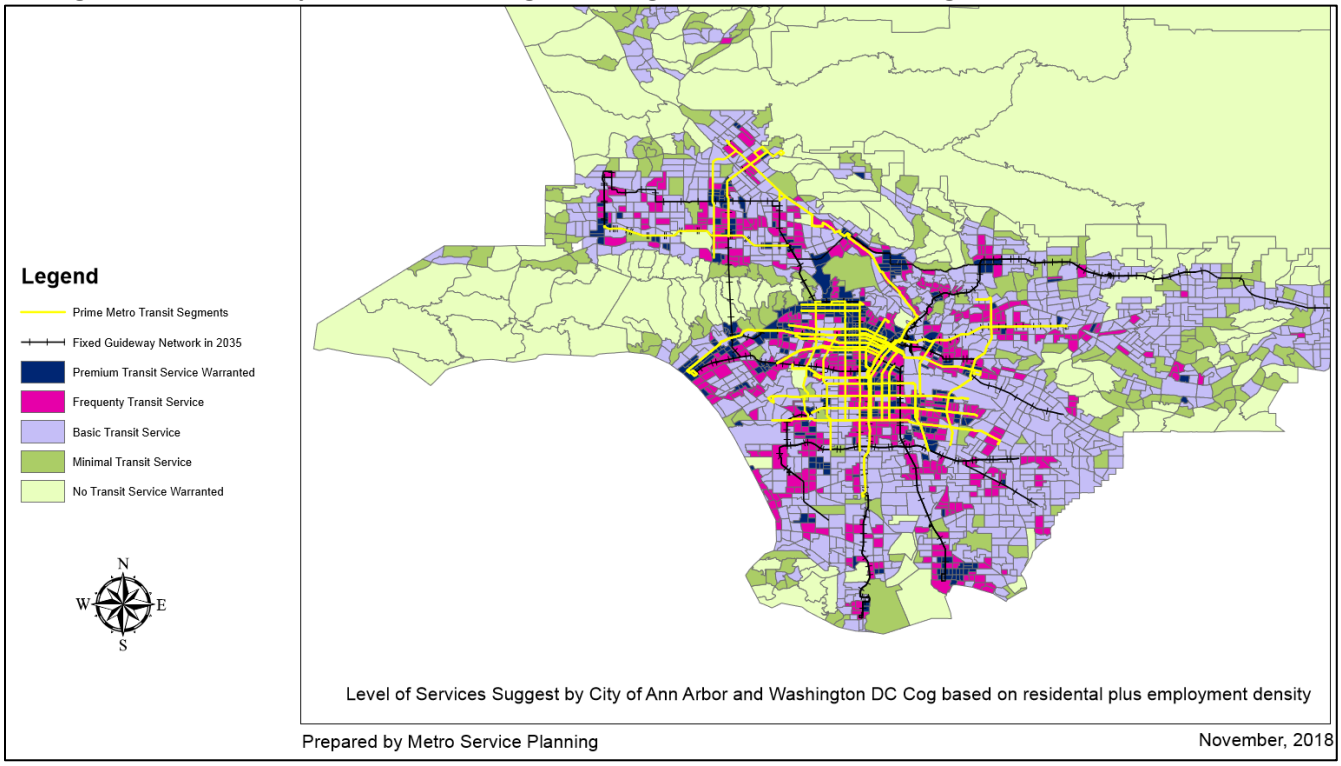


Exhibit 1 – Relationship between Mode and Density						
Service Level	**DU / Acre**		**Population / Square Mile**		**Jobs / Acre**	
	Low	High	Low	High	Low	High
Demand Resp	2	3	3,500	5,000	2,000	3,000
60 Min Freq	3	4	5,000	6,500	3,000	3,000
30 min Freq	4.5	6	7,500	10,00	4,000	5,000
10 min freq	7.5	10	12,500	16,500	6,000	8,000
LRT	9	12	15,000	20,000	8,000	10,000
Rapid	12	15	20,000	25,000	10,000	13,000

In a study completed for Ann Arbor Michigan, the researchers there found that population and employment density are two key factors that can be used to predict transit service.[2] Applying these two criteria to census tracts in Los Angeles the resultant mapping of transit propensity results are shown in Figure 2.

