ATTACHMENT B

City of Pasadena Transportation Impact Fee Update – Nexus Study

Prepared for:
City of Pasadena

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FEHR & PEERS

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Executive Summary

What is Transportation Impact Fee?

A Transportation Impact Fee (TIF) is a type of development impact fee created to address the impacts of new residents and workers utilizing transportation-related infrastructure, such as roads, intersections, bridges, as well as facilities that serve transit, pedestrians and/or non-motorized vehicles (e.g., trails, bike lanes, sidewalks, etc.). The fee anticipates and is aimed at addressing the impacts of growth on City streets, including protecting neighborhoods from increased traffic.

Who pays the Transportation Impact Fee?

Applicants of land use development and redevelopment projects—including residential, office, retail, and industrial developments—are responsible for paying Transportation Impact Fees.

How is the Transportation Impact Fee calculated?

The fee is determined through a Nexus Study conducted per the requirements of the Mitigation Fee Act. Fees established herein follow the fundamental legal tenets of having an essential nexus (relationship) and rough proportionality to the impacts which the fee is designed to mitigate. The methodology ensures the fee maintains a legally required essential nexus (relationship) and rough proportionality to the impacts it aims to mitigate. The analysis establishes a connection between the transportation-related effects of future development and the infrastructure improvements necessary to accommodate increased demand. The costs associated with these improvements are proportionally allocated based on the magnitude of anticipated growth.

How are fees assessed?

The fees are assessed based on the anticipated impact of new developments on the transportation infrastructure. The City of Pasadena Department of Transportation (DOT) administers the fee program and builds projects as fees are collected. The assessment process includes identifying the project's land use, calculating the net new units within the applicable land use category, and applying fees based on the adopted schedule. Developers are required to pay a one-time fee prior to receiving a Certificate of Occupancy. These impact fees apply exclusively to new development; however, developers must still conduct transportation studies and implement improvements if localized impacts are identified. The fee is subject to annual adjustments based on the Construction Cost Index.

1. Introduction

The City of Pasadena (the "City") is updating its city-wide Transportation Impact Fee (TIF) program to address the transportation needs of future development through 2035. The previous TIF was established in 2017 and had a horizon year of 2035. The updated program aims to ensure that new developments contribute their fair share of the cost of necessary transportation improvements using the City's latest Travel Demand Forecasting Model (TDF Model, Appendix C)[1] while factoring in their effect on vehicle miles traveled (VMT). The fees collected will help fund infrastructure projects, supplementing other sources like County sales tax measures and state or local grants. The program follows California's Mitigation Fee Act (AB 1600), which requires a direct nexus between development impacts and the fees imposed, ensuring they are proportional to the impact of the projects. The updated Transportation Impact Fee will use the new model data and be categorized based on land use. The list of transportation improvements and the methodology for calculating the TIF are detailed in the following sections of this report.

1.1 Regulatory Context

California Government Code

The California Government Code §§ 66000-66025, often referred to as the Mitigation Fee Act, governs how local governments can impose development impact fees. This legislation ensures that such fees are both legally defensible and equitable. The Mitigation Fee Act allows the City to adopt an ordinance that enables the fee and defines the program structure. The fee may be updated periodically when supported by a technical analysis and approved by City Council.

In establishing, increasing, or imposing a fee as a condition for the approval of a development project[2], Government Code §§ 66001(a) and (b) state that the local agency must:

- Identify the purpose of the fee.
- Identify how the fee is to be used.
- Determine how a reasonable relationship exists between the fee established and type of development project for which the fee is imposed.
- Determine how the need for the public facility relates to the type of development project for which the fee is imposed.

[1] The City of Pasadena Travel Demand Forecasting Model was originally developed in 2011 and updated twice in 2013 and 2017. The latest model has been calibrated and validated to 2017 base year conditions using actual traffic counts, census data, Streetlight travel pattern data, and land use data compiled by City staff. The latest Model Development Report is available in Appendix C.

[2] Development includes any land use activity that involves construction of residential, commercial, industrial, office, or other non-residential improvements which requires the issuance of a building permit. Such improvements are generally expected to create additional impacts to the City's transportation infrastructure once completed through additional travel demand associated with the proposed use.

- Demonstrate the relationship between the fee and the cost of the public facility.

Section 4.5 of this report summarizes findings complying with Government Code §§ 66001. Once the TIF update is adopted, this Nexus Study and the technical information it contains will be maintained and reviewed periodically by the City to ensure impact fee accuracy and to enable the adequate programming of funding sources. To the extent that transportation improvement requirements, costs, and development potential changes over time, the fee program will need to be updated.

California Assembly Bill 602

Effective January 1, 2022, AB 602 requires that impact fees levied on residential development must be calculated such that they are proportional to the square footage of future units. A nexus study must evaluate how existing and future residential development can be estimated by residential square feet or document why the use of residential square feet is not relevant as it would not appropriately reflect the relationship between the fee, facility demand, and residential land use. *Section 4.3* outlines methodologies for implementing the AB 602 requirement in the TIF update.

1.2 Existing Transportation Impact Fee

City of Pasadena’s transportation improvement fee program was originally established in November 2006. The most recent iteration of the adopted fee program was adjusted and adopted by City Council in July 2017 (Ordinance No. 7309).

The existing Transportation Impact Fee Study identifies transportation improvements needed to support growth, including roads, public transit, bikeways, and pedestrian walkways. The cost of these improvements are distributed between future and existing development based on the benefits received. The Fee Study divides land uses into five (5) categories: Single-Family Residential, Multi-Family Residential, Retail, Office, and Industrial. *Chapter 2* examines the City's existing Transportation Impact Fee program in comparison to similar programs implemented by other jurisdictions.

Government Code Section 66016.5(a)(4) requires local agencies adopting increases to existing transportation impact fees review the assumptions of the nexus study supporting the original fee and evaluate the amount of fees collected under the original fee. Since City of Pasadena’s existing transportation impact fee will decrease across most land use categories (**Table 9**) following the implementation of proposed new fees, an assessment of the Existing Transportation Impact Fee is not required.

2. Impact Fee Methodologies

This Chapter presents a comparison of the City of Pasadena's existing Transportation Impact Fee (TIF) program with TIF programs from other comparable jurisdictions that were identified in consultation with Pasadena Department of Transportation staff. The jurisdictions that were selected for comparison include Burbank, Santa Monica, West Los Angeles[3], Culver City, Orange, Anaheim, Fremont, and Palo Alto. The Cities of Glendale and Lancaster were evaluated for inclusion but were excluded from the analysis because the City of Glendale is currently in the process of updating its TIF program and the City of Lancaster's TIF program serves to facilitate project-level VMT mitigation under CEQA, whereas the TIF programs in the City of Pasadena and the jurisdictions that were selected for comparison do not.

2.1 Fee Categories

Table 1 and **Table 2** present the various development impact fee programs that have been adopted by each of the comparison jurisdictions for residential and non-residential land uses. As shown in the tables, each of the comparison jurisdictions assesses a transportation improvement fee on new residential and non-residential development. For residential development, parks & recreation fees are assessed in each of the jurisdictions, and fees for public art, public safety, and libraries are common. For non-residential development, several jurisdictions assess fees for public art, public safety, libraries, and affordable housing.

[3] West Los Angeles comprises the West Los Angeles Transportation Improvement and Mitigation Specific Plan area. Development projects that are proposed in this area pay distinct transportation improvement fees in addition to citywide impact fees for the City of Los Angeles in the categories of parks and recreation, affordable housing, and public art.

Table 1: Residential Development Impact Fee Categories

Fee Category	Pasadena	Burbank	Santa Monica	West LA	Culver City	Orange	Anaheim	Fremont	Palo Alto
Year Adopted	2017	2022	2013	2019	2021	2020	1993	2021	2007
Transportation	X	X	X	X	X	X	X	X	X
Residential									
Parks & Recreation	X	X	X	X	X	X	X	X	X
Public Art	X		X		X				X
Library		X				X			X
Police		X				X			X
Fire		X				X		X	X
Childcare			X						
Affordable Housing			X						X
Other		IT	Water Demand		Condo Tax		Sanitation	Capital Facilities	Comm. Facilities

Source: Fehr & Peers

Table 2: Non-Residential Development Impact Fee Categories

Fee Category	Pasadena	Burbank	Santa Monica	West LA	Culver City	Orange	Anaheim	Fremont	Palo Alto
Year Adopted	2017	2022	2013	2019	2021	2020	1993	2021	2007
Transportation	X	X	X	X	X	X	X	X	X
Residential									
Parks & Recreation		X	X						X
Public Art		X	X	X	X				X
Library		X				X			X
Police		X				X			X
Fire		X				X		X	X
Childcare			X						
Affordable Housing			X	X	X				X
Other		IT	Water Demand		Commercial/Industrial Tax		Sanitation	Capital Facilities	Comm. Facilities

Source: Fehr & Peers

2.2 Fee Level Comparisons

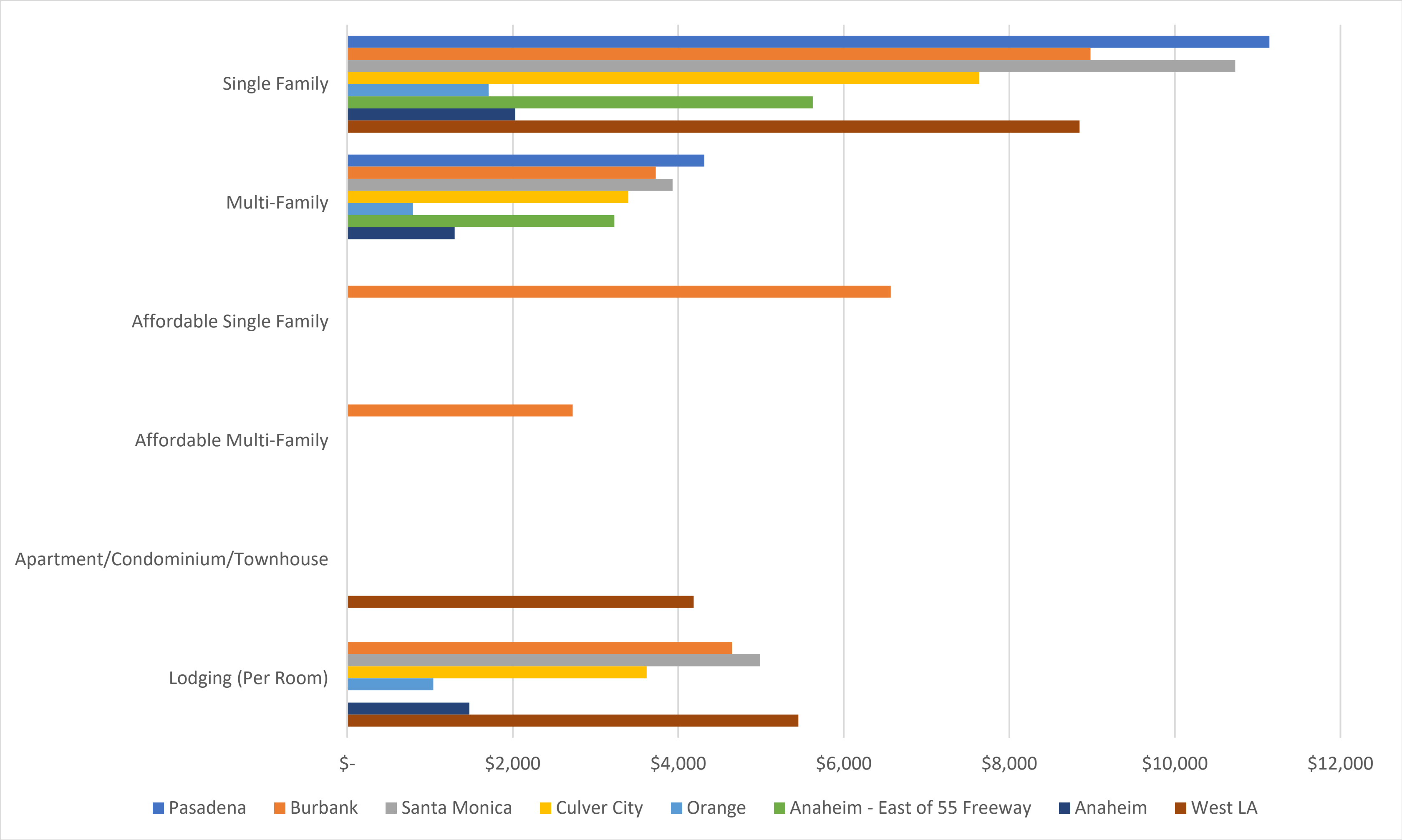
Figure 1 shows the comparison of transportation impact fees for residential and lodging land uses across each of the comparison jurisdictions except for Fremont, which charges a residential fee for both single family and multifamily development on a per bedroom basis, and Palo Alto, which charges a transportation impact fee for residential and non-residential land uses on a per trip basis (per net new PM peak hour trip). Fee levels in Santa Monica differ according to the proximity of development projects to public transit. Because of this, the fee levels shown in **Figure 1** reflect the average across the entire city. **Figure 2** shows the transportation fees for residential development in Fremont. Pasadena's residential transportation impact fees are the highest among compared jurisdictions for single-family uses. For multi-family uses, only West LA's 'Apartment' and 'Condominium/Townhouse' categories exceed Pasadena's current fee level.

Figure 3 shows the comparison of transportation impact fees for industrial land uses, **Figure 4** shows the comparison for office and medical office land uses, and **Figure 5** shows the comparison for retail land uses. For industrial land uses, Pasadena assesses a lower fee than all of the comparison jurisdictions except for the City of Orange. For office land uses, Pasadena assesses a lower fee than the other Los Angeles County jurisdictions, but higher than Fremont and the Orange County jurisdictions. For retail land uses, Pasadena assesses a lower fee than all of the other Los Angeles County jurisdictions except for Burbank and West LA's 'less than 250 KSF' category, but higher than Fremont and the Orange County jurisdictions.

Figure 6, **Figure 7**, and **Figure 8** show the comparison of transportation impact fees in other jurisdictions for land uses not currently assessed in Pasadena or grouped under broader categories like retail and office. These land uses include hospitals, film studios, auto sales, schools (public, private, vocational/trade), religious facilities, research & development facilities, business parks, convalescent/nursing homes, and assisted living/congregate care facilities. The fee comparisons shown in these figures are presented for informational purposes should the City of Pasadena elect to update its TIF program to assess a fee for additional land uses beyond what is currently required from the existing TIF program. **Figure 9** presents transportation impact fee comparisons for jurisdictions that assess a fee on a per trip basis, including Anaheim, Orange, and Palo Alto. It is important to note that the City of Orange only assesses a transportation impact fee on a per trip basis (per daily trip end) for atypical land uses that are not specified in the TIF program. In Anaheim, non-residential projects must pay a fee per peak hour trip end in addition to a fee that is unique by land use.

The fee schedules for these jurisdictions have been updated to reflect Fiscal Year 2025, except for the City of Orange (FY 2021), West LA (FY 2021), and Fremont (FY 2024), as FY 2025 data for these locations is not available online.

Figure 1. Transportation Impact Fees Per Dwelling Unit (DU) – Residential & Lodging Land Uses



Note: Single family and multi-family fees for Santa Monica represent the citywide average. Affordable housing fees for Burbank reflect the average across both minimum-required and above-minimum affordable units.

Figure 2. City of Fremont – Residential Transportation Impact Fees Per DU

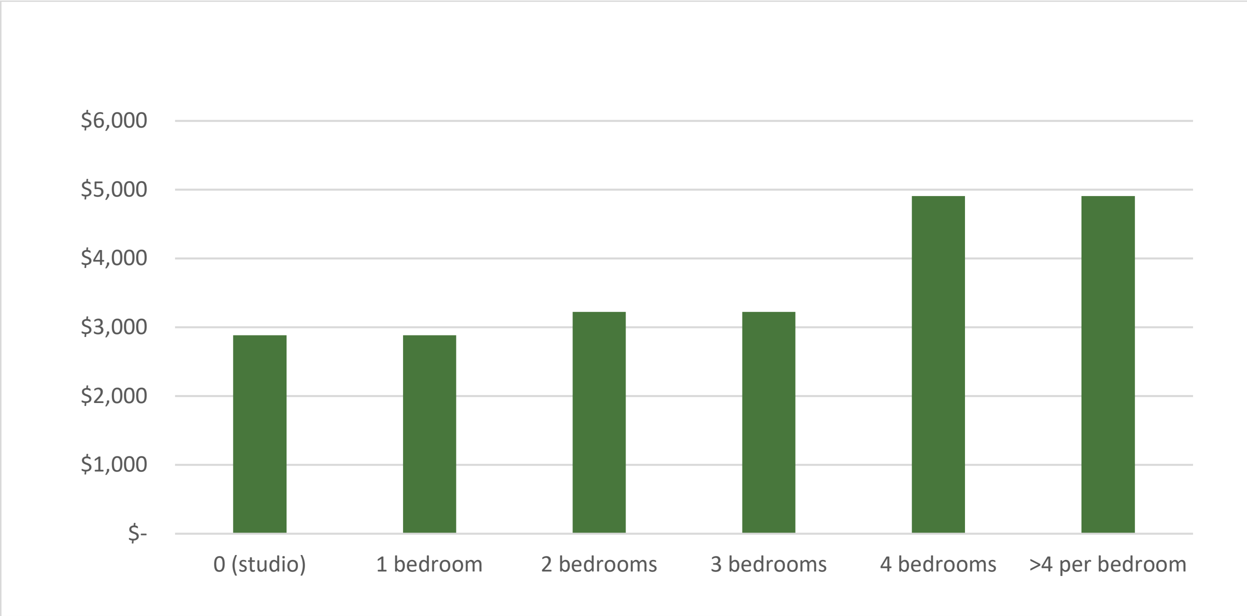


Figure 3. Transportation Impact Fees Per Thousand Square Feet (KSF) – Industrial Land Uses

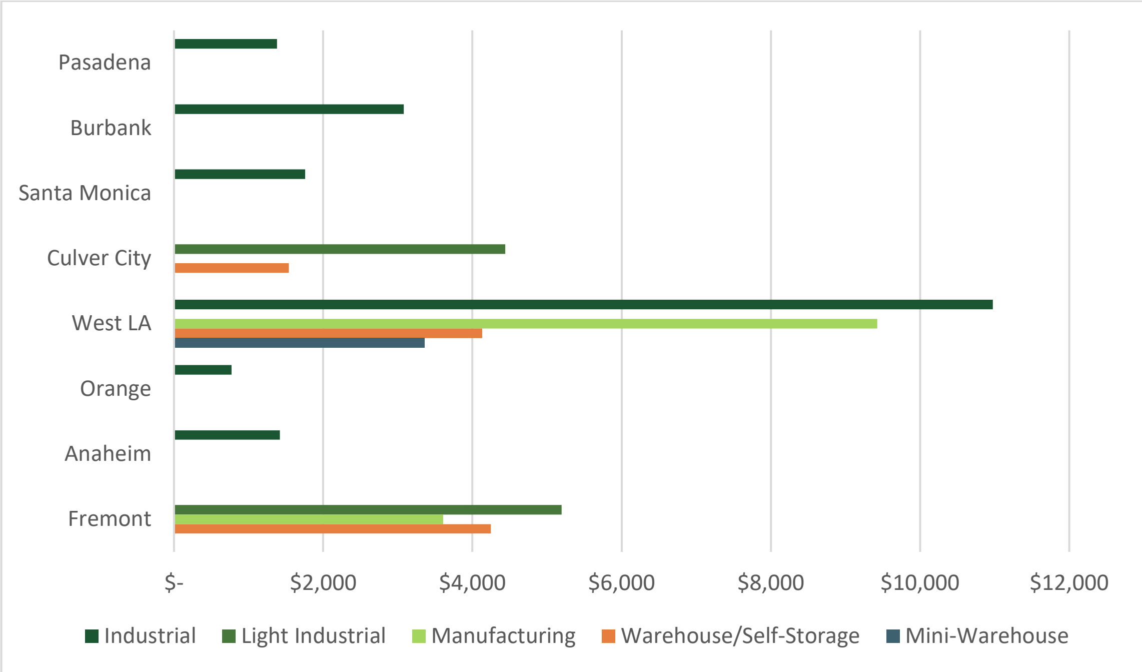
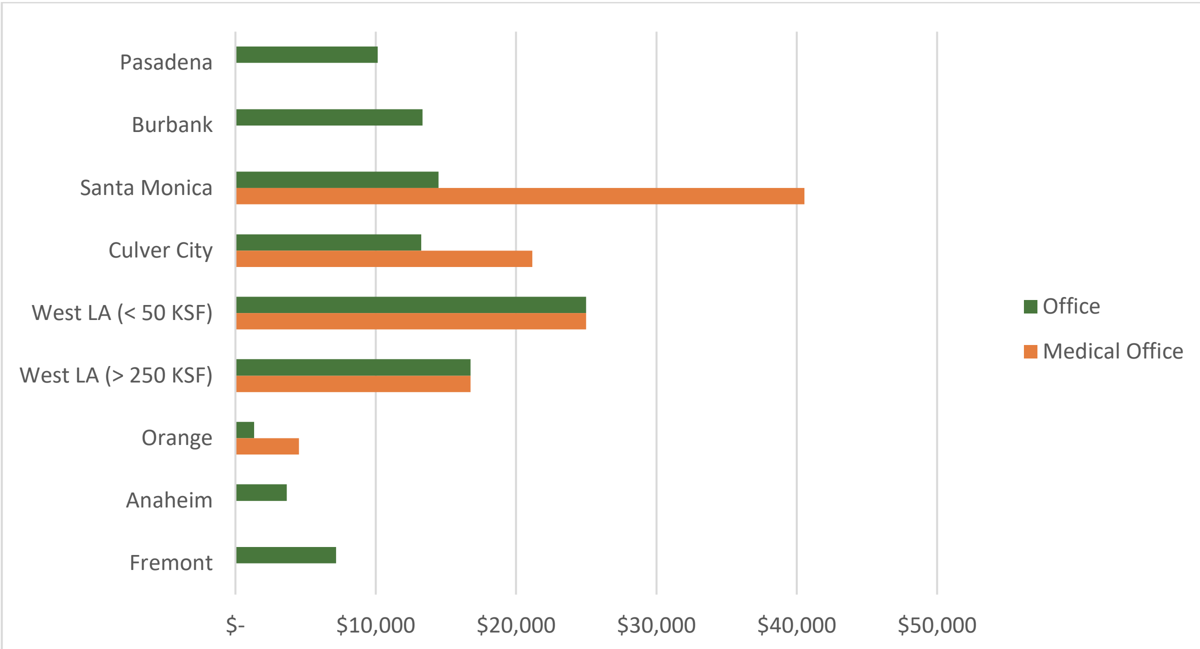
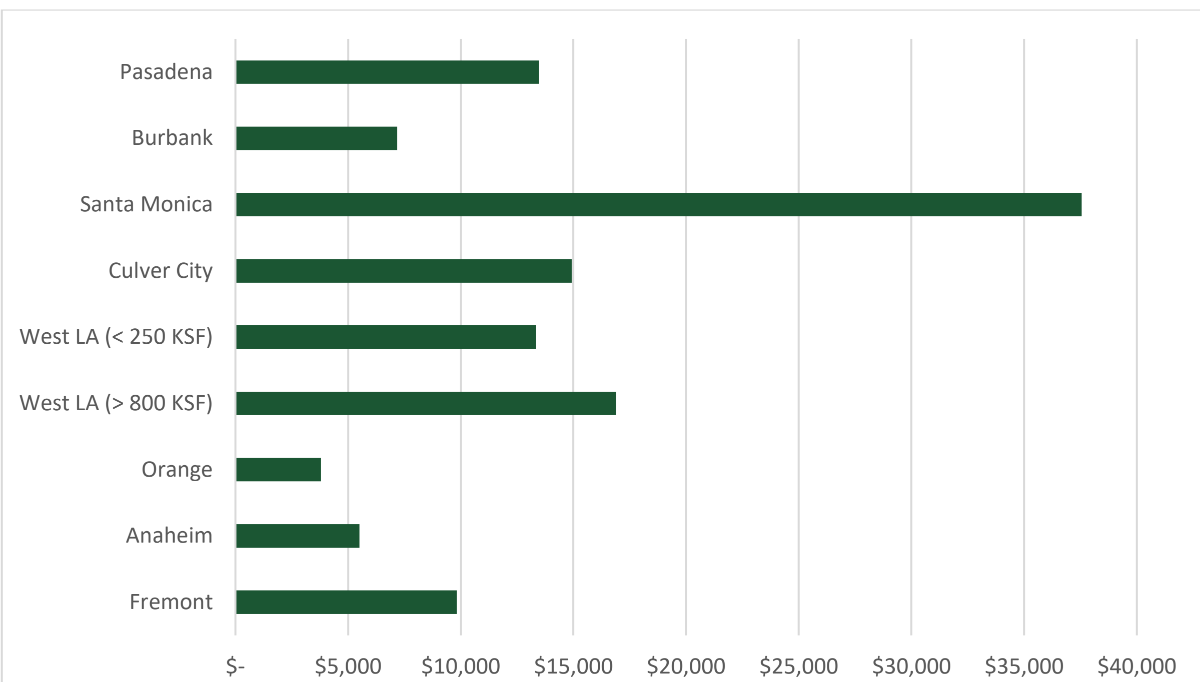


Figure 4. Transportation Impact Fees Per KSF – Office & Medical Office Land Uses



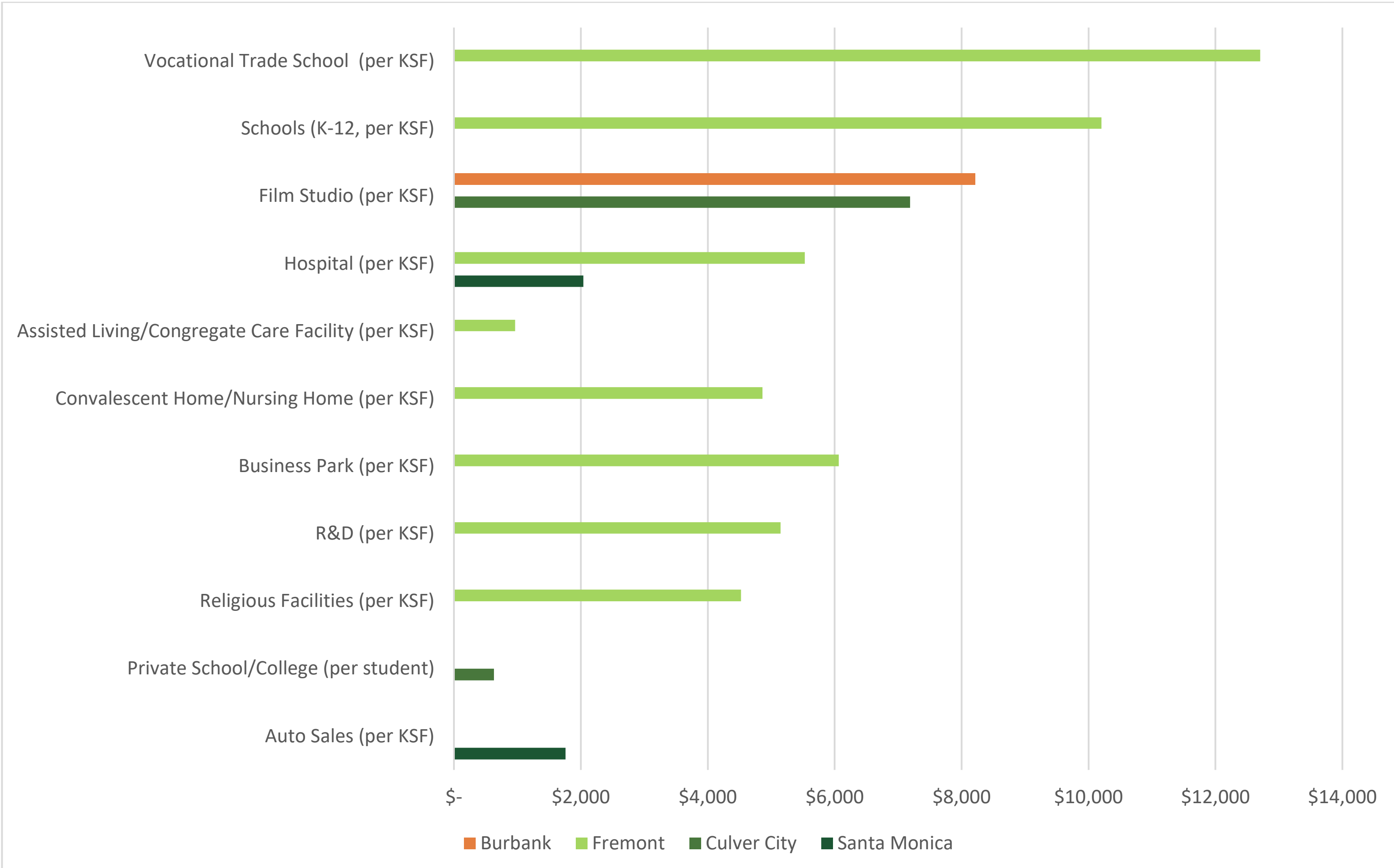
Note: Fees for West LA office and medical office projects between 50 – 250 KSF are interpolated.

Figure 5. Transportation Impact Fees Per KSF – Retail Land Uses



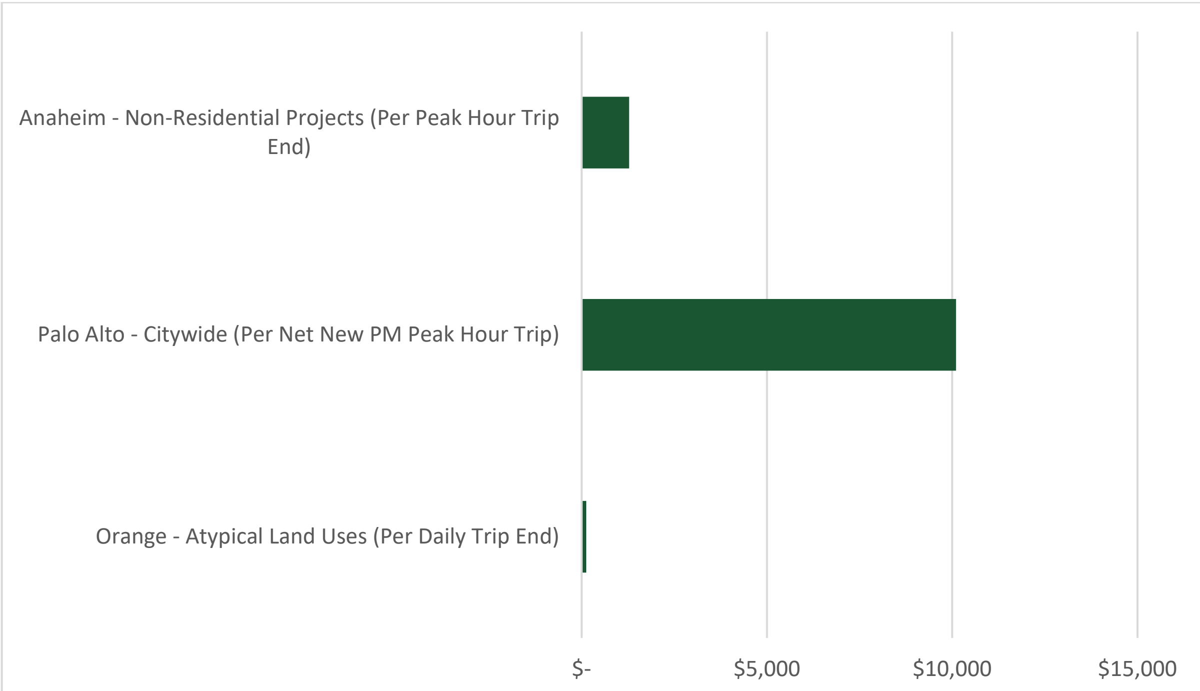
Note: Fees for West LA office and medical office projects between 250 – 800 KSF are interpolated

Figure 6. Transportation Impact Fees Assessed for Other Land Uses (Burbank, Fremont, Culver City & Santa Monica)



Note: Fees for Culver City film studio projects represent the average of two categories - Active Production and Passive Production.

Figure 7. Transportation Impact Fees Assessed on a Per Trip Basis



Note: In Anaheim, non-residential projects must pay a fee per peak hour trip end in addition to a fee that is unique by land use.

