Abstract

Increased effort and funding to reduce greenhouse gas emissions have led the State of California to incentivize housing development, including affordable housing, near high-quality transit (HQT)[1]. Yet there has traditionally been little information about the travel patterns of low-income residents living in affordable housing[2], making it difficult to accurately estimate the impact of affordable transit-oriented developments (TODs) on vehicle miles traveled (VMT). Researchers have found a combination of land use and built environment factors to influence VMT, commonly referred to as the 5 Ds: distance to HQT, density, design for walkability, destination accessibility, and diversity of land uses, in addition to a series of individual-, household- and building-level factors that this study also reviews.

This study builds on previous research in California on the travel patterns of low-income residents living in affordable units both near (<0.5 miles) and far (>0.5 miles) from HQT in the San Francisco Bay Area and Los Angeles using a multi-method research design. Data were collected, assembled, and analyzed for 292 tenants living in affordable units both near and far from HQT to provide a picture of trip frequency, length, mode, purpose, and vehicle ownership as a function of development characteristics, household demographics, and urban setting. Results showed a significant association between proximity of affordable units to HQT with fewer private vehicle trips and more walking trips ($p < 0.05$), but not VMT, at the sites where we surveyed in the Bay Area. Only affordable units near HQT were surveyed in Los Angeles. Job site accessibility to transit was also associated with lower vehicle mode share. VMT and transit mode share, however, were not associated with TOD factors. These mixed findings align with the mixed results found for other populations and settings. However, this study also had several limitations which may inhibit the generalizability of the quantitative results including small sample sizes, oversampling of women that do not work full time out of the home and a lack of certain controls. Qualitative results from focus groups highlight the many benefits of living in affordable TODs, especially those in highly accessible areas and in close proximity to many services and opportunities, but also the limitations to using transit to certain destinations that may not be accessible by transit.

This study underlines the importance of factors often associated with TODs (e.g., accessibility of destinations and design, among others) beyond proximity to transit in determining travel patterns. Further research is needed to better understand the factors that will reduce VMT of low-income households and to ensure that investments in TODs take into consideration the many of the other factors that are necessary to reduce VMTs and consequently greenhouse gas emissions. With the continued attention and investment in TODs it is important for equity and fair housing purposes to ensure that low income households are able to live in TODs as they are likely to increase in their opportunity and resource levels.

[1] We adopt the definition for high-quality transit (HQT) used by the California Strategic Growth Council's Affordable Housing and Sustainable Communities program in 2016: rail or bus rapid transit (BRT) service with peak period headways of fifteen minutes or less and routes with daily service.
[2] We define affordable housing as income-restricted housing that receive some form of subsidy.

Executive Summary

Background

To meet California's ambitious climate goals, the State has increased efforts and funding to reduce greenhouse gas emissions by incentivizing housing development near transit. After the dissolution of local redevelopment agencies in 2011 and the continued decline in federal resources, local housing agencies and affordable housing developers are increasingly relying on Greenhouse Gas Reduction Fund dollars to fill the gaps where other funding sources have dwindled. However, historically there has been little information about the travel patterns of specific populations such as residents of affordable units[3], making it difficult to accurately estimate the impact of siting affordable housing near high-quality transit (HQT)[4] on vehicle miles traveled (VMT) and subsequently greenhouse gas reductions.

Objectives

This study seeks to build on emerging research to better quantify the VMT impacts of building affordable housing near HQT, referred to in this report as transit-proximate developments (TPDs), and other factors associated with transit-oriented developments (TODs) in addition to household, building, and neighborhood level factors that are known to affect travel patterns. The study also explores the non-VMT benefits of siting affordable housing near high-quality transit. For the purposes of this report we refer to these benefits as "co-benefits" of living in an affordable transit-proximate development.

Methods

Primary data was collected from 292 residents living in 27 affordable units both near (<0.5 miles) and far (>0.5 miles) from HQT to better understand the influence of HQT-proximity to travel patterns of low-income tenants. The data collection methods included a travel log, household survey, site level survey, and secondary data collection. The most common VMT data collection instrument – travel logs – were validated using a smartphone app that relies on global positioning system (GPS) data to records users' trips. Property-level data was acquired from a survey of on-site resident service coordinators at all 27 of the study properties, including data about transportation demand management strategies and on-site services. Focus groups at four affordable TPDs with 35 low-income residents were also conducted to better understand the determinants of travel patterns and to characterize the co-benefits of living in affordable developments near transit stations.

Results and Conclusions

Surveyed residents in affordable TPDs took significantly fewer trips in private vehicles and significantly more walking trips than residents in affordable non-TPDs after controlling for

[3] We define affordable housing as income-restricted housing that receive some form of subsidy
[4] We adopt the definition for high-quality transit (HQT) used by the California Strategic Growth Council's Affordable Housing and Sustainable Communities program in 2016: rail or bus rapid transit (BRT) service with peak period headways of fifteen minutes or less and routes with daily service.

several individual, household, building, neighborhood and destination factors. Job site accessibility to transit was associated with lower vehicle mode share. VMT and transit mode share, however, were not associated with TOD factors. Consistent with other studies, income and vehicle ownership were positively associated with car trips and VMT. At the building level we found net density of the housing development to consistently be associated with fewer driving and more transit and walking trips and mode share as well as lower VMT. It is not clear whether the site density is proxying for another unobserved site or neighborhood characteristics, like the site design or the lack of on-street parking. Further research would be needed to tease out if the site density has independent effects on resident travel patterns. We also found results for site level parking availability that were inconsistent with other research (i.e., higher ratios associated with fewer driving trips and less driving mode share). Our qualitative findings point to the use of on-street parking, especially for sites with low parking ratios, which may be influencing these results. However, this study had several methodological limitations which may inhibit the generalizability of the quantitative results including small sample sizes, oversampling of women that do not work full time out of the home and a lack of certain controls.

The focus group results highlighted that participants' vehicle use is influenced by more than just access to HQT. In developments that were located in walkable areas full of amenities (commerce, recreational spaces, green spaces), residents still relied on private vehicles for specific purposes (e.g., medical care) and destinations (e.g., shopping) that may not be transit accessible.

The focus groups revealed that residents of affordable TODs valued the freedom, convenience, and accessibility that comes with living in a centrally located neighborhood with multiple transportation options. However, they also expressed the same freedom, convenience and accessibility that comes with owning a private vehicle. This was especially true in families with disabilities or specific medical needs. These qualitative findings may help interpret the quantitative findings, such as the insignificance of transit proximity on VMT.

This study underlines the importance of factors often associated with TODs (e.g., accessibility of destinations, and site design, among others) beyond proximity to transit in determining travel patterns. Further research is needed to better understand the factors that will further reduce VMT of low-income households, which may include conducting a before and after study for new affordable TODs, or lighter touch research design to increase participation and capture a more representative sample of the study population.

In summary, this study found a significant relationship between site and neighborhood level variables with travel patterns that support assertions that affordable TODs are an important strategy to reduce car usage among residents of affordable housing. However, siting affordable units within walking distance of HQT alone, is likely insufficient to reduce greenhouse gas emissions and greater attention is needed to walkable design, ensuring there are a diversity of land use destinations (e.g., grocery) near sites and that common destinations (e.g., jobs) are also accessible by transit. With the continued attention and investment in TODs, it is further important for equity and fair housing purposes to ensure that low income households have access to these neighborhoods as they are likely to increase in opportunity levels.

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Table 1 Commonly Used Acronyms

Acronym	Definitions
ACS	American Community Survey
AHSC	Affordable Housing Sustainable Communities
AMI	Area Median Income
BART	Bay Area Rapid Transit
CBD	Central Business District
CHTS	California Household Transportation Survey
CTAC	California Tax Credit Allocation Committee
GPS	Global Positioning System
HH	Household
HQT	High-quality Transit
ITE	Institute of Transportation Engineers
NHTS	National Household Travel Survey
RSC	Resident Services Coordinator
SRO	Single Room Occupancy
TAC	Technical Advisory Committee
TDM	Travel Demand Management
TOD	Transit-Oriented Development
TPD	Transit-Proximate Development
VMT	Vehicle-Miles Traveled

Table 2 Definitions of Commonly Used Terms

Term	Definitions
Affordable Housing	Income-restricted units constructed at least in part with public subsidies.
Accessibility	The measure of one's ability to reach work and amenities.
Co-Benefits	All non-VMT benefits of siting affordable housing near HQT, such as improvements in health due to increases in walking and bicycling trips and reduced transportation costs.
High Quality Transit (HQT)	Rail or bus rapid transit (BRT) service with peak period headways of fifteen minutes or fewer and routes with daily service (SGC, 2016).
Person Trip	The movement of one person between two activity locations.
Transit Oriented Development (TOD)	A dense and walkable neighborhood environment with diverse land uses and within walking distance of quality transit options. See section 2 for a discussion of TOD definitions.
Transit-Proximate Development	Housing development near high quality transit.
Travel Mode	Means of travel (e.g., walking, bus, train, bicycling, driving in a personal vehicle, ride share such as Uber or Lyft).
Area Median Income (AMI)	Median income of households in the county, by household size; used to determine affordable housing income thresholds.
Low-Income	Households with incomes below 80% of the area median family income.

1. Introduction

Developing affordable housing[5] near high-quality transit (HQT)[6] has great potential to positively impact the environment as well as the health and well-being of low-income residents. A significant body of literature demonstrates the benefits of locating housing near transit in terms of its reductions on private auto travel (Park et al., 2018; Arrington & Cervero, 2008; Lund, Cervero, & Wilson, 2004; Zhang, 2010; Nasri & Zhang, 2014); improvements in health due to increases in walking and bicycling trips to access transit and other destinations (Pucher, Buehler, Bassett, & Dannenberg, 2010; Saelens, Sallis, & Frank 2016; Sallis, Floyd, Rodríguez, & Saelens, 2012); and economic benefits associated with reduced transportation costs (Zhou and Zolnik, 2013). However, other research has demonstrated that the impact of locating housing proximate to transit on vehicle miles traveled (VMT) are highly dependent on context, and that transit oriented developments (TODs) may not reduce VMT in some cases (Chatman, 2013). Researchers have identified many factors of built and social environments—beyond the proximity to transit stations—that can contribute to variability in the travel behaviors of people that live in TODs, including land use and urban design characteristics, among others (Heath et al., 2006; Boarnet, Greenwald, & McMillan, 2008; Nasri & Zhang, 2014; Chatman, 2013).

Limited research examines the benefits of developing affordable housing in TODs for different types of households (Clifton et al., 2018; Mallett, 2012; Stiffler, 2011; Kroll and De La Cruz, 2014). This project builds on previous research by conducting an in-depth study of 292 residents of affordable housing developments, located near (<0.5 miles) and far (>0.5 miles) from HQT stations, across a variety of neighborhood types and household characteristics. The main questions this study sought to explore through primary data collection were: 1) Is transit proximity related to VMT and/or to the number and length of trips for residents of affordable housing when controlling for other household and neighborhood-level factors? and 2) What are some of the co-benefits of living in affordable TODs for different neighborhood types? To answer these questions, this study took a mixed-method approach using various data collection instruments including participant travel logs, GPS data collection via a smartphone app to validate the travel logs, participant surveys, building resident services coordinator surveys, and focus groups. This data was paired with secondary neighborhood-level data.

The following section summarizes literature on the various factors that influence VMT, with a more in-depth review of the emerging literature on travel behavior of residents in affordable housing as well as research on co-benefits of siting housing near transit beyond VMT. In Section 3 we present the detailed methods used to explore our research questions, followed by the results in Section 4 and conclusions in Section 5.

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[5] We define affordable housing as income-restricted housing that receive some form of subsidy
[6] The California Strategic Growth Council's Affordable Housing and Sustainable Communities program defined high quality transit for their 2016 guidelines as rail or bus rapid transit (BRT) service with peak period headways of fifteen minutes or less and routes with daily service.

2. Literature Review

Siting housing near transit in TODs has been a key focus of greenhouse gas reduction strategies for the transportation sector. There are many definitions of TOD. Core to all definitions is the proximity of housing to transit options. For instance, in the guidelines for the Affordable Housing and Sustainable Communities (AHSC) program of California's Strategic Growth Council, a TOD project area is defined as a housing development located within one half mile of a transit station/stop served by HQT. Yet, most researchers and transportation advocates have identified other features of developments that are necessary to influence travel behavior often referred to as the five Ds: density, diversity of land uses, walkable design, destination accessibility, and distance to transit (Ewing & Cervero, 2001; Ewing et al., 2009). Incorporating some of these factors into their definition, the California Department of Transportation defines TOD as a "moderate to higher-density development, located within an easy walk of a major transit stop, generally with a mix of residential, employment and shopping opportunities designed for pedestrians without excluding the auto" (California Department of Transportation, 2002).

Researchers have found that numerous factors affect how people travel, from individual and household level factors (e.g., age, employment status, income) to building level factors at the origin and destination (e.g., parking availability, walkable design), to neighborhood-level (e.g., neighborhood accessibility, density, design) and city/network-level factors (e.g., congestion). Here we review some of the literature relevant to put into context the current study of affordable transit-proximate housing developments and their relationship to travel patterns. We look at the less-developed but growing literature examining the relationship between transit-proximate affordable housing and travel patterns. Finally, we draw on several studies that have focused on the co-benefits of TODs such as health and economic impacts.

Studies have looked at a variety of travel outcomes, all relevant to auto usage and greenhouse gas emissions. Among these are the number of daily trips by travel mode (e.g., car, bike, rail, etc.), mode share (% of daily trips by mode), automobile ownership, trip generation (e.g., the number of times a person begins to travel by leaving their origin location) and travel distance by mode. Perhaps the most commonly used outcome when considering greenhouse gas emissions is the total daily miles traveled in a private vehicle, commonly referred to as vehicle miles traveled or VMT[7]. While VMT can be associated with auto ownership and trip frequency, it may diverge based on the number and distance of destinations. For this reason we report on several travel outcomes in our literature review and analysis. Finally, although researchers have paid a great deal of attention to the role of self-selection when studying the impact of TODs (i.e., if people move to TODs because they are more likely to take transit), we do not review this literature here as the issue of self-selection likely plays an insignificant role on affordable TODs due to the scarcity of affordable housing options in the regions we study (Chatman, 2006).

[7] While VMT can be a good first step when estimating emissions, it is just that – a first step, as it does not take into account vehicle efficiency, or the speed of driving of which can affect emissions.

2.1 Individual and Household-Level Factors

A wide variety of individual and household level factors influence travel behavior, from vehicle ownership and employment status and destination to whether or not there are school-aged children in the household. For instance, studies have found VMT and auto ownership to be positively associated with household size, age of the householder, the number of workers per household, annual household income, educational attainment, and vehicle ownership (Nasri and Zhang, 2014; Akar and Guldman, 2012; Singh et al., 2018).

2.1.1 Income

Studies have consistently found household income to be positively associated with auto ownership, car trip frequency, and VMT. For example, an analysis by Pucher and Renne (2003) of the 2001 National Household Travel Survey (NHTS) found that households with incomes less than $20,000 per year made an average of 3.2 trips per person per day and traveled 17.9 miles while households with incomes of $100,000 or greater made 4.8 trips per day and traveled 31.8 miles per person, per day. Income was also associated with vehicle ownership (Pucher & Renne, 2003). Researchers have also found income to be associated with mode choice. Higher income households have been found to be less likely to commute via bus or walking, although research has not found a significant association between income and the probability of commuting via rail (Chatman, 2006).

A 2017 study, which looked at regional VMT impacts of rail accessibility using the California Household Transportation Survey (CHTS) (2010-2012) found that lower income households had lower rates of VMT for households both near (<0.5 miles) and far (>0.5 miles) from rail stations than higher income households (Chapple et al., 2017).[8] Finally, the Center for Neighborhood Technology found that extremely low-income[9] and very low-income households[10] drove between 43 and 68 percent less than moderate-income households[11] for three studied geographic types (rural, metro regions and small cities) after controlling for transit accessibility, density, family size, and employment levels.[12]

[8] "Near" rail is defined as within a half mile of a rail station. The rail stations included had headways of 15 minutes or less.
[9] with incomes below 30% of Area Median Income
[10] with incomes between 30% and 50% of Area Median Income
[11] with incomes between 80% and 120% of the Area Median Income
[12] Geographic definitions for CNT Study: *Rural Area: "*Areas eligible for housing assistance from the USDA," *Metro Region:* "Non-Rural Areas composed of U.S. Census Urban Areas with a municipality of at least 150,000 residents who, on average, can reach at least 90,000 jobs in a half-hour on transit," *Small City:* "All non-Rural Areas that do not qualify as Metro Regions" (Newmark & Haas, 2015).

