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What's Behind Recent Transit Ridership Trends in the Bay Area? Volume I: Overview and Analysis of Underlying Factors

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16. Abstract

Public transit ridership has been falling nationally and in California since 2014. The San Francisco Bay Area, with the state's highest rates of transit use, had until recently resisted those trends, especially compared to Greater Los Angeles. However, in 2017 and 2018 the region lost over five percent (>27 million) of its annual riders, despite a booming economy and service increases. This report examines Bay Area transit ridership to understand the dimensions of changing transit use, its possible causes, and potential solutions. We find that: 1) the steepest ridership losses have come on buses, at off-peak times, on weekends, in non-commute directions, on outlying lines, and on operators that do not serve the region's core employment clusters; 2) transit trips in the region are increasingly commute-focused, particularly into and out of downtown San Francisco; 3) transit commuters are increasingly non-traditional transit users, such as those with higher incomes and automobile access; 4) the growing job-housing imbalance in the Bay Area is related to rising housing costs and likely depressing transit ridership as more residents live less transit-friendly parts of the region; and 5) ridehail is substituting for some transit trips, particularly in the off-peak. Arresting falling transit use will likely require action both by transit operators (to address peak capacity constraints; improve off-peak service; ease fare payments; adopt fare structures that attract off-peak riders; and better integrate transit with new mobility options) and public policymakers in other realms (to better meter and manage private vehicle use and to increase the supply and affordability of housing near job centers).

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What's Behind Recent Transit Ridership Trends in the Bay Area?

Volume I: Overview and Analysis of Underlying Factors

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Executive Summary: What's Behind Recent Transit Ridership Trends in the Bay Area?

ES.1. Introduction

Public transit ridership has been slipping nationally and in California since 2014. The San Francisco Bay Area, home to one of the world's most dynamic regional economies, as well as densely-developed, transit-friendly San Francisco, has the highest transit mode share in California, and until very recently had bucked national and state trends in declining transit use. The Bay Area Rapid Transit District (BART), in particular, had been the shining exception to the state's transit ridership woes, increasing boardings by nearly nine percent between 2013 and 2016.

Recent patronage data, however, suggest that the Bay Area may not be immune to the ridership declines plaguing most other American cities. In 2017 and 2018, the region lost over 27 million annual boardings, representing over five percent of all transit patronage. These losses are particularly concerning because the region has committed substantial public resources to improving and expanding public transit service, and, unlike patronage losses witnessed in the recent Great Recession, the Bay Area economy is booming.

This study examines recent transit ridership trends in the San Francisco Bay Area—the nine counties in the Metropolitan Transportation Commission (MTC) region—with a focus on the recent patronage downturn and its possible causes. It is, in many ways, a companion to a UCLA Institute of Transportation Studies report on falling transit use in Greater Los Angeles, completed in 2018 for the Southern California Association of Governments (Manville, Taylor, and Blumenberg, 2018a). Transit use in Southern California has fallen longer and farther than in the Bay Area, and our analysis there revealed a smoking gun: dramatic increases in household motor vehicle access associated with equally dramatic declines in the number of travelers dependent on public transit for mobility. We find no smoking gun here, but instead a constellation of factors that, in combination, are likely depressing Bay Area transit use.

We summarize the findings of our analysis in this executive summary. We begin with a review of what we know about changes in transit ridership, then turn to potential explanations for waning ridership, and finally conclude with recommendations for reversing the region's troubling transit use trends.

ES.2. What We Know about Changes in Transit Ridership

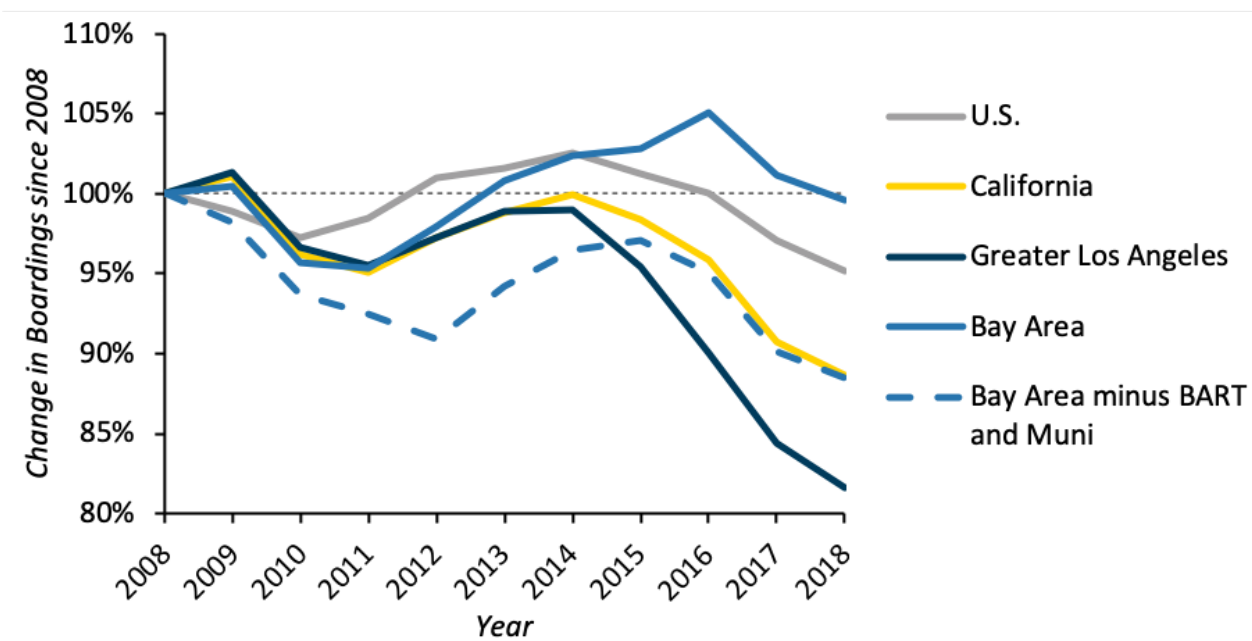
The data analyzed for this study reveal significant changes in Bay Area transit during the 2010s, in terms of patronage and provision of service across operators, modes, and times and days of service. We also observe changes in where people live and work in the region, in the available transportation services, and in the population sub-groups more or less likely to use transit, as well as in the frequency members of those sub-groups tend to ride. Our data come from varied sources, including the National Transit Database (NTD) (FTA, 2019), the California add-on of the National Household Travel Survey (FHWA, 2009, 2017), the U.S. Census and American Community Survey (U.S. Census Bureau, 2019), and the LEHD Origin-Destination Employment Statistics (LODES) (U.S. Census Bureau, n.d.), among other sources.

ES.2.1. Bay Area Transit Use Trends

Transit patronage in the Bay Area is slumping, but not collapsing as in some other regions in the U.S. Amidst a national decline in transit ridership that has approached crisis levels in a few metropolitan areas, the Bay Area has only recently started losing passengers. But while the overall downturn is relatively recent, there were troubling signs in the years leading up to it. After showing some signs of recovery after the Great Recession, Bay Area operators, excluding the San Francisco Municipal Transportation Agency (SFMTA or Muni) and BART began to lose riders in 2016, ahead of the region-wide drop in 2017. **Figure ES-1** shows that high transit ridership on BART and Muni, the region's two largest operators, masked earlier, and in some cases substantial, ridership losses on other operators. Still, a year later slumping ridership on Muni and BART pulled regional totals down. Moreover, regional population and employment increased during the 2010s, carrying overall ridership up with it; yet per capita ridership edged downward ten percent, from 72 annual trips per Bay Area resident in 2008 to 65 annual trips per capita in 2018 (FTA, 2019). The recent decline in ridership should be cause for concern, so too should the preceding decade of gradually falling transit use per capita, which was largely masked by rising population.

Some operators have fared better than others. In general, rail operators and operators that serve major job centers like downtown San Francisco, such as BART and Caltrain, have performed better than bus service providers and systems operating outside the region's core. Volume II presents detailed analyses of patronage and service trends on the region's eight largest operators: Muni, BART, Alameda-Contra Costa Transit District (AC Transit), Santa Clara Valley Transportation Authority (VTA), Peninsula Corridor Joint Powers Board (Caltrain), San Mateo County Transit District (SamTrans), Golden Gate Bridge, Highway, and Transportation

Figure ES-1. Delayed Ridership Losses in the Bay Area, Particularly on BART and Muni



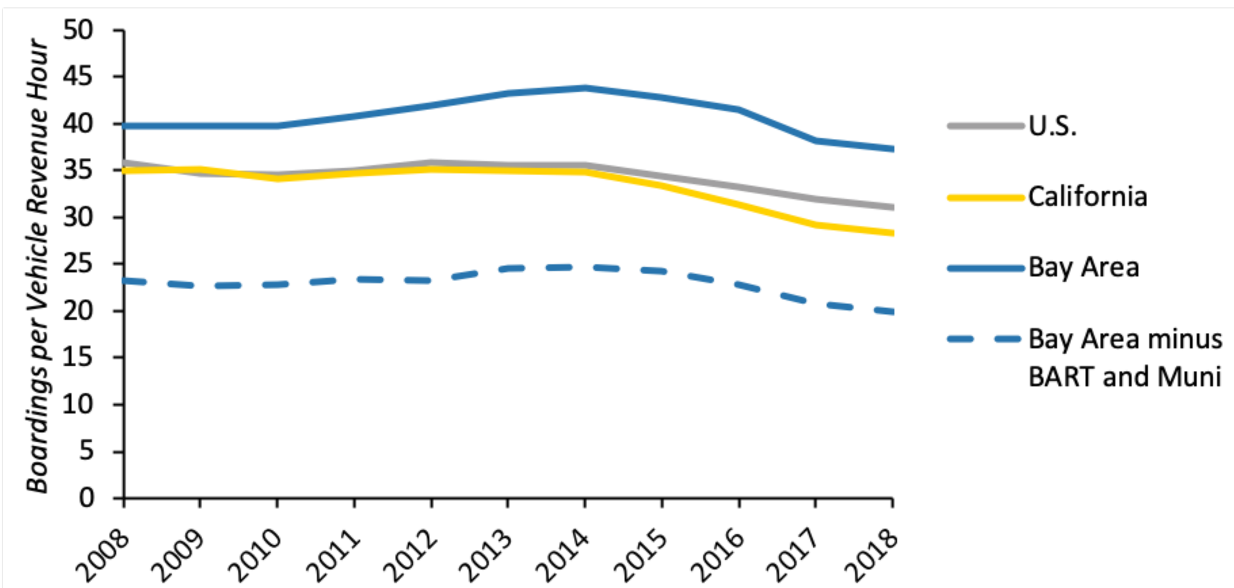
Data source: FTA, 2019

District (Golden Gate Transit or GGT), and Central Contra Costa Transit Authority (County Connection).

Perhaps more troubling, the decline in transit ridership has occurred even as most major operators have increased service in terms of both mileage and hours of operation since 2014, which should normally have boosted ridership. Mostly rising service and mostly falling patronage have combined to cause most measures of service productivity to decline across the board and on both buses and rail.

Figure ES-2 shows that regional service productivity—measured here as the number of boardings per hour of service—declined starting in 2014 (as service grew faster than riders), while overall ridership did not fall until 2017. The same pattern of earlier declines in boardings per service-hour holds when BART and Muni are excluded.

Figure ES-2. Productivity

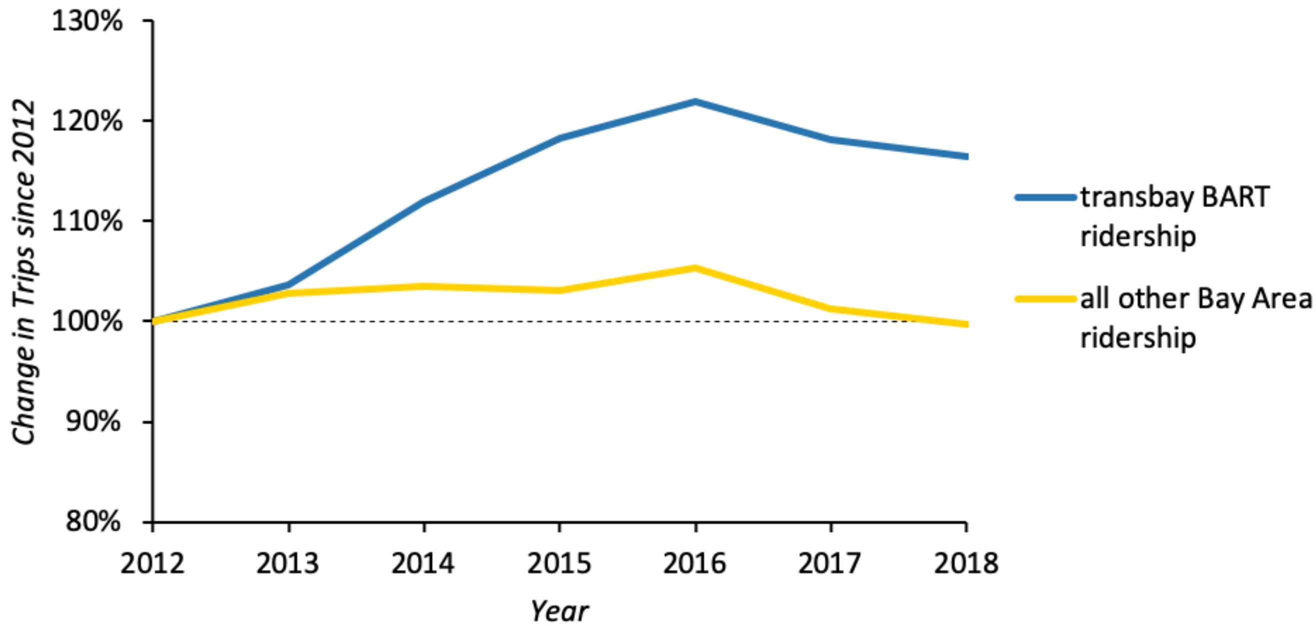


Data source: FTA, 2019

The problem of supplying more and more hours of service to residents who are taking fewer and fewer trips is compounded, at least in part, by the heavy loss of off-peak riders, while the remaining ridership is increasingly concentrated at peak times when capacity constraints prevent more service from being easily added. Further, the Bay Area's ridership declines have not occurred uniformly across the region. Overall, transit use in the Bay Area is becoming more commute-focused, with trips increasingly occurring in peak directions, particularly into and out of downtown San Francisco. For example, transbay BART trips accounted for 43 percent of the *entire region's* ridership growth from 2012 to 2015 (see **Figure ES-3**) (BART, 2019c and FTA, 2019)[1]. In contrast, the steepest transit ridership losses have come at off-peak times, days, directions, and on outlying lines.

1 . Transbay trips made up only around 15 percent of the region's transit ridership in 2015 (BART, 2019c and FTA, 2019). This is an estimate because internal BART data on transbay trips count linked trips, while the regional NTD data count unlinked trips.

Figure ES-3. Transbay BART Trips Accounted for Much of the Bay Area's Overall Ridership Growth



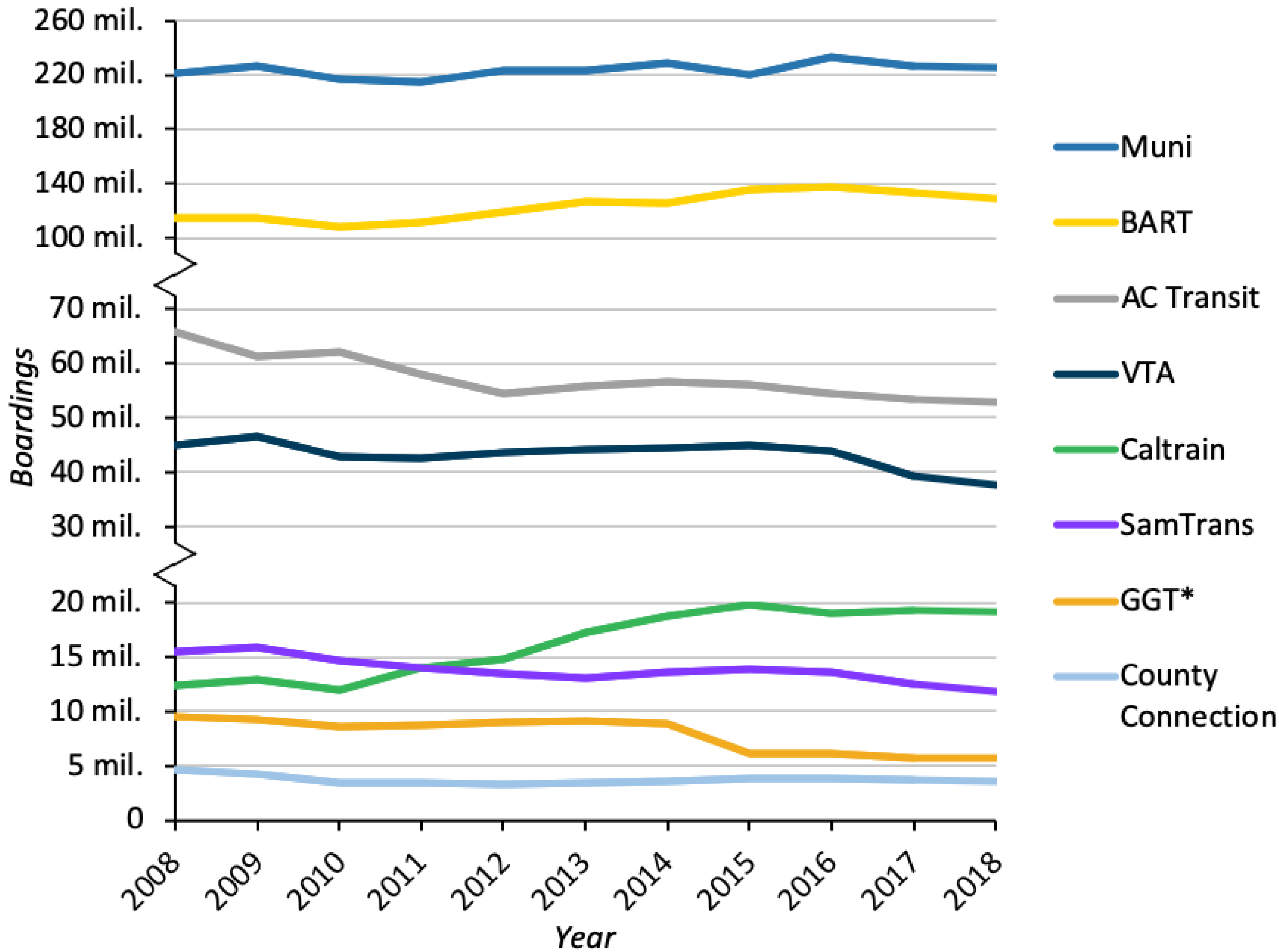
Data source: BART, 2019c and FTA, 2019

Ridership also is becoming more concentrated on certain systems and routes. As noted above, the size and relative success of BART in the early 2010s masked flat or falling ridership on most other Bay Area operators. **Figure ES-4** shows trends in annual boardings over the past decade for the region's eight largest operators. AC Transit, the region's third busiest operator, lost over 13 million annual trips since 2008, the most of any agency region-wide. VTA, SamTrans, GGT, and County Connection also lost riders from 2008 to 2017.