3. Transportation Impact Fee Projects

The City of Pasadena's transportation infrastructure projects for the fiscal years (FY) 2026 to 2030 will be funded (in part) through the City's fee program. Projects have been identified through the City's budget cycle, planning efforts, and community needs. Key Capital Improvement Program (CIP) project categories and examples are shown below:

1. **Active Transportation and Complete Streets:** The improvements include new bikeways in Class II, III, or IV based on needs identified through the City's Bicycle Transportation Action Plan, pedestrian needs identified through the Pasadena Pedestrian Transportation Action Plan (PTAP), and safety enhancement needs from the Local Road Safety Plan (LRSP).
    - *Pasadena Bicycle Program FY 2026-2030*: Focused on improving the city's bicycle infrastructure, this project has a proposed budget of $500,000.
    - *Pedestrian Crossing Enhancements Program FY 2021-2028*: Program is designed to improve pedestrian crossings across the city, with a proposed budget of $4.25 million.
2. **Traffic Operations, Traffic Signals, and Intelligent Transportation Systems (ITS):** The improvements include safety-focused multimodal improvements such as pedestrian hybrid beacons (HAWKS).
    - *Transportation System Safety Enhancements Project*: A comprehensive initiative to manage traffic and enhance safety for pedestrians and cyclists, with a proposed budget of approximately $1.1 million.
3. **Transit:** These projects include replacement to existing fleets and innovative sustainable mobility improvements.
    - *Bus Stop Improvement Program*: A comprehensive program to upgrade bus stops with accessibility and safety enhancements, with a proposed budget of approximately $4.3 million.
4. **Streets and Streetscapes:** These projects include general roadway improvements, Specific Plans and granular enhancements to specific corridors.
    - *Pedestrian Safety Enhancements on Oak Knoll Ave:* Focuses on improving accessibility along the right-of-way with a proposed budget of $300,000.

These projects are essential to Pasadena's long-term transportation planning goals in the General Plan, addressing various aspects like cycling infrastructure, pedestrian safety, and roadway efficiency. The full list of eligible projects through the City's fee program is shown in **Table 3.**

Table 3: City of Pasadena Infrastructure Projects

Project Category	Project Name	Type[1]	Source Document & Page Number[2]
Active Transportation / Complete Streets	Pasadena Bicycle Program FY 2026-2030	Bike	CIP (5.1)
	Citywide Neighborhood Traffic Management Program FY 2026-2030	Bike/Ped/Roadway	CIP (5.3)
	Arterials Speed Management Program FY 2026-2030	Roadway Capacity	CIP (5.4)
	Citywide Complete Streets Program FY 2025-2029	Bike/Ped/Roadway	CIP (5.5)
	Pedestrian Transportation Action Plan - Outreach and Conceptual Design	Ped	CIP (5.8) - 75511
	Citywide Continental Crosswalk Implementation	Ped	CIP (5.12) - 75917
	Compete Streets Project - Mountain St at Sierra Bonita Ave and Sinaloa Ave - Design Phase	Ped/Roadway	CIP (5.13) - 75107
	Rose Bowl Pedestrian & Bicycle Access Study	Ped/bike	CIP (5.14)
	Two-Way Traffic Conversion - Mentor Ave from Walnut St to Colorado Blvd - Feasibility Study	Roadway	CIP (5.16) - 75918
	Pedestrian Crossing Enhancements Program FY 2021-2028	Ped	CIP (5.17) - 75112
	El Molino Avenue Quick-Build Greenway Demonstration Project	Bike	CIP (5.18)
	Complete Streets Project - Rosemont Ave Pedestrian Safety Enhancements from Seco St to Orange Grove Blvd - Design Phase	Ped/Roadway	CIP (5.48)
	Arroyo Link Walking and Biking Path	Ped/bike	CIP (5.49)
Traffic Operations, Traffic Signals, ITS	Mobility Corridor Improvements FY 2026-2030	Roadway	CIP (5.19)
	Old Pasadena Traffic Improvement - FY 2026-2030	Roadway	CIP (5.20)
	ITS Equipment Upgrades/Replacement - FY 2021-2028	Ped	CIP (5.21) - 75117
	Citywide Leading Pedestrian Interval/Accessible Pedestrian Signal (LPI/APS) Implementation Program FY 2025-2029	Ped	CIP (5.22)
	Implementation of Citywide Transportation Performance Monitoring Network	Roadway	CIP (5.23) - 75602
	Installation of Traffic Signal and Curb Extensions at Sierra Bonita Ave and Orange Grove	Ped/Roadway	CIP (5.30) - 75134
	Installation of Pedestrian Hybrid Beacons (HAWKs) at Various Locations	Ped	CIP (5.35)

Project Category	Project Name	Type[1]	Source Document & Page Number[2]
	Mobility Hubs & First/Last Mile Improvements	Ped	CIP (5.36)
	Signal Preemption Equipment at Traffic Signals Citywide - Phase II	Roadway	CIP (5.38) - 75916
	Transportation System Safety Enhancements Project – FY 2021-2028	Roadway	CIP (5.39) - 75115
Transit	Purchase of Zero-Emission Pasadena Transit Vehicles and Supporting Infrastructure	Transit	CIP (5.40)
	Purchase of Zero-Emission Pasadena Dial-A-Ride Vehicles and Supporting Infrastructure	Transit	CIP (5.41)
	Systemwide Bus Zone Enhancements	Transit	CIP (5.42)
	Purchase of Replacement Transit Vehicles and Expansion Fixed-Route Transit Vehicles	Transit	CIP (5.43) - 75085
	Purchase of Dial-a-Ride Vehicles	Transit	CIP (5.44) - 75086
	Construction of Transit Operations Maintenance Facility	Transit	CIP (5.45) - 75707
	Bus Stop Improvement Program	Transit	CIP (5.46) - 75900
Streets & Streetscape	Intersection Improvements at Colorado Blvd and Garfield Ave	Ped/Roadway	CIP (2.14)
	Pedestrian Safety Enhancements on Oak Knoll Ave	Ped	CIP (2.15)
	Improvement of Green Street - Orange Grove Blvd to Hill Ave	Roadway	CIP (2.16)
	Safe Routes to School - Sidewalk Repairs	Ped	CIP (2.17)
	Civic Center/Mid-Town Public Improvements & Related Components - Phase II	Ped/Roadway	CIP (2.18)
	New York Drive Bridges - Preventive Maintenance	Misc	CIP (2.19)
	Arroyo Boulevard Bridge - Seismic Retrofit	Misc	CIP (2.21)
	Annual Citywide Street Resurfacing and ADA Improvement Program FY 2026	Ped/Roadway	CIP (2.1)
	Curb Ramp ADA Improvements Program FY 2022 - 2026	Ped	CIP (2.4) - 73937
	San Rafael Bridge Seismic Retrofit	Misc	CIP (2.9) - 73946
	Street Lighting Program FY 2024-2028	Misc	CIP (3.4) - 74422
Other	Playhouse Village - Colorado Blvd Enhancements from Madison Ave to Oak Knoll Ave - Feasibility Study	Ped/Roadway	CIP (5.51)
	Playhouse Village - N Lake Ave. from E Colorado Blvd. to Corson St. - Feasibility Study	Ped/Roadway	CIP (5.52)
	Traffic Signal and Pedestrian Improvements on Kinneloa Ave at Del Mar Blvd	Ped/Roadway	CIP (5.53)

Project Category	Project Name	Type[1]	Source Document & Page Number[2]
	Traffic Signal at Electronic Dr and Sierra Madre Villa Blvd	Roadway	CIP (5.54)
	Mountain Street Curb Extension	Ped	CIP (5.55)
	Complete Streets Project - Sunnyslope Ave at Estado St - Construction Phase	Ped/Roadway	CIP (5.56)
Local Roadway Safety Plan (LRSP)	Retro-reflective backing plates	Roadway	LRSP (77)
	Nearside Signals	Ped	LRSP (77)
	Rectangular Rapid Flashing Beacons (RRFB)	Ped	LRSP (77)
	Regulatory Signs	Roadway	LRSP (77)
	Lake Ave & Maple St High Visibility Crosswalks	Ped	LRSP (78)
	El Molino Av & Villa St High Visibility Crosswalks	Ped	LRSP (78)
	Optional Restriping	Roadway	LRSP (79)
	Fair Oaks Ave & Maple Street Safety Improvements	Roadway	LRSP (77)
	Washington Boulevard Safety Improvements btwn Forest Ave and Catalina Ave	Roadway	LRSP (77)
	Del Mar Boulevard Safety Improvements btwn Los Robles Ave and east City Limits	Roadway	LRSP (77)
	Lake Ave & Washington Bl Optional Safety Enhancements	Roadway	LRSP (78)
	Fair Oaks Ave & Washington Bl Optional Safety Enhancements	Roadway	LRSP (78)
	Fair Oaks Ave & Orange Grove Bl Optional Safety Enhancements	Roadway	LRSP (78)
	Colorado Bl & Sierra Madre Bl Optional Safety Enhancements	Roadway	LRSP (78)
	Arroyo Pkwy & Green St Optional Safety Enhancements	Roadway	LRSP (78)
	Lake Ave btwn Mountain and California Optional Safety Enhancements	Roadway	LRSP (79)
	Los Robles Ave btwn Washington and Maple Optional Safety Enhancements	Roadway	LRSP (79)
Pedestrian Transportation Action Plan (PTAP)	Allen Avenue Pedestrian Improvement Project from north City limit to Colorado Blvd.	Ped	PTAP (Appendix F)
	Del Mar Boulevard Pedestrian Improvement Project from Pasadena Avenue to east City limit	Ped	PTAP (Appendix F)
	Fair Oaks Avenue Pedestrian Improvement Project from north City limit to south City limit	Ped	PTAP (Appendix F)

Project Category	Project Name	Type[1]	Source Document & Page Number[2]
	Foothill Boulevard Pedestrian Improvement Project from Walnut Street to east City limit	Ped	PTAP (Appendix F)
	Lake Avenue Pedestrian Improvement Project from north City limit to Colorado Boulevard	Ped	PTAP (Appendix F)
	Lincoln Avenue Pedestrian Improvement Project from north City limit to Washington Boulevard	Ped	PTAP (Appendix F)
	Los Robles Avenue Pedestrian Improvement Project from north City limit to Walnut Street	Ped	PTAP (Appendix F)
	Raymond Avenue Pedestrian Improvement Project from Colorado Boulevard to E Glenarm Street	Ped	PTAP (Appendix F)
	San Gabriel Boulevard Pedestrian Improvement Project from Maple Street to California Boulevard	Ped	PTAP (Appendix F)
	Washington Boulevard Pedestrian Improvement Project from Lincoln Avenue to Lake Avenue	Ped	PTAP (Appendix F)

Note:
1. Ped = Pedestrian, Misc = Miscellaneous
2. CIP = Capital Improvement Program (FY 2026), LRSP = Local Road Safety Plan (2022), and PTAP = Pedestrian Transportation Action Plan (2024)

4. Nexus Analysis

The purpose of a nexus study is to establish the relationship, referred to as the "nexus," between anticipated new development and the need for new and expanded major public facilities. After establishing the nexus, the transportation fees to be levied for various land use types are calculated based on the proportionate share of the total facility use.

4.1 Methodology Overview

The improvements contained in the transportation project list will provide travel options for those driving, biking, and walking as part of a transportation system that is consistent with local and statewide policies. Growth in residents and employees is expected in the City of Pasadena with or without these transportation projects and the transportation impact fee program does not change the amount of anticipated growth. Pasadena's General Plan Mobility Element guides the continuing development of the transportation system to support planned growth. The anticipated development pattern will increase the use of the City's transportation system, including demand for local and regional roadways as well as pedestrian, bike, and public transit infrastructure. The impact fee is used to pay for transportation projects needed to accommodate the demands on the transportation system created by new development. These transportation projects were identified in or tied to guiding principles, objectives and/or policies in the General Plan Mobility Element. One of the goals of the impact fee is to provide improvements that result in the production of fewer vehicle miles traveled (VMT) on a "per capita/employee" basis.

VMT measures miles traveled by all vehicles (e.g., private automobiles, trucks, and buses) in the study area. In comparison to vehicle trips, VMT accounts for a vehicle's true impact on the transportation system as it considers both the number of trips a driver makes along with the distance traveled during each of those trips. VMT will likely increase with the addition of new residents and employees, the City aims to reduce VMT on a "per capita/employee" basis with land use policies that help Pasadena residents and workers meet their daily needs within a short distance from home, reducing trip lengths, and by encouraging development in areas with access to various modes of transportation other than auto[4].

The City's General Plan prioritizes VMT reduction as a key sustainability goal. Its guiding principles emphasize a livable community with enhanced mobility options beyond automobiles. The Mobility Element outlines four objectives for transportation system management: Promote a livable and economically strong community, encourage non-auto travel, protect neighborhoods by discouraging traffic from passing through neighborhoods, and manage multimodal corridors to improve citywide transportation services[5]. Projects aligned with these objectives will support the VMT reduction goal.

[4] City of Pasadena, Transportation Impact Analysis Guidelines, April 2022.
[5] City of Pasadena, General Plan Mobility Element, August 15.

4.2 VMT Benefits

The VMT benefits of transportation projects in **Table 3** were assessed through two pathways: (1) alignment with Mobility Element objectives and other City-adopted plans and guidelines, and (2) anticipated VMT reduction benefits documented in the California Air Pollution Control Officers Association's Quantifying Greenhouse Gas Mitigation Measures (CAPCOA)[6]. Beyond VMT reduction, many projects also improve accessibility, mode share, and safety, with additional benefits identified where applicable.

Active Transportation/Complete Streets, Local Roadway Safety Plan (LRSP), and Pedestrian Transportation Action Plan (PTAP)

These projects include new bikeways in Class II, III, or IV based on needs identified through the City's Bicycle Transportation Action Plan, pedestrian needs identified through the Pasadena Pedestrian Transportation Action Plan (PTAP), and safety enhancement needs from the Local Road Safety Plan (LRSP). According to CAPCOA, expanding bikeway network encourages a mode shift from vehicles to bicycles, which contributes to up to 0.5% VMT reduction. Providing pedestrian network improvement encourages people to walk instead of drive, which results in up to 6.4% VMT reduction. In addition, *Proximity and Quality of Bicycle Network* and *Pedestrian Accessibility* are two of the City's CEQA transportation metrics. Implementing these projects will help the City improve measures of bike facility access and average walkability.

Traffic Operations, Traffic Signals, ITS

These projects include citywide signal and ITS upgrades to effectively manage the transportation network through design and technology solutions. While there are often emissions reductions associated with these types of projects as running time per mile decreases, there are no associated VMT reductions. Although in some cases, these projects can induce additional VMT by lowering the cost and delay of traveling by vehicle, majority projects in the list are safety-focused multimodal improvements, such as the Transportation System Safety Enhancements Project, Citywide Leading Pedestrian Interval/Accessible Pedestrian Signal (LPI/APS) Implementation Program, and Installation of Pedestrian Hybrid Beacons (HAWKs). In addition, the City's strategic combination of roadway improvements and VMT-reducing projects will help mitigate the effects of induced travel.

Transit

Transit projects include bus stop improvements, the purchase of replacement, expansion and zero-emission vehicles for fixed-route transit and Dial-A-Ride services. These initiatives support the Land Use Element by enhancing non-auto transportation options, improving access to neighborhoods, community centers, and mixed-use boulevards. They also address mobility needs for non-drivers, consistent with *Mobility Element Policy 1.5-Consider the mobility needs of the disabled, students and especially seniors,*

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[6] California Air Pollution Control Officers Association (CAPCOA), Handbook for Analyzing Greenhouse Gas Emission Reductions, Assessing Climate Vulnerabilities, and Advancing Health and Equity, 2021.

when designing new infrastructure and developing transportation programs. According to CAPCOA, extending transit network coverage or hours encourage the use of transit and therefore reduce VMT and associated GHG emissions up to 4.6%.

Streets and Streetscapes, Other

These projects include general roadway improvements with a focus on enhancing walkability and pedestrian safety. These projects align with Mobility Element policies, such as *Policy 1.2 Promote greater linkages between land uses and transit, as well as non-vehicular modes of transportation to reduce vehicular trip related emissions*, and *Policy 1.11 Design Streets to reflect the mobility needs of the adjacent land use context to support healthy activities such as walking and bicycling*.

4.3 Impact Fee Calculation

The impact fees were computed as follows:

- The Pasadena TDF Model was utilized to determine the anticipated growth within the City by 2035.
- The number of new PM Peak Hour vehicle trips generated by the aforementioned growth was calculated.
- A portion of the total costs (approximately 12.1%) of the Pasadena mobility fee project lists were divided by the total number of new trips to determine the cost per PM peak hour trip.
- The percent of new trips generated by various land use types and trip length characteristics by land use were used to calculate the fees to account for VMT.

Each of these steps is explained in further detail below.

4.3.1 Growth Forecasts

The City of Pasadena TDF Model, a detailed and validated model for the City, provides the ability to evaluate the transportation system, generate performance measures for land use and transportation analysis, provide information on regional pass-through traffic versus locally generated trips, and graphically display these results. The model captures planned growth in the city, and is sensitive to emerging land use trends through improved sensitivity to built environment variables. The model forecasts AM and PM peak period daily vehicle and transit flows on the transportation network in the city.

The latest City of Pasadena TDF Model was used for nexus analysis, which forecasts the City's General Plan build-out conditions in Future Year 2035. A model select zone run was conducted to isolate traffic volumes on the roadway network associated with anticipated growth within the City. The project team reviewed the incremental growth in traffic volumes that occurs either through or in the vicinity of transportation improvements in the project list. The most intensely impacted corridors and locations that have projects associated with them were identified and the fair share was determined by comparing the relationship to the existing baseline traffic. **Table 4** summarizes the total PM peak hour volume forecasts associated with Anticipated City Growth in 2024 Baseline, 2035 Future Year, and the fair share allocation of the new development.

Table 4: PM Peak Hour Traffic Volume Forecast Growth

Scenarios	Total Traffic Volumes Generated by Anticipated Growth along/on Project Locations
[A] 2024 Baseline	65,523
[B] 2035 Future Year	73,424
[C] Volume Change	7,901
[D] New Development % Fair Share *(D = C/A)*	**12.1%**

Source: Fehr & Peers, 2025.

4.3.2 Cost of Project List

Detailed project cost estimates were prepared for the transportation improvements in the project list, as shown in **Appendix A**. The cost estimates were based on the capital costs required to construct the projects. The transportation impact fee program only takes into account the unfunded project costs since many of these projects are partially funded by other grants or funding sources. **Table 5** summarize the total costs along with unfunded project costs for each category of project in the mobility fee project list. Costs may not represent the total expenses, especially for segmented or phased projects. Additionally, the transportation impact fee program has limitations, such as restrictions on addressing existing deficiencies, and does not cover all improvements within the City. For instance, *Off-Street Parking Facility Maintenance and Repair Project, Annual ADA Citywide Sidewalk Improvement Program FY 2026 - 2030, and Miscellaneous Sidewalk Repair Program FY 2026 – 2030* in the CIP are excluded from the project list.

An administrative fee of 5% was added to the project list cost to provide oversight and implementation of the fee program by City of Pasadena DOT. Therefore, the total project costs including 5% administrative fee would be approximately $360 million.

Table 5: Project List Cost Estimates

Project Category	Unfunded Cost Estimate	% of Total Project List Cost
Active Transportation/Complete Streets	$106,782,725	31%
Traffic Operations, Traffic Signals, ITS	$36,134,721	10%
Transit	$98,299,675	29%
Streets and Streetscapes	$51,323,555	15%
Other	$3,672,000	1%
Local Roadway Safety Plan (LRSP)	$6,735,123	2%

Project Category	Unfunded Cost Estimate	% of Total Project List Cost
Pedestrian Transportation Action Plan (PTAP)	$41,221,036	12%
Total Cost Estimate	$344,168,835	100%
Total Project Cost (Include 5% Admin Fee)	$361,377,277	N/A

Source: City of Pasadena, 2025.

4.4 Transportation Impact Fee

As explained previously, fee programs require new development to contribute a fair share to complete regional improvements to mitigate the cumulative impacts of their projects to traffic conditions. The traffic volume forecast shows a 12.1% growth from existing conditions to future conditions in the PM peak hour as a result of new development. As shown in **Table 6**, new development would be responsible for funding the fair share (12.1%) of the approximately $360 million of the City's planned transportation improvements contained in the project list, which would be approximately $44 million. The City will need to use alternative funding sources to fund existing development's share of the planned transportation improvements. Potential sources of revenue include but are not limited to existing or new general fund revenues, existing or new taxes, special assessments, and grants. The City's impact fees were calculated by dividing the fair-share allocation (12.1%) of the project list costs by the growth of PM peak hour trips. **Table 6** presents the average "per trip" fee for the initial year of the fee program update. Transportation impact fees will be paid by a developer as a one-time fee prior to the issuance of certificate of occupancy.

Table 6: Mobility Impact Fees per Average PM Peak Hour Trip

Measure	Pasadena
[E] Total Project Cost (Include 5% Admin Fee)	$361,377,277
[F] 12.1% of Total Cost *(F = E * 12.1%, rounded to the nearest integer)*	$43,726,651
[C] PM Traffic Volume Growth (Vehicle Trips)	7,901
[H] Average Cost per PM Peak Hour Trip ***(H = F/C, rounded to the nearest integer)***	**$5,534**

Following the calculation of the average "per trip" cost, additional variables were added to the fee calculations to further account for the transportation impacts of various land use types.

- **PM Peak Hour Trip Generation**: ITE trip rates were used to estimate the number of trips by land use type to determine the equivalent fee on a per unit or square footage basis.
- **Average Vehicle-Trip Length**: The distance drivers are willing to travel is largely dependent on the purpose of their trip. For example, a person traveling to work may be willing to commute 10 miles each day (20 miles of total driving) but choose to shop and dine in their local community, resulting in shorter trips. The average vehicle trip lengths for various land use types (i.e., various trip types) are generated from the Pasadena TDF model.

The average trip length data was used to generate a VMT factor for each land use type. The VMT factor was based on the average trip length generated by a single-family household. Since single family households generate different trip types, such as work, school and shopping trips, they are thought to reflect an average of a variety of trip types. Therefore, the VMT factor for a single-family household is 1.0, and uses with longer average trip lengths are greater than 1.0 while uses with shorter trip lengths, such as locally serving retail, are lower than 1.0.

- **Percent of New Vehicle-Trips**: Trips generated by housing, employment centers and schools are considered to generate all "new" trips. However, a portion of trips associated with retail uses are not considered to be new trips; these trips are often referred to as "pass-by" trips. Pass-by trips are vehicles that are already traveling along a corridor that stop at a use on the way to their ultimate destination. For example, a person traveling from work to home may stop at a grocery store located along the corridor for a gallon of milk. In this situation, the grocery store is not generating a new trip as that vehicle would have already been traveling along the roadway. The pass-by trip credits are reflected in the fee calculations.
- **Residential Fee based on Unit Size:** Assembly Bill (AB) 602 requires impact fee programs to establish fees for residential uses based on the size of the unit. Given that trip generation rates for residential uses have traditionally been calculated on a 'per unit' basis regardless of size, additional data was collected to estimate the number of vehicle trips based on household size (i.e., square feet, SF). Data from the National Household Travel Survey[7] and American Housing Survey[8] was used to develop trip rates based on unit size for single family housing. Using data that represents the State of California, the trip generation based on household size was estimated based on the following:
    - The average daily trips per household were compiled based on the number of persons per household.
    - The number of persons per household based on the size (SF) of the unit was then compiled. The data was grouped into four ranges for single family units: 1) Less than 2,000 SF, 2) 2,000 – 2,999 SF, 3) 3,000 – 3,999 SF, and 4) 4,000 SF or greater.
    - According to the City of Pasadena, the median size of a new single-family home in Pasadena is 2,000 SF. Therefore, single family homes in the 2,000 – 2,999 SF size range were considered to be the typical size for a new home and used to create an Equivalent Dwelling Unit (EDU) factor for each of the size ranges noted above.
    - The same methodology was applied for multi-family units with a smaller size range considered based on typical product type: 1) 800 SF or Less, 2) 801 – 1,600 SF, 3) Greater than 1,600 SF. Multi-family units in the 801 – 1,600 SF size range were considered to be the typical size for a new unit and used to create an EDU factor for the remaining size ranges.
    - **Table 7** summarizes the EDU factors for single family and multi-family units applied to the impact fees. **Appendix B** contains detailed calculations.

[7] 2017 National Household Travel Survey California Add-On.
[8] 2021 California American Housing Survey.

Table 7: Equivalent Dwelling Units for Residential Uses per AB-602

Residential Type & Size Range	Average Persons per Household	Average Trips	EDU
Single Family Units			
< 2,000 SF	2.63	8.44	**86%**
2,000 – 2,999 SF	3.13	9.8	**100%**
3,000 – 3,999 SF	3.24	10.11	**103%**
≥ 4,000 SF	3.5	10.74	**110%**
Multi-Family Units			
≤ 800 SF	2.07	6.9	**79%**
801 – 1,600 SF	2.74	8.73	**100%**
≥ 1,601 SF	3.02	9.53	**109%**

Notes:
EDU = Equivalent Dwelling Unit. EDUs for single family units and multi-family units are calculated separately within their respective categories and are not directly comparable across categories.
Data compiled from 2017 National Household Travel Survey California Add-On and 2021 California American Housing Survey.

- **Accessory Dwelling Units (ADUs)**: An updated process for assessing fees on ADUs was established as part of Senate Bill (SB) 13. This legislation only allows a fee to be assessed on ADUs that are larger than 750 square feet. In order to be consistent with the procedures in the Planning Department, the City of Pasadena DOT will only assess a fee on ADUs that are greater than 800 square feet. In addition, the fee needs to be proportional to the size of the primary dwelling unit on the parcel. For example, if a 1,000 square foot ADU is proposed on a parcel with a 2,500 square foot primary residential unit, the size of ADU is 40 percent (1,000 ÷ 2,500 = 0.4) of the size of the primary dwelling unit. Then the fee assessed to the ADU would be 40 percent of the fee for a single-family residential unit in the 2,000 to 2,999 size range; $5,202 fee for units in applicable size range × 0.4 = $2,080.8 fee for ADU.
- **Government Code Section 66005.1[9]:** This section requires local agencies to set reduced traffic impact fees for housing developments located within transit priority areas that are scheduled to

[9] Government Code Section 66005.1 (a) – When a local agency imposes a fee on a housing development pursuant to Section 66001 for the purpose of mitigating vehicular traffic impacts, if that housing development satisfies all of the following characteristics, the fee, or the portion thereof relating to vehicular traffic impacts, shall be set at a rate that reflects a lower rate of automobile trip generation associated with such housing developments in comparison with housing developments without these characteristics, unless the local agency adopts findings after a public hearing establishing that the housing development, even with these characteristics, would not generate fewer automobile trips than a housing development without those characteristics:
(1) The housing development is located within a transit priority area and the major transit stop, if planned, is programmed to be completed before or within one year from the scheduled completion and occupancy of the housing development.
(2) Convenience retail uses, including a store that sells food, are located within one-half mile of the housing development.
(3) The housing development provides either the minimum number of parking spaces required by the local ordinance, or no more than one onsite parking space for zero- to two-bedroom units, and two onsite parking spaces for three or more bedroom units, whichever is less.

be completed within a year of the housing development. These developments must meet specific criteria such as proximity to convenience retail (within ½ mile) and parking restrictions. If these criteria are met, local agencies cannot impose higher fees for vehicular traffic impacts. For City of Pasadena, most of the forecast development of housing projects used to calculate the general fees are already located within transit priority areas, are within one-half mile of convenience retail uses, and provide minimum amounts of parking. Therefore, the general fee structure assumes these projects will have lower VMT impacts. Accordingly, the City expects that few multi-family housing projects would be eligible for additional TIF reductions, because the fee already accounts for a lower rate of automobile trip generation.

The updated transportation impact fees by land use type for the initial year of the fee program are shown in **Table 8**. As shown, the transportation impact fee for residential uses ranges from $1,705 for a median size multi-family residential unit to $5,722 for a median size single-family unit. For commercial uses, the impact fee ranges from $1.15 per SF for light industrial uses to $20.66 per SF for medical office uses. Some uses, such as ADUs that are 800 square feet or smaller, affordable housing, government buildings, religious uses, and parking structures, were excluded from the TIF analysis calculations, as the City did not wish to impose TIFs on those uses. Compared to the existing transportation impact fees, the updated transportation impact fees decreased across most land use categories, except for medical office uses (**Table 9**).

Table 8: Transportation Impact Fees by Land Use Type

Land Use Category	Unit[1]	ITE Code[2]	PM Trip Rate[2]	EDU/ % New Trips[3]	Trip Length	VMT Factor	Fee per Unit[4]
Residential							
Single Family	DU	210	0.94	100%	17.5	1.00	$5,202 per DU
			< 2,000 SF	86%			$4,474 per DU
			2,000 – 2,999 SF	100%			$5,202 per DU
			3,000 – 3,999 SF	103%			$5,358 per DU
			≥ 4,000 SF	110%			$5,722 per DU
Multi-Family	DU	221	0.39	100%	17.5	1.00	$2,158 per DU
			≤ 800 SF	79%			$1,705 per DU
			801 – 1,600 SF	100%			$2,158 per DU
			≥ 1,601 SF	109%			$2,352 per DU
ADU [>800 SF]	DU	***Proportional to single family unit***					
Non-Residential							
Lodging[5]	Room	310	0.59	100%	7.8	0.44	$1,437 per Room
Retail/Service	SF	821	9.03	70%	6.0	0.34	$11.89 per SF
Office	SF	710	1.44	100%	16.6	0.95	$7.57 per SF
Medical Office[5]	SF	720	3.93	100%	16.6	0.95	$20.66 per SF
Hospital[5]	SF	610	0.86	100%	6.0	0.34	$1.62 per SF
Research and Development[5]	SF	760	0.98	100%	16.6	0.95	$5.15 per SF
Light Industrial	SF	110	0.65	100%	5.7	0.32	$1.15 per SF

Notes:
1) Units = Dwelling Units (DU), Hotel (Rooms), and Square Feet (KSF).
2) Trip Generation, 11th Edition, Institute of Transportation Engineers. Setting/Location: General Urban/Suburban; Not Close to Rail Transit. PM peak hour trip rate per DU, Room, or KSF.
3) Pass-by Trips are accounted for retail uses.
4) Impact Fee = [PM Trip Rate] x [EDU/% New Trips] x [VMT Factor] x [Average Cost per PM Trip]
5) The study resulted in the designation of updated land use categories to better define proposed development and the establishment of updated fees in compliance with legislation passed within the past four years.

Table 9: Comparison of Existing and Proposed Transportation Impact Fees

Existing TR/TIF Category	Current FY 2025 Rate	Proposed TR/TIF Rate
Single family (per dwelling unit)	$11,141.89	$4,474 - $5,722
Multi-family (per dwelling unit)	$4,314.10	$1,705 - $2,352
Industrial use (per square foot)	$1.38	$1.15
Office use (per square foot)	$10.14	$7.57
Retail use (per square foot)	$13.48	$11.89
*Lodging use (per room)	$13.48/SF (treated as retail)	$1,437 per room
*Medical Office use (per square foot)	$10.14 (treated as office)	$20.66
*Hospital use (per square foot)	$10.14 (treated as office)	$1.62
*R&D use (per square foot)	$10.14 (treated as office)	$5.15

Note: Asterisk (*) indicates recategorized land use.

4.5 Findings: Compliance with Government Code Section 66001

This section summarizes findings demonstrating the nexus between fees imposed, the use of the fees, and the development projects on which the fees are imposed, in compliance with Government Code Section 66001.

Identify the Purpose of the Fee

Fees collected from the TIF program funds the implementation or construction of transportation improvements in support of livability, neighborhood protection, and mobility goals as identified in the current City's General Plan Land Use and Mobility Elements and to accommodate new development's additional demand on roadways and non-vehicular transportation infrastructure.

Identify how the fee is to be used.

Funds collected will be used to implement the municipal transportation projects (**Table 3**) required to address vehicular and non-vehicular demand generated by new development, improving the infrastructure for pedestrians and bicyclists, and increasing frequency of service on Pasadena Transit System.

