Incentivizing Zero-Emission Vehicle Ride-Hail/Public Transit Commutes in Los Angeles

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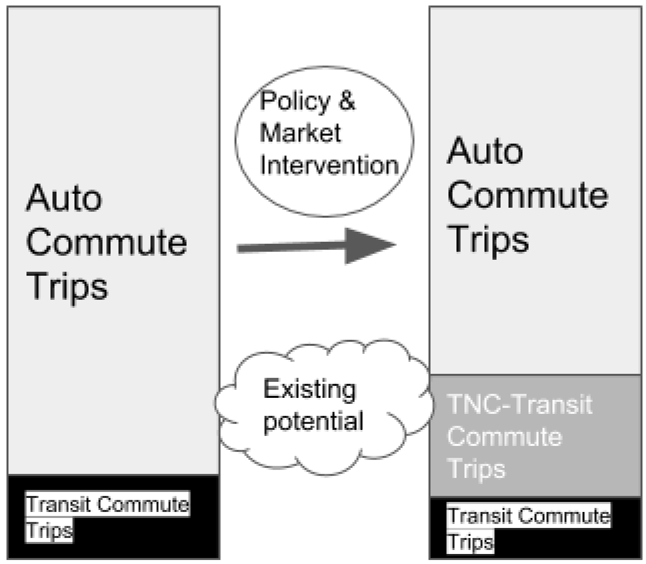
Table of Contents

Introduction

In this applied research project, the authors conducted a mixed-methods assessment to address a central research question: Can existing regulations and incentives be applied to current innovative mobility service to encourage Los Angeles's adoption of transit and zero-emissions vehicles (ZEVs) in linked TNC-transit commutes?



Project Research Objectives

The purpose of this project is to examine the potential for regulatory and policy mechanisms to link rapid transit and transportation network company (TNC) trips, and furthermore, to fulfill those linked trips with zero emissions vehicles. A successful intervention would increase in ZEV adoption and use, increase LA County transit use, and reduce AM peak vehicle trips to worksites. The first two possible outcomes would support the UCLA Sustainable Los Angeles Grand Challenge goal of powering 100 percent of Los Angeles's energy and transportation needs with renewable energy sources by 2050. The third outcome would result in air quality and congestion reduction, at least in the short term before induced demand effects (Hymel, Small, & Dender, 2010). These three outcomes are expanded below:

1. **Increase the proportion of ZEV miles traveled in LA County.** The rise of TNCs like Uber and Lyft creates an opportunity to introduce ZEVs into high-utilization applications, where they will have a disproportionate impact on zero-emissions vehicle miles traveled. Current or potential future market developments and policy interventions may assist with this adoption.

2. **Increase LA County public transit use, particularly among zero-emissions and renewably-fueled modes**. Switching from passenger vehicles to transit reduces greenhouse gas emissions in the short run and shifts future responsibility for fuel procurement from a vehicle owner to the transit operator. In this way, shifting to transit creates immediate reductions in greenhouse gas emissions and the potential for future increases in renewably-powered transportation. While currently the electricity that powers Metro Rail is not fully renewable, life-cycle GHG emissions will decline over time as the Los Angeles Department of Water and Power and Southern California Edison pursue renewable energy targets (Chester, Pincetl, Elizabeth, Eisenstein, & Matute, 2013). Metroliner bus services operating on the Silver and Orange Lines are powered by natural gas, for which a renewable substitute is available. Metro will soon implement a pilot project for battery electric buses on the Orange Line busway (Sotero, 2016).

3. **Reduce private vehicle trips to worksites during the morning peak period**. For decades, Los Angeles has been plagued with unhealthy air quality that exceeds federal standards, degrading public health and ecosystem health. The region has implemented air quality control measures to reduce morning peak-period commute trips, but the benefits of these trips can extend throughout the workday. Someone who arrives at the worksite without a car is not likely to drive for other trips during the day. The interventions assessed in this report target commute trips during the morning peak period.

Prior Research and Background

Research in support of this project's objective exists at the intersection of two emerging topics: greening the transportation network company vehicle supply and integrating transportation network company and transit trips. The research team identified only one prior academic work identified specific to our objective of introducing zero emissions vehicles into TNC service (Wagner, 2017). In this section, we review an expanded set of associated literature that informs our recommendations.

Transportation Network Companies

Overview

Although transportation network companies (TNCs) are well-established in American cities and oft-discussed in the news few rigorous academic studies have examined their growing influence on commute patterns and public transit use. TNC research is challenging because while companies collect massive volumes of data on customers, drivers, trips, and patterns, they are reluctant to share this information with researchers or even regulators (Lybarger, 2016).

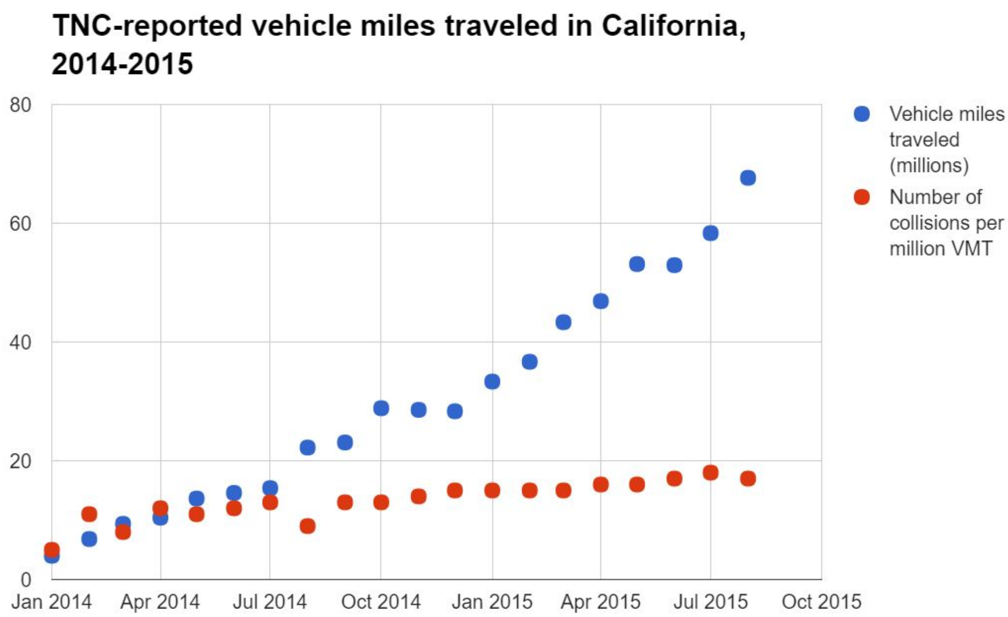
The recent emergence of TNCs, coupled with a lack of publicly available ridership data, has likely contributed to the small amount of research in this area. As of April 2017, no study had explicitly focused on the potential of TNCs to serve commuters, although a few studies have revealed the extent to which commuters use TNCs. Rayle et al. (2016) found that the majority (67 percent) of TNC passengers surveyed used the service for socializing and/or leisure, while only 16 percent used the service to access their workplace. Dawes and Zhao (2017) found a similar trend in a nationwide survey of TNC passengers, as 14 percent cited “going to work or school” as the primary purpose of their trip.

The growing body of literature around TNCs is slowly revealing trends in TNC demographics, functions, and interactions with local agencies.

Researchers have emphasized the rapid growth of TNC services. Although Uber and Lyft expanded beyond their launch city of San Francisco only as recently as 2011 and 2013, respectively, by 2015 Uber had over 162,000 drivers in 311 cities, while Lyft had over 100,000 drivers in 60 cities (Taylor, 2015). Uber claims that the number of trips in San Francisco has tripled each year, while the number of trips in New York City has increased fourfold. Although there were still ten times as many taxi rides as Uber rides in New York City by 2015, the number of Uber drivers exceeded the number of medallion taxicabs in the city that year (Taylor, 2015). Rayle et al. (2016) cite shorter and more consistent wait times as one reason for consumer preference for TNCs over taxis. Rayle also found that TNC passengers were younger and more educated than average for San Francisco residents. Waheed et al. (2015), meanwhile, point out that taxis face much stricter regulations than TNCs.

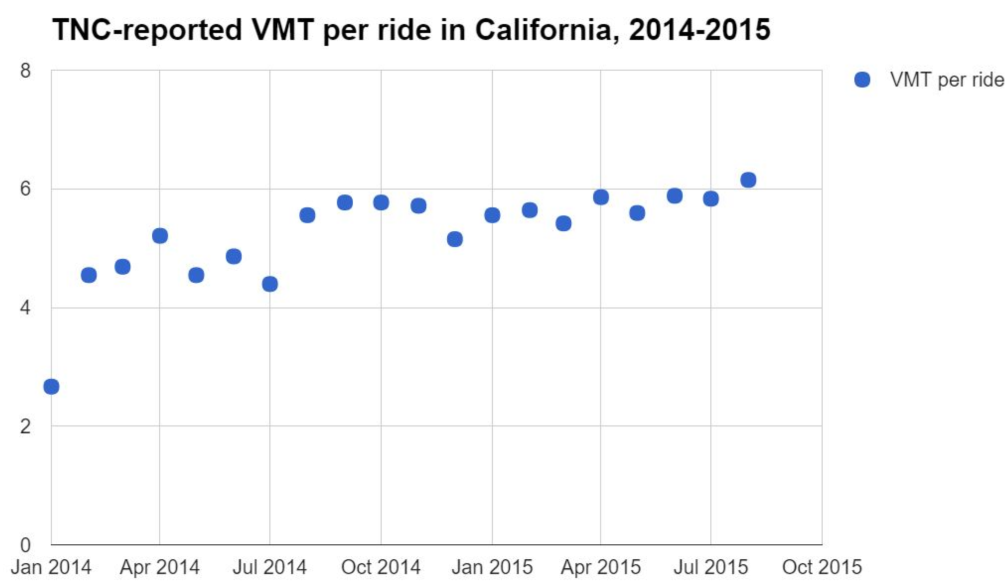
The California Public Utilities Commission, the primary regulator of TNCs in California, requires TNCs to report data on the number of new trainings, hours logged, and miles logged by drivers, among other metrics. This data further demonstrates the rapid spread of TNC activity in recent years. According the CPUC’s “Summary of Transportation Network Companies’ Annual Reports”, the number of drivers completing training each month increased from around 2,000 in September 2013 to nearly 31,000 in August 2015, and the number of rides given increased from around 500,000 in September 2013 to roughly 11 million in August 2015. The report also provides monthly data on the number of TNC-reported collisions in California, in total and per vehicle-mile traveled, and we thus estimated an increase in statewide TNC VMT from approximately 4 million in January 2014 to 68 million in September 2015 (Figure 1). We also estimated an increasing trend in VMT per ride during this time period, perhaps due to the increasing popularity of TNC services in California suburbs and the introduction of TNC services to less dense metropolitan areas (Figure 2).

Figure 1: TNC-reported vehicle miles traveled in California, 2014-2015



Source: *California Public Utilities Commission*

Figure 2: TNC-reported vehicle miles traveled per ride in California, 2014-2015



. Source: *California Public Utilities Commission*

TNC-Transit Integration

The authors are unaware of any academic literature published prior to April 2017 that focuses primarily on the potential of TNCs to complement public transit, although there is evidence that TNCs both complement and substitute for public transit depending on circumstances.

Several studies have examined the potential of various shared mobility services to integrate with transit. Research on bikesharing has found that a substantial number of bikeshare users report reductions in both automobile and public transit use, especially in large cities (Taylor, 2015). Research on carsharing has been more promising for transit, as several studies have found a reduction in car ownership and vehicle-miles traveled among survey respondents, along with an increase in walking, biking, and transit use (Taylor et al., 2015). Together, these studies suggest that shared mobility services may complement transit in the long run by reducing automobile ownership and use, but only if investments in transit are sufficient to compete directly with newer modes.

The potential for TNCs to complement transit depends on a number of factors. Taylor et al. (2015) argue that under the best circumstances, TNCs have the potential to spur dramatic reductions in VMT, greenhouse gases, pollution, parking demand, and broader infrastructure needs. TNCs can facilitate first- and last-mile connections with transit, and therefore may increase overall vehicle occupancy rates while decreasing VMT. However, there is even more potential for TNCs to encourage transit by reducing car ownership and thereby increasing the perceived marginal cost of automobile trips. As car owners do not pay for fuel, registration, insurance, or other incremental costs during each trip, they perceive the marginal cost of each trip to be lower than it is in reality. TNCs charge the user for each trip, and therefore offer a more direct disincentive to travel by automobile (Taylor et al, 2015). This could increase public transit use, but only if transit is affordable and efficient enough to compete directly with TNCs.

Survey-based studies have found evidence that TNCs both complement and compete with public transit. In a survey of 4,500 shared mobility users in seven US cities, the Shared Use Mobility Center (2016) found that 63 percent of TNC users generally use TNCs between 8pm and 4am, when public transit is less available. In a survey of 302 TNC users in San Francisco, 33 percent of TNC users stated that they would have used public transit if TNC service were unavailable, while only 4 percent of TNC users listed a public transit stop as their destination (Rayle et al., 2016). However, the small sample size and limited geographic range of the study means these results may not apply to other areas. Furthermore, public support for the integration of TNCs and public transit appears strong. Thirty-four percent of respondents in a nationwide online survey of TNC users advocated for a partnership between a TNC and a local transit agency, with half of those supporting partnerships (17% of respondents overall) advocating for a partnership that promotes access to public transit (Dawes, 2016).

Public-private partnerships involving TNCs and local government agencies are increasingly popular, and offer local governments a way to address social and environmental problems posed by TNCs. From a local agency's perspective, issues with private ownership of TNCs include disruptions in service, monopolistic inefficiency, diverted public revenue streams, and a lack of incentive to address social inequalities. However, local agencies can attempt to address these issues by establishing public-private partnerships with TNCs (Kuhr, Bhat, Duthie, & Ruiz, 2017).

Zero Emission Vehicles (ZEVs) Adoption

Clean Vehicle Adoption Overview

Research on clean vehicle adoption in the US has grown in conjunction with the introduction and maturity of new vehicle technologies in the US market. Clean vehicles include hybrid-electric vehicles (HEVs), plug-in hybrid-electric vehicles (PHEVs), battery-electric vehicles (BEVs), and hydrogen fuel cell electric vehicles (H-FCEVs). Gallagher and Muehlegger (2011/1) describe how this literature is grounded in earlier economic literature on discount rates and payback periods for new technologies that have higher upfront costs but lower incremental costs than competing products.

The introduction of HEVs spurred interest in applying these concepts to automobile purchases. As (Beresteanu & Li, 2011) describe, the Toyota Prius and Honda Insight first premiered in the US in 2000, selling for higher prices than conventional vehicles due to the presence of a battery. The federal government provided a tax deduction of up to $2,000 for new HEVs sold between 2000 and 2005, which was replaced by a tax credit of up to $3,400 through the Energy Policy Act of 2005 (Jenn, Azevedo, & Ferreira, 2013). State and local governments provided other incentives such as state income tax credits, sales tax exemptions, and high-occupancy vehicle (HOV) lane access (Beresteanu & Li, 2011). Gallagher and Muehlegger (2011/1) examined state-level tax incentives for hybrid adoption and estimated that sales tax exemptions had roughly ten times the effect of income tax deductions on hybrid vehicle purchases. Nonetheless, income tax credits continued to incentivize adoption of HEVs until 2010 (Jenn et al., 2013), the same year the first plug-in hybrid electric vehicles (PHEVs) were introduced (Al-Alawi & Bradley, 2013/5). The removal of subsidies, along with falling gas prices, may explain why the market share of HEVs peaked at 3 percent of total new vehicle sales in 2013 before declining thereafter (German, 2015).

Plug-in hybrids and fully electric vehicles

Research on clean vehicles has shifted focus to electric vehicles (EVs) capable of operating without gasoline. These include plug-in hybrid electric vehicles (PHEVs), which use a combination of electricity and gasoline, and battery electric vehicles (BEVs), which operate using electricity alone. Although the number of PHEVs and BEVs sold each quarter increased more than tenfold from early 2011 to late 2013, EVs amounted to only 0.82 percent of vehicles sold nationwide in 2015 (Shanjun Li, Tong, Xing, & Zhou, 2017). While there are more models and a greater variety of vehicle classes offered among PHEVs and BEVs than HEVs, a few models currently dominate the EV market (DeShazo, 2016).

Policymakers have used rebates, income tax credits, sales tax exemptions, fee exemptions, and HOV lane access privileges to encourage the adoption of PHEVs and BEVs (DeShazo, 2016) (Sheldon, DeShazo, & Carson, 2016). The federal government provides a $2,500 tax rebate for any vehicle with at least 4 kWh of battery capacity, plus an additional $417 rebate per kWh of capacity (DeShazo, 2016). The state of California currently provides a $2,500 rebate for BEV purchases and a $1,500 tax rebate for PHEV purchases on top of the federal rebates (DeShazo, 2016). These rebates encourage adoption by reducing each vehicle's total cost of ownership and payback period, both of which are lower when more factors are taken into account (Al-Alawi & Bradley, 2013/3).

Several studies demonstrate the importance of financial incentives and charging infrastructure for encouraging EV adoption. Hidrue et al. (2011) used survey data to model willingness-to-pay for electric vehicles, finding that some consumers would be willing to pay as much as $16,000 more for a state-of-the-art BEV than a conventional gasoline vehicle. However, low battery capacity and slow charging times strongly discouraged BEV purchases for some, with up to $75 per mile of driving range decrease and up to $3,250 per hour of charging time detracting from their willingness to pay, suggesting that subsidies are necessary to reach a mass market for BEVs (Hidrue et al., 2011). Sierzchula et al. (2014) used multiple regression to compare EV adoption in 30 countries and found the number of charging stations to be the strongest predictor of adoption, followed by financial incentives. Operating incentives such as electricity prices were not found to be significant. Similarly, Li et al.(2016) demonstrate that investment in charging stations is more effective than an equal investment in financial incentives for EV adoption. These studies suggest that financial incentives such as rebates encourage EV adoption, but that charging infrastructure is the main limiting factor for more widespread use of these vehicles.

Many researchers have also demonstrated that EV subsidies must be improved to address social equity and environmental justice issues, particularly because underserved communities tend to be excluded from traditional incentive programs. DeShazo (2016) reviewed existing literature on clean vehicle incentives and recommended that these subsidies be applied at the point-of-sale, either as sales tax exemptions or instant rebates. While rebates may be preferable to income tax incentives, even point-of-sale rebates failed to incentivize BEV purchases among lower income households (Silvia & Krause, 2016). As a result, DeShazo (2016) argues that rebate programs should be tiered based on income. For example, a behavioral simulation shows that a vehicle price cap of $60,000, coupled with an income threshold of $100,000, would allow per-vehicle rebate amounts to double and clean vehicle purchases to increase by 28 percent while still reducing total program costs (Sheldon et al., 2016). Other research has shown that African American and Hispanic communities are less likely to take advantage of clean vehicle rebates, even when controlling for income (Rubin & St-Louis, 2016). Further, electric vehicles tend to cluster in higher-income areas (T. D. Chen & Kockelman, 2016), implying localized emissions reductions in neighborhoods with relatively clean air.