There are also differences in the kinds of ridership losses observed across operators and modes between 2008 and 2017. Caltrain, for instance, experienced both substantial passenger growth (55%) and increasingly acute peaking. Ridership on BART, which rose and then fell during this period, became increasingly concentrated on peak-hour, peak-direction weekday transbay commute trips. By contrast, Muni, SamTrans, and AC Transit experienced little increase in demand peaking, though the latter two operators lost substantial numbers of riders. Muni's patronage remained high throughout, but riders appear to be shifting from slower local buses to both express bus service and rail. VTA and GGT have experienced both increased peaking as well as ridership losses. Smaller operators like County Connection have seen only moderate peaking and only moderate ridership losses.

Across operators, rail boardings have risen until a recent decline, while bus boardings have fallen faster and longer. Bus revenue hours are up more than rail, but bus speeds are down—so the added hours are not necessarily buying better bus service. Across the region, there is a generally widespread and ongoing concentration of transit patronage on particular lines and during peak times, which likely poses fiscal challenges for Bay Area transit operators, as spatially and temporally concentrated services are typically costlier to provide.

Figure ES-4. Annual Boardings by Bay Area Operator



** In FY 2014-2015, Marin Transit began reporting a number of lines that were previously counted under GGT (Downing, 2020).*
Data source: FTA, 2019

ES.2.2. Transit Rider Trends

Not only has the Bay Area experienced a change in when and where people ride transit but also in who rides transit and how much. To examine these trends, we draw from the National Household Travel Survey (a different data source than was used in Section ES.2.1 above), for which we can only analyze the central Bay Area counties (Alameda, Contra Costa, Marin, San Francisco, and San Mateo).

From 2009 to 2017 there was a small overall drop (3.8%) in the total number of trips made per capita on any mode in these central counties. These declines were largely driven by a drop in automobile trips, both for work and non-work purposes, and by a decline in the number of daily transit trips for non-work purposes.[2] This decline in personal travel in the Bay Area mirrors national trends (Godfrey, Polzin, and Roessler, 2019), and appears to be related to gradually decreasing out-of-home activities (such as shopping,

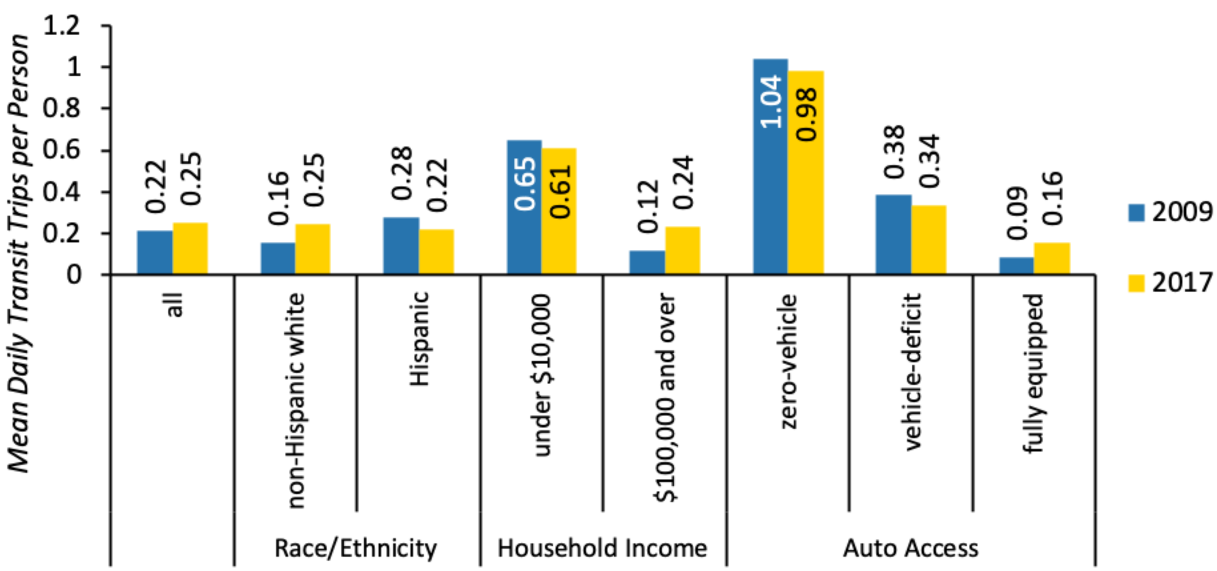
2 . While total person-trips have fallen, the average length of trips continues to increase, causing overall vehicle miles traveled to rise.

socializing, or movie-going) and increasing in-home activities (such as video streaming and on-line shopping) (E. Morris, 2019). When making trips, Bay Area residents did so increasingly by means other than transit or automobile; trips via non-auto or transit modes—including walk, bike, scooter, or ridehail—rose by eight percent for work trips, and 23 percent for non-work trips.

Average daily transit trips per capita increased slightly from 2009 to 2017 in the central Bay Area counties (though, as described in the prior section, not for the region as a whole), from 0.22 trips to 0.25 (see **Figure ES-5**), due mostly to increased transit commuting, which grew from 0.07 to 0.12 trips per day, or 67.6 percent. This increase in transit commuting—and decline in auto trips—contrasts sharply with what these data show for Greater Los Angeles over the same time period.

Bay Area transit increasingly serves as a peak-hour commuter service and less as a general mobility social service. Between 2009 and 2017, transit use declined among population groups that are typically heavy users of transit, such as those living in lower-income, zero-vehicle or vehicle-deficit [3] households, as well as Hispanics (See **Figure ES-5**). By comparison, transit use increased among groups that are not traditionally frequent transit users, such as those living in households earning over $100,000 per year and households with at least one automobile per driver. While the increase in transit use among higher-income and higher auto-access households is modest in magnitude, because nearly 80 percent of households in the central Bay Area counties owned at least one vehicle per driver in 2017 (FHWA, 2017), even this small upturn in transit use by such households translates into a fairly substantial increase in their overall transit ridership.

Figure ES-5. Potential Explanations for Lagging Transit Ridership



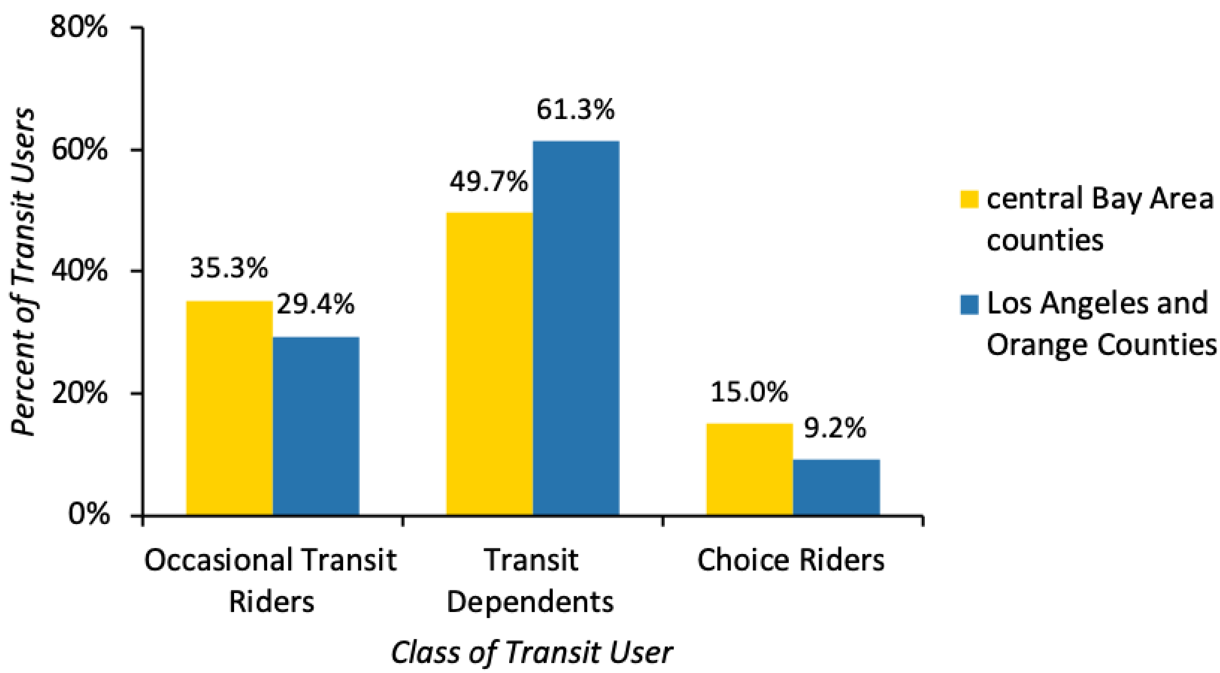
Statistical analyses that simultaneously account for multiple factors thought to influence travel offer additional insights. In these analyses, two characteristics stand out with regard to changing transit ridership patterns in the Bay Area: vehicle ownership and residential density. As noted above, ridership by those living in households with at least one vehicle per driver rose relative to those with limited vehicle access. Similarly, transit trip-making by residents of lower-density neighborhoods increased relative to their higher-density counterparts. In contrast, race and ethnicity, which are significant predictors of transit use across California generally, and in Greater Los Angeles in particular, play comparatively little role in changing ridership patterns in the Bay Area.

3. Vehicle-deficit households are those with less than one vehicle per driver; fully equipped households are those with at least one vehicle per driver.

While transit use by those in zero-vehicle and vehicle-deficit households tends to be much higher than in households fully equipped with vehicles, this gap narrowed considerably between 2009 and 2017. In 2009, residents of vehicle-deficit households made almost four times as many transit trips as those in fully equipped households; by 2017, however, this ratio shrank to just 1.8 times as often. Similarly, the gap in transit trip-making between those living in zero-vehicle households and those living in fully equipped households shrank substantially, from almost 8.6 times as much in 2009 to just under five times in 2017.

Finally, we employed a statistical technique called latent profile analysis to identify transit user types in California. The analysis classified three general types of transit riders, which we termed "Transit Dependents," "Occasional Riders," and "Choice Riders." We then examined the distribution of these transit user types in the central Bay Area counties, and whether the riding patterns of these three transit user types changed between 2009 and 2017. **Figure ES-6** shows that, compared to the Los Angeles and Orange Counties, there are fewer Transit Dependent users in the central Bay Area counties, but more Occasional Transit Riders and Choice Riders.

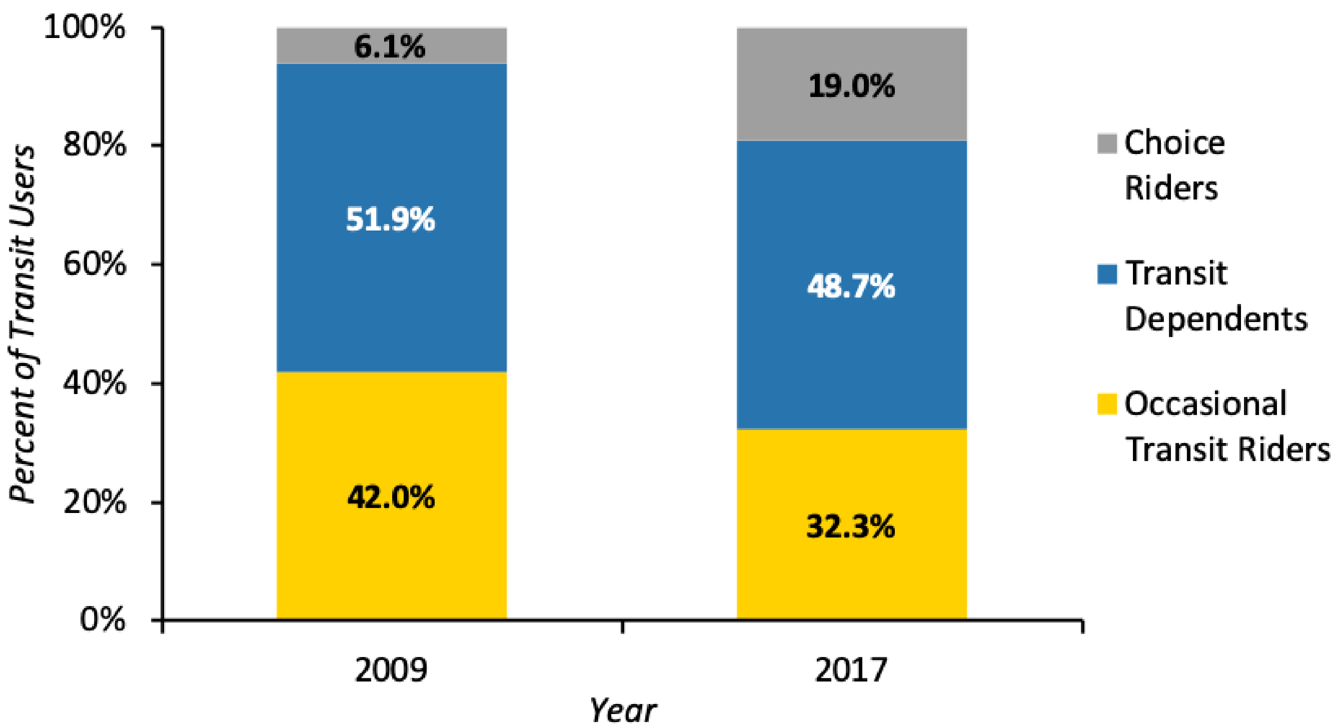
Figure ES-6. Bay Area Boardings per Capita versus Service per Capita



Data source: FHWA, 2009, 2017

Among transit riders in the central Bay Area counties, Choice Riders—who tend to have the highest incomes, have the most personal vehicles available, and take the longest transit trips—increased their transit use the most between 2009 and 2017 (See **Figure ES-7**). Moreover, the relative share of Choice Riders more than tripled, while the relative shares of Occasional Riders and Transit Dependents both shrank.