Determine how a reasonable relationship exists between the fee established and type of development project for which the fee is imposed.

Pasadena's General Plan projects growth in residents and employees by 2035. The anticipated development pattern is expected to elevate the demand for the City's transportation system, including increased traffic, VMT, transit ridership, and bicycle and pedestrian activity.

Furthermore, this growth exacerbates safety risks by increasing potential conflicts at intersections, pedestrian crossings, and other high-use areas. Consequently, safety improvements – such as intersection enhancements, protected non-motorized facilities, and modernized traffic controls – are essential to maintaining a safe and efficient transportation system while accommodating new development.

This demonstrates a direct link between new development and the necessity for transportation infrastructure improvements. To maintain service standards, the fees to be imposed on new development will ensure new development contributes its fair share of funds to mitigate the impacts caused by such development.

Determine how the need for the public facility relates to the type of development project for which the fee is imposed.

Funds collected through TIF will be used to implement transportation projects listed in **Table 3**. These projects were identified in the General Plan Mobility Element, the City's Capital Improvement Program, Pedestrian Transportation Action Plan, and Local Road Safety Plan. These projects are essential to Pasadena's long-term transportation planning goals to support increased demand for new developments.

The TIF program will not be used to address existing transportation deficiencies. The City has funded and is implementing several major intersection and roadway improvement projects to address existing and future traffic that are not funded through the Fee. Therefore, the TIF differentiates this relationship by aligning fees assessed with the projected impacts of each type of future development.

Demonstrate the relationship between the fee and the cost of the public facility.

The Nexus Study uses the Pasadena TDF Model to determine the anticipated growth within the City by 2035. A model select zone run was conducted to isolate traffic volumes on the roadway network associated with anticipated growth within the City. The project team reviewed the incremental growth in traffic volumes that occurs either through or in the vicinity of transportation improvements in the project list. The traffic volume forecast shows a 12.1% growth from existing conditions to future conditions in the PM peak hour as a result of new development. Therefore, new developments would be responsible for funding the fair share (12.1%) of the City's planned transportation improvements contained in the project list (**Table 3**). Section 4.2 demonstrates the calculations of the fee.

5. Fee Implementation and Administration

5.1 Administration Features and Costs

Transportation impact fees (**Table 8**) include a five percent (5%) administrative charge to cover overhead costs for City programs (legal, accounting, and administrative support) and fee program expenses such as revenue collection, cost accounting, public reporting, and fee justification analyses.

Since the impact fees developed in this study are based on future facilities costs in 2025 dollars, applying an annual escalator is appropriate to account for inflation. Therefore, beginning on January 1, 2026 and annually thereafter, these fees will be adjusted to reflect changes in the Construction Cost Index (CCI). This ensures that as costs rise, new development continues to contribute to funding improvements at the time of payment. The City of Pasadena DOT will calculate the updated impact fee each year.

Transportation impact fees will be paid by a developer as a one-time fee prior to the issuance of the certificate of occupancy. Additionally, a development project may be conditioned to provide local transportation and streetscape improvements to offset the negative effects on local circulation system due to increased traffic on adjacent roadways. These improvements may include, but are not limited to, signal system upgrades, phasing adjustments, lane reassignment, and enhancements to bicycle or pedestrian facilities that are not part of the transportation project list in this analysis. Developments may be eligible to credit the cost of any specific improvement required as a condition of approval against the required transportation impact fee so long as such improvement would be considered a part of the Transportation Impact Fee Project List contained in **Appendix A**.

5.2 Program Monitoring

The California Mitigation Fee Act requires all municipalities to complete both an annual public report and a five-year public report summarizing the status of their fee programs.

5.2.1 Annual Report

Government Code Section 66006(b) requires the City to publicly disclose following information, with the Annual Report due within 180 days of the end of each fiscal year:

- A brief description of the type of fee in the account or fund.
- The amount of the fee.
- The beginning and ending balance of the account or fund.
- The amount of the fees collected and the interest earned.

- An identification of each public improvement on which fees were expended and the amount of the expenditures on each improvement, including the total percentage of the cost of the public improvement that was funded with fees.
- An identification of an approximate date when construction will begin if the City determines that it has sufficient funds to complete financing for an incomplete public improvement; verification of previously reported projects began as scheduled; and the provision of reason for the delay and a revised start date if construction did not commence.
- A description of each interfund transfer or loan made from the account or fund.
- The amount of refunds made from the accounts.

5.2.2 Five-Year Report

Pursuant to Government Code Section 66001(d)(1), The submittal of the Five-Year Report to the City Council must occur every five years following the first deposit of impact fees into an account. The City Council is required to make specific legislative findings to continue its collection of the fees if any unexpended funds remain in the account, or must return any fees to the property owners who paid them. The Council must approve the Five-Year Report, which does the following:

- Identify the purpose of imposing the fee;
- Demonstrate a reasonable relationship between the fee and the purpose for which it is charged;
- Identify all sources and amounts of funding anticipated to complete financing any incomplete improvements that were identified when enacting the fee; and
- Identify the approximate dates when the anticipated funds are expected to be received.

Appendix A: Impact Fee Program Transportation Project List

Project Category	Project Name	Type[1]	Estimated Total Project Cost	Unfunded Project Cost	Source Document & Page Number[2]
Active Transportation / Complete Streets	Pasadena Bicycle Program FY 2026-2030	Bike	$500,000	$400,000	CIP (5.1)
	Citywide Neighborhood Traffic Management Program FY 2026-2030	Bike/Ped/Roadway	$1,199,915	$1,199,915	CIP (5.3)
	Arterials Speed Management Program FY 2026-2030	Roadway Capacity	$660,500	$660,500	CIP (5.4)
	Citywide Complete Streets Program FY 2025-2029	Bike/Ped/Roadway	$20,000,000	$20,000,000	CIP (5.5)
	Pedestrian Transportation Action Plan - Outreach and Conceptual Design	Ped	$2,200,000	$2,000,000	CIP (5.8) - 75511
	Citywide Continental Crosswalk Implementation	Ped	$18,300,000	$18,225,000	CIP (5.12) - 75917
	Compete Streets Project - Mountain St at Sierra Bonita Ave and Sinaloa Ave - Design Phase	Ped/Roadway	$4,500,000	$4,420,000	CIP (5.13) - 75107
	Rose Bowl Pedestrian & Bicycle Access Study	Ped/bike	$9,436,889	$9,436,889	CIP (5.14)
	Two-Way Traffic Conversion - Mentor Ave from Walnut St to Colorado Blvd - Feasibility Study	Roadway	$200,000	$103,000	CIP (5.16) - 75918
	Pedestrian Crossing Enhancements Program FY 2021-2028	Ped	$4,250,000	$2,991,771	CIP (5.17) - 75112
	El Molino Avenue Quick-Build Greenway Demonstration Project	Bike	$1,945,650	$1,945,650	CIP (5.18)
	Complete Streets Project - Rosemont Ave Pedestrian Safety Enhancements from Seco St to Orange Grove Blvd - Design Phase	Ped/Roadway	$400,000	$400,000	CIP (5.48)
	Arroyo Link Walking and Biking Path	Ped/bike	$45,000,000	$45,000,000	CIP (5.49)
Traffic Operations, Traffic Signals, ITS	Mobility Corridor Improvements FY 2026-2030	Roadway	$612,144	$612,144	CIP (5.19)
	Old Pasadena Traffic Improvement - FY 2026-2030	Roadway	$310,000	$280,000	CIP (5.20)
	ITS Equipment Upgrades/Replacement - FY 2021-2028	Ped	$950,802	$450,000	CIP (5.21) - 75117
	Citywide Leading Pedestrian Interval/Accessible Pedestrian Signal (LPI/APS) Implementation Program FY 2025-2029	Ped	$5,500,000	$5,500,000	CIP (5.22)

Project Category	Project Name	Type[1]	Estimated Total Project Cost	Unfunded Project Cost	Source Document & Page Number[2]
	Implementation of Citywide Transportation Performance Monitoring Network	Roadway	$3,182,428	$2,520,500	CIP (5.23) - 75602
	Installation of Traffic Signal and Curb Extensions at Sierra Bonita Ave and Orange Grove	Ped/Roadway	$970,000	$132,077	CIP (5.30) - 75134
	Installation of Pedestrian Hybrid Beacons (HAWKs) at Various Locations	Ped	$2,000,000	$2,000,000	CIP (5.35)
	Mobility Hubs & First/Last Mile Improvements	Ped	$24,000,000	$24,000,000	CIP (5.36)
	Signal Preemption Equipment at Traffic Signals Citywide - Phase II	Roadway	$280,000	$240,000	CIP (5.38) - 75916
	Transportation System Safety Enhancements Project – FY 2021-2028	Roadway	$1,097,710	$400,000	CIP (5.39) - 75115
Transit	Purchase of Zero-Emission Pasadena Transit Vehicles and Supporting Infrastructure	Transit	$43,300,000	$43,300,000	CIP (5.40)
	Purchase of Zero-Emission Pasadena Dial-A-Ride Vehicles and Supporting Infrastructure	Transit	$3,542,500	$3,542,500	CIP (5.41)
	Systemwide Bus Zone Enhancements	Transit	$3,000,000	$3,000,000	CIP (5.42)
	Purchase of Replacement Transit Vehicles and Expansion Fixed-Route Transit Vehicles	Transit	$42,445,364	$10,628,276	CIP (5.43) - 75085
	Purchase of Dial-a-Ride Vehicles	Transit	$7,884,316	$3,969,278	CIP (5.44) - 75086
	Construction of Transit Operations Maintenance Facility	Transit	$100,000,000	$31,540,000	CIP (5.45) - 75707
	Bus Stop Improvement Program	Transit	$4,332,093	$2,319,621	CIP (5.46) - 75900
Streets & Streetscape	Intersection Improvements at Colorado Blvd and Garfield Ave	Ped/Roadway	$400,000	$400,000	CIP (2.14)
	Pedestrian Safety Enhancements on Oak Knoll Ave	Ped	$300,000	$300,000	CIP (2.15)
	Improvement of Green Street - Orange Grove Blvd to Hill Ave	Roadway	$4,000,000	$4,000,000	CIP (2.16)
	Safe Routes to School - Sidewalk Repairs	Ped	$1,000,000	$1,000,000	CIP (2.17)
	Civic Center/Mid-Town Public Improvements & Related Components - Phase II	Ped/Roadway	$8,500,000	$8,500,000	CIP (2.18)
	New York Drive Bridges - Preventive Maintenance	Misc	$2,181,000	$2,181,000	CIP (2.19)
	Arroyo Boulevard Bridge - Seismic Retrofit	Misc	$5,844,000	$5,844,000	CIP (2.21)
	Annual Citywide Street Resurfacing and ADA Improvement Program FY 2026	Ped/Roadway	$54,200,000	$20,400,000	CIP (2.1)
	Curb Ramp ADA Improvements Program FY 2022 - 2026	Ped	$5,000,000	$2,201,950	CIP (2.4) - 73937
	San Rafael Bridge Seismic Retrofit	Misc	$10,215,001	$1,121,661	CIP (2.9) - 73946
	Street Lighting Program FY 2024-2028	Misc	$6,775,000	$5,374,944	CIP (3.4) - 74422

Project Category	Project Name	Type[1]	Estimated Total Project Cost	Unfunded Project Cost	Source Document & Page Number[2]
Other	Playhouse Village - Colorado Blvd Enhancements from Madison Ave to Oak Knoll Ave - Feasibility Study	Ped/Roadway	$250,000	$250,000	CIP (5.51)
	Playhouse Village - N Lake Ave. from E Colorado Blvd. to Corson St. - Feasibility Study	Ped/Roadway	$250,000	$250,000	CIP (5.52)
	Traffic Signal and Pedestrian Improvements on Kinneloa Ave at Del Mar Blvd	Ped/Roadway	$1,500,000	$1,500,000	CIP (5.53)
	Traffic Signal at Electronic Dr and Sierra Madre Villa Blvd	Roadway	$950,000	$950,000	CIP (5.54)
	Mountain Street Curb Extension	Ped	$297,000	$297,000	CIP (5.55)
	Complete Streets Project - Sunnyslope Ave at Estado St - Construction Phase	Ped/Roadway	$425,000	$425,000	CIP (5.56)
Local Roadway Safety Plan (LRSP)	Retro-reflective backing plates	Roadway	$689,910	$689,910	LRSP (77)
	Nearside Signals	Ped	$105,628	$105,628	LRSP (77)
	Rectangular Rapid Flashing Beacons (RRFB)	Ped	$499,590	$499,590	LRSP (77)
	Regulatory Signs	Roadway	$163,913	$163,913	LRSP (77)
	Lake Ave & Maple St High Visibility Crosswalks	Ped	$14,274	$14,274	LRSP (78)
	El Molino Av & Villa St High Visibility Crosswalks	Ped	$19,032	$19,032	LRSP (78)
	Optional Restriping	Roadway	$3,218,430	$3,218,430	LRSP (79)
	Fair Oaks Ave & Maple Street Safety Improvements	Roadway	$109,612	$109,612	LRSP (77)
	Washington Boulevard Safety Improvements btwn Forest Ave and Catalina Ave	Roadway	$190,891	$190,891	LRSP (77)
	Del Mar Boulevard Safety Improvements btwn Los Robles Ave and east City Limits	Roadway	$310,621	$310,621	LRSP (77)
	Lake Ave & Washington Bl Optional Safety Enhancements	Roadway	$59,951	$59,951	LRSP (78)
	Fair Oaks Ave & Washington Bl Optional Safety Enhancements	Roadway	$59,951	$59,951	LRSP (78)
	Fair Oaks Ave & Orange Grove Bl Optional Safety Enhancements	Roadway	$516,719	$516,719	LRSP (78)
	Colorado Bl & Sierra Madre Bl Optional Safety Enhancements	Roadway	$59,951	$59,951	LRSP (78)
	Arroyo Pkwy & Green St Optional Safety Enhancements	Roadway	$613,782	$613,782	LRSP (78)
	Lake Ave btwn Mountain and California Optional Safety Enhancements	Roadway	$55,288	$55,288	LRSP (79)

Project Category	Project Name	Type[1]	Estimated Total Project Cost	Unfunded Project Cost	Source Document & Page Number[2]
	Los Robles Ave btwn Washington and Maple Optional Safety Enhancements	Roadway	$47,580	$47,580	LRSP (79)
Pedestrian Transportation Action Plan (PTAP)	Allen Avenue Pedestrian Improvement Project from north City limit to Colorado Blvd.	Ped	$6,951,691	$6,951,691	PTAP (Appendix F)
	Del Mar Boulevard Pedestrian Improvement Project from Pasadena Avenue to east City limit	Ped	$4,817,903	$4,817,903	PTAP (Appendix F)
	Fair Oaks Avenue Pedestrian Improvement Project from north City limit to south City limit	Ped	$6,363,397	$6,363,397	PTAP (Appendix F)
	Foothill Boulevard Pedestrian Improvement Project from Walnut Street to east City limit	Ped	$1,614,389	$1,614,389	PTAP (Appendix F)
	Lake Avenue Pedestrian Improvement Project from north City limit to Colorado Boulevard	Ped	$3,563,718	$3,563,718	PTAP (Appendix F)
	Lincoln Avenue Pedestrian Improvement Project from north City limit to Washington Boulevard	Ped	$1,647,458	$1,647,458	PTAP (Appendix F)
	Los Robles Avenue Pedestrian Improvement Project from north City limit to Walnut Street	Ped	$4,113,529	$4,113,529	PTAP (Appendix F)
	Raymond Avenue Pedestrian Improvement Project from Colorado Boulevard to E Glenarm Street	Ped	$3,329,173	$3,329,173	PTAP (Appendix F)
	San Gabriel Boulevard Pedestrian Improvement Project from Maple Street to California Boulevard	Ped	$2,103,690	$2,103,690	PTAP (Appendix F)
	Washington Boulevard Pedestrian Improvement Project from Lincoln Avenue to Lake Avenue	Ped	$6,716,088	$6,716,088	PTAP (Appendix F)

Note:

1. Ped = Pedestrian, Misc = Miscellaneous
2. CIP = Capital Improvement Program (FY 2026), LRSP = Local Road Safety Plan (2022), and PTAP = Pedestrian Transportation Action Plan (2024)

Appendix B: AB-602 Calculations for Residential Units by Size

Table: Average Trip Generation by Dwelling Unit Size for Single Family and Multi Family Units to Comply with AB 602

1. Single Family

Persons per Household	Trips per Household*	Less than 2,000 sq.ft			2,000 to 3,000 sq.ft			3,000 sq.ft to 4,000 sq.ft			Greater than 4,000 sq.ft		
		Number of Units**	Percent of Units	Trips	Number of Units**	Percent of Units	Trips	Number of Units**	Percent of Units	Trips	Number of Units**	Percent of Units	Trips
1 person	3.82	2,606	27%	1.02	223	10%	0.38	47	8%	0.32	40	14%	0.55
2 persons	6.88	2,963	30%	2.08	785	35%	2.39	192	34%	2.33	65	23%	1.60
3 persons	9.44	1,548	16%	1.49	396	18%	1.65	103	18%	1.72	36	13%	1.22
4 persons	12.61	1,512	15%	1.95	460	20%	2.57	111	20%	2.47	57	20%	2.58
5 persons	14.72	710	7%	1.07	222	10%	1.45	59	10%	1.53	40	14%	2.11
6 persons	15.28	237	2%	0.37	101	4%	0.68	27	5%	0.73	20	7%	1.10
7 persons or more	21.08	217	2%	0.47	75	3%	0.70	27	5%	1.01	21	8%	1.59
Total		**9,794**	**100%**	**8.44**	**2,261**	**100%**	**9.80**	**566**	**100%**	**10.11**	**279**	**100%**	**10.74**
Average Persons Per Household		2.63			3.13			3.24			3.50		
Equivalent Dwelling Unit		86%			100%			103%			110%		

**Source: 2017 National Household Travel Survey California Add-On.*

***Source: 2021 California American Housing Survey.*

2. Multi-Family

Persons per Household	Trips per Household*	Less than or equal to 800 sq.ft			801 to 1,600 sq.ft			Greater than 1,600 sq.ft		
		Number of Units**	Percent of Units	Trips	Number of Units**	Percent of Units	Trips	Number of Units**	Percent of Units	Trips
1 person	3.82	955	45%	1.73	1,295	23%	0.88	579	13%	0.51
2 persons	6.88	560	27%	1.82	1,715	31%	2.11	1,472	34%	2.33
3 persons	9.44	253	12%	1.13	947	17%	1.60	743	17%	1.62
4 persons	12.61	234	11%	1.40	881	16%	1.98	857	20%	2.49
5 persons	14.72	72	3%	0.51	474	8%	1.25	386	9%	1.31
6 persons	15.28	19	1%	0.14	163	3%	0.45	155	4%	0.55
7 persons or more	21.08	17	1%	0.17	125	2%	0.47	149	3%	0.72
Total		**2,111**	**100%**	**6.90**	**5,601**	**100%**	**8.73**	**4,342**	**100%**	**9.53**
Average Persons Per Household		2.07			2.74			3.02		
Equivalent Dwelling Unit		79%			100%			109%		

**Source: 2017 National Household Travel Survey California Add-On.*

***Source: 2021 California American Housing Survey.*

Appendix C: Pasadena Travel Demand Forecasting Model Development Report

Pasadena Travel Demand Forecasting Model Development Report

Prepared for:
City of Pasadena

Ref. LA17-2944

December 2018

FEHR PEERS

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Introduction

The purpose of this report is to introduce and describe updates to the Travel Demand Forecasting (TDF) model built for the City of Pasadena. This report describes the model development process in general, and how this process was applied to develop the City of Pasadena model, including the sources of data used to develop key model inputs. This process was originally completed in 2011, then updated in 2013, and again in 2017. Most comparisons in the report compared the 2017 version of the model with the 2013 version.

General Discussion of the TDF Model

This section summarizes the answers to commonly asked questions related to TDF models and how the City can use a TDF model.

What Is a TDF Model?

A TDF model is a computer program that simulates traffic levels and travel patterns for a specific geographic area. The program consists of input files that summarize the area's land uses, street network, travel characteristics, and other key factors. Using this data, the model performs a series of calculations to determine the amount of trips generated, the beginning and ending location of each trip, and the route taken by the trip. The model's output includes projections of traffic volumes on major roads, and peak hour turning movements at certain key intersections.

How Is a TDF Model Useful?

The City TDF model is a valuable tool for preparing long-range transportation planning studies, such as Pasadena's General Plan and Mobility Element Update. The travel model can be used to estimate the average daily and peak hour traffic volumes and Vehicle Miles Traveled (VMT) on the major roads in response to future land use, transportation infrastructure, and policy assumptions. It can also be used to form a consistent basis by which to analyze the different potential land use scenarios. Additionally, using these traffic projections, transportation improvements will be identified to accommodate the changing traffic patterns associated with the General Plan's preferred land use alternative.

How Do We Know if the TDF Model is Accurate?

To be deemed accurate for projecting traffic volumes in the future, a model must first be calibrated to a year in which actual land use data and traffic volumes are available and well documented. A model is accurately calibrated when it replicates the actual traffic counts on the major roads within certain ranges of error established in *2010 California Regional Transportation Plan Guidelines (California Transportation Commission, 2010)* and it demonstrates stable responses to varying levels of inputs. The Pasadena model has been calibrated to 2017 base year conditions using actual traffic counts, census data, Streetlight travel pattern data, and land use data compiled by City staff.

Is the City of Pasadena TDF Model Consistent with Standard Practices?

The City of Pasadena model is consistent in form and function with standard travel forecasting models used in transportation planning. The model includes a land use/trip generation module, a gravity-based trip distribution model, and a capacity-restrained equilibrium traffic assignment process. The travel model utilizes Version 7.0 (Build 12410) of the TransCAD Transportation GIS software, which is consistent with many of the models used by local jurisdictions in California and throughout the nation. The Southern California Association of Governments (SCAG), the metropolitan planning organization (MPO) for Southern California, maintains their current regional travel demand model in TransCAD.

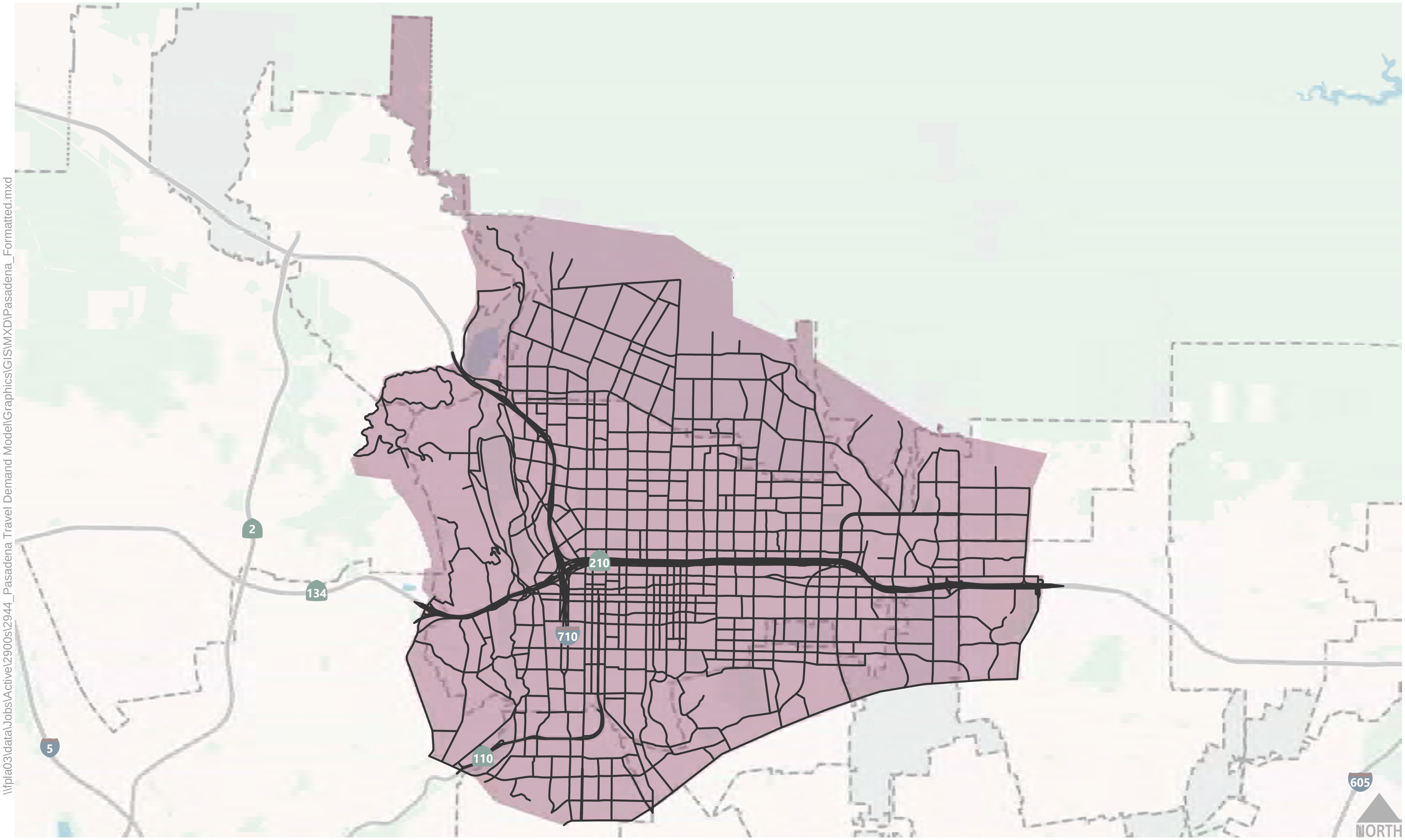
How Can the TDF Model Be Used?

The TDF model can be used for many purposes related to the planning and design of the City's transportation system. The following is a partial listing of the potential uses of the TDF model:

- To update the land use and circulation elements of the General Plan
- To conduct a city-wide traffic impact fee program
- To evaluate the traffic impacts of area-wide land use plan alternatives
- To evaluate the shift in traffic resulting from a roadway improvement
- To evaluate the traffic impacts of land development proposals
- To determine trip distribution patterns of larger land development proposals
- To support the development of transportation sections of Environmental Impact Reports (EIRs)
- To support the preparation of project development reports for Caltrans
- To calculate Vehicle Miles Traveled (VMT) and Vehicle Trips (VT) per capita per the City's transportation impact guidelines

Study Area and Street Network

Figure 1 shows the study area for the City travel demand forecasting model. The model area encompasses the City of Pasadena, and neighboring areas that have high levels of interaction with Pasadena. The study area contains all areas that may experience land use changes under the Pasadena General Plan Land Use Update.



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Model Street Network

Pasasena Model Area

Figure 1

Pasadena Model Area and Street Network

Summary of the Input Data

Data Collection

A data collection effort was undertaken at the outset of the model update process. Data sources include SCAG for street network and regional travel data, Caltrans Performance Measurement System (PeMS) traffic count data, independently collected traffic counts within Pasadena, GPS data for travel flow information, the City of Pasadena for land use, and street network data.

Land Use Data

Land use data is one of the primary inputs to the Pasadena model, and this data is instrumental in estimating trip generation. The model's primary source of land use data is the City's parcel-level land use database (maintained in a GIS format). This database provides information on how much development currently exists within each traffic analysis zone (TAZ), a detailed explanation of the TAZ system is provided below. For the 2017 update of the model, new developments and land use changes were listed individually and added or subtracted from the TAZ in which they are located. The land use data in the model is divided into a variety of residential and non-residential categories. The City of Pasadena model employs 27 data categories to describe land use in the City, these categories and their change from 2013 is shown in Table 1.

To refine the land use categories within the City, the Auto land use category was divided into general auto uses (Auto) and Auto Dealership. A new trip generation rate was developed for Auto Dealerships and a share of the land use in Auto was shifted to Auto Dealership. The trip generation rate for this land use was developed based on the *Trip Generation Manual, 10th Edition* (Institute of Transportation Engineers [ITE], 2017), Auto Sales (new) land use category.

The land use data in the model is also used to generate the population and employment, service population, for the VT and VMT per capita calculation. Each land use type has an associated factor, that is multiplied by the trip generation unit, 1,000 square feet, units, students, or acres, to generate residents in the case of the housing land uses and employees in the case of all other land uses. The previous version of the model did not include an employment factor for the educational land uses: Elementary School, High School, and College. Despite this gap in the factors, the they produced a total employment estimate for Pasadena that was similar to the American Community Survey (ACS) estimate of employment.

For the new model, employment factors were developed for Elementary School, High School, College, and Auto Dealership land uses. The employment factors for Elementary School and High School with in Pasadena were developed based on data from Pasadena Unified School District (USD). The factor for College was developed using the *Trip Generation Manual, 10th Edition*, trip generation information for Junior/Community College. As Caltech is a research institution and has different employment patterns from other colleges within Pasadena, a different employment factor was developed for Caltech that is based on data from Caltech. The factor for Auto Dealership was developed using *Trip Generation Manual, 10th Edition* trip generation information for the Auto Sales (new) land use.

So as not to overestimate the employment in Pasadena, the employment factors from the previous version of the model were proportionally reduced so that the total employment estimate, including the new factors, remains close to the ACS estimate of employment with in Pasadena.

The City's land use data is supplemented by SCAG TAZ-based data for areas bordering the City of Pasadena, the buffer area. The land use for these TAZs was updated to reflect the 2016 Adopted version of the SCAG model.

Table 1 also shows the land use changes from the 2012 SCAG Model to the 2016 SCAG model in the buffer area according to the SCAG land use categories.

The future year models remain largely the same as the previous versions of the future year models. All land uses remained the same except Auto, because some land use was transferred from the Auto land used classification to the Auto Dealership classification. Per TAZ, the same amount of land use (KSF) was transferred from Auto to Auto Dealership as in the 2017 model, except where the future amount of Auto was less than the amount transferred from Auto to Auto Dealership in the base year model. In these situations, where the future model anticipates less overall Auto land use, only the amount of Auto present in the future was transferred to Auto Dealership. Table 2 contains the land use changes from the previous Adopted 2035 model and the updated Adopted 2035 model.

Table 1
Pasadena Model
Summary Land Use Change

Model Land Use Category	Units	Model 2013 Land Use Total	New 2017 Land Use Total	Delta Total	Percent Change Total
Single-Family (SFU)	units	37,967	40,922	2,955	7.8%
Multi-Family (MFU)	units	57,716	56,650	-1,066	-1.8%
Senior Citizen Housing	units	2,203	2,203	0	0.0%
Lodging	ksf	1,185	1,280	94	7.9%
Retail	ksf	7,178	7,245	67	0.9%
Personal Services	ksf	578	767	188	32.5%
Restaurant	ksf	849	921	72	8.4%
Entertainment	ksf	1,340	1,337	-3	-0.2%
Automotive Related	ksf	1,432	1,205	-227	-15.8%
Auto Dealership (new in 2017)	*ksf*		*257*	*257*	*100.0%*
Office	ksf	13,624	13,840	216	1.6%
Medical Office	ksf	1,078	1,188	110	10.2%
Government Office	ksf	1,012	1,012	0	0.0%
Hospital	ksf	2,092	2,092	0	0.0%
Religious Facilities	ksf	1,966	1,967	1	0.1%
Cultural	ksf	703	712	9	1.3%
Police and Fire Services	ksf	130	130	0	0.0%
Park and Recreational Facilities	acres	833	833	0	0.0%
Industrial	ksf	4,569	4,239	-330	-7.2%
Utility Facilities	acres	125	125	0	0.0%
Elementary and Middle School	students	21,354	21,354	0	0.0%
High Schools	students	8,181	8,181	0	0.0%
College	students	32,410	32,410	0	0.0%
SCAG Retail[1]	employees	2,437	2,131	-306	-12.6%
SCAG Office[1]	employees	14,112	16,602	2,490	17.6%
SCAG Industrial[1]	employees	3,159	2,612	-547	-17.3%
SCAG Educational[1]	employees	6,047	6,650	603	10.0%

[1] Data adapted from SCAG TAZs, uses SCAG units of employment

Table 2
Pasadena Model
Summary Future Land Use Change

Model Land Use Category	Units	Old 2035 Land Use Total	New 2035 Land Use Total	Delta Total	Percent Change Total
Single-Family (SFU)	units	39,935	42,008	2,073	5.2%
Multi-Family (MFU)	units	69,985	69,300	-685	-1.0%
Senior Citizen Housing	units	1,967	1,967	0	0.0%
Lodging	ksf	1,525	1,525	0	0.0%
Retail	ksf	10,149	10,149	0	0.0%
Personal Services	ksf	734	734	0	0.0%
Restaurant	ksf	984	984	0	0.0%
Entertainment	ksf	1,186	1,186	0	0.0%
Automotive Related	ksf	893	708	-185	-20.7%
Auto Dealership (new in 2017)	*ksf*	*0*	*219*	*219*	*100.0%*
Office	ksf	21,413	21,413	0	0.0%
Medical Office	ksf	1,950	1,950	0	0.0%
Government Office	ksf	1,026	1,026	0	0.0%
Hospital	ksf	2,284	2,284	0	0.0%
Religious Facilities	ksf	1,796	1,796	0	0.0%
Cultural	ksf	783	783	0	0.0%
Police and Fire Services	ksf	88	88	0	0.0%
Park and Recreational Facilities	acres	836	836	0	0.0%
Industrial	ksf	2,183	2,183	0	0.0%
Utility Facilities	acres	110	110	0	0.0%
Elementary and Middle School	students	22,256	22,256	0	0.0%
High Schools	students	8,492	8,492	0	0.0%
College	students	33,035	33,035	0	0.0%
SCAG Retail[1]	employees	2,735	2,793	58	2.1%
SCAG Office[1]	employees	15,913	16,858	945	5.9%
SCAG Industrial[1]	employees	3,893	2,915	-978	-25.1%
SCAG Educational[1]	employees	6,862	7,275	413	6.0%

[1] Data adapted from SCAG TAZs, uses SCAG units of employment

Traffic Analysis Zone System

Travel demand models use traffic analysis zones (TAZs) to subdivide the study area for the purpose of connecting land uses to the street network. TAZs represent physical areas containing land uses that produce or attract vehicle-trip ends. The 2017 TAZ system is consistent with the 2013 Pasadena Travel Model.