Hydrogen fuel cell incentives

In comparison to PHEVs and BEVs, hydrogen fuel cell electric vehicles (H-FCEVs) offer similar emissions reductions and superior ranges and refuel times, yet face a less clear path to widespread adoption. Although H_2 does not occur naturally, it can be extracted from water using low-carbon electricity, enabling emissions reductions comparable to BEVs (Ball & Weeda, 2015). As a result, many climate change mitigation scenarios involve widespread H-FCEV adoption alongside BEV adoption (Ogden, Yang, Nicholas, & Fulton, 2014). The high cost and low energy density of BEV batteries make H-FCEVs relatively cost-effective for longer trips, with ranges exceeding 300 miles and refuel times below 5 minutes. Due to technological breakthroughs, experts in the late 1990s predicted rapid H-FCEV adoption, yet excitement for hydrogen diminished as biofuels and electric vehicles reached the market sooner (Ball & Weeda, 2015). However, industry partnerships and continued public investment has led to a resurgent interest in H-FCEVs (Ogden et al., 2014).

TNCs and ZEVs

Very little academic research has focused on the integration of transportation network companies and zero-emission vehicles, but these efforts have received attention in the press and from TNCs themselves. The authors are aware of only one publication on TNC-ZEV integration, which claims that rebates from California's Clean Vehicle Rebate Project motivate TNC drivers to purchase a ZEV more than the general public. However, this claim rests on the assumption that rebate users who are primarily motivated by vehicle cost are representative of all TNC drivers (Wagner, 2017).

Employee Commutes

Several companies invest in their employees' commutes by providing free parking, tax deductions for public transit use, and, in some cases, door-to-door shuttles. Our review of commutes literature focused on the role of the commute for two key human resources metrics: productivity and retention. Although there is limited research on the topic, studies suggest that subsidized commutes increase productivity by boosting morale, reducing absences, and encouraging retention, and thus carry an economic benefit for the employer.

Employers who subsidize their employees' commutes benefit by reducing employee absences. Hausnecht, Rodda, and Howard (2009) describe how previous research has indicated a positive relationship between distance to work and absenteeism, and they argue that this results from commute-related stress. A study of German workers estimates a 16 percent reduction in absences if all commutes were negligible (Gutiérrez-i-Puigarnau & van Ommeren, 2010). Furthermore, long and stressful commutes may encourage employees to work from home, which negatively affects the morale of co-workers according to a study of 240 professional employees (Offstein & Morwick, 2011); (Gutiérrez-i-Puigarnau & van Ommeren, 2010)

Employers also have an incentive to subsidize employee commutes to discourage employee turnover. Estimates suggest that replacing an employee costs an employer roughly 150 percent of the original employee's salary (Ramlall, 2003). As Mitchell et al. (Mitchell, Holtom, Lee, Sablynski, & Erez, 2001) point out, employees are more likely to stay at a job with a favorable commute. In a study of 186 former employees in three Midwestern US cities, 1.9 percent gave "commuting or travel" as their primary reason for leaving (Maertz & Kmitta, 2012/8). Although this suggests that commuting has a smaller impact, other studies have found that "ease of commute" factored into the job choices of 27.7 percent to 38.0 percent of survey respondents (Milman, 2003/3) (DiPietro & Milman, 2004).

Policy Setting and Background

State Policy Setting

Global Warming Solutions Act of 2006 and 2016 Update

AB 32 (2006) established a target for statewide GHG emissions of no more than 1990 levels by 2020 and granted the California Air Resources Board authority to implement programs to achieve this goal. SB 32 (2016) updated the 2030 target to 40 percent below 1990 levels, was that 2020 statewide GHG emissions would be less than or equal to 1990 GHG emissions. As part of the plan to achieve these GHG goals, the state is pursuing strategies to clean electricity, improve the fuel efficiency of vehicles, and reduce the carbon intensity of transportation fuels (California Air Resources Board, 2017).

Governor's Zero Emission Vehicle Action Plan

California Governor Jerry Brown signed Executive Order B-16-2012 (Governor, 2012), which set a statewide goal to have 1.5 million zero-emission vehicles on California roads by 2025. The Governor's 2016 Zero Emission Vehicle Action Plan (Governor's Interagency Working Group on Zero-Emission Vehicles, 2016) and the 2017 Climate Change Scoping Plan (California Air Resources Board, 2017) delineate strategies to achieve this goal. The 2017 Scoping Plan (2017) articulates a target of 4.2 million ZEVs and plug-in hybrid electric vehicles (PHEVs) by 2030 in order to put the state on track to achieve this goal.

Another motivation for the adoption of zero emission vehicles that several California regions do not meet federal attainment standards for Ozone, PM 2.5, and PM 10 in the Los Angeles air basin and in other air basins throughout the state.

As part of the Zero Emission Vehicle Action Plan, the state seeks, among other objectives, to:

- Achieve mainstream consumer awareness of ZEV options and benefits
- Make ZEVs an affordable and attractive option for drivers
- Ensure convenient charging and fueling Infrastructure for greatly expanded use of ZEVs
- Maximize economic and job opportunities from ZEV technologies
- Lead by example integrating ZEVs in to state government

SB 375 (2008)

In 2008 the California State Legislature passed the Sustainable Communities Planning Act created a framework for integrated transportation and land use planning to reduce greenhouse gas emissions from passenger vehicles. In passing SB 375, the legislature found that new vehicle technology and low carbon fuel will not produce reductions in greenhouse gas emissions necessary to meet future targets, therefore changed land use patterns and improved transportation policy are necessary. The law empowered the California Air Resources Board to set regional targets for reductions in per capita greenhouse gas emission from passenger vehicles. The Air Resources Board set Southern California's target at 8 percent below 2005 levels by 2020 and 13 percent below 2005 levels by 2035. These reductions are above and beyond those which will come from cleaner fuels and vehicles.

Los Angeles Regional Planning and Policy Setting

SCAQMD 2016 Air Quality Management Plan

The South Coast Air Quality Management District (SCAQMD) is out of compliance with state and federal air quality standards for Nitrogen Oxide (NOx), particulate matter (PM 2.5 and PM 10), and ground-level ozone and has been for many decades (Southern California Air Quality Management District, 2016). This noncompliance could eventually impact the region's federal transportation funding. The SCAQMD is required to adopt an Air Quality Management Plan (AQMP) every 4 years to detail the actions the region will take to reduce pollutant concentrations in order to meet air quality standards.

The SCAQMD AQMP is a component of the State Implementation Plan (SIP). Areas not in attainment with the National Ambient Air Quality Standards (NAAQS) can be subject to regulatory and fiscal sanctions. The Environmental Protection Agency Administrator must find a state out of compliance with the Clean Air Act if the state fails to submit a complete nonattainment area plan, updated SIP element, if a SIP is disapproved, or if the state fails to implement any element of an approved SIP. When the EPA Administrator finds a state out of compliance, the Federal Highway Administration is required to impose a highway funding moratorium for all projects not related to safety or mass transit. Sanctions are not triggered when a state or air district fails to reduce emissions below NAAQS by a specified date if the State implemented all elements of an approved SIP but those measures were ineffective.

As a separately-regulated ozone precursor, NOx is the South Coast Basin's greatest challenge in meeting ozone standards. Mobile sources currently constitute 88 percent of the region's total nitrogen oxide (NOx) emissions. It is projected that NOx emissions for 8-hour ozone will reduce to 255 tons per day by 2023 and to 214 tons per day by 2031 due to current regulatory actions. However in order to attain the 8-hour ozone standards, total Basin NOx emissions need to be further reduced to 141 tons per day (an additional 45%) by 2023 and 96 tons per day (an additional 55%) by 2031, according to the March 2017 final draft of SCAQMD's Air Quality Management Plan (AQMP). The plan explains how attaining the 8-hour ozone standard in 2023 should make it possible to attain the 1-hour ozone standard by 2022. NOx reductions should also lead to the attainment of the 24-hour PM 2.5 standards, but not the annual standards. Because the SCAQMD air basin did not expect to meet the annual 2.5 standard by the "moderate" attainment year (2021) using all feasible measures, the district requested and the state has granted a reclassification of the SCAQMD air basin as a "serious" nonattainment area for the 24-hour PM 2.5 standard, which pushes the deadline back to 2025.

AQMP's Control strategy

The AQMP control strategy is comprised of five main components: 1) traditional regulatory control measures 2) incentive-based programs 3) co-benefits from existing GHG reduction programs 4) further deployment of cleaner technologies and 5) reductions from state and federal mobile sources.

The SCAQMD's 2016 AQMP ozone control strategy heavily focuses on incentive-based programs to aid the transition to zero and near-zero emission vehicles (automobiles, transit buses, medium-and heavy-duty trucks). SCAQMD estimates the amount of incentive funding needed to attain the federal ozone standards is between $11-14 billion over a seven to fifteen year period. SCAQMD currently collects around $56 million/year in incentives funding for accelerated turnover of on- and off-road vehicles and equipment under SB 1107, the state's tire fee, and AB 923. In order to achieve the required NOx emission reductions, SCAQMD estimates it will need to make up a gap of approximately $1 billion per year.

The traditional regulatory measures consist of both SCAQMD and CARB control measures. Incentive strategies involve SCAQMD mobile and stationary sources in addition to California Air Resources Board's control measures. The traditional regulatory measure which affects commutes is Rule 2202, the employer-based On-Road Motor Vehicle Mitigation Options, detailed further in the next section.

Southern California Association of Governments 2016 Regional Transportation Plan/ Sustainable Communities Strategy

The 2016-2040 Regional Transportation Plan/Sustainable Communities Strategy (Southern California Association of Governments, 2016) (RTP/SCS) is the regional framework plan for integrated transportation and land use planning in support of per-capita reductions from light duty vehicle GHG at a level greater than what is possible with cleaner fuels and vehicles alone.

The 2016 RTP/SCS assumes that 46 percent of new housing and 55 percent of new employment locations developed between 2012 and 2040 will be located within high-quality transit areas, which comprise only 3 percent of the total land area in the Southern California Association of Governments (SCAG) region. The RTP/SCS also anticipates ten light rail projects, three heavy rail projects, two new streetcars, and extensions to the Metrolink system throughout the Southern California region.

The 2016 RTP/SCS includes policies to increase the use of carsharing and ridesourcing and estimates that these would result in a combined reduction in GHGs of 0.9 percent by 2040 (pg 114). This is on par with the GHG reductions expected from full deployment of the regional charging network.[1]

Metro Los Angeles Measure M Expenditure Plan / Long Range Transportation Plan

Metro prepares a long range transportation plan every 8 years to guide capital investments. Since the 2009 Long Range Transportation Plan was adopted on the heels of the 30-year half-cent transportation sales tax Measure R, adopted by voters in November 2008, Metro has indefinitely extended that sales tax and passed a new sales tax measure (Measure M, November 2016). Metro will adopt an update of its Long Range Transportation Plan in 2018, but the Measure M expenditure plan provides a preview of future capital projects.

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[1] a 1 percent reduction above and beyond baseline reductions expected from EV adoption without a full network in place

Figure 3: Los Angeles Current and Under Construction Metro Rail and Bus Rapid Transit System[2]

2 (Los Angeles County Metropolitan Transportation Authority, 2016)

Figure 4: Measure M Rail and Bus Rapid Transit System Map[3]

3 (Boland, n.d.)

Los Angeles Sustainable City pLAn

The Los Angeles Sustainable City pLAn (Office of the Mayor, 2015) sets forth a range of targets and goals, including some transportation targets related to this research project:

- Los Angeles will reduce vehicle miles traveled (VMT) per capita 5 percent by 2025
- At least 50 percent of all journeys will be on foot, by bike, or using public transit by 2035
- At least 5 percent of trips will be made via shared transportation, including carshare, bikeshare, and rideshare, by 2035.

Geographic Setting and Background

Transit Use

Los Angeles's reputation as an auto-dependent metropolis is common-place in popular media, but not necessarily backed by data. While an order of magnitude more trips in Los Angeles County were made by automobile than public transit, about one of every fifteen trips in the County is made on public transit (NuStats Research Solutions, 2013)[4]. For trips to work, 6.8 percent of County residents commute via public transit, with a mean commute time of 49.9 minutes (United States Census Bureau, 2016). Seventy-three percent drove alone, with a mean commute time of 28.6 minutes and 9.9 percent carpooled, with a mean commute time of 31.4 minutes. Of the top 20 most populated metropolitan areas in the United States, Los Angeles ranks 8th in transit commute share.

Table 1: Most Populated U.S. Metropolitan Areas by Selected Commuting Metrics

Metropolitan Area	Population Rank	Drive Alone Rate	Carpool Rate	Transit Rate	Transit Commute Rank
New York	1	49.9%	6.3%	32.1%	1
Los Angeles	2	75.3%	9.1%	5.2%	8
Chicago	3	70.8%	7.7%	12.2%	5
Dallas	4	81.1%	9.5%	1.6%	17
Houston	5	80.7%	10.1%	2.3%	15
Washington	6	65.7%	9.3%	14.7%	3
Philadelphia	7	73.4%	7.3%	9.8%	6

[4] Mode Share Los Angeles County from California Household Travel Survey (2012): 69.3 percent of all trips via automobiles and 6.7 percent of all trips via public transit

Miami	8	78.4%	8.8%	3.9%	11
Atlanta	9	77.9%	9.6%	3.4%	13
Boston	10	66.8%	7.1%	13.9%	4
San Francisco	11	59.0%	9.6%	17.5%	2
Phoenix	12	76.8%	10.9%	2.3%	15
Riverside	13	78.2%	12.3%	1.5%	18
Detroit	14	84.7%	8.0%	1.4%	20
Seattle	15	69.0%	9.4%	9.4%	7
Minneapolis	16	77.7%	8.0%	4.8%	9
San Diego	17	76.3%	8.2%	3.5%	12
Tampa	18	79.7%	8.6%	1.5%	18
Denver	19	77.2%	7.9%	4.0%	10
St. Louis	20	83.2%	7.1%	2.7%	14

This table compares metropolitan areas, which may include multiple counties or portions thereof
Source: (United States Census Bureau, 2016)

Scholars have long debated whether people who want to use transit move to transit or whether the presence of transit causes everyone to use it more often and drive less. Boarnet and others (2013) asked this question with the first ever experimental/control group before/after study of a new rapid transit line - phase 1 of the Exposition Light Rail line from Downtown Los Angeles to Culver City. Boarnet, et. al., found that those who lived within ½ mile of a new station reduced their household vehicle miles traveled by 10 to 12 miles per versus those who lived further from a station. Those living within ½ mile or greater than ½ mile of a station had no statistically significant differences in vehicle CO2 emissions before the Expo Line opened, but after opening those who lived within ½ mile of the line had approximately 30 percent less vehicle CO_2 emissions than those living further away.

Regional and Urban Form

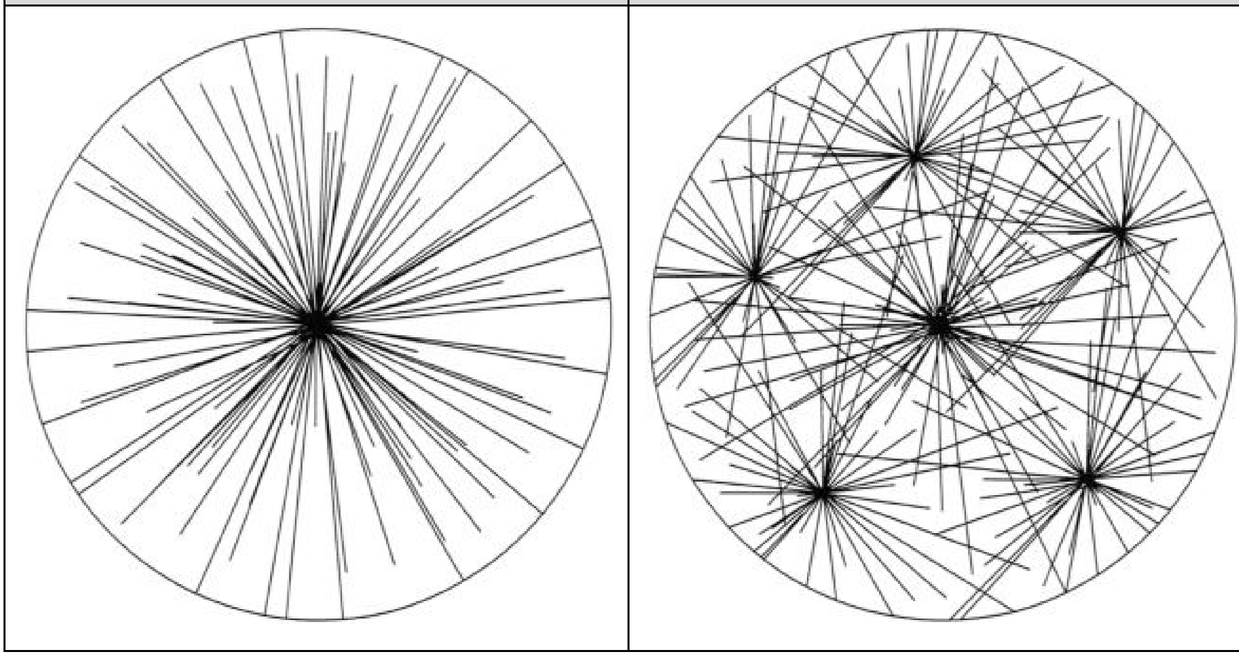
Versus other North American metropolises, the Los Angeles region has a high proportion of clustered jobs in subcenters or regional centers but relatively few jobs in the largest center, the Downtown Los Angeles Central Business District. Giuliano and Small (1991) identified 32 regional centers in Southern California, with 23 in Los Angeles County. A study of top 50 U.S. metropolitan areas using 2000 data found that Los Angeles had the lowest percentage of jobs in the central business district (~4%) but the highest percentage of jobs clustered in sub-centers (34%) (Angel & Blei, 2016).

Though no U.S. City is considered truly monocentric, Glaeser, Kahn, and Chu (2001) found that in 1996 several had over 25 percent of regional jobs within 3 miles of the central business district, for example New York (45.3%), San Francisco (44.5%), and Portland (30.3%). Los Angeles had only 6.9 percent of metropolitan employment within 3 miles of the CBD. Only Detroit had less (at 5.2%).

The figure below demonstrates the difference in commute patterns in monocentric and polycentric regions. A monocentric region is one in which a large percentage of employment is in a central business district. A polycentric region is where a large percentage of employment is in subcenters. A dispersed region is where employment is not concentrated in a central business district or subcenters.