2.2 Building-Level Factors

Several building-level factors have been found to impact travel behavior, from physical factors like site design and parking availability, to programming such as the availability of discounted transit vouchers and membership in car share programs.

2.2.1 Parking

Parking availability has been found to strongly influence travel behavior of households. Commonly, developers use the Institute of Transportation Engineers' (ITE) trip generation rates to determine the number of parking spots required, but studies have suggested that these rates significantly overestimate trips per unit in TODs as compared to conventional housing (Arrington & Cervero, 2008). Handy and Schneider conducted research across 30 sites in California and found that vehicle trips at smart growth sites[13] averaged half those predicted by ITE trip generation (Handy, Shafizadeh, & Schneider, 2013). Parking costs also play a role. In a study for the Washington State Department of Transportation researchers found that increasing the parking fees was significantly associated with lower VMTs (Frank, Greenwald, Kavage, & Devlin, 2011). Furthermore, in a study of travel behavior in California TODs, researchers concluded that residents were less likely to use transit for trips with multiple stops if they had access to free parking at work and if their employer subsidized vehicle expenses (Lund, Cervero, & Wilson, 2004).

2.2.2 Transit Vouchers and Bike/Carshare

Transit vouchers are a commonly used approach to incentive transit use and reduce VMT. Many affordable TODs in California have begun to provide them to residents – particularly those receiving funding from the Affordable Housing Sustainable Communities (AHSC) program. However, much of the research on transit vouchers and VMT is focused on employer commuter benefits programs, and not on residential building-based programs. A 2006 study by Herzog et al. surveyed employees at firms offering commuter benefits, and found that vehicle trips, VMT, emissions and fuel consumption all decreased among those participating in such programs. A 2015 evaluation of a transit voucher program at two medium-sized (60-70 unit) affordable multifamily TODs in San Mateo, CA, found that over half of surveyed residents did not bring a car when they moved to the development after learning that they would receive a free transit pass (TransForm, 2015).

Researchers have also begun to analyze the role of carsharing and bike sharing memberships on travel patterns and VMT. A study by Cervero and coauthors (2006) of San Francisco's City CarShare program found that membership in the program reduced daily VMT, especially if members owned a bicycle and lived in a high-density neighborhood in San Francisco. This

[13] "Smart growth" variables included: residential population within a half mile, jobs within a half mile, distance to the central business district, the average setback distance from the sidewalk for the building, on-street metered parking within 0.1 miles, PM peak-hour bus lines within 0.25 miles, PM peak-hour train line stops within half mile, the proportion of the site covered by parking. These variables were combined into a "smart-growth factor" that was assigned to each site and entered into the model.

decline in VMT, however, was offset with each additional vehicle per household member. Martin and Shaheen (2011) conducted a national online survey and found that the average VMT declined significantly for those who joined a carshare program.

2.3 Built Environment Factors

Researchers have identified numerous neighborhood-, transportation network- and city-level factors that influence travel patterns. Here we review the literature on several factors relevant to this study: transit proximity, residential and employment density, diversity and design of land, and destination accessibility.

2.3.1 Transit proximity

One of the basic building block of TODs is their proximity to transit, providing residents with different travel mode options. Indeed a large body of research shows that residents who live near transit are more likely to use it and less likely to drive, yet the evidence is very context dependent (Nasri and Zhang, 2014). In a California study, residents living in TODs were five times more likely to use transit for their commute compared to the average resident of the same city (Lund, Cervero, & Wilson, 2004).[14] Yet, residents were less likely to use transit for trips with multiple stops, if jobs had good accessibility via highways, if they had access to free parking at work, and if employers subsidized vehicle expenses. In a study of TODs throughout California, Chatman found that when comparing rail and auto commuting, longer commutes increased the likelihood of using rail as the primary mode (Chatman, 2006). However, in a New Jersey study, Chatman concluded that proximity to rail stations played a much smaller role in predicting auto ownership and use. Instead, the study found that housing type and tenure, density, bus service and on/off street parking availability played much larger roles (Chatman, 2013), leading the author to conclude that efforts to densify and diversify land uses should not exclusively focus on transit areas.

2.3.2 Density, Design, Diversity and Destination Accessibility

In addition to transit proximity, most definitions of TOD include the density of the neighborhood, walkable design, destination accessibility, and land use diversity (e.g., more than just residential), all of which are thought to encourage more walking, both to transit and other neighborhood destinations that could effectively reduce auto usage and distance traveled. Higher residential density, employment density, walkable design and mixed land uses have been shown to correlate with lower auto ownership and VMT, although similar to other variables, the extent of the impact varies depending on local context (Ewing & Cervero, 2010, Stone Jr. et al., 2007; Cervero and Murakami, 2010; Zhang, Hong, Nasri, & Shen, 2012; Brownstone and Golob, 2009; Zhang et al., 2012; Nasri and Zhang, 2012). In his study of California TODs, Chatman found that

[14] Sites were chosen based on: their location in an suburban area developed intentionally as a TOD, in station areas with headways of 15 minutes or less (except if commuter rail with headways of 20 to 50 minutes), a minimum of 50 residential units or 100 employees, located within walking distance of transit (up to a half mile).

land use mix (as measured by retail employment within given radii of residences) was strongly correlated with lower non-work auto mileage and higher rates of non-auto modes for commuting, perhaps due to the fact that more retail choices near home can lead to shorter automobile trips and/or increased substitution for non-auto modes (Chatman, 2006).

Destination accessibility, defined here as the measure of one's ability to reach work and amenities (Litman, 2011), incorporates factors such as the transportation network, travel time, and distance. California's AHSC program measures accessibility to work and amenities of project sites using maps of the number of key destinations (i.e. public schools, pharmacies, grocery stores that meet CalFresh Program requirements) within the project development area, as well as the Walkability Index. Studies have found that found that increased distance from the central business district (or low accessibility to work and amenities) was associated with higher VMT (Zhang et al., 2012). Accessibility can also be influenced by roadway congestion, as travel time can influence mode choice. Chatman (2006) found that residential network load density (the number of residents per unit of network capacity, a proxy for congestion) was correlated with lower non-work auto mileage and lower percentages of auto commuting.

In 2010, Ewing and Cervero conducted a meta-analysis of over fifty studies to identify which of the Ds has the greatest impact on VMT and other travel variables (walk trips and transit trips).[15] They concluded that individually, the relationships between travel variables and built environment variables was small, but that they could be significant when combined. The built environment variables with the strongest association with VMT were job accessibility by auto and distance to downtown although these variable included characteristics from several of the Ds (e.g., higher density, land use diversity, etc.) (Ewing & Cervero, 2010). More recently Park and coauthors (2018) studied the relationship between several built environment characteristics and travel outcomes at the national level, finding that auto-usage was most significantly associated with land use diversity and street network design of the stations areas; transit usage was more strongly related to transit availability and land use diversity. They found the weakest association with travel patterns to be the density of the station area.

2.4 Affordable TODs and VMT

Research on the travel patterns of low-income residents living in affordable TODs is growing. The first study in 2011 surveyed 875 households in 21 affordable housing developments (minimum of 80% income-restricted units) in San Diego to better understand parking requirements (Wilbur Smith Associates, 2011). The survey asked about demographics, household unit characteristics, vehicle availability, and parking behavior but did not look at VMT. The study found that almost half of the surveyed units had no vehicle and that the average vehicle ownership was nearly half that of market rate rental units in San Diego. Family units had higher rates of vehicle ownership (over one auto per unit) than units dedicated to people with special needs, single room occupancy (SRO), senior units, and studios, which all had less than

[15] This meta-analysis was a follow up to a previous meta-analysis conducted by the same authors in 2001. See: Ewing, R., & Cervero, R. (2001). Travel and the Built Environment: A Synthesis. *Research Record*, (1780).

0.5 average vehicle availability. Unit size (as measured by number of bedrooms) and income both had a positive correlation with vehicle ownership. Increased transit accessibility and walkability metrics was associated with lower average vehicle ownership (Wilbur Smith Associates, 2011).

In 2014, Kroll and De La Cruz surveyed 201 households in the Bay Area at two affordable housing TOD sites near Bay Area Rapid Transit (BART) stations and three non-TOD affordable housing developments. Four of the five sites offered free parking. The study concluded that residents in the urban TOD locations were significantly less likely to drive to their destinations than suburban non-TOD residents and that their trips were shorter overall. Furthermore, TOD residents were more likely to use public transit than non-TOD residents. However, while TOD sites offered improved access to some types of services, there was no significant difference in employment access between the TOD and non-TOD sites (Kroll & De La Cruz, 2014).[16] The study also asked residents to compare accessibility at their new location with their previous residence, which was typically in the same city or a neighboring city. Residents for both the TOD and non-TOD sites found that the access to services improved at their new location.

Stiffler studied a market-rate TOD, an affordable TOD, and a suburban neighborhood development in Carlsbad, California (Stiffler, 2011). While the sample was not large enough to find statistical significance, they found that non-TOD residents made more daily vehicle trips than TOD residents and that low-income TOD residents made more trips than market-rate TOD residents. TOD residents also had lower rates of auto ownership and VMT. However, the study did not control for household size or other known variables related to VMT. In focus groups, TOD residents expressed concern with the lack of convenience offered by transportation due to wait time required for both arrivals and departures and the frequency of stops en route (Stiffler, 2011).

The Non-Profit Housing Association of Northern California (NPH) surveyed 685 households at sixteen affordable housing developments in San Mateo and Santa Clara Counties. The sites included multi-family / non-targeted (no specific occupancy requirement) developments, developments targeted to senior households, and developments targeted to special needs and single room occupancy (SRO) populations. SRO and special needs development residents used transit more than seniors or non-targeted populations. The analysis concluded that limited parking availability, higher density, and higher levels of transit service resulted in increased use of transit at the sites (Mallett, 2012).

A survey of 42 affordable housing sites conducted for the City of Los Angeles (Gaul and Bearn, 2017) found that trip generation rates were lower for TOD units than for non-TOD units. Trip generation rates across all sites were lower than ITE trip rates for standard apartments. Furthermore, trip generation rates for seniors, persons with disabilities and residents of permanent supportive affordable housing were lower than ITE rates.

[16] To understand employment access, survey respondents were asked about the ease of finding a job (job opportunities) and the ease of reaching their jobs (ease of travel to work)

Finally, a 2018 study examined travel behavior and trip generation for affordable multi-family housing projects both near and far from transit in Los Angeles and the Bay Area (Clifton et al, 2018). Researchers collected trip generation data from 26 affordable multi-family housing developments and a household survey mailed to residents of 109 affordable housing developments. In addition they analyzed household trip rates, VMT, and automobile ownership rates using the California Household Travel Survey. The study found that low-income households living in multi-family housing own fewer vehicles, make fewer motorized vehicle trips, and generate fewer VMT than higher-income households. Vehicle ownership and use declined with increasing levels of urbanization and affordable housing sites generated 35% fewer motorized vehicle trips in the evening peak hour, on average, than would be predicted using current trip generation methods.

2.5 Co-Benefits of TODs

Locating affordable housing near transit has benefits beyond VMT and greenhouse gas reduction potential. The California Department of Transportation *Statewide Transit-Oriented Development Study* highlighted the following benefits that TODs can offer:

- Increasing public safety
- Increasing transit ridership
- Offering mobility choices
- Increasing household disposable income
- Supporting economic development
- Conserving resource land and open space
- Decreasing infrastructure costs
- Reducing air pollution and fuel consumption (Boroski, Faulkner, & Arrington, 2002)

These areas can be broadly categorized into themes of public health and economic benefits. By encouraging non-auto modes of transportation, TODs can increase physical activity and improve health outcomes. Using light rail transit for commuting purposes has been shown to result in reduced body mass index and reduced chances of obesity (MacDonald, et al., 2010). Studies have observed a positive correlation between the percentage of adults meeting the recommended weekly physical activity threshold and active commuting (Pucher, Buehler, Bassett, & Dannenberg, 2010). Furthermore, increased proximity of non-residential activities such as shopping and work has been shown to correlate with greater walking and cycling (Saelens, Sallis, & Frank, 2016).

In terms of economic benefits, TODs are believed to reduce transportation costs. Low-income families spend a larger portion of their income on transportation and owning an automobile is the second largest annual expense, after housing (Arrington & Cervero, 2008). Decreasing transportation costs could have significant benefits on increasing disposable income to be spent in other areas for low income households (Zhou & Zolnik, 2013). Finally, TODs have the potential to improve access to employment when job destinations are also transit accessible. A 2014 study of HUD voucher programs found that increasing car access could improve employment opportunities for very low-income adults, however, access to transit was found to have marginal effects on employment likelihood (Pendall, Hayes, George, & McDade, 2014). Low-income households that do not have automobile access are likely to benefit from living in transit rich areas as access to transit for households without cars can increase the likelihood of employment (Kawabata, 2003; Yi, 2006; Ong & Houston, 2002).

3. Methods

This study explores the relationship between affordable housing, proximity to transit, and travel patterns through primary data collection and analysis. For the purposes of this study we define affordable housing as income-restricted housing that receives some public subsidy. The main questions this study sought to explore were: 1) Are VMT, the number and length of trips related to transit proximity for residents of affordable housing when controlling for other household and neighborhood-level factors? and 2) What are some of the co-benefits of living in affordable TODs? To answer these questions, we took a mixed-method approach using various data collection instruments including a participant travel log, GPS data collection via a smartphone app, household survey, building resident services coordinator survey, and focus groups. This data was paired with secondary neighborhood-level data. Below we present the methods and stages of this 18-month study, which we divide into site database development, site selection, data collection and fieldwork, data cleaning, and analysis.

3.1. Site Database Development

Prior to site selection we developed a statewide database of affordable housing developments and their proximity to HQT. We collected lists of all affordable housing sites in 2016 from the California Tax Credit Allocation Committee (TCAC), the US Department of Housing and Urban Development, and the US Department of Agriculture's Multifamily Housing Development program. We combined and cleaned the housing data to remove duplicates as developments often receive funding from several sources. Information for each site included address, property manager, developer, total number of units and number of affordable units. For scattered site properties that allocated all units to one address, we called property managers to collect information about the number of units at each site and re-allocated unit counts to actual addresses. We geocoded address data using Google processor and mapped the data with the GIS software CartoDB.

We analyzed transit data to determine whether affordable housing developments were within a half mile of HQT. We used the definition of HQT from the AHSC 2016 guidelines as rail or bus rapid transit (BRT) service with peak period headways of fifteen minutes or less and routes with daily service. We used the General Transit Feed Specification (GTFS) data to collect transit data for the following agencies: Santa Clara Valley Transportation Authority (VTA), San Francisco Municipal Transportation Agency (SFMTA), Bay Area Rapid Transit (BART), Sacramento Regional Transit (RT), San Diego Metropolitan Transit System (MTS), LA County Metropolitan

Transportation Authority (LA Metro) and Foothill Transit. HQT stops were identified, and a separate dataset was created that only included stops that qualify as HQT.

Both the housing and transit data were imported into Python, a data processing software, to create half-mile buffers around HQT stops. Out of almost 6,000 properties and over 400,000 affordable units in California in 2016, roughly 20% were within a half mile of HQT (Table 3).

Table 3 Total Number of Affordable Housing Properties and Units by Proximity to High Quality Transit (HQT) in CA (2016)

	< ½ mile HQT	> ½ mile HQT	Total
Number of Affordable Units	83,683 (21%)	317,316 (79%)	400,999
Number of Properties	1,060 (18%)	4,687 (82%)	5,747

3.2. Site Selection

Our statewide technical advisory committee (TAC) informed our selection of regions and potential sites to study. The TAC was comprised of representatives from statewide agencies, affordable housing and transit researchers, advocates and developers. Under the guidance of the TAC, we analyzed existing data on California's affordable housing developments using "place type" categories that are based on features of the neighborhood's built environment. The intention was to select regions and sites that could be representative of the state's distribution of affordable housing stock. The memo provided to the TAC for the site selection analysis is included in Appendix A and summarized here.