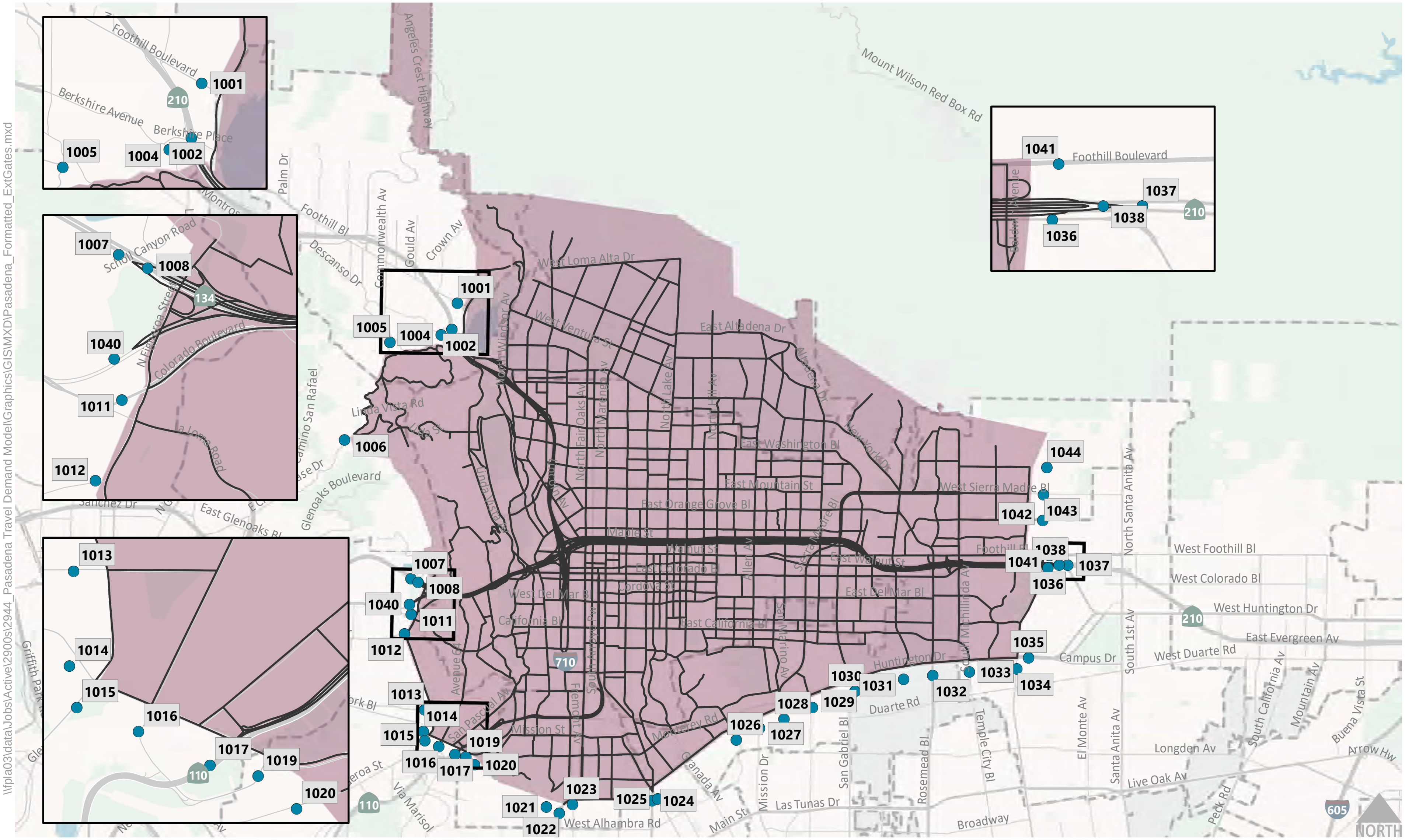
The resulting model TAZ system includes 488 zones in the model area, of which 349 zones cover the City of Pasadena. The remaining 139 cover the surrounding areas of South Pasadena, Sierra Madre, San Marino, East Pasadena, City of Los Angeles, Arcadia, and Altadena. As the SCAG TAZs in the Pasadena model area did not change in the 2012 or 2016, the Pasadena TAZs were not modified in the 2013 or 2017 updates of the Pasadena model. Detailed maps showing the TAZ numbers in all portions of the model area are included in Appendix A. Also included in the TAZ structure are the external stations or gateways at points where major roadways provide access into the model area. The external gateways represent all major routes by which traffic can enter or exit the study area and capture the traffic entering, exiting, or passing through the model area.

Table 3 contains a list of the 44 external gateways numbered from 1001 to 1044 that were established for this model. Figure 2 illustrates the locations of the external stations.

Table 3
Pasadena Model
External Stations

Station	Road	Segment
1001	Foothill Blvd	e/o Viro Rd
1002	I-210 Mainline	n/o of Belkshire
1003	*Dummy External*	
1004	Berkshire Ave	e/o of Dover Rd
1005	Chevy Chase Drive	n/o Highland Dr
1006	Chevy Chase Drive 2	w/o Linda Vista Rd
1007	SR 134 Mainline	w/o Figueroa
1008	SR 134 HOV	w/o Figueroa
1009	*Dummy External*	
1010	*Dummy External*	
1011	Colorado Blvd	e/o Genevieve
1012	Yosemite Dr	w/o Figueroa St
1013	Meridian St	w/o Figueroa St
1014	York Blvd	w/o Figueroa St
1015	N Figueroa	s/o York Blvd
1016	Avenue 64	s/o York Blvd
1017	Pasadena Freeway	s/o York Blvd
1018	*Dummy External*	
1019	Arroyo Verde Rd	s/o Pasadena Ave
1020	Monterrey Rd	s/o Kolle Ave
1021	Meridian Ave	s/o Pine St
1022	Huntington Rd WB	n/o Beech St
1023	Fremont Ave	s/o Huntington Dr
1024	N Atlantic Blvd	s/o Huntington Dr
1025	Garfield Ave	s/o Huntington Dr
1026	Virginia Rd	s/o Huntington Dr
1027	West Dr	s/o Huntington Dr
1028	San Marino Ave	s/o Huntington Dr
1029	Del Mar Ave	s/o Huntington Dr
1030	San Gabriel Blvd	s/o Huntington Dr
1031	Madre St	s/o Huntington Dr
1032	Rosemead Blvd	s/o Huntington Dr
1033	California Blvd	s/o Huntington Dr
1034	Baldwin Ave	s/o Huntington Dr
1035	Huntington Rd EB	e/o Baldwin Ave
1036	Colorado St	e/o Baldwin Ave
1037	I-210 Mainline	e/o Baldwin Ave
1038	I-210 HOV	e/o Baldwin Ave
1039	*Dummy External*	
1040	SR 134 Ramps	n/o Colorado Blvd
1041	W Foothill Blvd	e/o Baldwin Ave
1042	Orange Grove	e/o Baldwin Ave
1043	Sierra Madre Blvd	e/o Baldwin Ave
1044	Grandview Ave	e/o Baldwin Ave

Dummy Externals may be used for future forecasting endevors, where more external connections may be needed, such as the planned Interstate 710 extension.



- External Station
- Model Street Network
- Pasasena Model Area

Figure 2

Pasadena External Station Locations

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Street Network

The street network for the base year conditions in 2009 was developed by modifying the 2003 SCAG network within the Pasadena model area, by using 2009 Pasadena Aerial photography, and by gathering input from the City regarding roadway network assumptions. The model street network includes all freeways, state highways, arterials, collectors, and some relevant local roads within the study area (see Figure 1).

For the 2013 model update, several changes to the number of lanes were made to reflect changes in the network that occurred by September 2013. Additionally, an external gate was also added to the model to represent the SR-134 On- and Off-Ramps at Colorado Blvd. Although these ramps existed in 2009, they were not included in the previous model's roadway network.

For the 2017 update, changes were made to three additional roadway segments. These changes are summarized in . There were other changes in the overall transportation system in Pasadena, but not all changes in bike facilities and on-street parking caused a change in lanes or capacity. The network was modified to reflect changes associated with the following projects.

Table 4
Pasadena Model
Network Changes

Roadway	From	To	2013 Model		2017 Model		Bike Facility	Direction	Change	Installed
			Lane (per direction)	Capacity	Lane (per direction)	Capacity				
Lincoln Ave	Forest Ave	Washington Blvd	2	700	1	800		S-N	1 lane in each direction and a center turn lane, capacity increased because of turn lane	2013
Sierra Madre Villa Ave	Foothill Blvd	Orange Grove Blvd	2	650	1	750	Buffered Bike Lanes	S-N	1 lane in each direction, capacity increased because of wider lanes	2013
Marengo Ave	Villa St	Orange Grove Blvd	2	650	1	750	Bike Lanes	S-N	1 lane in each direction and a center turn lane, capacity increased because of turn lane	2013

The major street categories used in the model are described below.

Freeways

Freeways are high-capacity facilities that primarily serve longer distance travel. Access is limited to interchanges typically spaced at least one mile apart. Interstate 210 runs directly through the Pasadena model area in an east-west direction, then turns north-south on the west side of Pasadena where it extends north to the San Fernando Valley. State Route 134 (Ventura Freeway) is the east-west corridor that connects to Interstate 210 and the partially built 710 freeway connection on the west side of Pasadena. The Pasadena Freeway (CA -110) is a north-south facility that begins in the south of Pasadena and connects the City to downtown LA.

HOV Lanes

The high-occupancy vehicle lanes (HOV Lanes) are freeway lanes reserved for vehicles with a driver and one or more passengers. These lanes encourage ride-sharing in the freeway network by theoretically allowing these vehicles to move at a faster speed during peak periods. The Pasadena model contains the HOV lanes that run east-west starting on SR-134 (west of Pasadena) and continuing on to Interstate 210 in the east-west direction.

Principal Arterials

Roadways designated as principal arterials are typically major roads that are not limited-access freeways. In Pasadena, these facilities serve travel between the City and its neighboring jurisdictions. For example, one of the main principal arterial in Pasadena is the Sierra Madre Boulevard. Moreover, Colorado Blvd. Arroyo Parkway, and Los Robles Avenue have also being designated as principal arterials in Pasadena.

Minor Arterials

Roadway segments classified as Minor Arterials are major roads that provide connections within the City, between the City and neighboring areas, and through the City (cut-through traffic). Arterials in Pasadena typically have two lanes in each direction, with travel speeds of 30-35 miles per hour (mph). Examples of these arterials are Fair Oaks, Lake, and Hill Avenues.

Major Collectors

Collectors are facilities that connect local streets to the arterial and highway system, and may also provide direct access to local land uses. Collectors typically have one lane in each direction, with speeds of 25-35 mph

Minor Collectors

Minor Collectors are smaller facilities that connect local streets to the arterial and highway system, and may also provide direct access to local land uses. Collectors typically have one lane in each direction, with speeds of 25-35 mph

Local Streets

Some Local Streets have been added to the model; these streets primarily feed collector roads and are typically one lane in each direction, with speeds of 20-25 mph. These streets where added mainly to provide more realistic loadings to larger roadways and may not accurately represents the actual volumes experience on an average day.

For each of its records, the street network database includes a street name, distance, functional class, speed, capacity, and number of lanes. These attributes were checked using maps, aerial photographs, and other data provided by the City. The number of lanes, peak hour parking restrictions and free flow speeds were verified for the entire network. The capacities of roadway links and travel time factors were adjusted during the calibration process for each time period to reflect actual conditions at specific locations. Table 5 shows the initial roadway speeds, lanes and capacities used for each roadway class in the model. Where necessary, these values were adjusted to reflect current conditions at specific locations.

Table 5 - Typical Roadway Speeds and Capacities

Roadway Classification[1]	Average Speed Ranges (mph)	Total Through Lanes	Lane Capacities (vphl)
Freeway	55-65	1-6	1800-2100
HOV Lanes	65	1	1800-2200
Principal Arterials	25-50	2-8	350-850
Minor Arterials	25-45	2-8	400-850
Major Collectors	25-45	2-8	400-650
Minor Collectors	25-45	2-8	350-800
Freeway Ramps	30-65	1-4	1200-1800
Local Streets	20-35	2-4	400-700
Centroid Connectors[2]	20	2	90000

[1] Functional Class definitions are in concurrence with the City of Pasadena: 2004 Mobility Element.

[2] Centroid connectors are abstract representations of the starting and ending point of each trip, and thus should have no capacity constraints.

Description of the Model Calibration Process

Model calibration is the process by which parameters for the model are determined. These parameters are based on comparing travel estimates computed by the model with actual data from the area being modeled. This section provides a general description of the calibration steps and the adjustments made during the process to achieve accuracy levels that are within Caltrans guidelines.

Trip Generation Rates

Trip generation rates relate the number of vehicle trips going to and from a site to the type of land use intensity and diversity of that particular site. Each trip has two ends, a "production" and an "attraction". By convention, trips with one end at a residence are defined as being "produced" by the residence and "attracted" to the other use (workplace, school, retail store, etc.), and are called "Home-Based" trips. Trips that do not have one end at a residence are called "Non-Home-Based" trips.

There are eight trip purposes used in the Pasadena model:

1. Home-Based Work (HBW): trips between a residence and a workplace.
2. Home-Based Other (HBO): trips between a residence and any other destination.
3. Non-Home-Based (NHB): trips that do not begin or end at a residence, such as traveling from a workplace to a restaurant, or from a retail store to a bank.
4. School (SCHOOL): trips to and from a school.
5. College (COLLEGE): trips to and from a college.
6. Recreational (REC): trips to and from parks and other entertainment venues.
7. Internal to External Commute Trips (IXHBW): Work trips of model area residents who work outside the model area
8. External to Internal Commute Trips (XIHBW): Work trips of model area employees who live outside the model area.

Trip generation rates are initially defined for total trips and later split by trip purpose, for both productions and attractions.

The most widely used source for individual project vehicle trip generation rates in the transportation planning field is the *Trip Generation Manual, 10th Edition*. This book contains national averages of trip generation rates for a variety of land uses in what are generally suburban locations. The ITE land use categories tend to be very specific, while model land use categories (accounting for all land use in the City) tend to be more general. ITE rates are appropriate for smaller site-specific uses, such as traffic studies for development review, and they can provide a starting point for travel models by capturing the interaction between all land uses in the City. However, the unique local characteristics of Pasadena require the development of specific trip generation rates for the model.

A traffic impact study uses ITE trip generation rates because, in most cases, the project being examined shares characteristics with the information contained in the *Trip Generation Manual, 10th Edition*. In other words, both the traffic impact study and the ITE rates rely on single-use, isolated projects that have plenty of free parking and little or no interaction with other nearby uses. When assessing the impact of an individual project, the ITE rates are typically appropriate since they can correctly mimic the site being analyzed in the traffic impact study.

The Pasadena model, on the other hand, generates trips by purpose, and balances productions to attractions. The model also has trip rates calibrated to local conditions and other advanced trip generation features such as the cross classification of dwelling units by vehicle availability. Traffic impact studies rely on ITE trip rates that only vary based on land use type or size. While these trip rates are a valid starting point for model calibration and validation, they have a different purpose and are not necessarily suitable for demand forecasting without customization.

Certain ITE rates are more applicable to Pasadena model rates because of their comparable level of detail. For example, both ITE and the Pasadena model have a generic office category. Some ITE rates, however, cannot be used directly because the land use category is not the same as the City's land use classifications. For example, ITE's restaurant categories include high turnover restaurant, fast food restaurant, fast food restaurant with drive-through with seating, fast food restaurant with drive-through and no seating, etc. By necessity, Pasadena restaurant rates represent a compilation and average of those rates customized to the City. It is important to recognize that ITE rates are also averages, based on driveway counts at multiple locations, so the utilization of average rates within the Pasadena model is entirely appropriate.

The original model trip generation rates were initially based on residential trip generation surveys, the SCAG regional model, the San Diego Association of Governments' (SANDAG) trip generation survey, and ITE's Trip Generation 8th Edition. The trip generation rates developed for the Pasadena model used previously calibrated rates developed for the Santa Barbara, Santa Monica, and West Hollywood city-wide models. These model were selected because they share some socioeconomic and land use characteristics with the City of Pasadena. The rates were then modified to account for local conditions based on traffic counts, production-to-attraction balancing (discussed below), and the difference between ITE and model land use definitions. The final Pasadena trip generation rates are unique to the Pasadena model, and they are ultimately based upon the results of successful model calibration and validation. For the model update, rates remain the same but for the addition of Auto Dealership.

Production and Attraction Balancing

Local trips (internal-to-internal, or I-I) are trips that both start and end in the study area. One of the basic assumptions of any travel model is that the total number of local trips produced is equal to the total number of local trips attracted. It is logically assumed that if a journey is started somewhere, it must have an ending somewhere else. If the total productions and attractions are not equal, the model will typically adjust the attractions to match the productions, thus ensuring that each departing traveler finds a destination. While it is never possible to achieve a perfect match between productions and attractions prior to the automatic balancing procedure, the existence of a substantial mismatch in one or more trip purposes indicates that either land use inputs or trip generation factors may be in error. Therefore, in developing the trip productions and attractions for the Pasadena Model, a careful pre-balancing was conducted outside the model stream to eliminate any possible disparity errors.

In addition to production and attraction balancing, the percent of total trips for each purpose were checked for reasonableness. Table 6 shows the trip purpose as a share to total trips in the 2013 model, the updated model and based on the subset of the California Household Travel Survey (CHTS) that represents Pasadena. This information indicates that the trip generation component of the Pasadena model is performing reasonably.

Table 6 – Trip Purpose Percentages

Trip Purpose	Percent of Total Daily Vehicle Trips		
	2013 Pasadena Model[1]	2017 Pasadena Model[1]	CHTS Pasadena[2]
Home-Based Work (HBW)	25%	25%	21%
Home-Based Other (HBO)	42%	44%	49%
Non-Home-Based (NHB)	33%	31%	30%
Total	100%	100%	100%

[1] The trip purposes listed are the broad categories applied in most every travel model. The more specific Pasadena trip purposes are subsets of these broader trip purposes, and have been aggregated here for ease of comparison. IXHBW and XIHBW are subsets of the HBW trip purpose. School, College, and REC are subsets of the HBO trip purpose.

[2] 2012 California Statewide Household Travel Survey

Further Refinement

In addition to the standard trip generation procedures, certain enhancements were added to the Pasadena model to better capture local trip making characteristics and provide the ability to test certain policy options for future development scenarios. These enhancements include dividing the model area into four "area types" that represent vehicle ownership characteristics within the City.

Area Types

City-wide travel demand models frequently benefit from different trip generation rates for single land use categories. For example, single family residences may have different vehicular trip generation characteristics depending on where they are located within city boundaries. Our experience with other models indicates that vehicular availability within each zone is a major factor in vehicular trip generation, where these differences can across different regions within the city. Therefore, four different area types that account for vehicle availability were selected in the model.

Some models, such as the SCAG Planning Model, use a vehicle availability model to estimate vehicular trip generation. In developing the original Pasadena Model, National Household Travel Survey (NHTS) data was used to estimate the average number of vehicles on a per person basis within each of the TAZs in the Pasadena Model. The vehicles per person rates were obtained at a census tract level and subsequently applied at the TAZ level. Table 7 shows the average vehicles per person for the City of Pasadena and surrounding buffer area as obtained in NHTS dataset.

Table 7 - Vehicle Per Person in Pasadena

Parameter	Average Number of Vehicles per Person
Average	0.692
Maximum	0.907
Minimum	0.368
Standard Deviation	0.102
Area Type 1 (Old Pasadena)	NA
Area Type 2 (Avg. Vehicle Availability)	.590 to .793
Area Type 3 (High Vehicle Availability)	> .793
Area Type 4 (Low Vehicle Availability)	< .590

Table 8 - Daily Vehicle Trip Generation Rate Comparison

Land Use Type	Units	Model Area 1	Model Area 2	Model Area 3	Model Area 4
Single-Family (SFU)	units	8.93	9.79	10.30	8.76
Multi-Family (MFU)	units	6.11	6.90	7.21	6.49
Senior Citizen Housing	units	1.88	2.06	2.06	1.55
Lodging	ksf	2.82	3.09	3.09	2.58
Retail	ksf	35.72	46.35	39.14	36.05
Personal Services	ksf	41.36	44.29	45.32	36.05
Restaurant	ksf	51.70	82.40	82.40	72.10
Entertainment	ksf	36.66	41.20	40.17	39.14
Automotive Related	ksf	79.90	87.55	87.55	87.55
Auto Dealership (new in 2017)	*ksf*	26.17	28.68	28.68	28.68
Office	ksf	11.28	10.30	10.30	9.79
Medical Office	ksf	23.50	30.90	30.90	30.90
Government Office	ksf	28.20	61.80	28.84	28.84
Hospital	ksf	14.10	16.48	15.45	17.51
Religious Facilities	ksf	11.28	10.30	12.36	12.88
Cultural	ksf	26.32	28.84	28.84	25.75
Police and Fire Services	ksf	6.58	6.70	7.21	6.70
Park and Recreational Facilities	acres	23.50	26.78	25.75	25.75
Industrial	ksf	1.88	1.55	2.06	1.55
Utility Facilities	acres	18.80	25.75	25.75	25.75
Elementary and Middle School	students	1.22	1.24	1.34	1.44
High Schools	students	1.32	1.44	1.44	1.44
College	students	0.47	0.52	0.82	0.93
SCAG Retail[1]	employees	30.08	36.05	37.08	33.99
SCAG Office[1]	employees	3.29	3.61	3.81	3.09
SCAG Industrial[1]	employees	2.82	3.09	3.09	3.09
SCAG Educational[1]	employees	2.16	2.37	2.37	2.37

[1] ITE multifamily (MFU) rates range from 4.18 to 6.72 depending on the dwelling type. Variability among these trip rates was based on Area Type

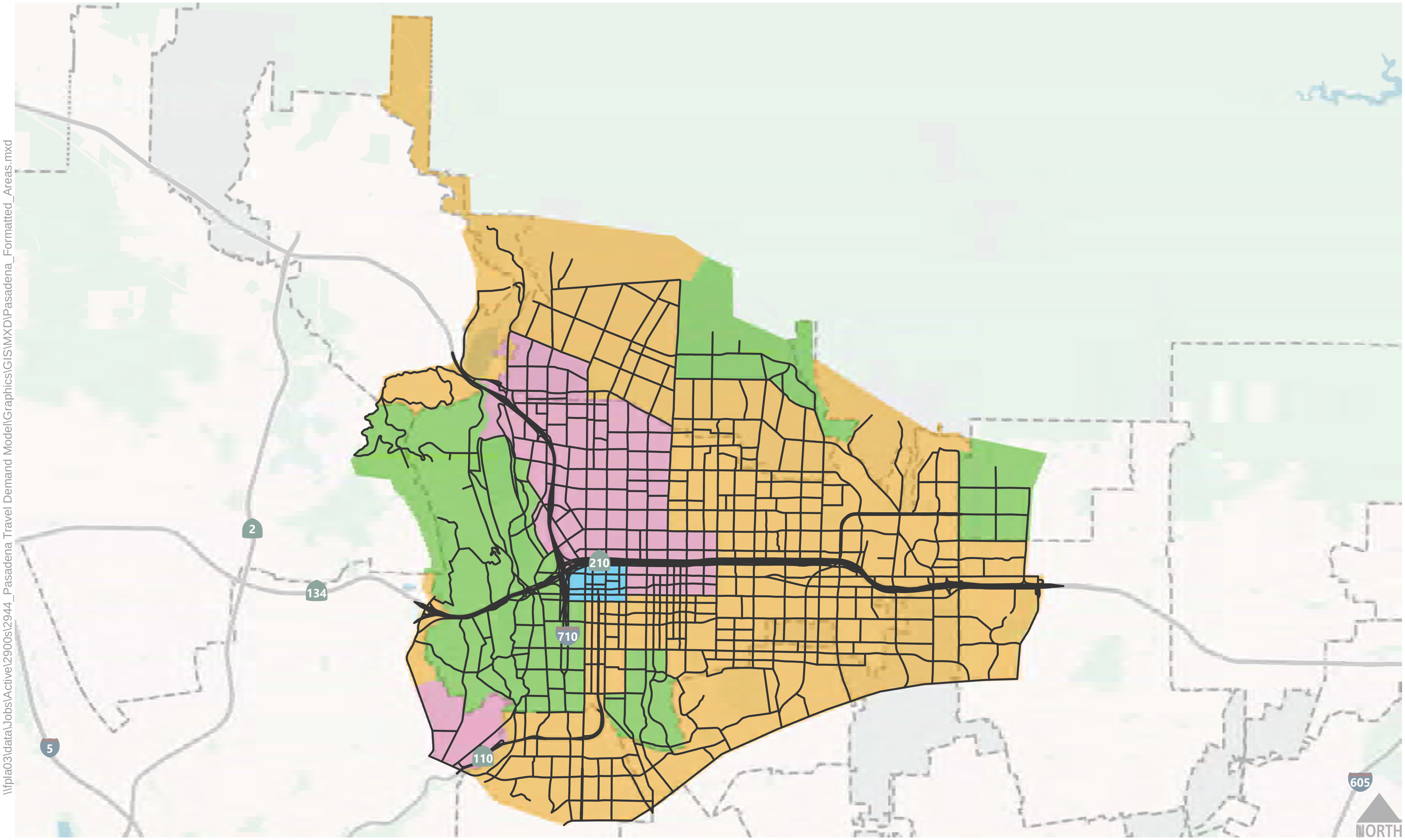
[2] Not all non-residential land use categories are present in each area type. 2010 trip generation rates were only developed for land uses present in 2010 in each area type.

Using this information, four area types were developed for the City of Pasadena Model. The TAZs were divided into area types by using the standard deviation (σ) calculated from the data set. The standard deviation is a statistical parameter used to measure the variability of particular data set from its mean (or average). The standard deviation used here, relates to the normal distribution. In a normally distributed data set, most of the data tends to cluster around the mean, and a smaller percentage of the data represent the upper and lower limits. For example, the bulk of the data (68.2%, representing 2 standard deviations) was grouped to represent Area Type 2, where those TAZs were assumed to have average vehicle availability. Trip generation rates for each land use in each area type are shown in Table 8.

A description of the area types is provided below:

- *Area Type 1 (Old Pasadena):* Irrespective of vehicle availability, there is evidence that urban density and parking benefit districts play a major role in trip generation characteristics, thus downtown Pasadena requires an area type of its own.
- *Area Type 2 (average vehicle availability):* As explained above, this is measured using one standard deviation (σ) below and one σ above the mean (0.590 to 0.793), which accounts for most Pasadena residents or 68.2% of the data set.
- *Area Type 3 (high vehicle availability):* Where the rate of vehicles per person is above 0.793, which accounts for 15.9% of the data.
- *Area Type 4 (low vehicle availability):* Where the rate of vehicles per person is below 0.590, which accounts for 15.9% of the data.

Figure 3 shows the area types applied to the TAZ structure of the Pasadena city-wide model.



Model Street Network

Model Area Type

Area 1

Area 2

Area 3

Area 4

Figure 3

Pasadena Model Area Types

Trip Distribution (Gravity Model)

Once the trip generation step has determined the number of trips that begin and end in each zone, the trip distribution process determines the specific destination of each originating trip. The destination may be within the zone itself, resulting in an intra-zonal trip. If the destination is outside of the zone of origin, it is an inter-zonal trip. Internal-internal (I-I) trips originate and terminate within the model area. Trips that originate within but terminate outside of the model area are internal-external (I-X), and trips that originate outside and terminate inside of the model area are external-internal (X-I). Trips passing completely through the model area are external-external (E-E).

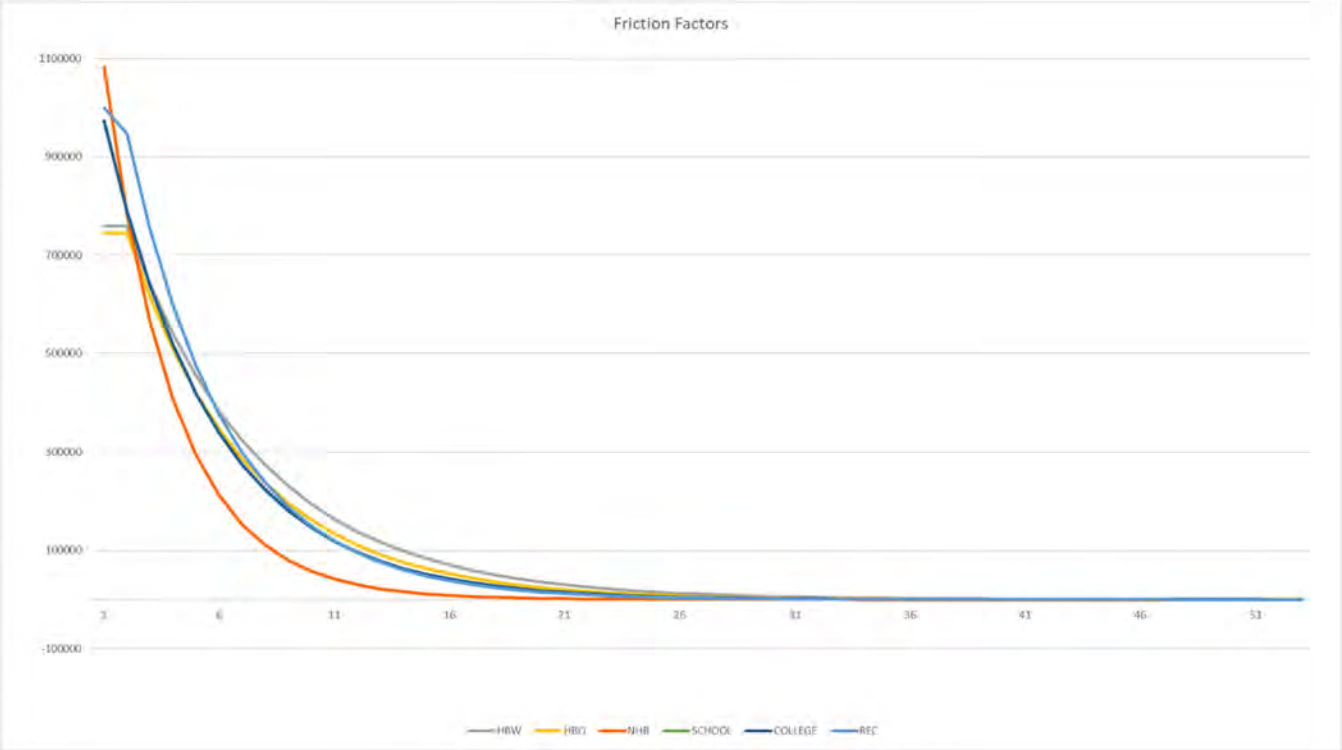
The trip distribution model uses a gravity model equation to distribute trips to all zones. This equation estimates an accessibility index for each zone based on the number of attractions in each zone and a friction factor, which is a function of travel time between zones. Each attraction zone is given its share of productions based on its share of the accessibility index. This process applies to the I-I, I-X, and X-I trips. The E-E trips are added to the trip matrix prior to final assignment.