Figure 5: Commutes in monocentric and polycentric regions[5]

Monocentric Region	Polycentric Region



Source: (Angel & Blei, 2016)

For those working in business districts, commute trips in polycentric regions are more challenging complex to serve with fixed-route, fixed-schedule public transit than such trips in a monocentric region. While the proportion of metropolitan workers in central business districts (and indeed business districts generally) has been eroding for decades, conventional wisdom holds that commute trips in a monocentric region can be effectively and efficiently served via a radial spoke and hub transit network. Indeed, the monocentric model of urban development is predicated on such hub-spoke travel (Alonso, 1964) (Mills, 1972) (Muth, 1969). Highest value, and as a result highest density, activities cluster near the center of such networks, so that each incremental line constructed from the center to the edge achieves its maximum accessibility when they, for example, connect peripheral residential areas with the primary employment area.

[5] Source: (Angel & Blei, 2016)

Ceteris paribus, each extension to the network in areas with high concentrations of population and jobs would lead to an increase in ridership that exceeds the proportional increase in network miles in stations.

While monocentric models of urban form and travel have weathered considerable criticism over the years (see, for example, (G. Giuliano, 1989)) for being increasingly poor descriptors of actual land use or travel patterns, public transit ridership in the U.S. is without question highest in metropolitan areas with very large central business districts served by radial transit networks: New York, Chicago, Boston, Washington, DC, and San Francisco.

In a polycentric region, like Los Angeles, employment is dispersed into multiple subcenters, and/or not in centers at all. Thus, a more distributed transit network is required to connect workers to jobs, often requiring a transfer between origin and destination. This is consequential because research shows that travelers find transfers to be far more burdensome that on-vehicle travel, which means that no-transfer trips are particularly attractive to transit users (Iseki & Taylor, 2009).

But while transit use is often highest to and from large central business districts served by radial transit networks, most employment and most employment growth is outside of such districts. As a result, there is a line of transit research suggesting that grid networks ae the most effective means of serving the dispersed destinations of polycentric cities — and that with legible, properly spaced networks, service frequencies can be kept high, and the perceived burdens of transfers relatively low. Jeffrey Brown and Gregory Thompson (Jaroszynski, Brown, & Bhattacharya, 2016) (Thompson, Brown, Bhattacharya, Jaroszynski, & Others, 2012) (Bhattacharya, Brown, Jaroszynski, & Batuhan, 2013) (Brown & Neog, 2012) (Brown & Thompson, 2012) (Brown & Thompson, 2008) have been the leading academic proponents of this view, while Walker (2012) has been perhaps the most articulate promoter of one-transfer grid-like networks.

Linking Los Angeles County Subcenters with Rapid Transit

Los Angeles is a polycentric region that has committed funding to a plan to expand its rapid transit network. Land use plans that focus future growth near current and future transit stations will leave intact the intercedent sprawl between stations. Those living in 20th century developments outside of transit-oriented districts will need alternatives to walking in order to access the expanding rapid transit network.

Over the next few decades, Los Angeles's rapid transit network will expand to reach more of the centers identified by Angel and Blei (2016).

Table 2: Centers identified by (Angel & Blei, 2016) **and current or future metro rapid transit accessibility**

Center/Sub Center	**Transit Access (*Italics* indicate under construction)**
Downtown Los Angeles	Red, Purple, Blue, Expo, Gold
Westwood/Century City	*Purple (2024)*
Santa Monica	Expo
Hollywood	Red
LAX Airport	Green, *Crenshaw (2019*)
San Pedro	Silver
Inglewood	*Crenshaw (2019*)
Pasadena	Gold
Long Beach	Blue
LA East	Gold
Hawthorne	Green
Canoga Park/Warner Center	Orange
Van Nuys	Orange
Downey	Green
Future extensions expected in 2018 LRTP	
Glendale, Southwest Burbank	Future North Hollywood-Del Mar BRT
Sherman Oaks	Future Sylmar/LAX rail
Commerce	Future Whittier Gold Line extension
Vernon/Huntington Park	Future Santa Ana Branch/Artesia rail
Lawndale	Future Green Line Torrance extension
Marina del Rey/Playa Vista	Future Lincoln Blvd BRT
Long Beach Airport, Van Nuys Airport, Burbank Airport	No Plans for Rapid Transit

Research Approach

The research team employed a mixed-methods approach to the applied research question. In addition to the literature review, this work included:

- A Planning Assessment: a spatio-temporal assessment of existing commute patterns in relation to Metro's Rail and Bus Rapid Transit network.
- Market and Regulatory Assessment: a qualitative and quantitative assessment of the applicability and magnitude of existing incentives and programs related to commutes, green vehicles, and TNCs.

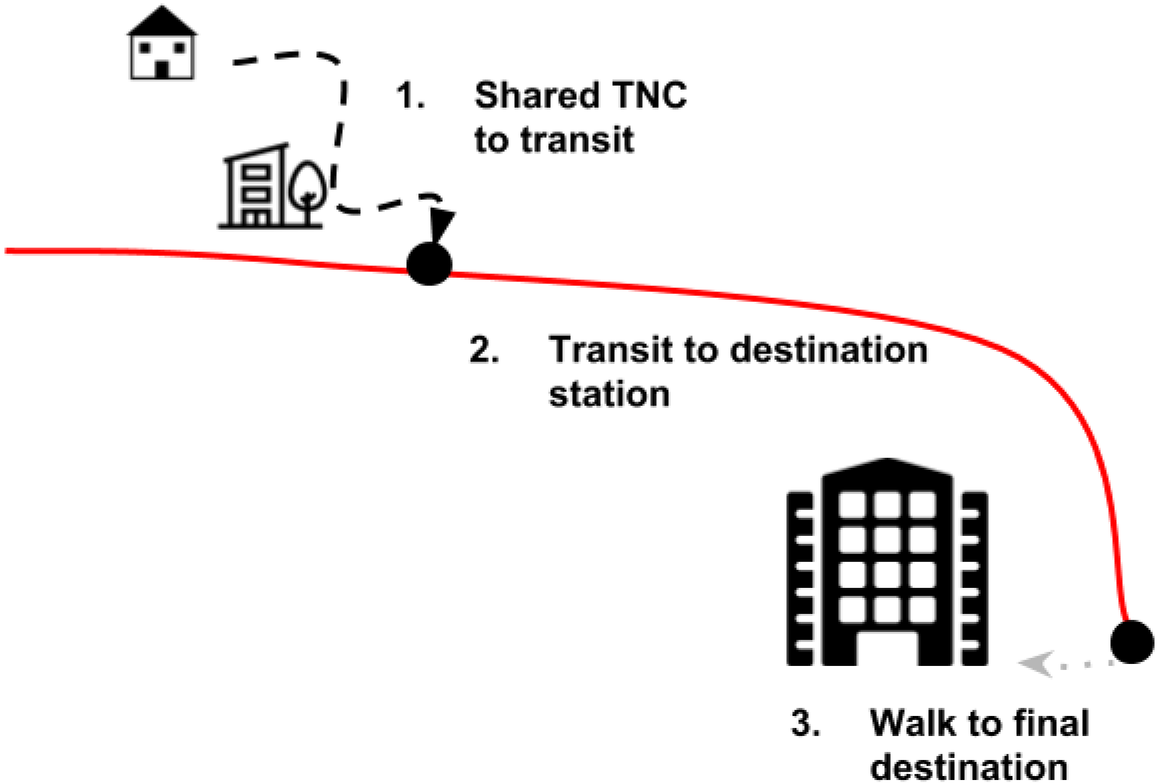
Planning Assessment

The purpose of the planning assessment is to identify areas in Los Angeles County where TNCs have the greatest potential to carry commute trips to the transit networks. Areas with the greatest potential will have the highest probability of passenger-matched trips and thus the lower cost and GHG emissions per passenger trip.

Model data from SCAG estimating job flows from every origin neighborhood to every destination neighborhood in the county forms the basis of this assessment. The unit of analysis in SCAG's data is the traffic analysis zone, or TAZ. TAZs are roughly the same size as Census tracts. In addition, the assessment takes into account 1) locations of the rapid transit stations in LA County and 2) driving and transit time estimates from the Google Maps API. The assessment is focused on identifying trips that could be served by a chained trip, as follows:

1) TNC trip to an origin transit station,
2) transit trip, and
3) walk from the destination-side transit station to the final destination.

Figure 6: Illustration of TNC-transit trips



These chained trips are referred to as “TNC-transit trips.”

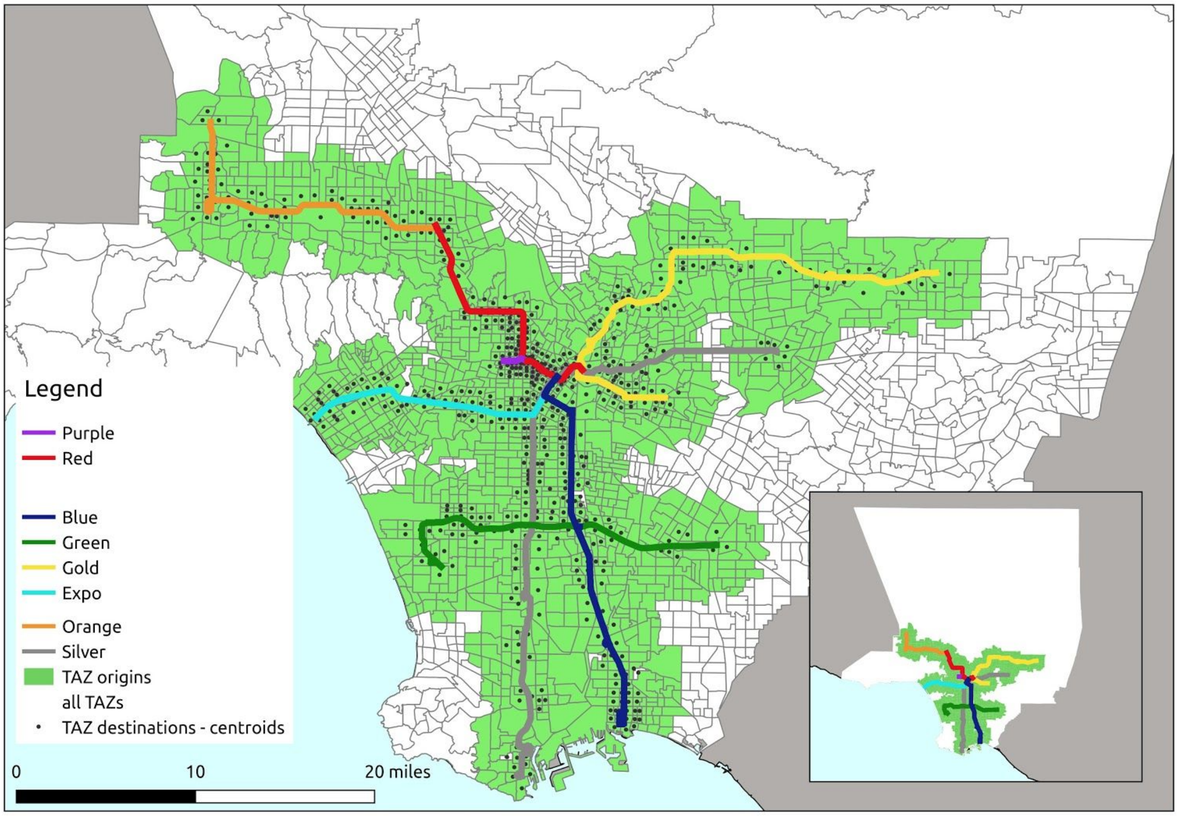
Overview of the planning assessment methodology

A few constraints are imposed on the model to simplify the problem of assessing TNC-transit trips:

- Only transit that runs frequently in an exclusive right-of-way is considered in the assessment. In Los Angeles County, this is the Blue, Red, Gold, Green, Purple, and Expo Lines on Metro Rail, and the Orange and Silver Busway Lines.
- Only origins within 3 miles as-the-crow-flies of a transit station are considered in the assessment.
- Only destinations within 1 mile as-the-crow-flies of a transit station are considered in the assessment.
- Travel times and catchment distances to origin and destination TAZs are determined by TAZ centroids. Within-TAZ variation is ignored.

Figure 7 below depicts the transit lines and the TAZs that are eligible for the analysis.

Figure 7: Transit Lines, Origins and Destination Zones Eligible for the Analysis



The assessment then entails:

1. Calculating the total travel time for each (O,D) TAZ pair where the trip consists of:
    - A drive trip to a transit station
    - A transit trip on Metro Rail or Busway, which may include transferring lines
    - A walk trip on the destination end

And where the trip routing — e.g. choice of origin-side station, choice of routing on the transit network, and choice of destination-side station — is optimized to minimize travel time.

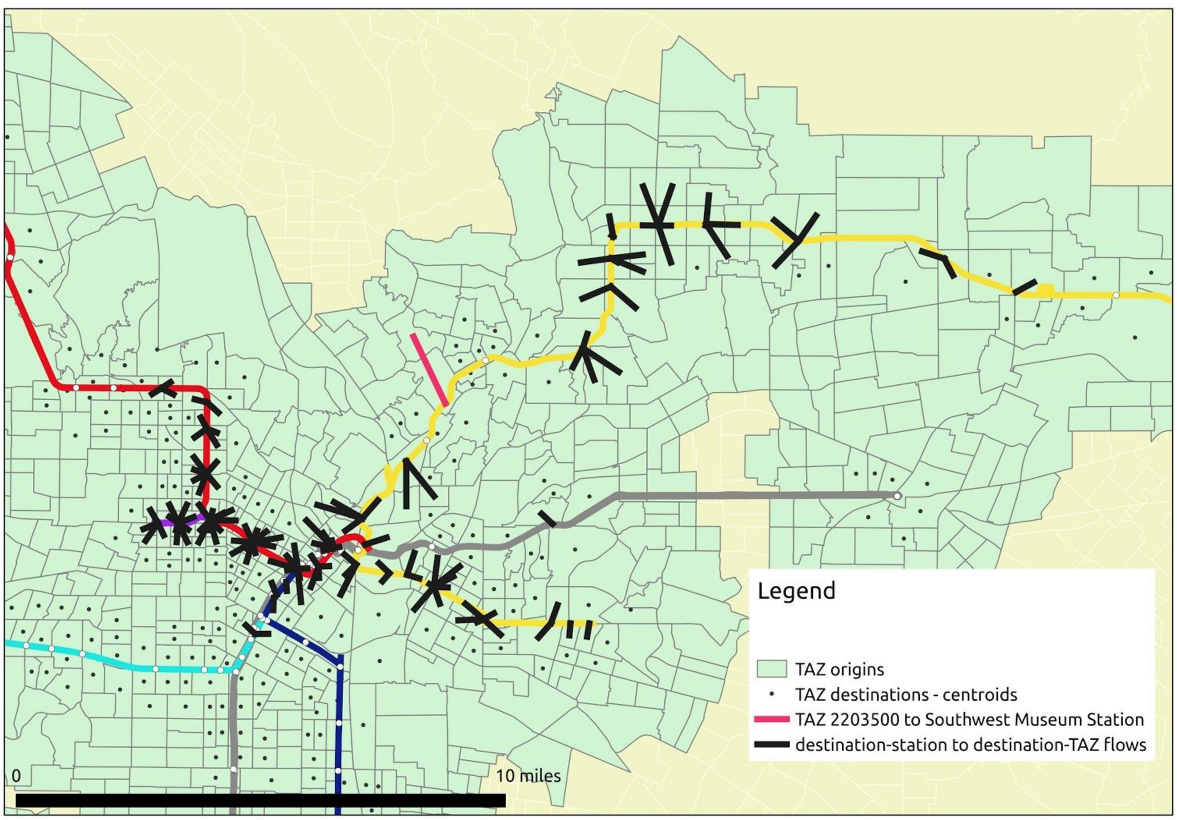
2. Selecting those (O,D) pairs who have a trip time below a given commute time threshold. We use thresholds of 30 minutes, 45 minutes, and 60 minutes.
3. From that selection removing pathological results: (O,D) pairs for which travelers would be unlikely to choose a TNC➡transit➡walk trip. In this analysis, trips which meet any of the following conditions are removed:[6]

[6] Note that further conditions could be imposed here. Very short transit trips could be filtered out, and origin-side TAZs that are walking distance from transit could be filtered out as well. More generally, what is pertinent is how a TNC+transit+walk trip competes (in cost and time) with the alternatives. These alternatives include driving the whole way, taking transit lines not on the exclusive right-of-way network, and others. Cost is an important consideration: this type of trip will be more relatively appealing where

    a. O and D are within 3 miles of one another
    b. Transit trip is null - the estimated time represents driving to a transit station and then walking from that same station
4. Summing the trip estimates for drive-alone trips in the AM peak period for these OD pairs by (origin TAZ, origin-side station) pair.
5. Grouping the (origin TAZ, origin-side station) pairs together based on the angle radiating outward from the station. The lines are grouped in 30 degree bundles. These bundles correspond to TNC trips that would be likely to match with one another in an Uberpool or LyftLine type of trip.

Figures 8 and 9 below illustrate a few examples of the destinations that could be reached from a given TAZ within 45 minutes using a combined TNC➡transit➡walk trip.

Figure 8: Sample of Origins and Destinations which can be reached within 45 minutes on TNC-transit trip



The figure shows a single origin-side line representation in pink, connecting a TAZ to the Southwest Museum station of the Gold Line. The black lines represent all the destination TAZs that can be reached from that origin TAZ with a 45 minute linked TNC➡transit➡walk trip. Note that there are no black lines within 3 miles of the origin TAZ. The figure provides some intuition

Driving is unappealing because parking is expensive, for example. For the purposes of time and simplicity, this analysis doesn't incorporate these important factors.