Figure ES-7. Latent Classes of Transit Users in the Central Bay Area Counties, 2009 and 2017



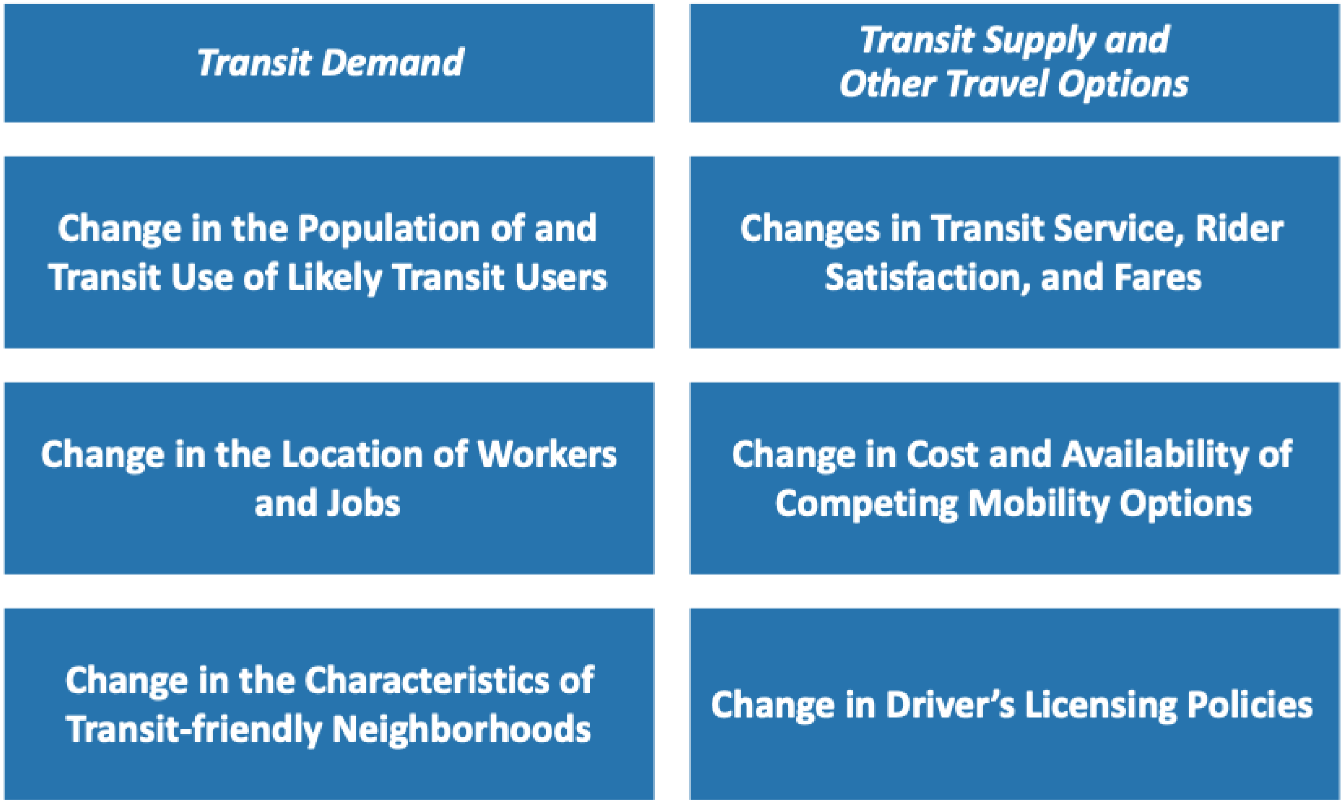
Data source: FHWA, 2009, 2017

In sum, Bay Area transit operators are serving relatively more well-off commuters and fewer low-income riders over time. Notably, travelers with high levels of vehicle access and those living in low-density neighborhoods have increased their ridership relative to those with low levels of vehicle access and residents in high-density neighborhoods. A growing proportion of transit riders are Choice Riders who, on average, have higher incomes and good automobile access. Further, there has been a substantial increase in the number of commute-related transit trips in the central Bay Area counties. Taken together, we find that while traditional transit users (with lower incomes and less vehicle access) still ride frequently, the ridership gap between such travelers and those with higher incomes and better vehicle access is narrowing, due largely to increased journey-to-work trips by the latter group.

ES.3. Possible Explanations for Lagging Ridership

In Part III of Volume I we focus on the possible underlying causes for the changes in transit ridership trends described above. We classify potential explanations for lagging transit ridership in two general categories, as shown in **Figure ES-8**: 1) changes in the demand for public transit, and 2) changes in supply of public transit and other transportation options. The first group includes factors, such as changes in household income or the number of recent immigrants, that lie largely outside of the control of transit managers. The second group includes factors like fares or driver's licensing policy over which transit managers or public-policy-makers exercise control.

Figure ES-8. Potential Explanations for Lagging Transit Ridership



ES.3.1. Changes among Likely Transit Users

As noted above, transit use tends to vary systematically by the socio-economic characteristics of travelers. For example, immigrants are more likely to ride than native-born residents, those with motor vehicles tend to ride less than those without them, and so on. Over time in the Bay Area, the share of high- and low-propensity transit users has changed, as has the frequency with which members of a given group ride.

Overall, and in contrast with most of the rest of California, changes in transit demographics have broken largely positively in the Bay Area. Between 2009 and 2017, when transit use was mostly climbing in the central Bay Area counties of Alameda, Contra Costa, Marin, San Francisco, and San Mateo, population growth and increasing ridership frequency among certain rider groups combined to cause moderate aggregate increases in transit trips there (see **Table ES-1**).

From 2009 to 2017, increasing population explains a roughly 19 percent growth in transit trips in the central Bay Area counties, while about 15 percent was the result of increasing transit use per each resident. As **Table ES-1** shows,[4] the largest effects on transit use

4. The "Population Effects" column represents the change in regional transit trips that would have occurred if every group was just as likely to ride transit in 2009 as 2017, but the size of the groups grew as observed in the data. The "Usage Effects" column represents the change in regional transit trips that would have occurred if the population of every group had stayed the same between 2009 and 2017, but each group's transit use habits changed as observed.

between 2009 and 2017 were among non-low-income and fully equipped households, two overlapping characteristics. Because these households comprise a large proportion of the population, the growth in their numbers *and* in their additional trips per capita combined contributed to substantial increases in aggregate regional ridership in the central Bay Area.

Table ES-1. Changes in Transit Ridership Due to Changes in Population and Usage Effects in the Central Bay Area Counties between 2009 and 2017

CHARACTERISTIC		POPULATION EFFECT	USAGE EFFECT
Car Ownership	Zero-vehicle	+5.4%	-1.7%
	Vehicle-deficit	+3.6%	-3.5%
	Fully equipped	+9.0%	+20.7%
Race/Ethnicity	Hispanic	+1.1%	-3.9%
Population Density	High population density	+15.5%	+2.0%
	Low population density	+4.5%	+10.5%
Income	Low-income	-3.0%	-4.5%
	Not low-income	+21.7%	+23.8%
All		+18.6%	+14.6%

Data source: FHWA, 2009, 2017

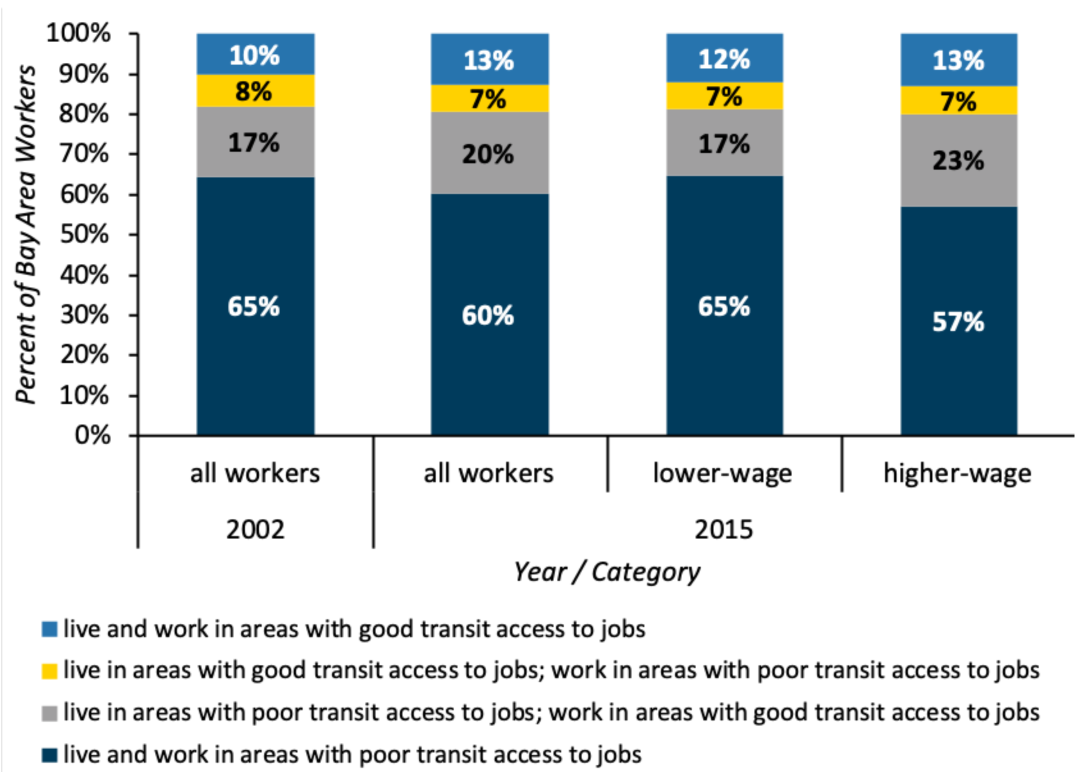
ES.3.2. The Changing Location of Workers Relative to Jobs

The arrangement of jobs and housing in a region can have multiple effects on transit use. Densely developed areas can make driving and parking more of a challenge, support frequent transit service, push origins and destinations close together, including houses and jobs, and encourage transit use for all manner of trips. Transit is well-suited to serve and link these concentrated centers of high-density housing and employment. Conversely, transit tends to play a much smaller role in linking suburban residents to dispersed job sites, where driving is often easy and parking free. Finally, dispersed development patterns where jobs are concentrated but located far from housing can increase longer distance transit *commuting* into major employment hubs (particularly when the transit service can avoid getting stuck in traffic), but travelers are less likely to use transit for *non-work* trips. In this case, the directional peaking of demand can prove an expensive challenge to accommodate. So the relative balance of jobs and housing in a region can importantly shape transit demand and use.

From 2002 to 2015, the largest Bay Area cities gained more jobs than resident workers, as did the Bay Area municipalities that already had the highest share of regional employment. Meanwhile smaller cities collectively gained more resident workers than jobs. Regardless of whether a given Bay Area municipality is jobs-rich or housing-rich, the jobs-to-residents ratio grew more unbalanced across the region and in most cities over time. These patterns may help to explain why transit commuting (especially for larger cities with job growth and strong transit connectivity) held steady or grew between 2002 and 2015, while non-commute transit trips have been in decline (as some people move to smaller cities with low transit access).

In 2015, three out of five Bay Area workers both lived *and* worked in areas with poor job access by transit, likely making it difficult for them to commute by transit (See **Figure ES-9**). But compared to 2002, both workers and jobs concentrated to some degree in areas with relatively high transit access to jobs. This trend might bode well for transit use in these areas.[5] Nonetheless, jobs in these areas grew at a much faster pace than resident workers. Indeed, cities in the Bay Area, especially large ones, became less "self-contained": fewer workers lived in the same city as their job, and even fewer residents worked in the city where they lived. These trends are consistent with the growing use of transit for commuting, and declining use for other trips, that we observe in the Bay Area.

Figure ES-9: Relative Home and Work Locations of Workers in the Bay Area



5 . However, jobs and residents in these areas were more likely to be higher-wage workers, who ride transit less, on average, than lower-income residents.

As cities became less self-contained, the average commute distance for Bay Area workers accordingly increased almost 15 percent in 13 years. Although lower-wage workers had shorter commutes (10.3 miles) than higher-wage workers (11.9 miles), the former workers were *less likely* to live and work in the same city. In concert, these trends help to explain both the increase in transit commuting to job centers, especially downtown San Francisco, and the growth in long-distance transit commuters.

Moreover, in 2015 higher-wage jobs and workers were more likely to be located in areas with good transit access to jobs than lower-wage jobs and workers (See **Figure ES-9**). Higher-wage workers were more likely to both live *and* work in these areas, while lower-wage workers were more likely to both live and work in areas with poor transit access to jobs.

Data show that areas with the best transit access to jobs tend to have higher median home values, a lower percentage of "rent-burdened" households,[6] and a lower percentage of low-wage households compared with other areas. Housing prices have grown faster in these areas than in other parts of the region. Lower-wage workers may find it increasingly difficult to both live *and* work in neighborhoods with robust public transit access to jobs, a conclusion consistent with data from other parts of our analysis showing that Bay Area transit commuters are becoming more well-off over time.

ES.3.3. Changes in Transit-friendly Neighborhoods

As housing costs have risen in the Bay Area, many surmise that gentrification has reduced transit access for poor people and immigrants. There is concern that efforts to encourage transit-oriented developments (TODs) along high-speed transit networks to increase ridership may displace lower-income, transit-riding households in these areas. However, and to our surprise, we do not find strong evidence of such changes in transit-friendly neighborhoods in the Bay Area. This may seem at odds with our jobs-housing balance findings above, but the prior analysis examined the home and work locations of *all* Bay Area workers and their access to jobs by transit. The transit measure used in the previous analysis incorporates both transit supply and proximate employment opportunities. Here, though, we focus on changes in household characteristics in areas with high transit supply or use—established measures of transit-induced gentrification.

We examined this issue by analyzing three different measures of transit-friendly Bay Area neighborhoods. Across all three of these definitions of neighborhood transit-friendliness, the percent of the households in poverty declined only slightly from 2000 to 2017 (to about 15%), while across the region the percent of households below the federal poverty line rose just slightly (to about 10%). So while there was some decline in households in poverty in transit-friendly neighborhoods between 2000 and 2017 relative to the Bay Area as a whole, the shifts were slight.

We also examined trends in the share of immigrant households in these neighborhoods, as well as the trend in zero-vehicle households, as, noted above, both are strong predictors of transit use. With respect to immigrant households, we do observe a moderate decline in immigrants from Latin America (from 9% to 7% by one of our neighborhood definitions) between 2000 and 2017, while the share of immigrants from Asia was largely unchanged. With respect to zero-vehicle households, we observe a modest increase in neighborhoods with our strictest definition of transit-friendliness, but slight decreases in the larger number of less-restrictively-defined transit neighborhoods.

To explore this latter finding a bit further, we differentiated "car-less" from "car-free" transit-friendly neighborhoods. In a nutshell, car-free neighborhoods are those with low rates of auto ownership and low rates of poverty. Car-free neighborhoods are far less common than car-less neighborhoods (which have relatively high rates of poverty), but more than tripled (from 1.1% to 3.5% of all Bay Area census tracts) between 2000 and 2017, while the share of car-less neighborhoods changed little.

6. Households paying 30 percent or more of their household income in rent

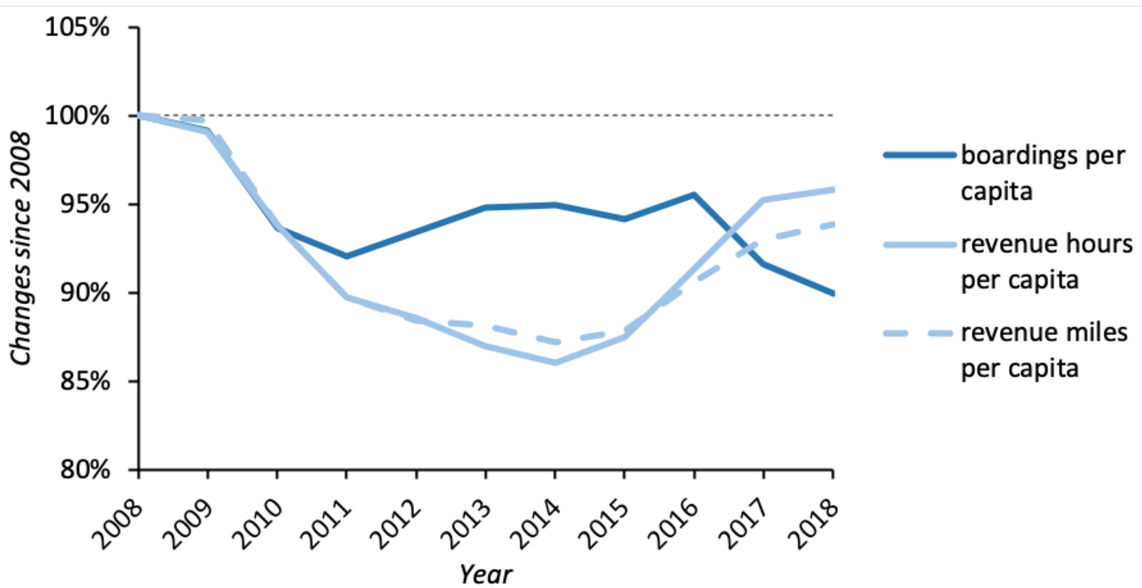
How do we reconcile these findings with data presented in Section E.3.2 above showing that workers are traveling farther and farther from home to their jobs in the Bay Area over time? First, we do see declines in Latin American immigrants and very slight declines in the shares of poverty households in transit-friendly Bay Area neighborhoods over time, though admittedly these modest changes do not square with popular narratives of wholesale gentrification-driven displacement. Second, this particular analysis focused on changes in the most transit-friendly neighborhoods with respect to poor residents, immigrants, and zero-vehicle households, while the previous jobs-housing analysis examined all workers across all Bay Area neighborhoods. Most Bay Area workers are not poor, and most do not live in transit-friendly neighborhoods. Increasing housing prices affect all workers, not just poor ones. It may be that lower-wage (but not poor) workers who do not qualify for income or housing subsidies may be particularly affected by rising Bay Area housing prices.

ES.3.4. Changes in Transit Service, Rider Satisfaction, and Fares

ES.3.4.1. Changes in Supply of Transit Service and Rider Satisfaction

We see no evidence that falling ridership is due to falling transit service levels in the Bay Area. While total population-adjusted service levels in the Bay Area have yet to fully return to pre-recession levels, **Figure ES-10** shows that the region mostly added riders between 2011 and 2014 when per capita service levels were falling, and mostly lost riders (though with considerable year-to-year

Figure ES-10. Bay Area Boardings per Capita versus Service per Capita



Data source: FTA, 2019 and U.S. Census Bureau, 2011, 2019

variation) since 2014 when service levels were climbing. As such, it is not possible to attribute declining regional ridership to cuts in transit service.

Nor can we attribute regional ridership declines to service changes on ridership-losing transit agencies alone, since while those Bay Area operators whose 2014-2016 ridership rose did add slightly more service than those whose 2014-2016 ridership fell, both groups added service since 2014 at roughly the same rate, and neither has actually cut service.