To select a "place type" methodology we reviewed several studies and typologies to assess their usefulness for this study including Salon (2013) and Clifton (2016). Upon analysis and consultation with the TAC, we chose to use the Clifton place types to allow for greater comparability with the Caltrans-funded study. In "Affordable Housing Trip Generation Strategies and Rates," Clifton and team (2016, 2018) sought to capture the fit between the physical built environment and transportation system using Census block group data. Based on the analysis of four community design measures (population, job density, intersection density and % single family homes) and 2 regional accessibility measures (% jobs within access of fixed transit, # jobs within 35 minutes car travel) they developed 5 place types (Figure 1): 1) non-urban, 2) suburban neighborhood, 3) urban neighborhood, 4) urban district, and 5) urban core.

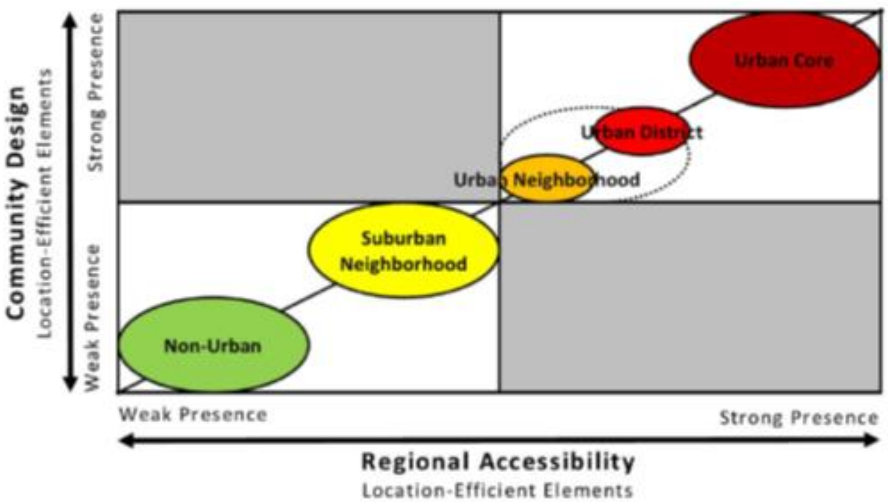


Figure 1. Place Typology Developed by Clifton (2016)

Using the data provided by Clifton, we assigned place types to the 5,747 affordable housing developments included in our database (Figure 2). Based on the analysis, we randomly selected among the stratified set of sites (according to place type and proximity to HQT) for developments with over 60 units and 100% affordable, so as not to compromise the confidentiality of participants and to ensure a large enough sample from each site. Sites were identified in Alameda, Contra Costa, Santa Clara and Los Angeles counties.

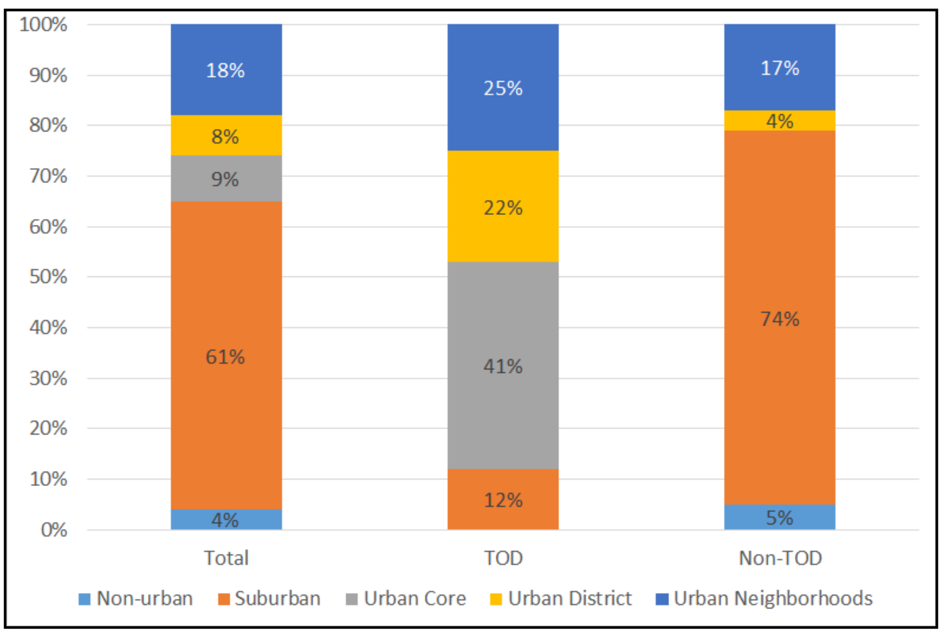


Figure 2. Neighborhood Types of Affordable Housing Units (2016)

Once the random stratified set of affordable housing sites were identified, we began to contact property managers or resident services coordinators at each site to gauge interest in participating in this study. There was a 43% participation rate for contacted sites (see Section 3.4 for a summary of sites and participants).

3.3. Primary Data Collection

Primary data collection occurred over a nine-month period, consisting of site visits to recruit, on- and off-board participants from the study. Participants were recruited from 27 sites (see Section 3.4). Additionally, we collected in depth information about travel patterns and co-benefits of living in affordable housing developments near HQT through focus groups at four of the sites in the Bay Area. Below we summarize the recruitment, on- and off-boarding procedures and the focus groups.

3.3.1. Site Visits

Data collection lasted approximately 7 days on average, with a site visit at the beginning for on-boarding and a visit at the end of the week for off-boarding. Site visits were to recruit participants, administer a household demographic survey, and collect data on resident travel patterns through a travel log. For a subset of participants we also installed a GPS app on their smartphones, which we removed during the off-boarding session. Ownership of a smartphone was not an eligibility criteria for participation in the study so as not to bias the results. Prior to the first site visit, the resident service coordinator posted recruitment materials at the site (see Appendix B).

One adult resident (aged 18 or older) from each household at a site was eligible to participate in the study. During the on-boarding site visit (Day One) researchers met with participants to obtain their informed consent, review instructions for filling out a travel log, and download a GPS app for participants who had smartphones that had operating systems compatible with the app. The travel log was designed to track a participant's travel patterns for one weekday during the study period. The GPS app collected the participant's location information for seven continuous days to validate the travel log and collect additional data on non-motorized transportation modes.

Between the two site visits, we texted participants to remind them to fill out their travel logs and to attend the off-boarding session. On the final day of the study period (Day Seven), we returned to: 1) review the travel log with the participant to ensure its completeness and accuracy, 2) administer a household demographic survey, and 3) uninstall the GPS app.

Participants were given a $50 gift card to Walmart or Target at the completion of the study. This amount was assessed to be high enough to encourage participation, but not so high that it would have functioned as a coercion for low-income households.

3.3.2. Focus Groups

We conducted four focus groups with residents of affordable housing near HQT in the Bay Area. Each of the four sites represented one of the four neighborhood place types this study focuses on: Oxford Plaza is located in the urban core, Riverwood Grove is in an urban district, Alta Mira is in an urban neighborhood, and Camellia Place is in a suburban neighborhood.

Once the focus group sites were recruited, we collaborated with property managers and resident services coordinators to recruit participants. Any resident above the age of 18 was allowed to participate, and all participants were compensated for their time with a $20 gift certificate. A total of 35 residents participated in the focus groups - 11 at Oxford Plaza, 8 at Riverwood Grove, 7 at Alta Mira, and 9 at Camellia Place.

A focus group guide was developed with open-ended questions designed to encourage peer-to-peer discussion among participants. In addition to a moderator, two other researchers attended focus groups to serve as note-takers. Each focus group lasted approximately one hour. To supplement the detailed notes taken during the discussions, we recorded the focus group conversations and transcribed them and analyzed them for key themes using the Dedoose qualitative analysis software. A set of themes and categorical codes were identified collectively among the three focus group researchers and cross-coder validation was conducted for each of the transcripts.

3.3.3. Primary Data Collection Instruments

Primary data collection instruments included a travel log, GPS smartphone app, household demographic survey, resident services coordinator survey, and focus group topic guide, described in detail below and included in Appendices D-H.

Travel Log

We adapted a standard travel log for participants to document their trips during a 24-hour period, including mode, destination and purpose (see Appendix D). On day one, we provided instructions and an example for how participants were to complete the travel log. We encouraged participants to choose a weekday in which their travel patterns were most "representative" of a typical day by referring to common destinations and purposes (e.g., commuting to work, running errands, dropping off and picking up children from school, etc.).

The travel log began at 4AM to accommodate participants who had early work hours. For each trip participants were asked to note their trip destinations, time of departure and arrival, trip purpose, travel mode, and the number of people they travelled with. When researchers returned for their second site visit with participants, they collected the travel diaries, confirmed that participants filled them out correctly and entered the data into an online form together with participants.

GPS Smartphone App

Researchers asked participants to download the e-mission[17] app, an open source smartphone GPS app for travel data collection (see Appendix E). E-mission was used to supplement the travel log for those who had enough storage on their smartphones in order to validate travel log data and to explore short and non-motorized trips that are known to be under-reported by participants (Stopher et al., 2007). We adapted existing protocols for smartphone deployment, participant training, quality control, and data retrieval. Participants did not need a data or cell phone plan in order to use the app.

During the first visit with study participants, we obtained informed consent to download the e-mission app on their phones. Participants downloaded and logged into the application on their

[17] https://e-mission.eecs.berkeley.edu/#/home

phone using a unique ID to maintain participant confidentiality. Locational data from the participant's smartphone was automatically sent to the research team's private server when they were connected to WiFi through a hotspot that we brought to the off-boarding session. Participants had e-mission installed on their phone for the seven-day period of data collection, and was deleted from participants' phones during the off-boarding visit.

Following the end of data collection, GPS data from the private e-missions server was downloaded, imported into the project database, and processed to review and confirm trip end locations and mode assignments.

Household Survey

We developed a household survey to collect data on household and individual characteristics that may influence travel behavior to help interpret results of the travel logs and GPS data. Survey questions included queries regarding household composition, employment and income, travel costs, common travel destinations by mode and access to parking on-site (See Appendix F). In addition, participants were asked to compare between their current and previous living situations, the ease and frequency of different transportation modes.

Focus Group Topic Guide

The goal of the focus groups was to explore the co-benefits of living in affordable units near HQT. The guide included topics that prompted participants to discuss their experiences pertaining to accessibility, cost-of-living, and safety, enabling the analysis of the full spectrum of benefits and challenges of living at the sites (see Appendix G). The topics covered at each of the focus groups included site location, options and quality of transportation, access to goods and services, and neighborhood amenities.

Resident Services Coordinator Survey

Resident Services Coordinators (RSC) at affordable housing developments possess valuable information about the property, its management and residents' needs. We developed an online survey for RSCs to capture data about travel, parking and other amenities at the site. Survey questions included queries about various strategies related to Transit Demand Management (TDM) including the number of parking spots per unit, whether discount transit passes are offered, accessibility of bike parking on-site, availability of carshare and bikeshare programs either on-site or nearby, and use of community room facilities on-site (see Appendix H).

Secondary Data Collection

We collected secondary data on site and neighborhood- level characteristics to complement the RSC survey. Information on the unit size mix and amenities provided (community rooms, open spaces, computer labs, etc.) was collected from the property websites. Neighborhood level TOD characteristics were collected from the Center for Neighborhood Technology's Housing and Transportation Affordability Index (H+T Index[18]). These block group-level datasets included an employment access index, population density, and percentage of housing units that are single

[18] https://htaindex.cnt.org/

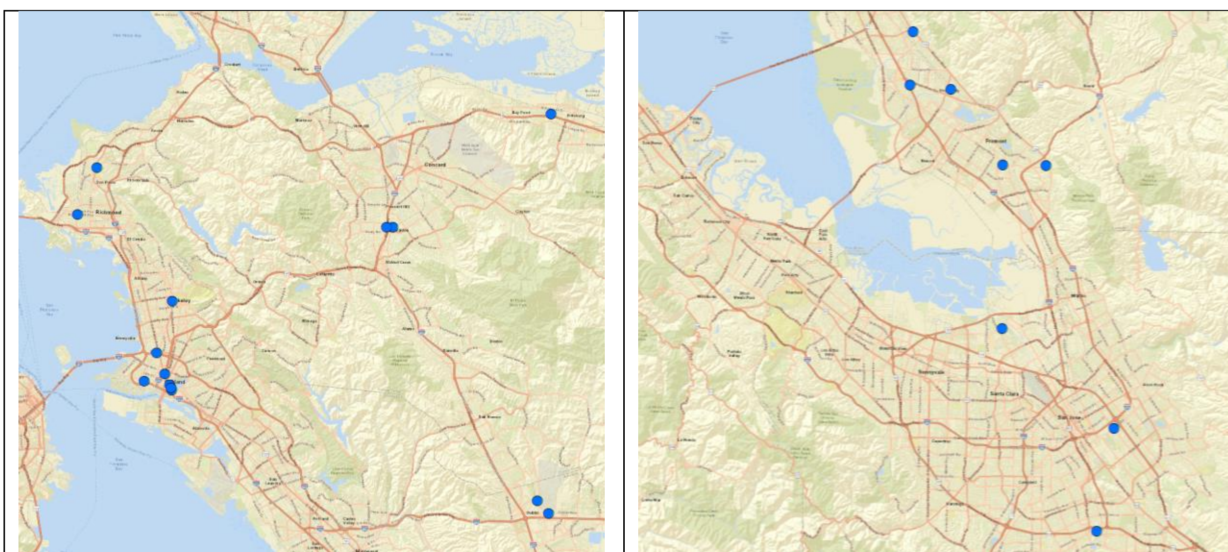
family housing which we used to try to capture TOD factors like diversity of land uses, accessibility, and density. The employment access index (jobs/mi²) is constructed using a gravity model that analyzes the quantity of and distance to all employment destinations in relation to any given block group (H+T Index, 2017). Additionally, we collected walkability data from Walk Score as an indicator of neighborhood design. Finally, we calculated the net dwelling unit density (units/acre) of a site using parcel acreage data.

3.4. Site & Participation Overview

A total of 292 individuals from 27 affordable housing sites completed the study. The overall participation rate across all sites was approximately 9% (Table 4). Twenty-two of the sites and 251 of the participants (86%) were located in the Bay Area, and the remainder (5 sites and 41 participants) were in Los Angeles County.

Table 4 Study Recruitment and Participation Rate

Total # of Affordable Units (all sites):	3,265
Participation Rate (average across each site):	9%
Total Participants On-Boarded:	331
Total Participants Off-Boarded:	292
Retention Rate:	88%



Sites in Alameda and Contra Costa Counties	Sites in Alameda and Santa Clara Counties

Figure 3 Location of Bay Area Study Sites

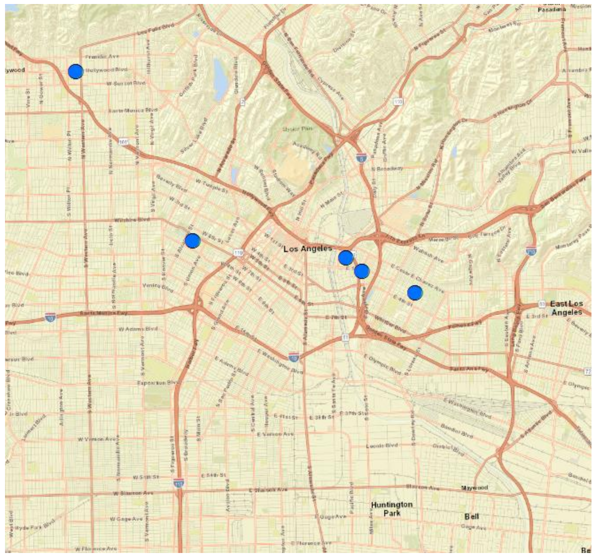


Figure 4 Location of Los Angeles Study Sites

A complete list of the study sites, select characteristics and participation rates is located in Appendix I. As observed in Table 5, of the 27 sites and 292 participants, 19 sites and 203 participants were within a half mile of HQT, and the remaining 8 sites and 89 participants were located farther than a half mile from HQT.