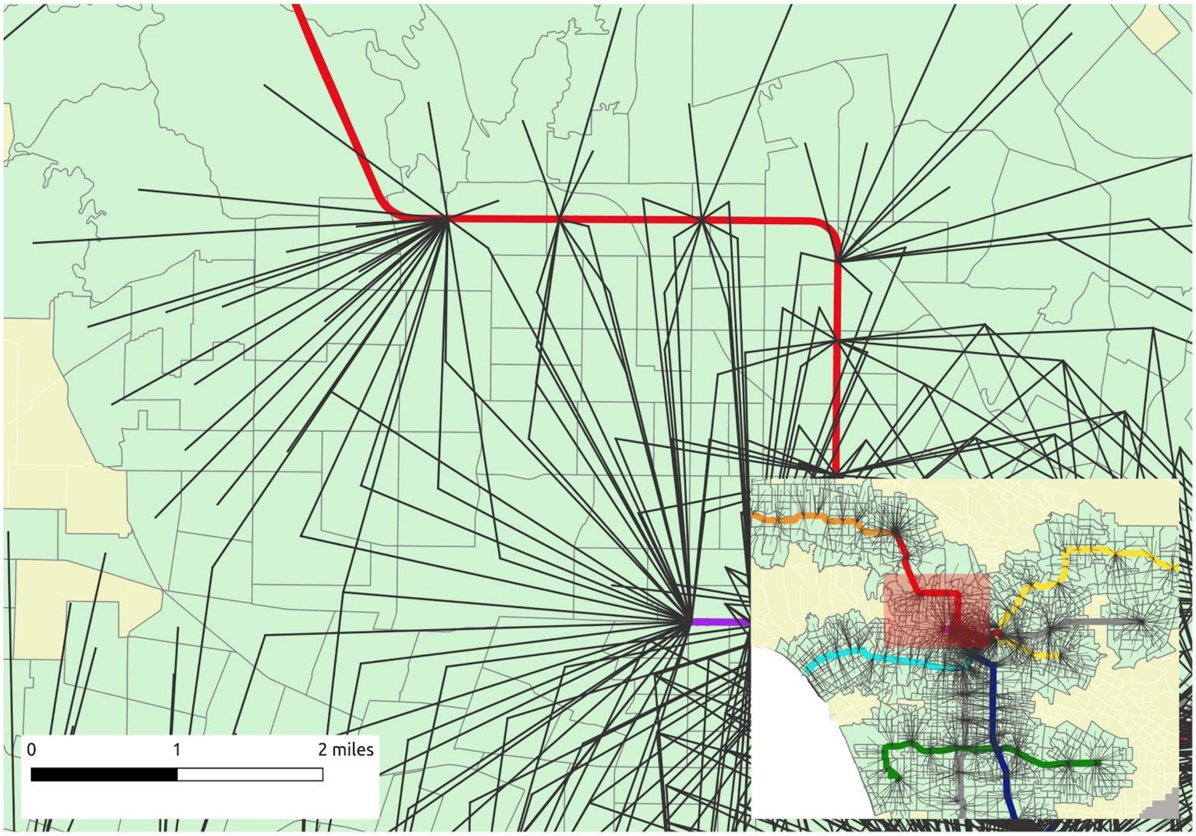
into what each of the origin-side lines represent. For each destination-side TAZ reached by a black line, the estimated number of trips between the origin and that destination are included in the sum assigned to the pink line.

Another example is shown in the next figure. This time, the pink line connects to the Harbor Freeway station of the Silver Line. Again, the black lines represent all the destination TAZs that can be reached from that origin TAZ with a 45 minute linked TNC➡transit➡walk trip.

Figure 9: Sample of South County Origins and Destinations Reachable via 45 minute linked TNC-Transit trip

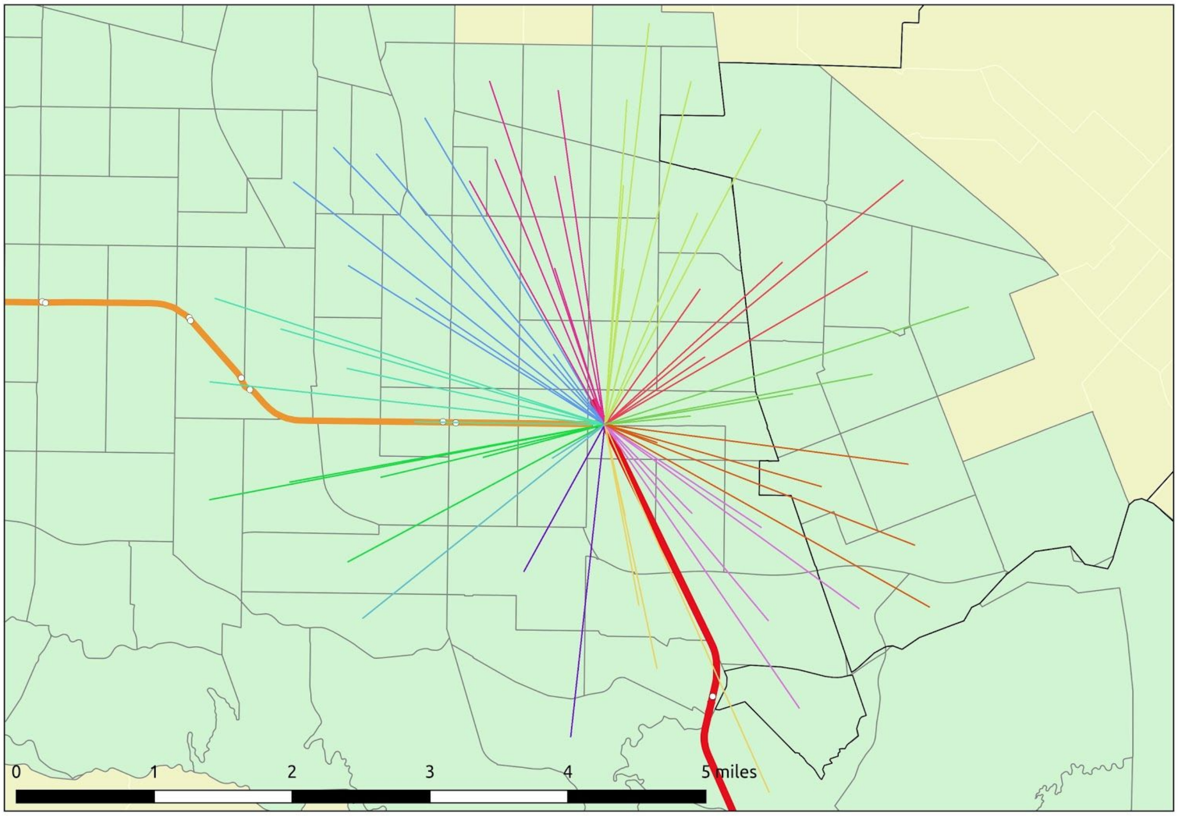
For each (origin TAZ, origin-side station) pair, this produces an estimate of the number of commutes that could be served by a TNC-transit trip shorter in duration than the threshold. The figure below depicts all of these lines connecting the origin TAZ to the origin-side station. Note that both of the above examples depict a single origin-side station for the origin TAZ. In Figure 10 below, it is shown that an origin TAZ can have more than one origin-side station if it is near multiple lines.

Figure 10: Station Ingress Lines for Origin TAZs



Grouping the lines by their angle radiating outward from the station, corresponds to the fact that there will be more rides, and more matched rides, in areas where routes to the station overlap. Figure 11 below depicts the groups for the North Hollywood Station of the Orange and Red Lines.

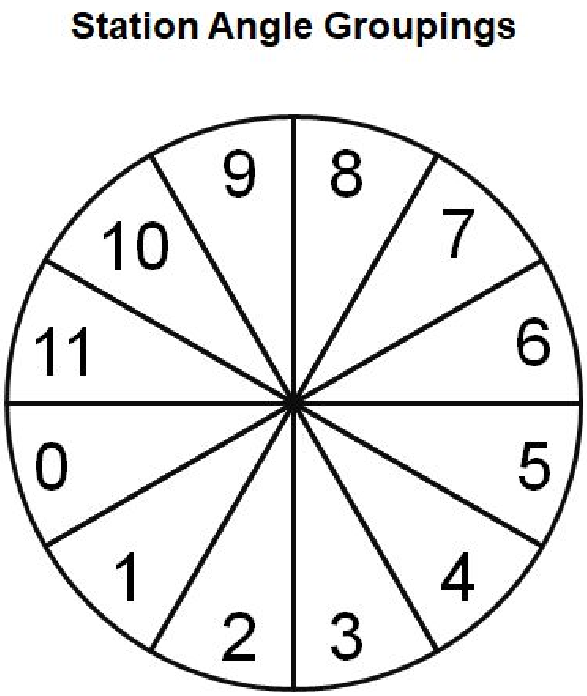
Figure 11: Origin-Station Ingress Trip Sector Groupings



Lines that are shown in the same color are in the same grouping by angle (See Figure 12). Recall that these lines represent (origin TAZ, origin-side station) pairs.[7]

[7] The choice of 30 degrees is arbitrary. It is a proxy for which trips would be likely to match that the authors believe is conservative. In reality, match probability would depend on the routing on a street grid as well as the proprietary algorithms of the TNC provider, notably these algorithms' tolerance for deviations from the shortest route from origin to destination. Note that the groupings are based on laying down a series of evenly spaced counter-clockwise angle divisions starting from 0, which is defined as parallel to the map projection horizontal. This set of divisions is also arbitrary, and it may be possible to achieve more optimal grouping of lines using, for example, a cluster analysis.

Figure 12: Station Area Angle Groupings



Station Angle Grouping	Cardinal Direction
0	WSW
1	SW
2	SSW
3	SSE
4	SE
5	ESE
6	ENE
7	NE
8	NNE
9	NNW
10	NW
11	WNW

Data sources

The following data sources form the basis of the assessment. Commentary on their strengths, drawbacks, and appropriateness follows.

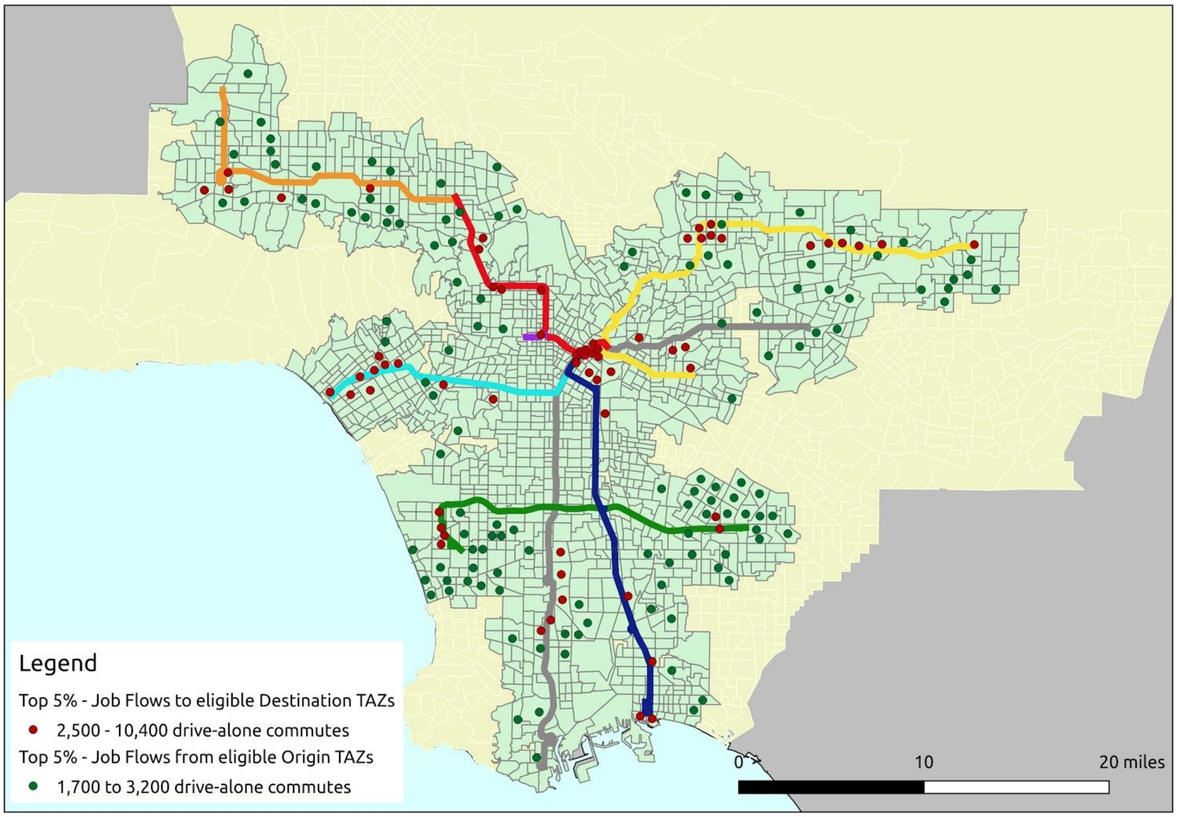
Job flows estimates from SCAG

As Southern California's regional Metropolitan Planning Organization (MPO), SCAG is responsible for building and maintaining a travel demand model for the region. SCAG's model is a trip-based model, more advanced than traditional four-step travel demand models, but less advanced than activity-based models. SCAG's model takes in socioeconomic data (population, employment, households, workers, and school enrollment), a roadway network, and a set of transportation analysis zones (TAZs) that are roughly the size of Census tracts. It outputs, among other things, vehicle trips by time of day, trip purpose, and mode (carpool vs. drive-alone) for each origin/destination TAZ pair. This assessment uses 2012 modeled origin-destination flows for drive-alone trips in the AM peak period (6-9 AM).

These data have the advantage of being geographically comprehensive, well-documented, and validated against household travel survey data.

To provide some intuition for these data, the figure below depicts the top 5 percent of drive-alone commute flows summed by origin TAZ in green and the top 5 percent of job flows summed by destination TAZ in red. (Where only origin TAZs eligible for this analysis, e.g. within 3 miles of a rail or busway station, are included, and likewise only eligible destination TAZs within 1 mile of exclusive right-of-way transit are included). The figure again underscores the polycentric nature of the Los Angeles region. It also illustrates the potential for linked TNC➡transit➡walk trips to serve work commutes.

Figure 13: Top Origin and Destination TAZ's in Analysis Area



Drive times from origin TAZ to stations from Google Maps Directions API

For each origin TAZ to each of its origin-side stations, the drive time from the Google Maps Distance Matrix API is included in the assessment. The Google Maps data have the advantage of taking into account street network density and typical congestion levels. The call to google maps was actually made in the afternoon, rather than the AM peak as would perhaps be ideal.

Transit times for each station pair from Google Transit Directions API

There are 203 GTFS station IDs in Metro's Rail and Metro Liner busway network. For each of the 203^2 = 41,209 pairs on this network, the travel time via transit from Google's Transit Directions API is included in the assessment. The `transit_mode = 'rail'` parameter was passed to the API. The lat,long coordinates of the origin-side station and the destination-side station were passed to the API. The time parameter specified a departure time of 8 AM on

Tuesday, March 7. A few notes on the resulting transit time returned from the API. It does not include wait time at the origin-side station. The authors assume this is fairly negligible, since all of the services on the rail and busway network run headways between 4 and 7 minutes during the AM peak. Thus, the expected additional time due to waiting is between 2 and 3.5 minutes, depending on the transit line. The time does include transfer time for any transfers.

The time returned is not guaranteed to be the travel time ***on*** the rail and busway network. The parameters passed, combined with the fact that transit trips on this network are generally the fastest, tend to produce a route that is on the rail and busway network. The authors investigated how frequently the transit routing deviated from the rail and busway network. Of the 41,209 station pairs, google maps API returned a route exclusively on the rail and busway network for 78.2 percent of the pairs. However, we should account for the fact that some pairs appear much more frequently than others in the linked trips between origin and destination TAZs. Of the 116,743 (O,D) TAZ pairs that can be connected by a linked TNC➡transit➡walk trip in less than 45 minutes, 88.5 percent of the transit trips are on the rail and busway network.

There was a small number (42) of Silver Line station pairs for which Google Transit Directions API would return a null result with the parameters described above. To get a time result for these station pairs, the `transit_mode = 'rail'` parameter was removed.

Estimated walk times as a function of crow-flies distance

The walk time at the end of the trip is estimated as a function of the crow-flies distance from the destination-side station to the centroid of the TAZ. With distance `dist`, first a pessimistic grid distance `grid_dist` is calculated. This assumes that the destination is reached as a hypotenuse of a right-triangle, e.g. that the street grid is oriented in the worst possible way for reaching the destination. Then, walk time `walk_time` is calculated by assuming a walking speed of 3 miles per hour, or .0008333 miles per second. (Seconds are used as the unit of time throughout the analysis.)

```
grid_dist = 2*dist/(2^.5)
walk_time = grid_dist / (0.0008333)
```

The estimated walk time is a somewhat clunky measure, given that actual walk time would depend greatly on where in a TAZ the destination is located. However, given that TAZs are our unit of analysis, this estimate provides a workable figure without having to decompose the data to some smaller unit of analysis, a process that would require a number of assumptions and would also add complexity to the assessment.

Market Assessment

In addition to research papers and white literature on TNCs, we reviewed publicly available information from regulators, local governments, news reports, and TNCs themselves to determine what services these companies provide. Based on information from the California Public Utilities Commission, we created an inventory of registered TNCs in California. Using press releases and marketing information directly from Uber and Lyft, we created an inventory of currently available TNC service variants (UberPOOL, Lyft Plus, etc.) in California, as well as commute and travel services offered directly to businesses. Furthermore, we browsed international marketing materials and news reports by TNCs to collect information on unique service variants that mimic or complement transit, as well as service variants related to clean vehicle use. Finally, we aggregated information from news reports, local agency press releases, and TNC press releases to inventory partnerships between TNCs and transit agencies in the United States.

Regulatory Assessment

We examined potential public-driven catalysts for introduction of ZEVs into TNC service under existing regulatory and incentive programs. Research methods included qualitative review of publicly-available laws, ordinances, regulations, plans, or guidelines that described programs potentially applicable to the research objectives. This included regulations and guidance pertaining to air quality, transportation, taxation, and occupational safety. We also spoke with public employees who administer these programs in Santa Monica. The materials reviewed appear in the policy setting and findings sections.

Results

Planning Assessment

The figures display station corridors — defined by 30 degree angle groupings radiating outward from the station — where there are more than 400 drive-alone trips that could be served by a linked TNC-transit-walking trip. In the first figure, the trip counts include only those trips that could be served by a linked trip less than 45 minutes in duration. The second figure shows those trips that could be served by a linked trip less than one hour in duration.