Data on changing rider satisfaction for three major Bay Area transit operators—BART, Muni, and VTA—are more mixed. Overall, passenger satisfaction has varied over the past 15 years but is now in decline across the board. Surveys identify service frequency and reliability, personal safety, system cleanliness, and crowding as key issues to riders, although concerns vary from agency to agency. While passenger satisfaction on these three systems have all been trending downward in their most recent rider surveys, the link between falling rider satisfaction and falling ridership over the past two years is far from conclusive. For one, satisfaction has fallen most sharply on BART, an operator with some of the Bay Area's most resilient ridership, and began dropping during the district's 2012-2016 ridership boom. Indeed, a number of common rider concerns, like overcrowding and uncleanliness, are symptoms of ridership *gains* (at least at certain times of day), not losses. We note that as ridership has become increasingly peak-period commute oriented, crowding is likely increasing into and out of major job centers, and in addition the increasingly well-off Bay Area transit commuters may have higher expectations than respondents to earlier surveys.

ES.3.4.2. Trends in Transit Fares and Fare Evasion

Though rising transit fares should, all else equal, lead to less transit use, from 2014 to 2017, changes in fares do not appear to be behind the recent patronage downturn. Adjusted for inflation, average fares per boarding across the region rose at the same steady rate as the past decade, while fares per passenger-mile were flat due to increasing average trip lengths. During this time, ridership fell, rose, and is falling again. In the recent patronage downturn, transit operators with increasing average fares fared no worse than their counterparts with flat or decreasing fares. And from what limited evidence we could gather, we see no link between rates of fare evasion and ridership trends either.

ES.3.4.3. Transit Costs and Subsidies

The Bay Area's investment in public transit has increased. Unfortunately, the cost-efficiency of transit service has declined, but we find that this too has not been responsible for the recent losses in ridership. Nonetheless, recent ridership declines are beginning to negatively affect agency revenues and subsidies, though this effect varies by operator and in many cases only slightly.

ES.3.5. Competing Mobility Options

ES.3.5.1. Private Automobiles and Fuel Prices

Competing mobility options present a mixed picture. In contrast to statewide trends, and in dramatic contrast to Greater Los Angeles, the number of zero-vehicle households in the entire Bay Area declined only slightly (and actually rose slightly in the central Bay Area counties, as discussed above), and solo driving for the commute also decreased. We thus conclude that increases in vehicle access and driving have not caused ridership declines. Similarly, we find no evidence of fluctuating fuel prices pushing people on or off transit.

ES.3.5.2. Ridehailing

Lacking data from ridehail providers themselves, we use other methods to examine the effect of newer services like Uber and Lyft on travel behavior. For example, there were large increases in livery "establishments" (which is the Census term used to describe independent contractor drivers for Lyft, Uber, taxis, and limousines) in the Bay Area after 2014, and especially in densely populated counties like San Francisco, San Mateo, and Alameda. We also review studies of ridehail in the Bay Area and nationally and conclude that ridehail use is likely higher in the Bay Area than perhaps any other region in the U.S. The Bay Area is a dense, transit-rich region, and research has shown that ridehail use is highest precisely where transit service is best (Brown, 2018). These data, as well as a growing body of research on ridehail use in the Bay Area and around the U.S., collectively suggest that ridehail services in the Bay Area subtract more transit riders (who substitute ridehail for transit trips) than they add (through better first-/last-mile connections to transit stops and stations).

While this evidence is strongly suggestive, the magnitude of the effect on transit ridership remains ambiguous. Several studies find that public transit and ridehail tend to serve two very different travel markets. Ridehail use tends to be highest in the evening and on weekends, which are not peak times for transit (but are the times and days when we have observed the largest loss of transit riders). In addition, ridehail passengers tend to be higher-income, better educated, and somewhat younger than the average traveler, as well as much more likely to use the service to go out in the evening or to an airport than ride to work (Rayle et al., 2016 and Feigon and Murphy, 2016).

However, the Bay Area may present a unique case. First, off-peak-hour trips and non-commute trip purposes account for the vast majority of net ridership losses on major Bay Area operators—the same travel markets where ridehail use tends to be highest. Second, even if ridehail and transit initially served different travel markets, more mature and ubiquitous ridehail networks have the potential to substitute for transit's core trips—especially in markets served longest by Lyft and Uber. Ridehail services began in the Bay Area and have operated in the region longer than anywhere else; studies find that TNC-for-transit substitution tends to increase the longer that ridehail operates in a city (Graehler, Mucci, and Erhardt, 2019 and Babar and Burtch, 2017). Finally, although per-capita transit ridership was already faltering, absolute ridership in the Bay Area only began falling after 2016, as ridehail was continuing to expand. Thus, the rise of ridehail and fall of transit use align—in terms of timing, location, and trip purpose—relatively well in the Bay Area.

ES.3.5.3. Private Employer Shuttle Services

There has been a rapid increase in employer shuttle commuters in the Bay Area. These shuttle services are collectively quite large, increasing overall regional (*public and private*) transit ridership, but they may pose a particular challenge for *public* transit. Despite this growth, evidence suggests that these services divert relatively few riders from public transit and replace more auto than public transit trips. In addition, shuttle services may cause other behavioral changes—such as lower rates of car ownership and/or longer-distance commuting—that could have secondary effects on transit ridership. Decreased car ownership might mean that travelers take transit more often (particularly for those living in San Francisco) for non-commute trips. In contrast, if shuttles allow higher-income residents to live in urban areas distant from their place of work, they may displace other, poorer urban dwellers who tend to ride public transit at even higher rates.

ES.3.6. AB 60: Driver's Licensing for Undocumented Immigrants

Finally, we examine a significant change in state transportation policy that allows undocumented residents to secure driver's licenses. Since January 2015, Assembly Bill 60 has allowed people who are unable to provide documentation of citizenship to apply for and receive driver's licenses from the California Department of Motor Vehicles (DMV). Assuming that at least some of the new AB 60 license holders previously relied on transit, changing state driver's licensing regulations may have contributed to declining transit use since 2015. Unfortunately, there are no available data to analyze this question directly. While we observe increased solo commuting by immigrants in recent years, the timing of this increase precedes the recent Bay Area transit ridership downturn. Statewide statistical models of the relationship between AB 60 and commute mode share, however, do show a small effect of the policy change on the commuting patterns of undocumented immigrants. Specifically, among undocumented Mexican immigrants—the largest group of undocumented immigrants in the state—travel to work by car and solo driving to work increased slightly following the implementation of AB 60, while transit commuting declined modestly during the post-AB 60 period. Unfortunately, data limitations mean that we are only able to examine work-related trips, and small sample sizes prevent us from focusing specifically on travel behavior in the Bay Area. Therefore, while evidence suggests that AB 60 has had a small effect on commute travel in California, the relationship between this policy change and transit ridership in the Bay Area is difficult to determine.

ES.4. Policy Framework

While our primary foci in this research were on what is happening to transit ridership in the Bay Area and what may be behind these changes, we consider the public policy implications of our findings as well. First, and as noted at the outset, many of the factors affecting transit use lie beyond the direct control of transit agencies, including parking policy, road pricing, housing affordability, regional land use policy, international migration and trade, and global economic expansion or contraction (Taylor and Fink, 2013). Changes in the shares of poor, immigrant, and zero-vehicle households in transit-friendly neighborhoods also make this list. But while all of these factors lie largely beyond the control of transit managers, not all are outside the reach of local and regional policymakers. Thus, stemming recent declines in transit use may require action by policymakers outside of transit agencies to ensure that the region's substantial transit investments pay off. We outline some of these actions below.

Table ES-2. Policy Framework

POLICY CATEGORY	RELATED FINDINGS AND EVIDENCE	CURRENT POLICIES AND PROPOSALS	RECOMMENDATION
TRANSIT OPERATOR POLICIES			
Transit service improvements	*Report Volume II*: Transit ridership has fallen most at off-peak times, in counter-commute directions, and in outlying areas; the most significant determinants of ridership are beyond the control of transit operators	Transit Performance Initiative, Muni Forward, East Bay Bus Rapid Transit, service and network realignment at other operators	Invest in rapid bus/rail services in dense areas with exclusive or semi-exclusive rights-of-way; invest in fleet and operational improvements to increase effective service capacity, reduce crowding, and enhance customer experience; look for ways to improve off-peak services to attract new riders; carefully evaluate proposed transit capital projects on their ability to effectively generate ridership by connecting concentrations of housing and employment, considering land use and development changes as both complements and alternatives
Demand-based fares	*Report Volume I and other research*: Fares increases are not driving recent ridership changes; peak capacity constraints limit the ability of some systems to accommodate increased peak demand; off-peak ridership is declining on many systems	Only a few Bay Area transit systems, notably BART and Caltrain, vary fares by distance	Investigate off-peak incentives to reduce peak crowding, shift some riders to the "shoulders" of peaks, and encourage off-peak ridership

POLICY CATEGORY	RELATED FINDINGS AND EVIDENCE	CURRENT POLICIES AND PROPOSALS	RECOMMENDATION
REGIONAL TRANSPORTATION POLICIES			
Regional integration and seamless mobility	*Other research:* Research shows that better information, easier transfers, and more seamless fare payment systems reduce the burdens of transit travel	MTC Connected Transportation/Seamless Mobility effort	Better integrate trip planning and fare payment across jurisdictions and service providers; investigate new mobility pilots to improve first-last mile access to transit and transportation services in areas and times of day with limited transit service
Data on private-sector transportation	*Report Volume I:* General lack of systematic data on private-sector shared mobility, especially ridehail; suggestive evidence of ridehail substitution for public transit	Bay Area Shuttle Census, data-sharing agreements with micromobility companies, Mobility Data Specification	Establish systems to obtain and maintain robust data from private new mobility and micromobility operators on an ongoing basis for public policymaking and planning purposes
Management of private vehicle travel	*Report Volumes I and II and other research*: Auto access and use is strongly and negatively associated with transit use	Express lane network expansion, congestion pricing studies, local performance-priced parking programs	Investigate and pilot-test road- and parking-pricing programs and projects to reduce congestion and increase the relative attractiveness of transit because traffic congestion makes transit less time-competitive and increases operating costs
REGIONAL LAND USE AND HOUSING POLICIES WITH TRANSIT IMPLICATIONS			
Land use near transit	*Report Volume I:* Three out of five Bay Area workers live *and* work in neighborhoods with poor transit access to employment	*Plan Bay Area 2040, Plan Bay Area 2050* development, MTC Resolution 3434	Broaden the focus of TOD to include land-use planning strategies that increase employment and housing densities near one another; consider financial incentives to promote such strategies
Affordable housing and transit	*Report Volume I:* Housing prices are associated with a decline in locally-residing workers, which may be depressing transit use in some areas	*Plan Bay Area 2040, Plan Bay Area 2050* development, CASA Compact	Continue and strengthen involvement in housing-related planning efforts, with the goal of increasing the supply of affordable housing near jobs

Data source: FTA, 2019 and U.S. Census Bureau, 2011, 2019

ES.4.1. Transit Service Improvements

Reviving off-peak transit use presents a dilemma for planners. On one hand, policies targeted at increasing non-commute, reverse direction, evening, and weekend trips are of great importance for addressing the most significant declining trip types. On the other, the most significant factors that influence transit use—such as household auto access and free parking at trip ends—tend to be beyond transit agencies' control. Policymakers must therefore decide whether to channel resources towards the most crowded peak-period, peak-direction trips to alleviate crowding and double down on their strongest market, or to improve off-peak, off-direction services where demand is slumping.

There are a number of strategies for restoring off-peak ridership: reducing midday, evening, and weekend headways; adding more service in counter-commute directions; and regulating or working with ridehail companies to make them better complements to transit. Each of these approaches entails both cost and risk, and their individual effects may be small or slow to manifest, though the success of such efforts in other cities, notably Houston, Texas, are promising. Still, increasing reliance on peak trips is very expensive, so a suite of off-peak investments may be worth pursuing.

The more expensive path to expanding ridership is currently being pursued in the Bay Area: increasing peak capacity on systems and routes struggling with peak-period crush loads. Examples here include lengthening trains at rush hour, adding more service in commute directions, creating more transit-only lanes, adding more core capacity at the center of the BART and Muni Metro networks, and eventually constructing a second Transbay Tube. Such strategies will help retain, and may grow peak-hour and peak-direction ridership, although they may do as much or more to improve trip satisfaction and speed for existing riders as to attract new ones.

In isolation, each of these improvements may be worth pursuing, with research and evidence to support their effectiveness, and peak-focused and off-peak focused strategies are not mutually exclusive. But policymakers should recognize that they may still be at odds in a world of limited resources. Moreover, agencies should shape every strategy, as best they can, around the factors that are the most influential determinants of ridership, like job and population density. Service increases, for instance, will do little good if they do not serve major job or activity centers.

Regardless of how operators strike this balance, certain improvements may address the particular contours of the Bay Area's ridership decline. For instance, programs to incentivize travelers to shift their trip-making from peak to off-peak times will both relieve crowding at rush hour and fill underutilized capacity off peak. We discuss below one way to do this: reducing or eliminating fares at off-peak times. Likewise, at both peak and off-peak times, reliable transit service with dedicated rights-of-way will attract riders, better compete with driving, and avoid street congestion, as evidenced by, for instance, SFMTA's Rapid lines. These frequent and separated services can be implemented cheaply and quickly through improvements like tactical transit lanes (Gahbauer and Matute, 2019).

Finally, we suggest a thorough assessment or reassessment of proposed transit capital projects outside of the region's core in light of the findings of this report. Historically, such rail investments have enabled decentralization in the Bay Area (Webber, 1976), and evidence in this report and other studies (Guerra and Cervero, 2011) show that rail stations far from downtown Oakland and San Francisco typically serve relatively few riders and reduce system and line productivity in terms of boardings per service hour. In light of our findings that transit services in outlying parts of the region today have, on average, experienced proportionally larger ridership losses than services in denser areas (See Volume II), we recommend that performance analyses of transit capital projects 1) include specific evaluations of how effectively the project connects concentrations of housing to workplaces and 2) consider the development of more housing in job-rich areas as either an alternative or complement to the project.

ES.4.2. Demand-based Fares

A strategy long favored by transportation economists on both efficiency and equity grounds entails having fares reflect (if not fully cover) the marginal cost of transit trips. Doing so may well increase fares on long-distance, peak-period, peak-direction transit trips that most tax system capacity, but substantially lower fares on shorter, mid-day, evening, and weekend trips where the cost of accommodating such trips is low. Accordingly, we recommend that the MTC work with Bay Area transit operators to explore the potential of variable pricing as part of its regional fare integration efforts.

Technology now allows fine-tuned adjustment of fares based on the time and location of boarding and alighting buses and trains;

simpler applications are possible as well. For example, systems could charge somewhat higher fares for peak-hour service but steeply discount fares for off-peak service, which would provide more revenues to support the high cost of accommodating peak-hour trips. Low (or even free) off-peak fares would encourage travelers to take inexpensive-to-accommodate off-peak trips. One way to implement such fares on buses might be to charge the highest base fare on boarding, but reduce the ultimate fare paid based on distance traveled and time if the passenger voluntarily "taps out" as they alight (while those who chose not tap out would be charged the full base fare).

Such pricing can encourage more riders but at little additional cost because systems typically have vehicles and operators available to carry additional off-peak trips (Yoh, Taylor, and Gahbauer, 2016). Most forms of demand-based variable fares are also a more equitable pricing method. According to Walker (2010), "To insist that peak service be priced equally to midday or weekend service is to argue that the riders of those off-peak services should subsidize the peak....As the average peak-period traveler usually has a higher income than an average midday traveler...insisting on flat fares all day could actually be seen as regressive."

ES.4.3. Regional Integration and Seamless Mobility

As the Bay Area, a global leader in information and communications technology innovation, moves increasingly toward integrated public/private trip planning and payment services, known as "Mobility as a Service" business models, traditional public transit services—some of which have been operating for better than a century—need to be fully integrated into them. Accordingly, we recommend that the Bay Area Partnership Board initiate a customer-oriented transportation program, with near-term actions focused in three areas. First, they should work to advance technology platforms that integrate trip planning and fare payment across jurisdictions and service providers. Travelers should be able to seamlessly pay for a ride on any transit operator (or combination of operators) the way they pay for anything else—by credit card, by mobile app, or by cash for the unbanked—instead of having separate, non-fungible accounts and applications for each operator. Second, they should explore and evaluate new mobility pilots, either in partnership with private sector mobility providers of various stripes or operated publicly, to improve first-last mile access to and from transit stations as a potential alternative to traditional fixed-route transit service in suburban parts of the region, where subsidies of traditional transit service are high and the utility of this service is low. And third, they should work to develop regional support for policy standards, such as standards for data-sharing with private ridehail and other shared mobility operators, discussed below.

ES.4.4. Data on Private-sector Transportation

To implement many of the policies above effectively requires not just comprehensive data on private shared mobility services but also a robust data framework to enable ongoing evaluations and support myriad planning efforts. Through voluntary agreements, permitting programs, or changes in laws and regulations, the MTC and its local government partners should ensure a continuous, real-time, and perpetual stream of data from private new mobility and micromobility operators. These data should be provided in a common format like the Mobility Data Specification. Obtaining such data may have benefits in many areas of planning and policy, but it is particularly necessary to understand the current dip in public transit use.