[2] The Study was conducted for the City of Ann Arbor Michigan in 2009 as part of the *Transportation Plan Update*. In their approach, thresholds were estimated from Urban Development Intensities in the Washington, D.C. area by Terry Holzheimer and residential densities from in *Public Transportation and Land Use Policy*.

Figure 2 -Transit Propensities in Los Angeles Using Ann Arbor and Washington DC Studies



The most notable result of application of the Ann Arbor model is the definition of major transit corridors in the Los Angeles area that are supportive of different types of service. The model suggests that the darker the area, the more likely people are to be disposed towards transit services. As the population and employment densities are reduced, as expected, the propensity for transit use also declines. This result using the Ann Arbor Study mirrors the result in the HDR work done for Raleigh North Carolina. Importantly, the Ann Arbor method was completed without looking specifically at the availability of transit service. This approach is very useful for informing the NextGen study as will be discussed later.

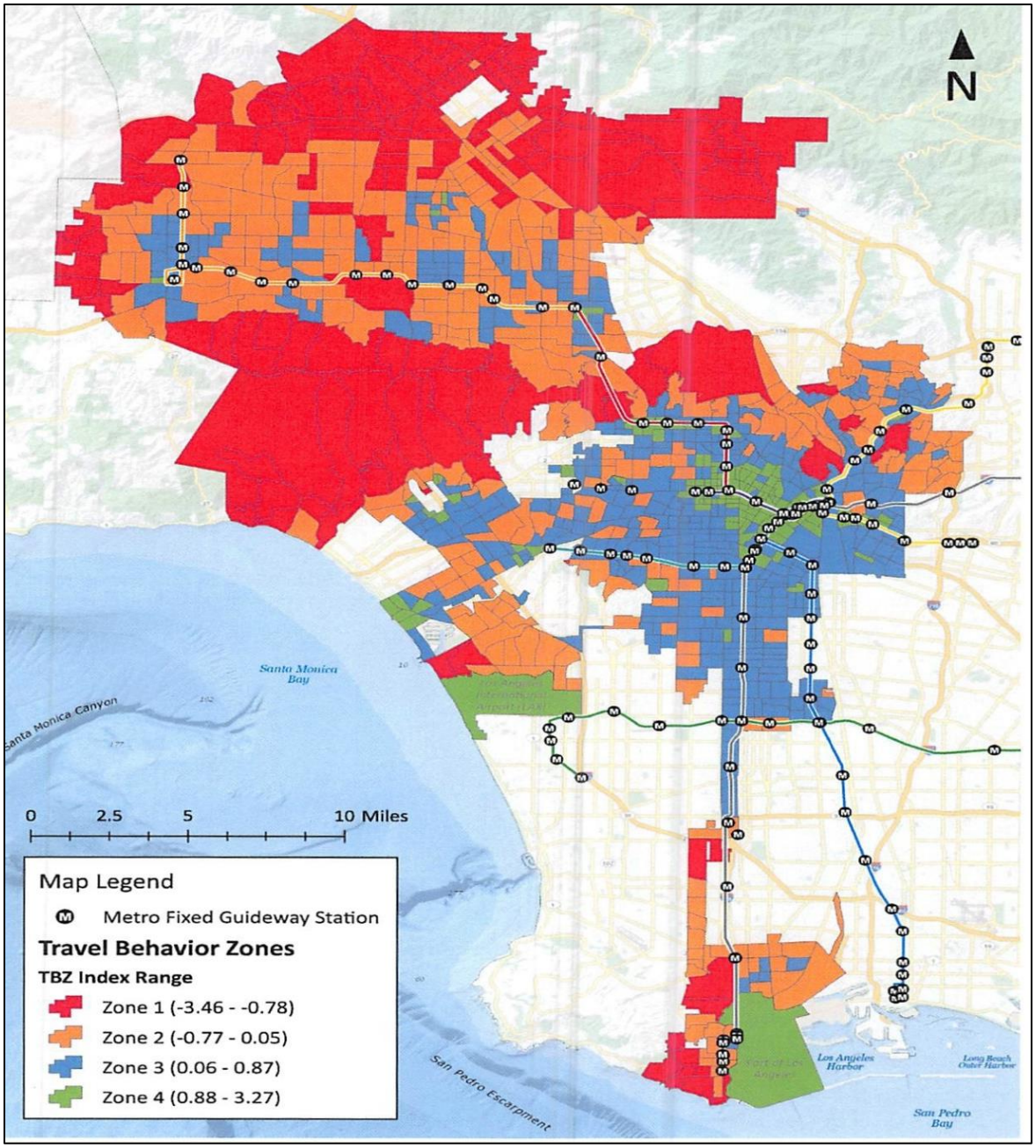
Finally, in this survey of socio-economic factors likely to affect transit ridership produced by others, the City of Los Angeles undertook an effort to define Travel Behavior Zones.[3] The values of their index run from 1 to 4 and are based on the following factors:

1. Population Density
2. Daytime Population density
3. Land Use Diversity Score
4. Intersection density
5. Distance to the nearest BRT or Rail Station
6. Distance to the nearest bus stop

[3] Technical Summary, *Characterizing Travel Behavior Zones* in Los Angeles, 2016.

The land Use Diversity score measures the mix of uses in an area and includes residential, retail (excluding big box stores), entertainment, office and institutional uses. Figure 3 displays the results of the City's analyses.

Figure 3 – Map of City of Los Angeles Travel Behavior Zones



Not surprisingly, the zones range from a low TBZ score (Red) to the highest TBZ score (Green and Blue). The City also superimposed a map of the rail transit system in Los Angeles as of 2016 before the EXPO line was extended to Santa Monica. Note, areas on the map that are white in color are not part of the City of Los Angeles. However, for the most part the rail system is in the densest TBZ locations.

NextGen Bus Study

The NextGen Bus Study is intended to redraw the bus system for Los Angeles. This process of refreshing the system extent was undertaken because of recent ridership declines and data taken from regional surveys that indicate that the bus system is not providing service to the places that people need to travel. As a result, Metro staff undertook a study to develop its own propensity index or score based on the 2010 Census, and its updates through 2016, as well as locations of major attractors of transit ridership, including schools, shopping centers, hospitals, and other institutions. The model was made significantly more robust than those of the literature survey above and produced results like the population and employment density formulations.

The TPS, however, is a device to estimate how likely individual census tracts might use transit service based on the underlying demographic and geographical data of the tract. Data sources used include the 2010 US Census, SCAG regional model data, various Los Angeles County resources from the GIS data portal, ArcGIS online resources, and data developed by Metro staff.

The TPS considers that there are three major components of predisposition to ride transit. They are:

1. Elements of Demand -e.g. Population and employment densities, including seniors, persons aged 18-34, and persons that are attending grades K-12. According to a recent TCRP Study that seeks to shed light on transit propensity, transit use is significant among millennials (ages 18-34). Hence, Metro staff included the millennials as identified in the census as one of the indicators[4].
2. Market Segments - e.g. characteristics relating to the reason for travel. Some people are commuters, some are Transit Dependent, and some are choice riders. Each one of these markets has attributes broken down as follows:
    a. Commuters - ages 35-54, and 55 years or older, have a higher education above 12th grade, and incorporate many single individuals.
    b. Transit dependents - comprised of individuals with zero cars available, lower income, ages 10-19, ages 55+, single mothers, and individuals with disabilities
    c. Choice riders, comprised of individuals between the ages of 20-34, have higher education beyond 12th grade, and are single (no children).
3. Built Environment - aspects of the environment that people must navigate to travel to and from. Attributes that fall into this area of the TPS include:
    a. An assessment of the walkability of the census tract based on the number connected street intersections
    b. the square footage of built development, and

[4] M. Coogan, G. Spitz, T. Adler, N. McGukin, R. Kuzmyak, and K. Karash, *Understanding Changes in Demographics, Preferences, and Markets for Public Transportation,* TCRP 201, TRB, National Academies of Science, Engineering and Medicine, 2018.

c. housing density

The three components of the TPS were weighted as follows:

a. Elements of Demand - 30%
b. Market Segments - 30%
c. Built Environment – 40%

The individual elements that make up the three categories were weighted according to the number of attributes for that category and all attributes within a category had an equal contribution.