Table 5 Number of Study Sites and Participants by Place Type and Transit Proximity

	< ½ mile of HQT		> ½ mile of HQT	
Site Place Types (Clifton 2016)	**# of Sites**	**# of Participants**	**# of Sites**	**# of Participants**
Urban Core	6	77	0	0
Urban District	5	50	0	0
Urban Neighborhood	5	49	2	19
Suburban Neighborhood	3	27	6	70
Total	**19**	**203**	**8**	**89**

3.5. Data Cleaning and Analysis

We reviewed and cleaned data for each of the instruments at the end of the collection period. Travel log data was reviewed for spelling and completeness before entering it into the online form. Origin and destination data from the travel logs were geocoded using the Google Maps Application Programming Interface (API). Common errors included cities being geocoded onto the places with similar or the same names (e.g. Albany, New York instead of Albany, California).

The e-missions GPS app was set up to only push data to the server when a participant's phone was connected to WiFi in order to avoid impacting participants' data plans. In order to analyze the participants' trip data, we ran the analysis pipeline, which is a Python-based algorithm that segments the location data into trips and sections. Data cleaning and analysis was conducted in Python. Before generating descriptive statistics and making comparisons with the travel log, we removed participants who didn't complete a travel log, trips outside of the data collection time frame, and trips where the mode could not be identified. We also removed participants with less than 4 trips and other outliers. There were several trips that the e-mission app detected as "air or high speed rail" trips. Upon closer inspection of the travel routes, we determined that these trips occurred on the highway, likely at high enough speeds to be misidentified as rail trips, and relabeled those trips as vehicle trips. Finally, for multimodal trips, we divided the data up into separate trips by mode (e.g., walking to the bus would be divided separate walking and bus trips). Finally, we manually modified ten multimodal travel log trips to make those trips comparable to the e-mission dataset.

Each of the GPS and travel log data were merged with data from the Household Demographic Survey, Secondary Site Level Dataset, and RSC Survey. Upon cleaning and coding the data, statistical analyses was conducted using the Stata statistical package. A multivariate regression model assisted in determining the relationship between residence in an affordable development near (<1/2 mile) HQT and VMT, while controlling for household/individual and built environment determinants of travel patterns, as described in the literature review and summarized in Table 6. Linear regression models were used to assess determinants of trip frequency by mode. Seventeen independent variables were included in the statistical models. A variance inflation factor (VIF) test was used to check for multicollinearity, with a threshold of 10 as cut-off point. None of the control variables displayed multicollinearity under these parameters.

We include variables to proxy for each of the Ds of TODs: density (residential density), land use diversity (% of block group that is single family residential and Walk score), design (Walk score and net density of site), destination accessibility (dummy for job destination within <1/2 mile of HQT, and employment access index), and distance to HQT (dummy for sites within ½ mile).

Table 6. Descriptive Statistics of Independent Model Variables

Variable	Obs.	Mean	SD	Min	Max
Individual and Household Level variables					
Age	292	46.91	14.81	18	84
Household Size	292	2.85	1.64	1	7
Presence of School-Aged Children*	292	0.59	0.49	0	1
Household Income Midpoint	292	24,711	16,840	5,000	125,000
Full Time Worker*	292	0.20	0.40	0	1
Part Time Worker*	290	0.22	0.41	0	1
Not Working*	290	0.46	0.50	0	1
Vehicle Ownership*	292	0.73	0.45	0	1
Building-Level Variables					
Parking Ratio	292	1.11	0.45	0.25	2.01
Number of Housing Units at Site	292	131	80	35	375
Net Density of Site (units/acre)	292	59	49	10	236
Neighborhood, City and Destination-Level Variables					
Residential Density (HH/acre)	292	37	54	6	223
Emp. Access Index (jobs/mi^2)	292	101,910	76,584	13,998	315,797
% HH in Single Family-Detached	292	16%	15%	0	67%
Walkscore of Res. Neighborhood	292	70	23	27	98
Job Destination < 0.5 miles from HQT*	274	0.10	0.31	0	1
Housing <0.5 miles from HQT*	292	0.70	0.46	0	1

* Dummy variable

4. Results

In this section we summarize the results of the study according to the questions we aimed to answer after providing a summary of the site and participant characteristics as well as summary statistics of travel behaviors and validation of the travel log. The results section concludes with insights from the focus groups.

4.1. Site and Neighborhood Characteristics

As described in Section 3 and Appendix A, place type categories aimed to summarize key community design and regional accessibility factors and guide site selection so that we were sure to sample from the diversity of California neighborhood types. Although the place types were designed to capture unique neighborhood design and accessibility characteristics, there was wide variability within place types for the sites we surveyed (see

Table 7 and Table 8). For instance, although urban neighborhoods have lower housing unit densities and employment accessibility than urban districts, for the sites we surveyed they also had lower shares of detached single-family homes than urban district sites.

Table 7 Design, Diversity and Accessibility Characteristics for Sites < ½ mile of HQT

Site Place Type	Average Housing Units per Acre (min-max)	Average % Single Family Detached (min-max)	Average Employment Access Index (Jobs/mi^2)	Average Walk Score (min-max)
Urban Core (n=6)	58 (14 – 223)	4% (0% – 12%)	177,091 (78,184 – 315,797)	87 (64 – 98)
Urban District (n=5)	35 (18 – 62)	20% (5% – 36%)	140,240 (104,791 – 200,424)	80 (37 – 97)
Urban Neighborhood (n=5)	23 (9 – 48)	13% (3%- 33%)	50,914 (28,851 – 110,954)	69 (57 – 82)
Suburban Neighborhood (n=3)	16 (8 – 31)	20% (18% -22%)	39.389 (28,665 – 46,537)	46 (38 – 61)

Table 8 Design, Diversity and Accessibility Characteristics for Sites > ½ mile of HQT

Type	Average Housing Units per Acre (min-max)	Average % Single Family Detached (min-max)	Average Employment Access Index (Jobs/mi^2)	Average Walk Score (min-max)
Urban Neighborhood (n=2)	15 (14 – 16)	20% (7%- 34%)	73,001 (39,358 – 106,644)	81 (76 – 87)
Suburban Neighborhood (n=6)	11 (6 – 23)	36% (3% -67%)	31,412 (13,998 – 51,452)	47 (27 – 76)

Property characteristics also varied across sites, as observed in

Table 9 and Table 10. The net density of each property did not necessarily increase from urban district to urban core sites, and some urban district sites had much higher net densities than urban core. Although there were fewer parking spaces per unit for urban core sites, there was a wider range for urban district sites, and one transit-proximate suburban site had only one onsite parking spot for every four affordable units. Overall, only 5 out of 27 properties (27%) offered discounted transit passes to their residents.

Table 9 Property Characteristics for Transit-Proximate Sites (< ½ mile of HQT)

Type	Average Net Density (min-max)	Average Onsite Parking Ratio (min-max)	# of Properties with Bike Parking	# of Properties Offering Discounted Transit Passes
Urban Core (n=6)	84 (11 – 138)	0.73 (0.32 – 1.01)	5	2
Urban District (n=5)	101 (28 – 236)	1.10 (0.58 – 1.89)	3	3
Urban Neighborhood (n=5)	39 (22 – 55)	1.37 (1.01- 2.01)	0	1
Suburban Neighborhood (n=3)	41 (22 – 58)	0.77 (0.25 -1.03)	2	0

Table 10 Property Characteristics for Sites Far from HQT (< ½ mile of HQT)

Type	Average Net Density (min-max)	Average Onsite Parking Ratio (min-max)	# of Properties with Bike Parking	# of Properties Offering Discounted Transit Passes
Urban Neighborhood (n=2)	54 (13 – 94)	1.46 (1.28- 1.63)	2	0
Suburban Neighborhood (n=6)	29 (10 – 87)	1.40 (1.11 -1.69)	1	0

4.2. Participant Demographics

Here we present a demographic overview of our sample population. For each measure, we also created a comparison "County Index" that is a weighted average (by total population) of the four counties that were included in the study – Los Angeles, Santa Clara, Alameda, and Contra Costa, in order to see representativeness within the geographic context of our sample. County-level data are from 2012-2016 5-year ACS estimates.

The vast majority of study participants were of working age, female (82%) and had more than one person in the household (72%). Overall 60% of the participants lived in households where there was a child under the age of 18 present. Of the 283 participants that answered survey questions about age, 6% were under 25 years old, 83% were between the ages of 25 and 65, and 11% were over the age of 65 (Table 11 and Figure 5). Of the working age group, 133 (52%) were not currently employed at the time of the study. This may reflect the time availability of residents to participate in the study, and the over-sampling of stay-at-home mothers. Of the 138 participants that were working age females with children in their household, only 25% worked fulltime and nearly half did not work at the time of the survey. Despite the low employment rate, of the 133 participants who were not working at the time of the survey, 47% had a member of the household that was employed at least part time, resulting in a household-level labor force participation rate of 73%.

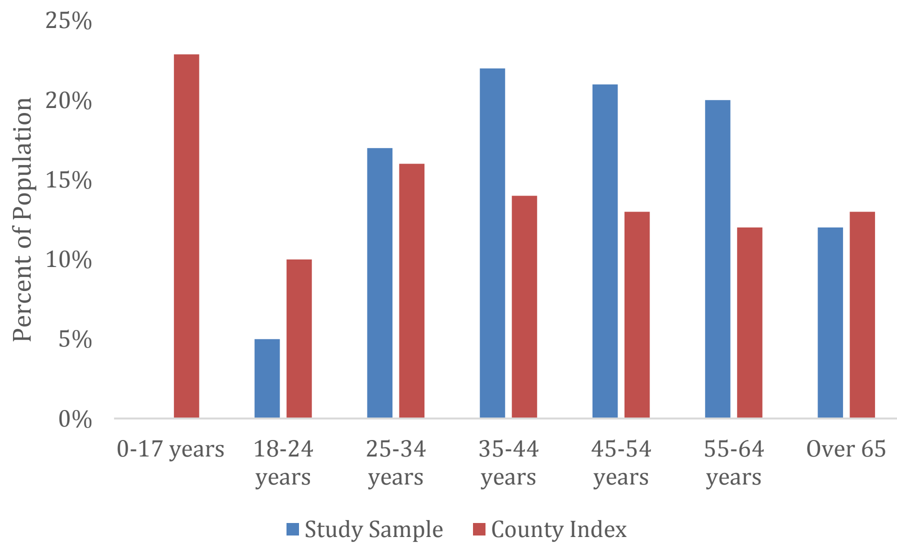


Figure 5 Age Distribution of Study Participants

Table 11 Participant Demographics for Transit-Proximate Developments by Place Type

Type	Median Age (min-max)	Median Household Size (min – max)	% with School Aged Children	% with at least one employed household member
Urban Core	46 (23 – 77)	3 (1 – 7)	67%	67%
Urban District	49 (20 – 82)	2 (1 – 6)	54%	74%
Urban Neighborhood	40 (18 – 82)	3 (1- 6)	61%	67%
Suburban Neighborhood	45 (26 – 69)	2 (1 -5)	44%	67%
All Place Types	46 (18 – 82)	2.5 (1 – 7)	59%	67%
County Index	36	3	27%	60%*

*Proxy: *2013-2017 ACS 5-Year Estimates – Employment Status for Total Population 16 Years or Over*

Table 12 Participant Demographics for sites > ½ mile from HQT by Place Type

Type	Median Age (min-max)	Median Household Size (min – max)	Participants with School Aged Children in the Household	% with at least one employed household member
Urban Neighborhood	45 (18 – 70)	3 (1 – 5)	31%	58%
Suburban Neighborhood	49 (18 – 84)	2 (1 – 6)	65%	62%
All Place Type	47 (18 – 84)	3 (1 – 6)	58%	61%
County Index	36	3	27%	60%*

*Proxy: *2013-2017 ACS 5-Year Estimates – Employment Status for Total Population 16 Years or Over*

Of the 292 study participants, 20 chose not to answer income questions and 23 did not know their household's income. Of the 249 participants that shared household income information, 61% had annual incomes below $25,000 (Figure 6). There was no noticeable difference between the income distributions of participants living less than a half mile from HQT and those living more than half a mile from HTW, and while there were differences between the study participants by place type, no clear trends emerged (Table 13).

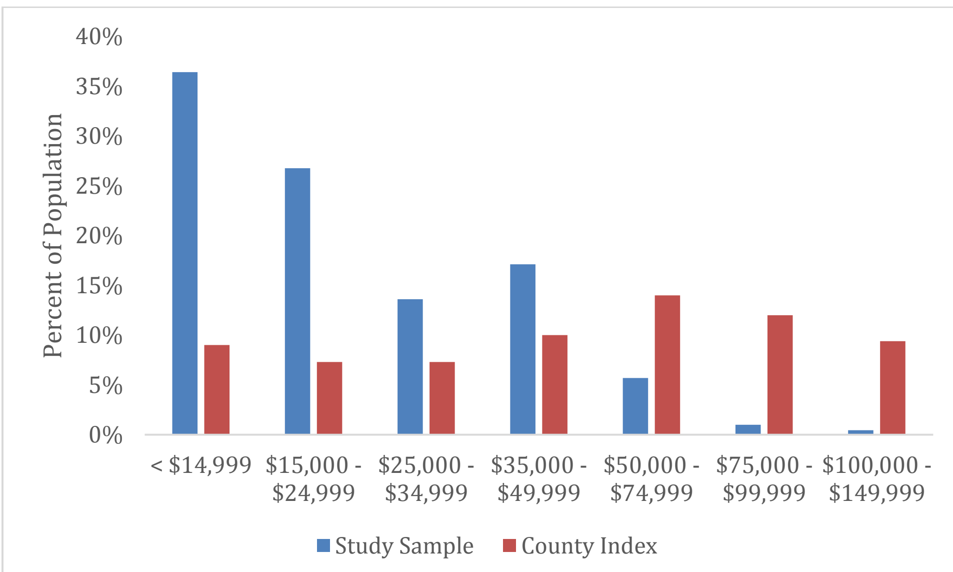


Figure 6 Distribution of Household Income Reported by Study Participants

Table 13 Percent of Total Participants in each Place Type by Income Category

Place Type	< $10,000	$10,000 - $14,999	$15,000 - $24,999	$25,000 - $34,999	$35,000 - $49,999	$50,000 - $74,999	$75,000 - $99,999	> $100,000
Urban core	15%	17%	19%	25%	12%	12%	0%	0%
Urban district	11%	20%	23%	16%	25%	5%	0%	0%
Urban neighborhood	20%	25%	16%	16%	13%	7%	2%	2%
Suburban neighborhood	15%	24%	32%	9%	16%	1%	2%	0%

A majority of participant households reported owning a vehicle (Table 14). The lowest household vehicle ownership rate was for participants that lived at affordable housing sites in suburban TPDs (67%), whereas the highest rate was for participants of suburban non-TPDs.

Table 14. Vehicle Ownership Rates for Households by Transit Proximity and Place Type

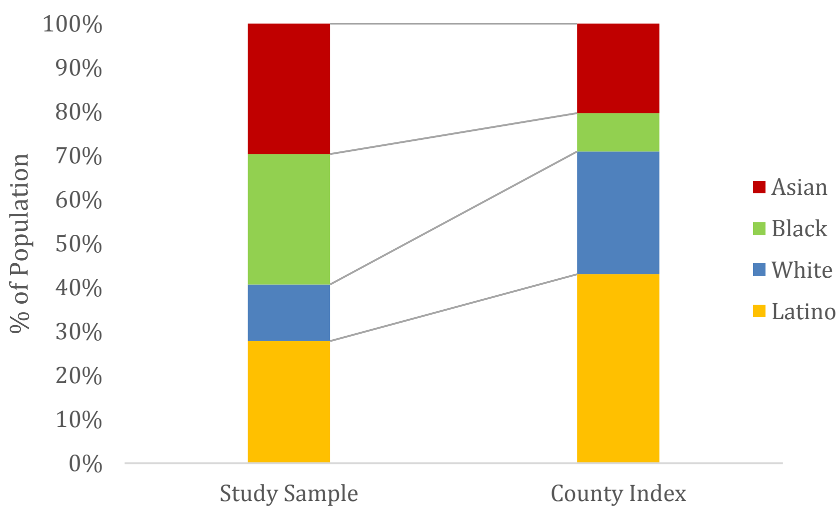
Place Type	TPD	Non-TPD
Urban Core	72%	NA
Urban District	70%	NA
Urban Neighborhood	76%	58%
Suburban Neighborhood	67%	80%
County Index	91%	

Table 15. Average Number of Vehicles for Households by Transit Proximity and Place Type

Place Type	TPD	non-TPD
Urban Core	1 (0-4)	NA
Urban District	0.86 (0-4)	NA
Urban Neighborhood	1.36 (0-5)	0.89 (0-4)
Suburban Neighborhood	1.04 (0-2)	1.17 (0-4)
County Index	2.22	

Finally, as observed in Figure 7, only 13% of participants self-identified as White, and roughly 30% of the participants self-identified as Latino, Black and Asian each.