This stage of the model was calibrated and validated using data from the California Household Travel Survey for trip length and Streetlight Data for trip distribution. These comparisons are described in more detail in the Model Validation section below.

Friction Factors

Friction factors, also known as travel time factors, determine the relative attractiveness of each destination zone based on the travel time between TAZs and the number of potential origins and destinations in each TAZ. These factors are used in the trip distribution stage of the model. The 2017 Pasadena model friction factors were initially based on data reported in national modeling reference documents such as National Cooperative Highway Research Program (NCHRP) 365 and modified using the 2012 CHTS Data explained in the Model Validation Section. The friction factor curves are shown below in Figure 4.

Figure 4 – Friction Factors



K Factors

To inform the trip distribution patterns observed in the Streetlight data, a K Factor matrix was added to the model. The K factors make certain travel patterns more or less attractive and are applied on top of the travel patterns predicted by the gravity model. As a method of updating the model to match the observed travel patterns described above, K Factors were applies based on Streetlight data. The factors were generated by comparing the percent of total travel origin-destination matrix for the base version of the model with the matrix for the Streetlight data. For each origin-destination pair, the Streetlight value was divided by the base model, to generate the base K Factors. Subsequent alterations were made to select K Factors to better match the Streetlight data observations. The table below summarizes the average K Factor for each model area.

Table 9 – Average K Factor by Area Type

Area Type	1	2	3	4
1	0.58	0.63	0.50	0.64
2	0.63	1.03	0.83	1.04
3	0.48	0.84	1.02	0.81
4	0.64	1.05	0.80	1.60

Trips between the Model Area and External Areas

One of the important inputs to a travel model is an estimate of the amount of travel between the study area and neighboring areas outside the model. These are typically called internal-external, or I-X/X-I, trips.

The United States Census Bureau surveys residential and work locations at the place level. Table 10 illustrates the distribution of work locations for Pasadena residents and the distribution of residential locations for Pasadena employees. The census data is specific to Pasadena, while the model area also encompasses parts of neighboring cities. It is assumed that a certain percentage of Pasadena employees who live outside the City of Pasadena live within the buffer area included in the model

Table 10 - Pasadena Commuting Patterns

Work Locations for Pasadena Residents		
Year	**% Working Inside Pasadena**	**% Working Outside Pasadena**
2015	24%	76%
Residential Locations of Pasadena Employees		
Year	**% Living Inside Pasadena**	**% Living Outside Pasadena**
2015	13%	87%

Source: US Census Bureau

Based on this data, the proportion of HBW trips entering and leaving the study area was estimated. For non-work trip purposes, information from the SCAG Regional Model was used to develop initial estimates of the percent of HBO and NHB trips that travel between Pasadena and to other regions in the Los Angeles metropolitan region.

Through Trips

Through trips (also called external-external, or EE trips) are trips that pass through the study area without stopping inside the study area. The major flows of through traffic in the Pasadena area use Interstate 210, State Route 134, Huntington Blvd, and the Pasadena Freeway (CA-110) with lower volumes of through traffic using other arterials. The size of these flows was estimated based on Caltrans traffic counts (PeMS) and the SCAG Regional Model. A sub-area extraction was performed in the SCAG Regional Model to obtain the traffic flow patterns coming in and out of the external stations, then the flows were adjusted using the Fratar algorithm to properly estimate the volumes as observed by the counts. In other words, the through trips were modified in conjunction with the external station weights so that results at the model gateways accurately represent observed data. The resulting through trip matrix is summarized in Table 11.

Table 11

Pasadena Model

Matrix of Daily Throught (EE) Trips

Origin - Destination	ID	1001	1002	1003	1004	1005	1006	1007	1008	1009	1010	1011	1012	1013	1014	1015	1016	1017	1018	1019	1020	1021	1022
Foothill Blvd	**1001**	0.00	0.00	0.00	5.56	0.00	0.00	0.00	0.00	0.00	0.00	3.86	5.28	30.40	15.29	11.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00
I-210 Mainline	**1002**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	19.52	9.35	36.30	17.18	25.81	0.00	271.98	0.00	0.00	110.18	0.45	1428.64
	1003	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Berkshire Ave	**1004**	0.00	0.00	0.00	0.00	0.00	11.20	0.00	0.00	0.00	0.00	0.00	3.24	10.59	3.20	17.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chevy Chase Drive	**1005**	0.00	0.00	0.00	0.00	0.00	708.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chevy Chase Drive 2	**1006**	0.00	0.00	0.00	5.96	708.20	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.49	0.00
SR 134 Mainline	**1007**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	21.66	80.17	215.78	1531.72	0.00	0.00	0.00	0.00	0.00	677.38	1.13
SR 134 HOV	**1008**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.32	14.24	0.00	0.00	0.00	0.00	0.00	25.16	0.00
	1009	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	1010	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Colorado Blvd	**1011**	0.00	3.40	0.00	0.21	0.00	0.00	1.17	9.07	0.00	0.00	0.00	0.00	7.89	6.61	233.04	114.77	0.00	0.00	0.00	0.00	118.46	0.00
Yosemite Dr	**1012**	3.60	17.32	0.00	0.47	0.00	0.00	78.97	1.25	0.00	0.00	0.00	0.00	52.37	18.00	1216.63	120.02	0.00	0.00	0.00	0.00	93.60	0.00
Meridian St	**1013**	5.91	28.22	0.00	1.17	0.00	0.00	218.95	11.13	0.00	0.00	0.00	38.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
York Blvd	**1014**	6.31	22.00	0.00	0.56	0.00	0.00	258.34	14.36	0.00	0.00	0.00	28.58	0.00	175.54	2976.15	311.15	0.00	0.00	0.00	0.00	636.23	0.00
N Figueroa	**1015**	6.25	27.08	0.00	3.33	0.00	0.00	1576.56	109.81	0.00	0.00	34.65	1286.70	0.00	3001.91	0.00	0.00	0.00	0.00	0.00	0.00	36.06	0.00
Avenue 64	**1016**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	158.16	0.00	387.78	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pasadena Freeway	**1017**	0.00	245.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.47
	1018	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Arroyo Verde Rd	**1019**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.37	0.00
Monterrey Rd	**1020**	0.00	37.39	0.00	3.61	0.00	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	491.33	0.00
Meridian Ave	**1021**	0.00	0.00	0.00	0.00	0.00	0.29	640.14	25.93	0.00	0.00	31.84	134.62	0.00	699.82	42.66	0.00	0.00	0.00	1.82	505.38	0.00	0.00
Huntington Rd WB	**1022**	0.00	1565.30	0.00	0.00	0.00	0.00	5.37	16.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fremont Ave	**1023**	0.00	2427.51	0.00	0.00	0.00	0.09	293.72	13.81	0.00	0.00	7.51	32.55	0.00	221.82	67.03	0.00	13.05	0.00	7.94	15.26	0.00	0.00
N Atlantic Blvd	**1024**	0.00	455.73	0.00	0.00	0.00	0.00	75.12	0.00	0.00	0.00	0.00	2.90	0.00	24.71	7.50	0.00	25.04	0.00	0.00	2.73	0.00	0.00
Garfield Ave	**1025**	0.00	919.91	0.00	0.00	0.00	0.14	286.11	12.88	0.00	0.00	255.13	76.07	0.00	1094.13	334.34	0.00	359.04	0.00	20.04	49.67	0.00	124.88
Virginia Rd	**1026**	0.00	159.11	0.00	0.00	0.00	0.03	68.74	0.88	0.00	0.00	0.00	0.33	0.00	68.36	40.15	0.00	84.24	0.00	10.24	7.81	0.00	24.86
West Dr	**1027**	0.00	0.00	0.00	0.00	0.00	0.00	2.52	11.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
San Marino Ave	**1028**	0.00	468.06	0.00	0.00	0.00	0.05	240.70	64.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Del Mar Ave	**1029**	0.00	51.48	0.00	0.00	0.00	0.08	369.21	41.62	0.00	0.00	2.93	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
San Gabriel Blvd	**1030**	0.00	1174.83	0.00	0.00	0.00	0.42	1203.64	90.76	0.00	0.00	33.30	1.23	0.00	11.41	6.35	0.00	115.40	0.00	0.00	2.31	0.00	16.11
Madre St	**1031**	0.00	81.96	0.00	0.00	0.00	0.05	167.15	20.55	0.00	0.00	6.92	1.89	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rosemead Blvd	**1032**	190.70	1799.11	0.00	13.31	0.00	0.80	2183.30	135.77	0.00	0.00	88.56	4.70	0.00	30.42	21.51	0.00	458.73	0.00	30.56	8.16	0.00	225.14
California Blvd	**1033**	86.73	842.41	0.00	7.30	0.00	0.36	1243.42	68.71	0.00	0.00	43.47	6.25	0.00	34.96	25.86	0.00	413.70	0.00	29.85	9.81	0.00	165.79
Baldwin Ave	**1034**	40.21	523.98	0.00	3.17	0.00	0.14	709.73	101.98	0.00	0.00	24.77	4.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huntington Rd EB	**1035**	8.64	82.35	0.00	0.61	0.00	0.04	166.70	16.80	0.00	0.00	5.11	1.75	0.00	70.18	97.53	0.00	979.62	0.00	56.69	62.28	0.00	1085.02
Colorado St	**1036**	77.90	859.18	0.00	8.97	0.00	0.49	1460.97	153.92	0.00	0.00	46.70	17.26	12.26	3.08	13.89	0.00	498.12	0.00	0.00	0.00	0.00	0.00
SR 134 Mainline	**1037**	0.00	20245.62	0.00	0.00	0.00	4.07	34872.87	0.00	0.00	0.00	568.03	217.08	336.92	68.07	429.84	0.00	1116.16	0.00	0.00	8.77	0.00	1.82
SR 134 HOV	**1038**	0.00	5446.40	0.00	0.00	0.00	0.18	0.00	5593.07	0.00	0.00	165.44	24.81	22.66	4.98	9.99	0.00	40.57	0.00	0.00	0.00	0.00	0.00
	1039	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SR 134 Ramps	**1040**	0.00	19.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W Foothill Blvd	**1041**	36.71	503.41	0.00	4.91	0.00	0.20	1204.04	173.28	0.00	0.00	34.22	13.08	29.04	7.59	40.95	0.00	930.34	0.00	0.00	1.07	0.00	105.34
Orange Grove	**1042**	4.63	39.39	0.00	0.33	0.00	0.02	138.54	12.19	0.00	0.00	3.42	1.40	2.69	1.02	4.75	0.00	140.45	0.00	0.00	0.62	0.00	42.18
Sierra Madre Blvd	**1043**	191.74	209.14	0.00	89.55	0.00	0.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Grandview Ave	**1044**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Sum	**659.34**	**38254.67**	**0.00**	**149.03**	**708.20**	**728.08**	**47465.99**	**6700.32**	**0.00**	**0.00**	**1375.38**	**2091.42**	**621.27**	**6185.16**	**7168.50**	**545.94**	**5446.44**	**0.00**	**157.14**	**784.08**	**2082.51**	**3221.37**

Origin - Destination	ID	1023	1024	1025	1026	1027	1028	1029	1030	1031	1032	1033	1034	1035	1036	1037	1038	1039	1040	1041	1042	1043	1044	Sum
Foothill Blvd	**1001**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	125.52	84.45	38.99	3.92	92.04	0.00	0.00	0.00	0.00	154.95	7.76	79.85	0.00	**659.34**
I-210 Mainline	**1002**	2168.85	407.80	1005.82	168.09	0.00	571.92	49.76	880.25	116.02	2014.24	866.11	912.56	78.97	690.51	20178.61	5496.85	0.00	39.31	586.66	43.60	59.35	0.00	**38254.68**
	1003	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
Berkshire Ave	**1004**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.56	0.00	0.00	0.00	1.03	0.00	0.00	0.00	0.00	32.21	1.44	67.50	0.00	**149.04**
Chevy Chase Drive	**1005**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**708.75**
Chevy Chase Drive 2	**1006**	0.22	0.00	0.22	0.06	0.00	0.04	0.28	0.62	0.04	1.29	0.59	0.38	0.04	0.71	6.33	0.84	0.00	0.00	0.76	0.03	0.20	0.00	**727.38**
SR 134 Mainline	**1007**	325.62	231.77	289.62	77.06	1.72	193.55	595.05	1076.34	189.50	2162.70	1182.60	1296.51	156.59	1076.85	34654.23	0.00	0.00	0.00	1193.82	138.90	95.72	0.00	**47466.00**
SR 134 HOV	**1008**	17.78	10.42	10.48	3.57	21.29	33.46	71.53	92.77	14.63	148.71	91.85	139.22	11.41	261.55	0.00	5554.87	0.00	0.00	148.48	12.83	12.77	0.00	**6700.32**
	1009	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
	1010	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
Colorado Blvd	**1011**	67.97	13.68	167.69	0.00	0.00	0.79	4.94	9.15	4.76	27.02	13.28	29.67	1.69	28.65	273.22	203.39	0.00	0.00	28.16	2.24	4.46	0.00	**1375.38**
Yosemite Dr	**1012**	51.61	4.35	55.27	0.11	0.00	0.00	0.00	2.31	1.66	8.33	9.55	9.25	2.25	16.63	300.93	7.38	0.00	0.00	16.29	1.88	1.38	0.00	**2091.42**
Meridian St	**1013**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.95	273.59	9.09	0.00	0.00	23.79	2.44	1.94	0.00	**621.27**
York Blvd	**1014**	406.07	53.04	1024.54	52.58	0.00	0.00	0.00	8.56	0.00	24.44	31.90	0.00	66.87	2.22	74.38	1.46	0.00	0.00	7.94	1.17	0.78	0.00	**6185.16**
N Figueroa	**1015**	46.35	7.40	272.12	23.67	0.00	0.00	0.00	3.39	0.00	15.02	20.68	0.00	73.25	12.12	553.63	2.88	0.00	0.00	47.15	5.42	3.08	0.00	**7168.50**
Avenue 64	**1016**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**545.94**
Pasadena Freeway	**1017**	5.14	22.90	379.93	109.34	0.00	0.00	0.00	97.65	0.00	388.32	462.15	1.16	862.40	369.00	1224.27	25.92	0.00	0.00	965.83	142.17	144.68	0.00	**5446.44**
	1018	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
Arroyo Verde Rd	**1019**	6.09	2.62	81.32	6.87	0.00	0.00	0.00	0.00	0.00	2.96	6.11	0.00	47.81	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**157.14**
Monterrey Rd	**1020**	15.37	4.82	113.39	14.71	0.00	0.00	0.00	2.76	0.00	12.23	17.77	0.00	69.18	0.00	1.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**784.08**
Meridian Ave	**1021**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**2082.51**
Huntington Rd WB	**1022**	0.00	0.00	132.04	9.81	0.00	0.00	0.00	13.35	0.00	197.04	176.26	0.00	970.56	49.32	15.81	0.00	0.00	0.00	29.43	40.32	0.00	0.00	**3221.37**
Fremont Ave	**1023**	0.00	0.00	4.88	0.00	0.00	0.00	0.00	0.00	0.00	18.09	7.47	0.00	78.11	7.16	11.40	0.00	0.00	0.00	14.48	4.61	0.00	0.00	**3246.48**
N Atlantic Blvd	**1024**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	31.70	9.78	0.00	874.61	89.46	16.96	0.00	0.00	0.00	56.61	77.55	0.00	0.00	**1750.41**
Garfield Ave	**1025**	3.52	0.00	0.35	0.71	0.00	0.00	0.00	1.62	0.00	4.80	5.19	0.00	37.89	1.81	3.99	0.00	0.00	0.00	1.61	0.95	0.00	0.00	**3594.78**
Virginia Rd	**1026**	0.00	0.00	1.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**466.56**
West Dr	**1027**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	321.33	20.04	16.07	0.00	0.00	0.00	15.60	17.28	0.00	0.00	**404.19**
San Marino Ave	**1028**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	29.81	4.31	0.00	0.00	0.00	0.00	0.00	1.82	0.00	0.00	**809.19**
Del Mar Ave	**1029**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	343.83	60.73	0.00	0.00	0.00	0.00	14.94	21.58	0.00	0.00	**906.39**
San Gabriel Blvd	**1030**	0.00	0.00	1.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	457.36	92.82	23.33	0.00	0.00	50.15	94.09	49.76	0.00	0.00	**3424.68**
Madre St	**1031**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	34.21	2.47	0.00	0.00	0.00	24.25	3.53	2.90	0.00	0.00	**345.87**
Rosemead Blvd	**1032**	19.47	43.99	5.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	831.66	137.04	63.32	0.00	0.00	171.13	98.37	54.49	0.00	0.00	**6615.27**
California Blvd	**1033**	4.44	7.66	5.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	126.39	0.00	0.00	0.00	0.00	**3122.55**
Baldwin Ave	**1034**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3106.04	265.78	116.30	0.00	0.00	68.05	119.66	513.69	0.00	0.00	**5597.91**
Huntington Rd EB	**1035**	86.37	769.83	38.38	0.00	320.16	8.32	144.12	923.10	0.00	1009.69	0.00	2522.72	0.00	0.00	0.00	0.00	0.00	21.28	0.00	10.70	0.00	0.00	**8487.99**
Colorado St	**1036**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	206.51	0.00	209.62	0.00	0.00	**3568.86**
SR 134 Mainline	**1037**	0.00	3.83	1.66	0.00	5.54	0.00	0.00	7.32	0.00	12.96	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2632.29	0.00	2.50	0.00	0.00	**60535.35**
SR 134 HOV	**1038**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	96.69	0.00	0.00	0.00	0.00	**11404.80**
	1039	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
SR 134 Ramps	**1040**	0.00	0.00	0.00	0.00	0.00	0.00	4.82	60.65	19.26	184.71	136.83	135.68	19.19	150.51	2618.34	77.35	0.00	0.00	144.63	15.73	19.15	0.00	**3606.12**
W Foothill Blvd	**1041**	17.54	111.10	2.63	0.00	41.55	0.70	28.81	173.85	0.00	167.12	0.00	113.22	0.00	0.00	0.00	0.00	0.00	154.49	0.00	359.74	0.00	0.00	**4254.93**
Orange Grove	**1042**	4.07	55.19	0.76	0.00	13.94	0.41	7.08	70.96	0.00	56.83	0.00	398.54	9.02	129.14	109.26	24.76	0.00	15.59	455.96	0.00	0.00	0.00	**1743.12**
Sierra Madre Blvd	**1043**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**490.86**
Grandview Ave	**1044**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
	Sum	**3246.48**	**1750.41**	**3594.78**	**466.56**	**404.19**	**809.19**	**906.39**	**3424.68**	**345.87**	**6615.26**	**3122.55**	**5597.90**	**8487.99**	**3568.86**	**60535.29**	**11404.79**	**0.00**	**3606.12**	**4254.93**	**1743.12**	**490.86**	**0.00**	**#########**

Trip Assignment

The trip assignment process determines the route that each vehicle trip takes from a particular origin to particular destination. The model selects these routes in a manner that is sensitive to congestion and the desire of drivers to minimize overall travel time. It uses an iterative, capacity-restrained assignment, and volume adjustments are made that progress towards equilibrium. This technique finds a travel path for each trip that minimizes travel time, while taking into account congestion delays caused by the other simulated trips in the model.

The general assignment process includes the following steps.

- Assign all trips to the links along their selected paths.
- After all assignments, examine the volume on each link and adjust its impedance based on the volume-to-capacity ratio.
- Repeat the assignment process for a set number of iterations or until specified criteria related to minimizing travel delays are satisfied.

Calibration of the street network included modification of the centroid connectors to more accurately represent the location at which traffic accesses local roads; adjustment of speeds from posted speed limits to reflect the attractiveness of the route and the prevailing speed of traffic, refinements to the turn penalties files, and finally an additional travel time factor was used.

Turn Penalties

Turn penalties are used to prohibit or add delay to certain turning movements. The Pasadena model prohibits traffic from getting off a freeway ramp and then immediately getting back on. The model also prohibits traffic from making turns across impassable medians. In addition, the model does not allow U-turns in order to avoid counter-intuitive traffic routing. Information on prohibited turns was maintained from the 2013 Travel Model.

Model Validation

Model validation is the term used to describe model performance in terms of how closely the model's output matches existing travel data in the base year. During the model development process, these outputs are used to further calibrate model inputs. The extent to which model outputs match existing travel data validates the assumptions of the inputs.

Traditionally, most model validation guidelines have focused on the performance of the trip assignment function in accurately assigning trips to the street network. This metric is called static validation, and it remains the most common means of measuring model accuracy.

Models are seldom used for static applications; however, by far the most common use of models is to forecast how a change in inputs would result in a change in traffic conditions. Therefore, another test of a model's accuracy focuses on the model's ability to predict realistic differences in outputs as inputs are changed. This method is referred to as dynamic validation. This section describes the highest-level validation checks that have been performed for the Pasadena model.

Additional steps to validate the Trip Distribution stage of the model are also discussed. As these validation methods rely on newer data sources and innovative data comparisons, there are no standardized validation thresholds for the Trip Distribution validation steps. Therefore, the VMT section below describes comparisons between the model and other data sources rather than strict validation criteria.

Static Validation

The most critical static measurement of the accuracy of any travel model is the degree to which it can approximate actual traffic counts in the base year. Caltrans has established certain trip assignment guidelines for models forecasting future year traffic in *Travel Forecasting Guidelines* (California Department of Transportation, November 1992). The validity of the Pasadena model was tested under daily, AM peak period, PM peak period, midday peak period, off-peak period, AM peak hour, and PM peak hour conditions. Model volumes were compared to existing traffic counts at 206 individual count sites for daily, peak period, and peak hour validation. The results are shown in, Table 12, Table 13, and Table 14.

Link volume results from model runs were examined and checked for reasonableness. Links where model results varied substantially from the observed counts were identified, and the characteristics of these links were reviewed to ensure that the link attributes reflected local operating conditions. In some cases, link characteristics such as speeds were modified to better reflect conditions on the ground.

Comparison Techniques

Travel model accuracy is usually tested using four comparison techniques:

- The volume-to-count ratio is computed by dividing the model volume by the actual traffic count for individual roadways (or intersections) area-wide.
- The maximum deviation is the difference between the model volume and the actual count divided by the actual count.
- The correlation coefficient estimates the overall level of accuracy between observed traffic counts and the estimated traffic volumes from the model. These coefficient ranges from 0 to 1, where 1.0 indicates that the model perfectly fits the data.
- The percent root mean square error (RMSE) is the square root of the model volume minus the actual count squared, divided by the number of counts. It is a measure similar to standard deviation in that it assesses the accuracy of the entire model.

Table 12 - Results of Daily Model Validation

Validation Item	Criterion for Acceptance	Model Results
Count Locations	NA	200
% of Links within Caltrans Standard Deviations	At least 75%	88%
% of Screenlines with Caltrans Standard Deviations	100%	100%
2-way Sum of All Links Counted	Within +/- 10%	-2%
Correlation Coefficient	Greater than 88%	0.98
RMSE	40% or less	20%

Table 13 - Results of Peak Period Model Validation

Validation Item	Criterion for Acceptance	AM Peak Period	MD Peak Period	PM Peak Period	Off Peak Period
Count Locations	NA	200	200	200	200
% of Links within Caltrans Standard Deviations	At least 75%	80%	82%	76%	75%
% of Screenlines with Caltrans Standard Deviations	100%	100%	100%	100%	100%
2-way Sum of All Links Counted	Within +/- 10%	0%	-4%	1%	-6%
Correlation Coefficient	Greater than 88%	0.96	0.98	0.97	0.98
RMSE	40% or less	30%	22%	26%	31%

Table 14 - Results of Peak Hour Model Validation

Validation Item	Criterion for Acceptance	AM Peak Hour	Off Peak Hour
Count Locations	NA	200	200
% of Links within Caltrans Standard Deviations	At least 75%	76%	81%
% of Screenlines with Caltrans Standard Deviations	100%	100%	100%
2-way Sum of All Links Counted	Within +/- 10%	5%	2%
Correlation Coefficient	Greater than 88%	0.96	0.96
RMSE	40% or less	31%	29%

Validation Guidelines

For a model to be considered accurate and appropriate for use in travel forecasting, it must replicate actual conditions within a certain level of accuracy. Since it would be impossible for any model to replicate all counts precisely, validation guidelines have been established by Caltrans and other agencies. Key validation standards for daily travel models based on the Caltrans guidelines are summarized below:

- At least 75 percent of the roadway links for which counts are available should be within the maximum desirable deviation, which ranges from approximately 15 to 60 percent depending on total volume (the larger the volume, the less deviation is permitted).
- All of the roadway screenlines should be within the maximum desirable deviation, which ranges from approximately 15 to 64 percent depending on total volume.
    - Screenlines are boundaries drawn across a street network to determine the total volume crossing the boundary. Screenline accuracy determines whether the volume moving across the model area is consistent with the observed volumes. The following screenlines were used for model validation:
        - Fair Oaks Avenue
        - Los Robles Avenue
        - Lake Avenue
        - Hill Avenue
        - Allen Avenue
        - San Gabriel Boulevard
        - Washington Boulevard
        - Orange Grove Boulevard
        - Walnut Street
        - Colorado Boulevard
        - Del Mar Boulevard
        - California Boulevard
- The two-way sum of the volumes on all roadway links for which counts are available should be within 10 percent of the counts.
- The correlation coefficient between the actual ground counts and the estimated traffic volumes should be greater than 88 percent.

Although not stated in the Caltrans standards, an additional Fehr & Peers validation guideline was applied to the Pasadena model:

- The RMSE should not exceed 40 percent.

Dynamic Validation

Several Dynamic Validation tests were also performed to validate that the model responds appropriately to changes on the land use and network. A summary of those changes and their effect on the model outputs are listed and shown in figures below. For each run the model responds to the changes appropriately.

Dynamic Tests:

- Add Households to Zone 250
  - Initial Daily Trip Generation: 7,950 trips
  - Add 10 Multifamily Households: 8,020 trips
  - Add 100 Multifamily Households: 8,641 trips
  - Add 1000 Multifamily Households: 14,823 trips
- Add Auto Dealership to Zone 227
  - Initial Daily Trip Generation: 5,740 trips
  - Add 10 KSF of Auto Dealership: 6,030 trips
  - Add 100 KSF of Auto Dealership: 8,607 trips

Figure 5 - Increase Speed on Colorado between Marengo and El Molino, from 35 mph to 45 mph

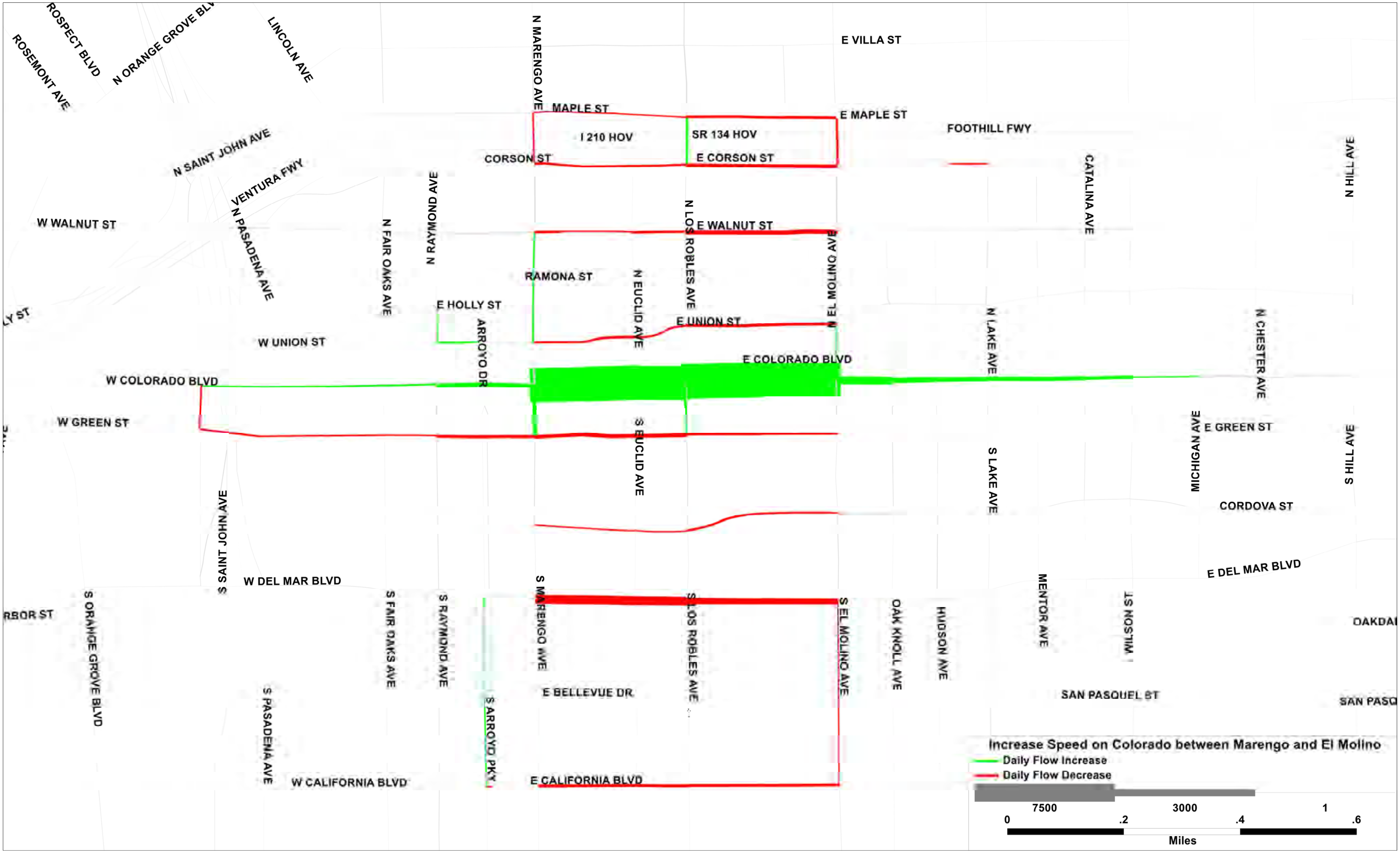


Figure 6 - Add Capacity on Wilson between Walnut and Green, from 600 to 900

Figure 7 - Add Lanes on Mountain between Wheeler and Lake, from 1 to 2 lanes in each direction

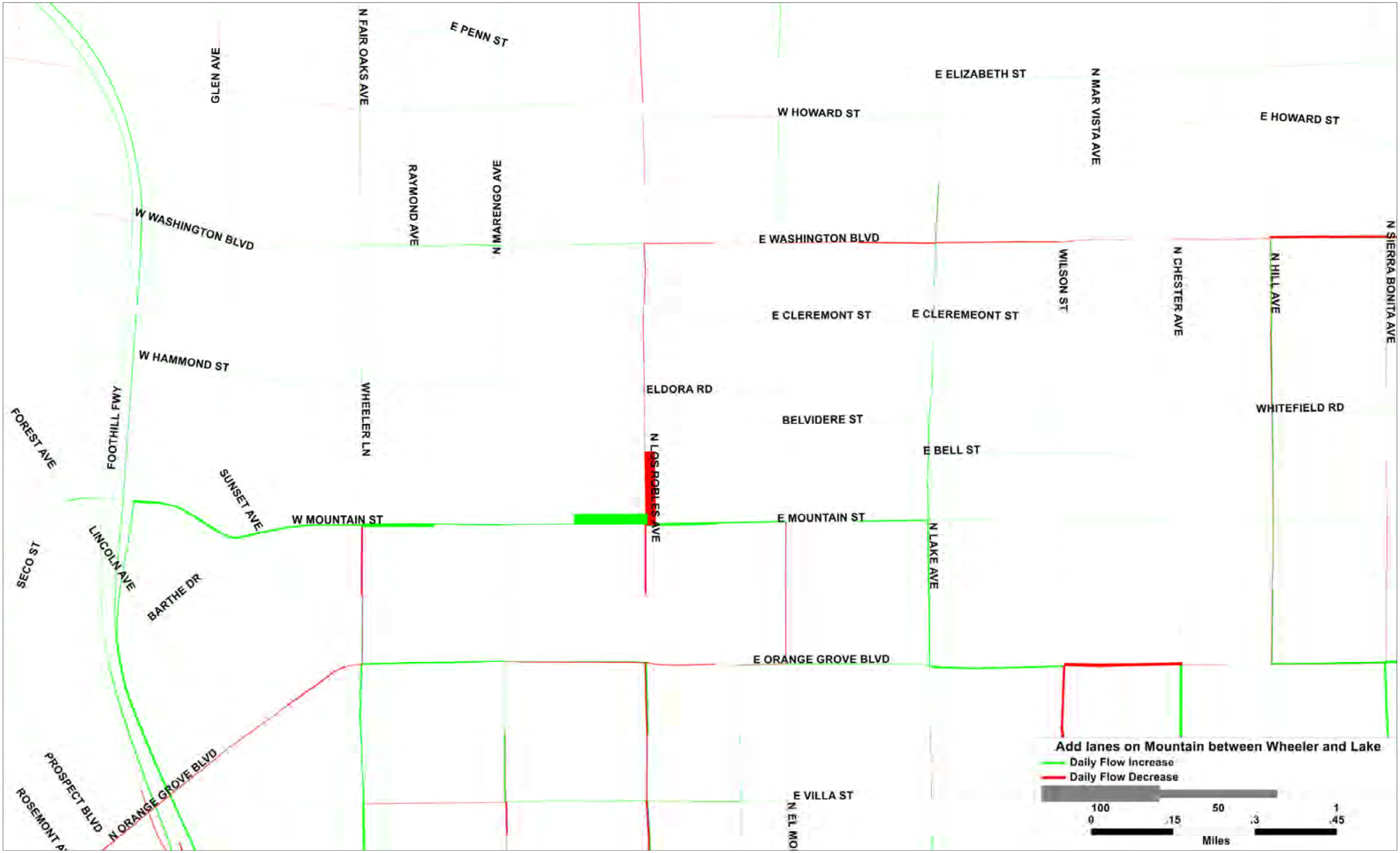


Figure 8 - Remove Lanes on Lake between Villa and Mountain, from 2 to 1

Vehicle Miles Traveled (VMT)

One of the Pasadena CEQA Thresholds is Vehicle Miles Traveled (VMT). This update to the Pasadena Model focused on comparing the VMT produced by the model with Streetlight Data, the California Household Travel Survey (CHTS), and the SCAG Model. The table below shows the new VMT estimate comparted to the estimate in the previous model and to other data sources estimated of VMT.