Other than Uber's Movement tool (Uber Technologies, 2019)—which does not cover the entire Bay Area and does not provide trip data at levels disaggregated enough to be useful in mobility planning (Marshall, 2019)—ridehail companies only regularly share their data at scale with the California Public Utilities Commission (CPUC) (SFCTA, 2017). Accordingly, we suggest that the MTC and other stakeholders work through the CPUC rulemaking process or other mechanisms so that these data become widely available for policy, planning, research, and regulatory purposes. New York City, for instance, systematically collects data on ridehail trip pickup and drop-off locations and times (New York City Taxi and Limousine Commission, 2019), with new information on fares, wages, and wheelchair-accessibility and more detailed GPS positions on the way (Marshall, 2019). New York offers a model for the robust collection and sharing of data, which has enabled numerous analyses to date (New York City Department of Transportation, 2019; Bialik et al., 2015; Silver and Fischer-Baum, 2015; Fischer-Baum and Bialik, 2015; and Bialik, Fischer-Baum, and Mehta, 2015).

In the nearer term, cities, counties, and transit agencies do have opportunities to secure data from private shared mobility operators at least on a smaller scale. For instance, some California cities and transit operators currently contract with ridehail firms to supplement transit service and provide paratransit. Where they do, the public agency should stipulate robust data-sharing procedures. Likewise, cities should mandate comprehensive data-sharing as a key provision of any micromobility permitting program, as municipalities like San Francisco have already begun to do. We suggest that the MTC work with local governments in the region to develop systematic and compatible reporting protocols to insure the collection of useful and comparable data.

ES.4.5. Management of Private Vehicle Travel

Recent drops in Bay Area transit ridership are occurring amidst increasing private vehicle use, worsening traffic congestion, and increasing concerns about vehicle emissions. Better management of the road network would increase economic efficiency, reduce delays, and make traveling by means other than solo driving (including riding public transit) more attractive. While motorists have long been wary of any efforts to meter road use, public outcry over worsening chronic congestion has motivated road- and parking-pricing programs and pilots in the Bay Area and around the U.S. to manage traffic congestion and generate needed revenues for transportation improvements.

These programs and pilots can significantly benefit transit by encouraging drivers to consider less costly alternatives to driving, including taking transit, and by making transit more attractive, particularly for short trips, by reducing street traffic and cruising for parking that slows down buses and streetcars. For these reasons, current regional pricing plans, programs, and pilots should be viewed and evaluated as important pro-transit policies.

ES.4.6. Land Use near Transit

While we applaud existing efforts to promote equitable transit-oriented development in the Bay Area, we suggest broadening the TOD concept beyond primarily locating residences adjacent to rail transit lines. First, long-range plans to build transit ridership should not only put housing near transit but also *jobs* near transit, as our research suggests that transit-adjacent jobs are increasingly powerful generators of transit use. Better yet, policies to locate more housing near job centers generally, will likely encourage transit ridership growth because transit use (in the Bay Area and elsewhere) is highest in relatively dense agglomerations of employment and housing. Land-use planning strategies to increase employment and housing density together, with well-designed affordability and anti-displacement policies, can restore demand for off-peak transit use and still retain peak transit riders across the region.

Transit-oriented development should be planned with more than just station-adjacent considerations in mind; it should encompass a variety of higher density, mixed use districts served by multiple types of transit service, including high-quality bus service. This broader perspective could entail efforts to increase the production of higher-density multi-unit housing in already built-up job centers to enable shorter commutes and to increase the relative attractiveness of transit (which is typically slower than driving). While such land use decisions are largely the domain of local governments, the MTC could motivate more transit-friendly development by increasing the housing and employment thresholds in its TOD policy, as recommended in the development of Plan Bay Area 2050 (MTC, 2019b). A report from the MTC's Horizon Initiative, for instance, calls for financial incentives to densify employment in Priority Development Areas (PDAs) near transit (MTC and ABAG, 2019, p. 71). The MTC could also expand its TOD policy by tying more funding sources, beyond transit capital expansion dollars, to TOD thresholds; this could involve stipulating rezoning near existing stops and stations or more generally zoning to better connect employment and housing as a funding condition. This updated policy could also consider transit access, including the use of new mobility services and other first- and last-mile connections, for both employment and residential development when updating guidelines for transportation and land-use planning programs such as the Priority Development Areas Planning and Technical Assistance and OneBayArea Grant programs.

ES.4.7. Affordable Housing and Transit

Employment in the Bay Area has been growing faster than housing, particularly in the central, transit-rich parts of the region. This chronic undersupply of housing, particularly near burgeoning job centers, has dramatically increased housing prices across all segments of the Bay Area housing market and is almost certainly behind the substantial increases in commute distances. Policies to enable more housing supply, particularly in job-rich, transit-friendly parts of the region will help ease upward pressure on both housing prices and commute lengths.

Further, transit use in the Bay Area remains highest among individuals living in low-income households, even as the average income of transit riders has been increasing. Therefore, a policy focus on increasing housing and employment in transit-rich areas (both inside and outside PDAs) must include efforts to ensure that low-income households can continue to live in and move into these neighborhoods. The California Department of Housing and Community (HCD) Development mandates that local governments plan for the housing needs of their residents through the Regional Housing Needs Allocation process. HCD determines the total number of new units required in each region, including the number of affordable units. ABAG then develops a methodology to distribute these new housing units across jurisdictions in the region. Unfortunately, this process tends to result in the allocation of much affordable housing to far-off areas with lots of developable land, but does little to encourage housing production in cities like San Francisco where housing is most expensive and demand is highest (Monkkonen, Manville, and Friedman, 2019).

Neither the MTC nor Bay Area transit agencies are responsible for housing policy; however, given the important relationship between housing and transit use, we recommend that the MTC continue and strengthen its involvement in housing-related planning efforts in the region, specifically by advocating for more housing, including affordable housing, near jobs. Increasing housing production, especially affordable housing, in already built-up areas is both challenging and expensive. But increasing housing density in transit-rich areas will help restore and grow transit ridership, particularly if it enables low-income families to live closer to jobs.

Additional affordable housing also may indirectly improve rider satisfaction. While we find little evidence that the presence of people experiencing homelessness on transit and other “quality of ride” concerns are discouraging patronage, such factors are depressing surveyed passenger satisfaction. More affordable housing can help house at least some of those now experiencing homelessness and can reduce the number of people literally forced underground into transit stations and onto transit vehicles in search of shelter. This is not a short-term solution, to be sure, but it is a far more equitable than sweeping unhoused people out of stations in the name of restoring ridership or passenger satisfaction.

Part I

Introduction

1. Introduction

1.1. Study Context and Purpose

Public transit ridership has been slipping nationally and in California since 2014. Annual unlinked boardings fell by over a half-billion trips nationally between 2014 and 2017. Per capita ridership in the Golden State has been falling since 2009, and in Greater Los Angeles it has been mostly declining since 2007.

The San Francisco Bay Area, home to one of the world's most dynamic regional economies, as well as densely-developed, transit-friendly San Francisco, has the highest transit mode share in California, and until very recently had bucked national and state trends in declining transit use. The Bay Area Rapid Transit District (BART), in particular, had been the shining exception to the state's transit ridership woes, increasing boardings by nearly nine percent between 2013 and 2016 (FTA, 2019).

But recent patronage data suggest that the Bay Area may not be immune to the ridership declines plaguing most other American cities. In 2017 and 2018, the region lost over 27 million annual boardings, representing over five percent of all transit patronage. These losses are particularly concerning because the region has committed substantial public resources to improving and expanding public transit service, and, unlike patronage losses witnessed in the recent Great Recession, the Bay Area economy is booming, employment is up, and motor vehicle travel is increasing. For Bay Area agencies and leaders trying to reverse this downturn, identifying its causes is a critical first step.

In this report (Volume I), we examine recent transit patronage trends in the San Francisco Bay Area in detail to understand what is behind these transit use trends, what they portend for the future, and what policymakers, planning agencies, and transit operators might do about them. To examine the factors influencing transit use and trends in the Bay Area, we focused our analysis on seven related research questions:

1. How is transit use changing in the Bay Area, both in terms of total number of riders and boardings per capita?
2. How is transit service changing, or not changing, in terms of operating speeds, service frequency, fares, modes, locations, subsidy, and rider satisfaction?
3. Where in the Bay Area is transit use changing? How is transit use shifting by sub-region, across transit operators, among transit modes and service types?
4. How are transit riders changing in the Bay Area in terms of socio-demographic, modal, and trip characteristics? Who rides transit? How often? Is this changing over time?
5. How are the locations of Bay Area residents and jobs changing over time, and what are the implications of these changes for transit use?
6. Who lives in the region's most transit-friendly neighborhoods and how is this changing over time?
7. How is use of competing modes—such as private vehicles (including vehicle access, driver's licensing, and fuel prices), ridehail, and private shuttles—changing over time, and what are the implications for transit use?

1.2. Research Design and Data

Our analysis focuses on the factors that influence recent transit ridership trends in the San Francisco Bay Area. Unfortunately, there is no single dataset or methodology that allows us to study the myriad potential explanations for declining transit ridership. Therefore, the various analyses in this report draw from a variety of data sources and employ multiple methodological approaches. Each chapter contains a brief overview of our methodology, which is in most cases supplemented with more detailed descriptions in the appendix.

Our focus is not on what explains transit use generally, as there is a large and well-established body of research on this broader question, which we briefly summarize in Chapter 2, but rather on explanations for recent *changes* in ridership. We draw from a variety of available data sources for the U.S., all of California, and the Bay Area for our analysis, including some, such as transit rider surveys, that are specific to the Bay Area. We focus on the San Francisco Bay Area—the nine counties in the Metropolitan Transportation Commission (MTC) region—but for context compare our findings to the U.S., California, and Greater Los Angeles, where appropriate (See Appendix A for further definitions).

In Part II of this volume, we examine what has been happening to transit in the Bay Area in terms of ridership and multiple dimensions of service at both the regional level (Chapter 3) and among the various Bay Area transit operators (Chapter 4, as well as Volume II). We also consider these ridership changes over time among different socio-economic categories of transit users (Chapter 5).

In Part IIIA, we focus on the demand-side of transit use. Here we consider changes in the socio-economic characteristics (Chapter 6) and residential location (Chapter 7) of Bay Area travelers that likely influence transit use trends. This includes shifts in residential location, employment location, and proximity to transit services (Chapter 8).

Part IIIB of Volume I examines supply-side issues, the flip side of the demand for transit. Here we describe changes in surveyed rider satisfaction (Chapter 9) and the cost of transit service (Chapters 10 and 11), including the public's perception of safety, reliability, and cleanliness, and the problem of fare evasion. We consider both motor vehicle use (Chapters 12 and 13) and, to the extent that we are able to do so, emerging alternatives to transit, such as riderhail services (e.g., Lyft and Uber) (Chapter 14) and employer shuttle services (e.g., the Google Bus) (Chapter 15). Chapter 16 completes our analysis with a review of the current policy environment, highlighting the changes in travel behavior among California's immigrant population, with particular attention to recent legislation permitting undocumented immigrants to receive driver's licenses.

Part IV presents a summary of our findings and conclusions and provides a framework for addressing the key issues identified in this report and their implications for future transit policy (Chapter 17).

Finally, the companion Volume II of this report presents a detailed account of patronage and transit service trends at each of the major transit operators in the region.

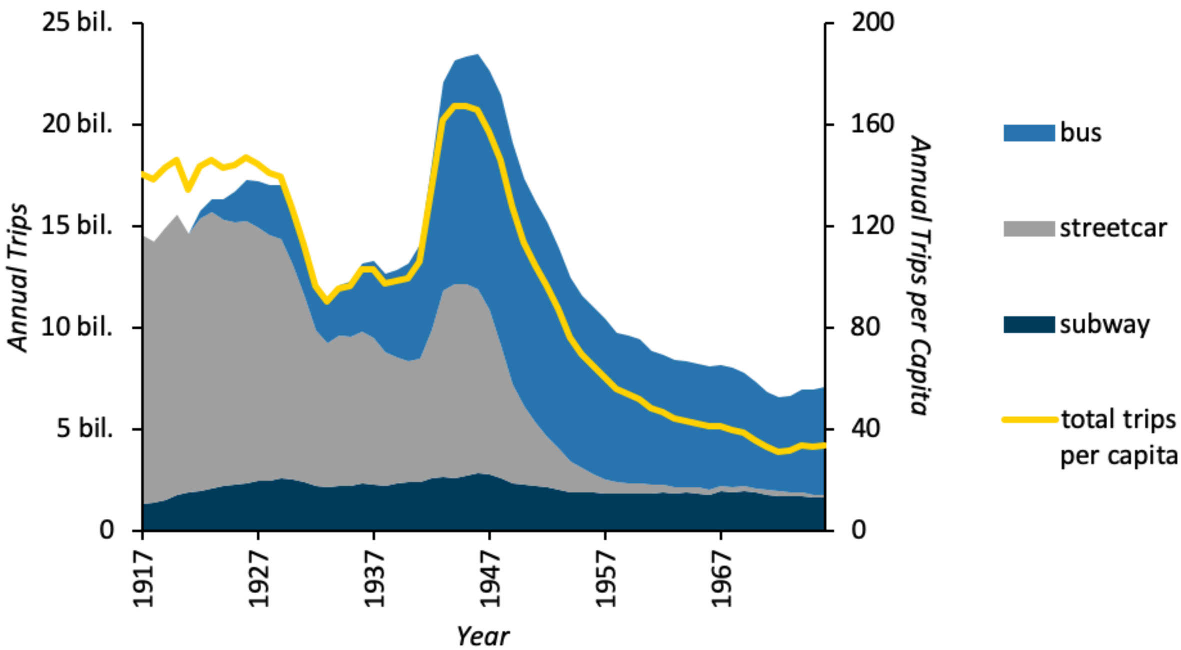
2. Previous Research

2.1. Historical Context

San Francisco is unique among cities west of the Mississippi River in both the density of its development on a peninsula surrounded by water on three sides, and the substantial (and iconic) role in its history played by public transit. The evolution and role of public transit in San Francisco (and to a somewhat lesser extent in the Bay Area's other older central city and adjacent suburbs in Oakland and Berkeley) shares more in common with major cities in the east and Midwest, than in the rest of the west.

A century ago, public transit in San Francisco and other major cities of the era was the workhorse of urban passenger transportation. During its heyday in the 1920s, as the nation was rapidly urbanizing, people of all walks of life rode cable cars, electric streetcars, subways, and early motorbuses for all manner of trips. Trips were spread throughout the day and week; indeed, owing both to six-day work weeks and higher levels of weekend shopping and errand-running, Saturdays were typically the highest ridership day of the week (Jones, 1985). Although automobile technology was improving rapidly and automobiles were growing more popular, transit use was still climbing, reaching its peak in 1926 before experiencing steady declines through the early 1930s during the Great Depression, as shown in **Figure 2-1** (APTA, 2019). Transit received a major boost with the onset of WWII, but went into steep decline afterward, eventually bottoming out in 1972. Annual per capita ridership followed a similar path.

Figure 2-1. U.S. Transit Ridership, 1917-1972



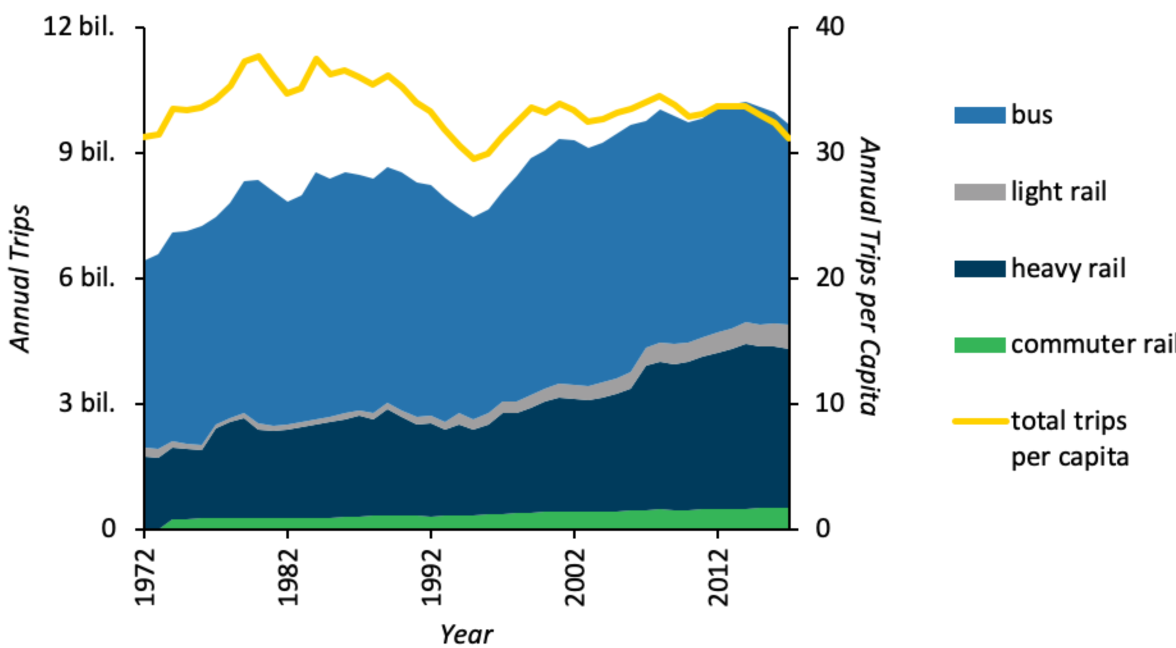
Data source: APTA, 2019

Growing automobile use and suburbanization were taking their toll on transit ridership. Struggling private transit operators were everywhere experiencing bankruptcies, abandonments, or public takeovers (Jones, 1985). By the 1960s, most big-city transit properties had become public operations, and transit operators everywhere—public and private—were scrambling to find new resources as their passenger bases were moving away from their service areas and increasingly commuting by auto (Jones, 1985). The federal government started subsidizing transit in 1961 through the Urban Mass Transportation Administration—now the Federal Transit Administration (FTA)—which provided funding for transit capital improvements, including the public acquisition of formerly private transit operators.