Figure 7 Participant Race or Ethnicity for Study Population (L) and County Index (R)



4.3. Descriptive Statistics of Participant Travel Behavior

The 292 participants logged a total of 1,339 trips during a 24-hour weekday. From this data (henceforth referred to as travel log data), on average participants logged 4.58 daily trips and had an average trip distance of 4.58 miles (Table 16). The most frequent mode of travel was driving alone for shopping purposes. In Table 17 we summarize the proportion of trips by mode and purpose. Nearly a quarter of all trips recorded were for shopping, 60% of which were done by car and over 20% by foot. Bus travel was a far more common mode than trains. The most common purposes for train trips were to go to the bank, social/recreational and educational. The majority of work trips were taken by car, followed by walking and bus. Very few bike trips were logged and therefore we grouped them in the "other" category.

Table 16. Summary Statistics on Participant Travel Behavior from Travel Log Data

Total Number of Trips:	1,339
Total Number of Participants:	292
Average Daily Trips per Participant:	4.58
Average Trip Distance:	7.22 miles
Most Frequent Mode:	Driving Alone
Most Frequent non-Home Purpose:	Shopping

Table 17 Share of Trip Purposes by Mode

Trip Purpose	Walk	Bus	Train	Free shuttle	Drove alone	Shared ride	Taxi/ TNC	Other	% of all trips
Bank/Finance	8%	8%	15%	0%	54%	0%	0%	15%	2%
Education	11%	14%	6%	0%	54%	11%	2%	2%	10%
Meal	32%	7%	2%	0%	40%	18%	0%	2%	7%
Personal/Medical	14%	21%	2%	4%	42%	15%	1%	1%	13%
Pick-up/drop-off	12%	5%	2%	0%	49%	29%	1%	1%	20%
Religious	14%	14%	0%	0%	29%	43%	0%	0%	1%
Religious	8%	31%	0%	0%	31%	31%	0%	0%	2%
Shopping	21%	14%	3%	1%	48%	12%	0%	0%	24%
Social/Rec	22%	9%	8%	1%	31%	24%	1%	3%	9%
Work	16%	12%	4%	0%	59%	9%	1%	0%	13%
All Purposes	17%	12%	4%	1%	47%	17%	1%	1%	100%

In **Error! Not a valid bookmark self-reference.** we report the total number of trips logged by place type (grouping all urban place types together) and transit proximity. Urban TPD participants had on average fewer trips than urban non-TPD participants, however no difference is observed for suburban participants. The significance of these differences is tested in section 4.5 in our multivariate statistical models. However, given the variability within place types, we analyze the design and density variables as place types were not found to significantly predict travel patterns.

Table 18 Summary Statistics of Trips by Place Type and Transit Proximity

Neighborhood Type	Total Number of Trips	Number of Participants	Average Trips per Participant
Urban TPD	789	182	4.34
Urban non-TPD	96	19	5.05
Suburban TPD	117	24	4.88
Suburban non-TPD	337	69	4.88

As noted above, the majority of trips were conducted in car and driving alone. The share of all trips by car increases from urban to suburban and from TPD to non-TPD (Figure 8). A greater percentage of trips were conducted in carpools for suburban participants, and for urban participants, more trips were in carpools for TPD participants than non-TPD participants. The proportion of transit and walking trips were higher for both TPD and non-TPD urban participants than for suburban participants. Notably, urban non-TPD participants had a higher proportion of transit trips than suburban TPD participants.

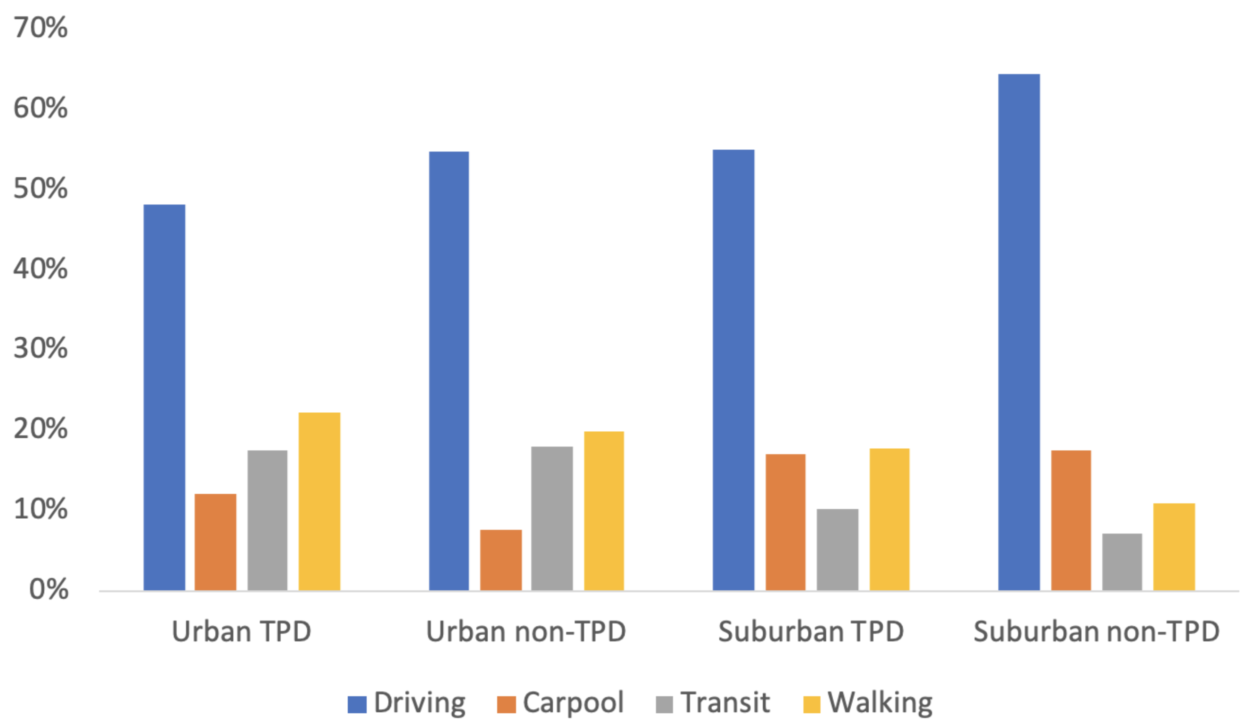


Figure 8 Percentage of Trips by Mode, Place Type and Transit Proximity (Travel Log)

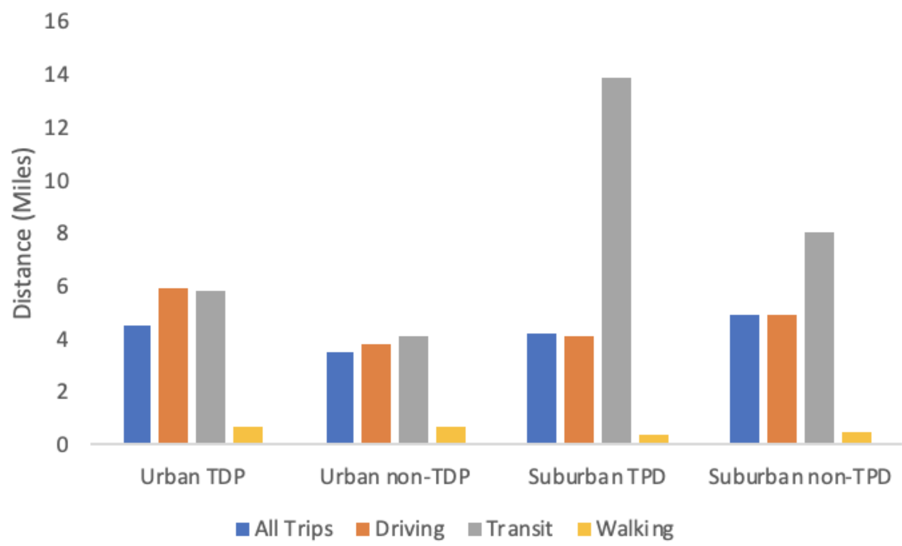


Figure 9 Mean Distance of Trips by Mode, Place Type and Transit Proximity (Travel Log)

When looking at average trip distance by mode (Figure 9) we find greater transit distances and shorter walking distances for suburban participants than urban participants.

There are several differences in trip data between Bay Area and Los Angeles participants (Table 19). All sites in Los Angeles were within a half mile of HQT, and either urban core or urban district place types. For comparison, we include Bay Area participants from these place types only. LA participants took more trips overall (including both by car and transit). A higher proportion of LA trips were by transit. However, VMT in LA was higher overall, potentially due to the higher number and proportion of trips by car, and the longer distanced between destinations. Bay Area residents took a higher proportion of trips by walking.

Table 19 Travel Comparisons between LA & Bay Area Urban Core and Urban District TPDs

Geography + Place type	# of Participants	Avg. VMT	Avg. # Car Trips	Avg. # Transit Trips	Avg. % Car Trips	Avg. % Transit Trips	Avg. % Walking Trips
Bay Area Urban Core + Urban District TPD	87	18.3	2.22	0.75	49%	22%	35%
LA Urban Core + Urban District TPD	41	33.6	3.23	1.35	65%	38%	22%

4.4. Validation of Travel Log using GPS data

The collection of travel data with both travel log and GPS techniques allows us to validate and cross-check our results. Du et al. (2007) found that conventional survey methods, which include travel logs, frequently omit short trips, particularly those included in trip chaining, defined as travel which includes a stop on the way to another destination – such as when one runs errands. Participants could have done trip-chaining but didn't think to log each stop as a separate trip. GPS-based travel surveys, like e-mission, fill this gap by capturing the start and end of every trip and expand data collection with multiple days of data and additional information, such as route and speed (Stopher & Greaves, 2007). Yalamanchili and coauthors (1999) found that GPS-based travel surveys captured twice as many trip-chaining trips as survey methods that require participants to recall their travel behavior.

This study included 84 participants that collected both GPS and travel log data. Of those 84 participants, 62 participants live in transit-proximate developments (TPD) and 22 participants do not (non-TPD).

Despite active recruitment, we did not collect GPS data on roughly two thirds of participants. There were numerous reasons for this including smartphone operating systems that did not support the app, insufficient storage on people's phones (e.g., many people had so many apps and images that they simply had no extra storage), and technical challenges with downloading the app. Some participants, especially older ones, did not feel comfortable with GPS tracking, however this was not a common reason for non-participation. There were also several dozen participants who downloaded the app, but no data was collected on the server. It is possible that these participants deleted the app after onboarding, however we suspect other issues related to the server, which was occasionally rebooted without warning, were the likely cause of missing data.

In order to validate the travel log data, we compared the GPS data for the day the travel log was completed for each participant (referred to as the "match date"). Although we had GPS data for 84 participants, our final analysis includes only 39 participants (28 in TPD and 11 in non-TPD) due to missing date information from the travel log for the other 45 participants. We compared the average number of trips per day and the average trip distance between the two datasets. We also compared the average number of trips per day and average trip distance between TPD participants and non-TPD participants for each dataset. Although the travel log differentiates vehicle trips by bus, rail, and auto, the GPS data only reports walking, biking, and vehicle trips, so we calculated descriptive statistics only for those three modes. We found that the average number of trips for vehicle trips is comparable across the datasets but the average vehicle trip distance for GPS trips is 8% longer than the average vehicle trip distance for trips estimated using the travel log data. We also found that the number of walking and biking trips were underreported in the travel log compared to the GPS dataset.

4.4.1. Number of Trips

We compared the average number of trips per day for 39 GPS and travel log participants. We also compared the average number of trips per day for walking, biking, and vehicle trips between TPD and Non-TPD participants within each dataset.

Figure 10 illustrates the relationship between the number of travel log and GPS trips on the match date; we see there is underreporting of trips in the travel log. Figure 11 illustrates the same relationship but separates into TPD and non-TPD participants. The TPD participants seem to have a slightly higher rate of underreporting travel log trips, but this is likely due to the fact that there are more TPD than non-TPD participants. This discrepancy between the trip rates of the GPS and travel log datasets is in line with previous studies that found respondents have a tendency to underreport trips, particularly shorter trips (Stopher et al., 2007).

Figure 12 shows the distribution of the number of trips per day for the GPS and travel log datasets. The GPS dataset has slightly more variation than the travel log dataset. This may be due to a combination of underreporting in the travel log and inconsistencies in the GPS app and algorithm where one trip is calculated as multiple trips. The variation is more likely due to the former explanation and is further explained below when comparing the average number of trips by mode.