Figure 14: Top Station Area Angle Groupings, 45 Minutes

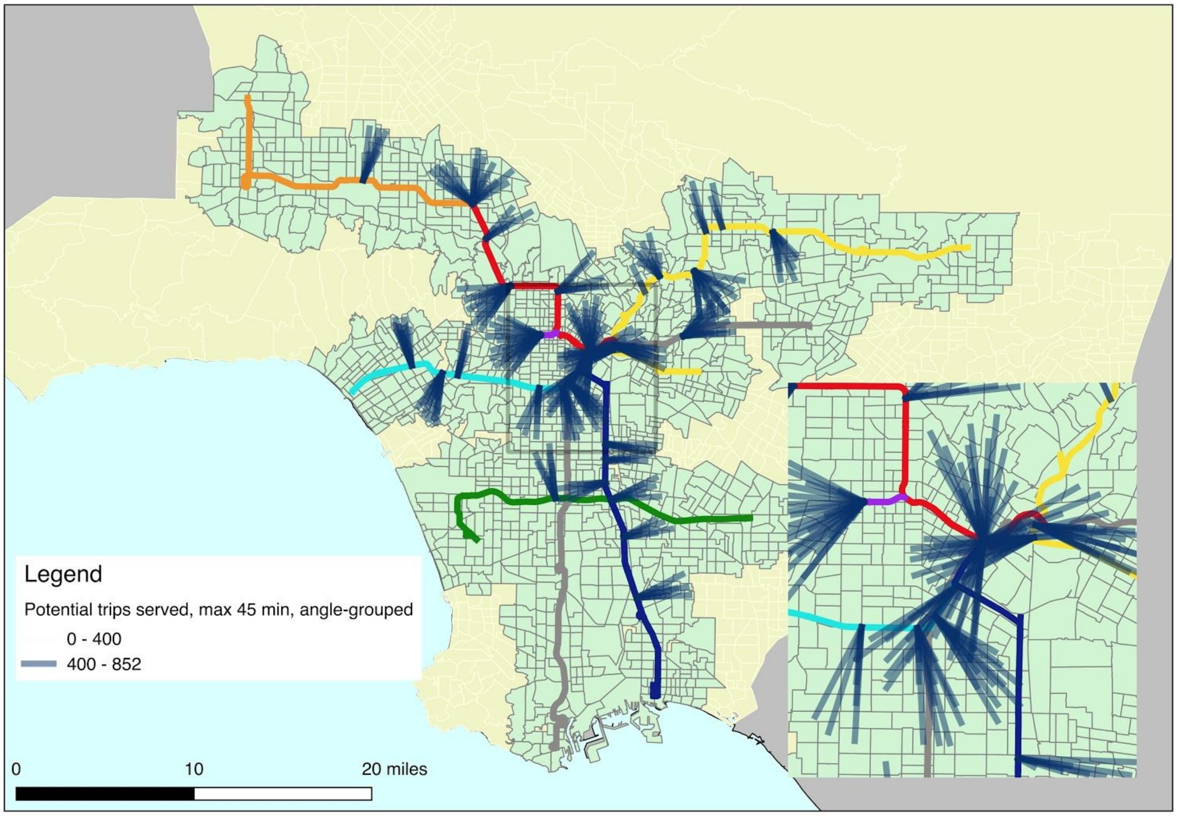
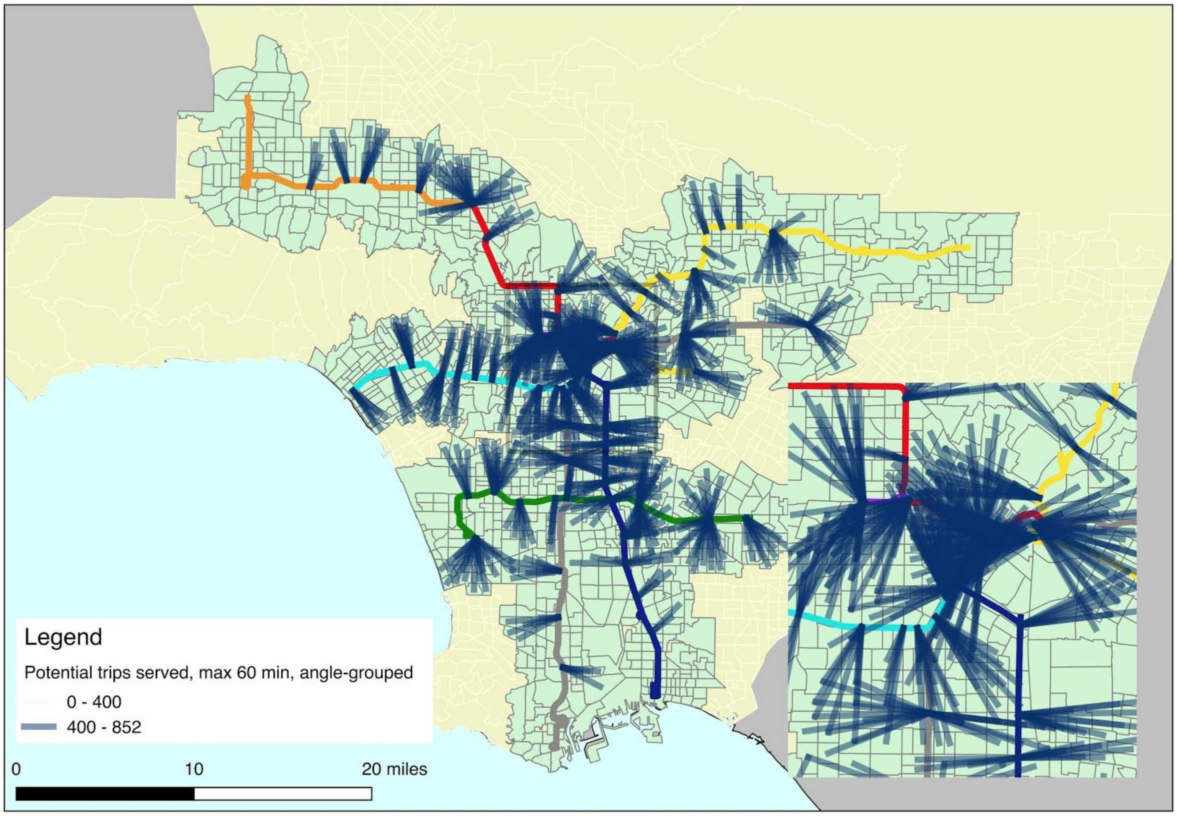


Figure 15: Top Station Area Angle Groupings, 60 Minutes



In general, we see that there is potential for matched rides serving this type of trip on most of Metro's rail and busway services. The stations closer to central Los Angeles and downtown tend to be more likely to have a high potential for a match, and the ends of the lines at the outlying areas do not tend to qualify. The number of potential trips served is highly sensitive to the maximum trip length used in the assessment. There are many more station corridors with high trip counts when we allow the trip time to be anything below one hour. The authors also tried a 30 min maximum, and the only angle-groupings that had more than 400 trips were two groups both leading to the Wilshire/Western station of the Purple line.

The following tables show potential trip counts for the top 50 stations, for maximum trip durations of 45 minutes and one hour respectively.

Table 3: Top Angle Groupings for Ingress Stations

Ingress Station	Angle Grouping	Possible Trips - 45 minutes	Possible Trips - 60 minutes	Lines
Hollywood / Highland Station	0	852	1201	Red
Wilshire / Western Station	0	808	1104	Purple
Grand / LATTC Station	1	787	1108	Blue

Hollywood / Highland Station	1	770	1091	Red
Highland Park Station	9	698	1041	Gold
Wilshire / Western Station	11	685	956	Purple
Vermont / Sunset Station	6	646	820	Red
Southwest Museum Station	9	643	878	Gold
South Pasadena Station	4	634	891	Gold
Cal State LA Busway Station	7	633	969	Silver
Del Amo Station	6	608	1099	Blue
South Pasadena Station	3	600	783	Gold
North Hollywood Station	8	593	862	Red / Orange
Wilshire / Western Station	1	576	790	Purple
Universal / Studio City Station	7	574	770	Red
Vermont / Athens Station	9	565	878	Green
Highland Park Station	10	564	865	Gold
Sierra Madre Villa Station	3	562	756	Gold
Memorial Park Station	9	549	833	Gold
North Hollywood Station	10	522	676	Red / Orange
Florence Station	5	488	891	Blue
Cal State LA Busway Station	6	485	837	Silver
Palms Station	2	480	753	Expo
Vermont / Sunset Station	7	474	677	Red
North Hollywood Station	7	464	680	Red / Orange
Firestone Station	6	459	775	Blue
Expo / Sepulveda Station	9	459	638	Expo
Union Station	5	457	763	Silver / Gold / Red / Purple
Expo / Western Station	2	452	739	Expo
Woodley Station	8	451	742	Orange
Sierra Madre Villa Station	4	450	618	Gold
Culver City Station	8	442	822	Expo
Willowbrook - Rosa Parks Station - Metro Blue Line	6	436	806	Blue
Little Tokyo / Arts District Station	0	433	579	Gold

103rd Street / Watts Towers Station	0	432	676	Blue
Metro Center	3	432	623	Expo
Metro Center	6	429	613	Red / Purple / Blue / Expo
Jefferson / USC Station	4	429	652	Expo
Metro Center	9	420	#N/A	Red / Purple / Blue / Expo
Metro Center	2	419	562	Red / Purple / Blue / Expo
Compton Station	6	415	649	Blue
South Pasadena Station	5	411	622	Gold
Metro Center	8	408	580	Red / Purple / Blue / Expo
Palms Station	1	405	639	Expo
Lake Station	9	404	586	Gold
Harbor Freeway Station	8	398	442	Green/Silver
Slauson Station	5	396	731	Blue

Market Assessment

Transportation Network Companies

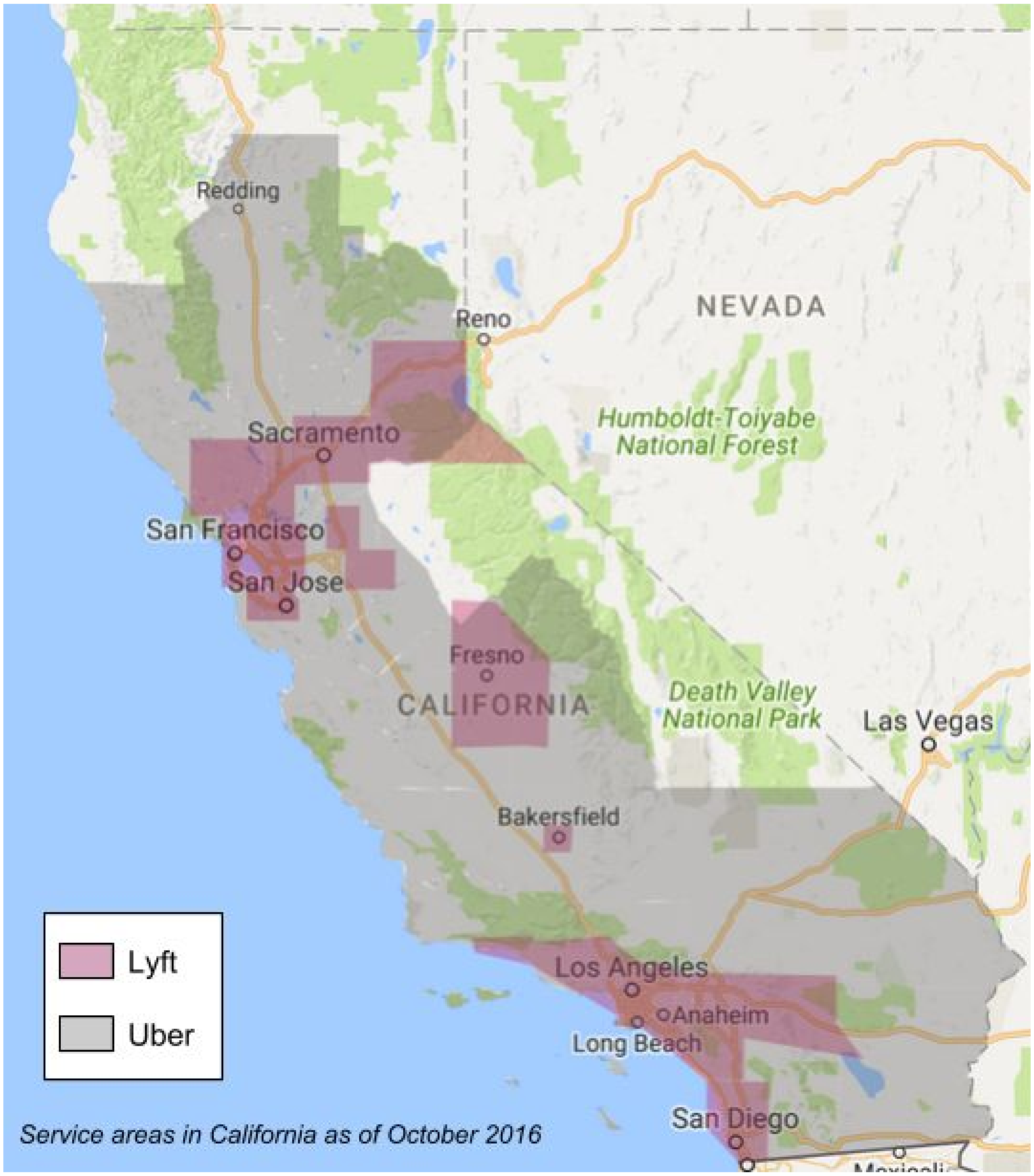
TNCs in California and Los Angeles

The California Public Utilities Commission (CPUC) defines a Transportation Network Company (TNC) as “a company or organization operating in California that provides transportation services using an online-enabled platform to connect passengers with drivers using their personal vehicles” (California Public Utilities Commission, n.d.). TNCs existed in a legal gray area until September 2013, when the CPUC established the TNC regulatory category and began issuing permits to TNCs. As of October 2016, the CPUC has issued permits to eight TNCs, including four which are specifically licensed to transport children (California Public Utilities Commission, 2016). The CPUC also has records of two now-defunct TNCs on its list of permit applications (CPUC 2016c), as well as one additional TNC with an unclear operational status on its “Trade Dress” page (California Public Utilities Commission, 2016). As drivers must be using their personal car to qualify as a TNC, the category excludes other shared mobility services such as buses, taxis, limousines, and vanpools, although increased technological sophistication is causing these products to resemble TNCs in many ways.

The dominant transportation network companies offer a similar core product in addition to luxury and shared ride options. Uber and Lyft offer a similar core product, known as UberX and Lyft, respectively, in which customers obtain on-demand rides through a smartphone application. When a customer requests a ride, the nearest available driver obtains the customer's name and location after accepting the request. As the customer must submit electronic payment information before requesting a ride, payment is made automatically without any physical transaction. For their core product, Uber and Lyft allow up to 4 riders per request, although they each offer high capacity versions for up to 6 riders, known as UberXL and Lyft Plus.

Uber's service area extends throughout nearly all of California, while Lyft's service areas are clustered around major cities. Figure 16 shows the service area for Uber in California.

Figure 16: Service areas of TNCs in California



TNC Service Variants

Uber and Lyft each offer a range of luxury and shared-ride variants of their core products, as shown in Table 5. Uber's shared-ride option, UberPOOL, offers 1 to 2 riders a lower fare in exchange for the possibility that the driver may pick up additional passengers traveling along the same route. Lyft offers a nearly identical service known as Lyft Line. The potential of these services to increase transportation system efficiency is particularly noteworthy for researchers and policymakers (Miller, 2016).

Table 4: Services offered by Lyft and Uber in California

TNC	Core/Ridehail	Shared-ride	High-capacity	Luxury
Uber	UberX	UberPOOL	UberXL	UberSELECT, UberBLACK, UberLUX
Lyft	Lyft	Lyft Line	Lyft Plus	Lyft Premier

In other cities around the world, Uber offers service variants with transit-like or green vehicle attributes.

Although limited data has prevented researchers from determining which vehicles TNC drivers use, specific initiatives by TNCs offer insight on how drivers may be encouraged to adopt ZEVs. Uber has introduced a hybrid-only service known as UberGREEN in various cities outside of the United States, including Paris, Lisbon, Porto, Johannesburg, and Cape Town[8], though the service was discontinued in all but Paris. In Hong Kong, Uber offers a Tesla-only ZEV variant as a combination of UberGREEN and a luxury service.

Uber and Lyft has also experimented with transit-like services where passengers are directed to pick-up points in order to allow for more direct routing of vehicles shared with other passengers. In Manhattan, UberPOOL requires peak period commuters to walk to a nearby corner for pickup (Uber, n.d.). In Toronto and Seattle, Uber experimented with an UberHOP fixed route services that operate during peak commute times with specified origins and destinations, but it discontinued the experiment in Summer 2016[9]. The UberHOP service continues in Manilla. In March 2017, Lyft introduced a new Lyft Line variant known as Lyft Shuttle in San Francisco and Chicago. Similar to UberHOP, Lyft Shuttle has dedicated routes and stops, as well as a fixed rate without “primetime” (Lyft’s equivalent of surge pricing). The service is currently limited to commute times, 6:30 to 10 am and 4 to 8 pm.

TNC General Leasing Programs

TNC companies and third parties have arranged short-term leasing programs to provide prospective TNC drivers with qualifying vehicles. TNC drivers can pay for these leases directly through embellished revenues.

Table 5: Sample Weekly Lease Rates for Uber Xchange Program

Vehicle	Weekly Rate	Source

[8] https://www.psfk.com/2016/06/ubergreen-electric-vehicles-makes-paris-cleaner.html, https://newsroom.uber.com/portugal/ubergreenen/, https://newsroom.uber.com/south-africa/ubergreenjhb/

[9] The service has re-emerged as Uber Express POOL.

2013 Toyota Camry L	$130	Uber
2015 Honda Civic	$150	Driver-Reported
2016 Toyota Corolla	$155	Driver-Reported
2016 Chevy Cruze	$200	Driver-Reported
2015 Toyota Prius	$183	Driver-Reported

Source: (Newcomer & Zaleski, 2016)

In 2016, the Uber Xchange program offered drivers no mileage cap, routine maintenance, and requires a deposit. In 2016, Lyft's Express Drive program offered vehicles at rates between $165-$235 per week (Lyft, 2016)

TNC Green Leasing Programs

Through a 2015 partnership with Chinese vehicle manufacturer BYD, Uber drivers in Chicago could lease or rent the fully electric BYD e6 (Groom, 2015). Similarly, the Los Angeles-based Evercar provided a ZEV Nissan Leaf to TNC drivers for $5 per hour with a $55 daily cap ("EverCar?," 2016), but suspended operations in October 2016 (Hall-Geisler, 2016).

TNC Shared-ride Subscription Discounts

Uber and Lyft have also experimented with monthly passes for their shared ride services. Uber offered monthly and biweekly passes for New York City customers in July and August 2016 through a partnership with Gilt City, an online retailer. The passes, priced at $49 for two weeks and $79 for one month, allowed free UberPool rides for passengers anywhere in Manhattan below 125th Street from 7 to 10 am or 5 to 8 pm. Uber offered a similar promotion for Washington, DC residents known as a "POOL pass", priced at $30 and capped at 20 rides, which provided $1 UberPOOL rides throughout the DC metro area during August 2016. Lyft followed suit later in the year, offering the "Lyft Line Pass" during November 2016 in Los Angeles, Miami, San Diego, Chicago, Atlanta, and Washington, D.C. They offered two variants - $20 for unlimited $2 line rides, or $29 for unlimited free rides. It is not clear if these promotions continued after the months in which they launched.

TNC Scheduled Rides

In 2016 and 2017, both major TNCs began allowing passengers to schedule rides in advance, which can help TNCs predict future demand. Lyft allows passengers to schedule Lyft ride-hail trips for a 10-minute pickup window up to 7 days in advance with a 10-minute pickup window and guarantees pricing in advance ("Now Live: Scheduled Rides," n.d.). Uber allows passengers to schedule UberX ride-hail trips for a 15 minute window up to 30 days in advance, with pricing subject to surge conditions at the time and location the trip is made (Uber, 2016b).