The infusion of federal support was helpful but fell far short of the funding needed to modernize transit as federal funds could only be used for the purchase of rolling stock and capital equipment before 1974, leaving local agencies to cover operating expenses to support expanding fleets of new, federally-financed transit vehicles. In California, this need for operating funds eventually led to passage of the Transportation Development Act in 1971, which supported public transit services including new rail construction (Taylor, 1991). Through the 1970s, many agencies began to design and construct extensive rapid transit systems such as BART to attract suburban commuters to expand their ridership base (Jones, 1985). Rail transit was seen as a solution to growing traffic congestion and air pollution caused by automobiles. Federal (and state) support increased over the years, and the investments paid off as absolute public transit patronage rebounded since its nadir in the 1970s, growing by nearly half since the early seventies though transit service has grown faster than ridership, and transit subsidies have grown faster still (Taylor and Morris, 2015).

While we will turn to Bay Area-specific transit use trends later in this report, national historic trends provide important context. **Figure 2-2** shows that overall transit ridership grew from 6.5 billion annual trips in he early 1970s to 10.5 billion by 2008, where (despite a brief downturn during the Great Recession) it had generally stabilized, until beginning to erode dramatically starting after 2014. Between 1995 (when transit use reached a low point) and 2017 overall transit use grew by over 30 percent, though the per capita rise was a more modest 5.5 percent. It is now basically the same as it was in 1972 (APTA, 2019).

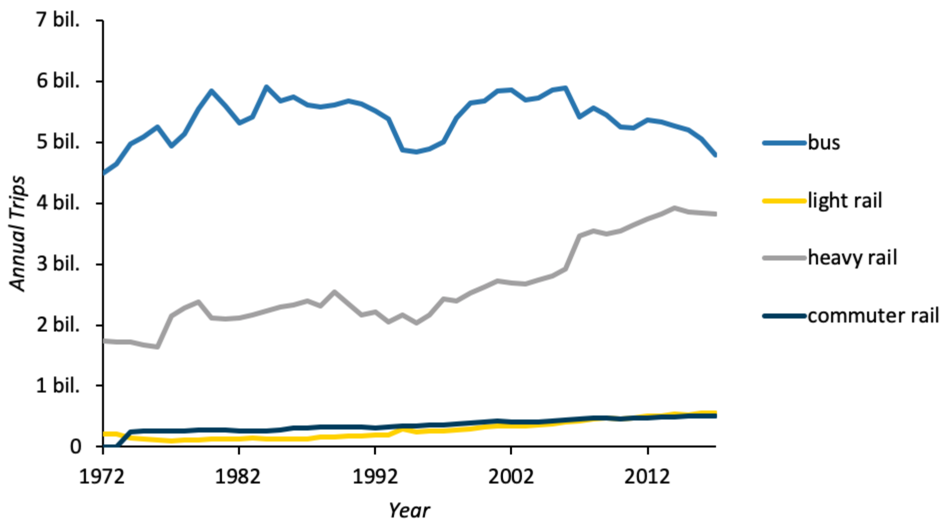
Figure 2-2. U.S. Transit Ridership, 1972-2017



Data source: APTA, 2019

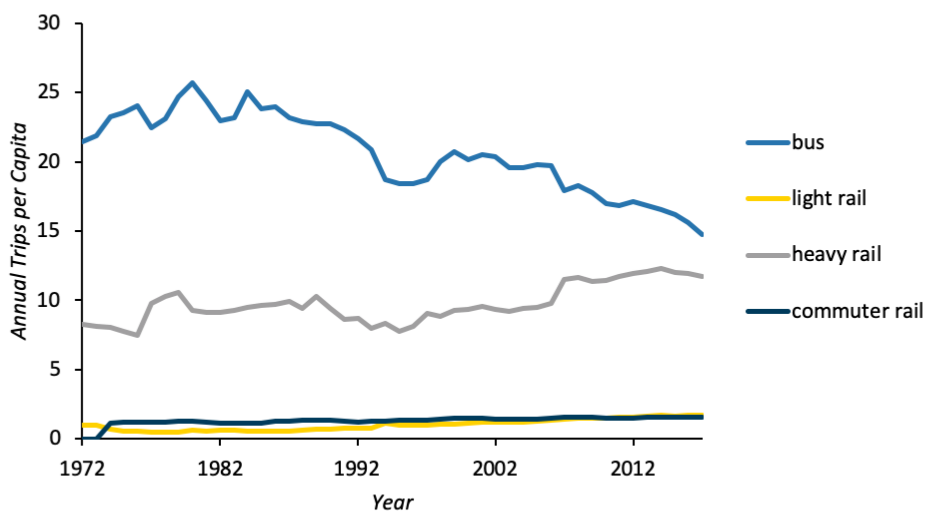
Ridership differences by mode been particularly dramatic since 1995. Rail ridership has seen significant gains in patronage, reflecting decades of increased investment in the mode as shown in **Figure 2-3**. Since 1995, commuter rail use has grown by half and urban rail (light and heavy rail) use nearly doubled. Bus ridership by contrast, has been flat or declining despite population growth. As a result, the share of all transit trips on urban rail increased from 30 to 45 percent. Commuter rail now accounts for over 5 percent of all transit trips versus 4.5 percent in 1995. In contrast, 65 percent of all transit trips were on buses at that time compared to just about half in 2017. Rail ridership per capita (especially heavy rail like BART) has trended upward while bus ridership per capita has steadily fallen since the start of the millennium, as shown in **Figure 2-4**.

Figure 2-3. U.S. Transit Ridership by Mode, 1972-2017



Data source: APTA, 2019

Figure 2-4. U.S. Transit Ridership per Capita by Mode, 1972-2017



Data source: APTA, 2019

Today, despite heavy investment, American public transit is losing its market share. U.S. transit systems carried almost exactly the same number of trips in 2017, 10.1 billion (FTA, 2019) as 60 years ago, 10.4 billion trips in 1957 (APTA, 2019) even though the population nearly doubled from 172 to 326 million in that time (U.S. Census Bureau, 2000, 2019). Per capita ridership has thus nearly halved. This long-term erosion in transit's share of personal travel has accelerated considerably since 2014, as overall ridership has dipped by nearly 600 million annual trips (FTA, 2019). The recent national decline has been primarily among bus and heavy rail trips, while commuter rail and light rail patronage has continued to climb somewhat. The Bay Area has not been immune from these trends, though it held out longer than most of the rest of the country.

Falling ridership is not the only problem facing the transit industry. Even as transit use grew slowly over the past five decades, the increasing dependence on work trips into and out of job centers at rush hours frequently taxed transit capacity. As we will see below, this dependence has only grown in the Bay Area since 2009. As a result, at other times and in other directions, demand fell well below the capacity of vehicle stock and operators (Jones, 1985). This tendency toward "peaking" raised costs: transit agencies scaled their systems to meet peak demand, only to have available vehicles and labor go underutilized most of the day. Public subsidies per passenger increased, and overcrowding caused discomfort to the increasing proportion of peak-period, peak-direction riders (Taylor, Garrett, and Iseki, 2000 and Yoh, Taylor, and Gahbauer, 2016). Again, we discuss the waxing transit peaking problem in the Bay Area in considerable detail in the pages that follow.

What explains the recent drop in Bay Area transit ridership? Are the causes the same or different from those affecting the rest of the country? Transit use depends on a wide variety of factors, some within operators' control (so-called "internal factors"), and some beyond it ("external factors"). Agencies may influence ridership by varying the supply of transit: changing the type of service offered, the level of service, and the quality of service. For instance, research suggests that increasing vehicle revenue miles and hours raises ridership, as do improvements to service quality like route network design (Liu, 1993; Gómez-Ibáñez, 1996; Kain and Liu, 1996; Kohn, 2000; and Thompson, Brown, and Bhattacharya, 2012). In fact, some recent studies show that changes in vehicle revenue miles are the most important factor in explaining variations in transit ridership per capita in the U.S., though such analyses are logically flawed in that they do not account for the degree to which supply and demand are interrelated (Alam, Nixon, and Zhang, 2015 and Boisjoly et al., 2018); transit supply and demand are thus, in econometric parlance, endogenous. We look at the impact of service changes and fare policy in the Bay Area in Chapters 3 and 10, respectively.

In contrast, demand for transit service may be independent of transit supply and depend on other factors such as riders' income, employment, access to other forms of transportation like private automobiles, taxis and increasingly available ridehail services, and even the weather (Taylor and Fink, 2013). Studies find that population density, percent of zero-vehicle households, and median household income explain far more than the availability of transit service (Gómez-Ibáñez, 1996; Chung, 1997; and Taylor et al., 2009) which may simply respond to changes in consumer demand.

Given that the Bay Area's ridership decline is so recent, there has been little research to date about its causes. One study suggests that employment growth between 2009 and 2013 can explain most of the overall growth in ridership on BART (Erhardt, 2016), but this factor does not account for the loss of trips experienced by other operators such as Muni. The same study suggests that changes in service miles had a lesser, though statistically significant, effect on each agency, though there has been an increase in service miles in the Bay Area even as overall ridership is falling, suggesting that outside factors may be more significant than changes in transit supply.

Two of the most significant traveler attributes associated with transit use are auto access and income. Both are particularly relevant in California, though they are interrelated since income influences auto ownership and access to an automobile can have an important impact on personal and family income (Liu, 1993; Gómez-Ibáñez, 1996; Ong, 2002; Taylor et al., 2009; and Baum, 2009).

Generally speaking though, higher income leads to less transit use while those without access to cars tend to ride transit far more (Liu, 1993; Kain and Liu, 1996; Taylor et al., 2009; and Manville, Taylor, and Blumenberg, 2018a). In this report, we examine changes in both income and auto access in the Bay Area in Chapter 5, 6, and 12.

2.2. Income and Transit Use

Poor people, people living in households with few or no private automobiles, and immigrants (and especially less-educated recent immigrants) are especially likely to ride public transit (Anderson, 2016). Studies of transportation behavior find a strong negative association between income and transit use in the U.S. (Giuliano, 2005). This is a historical development; prior to the explosion of motor vehicle ownership and use a century ago, public transit was regularly used by a broad cross-section of society (Jones, 2008). However, as more middle-income people bought and drove private vehicles, transit use and (then mostly private) investment in the mode declined, and the average transit rider became poorer. Low-income travelers' pragmatic decision-making partly drove this change—taking transit is cheaper than owning, registering, insuring, fueling, and maintaining a private vehicle (Gardner and Abraham, 2007). As transit users have grown poorer and poorer relative to the population as a whole, public transit in many places increasingly resembles a social service (Garrett and Taylor, 1999 and Taylor and Morris, 2015).

However, the relationship between transit use and poverty is not a simple one. Differences exist by mode; the average commuter rail user is wealthier than the average American, while the average bus user is markedly poorer (Taylor and Morris, 2015). Meanwhile, the quality of the modes differs and reflects user constraints, as buses often travel slowly in congested areas while commuter rail systems travel quickly, serve high-density central business districts, and provide an attractive alternative to driving (Tirachini, Hensher, and Jara-Díaz, 2010). Exceptions to the poverty/transit user connection also vary substantially by region and area. For example, New York City has by far the largest share of transit users in the country—35 percent of unlinked passenger transit trips in 2017 took place on New York's Metropolitan Transportation Authority (MTA) bus or rail (APTA, 2019)—and its many users have higher median incomes than those of the average American (NuStats, 2009). In New York and other older, densely populated cities of the Northeastern U.S., transit commuters tend to be wealthier than transit commuters in the Sunbelt and the rest of California (Maciag, 2014).

2.3. Zero-vehicle Households and Transit Use

The strongest single predictor of transit use for a trip is the lack of private vehicle access for that trip, as car ownership is strongly negatively associated with transit use (Taylor and Morris, 2015). As mentioned above, many poor people take transit because they cannot afford to own and operate cars; however, most poor people in the U.S. do own cars (Blumenberg and Pierce, 2012). Similarly, while poor people take transit at higher rates than other people, most poor people do not regularly take transit (Anderson, 2016), and instead rely on rides in other people's vehicles or alternatives like biking or walking.

Additionally, while carlessness is typically associated with poverty, some non-poor people make housing and employment choices that enable life without a car. Brown (2017) distinguishes between "car-less" and "car-free" households. Using 2012 California Household Travel Survey data, Brown estimates that 79 percent of zero-vehicle households were car-less—without a private vehicle due to financial or personal constraints—while 21 percent were car-free—without a private vehicle due to personal lifestyle choices (Brown, 2017). As noted above, the car-free lifestyle may appeal to a generation that values dense urban living and physical proximity to activities, and has financial resources at their disposal (Moos, Pfeiffer, and Vinodrai, 2017). Therefore, not all zero-vehicle households need rely on low-priced alternatives to driving like transit; as an extreme example, a wealthy zero-car household might primarily use limousine services to get around Manhattan. Others may take advantage of emerging mobility services which offer new options for travel, including purchasing auto trips one at a time. This is especially true in the Bay Area, an early adopter of private services like Bird, Uber, and Lyft (Circella et al., 2018). The San Francisco metropolitan area boasted the highest levels of ridehail use (e.g., Lyft and Uber) nationally in the 2017 National Household Travel Survey (Conway, Salon, and King, 2018). Other mobility options (collectively referred to as "shared mobility") include bike-share systems, car-share systems like ZipCar, electric scooters, and electric bicycles (NACTO, 2018). The precise effect of new shared mobility options on transit use is not yet well understood; however, we note that even travelers in low-income zero-vehicle households increasingly have new travel options.

2.4. Immigrants and Transit Use

Immigrants also represent a major pool of likely transit users, and research has shown a positive association between foreign origin and transit use (Chatman and Klein, 2009). But the effect on transit use varies by changes in the size, composition, and years in the U.S. of foreign-born population groups. Immigrants are more likely to take transit than native-born travelers—and thus regions with large foreign-born populations like the Bay Area and Los Angeles have higher transit use, all else equal. In fact, immigration explained most of the increase in transit commuters in California from 1980 to 2000 (Blumenberg and Evans, 2007). Other research shows that much of the drop in transit ridership in Greater Los Angeles can be attributed to a dramatic increase in auto ownership since 2000 (especially among Hispanic immigrants) (Manville, Taylor, and Blumenberg, 2018a), but as we discuss further in this report in Chapter 12, this trend does not seem to have been the case in the Bay Area, though changes in the composition of the immigrant population in the Bay Area may affect future ridership.

While foreign-born people use transit at higher rates because they tend to be poorer and own fewer vehicles than the average American, a unique "transit immigrant effect" exists beyond income and vehicle access (Blumenberg and Smart, 2010). Several studies show that, even when controlling for a variety of socio-economic factors, immigrants travel by means other than driving—walking, bicycling, carpooling, and transit—at higher rates than native-born travelers (Blumenberg and Shiki, 2007). However, as the time of residence in the US increases, this effect diminishes.

Several theories explain the immigrant effect including that higher levels of transit use in the behavior of the sending country socializes people to prefer transit to driving (Blumenberg, 2009); enclave effects and social networks may engender more carpooling and other types of collective behavior (Blumenberg and Smart, 2010). And as approximately 10.7 million unauthorized immigrants (or 24% of the foreign-born population) lived in the U.S. in 2016, many immigrants lack access to drivers' licenses (Passel and Cohn, 2018).

Nationally, the sending countries of immigrants have changed over time, with Asian immigrant entries surpassing Hispanic entries since 2010 (Radford, 2019). This is consequential because foreign-born residents tend to travel differently depending on region of origin and time in the U.S.; recent immigrants from Asia are far more likely to commute by driving alone than recent immigrants from Latin America (Blumenberg, 2009). And, Hispanic immigrants tend to ride transit at higher rates than do the native-born; Asian immigrants also take transit more than the native-born do, but at lower rates than Hispanic immigrants (Blumenberg and Shiki, 2007).

Recently, Assembly Bill 60 (AB 60) granted access to drivers' licenses for California's unauthorized immigrants. At between 2.35 and 2.6 million, California has the largest population of unauthorized immigrants in the U.S., which comprised more than six percent of the state's total population in 2014 (Hayes and Hill, 2017). Former Governor Jerry Brown signed AB 60 in 2013, and the California Department of Motor Vehicles (DMV) began to issue licenses in 2015 (California DMV, 2018). In the law's first year, the DMV issued 605,000 licenses, and has since issued over one million so-called AB 60 licenses. While the effect of this policy on the number of issued licenses is apparently substantial (See Chapter 16), researchers have struggled to evaluate how licensure access affects actual travel behavior. Evidence from 2006 interviews with undocumented residents in California suggests that many undocumented immigrants already drove without licenses and weighed the risks of illegal activity against the benefits of mobility and necessity of regular employment (Lovejoy and Handy, 2011).