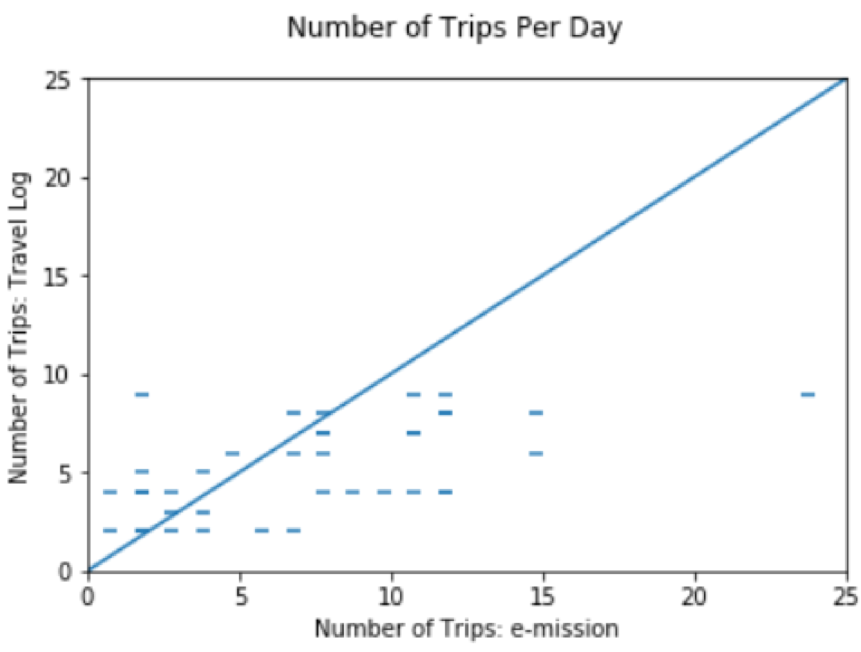


Figure 10 Number of Trips per Day for GPS and Travel Log

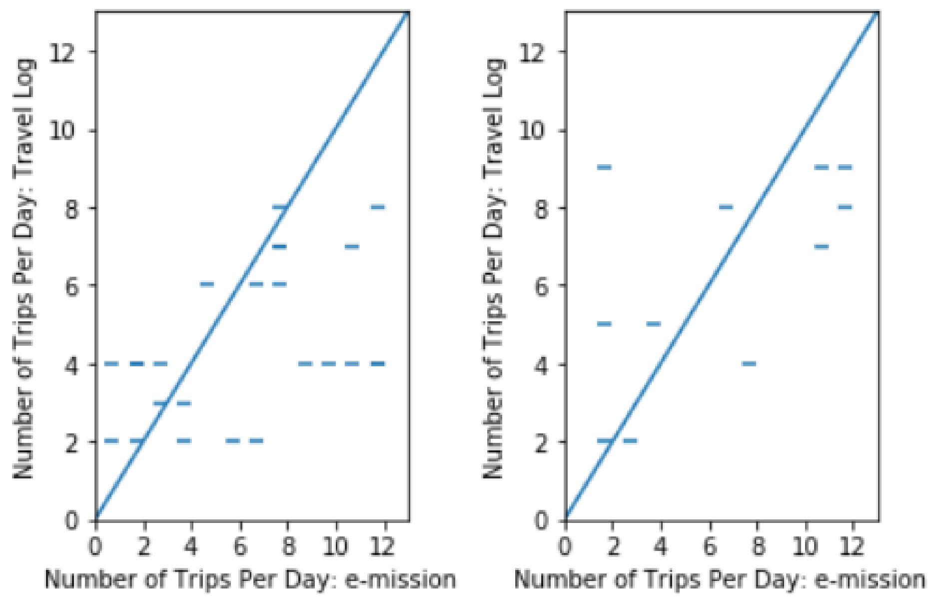


Figure 11. Number of Trips per Day for TPD (L) and Non-TPD (R) Participants

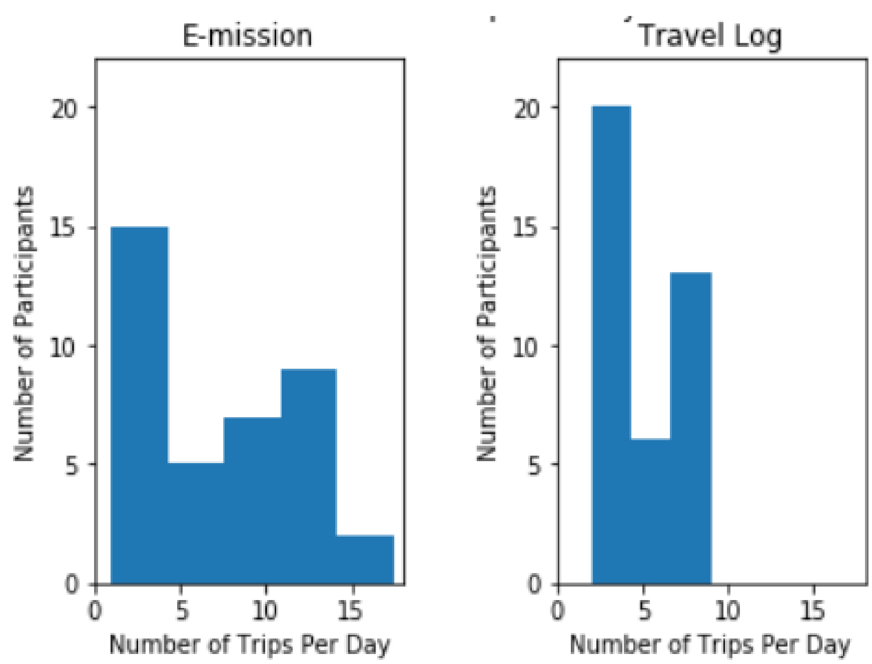


Figure 12. Distribution of the Number of Trips per Day for GPS and Travel Log

Overall, there is a notable difference between the GPS and travel log datasets for the average number of walking trips while the average number of bike and vehicle trips are comparable. Although the average number of biking trips is the same, the sample size for GPS and travel log bike trips is so small that the findings are not compelling. The GPS data yields 36% more walking trips per day than the travel log data. This may occur for several reasons. Since the GPS dataset is generated by processing GPS data with an algorithm, the algorithm could have misidentified certain trips as walking when they were actually vehicle (e.g. transit or auto) trips occurring along congested streets. However, given the difference between the average number of walking trips between the two datasets and studies comparing manual and GPS-based travel diaries, we believe participants likely underreported trips in the travel log.

Within each dataset, we compared TPD and non-TPD participant trip-making. Given the different sample sizes of TPD and non-TPD participants, we applied unequal variances t-tests (also known as Welch's t-test) to test if there is a significant difference between TPD and non-TPD participant trip-making for each mode ($p<0.1$). For the GPS dataset, there is no significant difference between TPD and non-TPD participants for the average number of trips per day for walking, biking, or vehicle trips (Table 20). For the travel log dataset, the difference between TPD and non-TPD participants for the average number of walking trips is not significant while the difference for the average number of vehicle trips is significant. The biking trips were not comparable because there was only one trip logged for non-TPD participants.

Table 20. Average Number of Weekday Trips for GPS and Travel Log Data

	Walking		**Biking**		**Vehicle**	
GPS (n=39)	**GPS**	**Travel Log**	**GPS**	**Travel Log**	**GPS**	**Travel Log**
All	3.4 (n=34)	2.5 (n=15)	1.5 (n=8)	2.5 (n=15)	4.7 (n=34)	4.5 (n=34)
TPD	3.5 (n=26)	2.6 (n=14)	1.6 (n=7)	2.6 (n=14)	4.7 (n=23)	3.9 (n=23)
Non-TPD	2.9 (n=8)	2 (n=1)	1.0 (n=1)	2 (n=1)	4.5 (n=11)	5.6 (n=11)

Note: Differences between TPD and Non-TPD for all modes are not significant for GPS data, but are significant for Travel Log data at 0.1 level of significance

4.4.2. Trip Lengths

We compared the average trip distance for 39 GPS and travel log participants. We also compared the average trip distance for walking, biking, and vehicle trips between TPD and non-TPD participants within each dataset. The average trip distance for travel log is 16% higher than GPS, with an average trip distance of 5.2 and 4.5, respectively.

Figure 13 illustrates the relationship between the average trip distance for the travel log and GPS trips on the match date; we see travel log trips are generally longer than GPS trips. Figure 14 illustrates the same relationship but separates into TPD and non-TPD participants. Both TPD and non-TPD participants show that travel log trips are generally longer than GPS trips. The difference in trip distances may be due to the way trip distances are calculated for travel log and GPS trips. Since the GPS trip distances are calculated through a GPS-app, the app has some lag time in detecting the start of a trip. When inspecting several individual GPS trips, we observed that trips that likely originated from a participant’s residence would be logged as starting in the vicinity of the residence rather than right at the building. On the other hand, travel log trip distances were calculated using the reported start and end destinations so there was no lag distance. Figure 15 and Figure 16 show the distribution of average and individual trip distances for the 39 participants, respectively. The GPS dataset has significantly more short trips, which is in line with the studies referenced in the previous section (number of trips).

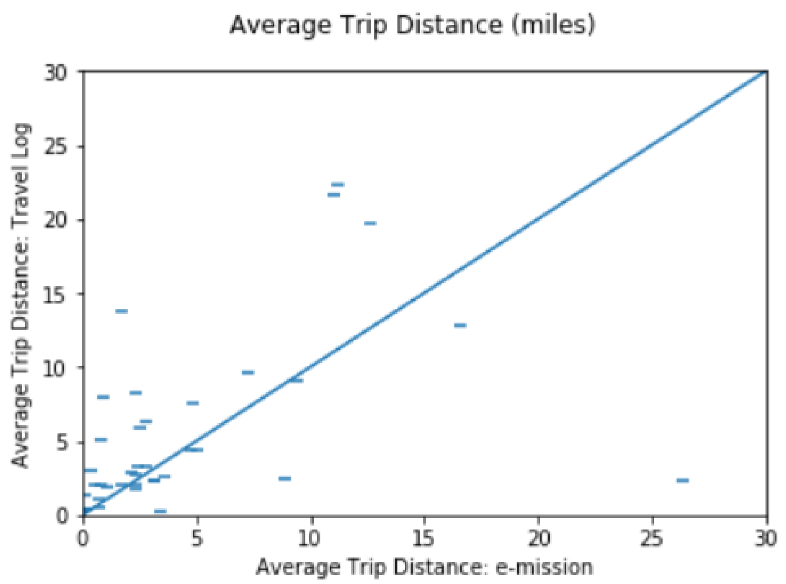


Figure 13. Average Trip Distance for GPS and Travel Log

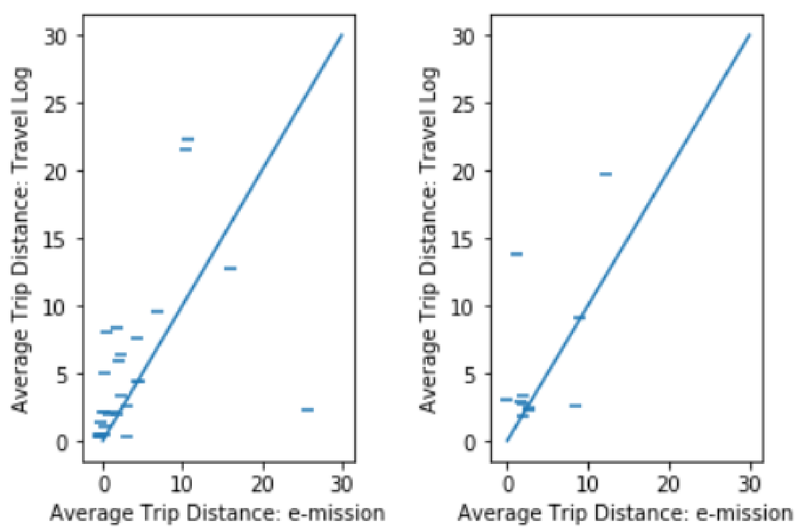


Figure 14. Average Trip Distance for TPD (L) and Non-TPD (R) Participants

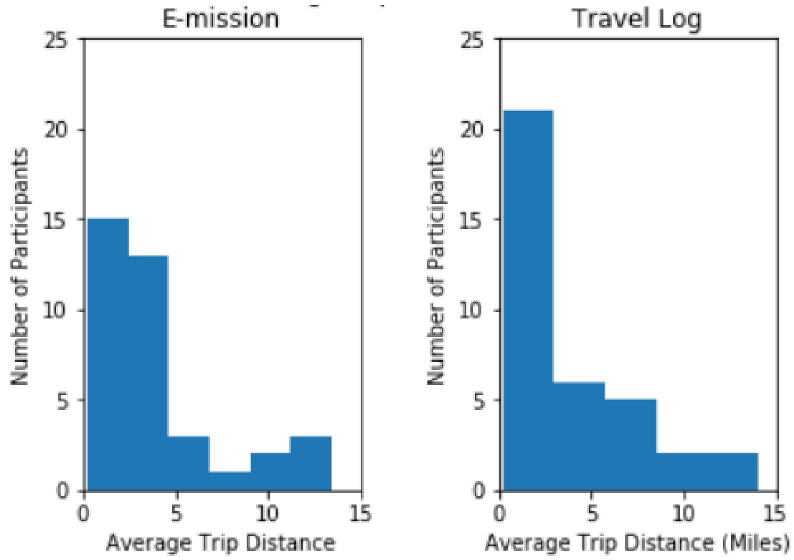


Figure 15. Distribution of Average Trip Distances for GPS and Travel Log

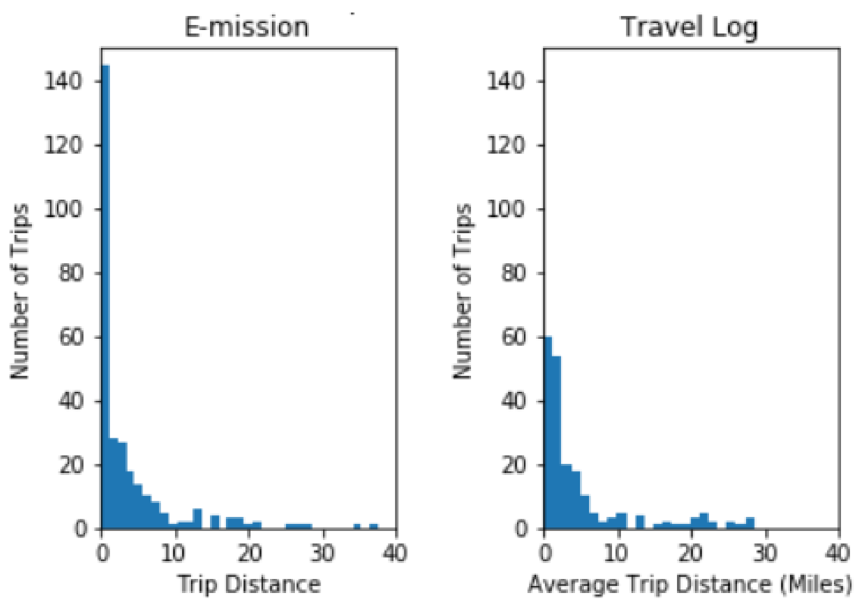


Figure 16. Distribution of Individual Trip Distances for GPS and Travel Log

The average distance of all walking and vehicle trips seem comparable between the two datasets. The average length of travel log bike trips is much higher than the average length of GPS bike trips, but the sample size for GPS and travel log bike trips is so small that the findings are likely not meaningful. The average GPS vehicle trip is 8% longer than the average travel log trip. One reason this discrepancy may have occurred is because the GPS trip distance is the actual distance traveled, which may not always be the most direct or efficient, while the travel log trip distance is a calculation of the most direct route between the origins and destinations participants provided.

Within each dataset, we compared TPD and non-TPD participants' trip distances. Similar to the number of trips analysis, we applied unequal variances t-tests (also known as Welch's t-test) to test if there is a significant difference between TPD and Non-TPD participant trip-making for each mode ($p<0.1$). There were no significant differences between TPD and Non-TPD participants' trip distances for walking, biking, and vehicle trips.

Table 21. Average Length of Weekday Trips (GPS vs. Travel Log)

	Walking		**Biking**		**Vehicle**	
	GPS	***Travel Log***	***GPS***	***Travel Log***	***GPS***	***Travel Log***
All	0.5 (n=34)	0.4 (n=15)	0.3 (n=8)	1.5 (n=2)	7.0 (n=34)	6.5 (n=34)
TPD	0.6 (n=26)	0.4 (n=14)	0.3 (n=7)	1.5 (n=2)	7.1 (n=23)	6.7 (n=23)
Non-TPD	0.3 (n=8)	0.2 (n=1)	0.17 (n=1)	N/A (n=0)	6.8 (n=11)	6.1 (n=11)

Note: Differences between TPD and Non-TPD were not significant ($p>0.1$)

Similar to other studies, we find that participants tend to under-report walking trips as well as shorter trips. However, the difference is less pronounced for vehicular trips. For this reason we report the GPS results for walking trips in section 4.6 on co-benefits below.

4.5. Travel Behavior Determinants of Affordable Housing Residents

Here we report the results from multivariate statistical analyses to determine if participant VMT is associated with proximity to high-quality transit controlling for household, site and neighborhood-level characteristics that have been found to influence VMT (as discussed in the literature review in Section 2).

4.5.1. Does Transit Proximity affect VMT of Affordable Housing Residents?

We ran a multi-variate ordinary least squares (OLS) regression of total daily VMT per participant (dependent variable) for the one day of travel log data on various individual, site-level, and neighborhood level characteristics including those associated with TODs (

Table 22). VMT in this context is comprised of a participant's drive alone or shared ride trips for one "representative" day in their travel log.

Table 22: Results of Multivariate OLS Regression of VMT

Variable	Coefficient	Significance
Individual and Household Level variables		
Age	-0.51877	***
Household Size	-3.52272	**
Presence of School-Aged Children	5.922135	
Household Income Midpoint	0.000364	**
Part Time Worker	-6.42828	
Not Working	0.34996	
Vehicle Ownership	12.36485	*
Building-Level Variables		
Parking Ratio	-3.16955	
Number of Housing Units at Site	-0.0439	
Net Density of Site (units/acre)	-0.16829	**
Neighborhood, City and Destination-Level Variables		
Residential Density (HH/acre)	0.041007	
Emp. Access Index (jobs/mi^2)	-1.9E-05	
% HH in Single Family-Detached	-2.24976	
Walk Score of Neighborhood	-0.10915	
Job Destination < 0.5 miles from HQT	-3.12655	
Housing <0.5 miles from HQT	-5.26748	
Dummy for sites in LA	11.91816	
Constant	72.17369	***

***p-value<.01 ** p-value <.05 * p-value <.10

There is no statistically significant relationship between VMT and any of the TOD variables. Model results were very sensitive to different specifications, which could indicate that either the sample wasn't sufficiently large to capture the variation in TOD factors, or unmeasured factors that explain VMT variability were not included.