The Total Score includes the following 19 measures:

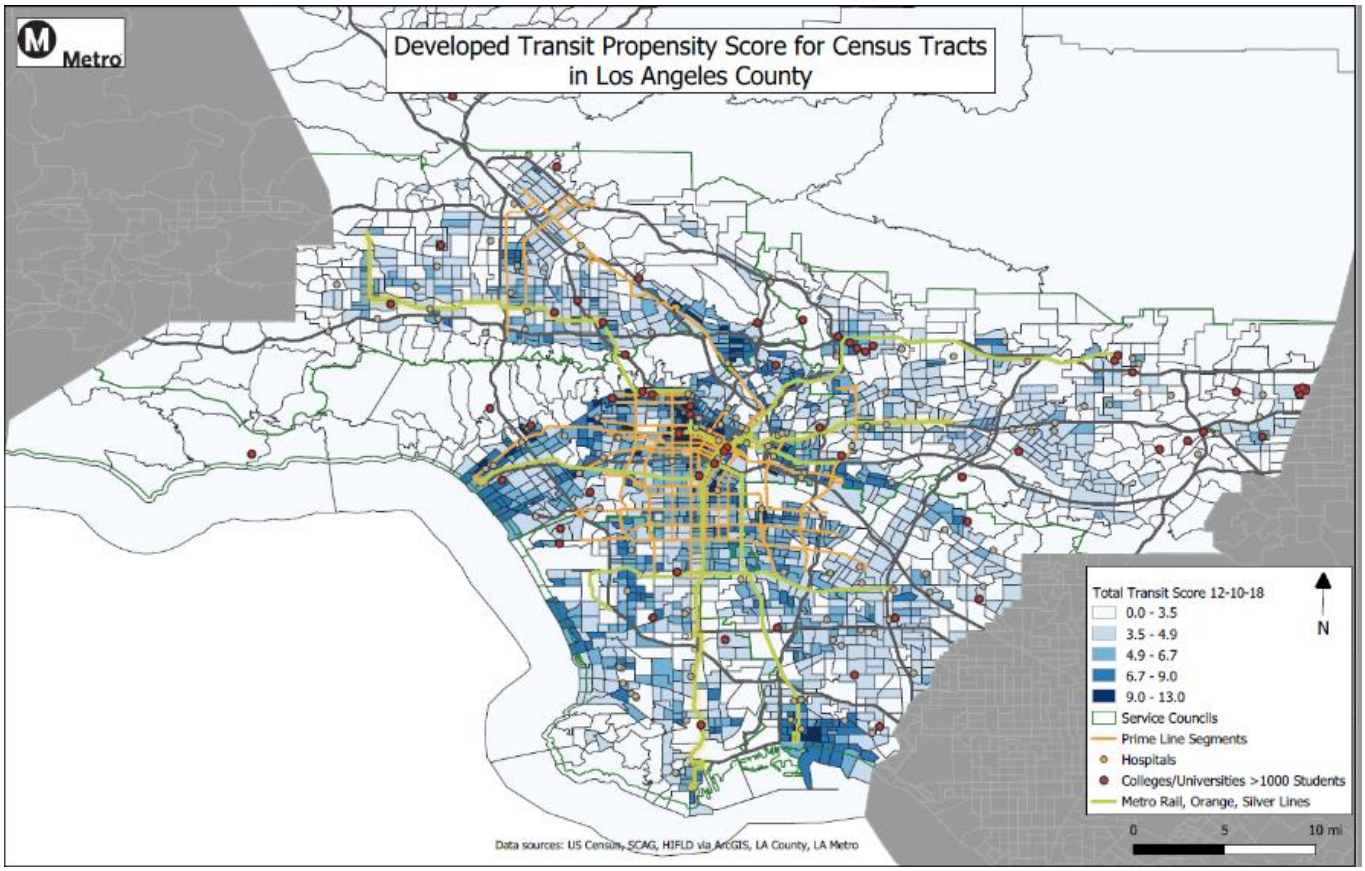
- Population per Acre
- Employment per Acre
- Non-Industrial Employment per Acre
- School Enrollment per Acre (includes Elementary, Middle, and High Schools)
- University population (includes enrollment and employment)
- Home-Based Shopping Trips per Acre
- Zero Car Households per Acre
- Poverty / Low Income Households per Acre
- School Age Students (age 10 -19) per Acre
- Seniors over 55 as of 2010 per Acre
- Single Mothers per Acre
- Disabled population per Acre
- Individuals Aged 20 to 34 per Acre
- Population with a bachelor's degree or higher per Acre
- Population that is single per Acre
- Individuals Aged 35 to 54 per Acre
- Walkability of the Census Tract (either a score of 0 or a 5)
- Housing units per Acre
- Square feet of occupiable space per acre