Table 15 – Vehicle Miles Traveled (VMT) Comparison

Source	Daily Pasadena VMT	Daily Pasadena VMT per Capita
2013 Model	5,591,328	22.6
2017 Model	5,706,256	22.8
Source	**Daily Freeway VMT**	**Daily Total VMT**
2017 Model	3,298,237	8,893,871
Caltrans HPMS[1]	3,009,197	NA
SCAG Model	NA	8,084,133
Percent Difference	109.61%	110.02%
Ratio	1.096	1.100

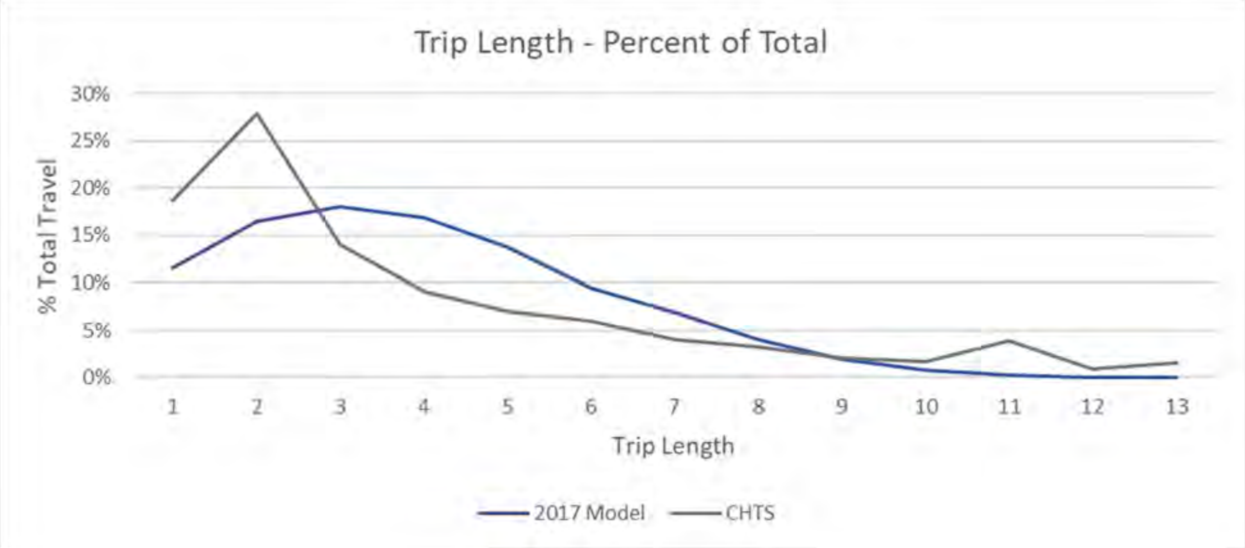
[1] Caltrans Highway Performance Monitoring System, 2016

2012 California Household Travel Survey (CHTS)

An important component of VMT analysis is trip length because VMT is based on the number of trips multiplied by trip length. The trip generation step determines the number of trips produced, and trip distribution determines the trip length. To validate the trip length in the model, Fehr & Peers analyzed data from the 2012 California Household Travel Survey (CHTS). This data includes trip information based on travel-diary entries from across the state of California. Trips were identified to be within the model area, both inside the City of Pasadena and in the buffer area, based on the census tract of the trip origin or destination.

The number of trips from the model and CHTS were summarized by one-mile trip length bins from 1 mile to 13 miles. The model was calibrated to better match the trip length pattern reported in CHTS showing a spike in the number of trips with a 2-mile length, then decreasing, shown in Figure 9. The model calibration, particularly altering the friction factors, resulted in a larger proportion of short trips as observed in the CHTS.

Figure 9 – Trip Length Comparison



The 2017 Pasadena model is 75% correlated with CHTS trip length pattern, showing a strong relationship between the two datasets. Table 16 shows the average trip length in the updated Pasadena model, compared to CHTS.

Table 16 – Trip Length Comparison

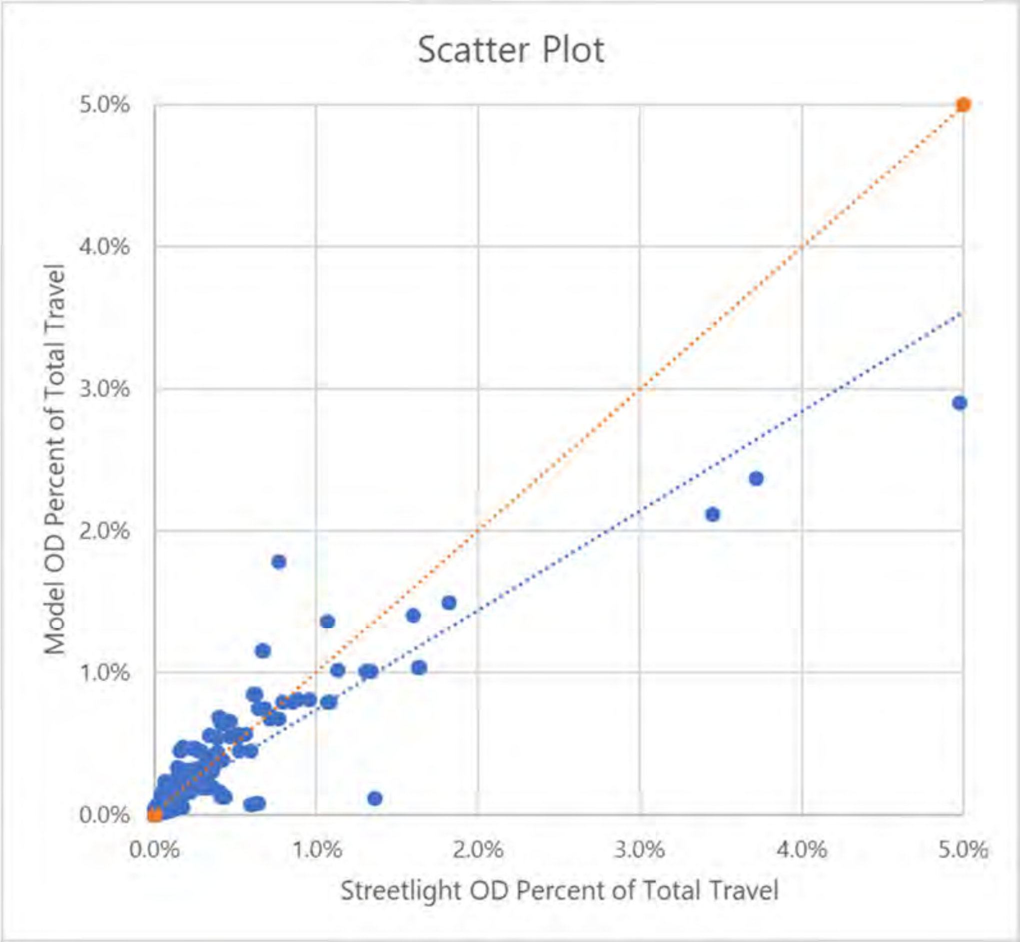
Source	Average Trip Length (commute)	Average Trip Length (non-commute)	Correlation to CHTS
CHTS	7.68		NA
2017 Model[1]	4.31	4.26	75%
1 Trip Length for this comparison is calculated in a different manner than the trip length used for the CEQA Thresholds Trip Length			

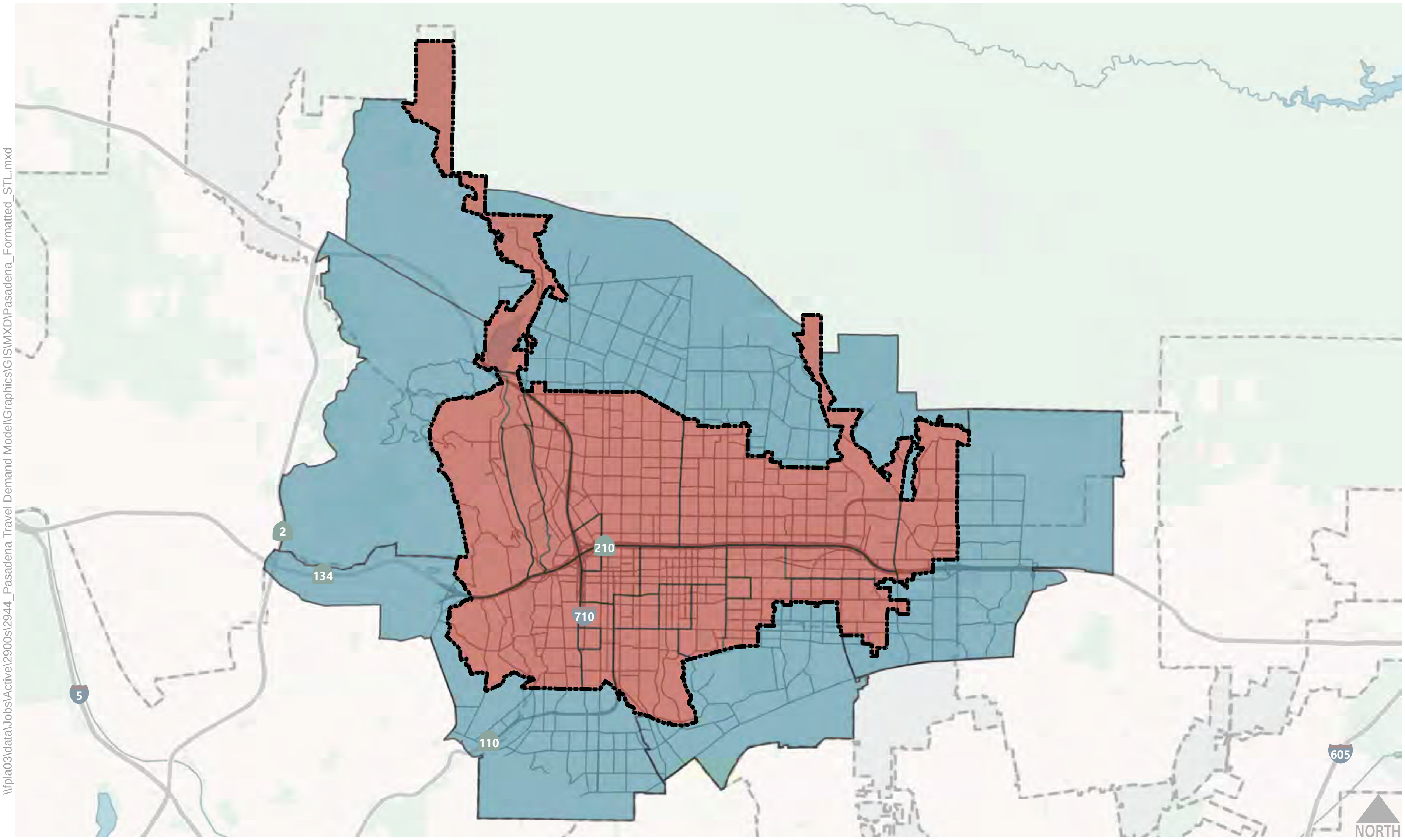
Streetlight Data

The CHTS data was used to calibrate the model's trip length distribution. To better calibrate where these trips are distributed, Streetlight data was analyzed. Streetlight data is a third-party provider of GPS and cell phone travel data. Streetlight data uses a sample of observed travel patterns to provide estimates of where people travel. Fehr & Peers used Streetlight Data to calibrate the model travel patterns. This data source reports travel magnitude between a set of origins and destinations input by the user. To facilitate comparison, the Pasadena TAZs were aggregated to the 29 Streetlight Zones, developed in coordination with the City of Pasadena and shown in . The percent of total travel between each origin-destination pair was compared between the Pasadena travel model and the Streetlight data.

As described in the K Factor section, the Streetlight data was used to generated K Factors, which resulted in trip distribution patterns that better match the observed travel patterns. The scatter plot below, Figure 10, shows the model data compared with the Streetlight data, with each point represents an origin-destination pair. The orange line in the scatter plot represent how the data would look of the two data sets matched exactly. The trip distribution in the updated model is 91% correlated with the Streetlight trip distribution, showing a strong relationship between the model and the observed travel patterns.

Figure 10 – Scatter Plot Comparing Streetlight and Pasadena Model Trip Distribution





Pasadena City Boundary

Pasadena Streetlight Zones (22 zones)

Buffer Streetlight Zones (7 zones)

Figure 11

Regional Zones that extend across LA County were also included but are not depicted here

Streetlight Zones

Mode Shift Analysis Tool

The Mode Shift Analysis Tool (MSAT) has been developed for the Pasadena travel demand model in order to analyze and demonstrate the effectiveness of traffic reduction associated with changes to local transit service expansion (TSE) and transportation demand management (TDM). Fehr & Peers developed a robust tool in TransCAD, using the GISDK programming language, to properly incorporate and quantify TSE and TDM benefits in the City of Pasadena. Fehr & Peers is continually doing research in understanding TDM and has updated the model's sensitivity to be consistent with new research being done for the California Air Resources Board.

MSAT Approach

The MSAT is a local adaptation of a number of TDM models developed to date by the US EPA and the FHWA. Specifically, some of the mathematical procedures associated with this tool are outlined in the COMMUTER Model v2.0[1] produced by the US EPA. In addition, the California Air Pollution Control Officers Association (CAPCOA): *Quantifying Greenhouse Gas Mitigation Measures*[2] recent publication has been incorporated as a guiding post for reasonableness checking. This document brings together research that provides expected trip reductions ranges for various TSE and TDM strategies.

From the outset of model development, Pasadena trip generation rates were calibrated to reflect current mode splits. The current mode split (Base Year Model 2017) in Pasadena reflects existing levels of transit service and current levels of TDM strategy deployment. Improvements to the transit service results in fewer auto trips and therefore reductions in VMT and associated GHG emissions. Similarly, increasing the level of current TDM strategies and expanding into new strategies also reduces vehicle trips and associated GHG emissions.

MSAT is a trip reduction process in the Pasadena travel demand model that estimates the effects of improved transit service (as in the case of the Metro Gold Line transit expansion), and TDM measures (also referred as Best Management Practices "BMPs" by the Air Resources Board) on roadway volumes and city-wide VMT. In Pasadena, non-auto trips make up a very small portion of total travel. However, the mode

[1] Procedure Manual for the COMMUTER Model v2.0, Transportation and Regional Programs Division, Office of Transportation and Air Quality, U.S. Environmental Protection Agency. (J. R. Kuzmyak, Sierra Research, Inc., and Cambridge Systematics, Inc., 2005).

[2] California Air Pollution Control Officers Association (CAPCOA) report: Quantifying Greenhouse Gas Mitigation Measures – A Resource for Local Government to Assess Emission Reductions from Greenhouse Gas Mitigation Measures, August, 2010.

share is different for commute trips than for non-commute trips. MSAT was developed to quantify mode share changes at the commute and non-commute level for analysis and forecasting purposes.

The MSAT model simplifies the quantification of workplace commuting programs, transit service expansion, and parking management policies by making selective mode share changes to the initial modal shares in the Pasadena model. The procedure is heavily based on the 2005 COMMUTER Model v2.0, which was an update of the Federal Highway Administration's TDM Evaluation Model[3], developed in 1993. These models have undergone significant sensitivity testing and have been applied widely across the country by planning agencies, transportation agencies, and other organizations. Therefore, the mathematical processes used by them were deemed appropriate for the Pasadena's city-wide model.

Strategies Analyzed

MSAT is able to evaluate the effects of various types of trip reduction strategies, these strategies can be divided into three categories: commute trip reduction programs, transit service improvements, and parking pricing strategies.

Commute Trip Reduction Programs:

1. Transit Fare Subsidy
2. Employee Parking Cash-out
3. Workplace Parking Pricing
4. Employer-Sponsored Vanpool/Shuttle
5. Ride Share Program
6. Commute Trip Reduction Marketing

Transit Service Improvements:

7. Transit Network Expansion
8. Transit Service Frequency (headways)
9. Transit Speed Increase & Bus Rapid Transit (BRT)

Parking Policy/Pricing:

10. Parking Supply Limits
11. Unbundled Parking Cost
12. On-Street Market Pricing

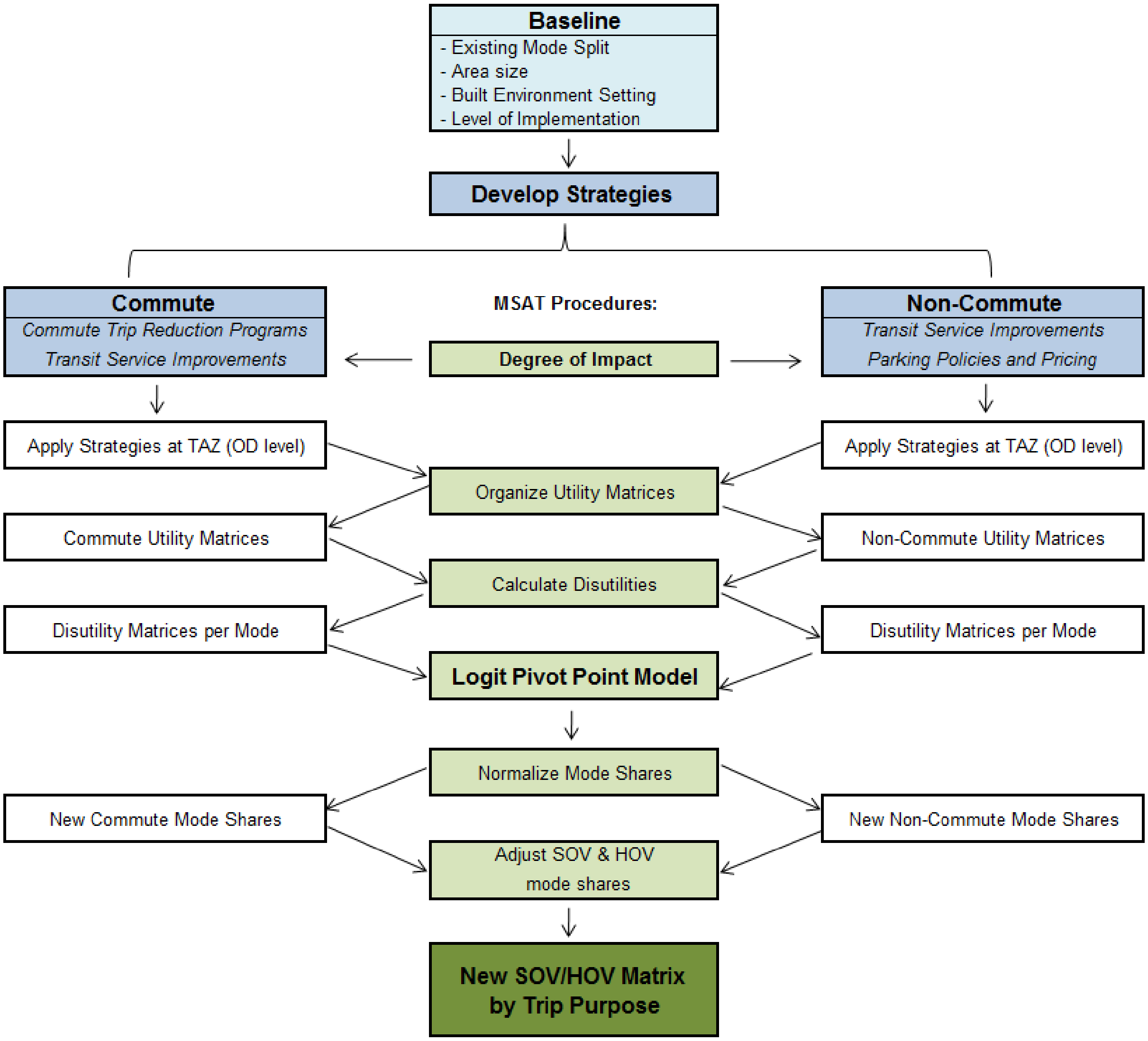
[3] The TDM Evaluation Model was developed by COMSIS Corporation in 1993 in conjunction with a comprehensive program of research and development of reference and guidance tools by the Federal Highway Administration and Federal Transit Administration.

The 12 strategies outlined have different quantifiable effects on the transportation system, the employer-based commute trip reduction strategies quantify monetary and non-monetary actions, like rideshare matching, transit subsidies, preferential parking, and other marketing efforts that incentivize ride sharing, transit usage, walking, and bicycling trips. The first six strategies affect only work trips (i.e., HBW, internal-external HBW, and external-internal HBW).

Transit service programs; quantify the effects of reduction in transit in-vehicle-travel-times (IVTT) and out-of-vehicle-travel-times (OVTT), increase in bus service frequencies, speeds, or deployment of new transit/bus lines. The transit service improvements affect all trip purposes (i.e., commute and non-commute).

Parking strategies quantify trip reductions induced by parking management policies, which deal with the supply and pricing of parking. Empirical studies show that managing the availability or costs of parking has the greatest effect in trip reductions as compared to other TDM programs. These parking strategies, implemented mostly at the neighborhood level, only affect non-commute trips (i.e., NHB, HBO, College, and recreational trips).

Figure 12 – Mode Shift Analysis Tool Structural Procedure



Sensitivity Testing and Updates to 2017 Model

A variety of tests were performed on the MSAT to evaluate its correct application of the computational routines performed for the twelve TSE and TDM strategies described above, and to assure that its predictions were realistic and consistent. The coefficients used in this tool were taken from a previously calibrated TDM model for the SCAG region and were tested to assure their applicability. In addition, recent Fehr & Peers TDM research, which provides the range of effectiveness for different TDM and TSE strategies at the VT and VMT level was used as reasonableness checking for the tool.

Table 17 shows the expected levels of VT reductions for each of the strategies available in the mode shift analysis tool.

Table 17 - Mode Shift Analysis Tool Strategies Tool Kit

No.	Strategy	Trip Type[1]	2013 VT Reduction Ranges[2]	2017 VT Reduction Ranges[2]
Commute Trip Reduction Programs				
1	Transit Fare Subsidy	co	1 - 20.0%	<16%
2	Employee Parking Cash-out	co	< 7.7%	<7.7%
3	Workplace Parking Pricing	co	< 19.7%	<14%
4	Employer's Vanpool/Shuttle	co	<15%	<7.4%
5	Ride Share Program	co	<15%	<8.3%
6	CTR Marketing	co	6% - 21%	<26%
Commute Trip Reduction Programs				
7	Transit Network Expansion	co, nc	< 8.5%	<10.5%
8	Transit Service Frequency (headways)	co, nc	< 2.6%	<6.3%
9	Transit Speed increase & BRT	co, nc	< 3.3%	<3.2%
Parking Policy/Pricing:				
10	Parking Supply Limits	co, nc	<12.5%	<12.5%
11	Unbundled Parking Cost	nc	<13%	<12%
12	On-Street Market Pricing	nc	< 5.5%	<14.5%

[1] Commute (co), non-commute (nc)
[2] Reductions are applied at the TAZ level, thus the total city-wide Pasadena reductions maybe much smaller.
Source: Fehr & Peers, 2011.

Metro Gold Line transit ridership was also analyzed between 2013 and 2018 to better understand the local context for CTR strategy 7.

Table 18 shows the increase in ridership with the recent Gold Line network expansion. Fehr & Peers also did sensitivity testing with MSAT and showed that the In-Vehicle Travel Time and Out-of-vehicle Travel Time coefficients accurately represent the changes that were experienced in Pasadena. The model showed a reduction of approximately 500 vehicle trips, and the observed ridership showed an increase of approximately 2,600 transit riders. According to a recent Metro survey[4], twenty percent of new transit riders shifted from auto. Twenty percent of 2,600 is approximately 500 vehicle trips which is consistent with the Pasadena model testing. Therefore, current IVTT and OVTT coefficients accurately account for changes in transit network expansion.

Table 18 - Metro Gold Line Daily Ridership

Station	2013 Ridership	2018 Ridership	Growth
80416 - FILLMORE STATION	2,945	3,258	313
80417 - DEL MAR STATION	2,929	3,402	473
80418 - MEMORIAL PARK STATION	4,782	5,573	791
80419 - LAKE STATION	3,556	4,032	476
80420 - ALLEN STATION	3,001	3,558	557
Total	17,213	19,823	2,610
Conversion From Auto (20% According to Metro Survey)			522
MSAT Vehicle Trip Reduction			544

Table 19 below shows the adjustments made to the MSAT coefficients to maintain consistency with the latest TDM research available and Metro ridership data. The IVTT and OVTT coefficients did not change based on comparisons between MSAT testing and observed Metro ridership. Cost and Parking Cost coefficients were reduced based on sensitivity testing and maintaining consistency with the latest TDM research.

Table 19 - Mode Shift Analysis Tool Coefficients Recalibration

In-Vehicle Travel Time (IVTT)	Out-of-vehicle Travel Time (OVTT)	Cost	Parking Cost
2013 Pasadena Travel Model			
-0.025	-0.053	-0.625	-0.625
2017 Pasadena Travel Model			
-0.025	-0.053	-0.45	-0.45

[4] Customer Survey of Expo Riders, LA Metro, http://thesource.metro.net/2016/09/12/customer-survey-of-expo-line-riders/

Running the Model

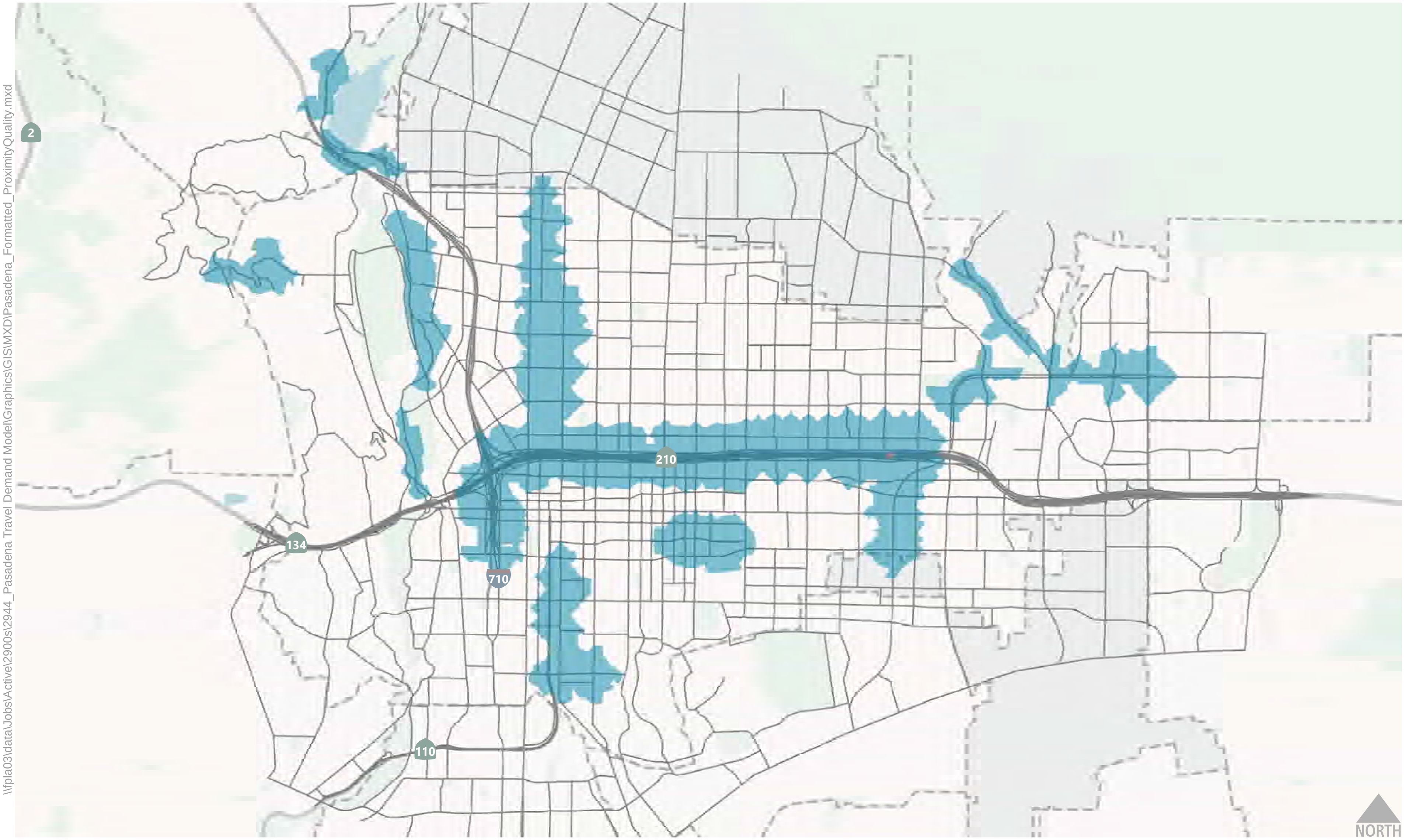
The Graphical User Interface (GUI) developed for the City of Pasadena Travel Demand Model and for the Pasadena's Mode Shift Analysis Tool was built to conveniently allow the user to run the model with the click of a button, without going into the technicalities of the programs beneath the model. Both GUIs closely follow the stages in the model and give the user the ability to run one stage of the model at a time or running the entire model system by the click of a button. Model Installation

See Attachment 1.

Model Post Processing

The model produces outputs that feed directly into a post processing tool that calculated the Pasadena CEQA Thresholds. The "Performance Metrics 2017 Existing" spreadsheet calculates all four metrics. The steps for using tool are listed below.