At the building level, development net density was negatively associated with VMT. It is possible that the net density of the site may be associated with either the site design (e.g., walkability) or perhaps neighborhood design, making driving less appealing. Further investigation into high-density affordable housing developments might help illuminate why a negative association with VMT exists – such as lower on-street parking availability – regardless of proximity to high-quality transit. Further research is needed to understand this relationship and if site density is capturing unobserved variability of another factor influencing VMT. While parking ratios were insignificant, qualitative data collected during our surveys indicated that residents at sites with insufficient parking parked on-street (particularly in lower density suburban and urban neighborhood locations).

VMT also declined with increasing participant age as well as household size. Vehicle ownership has a robust positive relationship with VMT in our sample. As incomes increase, there is a small but statistically significant relationship with VMT.

The insignificant relationship of TPD and VMT could be attributed to a number of factors that this research can build on – such as transit quality or distance to other amenities that are not as readily or conveniently accessible by transit from a housing site. Many employed participants in TPD developments, for example, worked in outlying areas that were not connected to the transit network. This was particularly common in suburban neighborhood TPD sites in the Bay Area, and for each of the urban core and urban district TPD sites in LA.

4.5.2. Does Transit Proximity affect Total Daily Driving Trips?

The next multivariate regression model (Table 23) analyzes the relationship between total number of driving trips of a participant's representative day with various TOD factors.

Table 23: Results of Multivariate OLS Regression of # of Driving Trips (Travel Log)

Variable	Coefficient	Significance
Individual and Household Level variables		
Age	-0.04019	**
Household Size	0.29392	
Presence of School-Aged Children	-0.16228	
Household Income Midpoint	1.83E-05	
Part Time Worker	-0.11041	
Not Working	0.345918	
Vehicle Ownership	1.952266	***
Building-Level Variables		
Parking Ratio	-1.24868	**
Number of Housing Units at Site	-0.00475	
Net Density of Site (units/acre)	-0.01474	**
Neighborhood, City and Destination-Level Variables		
Residential Density (HH/acre)	0.000595	
Emp. Access Index (jobs/mi^2)	-9.47E-06	
% HH in Single Family-Detached	-3.06835	
Walk Score of Res. Neighborhood	-0.00949	
Job Destination < 0.5 miles from HQT	-0.33295	
Housing <0.5 miles from HQT	-1.58453	*
Dummy for sites in LA	0.788771	
Constant	8.758063	***

***<.01 **<.05 *<.10

There was a statistically significant negative relationship between the number of driving trips and transit proximity, even when controlling for parking ratio, which was also negatively associated with the number of driving trips and vehicle ownership, which was positively associated with driving trips. The association between vehicle trips and transit proximity could mean that residents are only making automobile trips for purposes that absolutely cannot be made by non-automobile modes – such as commuting, or school drop-off and pick-up, which may be longer distances (thus the insignificant VMT results). The negative relationship between parking ratios and vehicle trips (i.e., higher ratios associated with fewer vehicle trips) merits further research, especially into on-street parking availability and price. Qualitative observations, especially at some of the suburban TPD sites, led us to believe that residents frequently park on the street or nearby, especially at sites with low parking ratios.

The other significant associations with vehicle trip frequency were the net density of the site and age of the participant, which were both negatively associated with the number of vehicle trips.

4.5.3. Does Transit Proximity affect the Vehicle Mode Share of Daily Trips for Affordable Housing Residents?

The following multivariate regression models look at proportion of trips by mode, broken down between car and transit trips (Table 24).

Table 24: Multivariate OLS Regression of Car or Transit Mode Share

	Percent Trips by Car		Percent Trips by Transit	
Variable	**Coefficient**	**Sig.**	**Coefficient**	**Sig.**
Individual and Household Level variables				
Age	-0.00555	*	0.000891	
Household Size	0.025446		-0.0263	
Presence of School-Aged Children	-0.08629		-0.01586	
Household Income Midpoint	7.92E-07		-1.57E-07	
Part Time Worker	-0.0803		0.013111	
Not Working	-0.08788		0.105853	*
Vehicle Ownership	0.421236	***	-0.25785	***
Building-Level Variables				
Parking Ratio	-0.16685	*	0.054531	
Number of Housing Units at Site	-0.00052		0.000173	
Net Density of Site (units/acre)	-0.00239	*	0.001115	**
Neighborhood, City and Destination-Level Variables				
Residential Density (HH/acre)	-0.00053		-0.0004	**
Emp. Access Index (jobs/mi^2)	-1.36E-06		2.38E-07	
% HH in Single Family-Detached	-0.12209		-0.19429	
Walk Score of Res. Neighborhood	-0.00253		-0.00108	
Job Destination < 0.5 miles from HQT	-0.17613	*	0.009416	
Housing <0.5 miles from HQT	-0.09169		0.001991	
Dummy for sites in LA	0.098859		0.204218	***
Constant	1.506991	***	0.300991	*

***<.01 **<.05 *<.10

There is no statistically significant relationship between the share of auto or transit mode trips and transit proximity. Jobs proximity to HQT was negatively associated with the proportion of auto trips, and neighborhood density was negatively associated with transit mode share – a relationship that merits further research.

The net density of the site is negatively associated with auto mode share and positively associated with transit mode share, again potentially capturing other unobserved characteristics of the site or neighborhood. Consistent with our previous models, vehicle ownership shows robust significance for both proportion of car trips (positive) and proportion of transit trips (negative). Unemployed participants were more likely to have higher proportions of transit mode shares than fulltime workers.

4.6. What are the Co-Benefits of Affordable TODs?

As described in the literature review, researchers have identified a wide range of co-benefits of TODs beyond reduced VMT, ranging from reduced travel costs, to greater mobility choices and freedom. We aimed to capture the co-benefits of affordable TODs through both quantitative and qualitative focus group analysis. First, we summarize some of the quantitative findings around increased use of non-motorized transit and ease of commute, followed by the themes that emerged from the focus groups.

4.6.1. Do participants walk more in affordable TODs when compared to non-TODs?

We tested the frequency of walk trips in our travel log data to determine if transit proximity or other TOD factors influenced this travel mode (Table 25). We find from our analysis of the travel log data that transit proximity is significantly associated with the number of walk trips taken. The metric for land use diversity (or lack thereof) - % of single family homes – is also positively associated with walk trips. This may be related to recreational walking, or perhaps the metric does not adequately capture land use diversity but rather proxies for perceived safety. It would be important to further explore this relationship and to test other land use diversity metrics. Net density again is positively associated with walking trips, again perhaps proxying for neighborhood design factors. Finally, vehicle ownership and household income are both negatively associated with walking trips.

Table 25: Frequency of Walking Trips (Travel Log)

Variable	Coefficient	Significance
Individual and Household Level variables		
Age	0.006173	
Household Size	0.036709	
Presence of School-Aged Children	-0.00209	
Household Income Midpoint	-1E-05	**
Part Time Worker	0.013766	
Not Working	0.247299	
Vehicle Ownership	-0.57437	*
Building-Level Variables		
Parking Ratio	0.41367	
Number of Housing Units at Site	0.002367	
Net Density of Site (units/acre)	0.003266	**
Neighborhood, City and Destination-Level Variables		
Residential Density (HH/acre)	0.00194	
Emp. Access Index (jobs/mi^2)	8.04E-07	
% HH in Single Family-Detached	2.024999	***
Walkscore of Res. Neighborhood	0.009596	
Job Destination < 0.5 miles from HQT	0.598889	
Housing <0.5 miles from HQT	0.568107	*
Dummy for sites in LA	-0.09833	
Constant	-1.41787	

***<.01 **<.05 *<.10

Walking and Biking Trip Frequency using GPS data

As discussed previously, participants frequently under-report walking and biking trips in their travel logs. For this reason, we also explored the differences between TPD and non-TPD sites for walking and biking trips using the GPS data collected for 85 study participants. Neither the difference between the number and length of walking and biking trips for TPD and non-TPD residents was not statistically significant (Table 26 and($p > 0.1$)

Table 27).

Table 26 Average Number of Weekday Trips (GPS data)

	Walking	Biking	Vehicle
All	1.9 (n=82)	0.4 (n=34)	3.0 (n=81)
TPD	2.0 (n=60)	0.4 (n=28)	2.9 (n=59)
Non-TPD	1.6 (n=22)	0.3 (n=6)	3.2 (n=22)

Note: Differences between TPD and Non-TPD for all modes are not significant ($p > 0.1$)

Table 27 Average Length (miles) of Weekday Trips (GPS data)

	Walking	Biking	Vehicle
All	0.6 (n=82)	0.8 (n=34)	10.8 (n=81)
TPD	0.6 (n=60)	0.9 (n=28)	11.1 (n=59)
Non-TPD	0.6 (n=22)	0.3 (n=6)	10 (n=22)

Note: Differences between TPD and Non-TPD were not significant ($p>0.1$)

4.6.2. Is walking mode share affected by residence in affordable TODs?

In

Table 28 we analyze the relationship between TOD characteristics and walking mode share. None of the TOD variables are significantly associated with walking mode share. Net density as well as the number of housing units at the site are positively associated with walk mode share.

Similar to the frequency of walking trips, vehicle ownership and household income are negatively associated with walk mode share.

Table 28: Results of OLS Regression of Percentage Walk Trips on TOD (Travel Log)

	Percent Trips by Walking	
Variable	**Coefficient**	**Sig.**
Individual and Household Level variables		
Age	0.00281	
Household Size	0.008656	
Presence of School-Aged Children	-0.00793	
Household Income Midpoint	-1.80E-06	*
Part Time Worker	0.020029	
Not Working	0.069484	
Vehicle Ownership	-0.1551	**
Building-Level Variables		
Parking Ratio	0.115065	
Number of Housing Units at Site	0.000825	*
Net Density of Site (units/acre)	0.001038	***
Neighborhood, City and Destination-Level Variables		
Residential Density (HH/acre)	0.000868	
Emp. Access Index (jobs/mi^2)	3.07E-07	
% HH in Single Family-Detached	0.392065	
Walk Score of Res. Neighborhood	0.003339	
Job Destination < 0.5 miles from HQT	0.138685	
Housing <0.5 miles from HQT	0.07645	
Dummy for sites in LA	-0.0921	
Constant	-0.49722	

***<.01 **<.05 *<.10

4.6.3. What is the Availability, Utilization, and Impacts of Transit Passes at Affordable TODs?

As described previously, a number of multifamily affordable TODs include local transit vouchers as an amenity for their residents. Siting affordable housing near transit may not automatically result in a mode change among residents, potentially because of reasons such as cost barriers to using transit services, which offering transit passes seeks to alleviate.

Table 29 summarizes transit pass availability at our selected sites as well as average trip frequency, car and transit mode share. Most of our sites did not offer transit passes, and only 6 of our 19 TPD sites (31.5%) offered passes. None of our 8 non-TPD sites offered transit passes. Sites that do offer passes tended to show a lower amount of total car trips and higher average number of transit trips. In terms of mode share, residents at transit pass sites took nearly 8% more of their trips on transit compared to participants in sites that did not offer discounted transit passes.

Table 29: Discount Transit Pass Availability & Travel Patterns

Discounted Transit Pass at Housing Site?	Number of Sites	Number of Participants	Avg. Total Car Trips per Participant	Avg. Total Transit Trips per Participant	Avg. Percent of Trips by Car per Participant	Avg. Percent of Trips by Transit per Participant
Yes	6	100	2.46	1.06	55%	29%
No	20	191	4.21	0.70	81%	19%

In addition to the site-level transit pass data collected from the Resident Services Coordinator survey, these results were compared to several questions regarding transit pass availability and usage in the Household Demographic Survey. In this survey instrument, residents were asked "Do you receive discounted transit passes as a resident of this property". The collective responses revealed a trend of residents either not receiving or unaware of transit pass availability at their site – summarized in Table 30.

Table 30: Discounted Transit Pass Awareness & Validation

	Residents Reported Receiving Discounted Transit Pass	Residents Did Not Report Receiving Discounted Transit Pass	Total
Transit Pass – Reported by RSC	44 (44%)	56 (56%)	100
No Transit Pass - Reported by RSC	17 (8%)	175 (92%)	192
Total	61	231	292

Approximately 56% of residents living at transit pass sites reported either not receiving or not being aware of transit pass availability. This could be attributed to limits on the resource (e.g. each household only receiving one pass), and that the participant may not have been the person who received and used the pass directly. This could also potentially signal several challenges faced by residents and building staff. Despite living in a TPD, residents might still be reliant on non-transit modes, and taking transit may not be an option to them given their circumstances. Thus, seeking out cost-cutting resources for a mode that may not be convenient or feasible for their everyday needs may not be an immediate priority. This could also point to challenges experienced by property management and resident services staff in disseminating information about transit amenities, particularly given the gamut of other amenities and resources that these staff have to constantly publicize. This may also indicate the need for additional funding for on-going support and integration of services to engage with and fully support residents.

4.6.4. Focus Group Results

Focus groups were held at four sites to represent transit proximate developments in each of the neighborhood types: Oxford Plaza (urban core), Riverwood Grove (urban district), Alta Mira (urban neighborhood) and Camelia Place (suburban neighborhood). Overall, we found that vehicle usage of focus group participants was dependent on more than access to HQT, especially for sites that were not walkable or close to amenities and services (i.e., not TODs, but what some refer to as “transit-adjacent developments”). Yet most focus group participants enjoyed their proximity to numerous transit options, making travel throughout the region more convenient, even among participants with private vehicles. However, participants also valued the freedom, convenience and accessibility that comes with owning a private vehicle. Some participants used transit for cost savings purposes, when gas prices went up or to save money on parking. Nevertheless, participants from each of the focus group sites noted the insufficiency of parking spaces to meet their household needs. The findings are summarized below by the key themes that emerged.

Location

Focus group participants shared that their vehicle use is heavily dependent on more than access to high-quality transit. For developments that aren’t located in areas that are walkable and accessible to amenities and services, participants talked about relying heavily on vehicles. Focus group participants’ feelings toward the neighborhood and general place of residence varied from site to site. Alta Mira residents, the urban neighborhood site in Hayward, felt they were disconnected from the rest of the town, and disliked that the development was far from any recreation opportunities or amenities. As one participant explained, *“I kinda just tell like everybody that comes to visit me, we’re out in the middle of nowhere. It’s like they developed the apartment and the living, but not really the actual living around it. It’s kinda like they just threw us out here and they’re like okay now figure it out.”*

Other than Alta Mira, residents of the other sites spoke positively about where they were located. The level of satisfaction with the area they lived in seemed to be mostly dependent on availability of resources within their vicinity. Residents at Camelia Place in Dublin, the suburban TOD, were positive about their location, as it was surrounded with trails and recreational green spaces, as well as having been built off a commercial corridor that provided plenty of amenities and options for recreation. Residents of Oxford Plaza, the urban core location in Downtown Berkeley praised the various restaurants and events happening nearby.

Proximity to Grocery Options

When asked about their accessibility to grocery options, residents’ responses varied based on location. Each site was located at a different distance from nearby grocery options, so naturally, this created vastly different responses when asked about shopping habits and accessibility. Oxford Plaza had plenty of affordable options within blocks. A resident of this site spoke about their travel habits when grocery shopping. *“Instead of taking my car, I would just walk to Walgreens to pick up milk, something you need right away. You don’t have to go anywhere.”*

Alternatively, Alta Mira residents reported needing to drive across town in order to shop for produce. One tenant described how living in a food dessert led them to drive more, which necessitated car ownership. *“We don’t really have too many options that are close to us for groceries[...]. There’s nothing we can really do local. We have to travel somewhere. You have to have transportation.”*

Employment

Most focus group participants use public transit to reach their place of work, and most continued working for the same employer despite moving to TPD. Although their new home brought many of them to a city different than their previous residence, they were able to take advantage of the access transit, reducing their need to drive to work. One person expressed the convenience of not having to change their travel patterns drastically: *"I've been at my job for 18 years so I wasn't looking for another job. It takes me about 45 minutes on BART. It's convenient for me, I'm so glad that public transportation is just like 5 minutes away because it gets me to downtown Oakland in like 45 minutes, so it's just a great place for me to live."*

Proximity to transit was especially important for residents with disabilities who needed to commute to work. One resident who was unable to drive to work, because of a disability sustained on the job discussed how living close to BART and bus allowed for him to expand his job search: *"It was extremely hard for me to find a job. Then I moved to this location and live close to the BART station, then I started applying to jobs in different cities - like to San Francisco or to Oakland, nearest the bus station area. Luckily I found a job in Alameda County. It is because of the BART that I can commute.*" Commuting on public transit meant this participant could go farther and no longer needed to pull over to rest during long commutes. BART and bus provided him with the opportunity to not be limited by his disability in his commute to work.