Each measure has the tract scores distributed into a natural break (Jenks Methodology) distribution of 5 groups, and then given a score of 1 through 5. Then, all the scores for each component are added and divided out to a total score of 5 for each component. A multiplier of 4/3 is used to account for the extra weight of the built environment component. The three final components are added to come up with a final score, which is again distributed into natural breaks.

Walkability is a measure that seeks to blend the density of intersections (nodes) with a limited block length. A tract is walkable when the connected node ratio (CNR) is at least 0.9 and the average block length is no more than 600 feet for given street block. CNR is the number of street intersections divided by the number of intersections plus cul-de-sacs and street ends. These thresholds were chosen based on

a variety of measures suggested by urban geographers and seeing which ones line up the best with Metro transit boardings. The walkability score is not unlike the one used by the City of Los Angeles. The resultant TPS is shown in Figure 4. Metro is continuing to refine its definition of walkability and has contracted with "Walkscore.com" to provide more detailed information on walkability. This document will be updated upon receipt of that information.

Figure 4 – Resultant Transit Propensity based on the Los Angeles Metro Methodology

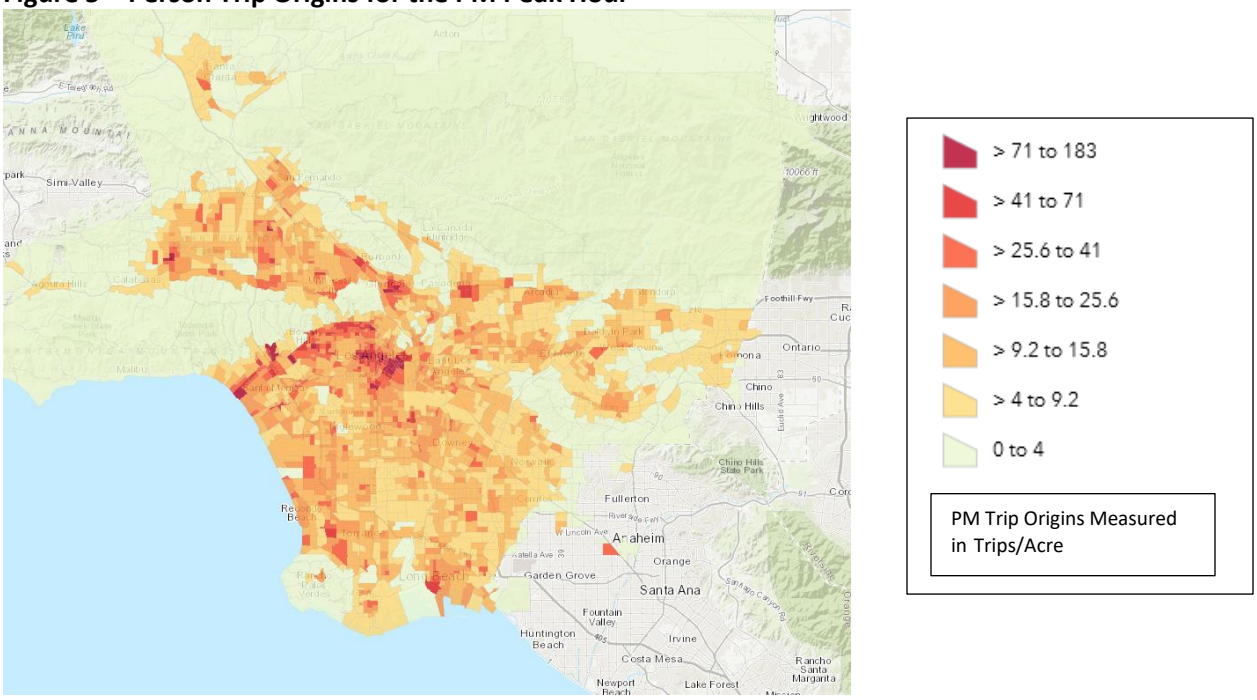


Conclusion

Metro staff successfully created a TPS for the City and County of Los Angeles. The results of the application of the scoring methodology reveal similar patterns found in an examination of the two-variable model shown in Figure 2 as well as mirrors studies performed by the Service Development Department relative to riders by time of day. Both methods provide substantial evidence that the TPS can be used as a predictor of transit use.

As shown in Figure 5, the PM peak origins mirror the distribution of propensities displayed in Figure 4. The conclusion is that the Metro TPS adequately models areas that require transit service.

Figure 5 – Person Trip Origins for the PM Peak Hour



Appendix

Scores for each of the categories are sorted using natural breaks in the data (Jenks).

- A total score greater than 0 and less than 3.5 was assigned a score of 1