While California has both large Hispanic and unauthorized immigrant populations, the distribution of the foreign-born population is not uniform across the state. Of the 10.5 million immigrants living in California in 2017, 38.5 percent were born in Asia, 51.3 percent in Latin America, and 10.2 percent elsewhere (U.S. Census Bureau, 2019). However, the Bay Area has twice as many immigrants from Asia as from Latin-America (U.S. Census Bureau, 2019).

2.5. Jobs, Housing, and Transit Use

Another possibility for the drop in transit ridership centers on the relocation of households away from expensive cities and neighborhoods to outlying areas where housing is more affordable but transit service and use is more limited. In the past, scholars and policy makers have focused on the jobs–housing balance—the spatial location of employment relative to housing within geographic areas—as a predictor of vehicle miles of travel and traffic congestion (Salon et al., 2012). The underlying notion is moving workers closer to jobs (or vice versa) will result in less travel and, perhaps, greater non-auto travel (Salon et al., 2012; Cervero, 1989; Peng, 1997; and Sultana, 2002), though the latter is far from certain.

Some scholars argue, however, that factors other than proximity to employment, such as larger homes and lot sizes and improved neighborhood amenities (e.g., high-quality schools, low crime rates, availability of parks) are more important to residential location choice and employment and travel outcomes (Giuliano and Small, 1991). Households may be willing to trade off longer commutes for these benefits, which may decrease their use of transit.

In either case, the prospects of achieving better jobs-housing balance has often been hindered by land use policies that restrict residential densities, raising housing prices and preventing some workers from living in the same city in which they find jobs (Levine, 1998 and Cervero, 1996). Additionally, as housing prices rise through gentrification low-income renters may be priced out of neighborhoods with high transit access, and be forced to commute farther (Levine, 1998; Cervero, 1996; Schuetz, 2019; Joint Center for Housing Studies, 2018; and Moos, Revington, and Wilkin, 2018). Though, at least some of those low-wage workers may search for jobs in closer proximity to their new homes, thereby increasing jobs-housing balance but potentially at the cost of lower wages (Glaeser and Gyourko, 2018).

Changes in the location of jobs and households may lead to increased vehicle use which is likely to have several impacts on public transit supply and use. First, living in outlying areas may motivate former transit-dependents and occasional transit users to substantially reduce or even eliminate the number of transit trips they take. Second, decreased reliance on transit due to increasing vehicle use is likely to undermine popular support for transit service, potentially resulting in reduced subsidies to transit agencies and consequent cuts to transit service. Third, increased vehicle use may spur long-term changes to land use patterns (e.g., decentralization) that reduce the viability and efficiency of transit as a mode of transport, except perhaps for services designed to facilitate the commutes of suburban workers to jobs located in downtown areas. Fourth, a car-free lifestyle facilitated by proximity to transit may appeal to a generation that values dense urban living and physical proximity to activities (Moos, Pfeiffer, and Vinodrai, 2017), but these residents may be less inclined to use transit than those with fewer alternatives.

2.6. Transit-friendly Neighborhoods

Related to the above, transit ridership may be negatively affected by the changing composition of transit-friendly neighborhoods, neighborhoods that could be expected to provide a core of transit users. One characteristic of such areas is a high percentage of poor people, immigrants, and other residents with few or no private automobiles, who have historically located in transit-rich neighborhoods (Glaeser, Kahn, and Rappaport, 2008). However, gentrification may make it increasingly difficult for "car-less" households—households without private vehicles due to financial or personal constraints—to live in transit-rich neighborhoods. Much of the literature on this topic centers on neighborhood change and potential displacement surrounding rail stations and the findings are mixed. Examining 14 metropolitan areas with new transit stations, Kahn (2007) finds some evidence of gentrification in certain cities, particularly around "walk and ride" stations; however, he did not find evidence of this effect in San Francisco. In his study of Portland, Dong (2017) likewise does not find evidence of rail-transit induced gentrification. Similarly, in their study of 14 urbanized areas, Baker and Lee (2019) do not find widespread evidence of gentrification around light rail stations; however, they do find strong effects in San Francisco. Finally, Chapple et al. (2017) find that in California, neighborhood change, though not necessarily displacement, is associated with TODs, particularly in urban cores. Even if higher-income residents replace frequent transit users in TODs, the newly increased densities of development should lead to a net increase in potential transit *users,* though perhaps not a net increase in transit use if new TOD residents do not ride as frequently as those replaced. For example, Dominie (2012) examined transit commuting before and after the development of new rail transit stations and station-area development in Los Angeles and found that overall transit commuting declined in most station areas, even if the overall station-area populations grew. We explore recent changes in the composition of transit-friendly areas in Chapter 8.

2.7. Ridehail and Transit Use

Finally, the growing popularity of ridehail services like Lyft and Uber, mentioned above, has been blamed, by some, for the decline in transit use, though the true effects are uncertain. While ridehail *may* be replacing some trips once made on bus or rail, it could also be encouraging more transit use by bringing new riders to rail stations or bus stops (the so called "last mile" problem). Conversely, it might be having little noticeable effect either way, as the two modes could be serving different travel markets. Surveys of ridehail passengers run the gamut (Schaller, 2018 and Feigon and Murphy, 2016), with some agreement that high ridehail times like Friday and Saturday nights do not coincide with times of high transit use (Rayle et al., 2016 and Castiglione et al., 2017). There is some evidence that in metro areas where ridehail service is more mature, it may be displacing some transit service (Graehler, Mucci, and Erhardt, 2019 and Babar and Burtch, 2017), though Hall, Palsson, and Price (2018) dissent. It also may be that ridehail users differ demographically from core transit riders—the former tend to be younger, more well-educated, and higher-income—and, therefore, less likely to use transit in the first place (Dias et al., 2017). If ridehail services are having an effect, it would be in its first home, the Bay Area. We report on the potential impact of ridehail services on Bay Area transit in Chapter 14, but given the newness of these services, research data are limited and these private companies limit access to their own information, so any conclusions are at best preliminary.

2.8. Conclusion

All of the factors reviewed here are at work to varying degree in the Bay Area today. The increasing reliance on peak-period downtown commuting continues up to the present day, for example. Other common explanations for declining transit use nationally include service and budget cuts, plummeting reliability, Uber and Lyft, and relatively cheap gas (Bliss, 2017). Regional studies suggest, however, that the causes may be more connected to factors unique to particular locations. We have already mentioned that the steep decline in transit use in the Los Angeles region appears largely due to increased auto access, something not evident in the Bay Area (Manville, Taylor, and Blumenberg, 2018a). In New York, the MTA has purportedly spent far too little on rail, and in particular rail transit maintenance (Kabak, 2018); in Los Angeles, Metro has been accused of spending far too much (Nelson, 2017; Nelson and Weikel, 2016; and Rubin, n.d.). In D.C., deadly train crashes and the line-closing repair work that followed forced riders off in dramatic plunges (Aratani, 2016); in other cities, gradual service cuts have supposedly caused a slower ridership erosion (Grabar, 2016). In short, factors influencing ridership may be mostly universal, but their relative importance appears to vary dramatically from region to region. Thus, the experiences elsewhere can be informative and suggestive, but they are not conclusive. To know what's behind recent ridership losses in the Bay Area, we need to look specifically at the region, its transit operators, and its transit riders. And it is to that task we now turn.

Part II

What's Going on with Bay Area Transit Use?

In Part II, we examine ongoing trends in transit supply and use in the Bay Area. We focus on trends at the regional level as well as the performance of specific operators. We also examine transit use from the user side through analysis of travel survey data.

In Chapter 3, we analyze trends in transit supply and patronage over the entire Bay Area. Like the nation and California as a whole, the region has experienced significant ridership declines in the past few years. However, these losses have occurred more recently in the Bay Area than in the state or nation—although closer examination of specific operators reveals that relatively strong ridership numbers on BART and the San Francisco Municipal Transportation Agency (Muni or SFMTA) have masked steeper declines from other regional transit operators. Notably, regional transit productivity has been declining for a longer period of time than total patronage. Service hours and miles have in recent years continued to rise even as ridership as fallen. In short, changes in overall transit supply are not responsible for declining patronage. Declining ridership is also not likely attributable to expansion of rail mileage. Finally, we separately examine the performance of bus and rail and find relatively similar trends for both modes, at least compared to the growing modal differences in other parts of the county. Again, these findings imply that supply-side factors are not responsible for declining transit patronage.

In Chapter 4, we examine the performance of the eight largest Bay Area operators. While the extent varies by agency, we find significant evidence of peaking, the concentration of riders at peak times, in core areas, in commute directions, etc. In other words, ridership changes at off-peak hours, on weekends, on outlying routes, in non-commute directions, and on smaller operators account for a large and disproportionate share of the whole region's patronage decline (Wasserman, 2019). On the other hand, the performance of operators in urban cores where residential and employment density are highest, like Muni and AC Transit, have experienced less peaking, though not necessarily less overall losses. Broadly, job growth and its relation to urban form help explain why some operators have experienced acute peaking but healthy ridership, others little peaking but falling ridership, and still others both problems.

In Chapter 5, we use data from the oversample of California households in the 2009 and 2017 National Household Travel Surveys (NHTS) to describe changes in transit use among demographic groups traditionally likely to use transit. These data allow us to compare the central Bay Area to Los Angeles and Orange Counties and to California as a whole. We find that transit use decreased among Hispanic respondents, low-income households, zero-vehicle households, and households with less than one car per driver ("vehicle-deficit" households). Notably, these declines were more moderate in the central Bay Area counties than in Los Angeles and Orange Counties and the state as a whole. At the same time, we find that transit use generally increased among non-Hispanic whites, higher-income households, and households with more than one car per driver, a trend that was particularly strong in the central Bay Area counties. In short, we find that groups that have historically been heavy transit users are taking transit less while groups that have historically been heavy transit users are using transit more. Multivariate analysis of the two survey years similarly shows that ridership by those living in households with at least one vehicle per driver rose relative to those with limited vehicle access, while transit trip-making by residents of lower-density neighborhoods increased relative to their higher-density counterparts. Finally, we use latent profile analysis to identify distinct transit user types and find that higher-income, car-owning, long-distance individuals constituted a larger share of transit users in 2017 than in 2009. Together, our results suggest important changes in transit use by individuals in several socio-demographic categories. In particular, we find that the gap in transit use between groups with historically heavy use of transit and groups that have not historically been heavy transit users is shrinking.

3. Regional Transit Trends

3.1. Introduction

In the Bay Area, transit patronage is slumping but not collapsing. Amidst a national decline in transit ridership that has approached crisis levels in some metropolitan areas, the Bay Area has only recently started losing patronage. However, in just two years, 2017 and 2018, the region lost 27.5 million annual boardings, falling 5.2 percent, from 531 million to 504 million annual boardings. In this chapter, we examine the contours of this decline, finding some unique aspects of the Bay Area's ridership trends and ruling out a few possible causes.

The Bay Area began losing riders in 2017, two years after the nation and California as a whole. While this difference in timing does suggest factors behind the decline are particular to the Bay Area, we also find some troubling signs in ridership fundamentals dating back before the overall decline in regional ridership. For instance, as regional population and employment have boomed, per capita ridership has remained flat at best since the Great Recession recovery began. High ridership on the region's largest operators, especially growth on BART, masked earlier faltering ridership on other agencies, and regional transit productivity began to fall years before overall ridership. However, we cannot attribute this decline to service cuts—in fact, service hours and miles have increased as ridership has fallen. Nor are rail expansion or modal differences in service supply trends likely causes either.

The analysis in this section draws on the National Transit Database (NTD),[1] the FTA's repository of ridership, service, and financial statistics for transit operators nationwide (FTA, 2019).

3.2. The Bay Area's Transit Ridership Slump

Transit ridership in the Bay Area is declining. This should come as no surprise to anyone who has read this far in this report. However, before delving into the reasons for the recent downturn, the decline itself merits examination, given its scale and its timing.

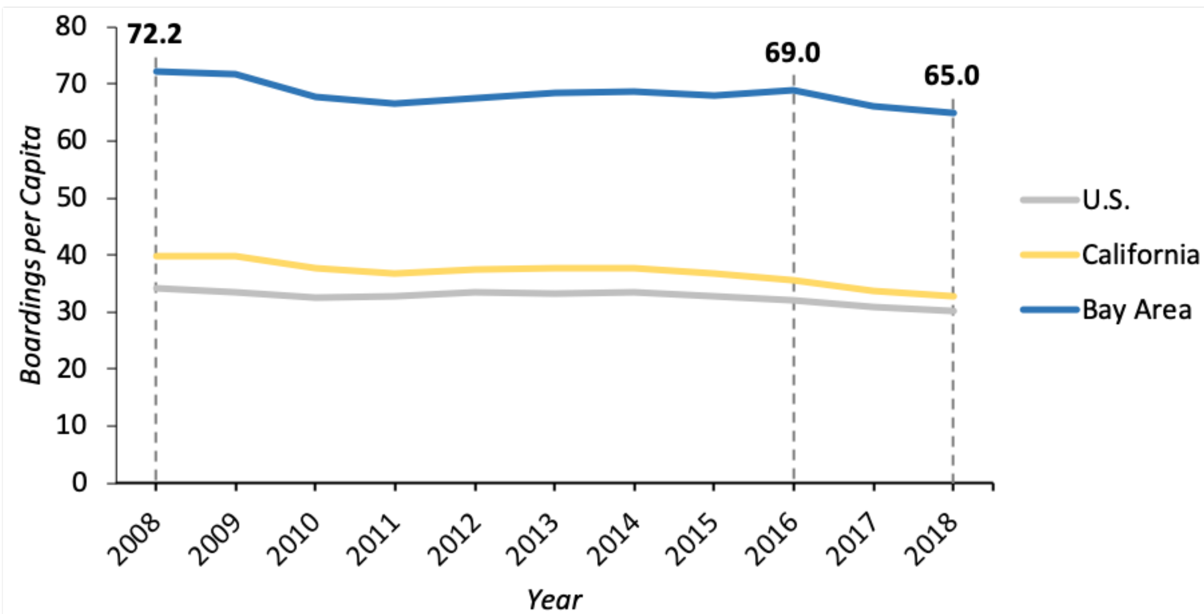
Unlike most of the rest of the country, Bay Area ridership held steady until around the end of 2016. Indeed, regional ridership had been growing around two to three percent per year since 2011, a fairly consistent rise that had more than made up for patronage losses during the Great Recession. But in 2017, region-wide patronage fell around four percent, or nearly 20 million annual boardings. Ridership therefore fell to just over 2013 levels in a single year, a significant step back. Annual boardings dropped another 1.5 percent in 2018 compared to the 2016 total. In the Bay Area, transit use continues to veer off the rails—even if it has not careened completely off the tracks, as in other metropolitan areas.

A look at boardings per capita shows the scale of the region's problem. The Bay Area has experienced substantial population growth in the past decade, growing 11 percent from 2008 to 2017 (compared to 7% nationally and 7% in Greater Los Angeles) (U.S. Census Bureau, 2011, 2019). Thus, Bay Area operators' seemingly healthy ridership throughout most of the 2010s has been due in no small part to having a growing number of people from which to draw riders. Trends in ridership per capita show this (See **Figure 3-1**). On the positive side, Bay Area agencies have long carried around twice as many trips per person as the U.S. and California averages. Still, after a post-Great-Recession recovery, per capita ridership stayed generally flat between 2013 and 2016. At no point

1. The NTD reports statistics by year, which are labeled in the dataset as calendar years but are actually the aggregate of each operator's fiscal year (whose start and end dates vary between operators). Following the lead of other scholarly publications, we reference annual NTD data by calendar year in graphs and text.

since the start of the Great Recession has per capita ridership come close to its 2008 high. Rather, from 2008 to 2016, the region saw a net slow decline in ridership per capita, falling from 72 trips per person to 69. And in 2017, ridership per capita plummeted, dropping from 69 to 66 trips per person in a single year. This was the steepest one-year drop since the height of the Great Recession. Per capita ridership fell further, to 65 trips per person, in 2018. Thus, even as the region adds more and more residents, they are riding less and less on average—and dramatically so since the start of 2017. So while the recent, steep drop in per capita ridership should be cause for concern, so too should the preceding decade of gradually falling transit use per capita, which was largely masked by rising population.