1. Input the Existing model scenario path in cell D2
2. Enter "Yes" or "No" if the project is in within Level 1 or 2 Bike or Transit Network in cells D3 and D4
    a. Figure 13 and Figure 14 show the areas considered Level 1 or 2 Bike or Transit. These are also provided as KMLs in the "...2017_Existing\Outputs\0_Analysis\ProximityQuality KML" folder and can be viewed in Google Earth.
3. If periods change, fill in period names (up to 5) to determine which files are imported starting on cell C5
4. If post processing folders change, fill in postprocessing file names starting in cell C9
5. If network or regional travel flows are modified, complete the following:
    a. Copy network data (link IDs, length, and type) to DATA worksheet
    b. Copy SZ matrix statistics for each period (up to 5) to DATA worksheet
    c. Copy regional VMT by speed bin and gate for each period (up to 5) to DATA worksheet
    d. Fill out external gate correspondence for centroids and gates on the DATA worksheet
6. Enter Project Name in cell B14
7. Click "Import Volumes from SZ Assignment" to import files and update Performance Metrics tab



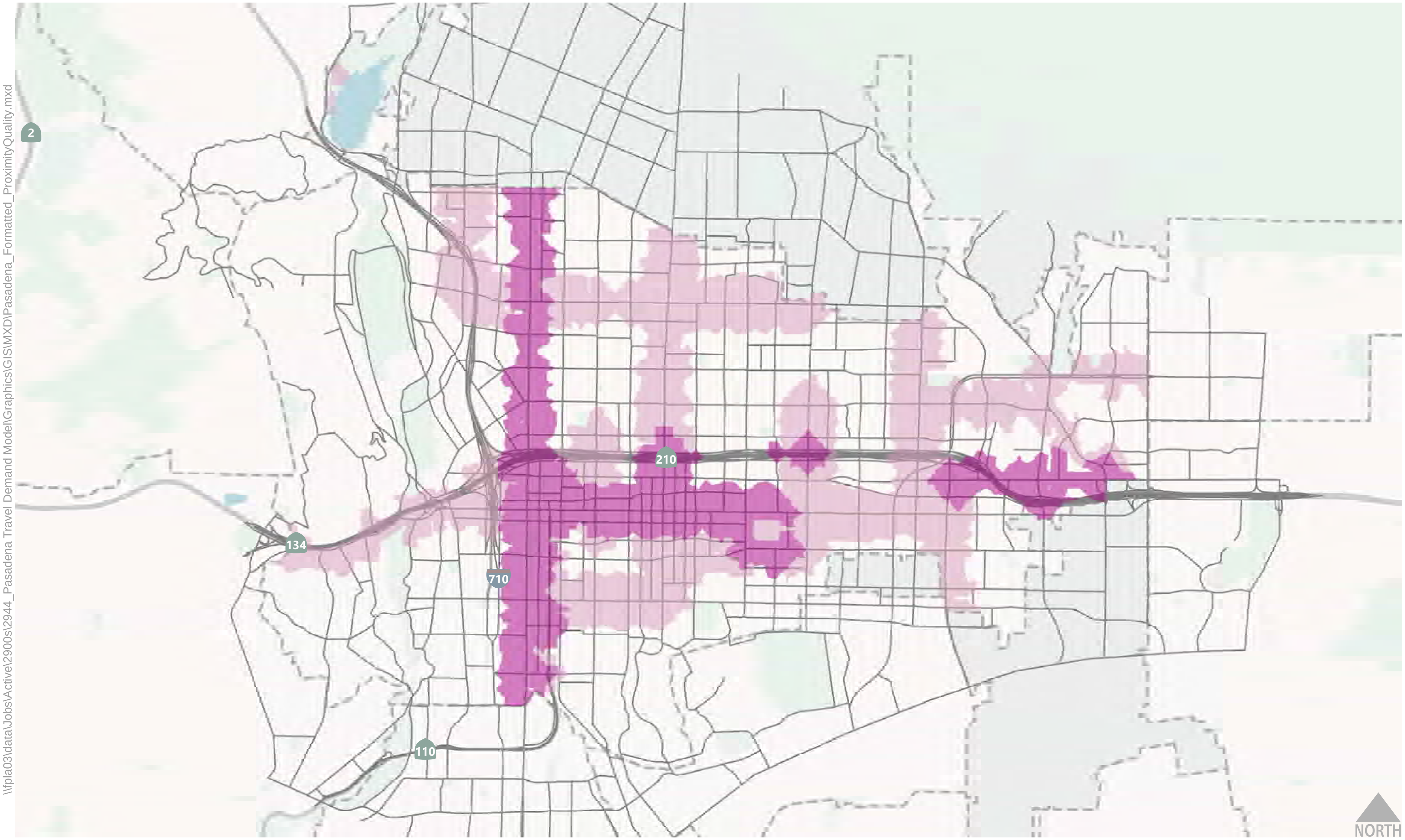
Model Street Network

Proximity Analysis

Bike Level 2

Figure 13

Proximity Analysis: Bike



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Model Street Network

Proximity Analysis

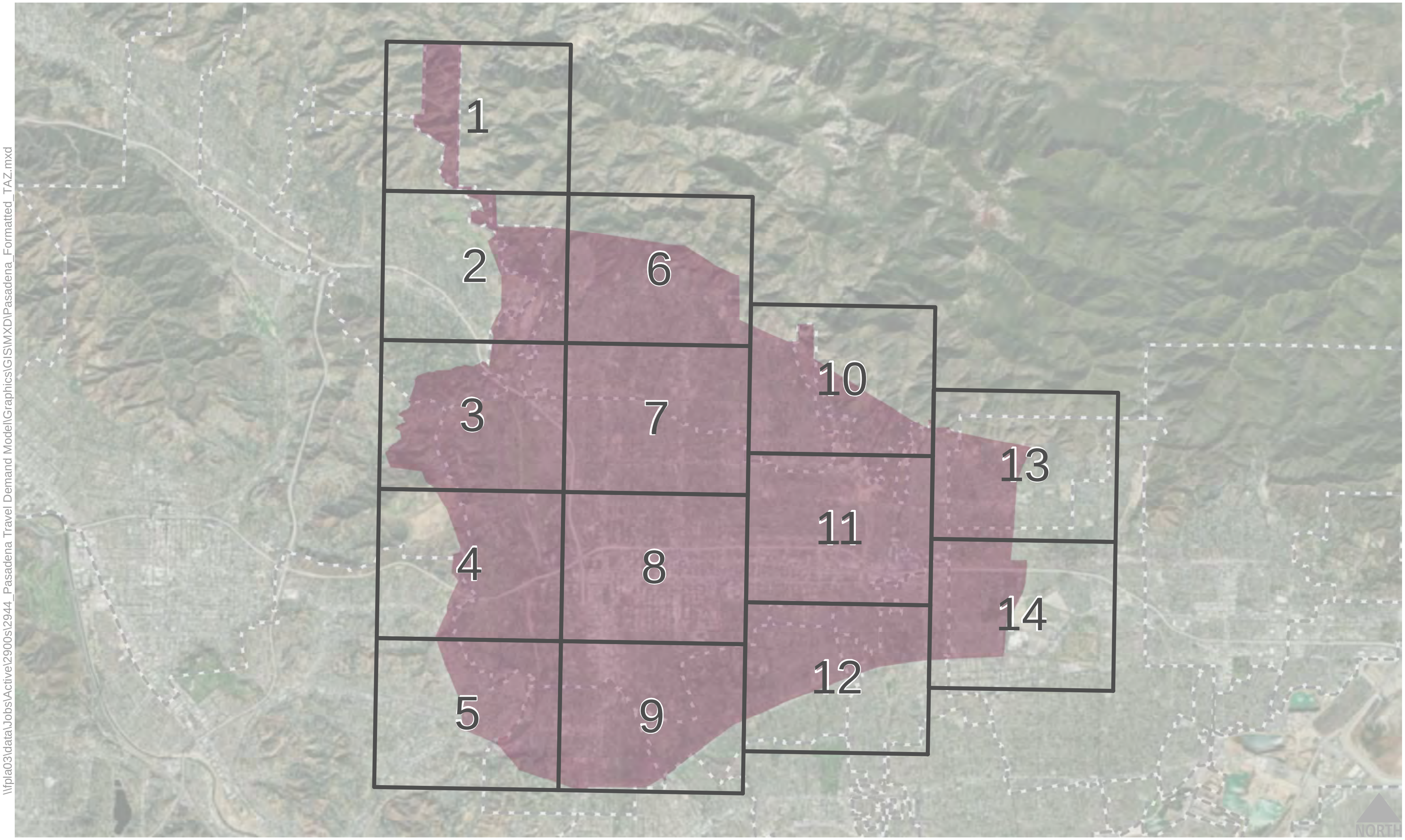
Level 1 Transit

Level 2 Transit

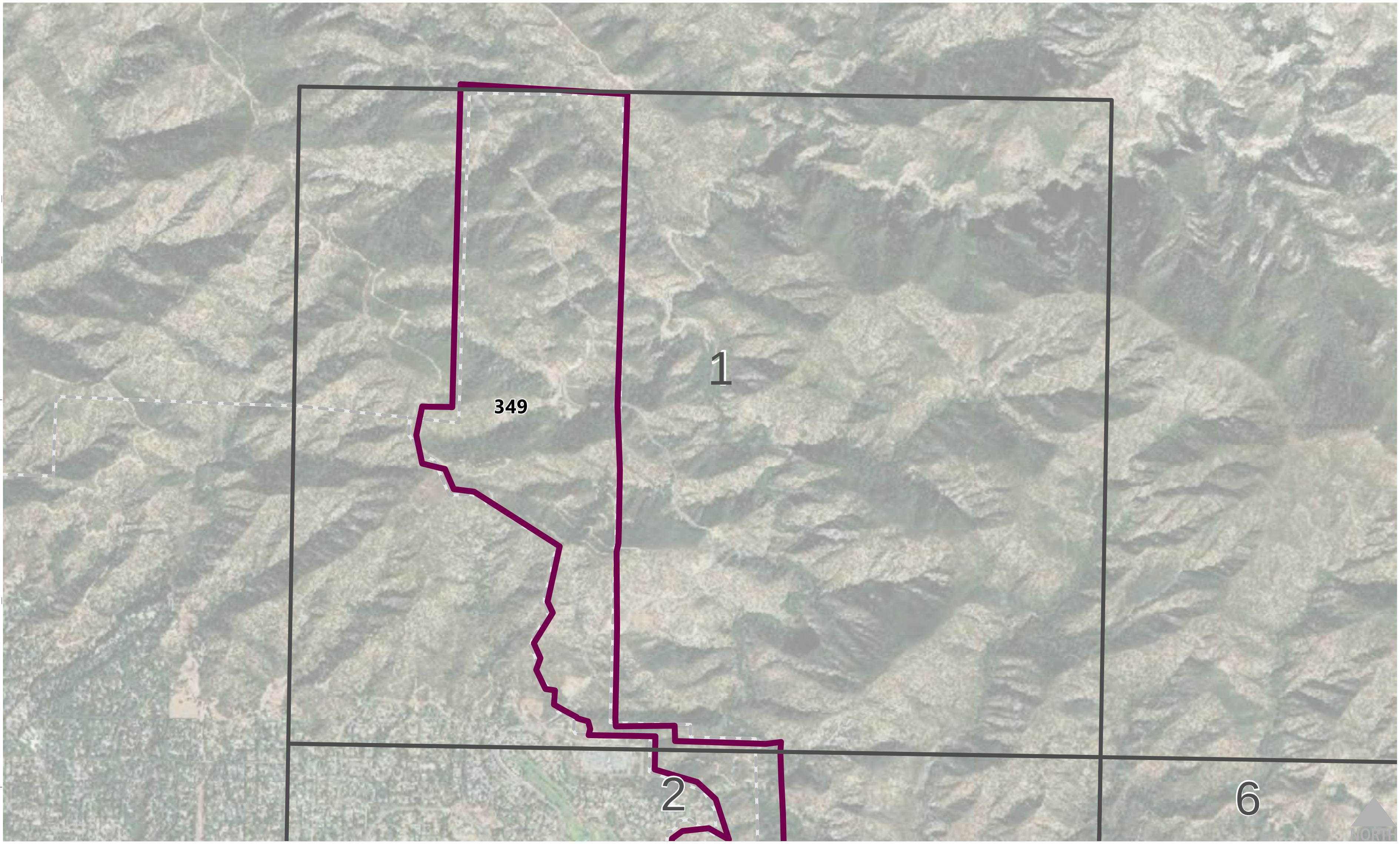
Figure 14

Proximity Analysis: Transit

APPENDIX A:
Traffic Analysis Zones Key Map



Traffic Analysis Zones



TAZ
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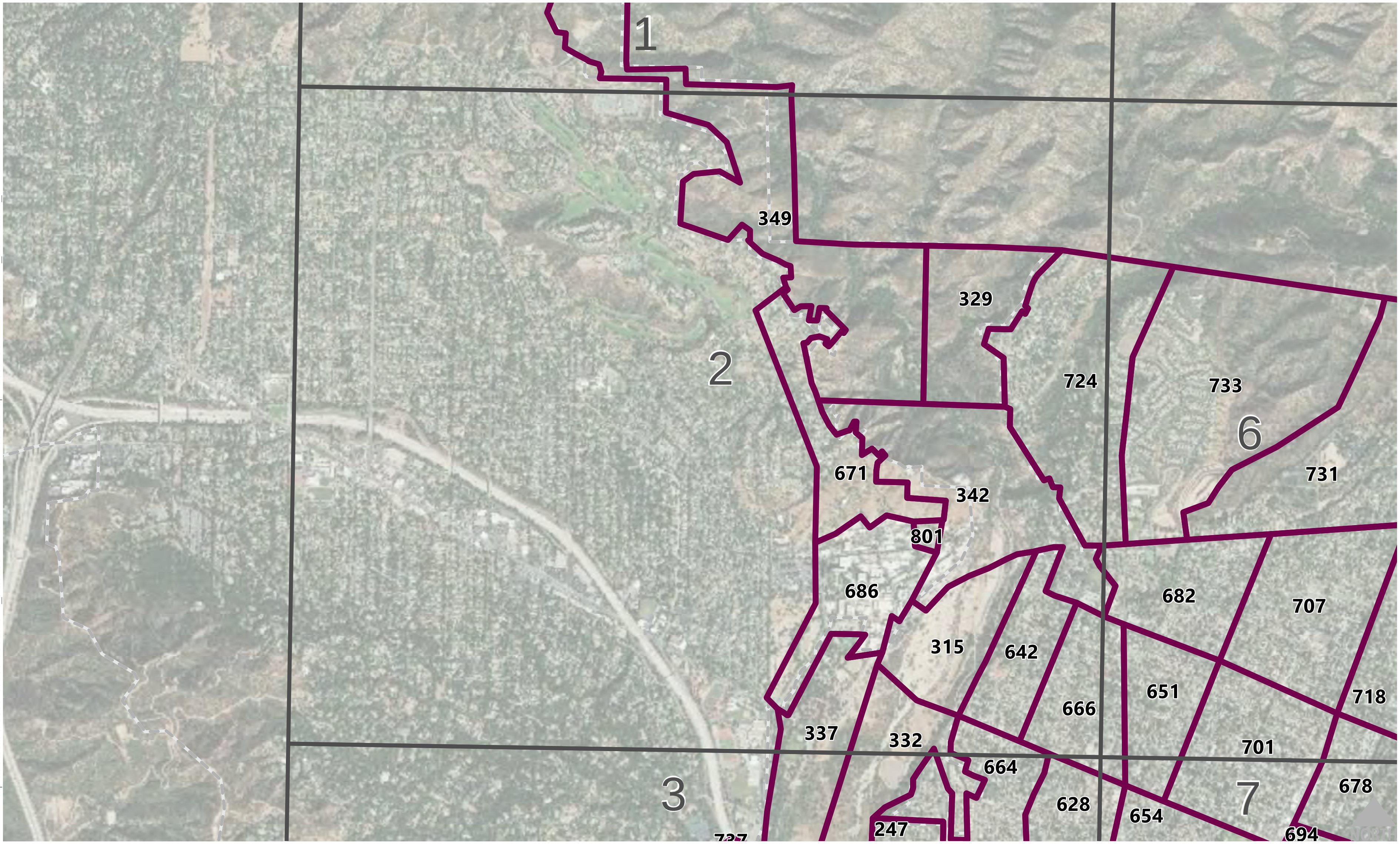
Traffic Analysis Zones



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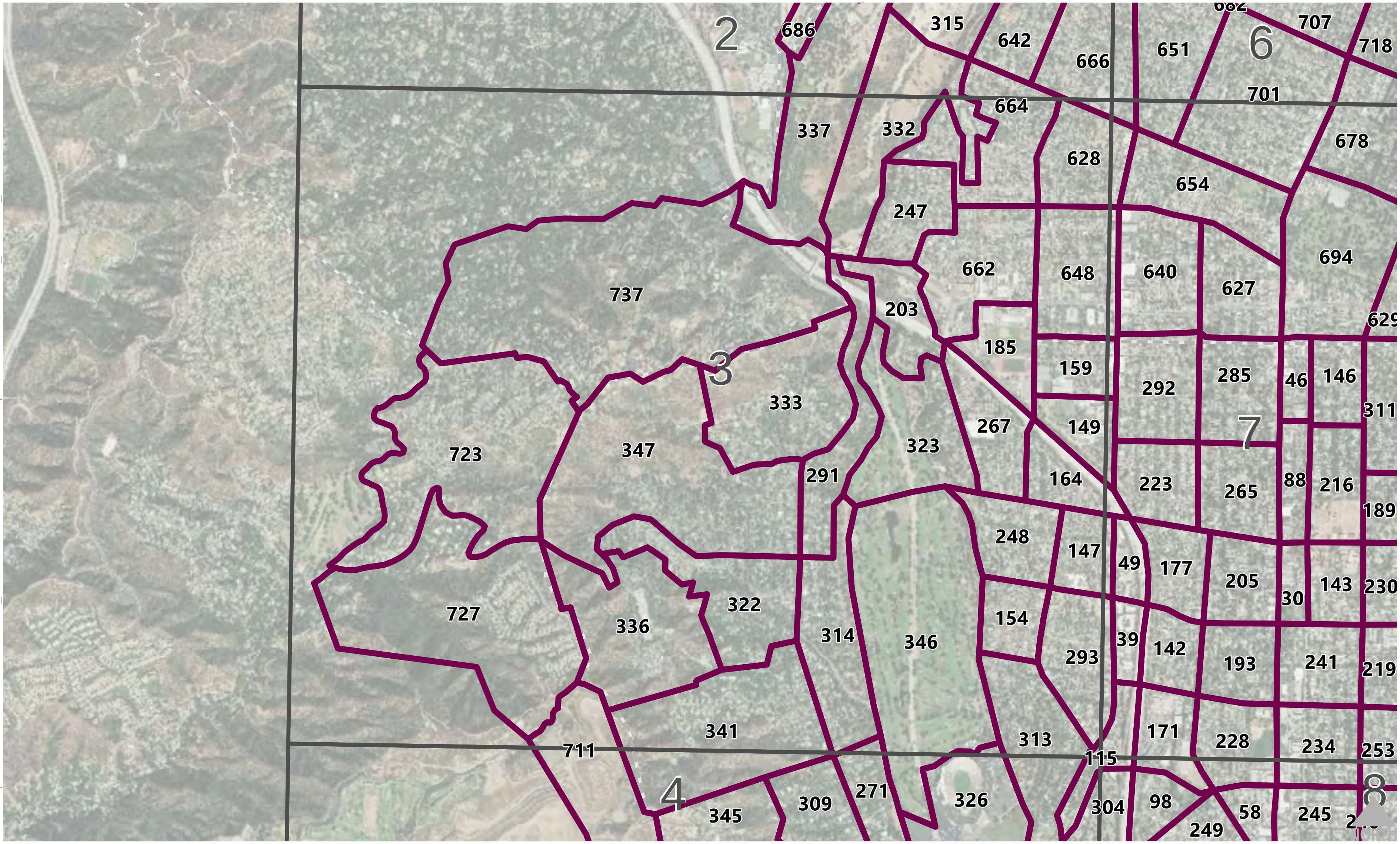

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TAZ

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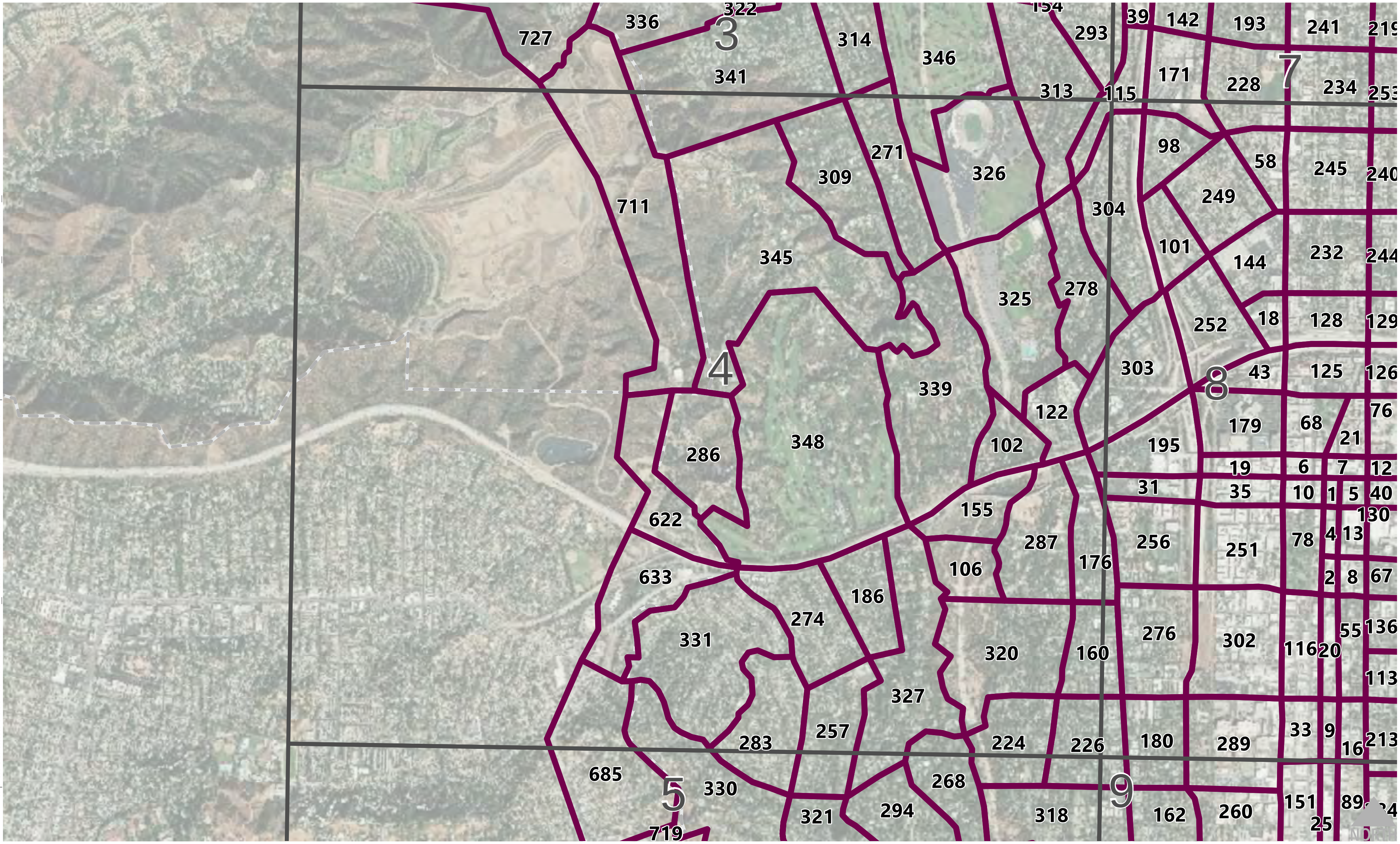
Traffic Analysis Zones



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TAZ

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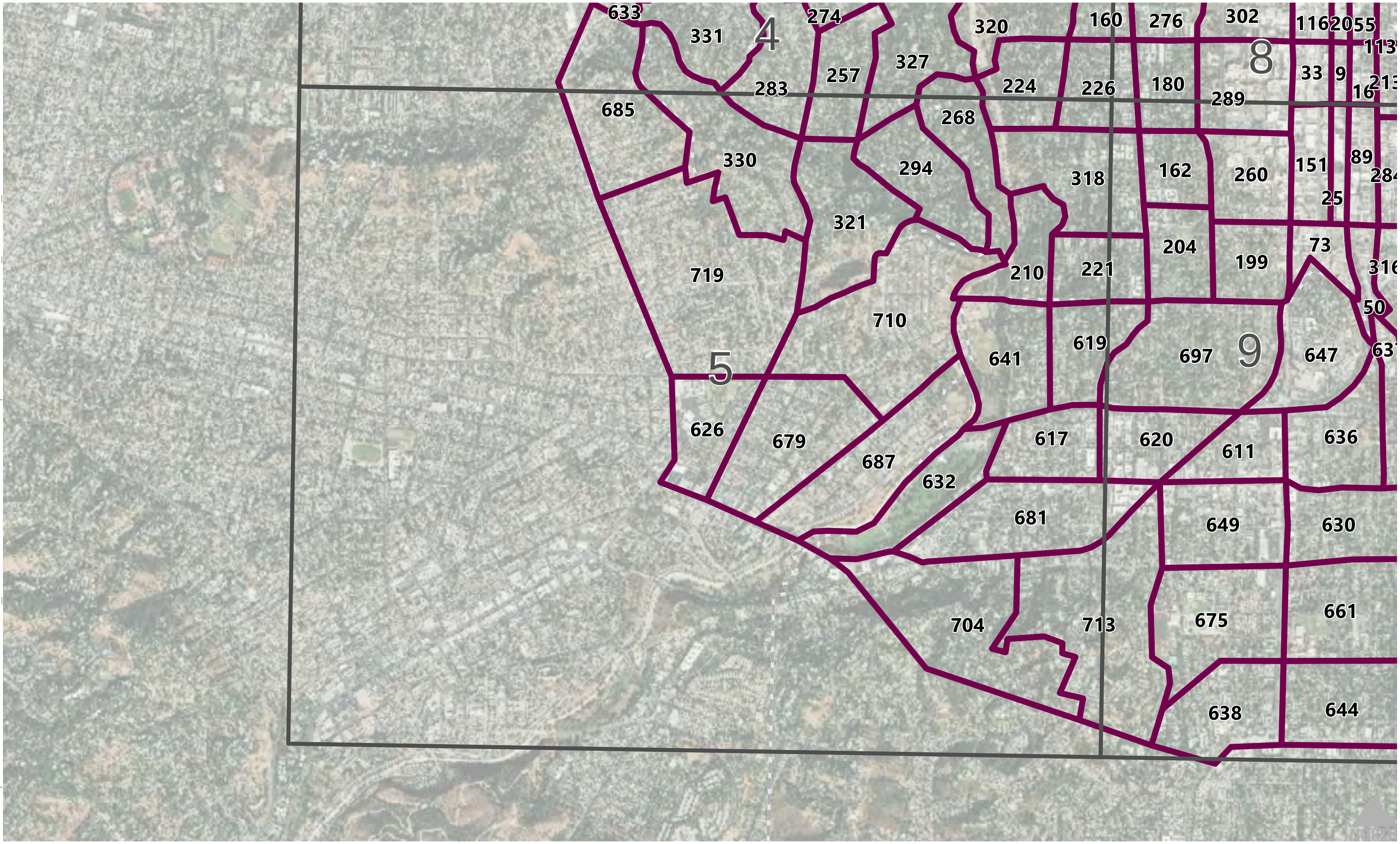
Traffic Analysis Zones



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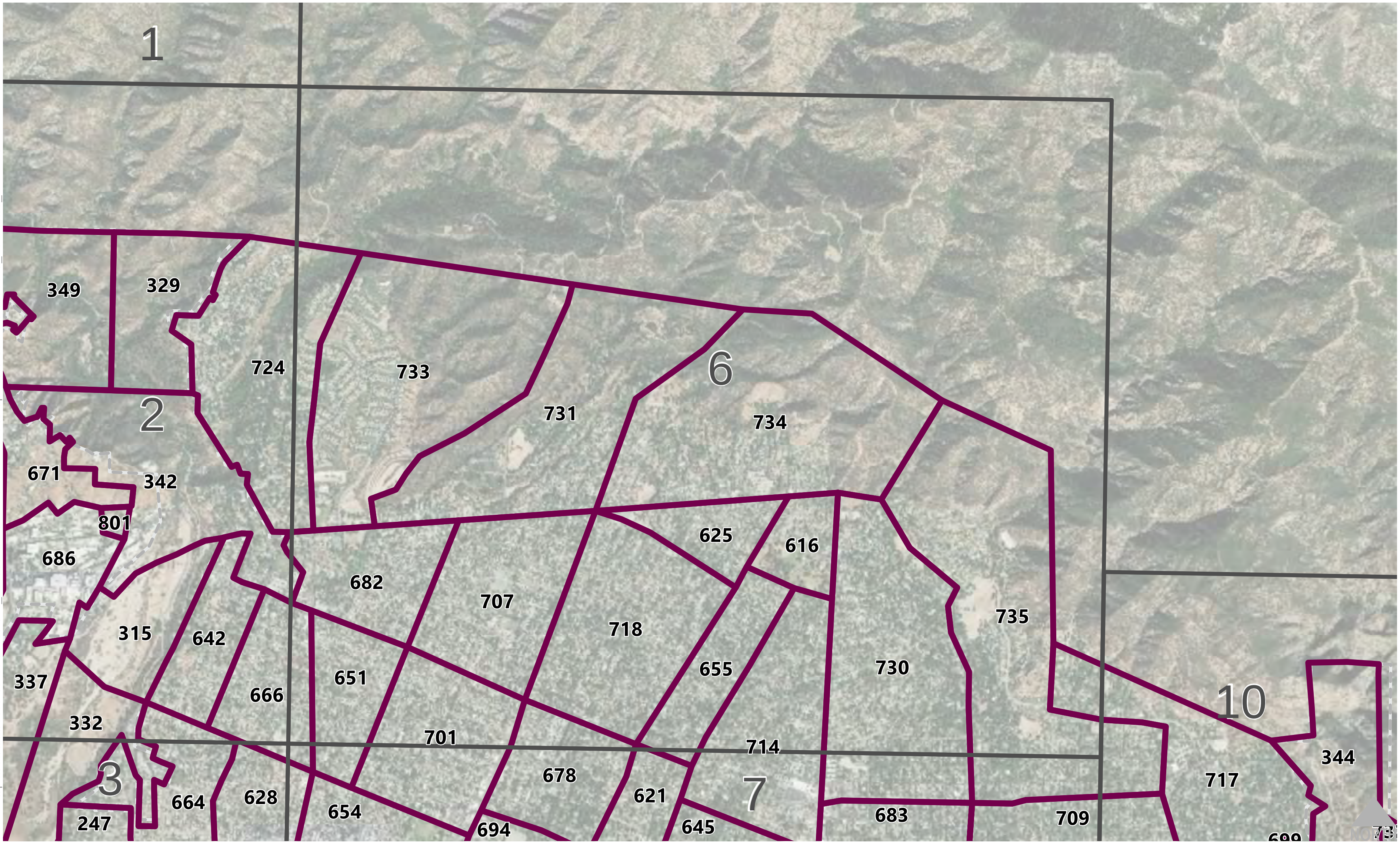