- Total Score between 3.5 and 4.9 was assigned a score of 2
- Total Score between 4.9 and 6.7 was assigned a score of 3
- Total Score between 6.7 and 9.0 was assigned a score of 4
- Total Score between 9.0 and 13.0 (maximum score attained by any census tract) was assigned a score of 5

The details of the scores by category are shown in Exhibit 2. The latest formula used to calculate the TPS is shown in Exhibit 3. The table of Variables is described in Exhibit 4.

Exhibit 2 --Details of Each Measure				
Measure	**Numerator**	**Denominator**	**Natural Break Points**	**Dta Source**
Population per Acre	Total population	Total Land Acreage of Census Tract	0-12.16 (1) 12.16-25.30 (2) 25.30-43.05 (3) 43.05-76.80 (4) 76.80-147.64 (5)	2010 US Census
Employment per Acre	Employment Locations	Total Land Acreage of Census Tract	0-7.003 (1) 7.003-20.049 (2) 20.049 -47.576 (3) 47.576-117.288 (4) 117.288-268.663 (5)	2010 US Census
Non-Industrial Employment per Acre	Non-Industrial Employment Locations	Total Land Acreage of Census Tract	0-6.355 (1) 6.355-19.570 (2) 19.570-47.065 (3) 47.065-106.699 (4) 106.699-239.838 (5)	2010 US Census
School Enrollment per Acre	Enrolled Students in identified Elementary, Middle, High, and Day Schools	Total Land Acreage of Census Tract	0-1.832 (1) 1.832-5.834 (2) 5.834-12.560 (3) 12.560-26.451 (4) 26.451-54.201 (5)	California State Data Compiled by Metro Staff
University Population	University Enrollment plus Employment	N/A	0-1,216 (0) 1,216-5,532 (1) 5,532-13,105 (2) 13,105-26,305 (3) 26,305-43,733 (4) 43,733-66,025 (5)	ArcGIS Online
Home-Based Shopping Trips per Acre	Home-Based Shopping Trips	Total Land Acreage of Census Tract	0-1.569 (1) 1.569-4.729 (2) 4.729-10.664 (3) 10.664-29.043 (4) 29.043-52.738 (5)	Southern California Association of Governments
Zero Car Households per Acre	Zero Car Households	Total Land Acreage of Census Tract	0-1.203 (1) 1.203-3.878 (2) 3.878-8.315 (3) 8.315-15.563 (4) 15.563-28.193 (5)	2010 US Census
Poverty / Low Income Households per Acre	Population in Poverty	Total Land Acreage of Census Tract	0-3.365 (1) 3.365-8.765 (2) 8.765-17.606 (3) 17.606-38.316 (4) 38.316-78.695 (5)	2010 US Census
School Age Students per Acre	School Age Students (Population Age 10-19)	Total Land Acreage of Census Tract	0-1.863 (1) 1.863-3.958 (2) 3.958-6.626 (3) 6.626-11.483 (4) 11.483-23.428 (5)	2010 US Census