Access to Medical Services

Several focus group participants expressed difficulty in finding affordable medical care near their homes. A few of the participants mentioned that affordable medical care became more difficult to reach since moving, as they are now farther from their original medical providers. *"All my doctors are in Oakland and I've had an awful time getting a doctor here in Hayward because most of them are closed. And it takes me 4-5 buses, which is a 6-8 hour round trip. 4 buses at least."* Another resident of a different city had similar sentiments. "*I have to go all the way to Oakland for my doctor. I've been trying to find a doctor here in Berkeley. I haven't had any luck. They give me these numbers to call, they're not accepting new patients.*" The burden of having to travel long distances to access primary medical care resulted in one resident needing to find childcare. *"Well, I go to Kaiser in Richmond and so I don't have a car [...] I had an appointment today and I couldn't take my baby with me."*

Access to School

Participants frequently brought up that their or their child's schools are easy to reach primarily due to proximity and accessibility via transit or walking. As one participant describes, *"So my kids, they take the bus, they take the school bus. And the school bus stop is really close here."* Another participant described their child's commute to school, "*Yeah I walk. It's across the street, so it's really easy. Sometimes he can walk by himself."*

Neighborhood Entertainment and Services

Overall participants seemed to be satisfied with their access to entertainment and recreation options. At Oxford Plaza residents seemed to be overwhelmingly pleased with their access to neighborhood events. Participants described a wide range of community events, places, and activities. One participant from this urban core site described their connection to the neighborhood and its opportunities as, *"We have three museums within a close distance. You know I volunteer at the Berkeley Historical Society and there's just all these great opportunities. We've got the David Brower center right here so there's no shortage of things to do. Of course, Berkeley City College right here. There's a lot of different things to be able to enhance and enrich ourselves and our loved one's lives."* At Oxford Plaza there was more of an emphasis on community entertainment, events, and activities occurring outside of the property, whereas at the other sites there seemed to be more of an emphasis on the entertainment and activities organized on-site.

Participants at Alta Mira also seemed satisfied with their access to malls, shopping centers, and community public spaces, like libraries and parks, but some did express concerns regarding limited access to restaurants within a reasonable distance. One participant explained, *"There aren't really any restaurants real close till you get towards downtown."*

Municipal and Onsite Resources and Services

At all sites, participants described taking advantage of the social services offered by their communities. However, this was especially true at Oxford Plaza, where residents shared a plethora of resources with one another. One participant from Oxford Plaza described her satisfaction with the services Berkeley provides for those with disabilities, *"I think the advantage that Berkeley is really supportive with disabled communities. When my son started Berkeley High I was able to train him to walk across the street so that was a blessing. Even now that he's 18 he's doing a community program so they're helping him learn how to catch BART and bus locally so just having the simplicity of him knowing his whereabouts."* Another participant at Oxford Plaza explained, "*The city has a Youth Works for teens and stuff for summer. My son did one."* Throughout the discussions, participants described turning to a variety of community services and resources, including health clinics, legal aid, career centers, and food assistance organizations.

In addition to community services, participants also described appreciating the services, events, and after-school programs that their buildings organized. As one participant explained, *"They keep the kids really busy, they have a lot of activities for them. They have after school club homework program, I mean they're always doing something."* At Camellia Place, participants enjoyed food donations by nearby businesses in addition to events and services provided at their property. These site-based services may reduce participants' needs to travel to other places to access services such as childcare or after-school activities.

Access to Transit Options

Many participants cited proximity to transit options as one of the primary benefits of living in their current homes. Participants reported that having access to public transit made commuting to employment opportunities, running errands, and visiting friends and family more enjoyable and convenient. One respondent described her experience living in one of the transit-oriented developments, *"It's just a perfect place for me because I don't drive, and public transportation, bus and BART is there. I can go anywhere I want to in the surrounding area on public transportation, and so it's the perfect place for me."* Another responses included, *"I like this place. One of the reasons is because it is very close to the BART."* and *"I think it's very convenient for me to have BART because I can just go to school and take a bus or other places I have to go. I'm happy I get to live by BART."* Furthermore, throughout the discussions participants also highlighted the critical role that transit plays in their day-to-day lives, as one participant explains, *"So coming here, transport has really helped with job search, doctors search, grocery shopping, everything."*

Even participants that had access to private transportation reported that they enjoyed the convenience of living within a close distance to transit options, especially BART. One participant described the convenience of being able to choose between using transit or driving their car to work, *"The advantage of this place is that we are very close with the BART, connecting us to all the Bay Area. I am working in Oakland, and for me sometimes I want to drive, I can drive 30 minutes or sometimes I just walk by to the BART and commute in the BART and it's very accessible, very easy."* Another participant described the convenience of being able to travel with their children by transit, *"As far as BART being next to us, it's very convenient. If I do have to go to Oakland, cause my aunt goes over there, Oakland's right here. I don't have to take the car and my kids get to experience different types of transportation."* Another participant described preferring to use transit throughout the week, despite owning a car, *"I drive only on Sundays. But other than that, I ride bus and BART through the week because I like it."*

Although some participants do not use transit day-to-day, they too mentioned that they enjoy having transit as a back-up option. One participant explained *"But like I said, it's helpful -- the car may break down or something may happen and I might need to catch the bus or the BART so it's nice having the medium of not being too far out from everything else."*

Walkability

Many of the respondents at Oxford Plaza described the convenience of being able to walk to their destinations. One participant shared her experience commuting to work while living at Oxford Plaza, *"When I was going to work I just would conveniently walk there because my job was like 5 blocks away from here and if I was late I would just go across the street and get on the bus."* Another participant described how easy her disabled son's commute to school was prior to graduating, "*My son took the school bus, he could walk right there. It was great, everything was great, and it continues to be great*." Other participants described the convenience of being able to walk "everywhere" and being able to walk to nearby stores to pick up household necessities like milk. Respondents in less accessible areas like Alta Mira felt that walking to common destinations was not a realistic option. Instead, most participants described having to rely on private vehicles to access destinations.

Transportation Costs

Participants that traditionally rely on their private vehicles described times when they rely on transit to save money. As one participant explains, *"The reason why we take rail is cause I have a big truck and the gas prices are sky high. So I switch off the light rail and truck."* Some participants also mentioned using transit when trying to save money on parking when traveling to special events. For example, two participants at Alta Mira explained that they take BART when traveling to Oakland A's games to save money by avoiding having to pay for parking.

Transit Reliability

Many participants brought up issues pertaining to transit unreliability, especially at Riverwood Grove. As one participant explained, "*VTA is really, really bad with their schedules. They're more often late than they are on time*." Throughout the discussions, participants mentioned they were hesitant to rely on transit to get to work or other places on time, such as medical appointments. In some cases, participants explained that they chose to drive to appointments to avoid being late.

Participants also brought up issues with poor interconnectivity of transit systems and modes. One participant described their commute to work using multiple transit systems, "*The only thing that is terrible about my commute is the fact that I get off at the Fruitvale station [referring to BART] and I have to catch a connecting bus to get to work and they're almost never in sync. Even though it's only a 30 minute commute for me, there's a 45 minute wait half the time.*" Participants at Oxford Plaza did not bring up transit reliability, which may be due to the fact that the location is served more frequently by buses and trains because of its central urban location.

Access to Private Vehicles

Participants reported valuing the freedom, convenience, and accessibility that comes with owning a private vehicle as well. Some participants reported that having access to private transportation was crucial because of a disability they or someone in their family have. When discussing access to medical care, one participant shared, *"But again, me having private transportation is a blessing because of my son, who is special needs."* Having access to a vehicle allows them to have reliable transportation to medical care and also makes traveling to medical equipment more convenient. As one participant explains, *"My wife drives so it's a little easier and more convenient for her. She's on disability and she's gotta carry her oxygen bottle in the car so it's easier."*

Access to a vehicle may also open up employment, educational, and social opportunities for those with disabilities. As one participant shared, *"For me, the kind of work I do, I do need to drive. I do medical case management so I do need to be able to drive to see my patients. If I were not able to drive I think it would make me, doing the work I do impossible. I mean I would have to completely switch over to something else. I'm disabled with polio so it's pretty specialized what I'm able to do."*

Participants with access to a vehicle also seemed to appreciate the freedom that comes with it. As one participant described, *"Me, myself, I do have a vehicle so I'm lucky to get from one place to another[...]."* Another participant described transitioning from relying primarily on public transit to buying a car as "*really moving up*" indicating the status symbol of car ownership.

Furthermore, one participant described appreciating the fact that owning a vehicle enabled them to access farther out recreational activities. They explain, *"Sometimes it's good to have your own transportation in case you wanna get out of the area ya know, on a weekend or a Sunday or Saturday."*

In the discussion at Alta Mira, the more suburban site, residents highlighted the fact that in some locations, a vehicle may be necessary to fulfill household needs if necessities are inconveniently spread throughout the area. At this site, participants commonly noted the need to travel far out when running errands, such as grocery shopping. As one participant explains, "*Yeah, I think you need a car. Because even with shopping, I mean unless you're avid walkers, you have to get there. I don't know anybody who wants to walk 30 minutes just for some milk [...]."*

Parking Availability

At all sites, participants mentioned that they faced issues related to insufficient parking for their household's needs. Some participants, especially at Alta Mira, where most of the off-street parking was allocated to BART, reported receiving fines and tickets as a result of not having access to enough off-street parking for their household. In one instance a family had to make a difficult tradeoff between having access to adequate private transportation for their family and being able to put food on the table. The participant explained, *"I had to get rid of my car, my second car because I was getting tickets and I couldn't afford to pay them. It was either food or tickets. So, I got rid of one car, but I have to take my husband to work, take my daughter to school, come back, pick up my husband, pick up my daughter. It's just I'm on the run every morning."*

Although convenient access to transit provides participants with the ability to access many day-to-day destinations, participants felt that having access to at least one or more parking spaces per household is necessary. Some participants even expressed it as a health and safety issue. As one participant explained, *"We still need one parking space at least per tenant because it's easy to say you'll go by bus or BART, but then you have kids and your kid has 104 degree fever. You have to rush to the doctor, obviously we are not rich people living here, we will not be able to call a taxi so we need a car."*

5. Discussion and Conclusions

The State of California is increasingly incentivizing housing development, including affordable housing, near high-quality transit as part of its greenhouse gas reductions strategy. Yet there has traditionally been little information about the travel patterns of the specific population living in affordable housing, making it difficult to accurately estimate the VMT impact of siting affordable housing near high-quality transit. This study sought to begin to fill this information gap and build on emerging studies on trip generation and travel behaviors to better quantify VMT impacts of affordable TODs.

We collected primary data from various sources to better understand these travel patterns and to characterize the co-benefits of living in an affordable TOD. We also sought to validate the most common VMT data collection instrument – travel logs – using a GPS app. We found that according to our travel log data, low income residents at affordable sites near HQT take fewer vehicle trips and more walk trips than residents at affordable sites that are greater than 0.5 miles from HQT. Job site accessibility to transit was also associated with lower vehicle mode share. VMT and transit mode share, however, were not associated with TOD factors. Consistent with other studies, income and vehicle ownership were positively associated with car trips and VMT. At the building level we found net density of the site to consistently be associated with fewer driving and more transit and walking trips and mode share as well as lower VMT. It is not clear whether the site density is proxying for another unobserved characteristic, like the site design or the lack of on-street parking. Further research would be needed to tease out if the site density has independent effects on resident travel patterns. Finally, we found results for site level parking availability that were inconsistent with other research (i.e., higher ratios associated with fewer driving trips and less driving mode share). Our qualitative findings point to the use of on-street parking, especially for sites with low parking ratios, which may be influencing these results.

As discussed in the literature review, there are a number of other factors that can influence VMT beyond proximity to transit stations, and through our focus groups and surveys we identified many of the barriers to greater transit usage including the inaccessibility to jobs and inconvenience to certain destinations, among other barriers. The fewer vehicle trips, but insignificant VMT may be related to longer commutes done by car for TOD residents, due to distant jobs far from transit. The findings do point, however, the importance that policies and investments consider the other four D's (density, design, diversity and destination accessibility) when planning for TODs.

It is important to note several study limitations that may limit its generalizability. The study was designed to be exploratory and the statistical insignificance of TOD on VMT may be a result of our relatively small sample, which was limited by budget and recruitment challenges. The stratified random sample across place types, a method that was designed to be representative of the types of neighborhoods where affordable units are currently located, led to under-sampling for certain place types that may be closer to the "ideal TOD" that policy makers are striving towards (e.g., higher density, accessible design, diverse land uses and destination accessibility). Despite the study incentive of $50, the study design which involved a follow-up visit, lengthy survey, and travel log "homework" made it especially difficult to recruit, especially at low density sites where residents seemed relatively unengaged in community events. Stay at home moms were the most frequent participants, likely due to time availability and their presence at sites. The types of trips conducted by this population may be more convenient by vehicle (e.g., grocery and school drop off) than transit, potentially biasing our results. Although we aimed to get a random sample, we ultimately relied on the willingness of sites to participate, which could have potentially biased results.

Despite under-reporting non-motorized trips, we found that the travel log data was relatively robust when compared to GPS data. Trip lengths were under-reported by almost 10%, however. GPS data did reveal more and longer walking trips for TOD residents, however possibly due to the small sample of GPS participants, the difference was not significant.

Our focus groups illustrated some of the limits to transit proximity alone to reducing VMT, although overall TOD participants valued central locations and having many transportation options nearby. Some of the sites, although technically within walking distance of transit, were in suburban and somewhat remote locations with low accessibility to many destinations, even by transit. Disability, unreliability, and other characteristics that may make using transit inconvenient were highlighted as reasons that some participants preferred car travel, especially for certain trip purposes like medical visits.

Yet, the findings from our focus groups do make the case for TOD that provides multiple travel options, is conveniently located and in a walkable context with services and retail nearby. Participants reported valuing the freedom, convenience, and accessibility that comes with living in a centrally located neighborhood with many transit options. But they also noted the same freedom, convenience and accessibility that comes with owning a private vehicle. This was especially true in families with disabilities or specific medical needs. Focus group participants living in TODs discussed expanded access to jobs, even enabling broader job searches, but more limited access to healthcare, which was often far away from TOD sites.

Few of the developments we surveyed offered transit incentives such as discounted passes. Furthermore, we found that over half of the participants that lived in developments that offered such passes either did not use or were unaware of their availability. This finding points to the need for better outreach and education around transit opportunities and programs for TOD residents. One of our original proposed research designs, conducting a before and after survey of people on the wait list to a new affordable TOD, was infeasible due to time and budget constraints. However such a study design may be helpful in understanding what happens when low income households move from non-TODs to TODs, to better understand the impact of affordable TOD.

Despite the insignificant relationship with VMT, the continued State and local policies that focus on TODs will ensure that such areas continue to get investments that will make them more attractive, convenient and sustainable. For this reason, it is possible that the TPDs we studied will contain the amenities (e.g., grocery, entertainment, childcare, etc.) and become more accessible to destinations (e.g., jobs, medical services) via transit, thereby transforming existing TPDs into higher opportunity areas into the future and possibly reducing VMT and GHG emissions of existing residents. It is important that California policymakers continue to ensure that low income households are able to access these areas into the future. In addition to ensuring the development of affordable housing in TODs, however, this study points to the need to make jobs and other destinations more accessible via transit, to improve the walkability of neighborhoods both through design and ensuring local destinations near affordable housing sites, and to expand transit services and ensure destinations (e.g., medical, commercial, jobs, schools, etc.) locate near existing transit.

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