TNC Partnerships with Employers

Uber and Lyft offer employer-facing products, known as Uber for Business and Lyft Mobility Solutions, respectively. Both companies provide platforms for employers to track rides, to schedule rides in advance, and to automate expense reports through partnerships with expense processing company Concur.

Over 50,000 businesses use Uber's service, including Salesforce, Goldman Sachs, Dell, Zillow Group, Wunderman, and Adroll (Preimesberger, 2017). Uber for Business can be used for rides in any city where Uber operates, although employers have the ability to restrict their accounts based on date, time, and location of trips. Employers can also schedule Uber rides up to 30 days in advance for detailed trip planning.

Lyft's counterpart, Lyft Mobility Services, allows employers to offer monthly ride credits to their employees, which can be restricted to rides from workplaces, events, or public transit stops as well as rides occurring at specific times. For example, Stripe, a payment processing company in San Francisco, offers employees free Lyft rides from their office after 8 pm. Lyft Mobility Services also enables employers to book rides in advance, although only within a 24 hour window. While the overall number of employer participants is unknown, several prominent technology companies use Lyft Mobility Services, including Postmates, Stripe, Thumbtack, and Yelp.

TNC Partnerships with Commuter Benefits Providers

TNC services have partnered with benefits administrators to utilize pre-tax commuter benefits typically targeted at vanpoolers and mass transit riders. Uber has partnered with WageWorks, an administrator of commuter benefits for employees, to allow commuters to use pre-tax dollars to pay for UberPOOL. The Uber service launched in Los Angeles in 2016 (Uber, 2017) and a similar Lyft service launched in 2017 (Hinchliffe, 2017).

TNC Partnerships with Transit Agencies

Many transit agencies in the United States have incorporated TNCs into their plans, policies, and marketing strategies. Nationwide, public transit ridership has increased as transportation network companies have expanded operations (Tsay, Accuardi, & Schaller, 2016). However, this trend may be a result of other factors, and it is unlikely to hold across all locations and time periods. In California, Lyft and Uber have partnered with several transit agencies to offer a variety of service enhancements and modifications, which are summarized in Table 6.

Two California transit agencies have agreed to integration partnerships with TNCs. Los Angeles Metro formed a short-lived partnership with Uber for the May 2016 opening of the Expo Line extension in Santa Monica by jointly marketing the new service. Additionally, Uber offered a $5 discount for all UberPool rides to and from the Expo Line extension between Friday, May 20 and Sunday, May 22 (Nelson, 2016) (Hymon, 2016). In their announcement of the arrangement, Uber explicitly mentioned that it could be a solution to the first-and-last mile problem of transit station access (Uber, 2016a).

In February 2017, the Transportation Authority of Marin announced a partnership with Lyft to coincide with the opening of the Sonoma Marin Area Rail Transit line connected Sonoma and Marin counties. For the first six months of SMART service, riders received $5 off all Lyft Line rides above $2 in which a SMART station is an origin or destination (Prado, 2017).

A number of local agencies outside of California have partnered with Uber and Lyft to incentivize transit-linked trips. In March 2016, Altamonte Springs, Florida launched a one-year pilot program with Uber in which rides to and from the city's commuter rail station would receive a 25 percent discount. In August 2016 which provided free trips to and from the city's Dry Creek light rail station (Aguilar, 2016).

Table 6: TNC-Transit Integration Partnerships in United States as of April 2017

Agency	TNC	Date	Program
Pinellas Suncoast Transit Authority	Uber, Lyft	February 2016 - present	Up to $5 off rides to and from bus stops in Pinellas County between 6am and 11pm[10]
City of Altamonte Springs, Florida	Uber	March 2016 - March 2017	25% discount on all rides to and from Altamonte Springs Sunrail commuter rail station[11]
Los Angeles Metro	Uber	May 2016	Up to $5 of UberPool rides to and from Expo Line Phase 2 stations from Friday, May 20 to Sunday, May 22
Southeast Pennsylvania Transit Authority	Uber	May 2016 - September 2016	40% discount (up to $10) on all rides to and from 11 commuter rail stations in four counties[12]
City of Centennial, Colorado; Southeast Public Improvement Metropolitan District	Lyft	August 2016 - February 2017	Free rides to and from Dry Creek light rail station between 5:30am and 7pm, Monday through Friday[13]
City of Summit, New Jersey	Uber	October 2016 - March 2017	Discount on up to 2 rides per day to and from Summit train station between 5am and 9pm. Free for residential parking pass holders, $2 for other residents, restricted to first 100 commuters to sign up[14]

[10] (Irwin, 2017) ("Direct Connent | PSTA," n.d.)
[11] (Comas, 2016)
[12] ("Uber finds a partner with some public transit systems," n.d.) (SEPTA, n.d.)
[13] (Aguilar, 2016)
[14] (Addady, n.d.)

Metrolink	Lyft	November 2016	One-time $50 credit for Lyft rides to and from Union Station[15]
Transportation Authority of Marin	Lyft	Late Spring 2017 - 6 months after opening	$5 discount on Lyft Line rides over $2 to and from SMART rail stations[16]

Zero Emissions Vehicles

In cases where driving for a TNC is a primary source of income or a driver engages in longer sessions (e.g. for 5 consecutive hours on a weekend evening), refueling time will limit a TNC driver's uptime and revenues. The authors limited most research to hydrogen fuel cell electric vehicles (H-FCEV) because their range (above 300 miles) and refuel time (under 10 minutes) is most competitive with internal gasoline internal combustion engine vehicles for TNC applications. The authors also considered some fast-charge capable battery-electric vehicles.

Hydrogen Fuel Cell Electric Vehicles

In California, three H-FCEV models were widely available for purchase by the end of 2016: the Toyota Mirai, Hyundai Tucson, and Honda Clarity (California Air Resources Board, 2016). Table 1 shows the range and refuel time for each of these models. Data from California's Clean Vehicle Rebate Project indicates that rebates have been issued for 1,016 H-FCEVs since 2010 (Center for Sustainable Energy, 2017).

Table 7: H-FCEVs available on market by 2017

Make and model	Year introduced	Range (miles)	Refuel time (minutes)
Honda Clarity	2016	366[17]	3-5[18]
Hyundai Tucson Fuel Cell	2016	265[19]	<10[20]
Toyota Mirai	2016	312[21]	5[22]

The Toyota Mirai, Hyundai Tucson, and Honda Clarity all offer complimentary hydrogen fuel for three years, up to a maximum of $15,000.

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15 (A. Chen, 2016)
16 (Prado, 2017)
17 https://automobiles.honda.com/clarity#how-far
18 https://automobiles.honda.com/clarity#how-long-does-it-take
19 https://www.hyundaiusa.com/tucsonfuelcell/index.aspx
20 https://www.hyundaiusa.com/tucsonfuelcell/index.aspx
21 https://ssl.toyota.com/mirai/fcv.html
22 https://ssl.toyota.com/mirai/fcv.html

Hydrogen Refueling Infrastructure in Southern California

Charging infrastructure is a key determinant of EV adoption and hydrogen fueling infrastructure appears to be the largest barrier to H-FCEV adoption, particularly in Southern California. Whereas BEV chargers connect to an extensive electricity grid, H-FCEV refueling requires an entirely different distribution network (Ball and Weeda, 2015). In recent years, progress has been made in hydrogen refueling technology and policy, with new codes and standards accompanying technical developments in hydrogen compression, dispensing, and storage. Yet challenges in siting, permitting, building, and maintaining hydrogen fuel stations have caused infrastructure deployment to lag behind vehicle commercialization (Lipman & Witt, 2014). Automakers, energy suppliers, and regulators have pursued a "cluster strategy" for developing H-FCEV infrastructure, in which vehicles and stations are introduced in a handful of small cities within a region to provide convenient refueling for early adopters (Ogden & Nicholas, 2011).

The California Fuel Cell Partnership (2009) identified Santa Monica, Irvine, Torrance, and Newport Beach as the primary H-FCEV clusters in Southern California. As Figure 17 shows, refueling stations have been sited in Santa Monica and in the vicinity of Torrance, but infrastructure is not concentrated in these localities. LA County is projected to have the largest need for additional stations by 2022 without additional public investment (California Air Resources Board, 2016). For this reason, California has invested $46.6 million in additional funds for fueling stations since 2014, with each station receiving a $2.125 million public subsidy (California Energy Commission, 2014).

Figure 17: Hydrogen fueling stations, Metro stations, and public transit ridership in LA County in 2017

Hydrogen Fueling Stations and Metro Rail and Busways

Map created by Riley O'Brien. Source: Alternative Fuels Data Center (2017), Metro (2017), and ACS 2014 5-Year Estimates

Although the network of hydrogen vehicles and infrastructure continues to grow, further public subsidies are needed to meet statewide H-FCEV goals. Large-scale deployment of hydrogen vehicles would yield substantial reductions in greenhouse gas and localized air pollutant emissions, yet this is impossible without extensive government support (Jacobson, Colella, & Golden, 2005). California's 2016 ZEV Action Plan outlines various goals for hydrogen vehicle and infrastructure deployment, including an expansion of the refueling network to 100 stations by 2023 (Governor's Interagency Working Group on Zero-Emission Vehicles, 2016). Although only 331 FCEVs are registered in California as of 2016, this amount is expected to increase to 13,500 by 2019 and 43,600 by 2022 (California Air Resources Board, 2016).

Long Range, Fast-Charge Capable Battery-Electric Vehicles

Level 3 direct current (DC) fast charging is the most immediate recharging option for BEVs. However, even with a level 3 fast charger, a vehicle with over 150 miles of range will take one hour or longer to recharge. Table 8 below lists currently-available battery-electric vehicles with at least 150 miles of range. Four of the five vehicles below use proprietary chargers. Only the Chevrolet Bolt uses the Society of Automotive Engineers standard for fast charging.

Table 8: Long Range, Fast-Charge Capable Battery-Electric Vehicles

Vehicle	Seats	Maximum Electric Range	MSRP	Fast Charge Connector
Chevrolet Bolt	5	238 miles	$37,500	SAE Combo
Nissan Leaf	5	151 miles	$29,900	CHAdeMo
Tesla Model 3	5	220 miles	$35,000	Supercharger
Tesla Model S	5	315 miles	$71,000	Supercharger
Tesla Model X	7	237 miles	$85,000	Supercharger

Data source: Plugincars.com

ZEV-TNC Cost Model

A TNC cost model was developed but ultimately not used in the analysis. We developed the cost model to identify per-trip or per-mile subsidies which could be used to influence vehicle acquisition and use decision by TNC drivers. Due to limitation in available input data and research studies on costs and revenues for TNC drivers, the cost model was of limited use for this purpose.

The cost model was useful, however, in determining whether trip-based or vehicle-based subsidies would be more effective in increasing ZEV-TNC miles. Few drivers acquire a vehicle for the express intent of entering it into TNC service, and therefore decisions about vehicle acquisition are separate from decisions to provide TNC service. Trip-based incentives, a public subsidy for operating a ZEV provided as a premium over TNC revenues are uncertain and would have limited impact on the vehicle purchase decision.

Transit

A 30-day adult pass on Los Angeles Metro is $100 (Los Angeles Metropolitan Transportation Authority, 2018). Metro offers group rates to employers which purchase and manage large volumes of TAP farecards. As an example, UCLA’s Go Metro program offers discounted quarterly passes at $150 for staff and faculty and $65 for students (UCLA Transportation, 2018).

Regulatory Assessment

The authors assessed the scope and effects of various local, regional, state, and federal regulations intended to affect employee commutes, incent zero emissions vehicles, and increase transit ridership.

Southern California Air Quality Management District Programs

As part of its Air Quality Management Plan, the South Coast Air Quality Management District has enacted an ongoing implementation measure intended to reduce vehicle commutes to employers.

Rule 2202 On-Road Motor Vehicle Mitigation Options

As part of South Coast Air Quality Management District's (SCAQMD) effort to help reduce emissions from mobile sources, it adopted Rule 2202 also known as "On-Road Motor Vehicle Mitigation Options" in December 1995. The rule offers employers various emission reduction and trip reduction options to choose from in order to meet the emission reduction target (ERT) for their workplace. The rule applies to employers with 250 or more employees and each worksite must have a dedicated Employee Transportation Coordinator (ETC) whose job is to implement and track program implementation.

Table 9: On-Road Motor Vehicle Mitigation Compliance Options

Emission Reduction Strategies	Trip Reduction Strategies
Mobile Source Emission Reduction Credits (MSERCs)	Peak Commute Trip Reductions
Air Quality Investment Program (AQIP)	Other Work-Related Trip Reductions
Short Term Emission Reduction Credits (STERCs) from Stationary Sources	Off-Peak Commute Trip Reductions
Emission Reduction Credits (ERCs) from Stationary Sources	Vehicle Miles Traveled (VMT) Program
Area Source Credits	

Source: (South Coast Air Quality Management District, 2016)

Employers must detail how their worksite plans to meet their emissions reduction target through an annual submittal of an emission reduction program. The AQIP compliance alternative is available to employers that are out of compliance or would rather pay for air quality improvements elsewhere than implement a commute reduction program. The annual fee for the AQIP program is $131.31 per worksite plus $46.73 per employee reporting to work during the peak window. This amounts to $11,810.61 for a worksite with 250 employees.

A Rule 2202 compliance option is to implement an Employee Commute Reduction Program that details the measures an employer will implement in order to achieve their location's target average vehicle ridership (AVR) ratio. AVR is calculated based on the number of vehicles arriving at a worksite during the AM peak period divided by the number of employees at the worksite. Arrivals in zero emissions vehicles and public transit are not counted as vehicle commutes in the numerator. To qualify as non-vehicle commutes vanpools and carpools segments of trips must be at least 51 percent of the total trip distance.

Most approaches require AVR calculations via an annual survey of employees. The survey does not include questions on rail transit or transportation network companies as a commute mode.

Annual filing fees for review of an Employee Commute Reduction Program are up to $1,083.84 per employer. Employers which achieve or make progress towards their AVR targets are eligible for reduced filing fees. For employers which do not achieve the AVR target for their zone, The SCAQMD must find that the employer is making a good faith effort to achieve the AVR targets, or the employer is subject to alternate compliance options including the AQIP fee.

Mobile Source Air Pollution Reductions Review Committee

The Mobile Source Air Pollution Reduction Review Committee has authority over a discretionary fund which allocates approximately $14 million per year to programs which reduce air pollution from vehicles. Recent funding has major event transit service and alternative fueling stations. The discretionary nature of the fund makes it a plausible source for innovative pilot projects.

City of Santa Monica

Rule 2202 Implementation

Under a Memorandum of Understanding (MOU) with SCAQMD, local governments can implement Rule 2202 and monitor compliance with employers under their jurisdiction. The City of Santa Monica is the only local government in Los Angeles County which has a local enforcement MOU, which was approved in 1994.

The City monitors over 900 businesses with 10 or more employees. Under the memorandum, the city's regulations must be at least as strict as the SCAQMD's, and Santa Monica's

10-employee threshold and minimum AVR of 1.75 both exceed the SCAQMD's thresholds. The SCAQMD reviews Santa Monica's enforcement every 5 years.

As part of Rule 2202 implementation, Santa Monica has adopted a local Transportation Demand Management Ordinance (Santa Monica Municipal Code 9.53). Employers work with the City to set up worksite transportation plans, or, for employers with more than 29 employees, and emissions reduction plan. As part of the emission reduction plan, employers must designate an employee transportation coordinator, survey their employee annually about how they commute, and identify and implement strategies to increase biking, walking, riding transit, and carpooling. Any direct incentives for alternative employee commutes bust be at least $10/month.

Fees to review plans are $15.38 per employee for businesses with more than 29 employees and $18.65 per employee for businesses with 10-29 employees. This amounts to $3,845 for a business with 250 employees, which exceeds the AQMD plan review fee of $1,083.84 per employer. Santa Monica discounts the fee by 40 percent for businesses which achieve their AVR targets for 1 year, 50 percent for 2 consecutive years, and 60 percent for 3 consecutive years.

Transportation Demand Management for New Developments

Because Rule 2202 only applies to employee commute trips. Trips directly between home and work make up only about 14 percent of all trips and 18 percent of person miles traveled in the Los Angeles metropolitan area (Federal Highway Administration, n.d.).

To address other trips, the City of Santa Monica has enacted a Transportation Demand Management to regulate trips from new developments in the city (Transportation Demand Management Ordinance, n.d.). This regulation does not fall under the authority of Rule 2202 and therefore has more flexibility. For instance, while Rule 2202 is focused on vehicle emissions and excludes Zero Emissions Vehicles from calculations, Santa Monica's ordinance includes these vehicles because they impact parking and roadway demand.

Santa Monica's target for new developments ranges from 1.75 average vehicle ridership in outlying areas further from transit to 2.2 near transit and in the downtown core. The SCAQMD's average vehicle ridership requirements outside of Santa Monica range from 1.3 countywide to 1.75 in downtown Los Angeles. Developers must submit a Transportation Demand Management plan which includes strategies for trip reduction to the city prior to project approval. Existing strategies include free transit passes, parking cashout, and vanpool subsidies.

Santa Monica requires that modes that are excluded from the AVR numerator be used for at least half of the total trip distance (SMMC 9.53). Thus, for a linked TNC-transit commute trip, the transit trip must be at least as long as the TNC trip to be excluded from AVR calculations. This is similar to Rule 2202.

California ZEV Purchase Incentives

The State Clean Vehicle Rebate Pilot (CVRP) program has proposed funding up to $5,000 per vehicle and for low-income eligible residents, with additional funding of up to $1,500 (total of $6,500 per vehicle) ("Clean Vehicle Rebate Project," n.d.). CARB allocated $160 million the CVRP program for the 2015-16 Fiscal Year, an amount that SCAQMD (2016) expected would fund a minimum of 15,000 zero-emission or partial-zero emission vehicle rebates per year.

Clean Vehicle Rebate Program

California's Clean Vehicle Rebate Program provides $5,000 for hydrogen fuel cell electric vehicles, $2,500 for battery-electric vehicles, and $1,500 for plug-in hybrid electric vehicles ("CVRP Eligible Vehicles," n.d.). For individual rebates household incomes are capped at $150,000 for single filers, $204,000 for head-of-household filers, and $300,000 for joint filers ("Income Eligibility," 2016). A $2,000 rebate bonus is available for households with incomes less than 300 percent of the federal poverty level.

For rental car and carshare fleets, rebates are capped at 20 rebates per calendar year per business (Clean Vehicle Rebate Project, 2015). Public fleets can obtain 30 rebates per calendar year.

Individual and business rebates require a 30-month ownership period. Rental and car share fleets can select a reduced rebate amount and shorter required ownership period.