Seniors over 55 per Acre	Population over 55 as of 2010	Total Land Acreage of Census Tract	0-2.168 (1) 2.168-4.164 (2) 4.164-7.151 (3) 7.151-12.595 (4) 12.595-25.213 (5)	2010 US Census
Single Mothers per Acre	Population of Single Mothers	Total Land Acreage of Census Tract	0-0.727 (1) 0.727-1.672 (2) 1.672-3.089 (3) 3.089-5.613 (4) 5.613-13.287 (5)	American Community Survey 2017 5-year estimates on 2010 US Census Data
Disabled Population per Acre	Disabled Population	Total Land Acreage of Census Tract	0-118.29 (1) 118.29-244.50 (2) 244.50-422.61 (3) 422.61-771.58 (4) 771.58-1,815.98 (5)	2010 US Census
Individuals Aged 20 to 34 per Acre	Population Aged 20 to 34 as of 2010	Total Land Acreage of Census Tract	0-4.356 (1) 4.356-10.338 (2) 10.338-22.881 (3) 22.881-51.363 (4) 51.363-108.526 (5)	2010 US Census
Population with a bachelor's Degree or Higher per Acre	Population with a bachelor's Degree or Higher	Total Land Acreage of Census Tract	0-467.21 (1) 467.21-1,134.34 (2) 1,134.34-2,381.76 (3) 2,381.76-4,597.32 (4) 4,597.32-8,954.04 (5)	American Community Survey 2017 5-year estimates on 2010 US Census Data
Population that is Single per Acre	Population that is single	Total Land Acreage of Census Tract	0-794.22 (1) 794.22-1,704.39 (2) 1,704.39-3,072.09 (3) 3,072.09-5,996.47 (4) 5,996.47-11,934.60 (5)	American Community Survey 2017 5-year estimates on 2010 US Census Data
Individuals Aged 35 to 54 per Acre	Population Aged 35 to 54 as of 2010	Total Land Acreage of Census Tract	0-3.157 (1) 3.157-6.440 (2) 6.440-11.062 (3) 11.062-21.550 (4) 21.550-45.307 (5)	2010 US Census
Walkability of the Census Tract	N/A	N/A	No break points, score was either 0 or 5	Developed by Metro Staff
Housing Units per Acre	Housing Units	Total Land Acreage of Census Tract	0-5.389 (1) 5.389-10.853 (2) 10.853-19.303 (3) 19.303-34.062 (4) 34.062-78.316 (5)	2010 US Census
Square feet of Occupiable Space per Acre	Square feet of occupiable parcel space	Total Land Acreage of Census Tract	0-5,053.41 (1) 5,053.41-12,339.41 (2) 12,339.41-25,368.68 (3) 25,368.68-48,855.67 (4) 48,855.67-119,094.18 (5)	Los Angeles County Assessor's Data

Exhibit 3: Latest Calculation Formula

Latest Formula:

("Pop_AC_Score" + ("Em_AC_Score" + "NE_AC_Score") / 2 + "School_AC_Score" +"UniSC" +"Shop_AC_Score")/5 +

(("Zero_HH_Score" + "Pov_Score" + "P1019SC" + "P55SC" + "MotherSC" + "DisabSC") / 6 + ("P2034SC" + "Bach_SC" + "SingleSC") / 3 + ("P3554SC" + "P55SC" + "Bach_SC" + "SingleSC") / 4)) / 3 + ("Walkable_Score" +"HU17SC" +"SqftSC") / 3)*4/3