TAZ
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Cities

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Traffic Analysis Zones

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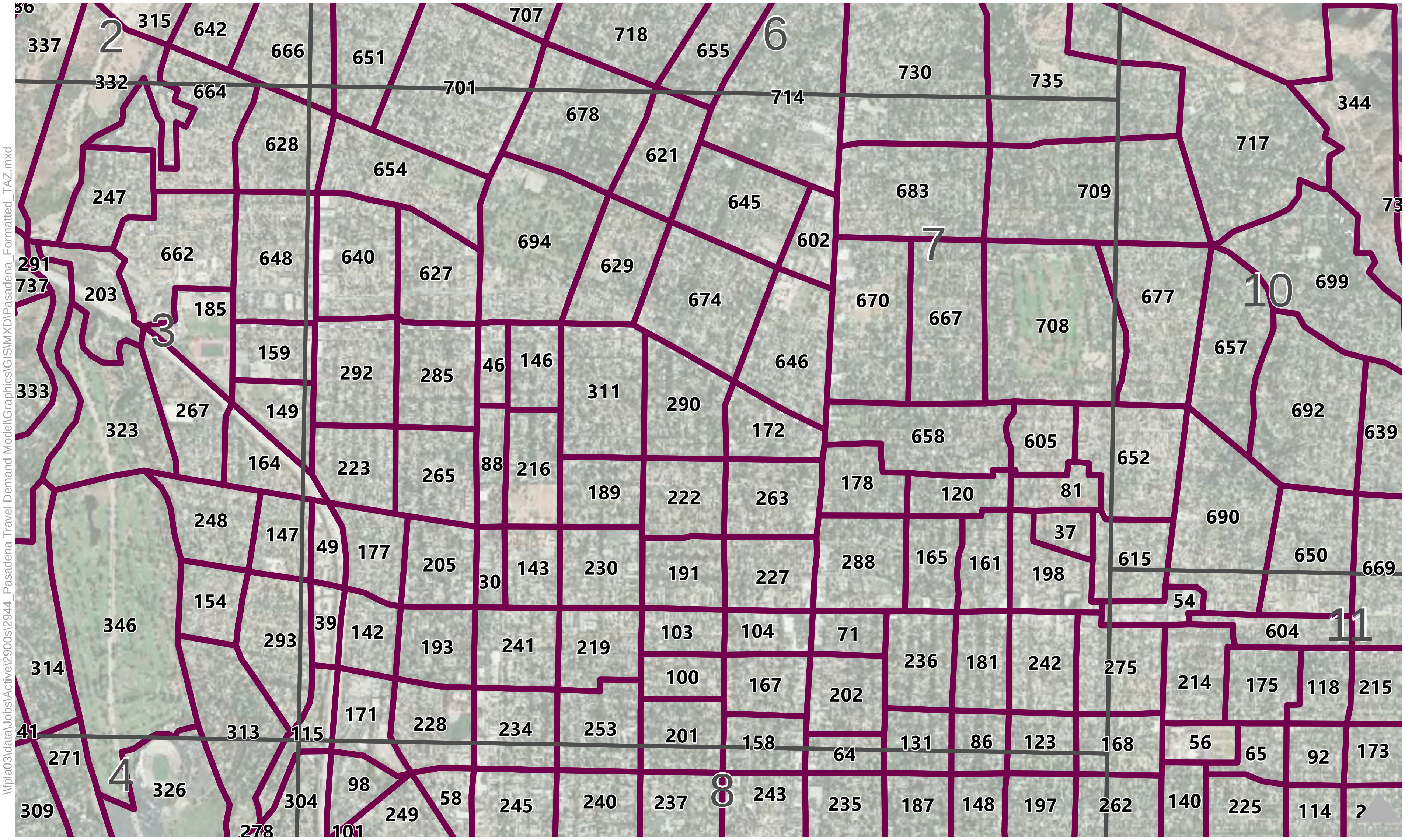

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TAZ
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Cities

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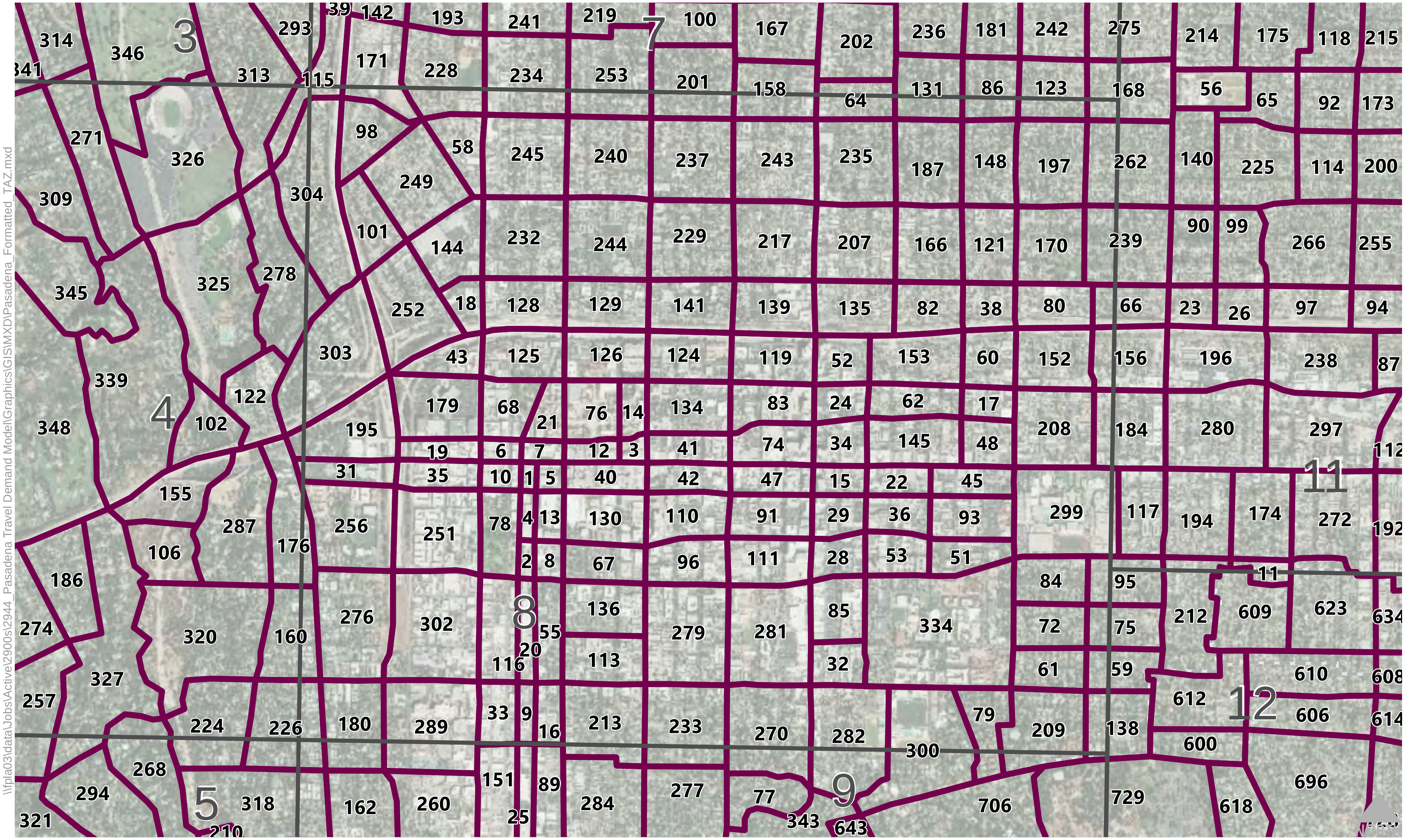
Traffic Analysis Zones



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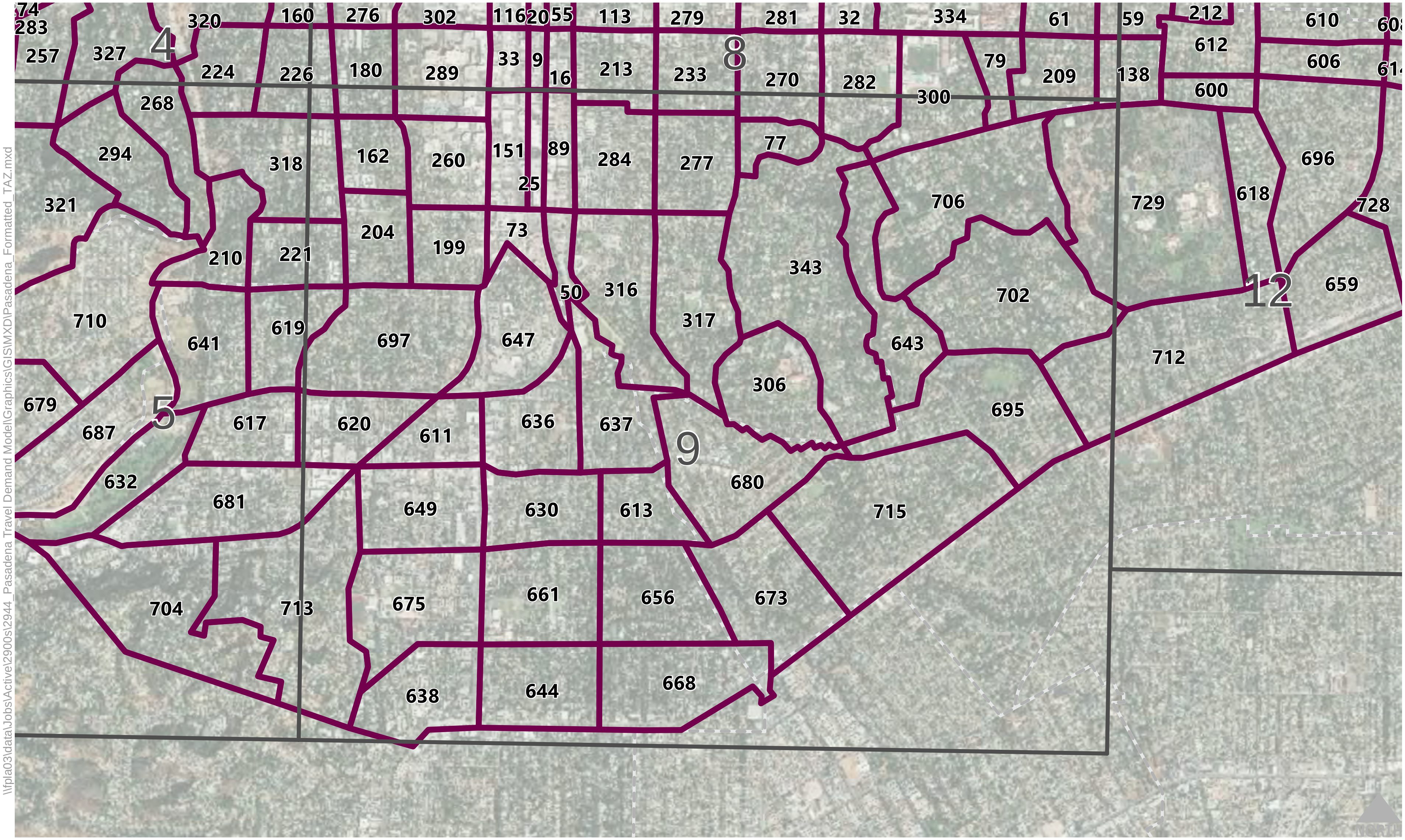

TAZ

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Cities

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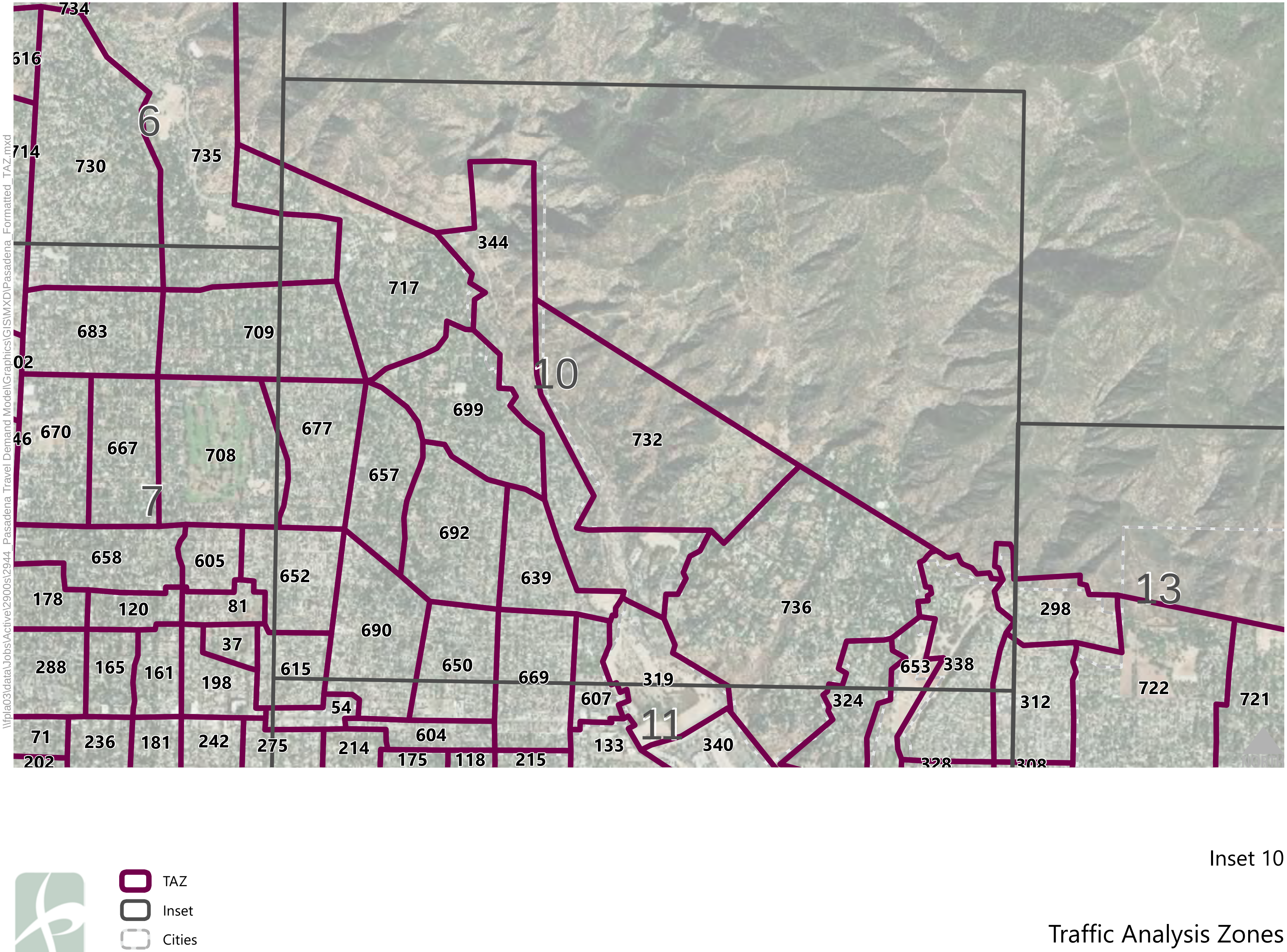
Traffic Analysis Zones



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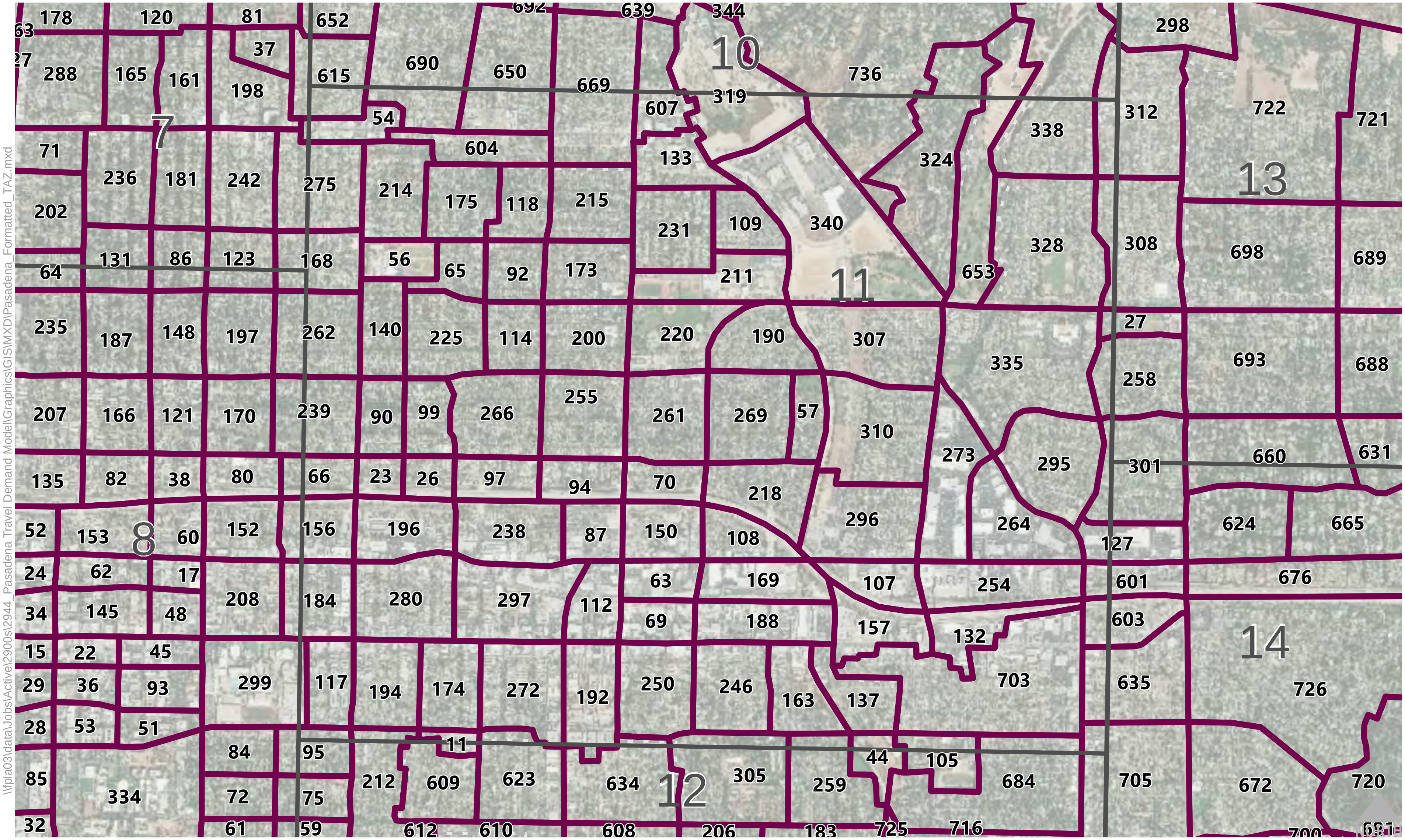

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TAZ

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Cities

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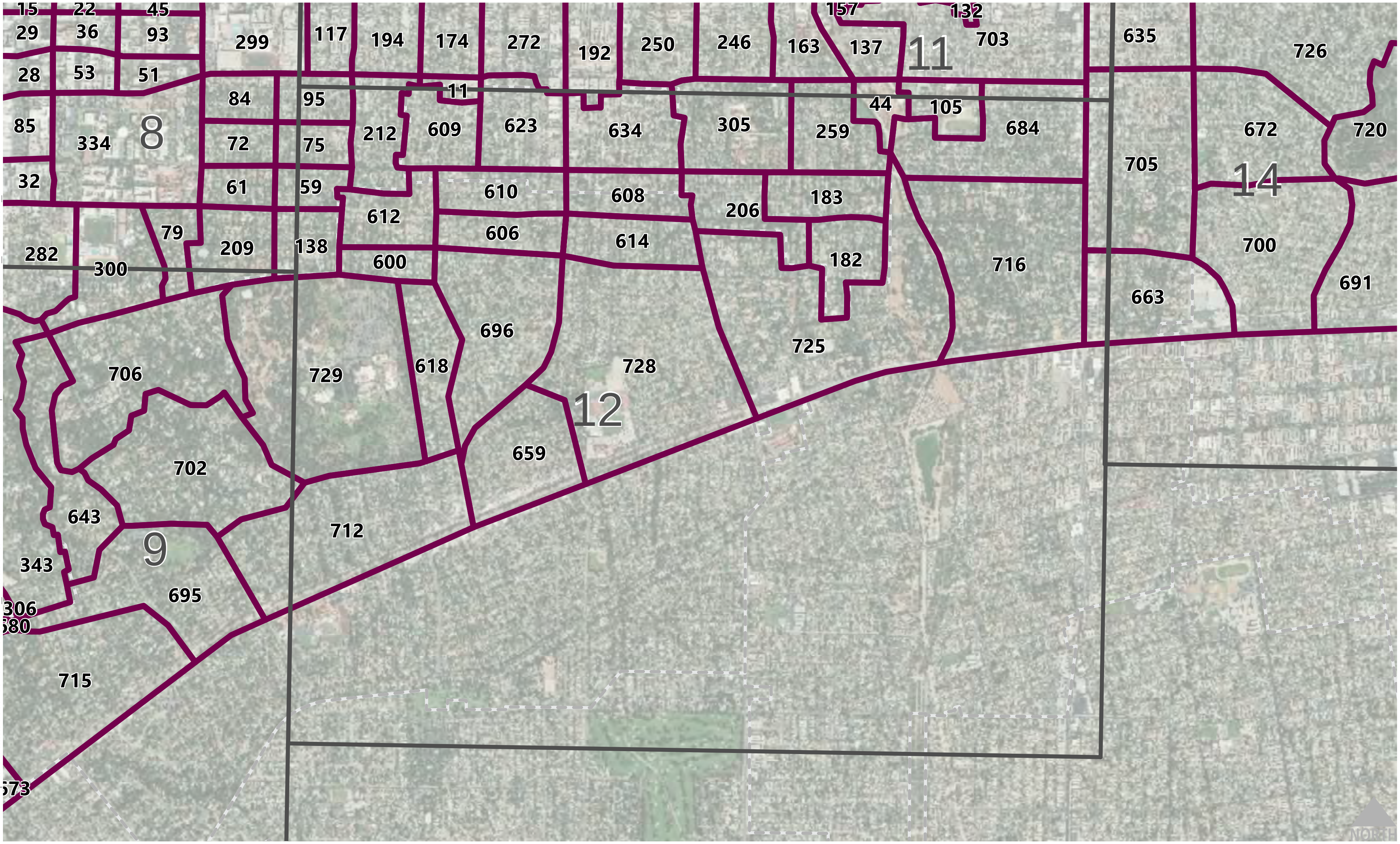
Traffic Analysis Zones



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TAZ

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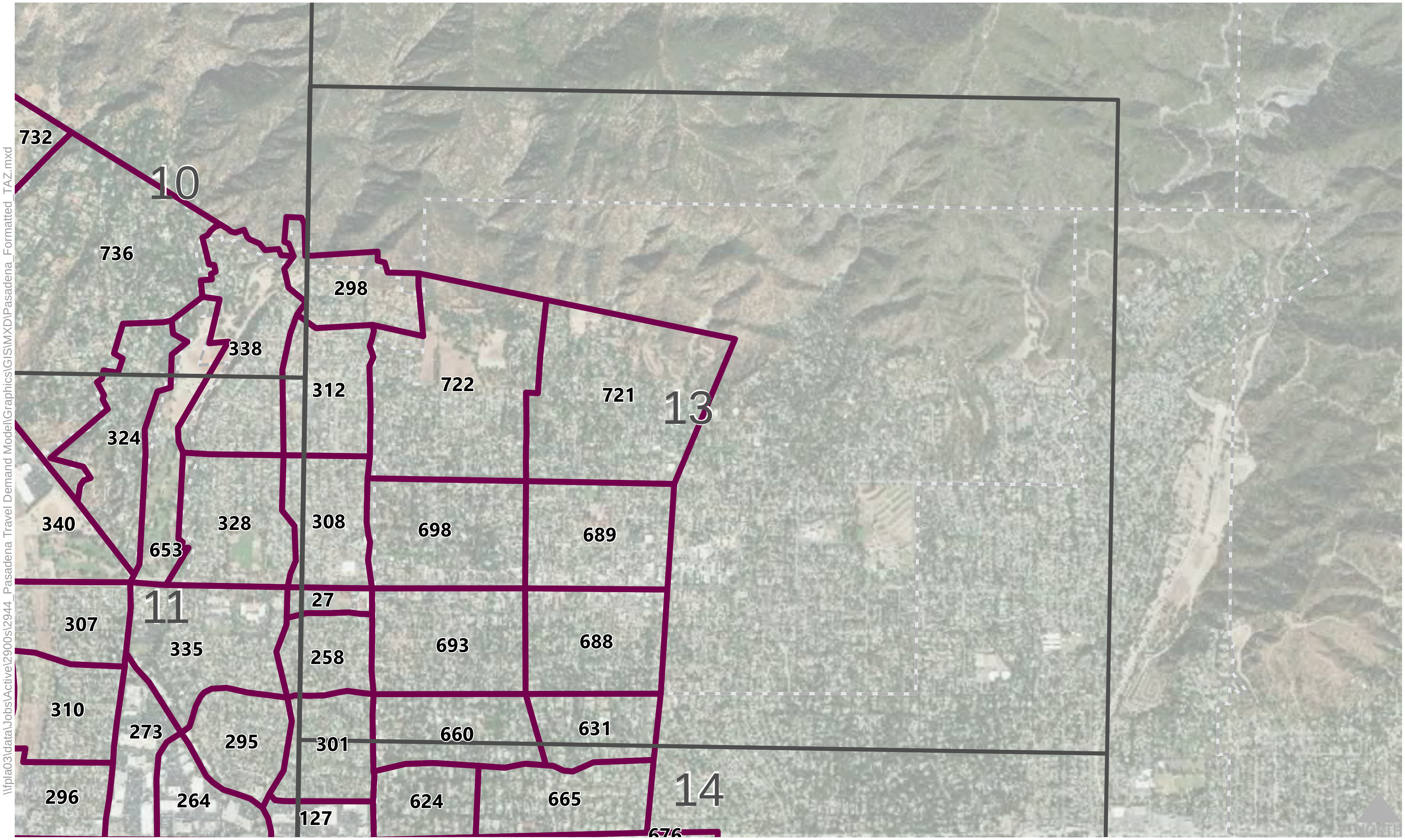
Cities

Inset 12

Traffic Analysis Zones



TAZ
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Cities

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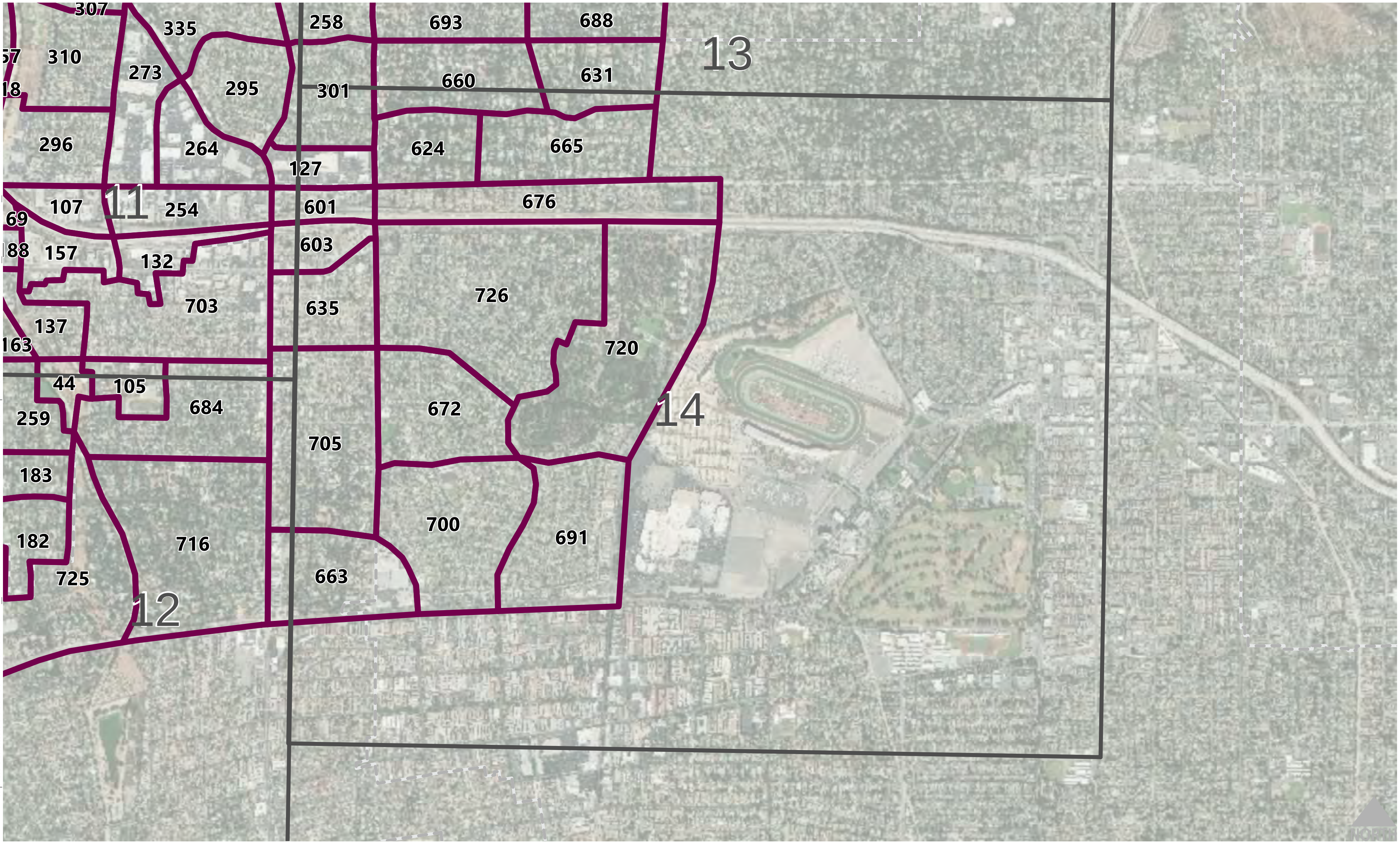
Traffic Analysis Zones



TAZ
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Cities

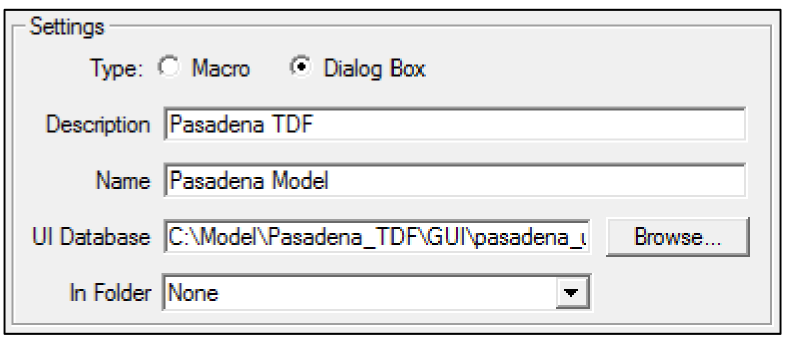
Inset 14

Traffic Analysis Zones

Attachment 1

Pasadena Model Installation Instructions

- Extract the contents of the **Pasadena.zip** file to the directory where the model files will be stored on the computer's local drive (**"C:\Model\Pasadena_TDF\"**, for example).
    - This directory must not contain any spaces or periods.
- Three model scenarios are included in the zip file: 2017 Existing, 2035 Adopted, and 2035 Preferred.
- The **"GUI"** folder contains the graphical user interface (**Pasadena_UI.dbd**).
- The **"Script"** folder contains the model script (**Pasadena_TDF_20181106.rsc**) which can be opened in any text editor.
- Copy the **"Pasadena"** folder from inside the **"GUI"** folder to the **"bmp"** folder inside the TransCAD installation directory (**"C:\Program Files\TransCAD 7.0b12410\bmp"**). This folder contains the images used in the graphical user interface (GUI).
- Check the permissions for the TransCAD installations directory (**"C:\Program Files\TransCAD 7.0b12410\"**) and ensure that the user has *write* permission to the folder.
- Open **TransCAD 7.0 b 12410**
- From the **"Tools"** menu, select **"Setup Add-Ins…"** and click the **"Add"** button.



    - Select the **"Dialog Box"** radio button for **"Type"**.
    - The **"Description"** field can include any text (**"Pasadena TDF"**, for example).
    - The **"Name"** field *must* be **"Pasadena Model"**.
    - For the **"UI Database"**, click the **"Browse…"** button and the select the GUI file (**Pasadena_UI.dbd**) from the directory where the model files are stored.
- Click **"OK"** to close the setup window.
- Open the model GUI by selecting it from the **"Tools"** menu under **"Add-Ins"**.

Attachment 1

- If prompted to select the model table, when attempting to open the Pasadena add-in for the first time, browse to the **Pasadena.bin** file in the directory where the model files are stored.
    - If this step is necessary, open the bin file in TransCAD to check that the paths in the bin file match where the files are stored. If they do not, change the paths.