Enhanced Fleet Modernization Program

California's Enhanced Fleet Modernization Program (EFMP) & Plus-Up Pilot Project offers incentives incentives for consumers who replace their retired vehicle with a cleaner new or used vehicle. Low-income (≤225% of federal poverty line) consumers receive up to $6,500 by purchasing a traditional hybrid and $9,500 by purchasing a PHEV or BEV. Consumers must also live in a disadvantaged community, as identified by CalEnviroScreen, to obtain these incentives (California Air Resources Board, n.d.).

Replace Your Ride is the South Coast Air Quality Management District's branded EFMP program. Participants must reside within the boundaries. Trade-in vehicles must be operational and state exceed emissions levels for model year 2000 or newer. Additionally, SCAQMD provides an option for those who do not replace their vehicle to obtain a benefit which can be used for carshare, vanpool, or transit.

Table 10: SCAQMD Replace Your Ride Income-based Incentives

Income Level	FPL %	BEV Incentive	Plug-In Hybrid Incentive	Incentive for public transit or rideshare pass
Low Income	≥225%	$5,000 + $2,000 for equipment	$5,000	$4,500
Moderate Income	225-300%	$4,000 + $2,000 for equipment	$4,000	$3,500
Above Moderate Income	300-400%	$3,000 + $2,000 for equipment	$3,000	$2,500

Source: (“RYR,” n.d.)

Internal Revenue Service Commuter Benefit Regulations

The Internal Revenue Service (IRS) allows employers to offer up to $260 in commute benefits as a non-taxable fringe benefit provided that the commute benefits comply with federal tax regulations (Internal Revenue Service, 2017). The IRS has approved to two compliance approaches for commuting benefits: via employer or employee-operated vanpools and employer shuttle buses as well as the provision of public and private transit passes. Both the vanpool/shuttle bus and transit pass option require that employees travel in vehicles that seat at least 6 adults, not including the driver. The vanpool/shuttle bus option also requires that at least 80 percent of the miles are used for transporting employees at least one-half of the vehicle’s seats.

IRS regulations allow the tax-free benefit be combined among the two commuting approaches so long as the total value does not exceed $260. Any value over $260/month is subject to taxation as a fringe benefit. Use of this tax-free commuter benefit requires advanced elections and pre-purchase of transit passes or other services.

In 2016, Uber and Lyft began offering commute services that comply with the IRS regulations, only offering passenger-matched trips in six-passenger vehicles (Moran, 2016). For Lyft, this is a Lyft Plus operating in LyftLine mode. For Uber, this is an uberXL operating in uberPOOL mode. These benefits qualify under the transit pass commuting approach.

Several IRS advice letters provide guidance on in which innovative mobility service use may be eligible for the commuter tax benefit. Letter 2016-0011 (Internal Revenue Service Office of the Chief Counsel, 2016) clarifies many aspects of the program:

> “A transit pass is any pass, token, farecard, voucher or similar item entitling a person to transportation (or transportation at a reduced price) if such transportation is on mass

> transit facilities or is provided by any person in the business of transporting persons for compensation or hire in a commuter highway vehicle [section 132(f)(5)(A)]."
>
> "A qualified transportation fringe includes cash reimbursement for transit passes, provided the reimbursement is made under a bona fide reimbursement arrangement. However, cash reimbursement for transit passes under a bona fide reimbursement plan is only allowed if no voucher or similar item which may be exchanged only for a transit pass is readily available for direct distribution by the employer to employees [sections 132(f)(3) and 1.132-9(b) Q/A 16(a),Q/A-16(b)]."
>
> "A transit system voucher is an instrument, which may be purchased by employers from a voucher provider, accepted by one or more mass transit operators (for example, train, subway, and bus) in an area either as fare media or in exchange for fare media [section 1.132-9(b) Q/A-16(b)(2)]. "
>
> "A voucher provider is any person in the trade or business of selling transit system vouchers to employers or any transit system or transit operator that sells vouchers to employers for the purpose of direct distribution to employees [section 1.132-9(b) Q/A-16(b)(3)]. The requirement that a voucher be distributed in-kind by the employer is satisfied if the voucher is distributed by another person on behalf of the employer [section 1.132-9(b) Q/A-16(b)(1)]."

This section would seem to permit a third-party commuter benefits administrator to bundle an unlimited monthly transit pass with a TNC subscription product or declining balance purse, provided that the service is restricted to 6+ passenger shared TNC products.

Furthermore, 2016-0011 would seem to allow for flexible payment options that would allow for other mobility services.

> "A voucher or similar item is readily available for direct distribution by an employer to employees if and only if the employer can get it from a voucher provider that does not impose fare media charges greater than 1 percent of the average annual value of the voucher for a transit system, and does not impose other restrictions causing the voucher not to be readily available [section 1.132-9(b) Q/A-16(b)(4)]. "
>
> "Rev. Rul. 2006-57, 2006-47 I.R.B. 911, provided guidance on the use of smartcards, debit cards, or other electronic media to provide employees with transportation fringe benefits. One type of debit card discussed in Rev. Rul. 2006-57 was terminal-restricted debit cards, which are debit cards that are restricted for use only at merchant terminals at points of sale at which only fare media for local transit systems is sold. While terminal-restricted debit cards could qualify as a transit pass in 2006, other types of debit cards did not. Rev. Rul. 2006-57 provided that, as use of terminal-restricted debit cards increased, the IRS intended "to issue guidance clarifying under what situations the

> [terminal-restricted debit] cards are considered to be readily available and thus preclude cash reimbursement for transit benefits." In the interim, Rev. Rul. 2006-57 provided that the IRS would not challenge the ability of employers to provide qualified transportation fringes in the form of cash reimbursement for transit passes when the only available voucher or similar item was a terminal-restricted debit card."

This section would seem to permit the use of terminal-restricted debit cards only good for several merchants merchants (e.g. Uber/Lyft), but those merchants would need to implement controls that allow the payment method to only be used for IRS-qualified products. Such an arrangement could be used to provide the employee with the option of choosing either IRS-qualified commuter products from Uber or Lyft on a per-trip basis.

IRS-Qualified Zero Emission Vehicles

As of model year 2018, only three vehicles sold in the United States have a capacity of at least six adult passengers and are able to partially operate in zero-emissions mode. Only one of these vehicles exclusively operates in zero emissions mode.

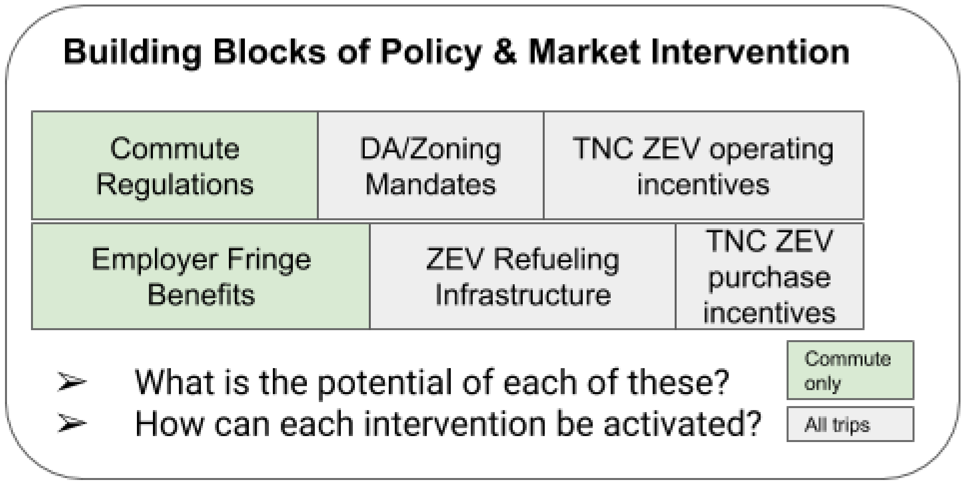
Table 11: Qualifying Vehicles

Make/Model/ (Year)	Technolog y	ZEV Range	Total Range	Starter MSRP
Volvo XC90 T8 PHEV (2018)	PHEV	19		$68,795
Tesla Model X (all)	EV	237	237	$93,000+
Chrysler Pacifica Plug-in Hybrid (2018)	PHEV	33	566	$41,995

The Chrysler Pacifica Plug-in Hybrid is the only one of these vehicles with a third row of seats which can be accessed while the second row is occupied. In March 2018, Chrysler announced it would supply Alphabet[23] automated vehicle subsidiary Waymo with thousands of plug-in hybrid Chrysler Pacificas (Korosec, n.d.) to operate as driverless taxis in the Phoenix area. The 2018 Chrysler Pacifica PHEV is not level 3 fast-charge compatible.

[23] Google's parent company

Discussion



The authors sought to identify the potential of various interventions to affect ZEV TNC-transit commutes. This section discusses challenges and opportunities for doing so. The following section presents recommendations to specific parties to induce ZEV TNC-transit trips in Los Angeles.

ZEV TNC Trips: Unicorns of the Road?

The introduction of ZEV TNC trips and eventual adoption of ZEV TNC trips to transit are hindered by two key problems.

The first problem is a causality dilemma of supply and demand: Do public or private entities create demand incentives for ZEV TNC trips before there are enough in service to have an acceptable probability that requests for ZEV TNC trips would be fulfilled by ZEVs? Do TNC drivers choose to supply ZEV TNC trips without a guarantee or with uncertainty of increased revenues provided by demand incentives?

Second, a compound matching problem exists when additional vehicle requirements are specified for a trip. For each new specified attribute (e.g. only a large vehicle, a ZEV, a blue car, a Honda) the probability of a passenger-driver match within a given wait time decreases exponentially. Making a ZEV-TNC trip with an IRS-qualified vehicle to make an employer-provided trip tax deductible to the employee introduces a compound matching problem.

The complexity of achieving a compound match for a 6+ passenger ZEV TNC trip can be illustrated in a simplified example. Assuming 20 percent of all TNC vehicles are 6+ passenger vehicles and 5 percent of all TNC vehicles are ZEVs, then only 1 percent of vehicles would

IRS-qualified 6+ passenger ZEVs[24]. For every 100 randomly distributed vehicles, only 1 will be an IRS-qualified 6+ passenger ZEV. In this case, only in 1 percent of trip requests will the nearest randomly-distributed vehicle be a 6+ passenger ZEV. The other 99 percent of trip requests would require additional wait time for a vehicle that meets all requirements. As the specified vehicle is further away, required wait times would increase to the point of impracticality.

Pre-scheduling trips could mitigate wait times or matches with another passenger request by pre-deploying vehicles to areas of anticipated, though pre-deployment may require non-revenue deadheading.

TNC-Transit Trips

Concentrating supply and demand incentives geographically can aggregate limited supply and demand to help overcome the causality dilemma and compound matching problem by deploying qualified vehicles in limited coverage areas. Incentives could be targeted around a transit station area or one or more angle groupings around a station.

An initial focus on certain station areas with fewer but higher incentives can build trip supply and demand in order to improve probability of passenger-matched trips. Additionally, aggregating origins and destinations to a single transit station can further increase the probability of a passenger-matched trip as multiple passengers will share an origin or destination. Passenger-matched trips have lower per-passenger costs and GHG emissions than dedicated trips. However, if using a ZEV is a requirement for a potential passenger-matched trip, this could lead to situations where an ICEV TNC with a passenger and common origin or destination could match but the match is refused because of the ZEV-only requirement. Matching to an existing ICEV trip where multiple passengers are going to a transit station could be environmentally-preferable versus inducing an additional ZEV trip[25].

Pre-scheduling trips within a limited geographic area could also lead to higher probability of a match and more efficient routing, where passenger’s pickup times are adjusted slightly in order to reduce total VMT.

One potential challenge to using employer fringe benefits to induce TNC-transit and ZEV TNC transit commutes is that these trips may be seen as inferior to point-to-point TNC commute trips. Los Angeles’s dispersed, polycentric could actually be an advantage in favor of transit-linked

[24]For purposes of this simplification, ZEVs are assumed to be uniformly distributed across vehicle passenger capacities. Currently deployed ZEVs are less likely than ICEVs to be 6 passengers because of there are few 6+ ZEVs on the market. Though the analysis was beyond the scope of this study, ZEVs may be less likely than PHEVs and ICEVs to be entered into TNC service because of range and refueling limitations and discrepancies in the income level of ZEV owners and TNC drivers.
[25] Even in cases where the ZEV trip is 100 percent powered by renewable energy, upstream and downstream impacts are likely be of greater magnitude than additional ICEV fuel consumption due to additional passenger weight.

trips. Origin-to-destination shared-ride TNC trips in dispersed, polycentric Los Angeles would have longer travel distances and a lower probability of a match, both of which would increase costs. Origin to transit station shared-ride TNC trips would reduce total trip length while providing a common destination, increasing match probability and reducing expenses. This study found insufficient data on TNC prices to model break-even distance for which a monthly fees associated with point-to-point commutes would exceed the IRS threshold of $260/month or $6.20 per one-way trip for a 21-day working month.

Employer Commute Programs

For purposes of this section, the authors assume that an employer may be willing to subsidize employer commutes for two reasons:

1. to avoid regulatory fees that they would incur in absence of a subsidy. In these cases, the employer is willing to pay a ceiling
2. as a fringe benefit to improve employee productivity, morale, and retention.

An employer's willingness to pay to avoid regulatory fees is small in comparison to providing fringe benefits.

Employer Subsidized Commutes as a Regulatory Fee Avoidance Scheme

Employers subject to Rule 2202 can avoid conducting employee commute surveys if they elect an alternative compliance option — purchasing the Air Quality Improvement Program's tradable credits to invest in off-site emissions reductions. This program provides an upper limit to an employer's maximum willingness to pay to avoid even higher regulatory fees.

The annual cost of the AQIP program is $131.31 per worksite plus $46.73 per employee reporting to work during the A.M. peak period. This amounts to $11,813.31 for a worksite with 250 employees. Instead of the AQIP, a company could elect the Employee Commute Reduction Program option, which has a fee of $810.50 for a worksite with 250 to 499 employees.

The company would incur some additional compliance costs to survey employees and implement a plan to achieve average vehicle ridership targets. A company which switched from AQIP to ECRP could achieve savings of $11,002 per year minus any added administrative costs. The hypothetical company in the Table 12 example would be willing to pay $343.83 per year or $28.65 per month for each of 32 employees to no longer drive to work.

Table 12: Hypothetical company with 250 employees at a work site and 1.43 AVR

	Actual	Target
AVR	1.43	1.75
Employees driving to work	175	143

Change		-32

Employer-Subsidized Commutes as a Fringe Benefit

Employers may also see employee commutes as a fringe benefit to improve employee productivity, morale, and retention. In this case, there will be some correlation between wage levels and employer willingness to pay, if only because of the employer's value of an extra 30 minutes of productivity per day is higher for high-wage, salaried workers. If employers desire for that expense not to be taxable for the employee or employer, they would impose the IRS maximum of $260 on the benefit.

Table 13: Summary of Employer Value for Potential Subsidy Sources

Option	Per-Employee Monthly Value	Costs borne by
IRS Non-taxable commuter transportation fringe benefit	$260 (maximum)	Employer
Hypothetical AQIP to ECRP with AVR targets	$28.65 (willingness to pay)	Employer
City of Santa Monica - 60% review fee discount for 3 consecutive years of AVR targets	$0.77 (willingness to pay)	Employer

ZEV Acquisition Incentives

California's Clean Vehicle Rebate Project is the primary program by which consumers can receive a subsidy for an EV purchase or lease. The program is not targeted at TNCs and has limited ability to influence a prospective TNC driver's vehicle acquisition decision. An economically-rational prospective TNC driver without a vehicle who seeks to acquire a vehicle primarily to supply TNC service would be less likely to purchase or enter into a 30+ month lease for a new vehicle[26] when they would earn the same revenues with any TNC-qualified vehicle (e.g. a used 2005 Prius valued at $6,000). Furthermore, the prospective range and refueling limitations of a ZEV would handicap a ZEV versus an ICEV for a driver who does not yet know their driving patterns or does not have a strong preference for a BEV.

The program may be more likely to influence a current TNC driver's vehicle upgrade decision. For the subset of drivers who know their typical driving patterns, they may know if a ZEV vehicle would meet their needs. A driver with a preference for a ZEV may elect to purchase or lease a ZEV.

[26] Minimum lease term for CVRP

Monthly and weekly vehicle lease programs provide an additional option for TNC vehicle acquisition. Lease programs are likely to be selected by those who must acquire a TNC-qualified vehicle to enter into TNC service and have uncertainty about the length of time they will supply TNC service.

Additionally, ZEV TNC leases are likely to be most attractive to those who will supply TNC service near ZEV refueling facilities and have a driving profile that matches ZEV range and refueling limitations.

It is likely that those acquiring vehicles via weekly or monthly lease for use in TNC service will be high-utilization drivers and therefore highly sensitive to range limitations and refueling times. This would make HFCEVs a more attractive option.

ZEV TNC Operation Incentives

ZEV operation incentives can be strictly targeted to TNC applications. These incentives could be used to induce existing ZEV owners into TNC service on a limited term. Any revenue premium for supplying ZEV TNC service may also provide an influential incentive for prospective TNC drivers who are acquiring a vehicle or TNC drivers who are upgrading a vehicle.

Two operating incentive design options would encourage different trips and vehicles:

- A per-trip incentive would encourage shorter trips, which would be more likely to be in core urban areas where trip distances are shorter, including to and from transit stations. Thus, a per-trip incentive would perhaps encourage more low-mileage range BEVs into TNC service in urban areas.
- A per-mile incentive would encourage longer trips and longer-range vehicles, either HFCEVs or more expensive high-mileage range BEVs.

ZEV TNC operation incentives would work well in cases where a blanket incentive or subsidy is offered to all TNC service a single driver or group of drivers supplies with ZEVs. In cases where a targeted incentive is offered only for certain types of trips made by certain individuals to or from certain places, this introduces new complexity which exponentially reduces the probability of a trip and vehicle match.

ZEV TNC Tradable Credits

ZEV TNC tradable credits are an option for cases where a targeted incentive is desired only for certain types of trips made by certain individuals to or from certain places. A transit agency which only wanted to subsidize ZEV TNC trips to or from their stations or an employer which only wanted to subsidize ZEV TNC trips to or from the worksite would have difficulty exclusively securing ZEVs for these trips because of compound matching and causality dilemma described earlier. Tradable credits would allow the party which sought to subsidize a ZEV TNC trip to transfer the ZEV attributes from an unrelated, untargeted ZEV TNC trip to a targeted TNC trip made with an ICEV as a fallback in order to provide a match or reduce wait times.

A system of tradable credits could be administered internally by a TNC platform, or externally by a third party or government regulator. An internally-administered program would require transparency from TNCs and possibly third-party verification. An externally-administered program would require additional reporting and verification.

ZEV TNC tradeable credits could be generated and verified to standards similar to or exceeding ZEV manufacturer credits, electricity-sector renewable energy certificates (RECs), or biofuel renewable identification numbers (RINs). Each of these programs is a market-based approach to achieving a supply target that policymakers seek the associated environmental benefits.