Exhibit 4 – Data Table Elements

Number	Column Name	Description
1	fid	Field ID (not used)
2	GEOIDIO	US Census Geo-ID (primary identifier)
3	ALAND10	Area of Land
4	AWATER10	Area of Water
5	INTPTLAT10	Latitude
6	INTPTLONIO	Longitude
7	Pop	Population
8	Emp	Employment
9	Nonjndus	Non-Industrial Employment
10	Zero_HH	Zero-Car Households
11	Pov	Households in Poverty
12	Walkable	Is the Census Tract Walkable
13	Pop_AC	Population per Acre (using AAcre)
14	Em_AC	Employment per Acre (using AAcre)
15	NE_AC	Non-Industrial Employment per Acre (using AAcre)
16	Pop_AC_Score	Natural Breaks Score 1-5 for Population per Acre
17	Em_AC_Score	Natural Breaks Score 1-5 for Employment per Acre
18	NE_AC_Score	Natural Breaks Score 1-5 for Non-Industrial Employment per Acre
19	Walkable_Score	Walkability Score (Either a 0 or a 5)
20	Zero_HH_AC	Zero-Car Households per Acre (using AAcre)
21	Pov_AC	Households in Poverty per Acre (using AAcre)
22	Zero_HH_Score	Natural Breaks Score 1-5 for Zero Car Households per Acre
23	Pov_Score	Natural Breaks Score 1-5 for Households in Poverty per Acre
24	School	School Enrollment
25	School_AC	School Enrollment per Acre
26	School_AC_Score	Natural Breaks Score 1-5 for School Enrollment per Acre
27	Shop	Home-Based Shopping Trips
28	Shop_AC	Home-Based Shopping Trips per Acre
29	Shop_AC_Score	Natural Breaks Score 1-5 for Home-Based Shopping Trips per Acre
30	AAcre	Land Area in Acres
31	PP10JL9	Population 10-19 years of age
32	PP20_34	Population 20-34 years of age
33	PP35_54	Population 35-54 years of age
34	PP55	Population 55+ years of age
35	Bach%	Percent of Population with a Bachelor Degree
36	Bach_AC	Population with a Bachelor Degree per Acre
37	Bach_SC	Natural Breaks Score 1-5 for Population with a Bachelor Degree per Acre
38	P1019AC	Population 10-19 years of age per Acre
39	P3554AC	Population 35-54 years of age per Acre
40	P55AC	Population 55+ years of age per Acre
41	P2034AC	Population 20-34 years of age per Acre

Number	Column Name	Description
42	P1019SC	Natural Breaks Score 1-5 for Population 10-19 years of age per Acre
43	P2034SC	Natural Breaks Score 1-5 for Population 20-34 years of age per Acre
44	P3554SC	Natural Breaks Score 1-5 for Population 35-54 years of age per Acre
45	P55SC	Natural Breaks Score 1-5 for Population 55+ years of age per Acre
46	Disab%	Percent of Population Disabled
47	DisabAC	Population with a Disability per Acre
48	DisabSC	Natural Breaks Score 1-5 for Population with a Disability per Acre
49	Single	Percent of Population that is Single
50	Mother	Percent of Population that is a Single Mother
51	SingleAC	Single Population per Acre
52	MotherAC	Single Mother Population per Acre
53	SingleSC	Natural Breaks Score 1-5 for Single Population per Acre
54	MotherSC	Natural Breaks Score 1-5 for Single Mother Population per Acre
55	UniPop	University Population (including part-time/full-time enrollment and employment)
56	UniSC	Natural Breaks Score 1-5 for University Population (Note that this is NOT per acre)
57	SqftParcel	Square Feet of livable/workable space per parcel
58	Parcels	Number of Parcels
59	SqftAC	Square Feet of livable/workable parcel space per acre
60	SqftSC	Natural Breaks Score 1-5 for Square Feet of livable/workable parcel space per Acre
61	HU	Housing Units
62	HU_AC	Housing Units per Acre
63	HU_SC	Natural Breaks Score 1-5 for Housing Units per Acre
64	Total Score 3	Total Transit Propensity Score (latest score)