ZEV TNC tradeable credits could be denominated on a passenger-mile, vehicle-mile, or passenger-trip basis. A passenger-mile basis would allow for a one-to-one match between the passenger trip that a party intended to subsidize on a ZEV TNC but was instead fulfilled with an ICE and generate extra credits for shared ride ZEV TNC trips that matched multiple passengers. A per-vehicle mile basis would provide ZEV TNC operators with certainty about credits to be generated regardless of match. A per passenger-trip basis would create greater incentives for shorter, matched trips but would not provide an equivalent match for the intended ZEV TNC passenger trip.

Parties which wish to incent ZEV TNC trips could specify a priority for trips to be made first with BEVs or HFCEVs, then PHEVs operating as ZEVs, and then to automatically apply ZEV TNC credits for trips fulfilled with ICEs. The tradeable credits could also be used in annual compliance applications. For instance, employers with commute regulation obligations may use ZEV TNC credits to offset, *ex post*, single-passenger ICE TNC commute trips in order to exclude the vehicle from AVR calculations and achieve targets.

A ZEV-TNC tradeable credits system could be implemented by setting standard for percentages of ZEV trips or passenger miles to or from airports, which have special regulatory powers under CPUC TNC regulations.

Recommendations

This section contains recommendations to incent the introduction of ZEV-TNCs and induce TNC-Transit trips using ZEV-TNCs.

Because 6+ passenger vehicles are more common in TNC service than ZEV, inducing TNC-Transit trips through IRS commuter fringe benefits is presently a proposition with less substantial barriers than inducing ZEV TNC trips and especially ZEV TNC-Transit trips.

This section presents recommendations to incent:

1) the introduction of ZEV TNC vehicles and the maximization of their miles traveled
2) linked shared-ride TNC trips to and from transit stations
3) a combination of 1) and 2) for a combined ZEV TNC-transit trip

Recommendation for Employers

Employers could provide employees with a $260 monthly package that includes both a $100 Metro 30-day pass and $160 per month for TNC services. To implement such a package, Metro another interested entity would need to work with commuter benefits administrators[27] to create and market the packaged product.

A declining balance or subscription for $160 per month would yield about $7-$8.50 per work day, depending on how many work days occurred in a month. This amounts to $3.50 to $4.25 per trip. Employers or benefits administrators could specify several requirements for TNC providers:

1) That the TNC provider is required apply these funds only toward IRS-qualified vehicles (6+ passengers) and operations (shared ride, passenger matching enabled; e.g. UberPool or LyftLine)
2) That the TNC provider is required to apply these funds only on trips between home and work or home and a transit station
3) That the TNC trips are fulfilled with ZEVs[28]

Recommendations for TNC Companies

Fluctuations in TNC supply and demand mean that subsidized ZEV vehicles may not only serve incentivized trips and that a ZEV may not always be available to serve an incentivized trip. TNCs have layered service model and can guarantee trips even if unmatched (i.e. trip behaves like an UberX trip rather than an UberPool trip).

[27] For example, WageWorks, TransitChek, Ameriflex, Beneversal, eTRAC, GoNavia, Commuter Check, PayFlex, Wex

[28] if a requirement, this may lead to long wait times

Table 14: Business Rules for "Green Commuter" Product ZEV Trips

Category	Rule
Vehicle dispatch priority	1. 6+ passenger ZEV, 2. 6+ passenger PHEV, 3. 6+ passenger ICEV 4. 4 passenger vehicle (not IRS-qualified)[29]
Trip Geofencing	Between station and home
Operational Mode	Shared ride/passenger matching: UberPool, UberPool Express, Lyft Line, Lyft Shuttle
Eligible Trip Times	Employer-designated based on work hours, with some flexibility for exceptions to work hours[30]. For example, 5AM to 10AM on weekdays for trips from home to the station and 3PM to 10PM on weekdays for trips from the station to home.

Two green commuter pricing options would incent different user behavior. A subscription model provides price certainty, but minimal influence over user behavior. A declining balance model would encourage conservation and responsiveness to price signals (surges), but may also require discounts or less sensitivity to surge pricing to fulfill all monthly trips within the allotted balance.

Either a subscription model or declining balance model could allow for point-to-point TNC trips between home and work. Point to point trips may be attractive on occasions where trips are highly time-sensitive, there are transit system disruptions, or trips during hours of lower transit frequencies. Under a subscription model, an employee could receive a monthly allotment of point-to-point trips. Under a declining balance model, an employee could bank value by walking or biking some days and have extra value for point-to-point trips.

TNCs already work directly with employers under the Uber for Business and Lyft Mobility Services product names and could offer a green commuter product to employers our through commuter benefits administrators. Employers may want a feature verify subsidized trip commute behavior for regulatory purposes or enforcement of employer policy.

TNC companies can also directly subsidize ZEV leases, provide targeted bonuses to TNC drivers who complete threshold of weekly trips using a ZEV, and invest in ZEV refueling infrastructure.

[29] In the event that a 6+ passenger vehicle is unavailable to fulfill the trip, some other source of funds could pay for the trip or the trip could be free to guarantee a ride within a reasonable wait time and maintain compliance IRS rules. The source of funds could be a bonus the TNC company grants commuter users for a monthly subscriptions or frequent use, like a rewards program

[30] An IRS-qualified transportation commute benefit should only be used for trips to and from work.

Using Technology to Assist the Introduction of ZEV TNCs

TNC companies that wish to incent ZEVs can offer drivers a tool which analyzes their past driving patterns to assess 1) whether a ZEV's range and refueling profile may be appropriate and 2) whether the driver's trips often pass near hydrogen an level 3 electric fast charge facilities.

TNC companies could also create a feature to ascertain when PHEVs are operating in EV mode. This could be done by which accessing vehicle operations data from the OBD-II port or other means. Such a feature could qualify certain trips or passenger miles as ZEV service for PHEVs which have limited ZEV range augmented by a gasoline engine.

Recommendations for Public Agencies

Los Angeles County Metro

Los Angeles Metro is launching a partnership with private transportation company Via to provide on-demand first and last mile connections to three MetroRail stations (Huang, 2017). The 12-month pilot does not plan to use ZEVs. Metro should consider areas of increased demand identified in the Planning Analysis.

Table 15: Top Stations for Transit-TNC Commutes

Station	Possible Trips	Station	Possible Trips
North Hollywood Station	5,683	Willowbrook - Rosa Parks Station	2,903
Silver - Cal State LA	4,830	Redondo Beach Station	2,866
Wilshire / Western Station	4,249	Vermont / Sunset Station	2,689
Highland Park Station	4,242	Florence Station	2,678
Silver - El Monte	4,152	Southwest Museum Station	2,620
Green/Silver - Harbor Freeway Station	4,107	Del Amo Station	2,553
Silver - Figueroa & 7th	4,060	Grand / LATTC Station	2,420
Lakewood Blvd Station	4,015	Compton Station	2,361
South Pasadena Station	3,615	Vermont / Athens Station	2,328

Silver - Slauson	3,600		Norwalk Station	2,298
Long Beach Blvd Station	3,539		Wilshire / Vermont Station	2,288
Hollywood / Highland Station	3,467		Union Station	2,276
Metro Center	3,411		Palms Station	2,264
Silver - Flower & 7th	3,411		Silver - Carson	2,239
Sierra Madre Villa Station	3,241		LATTC / Ortho Institute Station	2,219
Hawthorne / Lennox Station	2,939		Culver City Station	2,176

Station selection should also consider station infrastructure, service pricing and local market conditions in addition to the results of the planning assessment. Metro or Via may also consider targeting mail or door hanger advertising to top angle groups listed in the planning assessment section.

The 12-month pilot will help Metro identify demand and opportunities for curb space management near its station areas to improve drop-off and pick-up experience and safety. These findings would be applicable to any future ZEV TNC-Transit trips. If Metro wanted to attract ZEV TNC-Transit trips in the near-term, it should prioritize the stations in Table 13 and monitor new hydrogen and level 3 electric facilities near Metro stations.

Table 16: Top Stations Based on Current and Planned Significant Fast-Charge and Hydrogen Infrastructure

Station	ZEV Refueling Facility and Driving Distance
Silver - Cal State LA	Hydrogen Facility at CSULA (0.3 miles) 4,830
Silver - El Monte	L3 Electric SAE Combo Fast Charger - Shopping Center (0.6 miles)
Lakewood Blvd Station	L3 Electric SAE Combo Fast Charger - Downey Promenade (0.9 miles) 4,015
South Pasadena Station	Hydrogen Station at 1200 Fair Oaks (0.7 miles)
Hollywood / Highland Station	Hydrogen Station 57000 Hollywood Blvd (1.4 miles)
Hawthorne / Lennox Station	Tesla Supercharger Station (12 units) SpaceX - 2.4 miles Hydrogen - 10400 Aviation Blvd (2.1 miles) under construction
Redondo Beach Station	Tesla Supercharger Station (8 units) (0.2 miles)9 Hydrogen Facility at 15606 Inglewood Ave (0.9 miles)
Vermont / Sunset Station	Hydrogen - 5700 Hollywood Blvd (1.5 miles)

Norwalk Station	L3 Electric SAE Combo Fast Charger 10930 Rosecrans (1.2 miles)

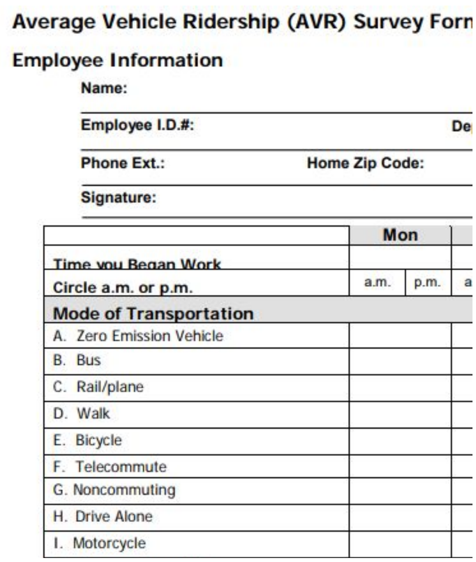
refueling infrastructure as of March 2018

Current near-station charging infrastructure uses two connector types. If Metro wished to develop level 3 charging infrastructure at its stations it should monitor developments in IRS-qualified vehicle options to determine appropriate connectors which would be compatible with these vehicles or encourage users to bring cross-compatibility adaptors.

Metro can also create a green commute certification to recognize employers that offer TNC-transit and other products or achieve certain adoption thresholds.

South Coast Air Quality Management District

The South Coast Air Quality Management District should update templates for annual employer surveys used in Rule 2202 compliance to add new modes, such as commuter rail, Metro rail, and taxis or transportation network companies, motor-driven scooter. Currently rail and plane are aggregated into a single response option on the template and sample surveys from other organizations. As more trips are made using multiple, linked modes, SCAQMD should either clarify that the survey seeks the mode used for 51 percent or more of the total trip distance or make accommodations for employees to list multiple modes for a single commute (e.g. bikeshare to transit).



Average Vehicle Ridership (AVR) Survey Forn

Employee Information

Name:

Employee I.D.#: **De**

Phone Ext.: **Home Zip Code:**

Signature:

	Mon	
Time you Began Work Circle a.m. or p.m.	a.m. p.m.	a
Mode of Transportation		
A. Zero Emission Vehicle		
B. Bus		
C. Rail/plane		
D. Walk		
E. Bicycle		
F. Telecommute		
G. Noncommuting		
H. Drive Alone		
I. Motorcycle		

The SCAQMD should also clarify that commute trips made via Transportation Network Companies count as single-occupant vehicle trips. Such trips displace parking, not vehicle trips, which is the focus of Rule 2202. While shared trips where passengers are successfully matched may be best expressed as a >1 passenger trip, a lack of available data makes such calculations difficult.

To the extent possible, SCAQMD make anonymized response data available to city and regional planners and policy makers charged with developing and implementing transportation demand management strategies. Employee surveys used in Average Vehicle Ridership calculations are among the richest public datasets available for commutes and could be used to identify new shared mobility opportunities.

An SCAQMD-sponsored reporting app that collects rich data on commutes could integrate with mobility service providers for data sharing and verification (e.g. for the average number of passengers in a vehicle for a shared TNC commute trip). An integrated app could also verify that a single-passenger TNC commute trip was made in a zero-emissions vehicle, or the TNC acquired sufficient tradeable credits to cover the trip. The app could also produce data that is anonymized and shared with others.

The SCAQMD should also consider transit station locations when making grants for electric vehicle service equipment and hydrogen fueling station projects.

The region continues to face compliance challenges for NOx and ozone levels. While recent AQMPs sought reductions from stationary sources and heavy-duty trucks, the SCAQMD may in the future elect to strengthen employee commute reduction programs.

Increases in the cost of alternative compliance options could drive more employers to subsidize their employees' alternative commutes. The annual cost of the AQIP program is $131.31 per worksite plus $46.73 per employee reporting to work during the peak window.

California Air Resources Board

The California Air Resources Board funds the Clean Vehicle Rebate Project. With some changes, the program requirements could be used to incent ZEV-TNC trips by targeting the subset of drivers for whom the vehicle acquisition decision is coupled with the decision to enter into TNC service.

An option to target subsidies for vehicles have a high-utilization by TNC drivers is to have special rules for vehicles used for weekly lease in TNC applications. The price premium of weekly TNC lease programs should guarantee those vehicles are well-utilized in TNC applications, as drivers will retire the vehicles once they no longer are earning sufficient TNC revenues to cover lease payments.

Rental fleets are limited to 20 rebates per calendar year per business. The ARB could increase this cap for vehicles offered for weekly lease in TNC applications. Additionally, the rebate could be increased or augmented with a state tax credit for vehicles which log at least 15,000 miles per year in revenue TNC service. In exchange for these changes, the ARB could require ongoing data from ZEV TNCs for policy and enforcement of minimum mileage standards.

The ARB could also consider changes to the ZEV mandate that grants ZEV credits proportional to vehicle utilization during an initial operating period (e.g. 30 months). Credits accrue to manufacturers and are tradeable. Credit revenues can lead ZEV manufactures discount vehicle costs. Making credits proportional to vehicle utilization would bring higher incentives to manufacturers which sell vehicles for TNC service, lowering the purchase price for those applications.

The ARB could also consider offering expanded CVRP rebates to individuals who verify some minimum threshold of passenger miles in TNC service in their first year of operation.

California Energy Commission

The Commission should view ZEV TNCs as a key opportunity for vehicles with the operation profile of H-FCEVs. In particular, TNC applications make greater use of their longer range and shorter time to refuel versus BEVs. To encourage H-FCEV TNCs connecting to transit, the Commission should consider transit station location when funding hydrogen facilities. The commission should also consider areas where TNCs concentrate for H-FCEV TNCs.

State of California

The State can consider tax treatments to encourage ZEV TNC miles, including excluding from income calculations a portion of TNC revenues derived from ZEV service.

Cities

Cities considering implementing TDM ordinances and establishing their own Rule 2202 local enforcement MOUs should adopt higher AVR targets, and a stricter standard of regulatory review.

California Public Utilities Commission

The State Public Utilities Commission should work with the Air Resources Board to establish ZEV-TNC tradeable credits.

Internal Revenue Service

A Federal legislative change could provide the greatest incentive to ZEV TNC trips by eliminating problems of compound matching problem and a shortage of 6+ passenger ZEVs. Currently, employers can provide up to $260 per month in commuter transportation benefits, or an employee can elect to use up to $260 in pre-tax wages for qualified commuter transportation program. A change to 29 CFR Part 132(f)(5)(B) to include any zero-emissions vehicle with a passenger capacity of 4 or greater would allow employers to subsidize an employee’s ZEV-TNC or ZEV-TNC-transit trip with the first $260 per month excluded from an employee’s taxable fringe benefits. To provide zero emissions vehicles with a comparative advantage, the passenger requirement should be kept at six for internal combustion engine vehicles.

Late 2017 changes to the Internal Revenue Code reduce the tax deductibility of transportation fringe benefits. Previously, the expense of providing the benefit could be deducted by the employer and the first $260 in benefits were excluded from the employee’s income. Now, either the employer or employee can deduct the expense, but not both. Additionally, lower corporate tax rates give employers less of a tax incentive to make expenses which were previously deductible.

Research Limitations and Knowledge Gaps

Transportation network companies and zero emissions vehicles are rapidly developing. Much changed between project initiation in the Winter of 2016 and the final report in Spring 2018. Regulation also changed. A key change in the December 2017 tax bill reduced the tax avoidance value of using employer-provided transportation commute benefits to subsidize TNC-Transit commutes. A brisk policy and market environment undoubtedly limited the applicability of our applied research results for such a narrow question.

The research suffered from a lack of data on TNCs. To properly design incentives to induce ZEV-TNCs, policymakers will need rich data on TNC driver profiles and operations. Several key questions must be answered before designing targeted incentives: how many miles are driven in a session?; how long are breaks between sessions?; what is the average trip distance? These data would be used to understand the proportion of drivers for whom ubiquitous level 2 fast charging would suffice. For example, a driver who entered into TNC service for 40 miles in the mornings before work and 90 miles in the evenings after work could use a 120-mile range EV with level 2 fast charging at work. A driver who drives 300 miles over 12 hours would require a H-FCEV.

Abbreviations

AQIP	Air Quality Improvement Program
AQMP	Air Quality Management Plan
AVR	Average Vehicle Ridership
BEV	Battery-Electric Vehicles
CARB	California Air Resources Board
CPUC	California Public Utilities Commission
CLRP	Clean Vehicle Rebate Program
EFMP	Enhanced Fleet Modernization Program
EPA	Environmental Protection Agency
ERC	Emission Reduction Credits
ERT	Emission Reduction Target
ETC	Employee Transportation Coordinator
EV	Electric Vehicles
GHG	Greenhouse Gas
HEV	Hybrid-Electric Vehicles
HFCEV	Hydrogen Fuel Cell Electric Vehicle
MOU	Memorandum of Understanding
MPO	Metropolitan Planning Organization
MSERC	Mobile Source Emission Reduction Credits
NAAQS	National Ambient Air Quality Standards
NOx	Nitrogen Oxide
PHEV	Plug-in Hybrid Electric Vehicles
ICEV	Internal Combustion Engine Vehicle
IRS	Internal Revenue Service
REC	Renewable Energy Certificate
RIN	Renewable Identification Number
RTP/SCS	Regional Transportation Plan/Sustainable Communities Strategy
SCAG	Southern California Association of Governments
SCAQMD	South Coast Air Quality Management District
SIP	State Implementation Plan
STERC	Short Term Emission Reduction Credits
TAZ	Traffic Analysis Zone
TNC	Transportation Network Company
VMT	Vehicle Miles Traveled
ZEVS	Zero Emissions Vehicles

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