Figure 3-1. The Scale of the Ridership Decline



Data source: FTA, 2019 and U.S. Census Bureau, 2011, 2019

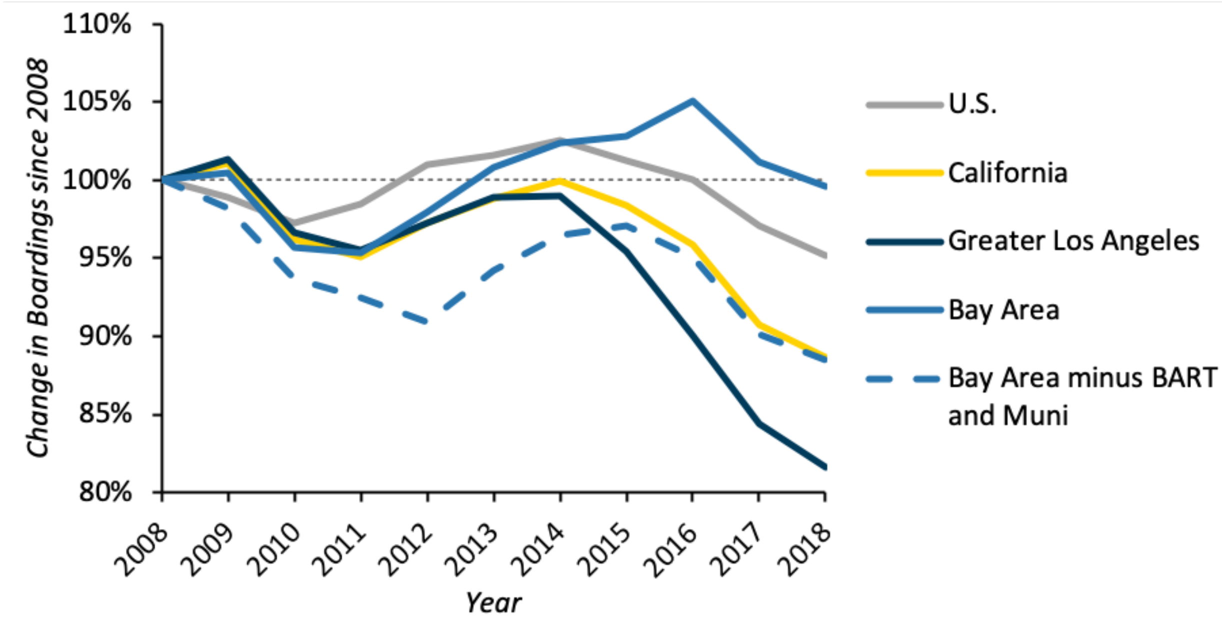
Again, falling ridership is not unique to the Bay Area. Indeed, across the state and country transit patronage is down. The difference, though, is in timing. **Figure 3-2** shows how absolute ridership in the U.S., California, Greater Los Angeles, and the Bay Area has changed since 2008. The first three peaked in 2014 and have declined ever since, steepening every year. In contrast, Bay Area transit patronage continued to climb until 2016, only falling thereafter. Notably though, ridership outside of BART and Muni began to decline a year earlier, a difference discussed further below.

As the per-capita ridership trends[2] in **Figure 3-1** demonstrate, delayed ridership losses should not be celebrated as a sign of the Bay Area's fundamentally stronger ridership trends. Rather, put together, these two measures suggest that the Bay Area's above-national-average topline ridership numbers have masked earlier warning signs.

Still, the timing difference between the Bay Area and the rest of the country is notable. This lag may mean that a wholly different

2 . Because overall ridership numbers are easier to grasp than per capita patronage, they attract more media attention, but ridership per capita is a better measure of market penetration (and to a lesser extent, market share).

Figure 3-2. Delayed Ridership Losses in the Bay Area, Particularly on BART and Muni



Data source: FTA, 2019

set of factors are behind the Bay Area's drop, or that the same factors affecting other regions were simply delayed here. In the pages that follow, we will build a case both for the unique or uniquely strong factors faced by the region and its largest transit operators and, to a lesser extent, for the commonalities with the rest of the nation faced by smaller operators.

We dedicate a whole second volume to differences and similarities in ridership trends between Bay Area operators, summarized in Chapter 4. But one key point merits mention here: **Figure 3-2** shows that the timing and magnitude of the region's ridership trends look quite different when Muni and BART are excluded. As in most metropolitan areas, ridership is asymmetric across agencies, meaning that a few operators carry most of the trips. In the Bay Area, Muni and BART carried over 70 percent of 2018 regional ridership. In fact, their combined share of transit trips in 2018 was the highest of any year in the NTD's online data, dating back to 1991 (FTA, 2019). Therefore, not only are riders within each agency concentrated at peak times and directions, as we detail in Volume II and Chapter 4, but they are also increasingly concentrating onto the busiest operators.

Bay Area transit ridership, apart from these two agencies, more resembles the rest of the nation (See **Figure 3-2**). Without Muni and BART, ridership never fully recovered from the Great Recession, during which patronage dropped just over nine percent between 2008 and 2012. Thereafter, non-BART-and-Muni ridership peaked in 2015—one year after the U.S. peak and one year before the Bay Area (including BART and Muni) peak—and has fallen on a similar slope as the country and state ever since.

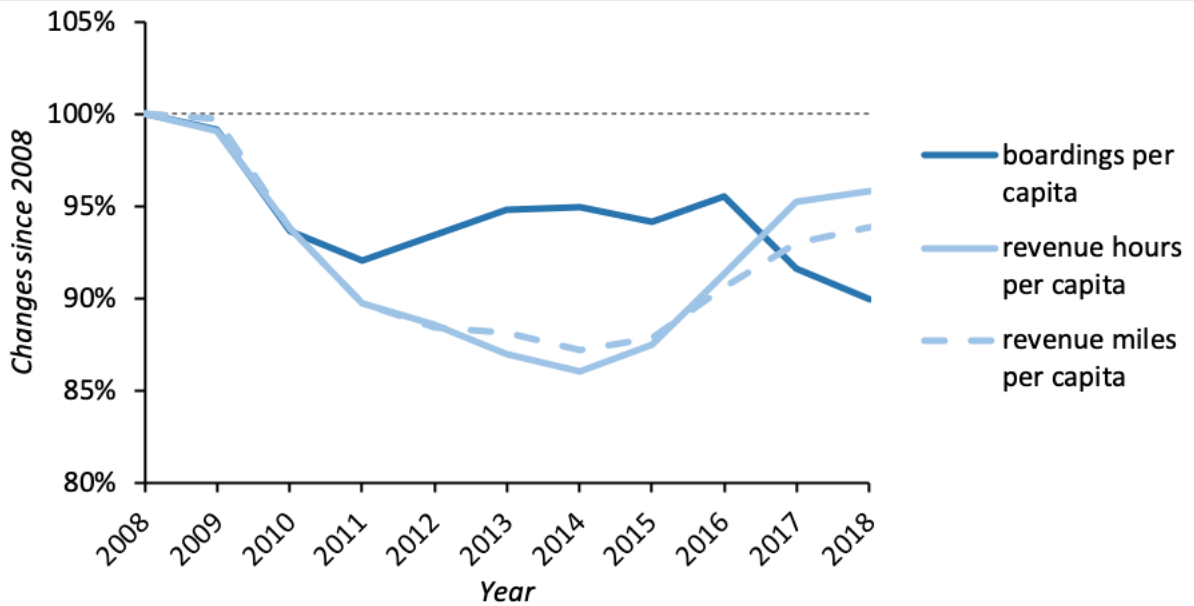
Why the difference between BART and Muni and the other Bay Area operators? Most of these other agencies do not operate in dense, transit-friendly environments, particularly downtown San Francisco; their operating environments, and patronage patterns are more like the rest of the state and nation. Thus, if factors different from the rest of the U.S. are behind the Bay Area's ridership trends, they likely primarily affect the largest operators, while the rest of the region operates under many of the same forces observed elsewhere.

3.3. Service Supply

In many agencies across America, service cuts and ridership declines have created a vicious cycle. As headways rise and reliability falls, riders find other ways to travel, reducing operator farebox revenues that precipitate another round of cutbacks. Substantial evidence suggests that transit in the New York (Colon, 2018) and Washington, D.C. (Aratani, 2016) regions, which host very high levels of transit use (FTA, 2019), have fallen into this downward spiral. The Bay Area, though, appears to have escaped it. This seemingly positive finding belies a perhaps more worrisome conclusion: ridership in Northern California is falling *in spite of* more service availability.

Figure 3-3 shows region-wide trends in revenue hours and miles per capita versus boardings per capita. Overall, the three tracked neatly during the Great Recession. During the gradual economic recovery between 2010 and 2014, ridership recovered somewhat, while the lingering effects of recession-induced budget cuts likely kept agencies from restoring service, at least initially. Since then, most Bay Area transit agencies have added service, in some cases substantially, yet ridership has begun to fall.

Figure 3-3. Bay Area Boardings per Capita versus Service Hours per Capita

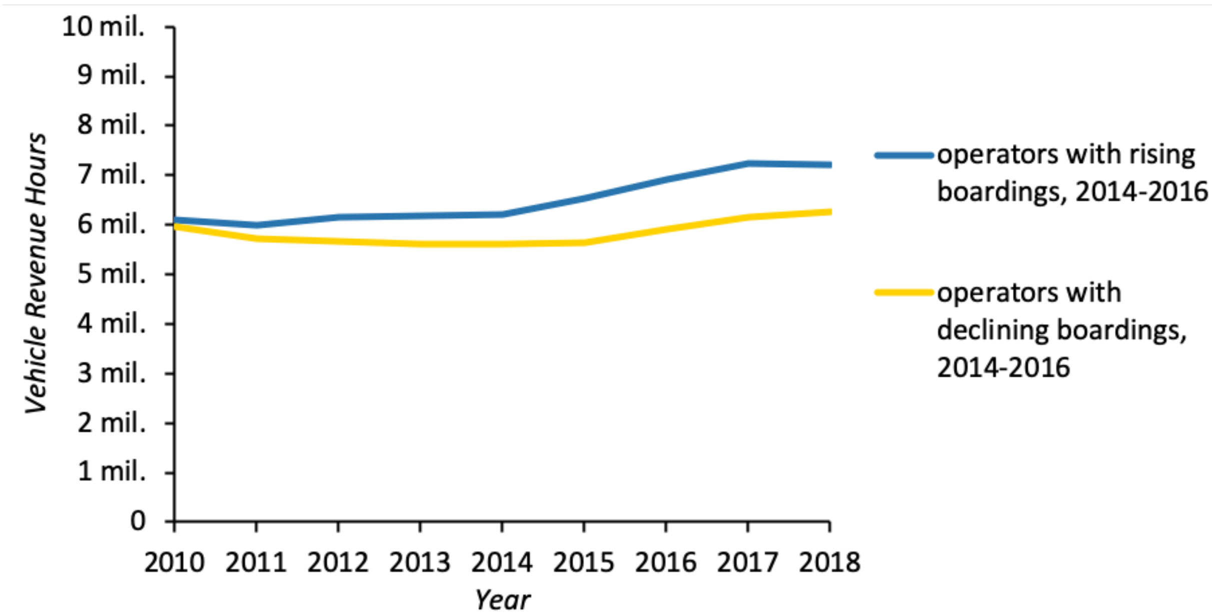


Data source: FTA, 2019 and U.S. Census Bureau, 2011, 2019

Revenue *miles* of service per capita follow a similar trendline as revenue *hours* of service per capita: increasing just as ridership is decreasing (Service miles lag slightly behind service miles due to increasing congestion on existing routes or reallocation of service to more congested areas.) (See **Figure 3-3**). BART, for instance, has opened two new extensions in as many years (Rudick, 2017 and BART, 2019a), and the Sonoma-Marin Area Rail Transit (SMART) system opened recently as well (SMART, 2017). But these service-mileage-boosting routes have not increased the region's overall ridership numbers. Put simply, whether measured by miles or by hours, service is up and patronage is down.

Ridership trends do vary between operators (See Chapter 4 and Volume II), but changes in service supply are not stongly coorelated. From 2014 to 2016—the critical period in which national transit ridership was falling but Bay Area ridership rising — some Bay Area operators saw ridership fall, while on others, it rose (Before 2014, most operators were gaining trips; after 2016, ridership fell on nearly every agency.). **Figure 3-4** shows that, while Bay Area operators whose 2014-2016 ridership rose did add slightly more service than those whose 2014-2016 ridership fell, both categories added service since 2014 at roughly the same rate.

Figure 3-4. Service Changes on Bay Area Operators, Grouped by Whether They Gained or Lost Riders during the Critical 2014-2016 Period

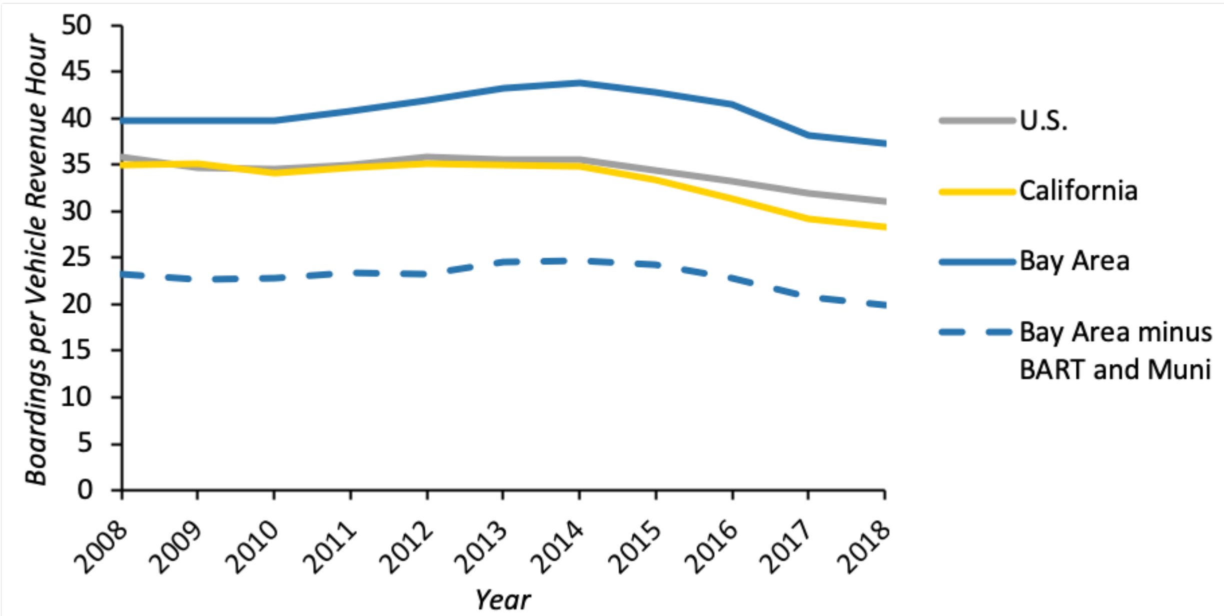


Data source: FTA, 2019

These dual trends of falling patronage and rising service have caused transit productivity to drop. Productivity—measured here as the number of boardings per hour of service—is a key indicator of how effectively agencies are operating. Like the ocean receding before a tsunami, productivity often ebbs (despite service increases) some time before ridership itself crashes down. This was the case in Greater Los Angeles, where productivity has fallen every year from 2013 on, two years before overall ridership began its descent (FTA, 2019). The Bay Area has followed the same pattern on a slight delay. **Figure 3-5** shows that regional productivity declines commenced in 2014, while overall ridership didn't fall until 2017. Even excluding BART and Muni, productivity has followed a similar pattern.

The Bay Area's recent productivity drop is steeper than America's overall. In fairness, Bay Area transit service productivity is still markedly higher than the state and the nation—a distinction it has held all but one year since 1991 (FTA, 2019). But without Muni and BART, the region's productivity actually lies below both California's and America's. Supplying more and more hours of service to residents who are taking fewer and fewer trips raises a conundrum: as detailed in the following chapter and Volume II, these

Figure 3-5. Productivity



Data source: FTA, 2019

countervailing trends are explained at least in part by the loss of off-peak riders on systems and routes, while the ridership that remains is increasingly concentrated at peak times when capacity constraints prevent more service from being easily added.

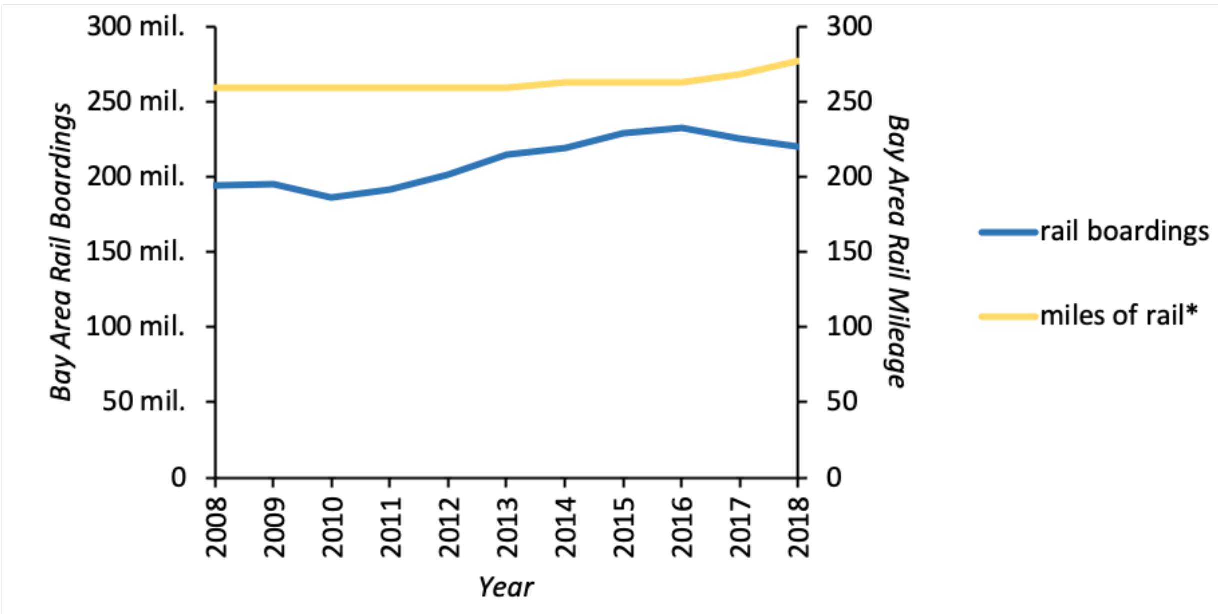
3.4. Trends by Mode

Like in Greater Los Angeles, Bay Area ridership trends vary significantly by mode (Manville, Taylor, and Blumenberg, 2018a). However, unlike Greater Los Angeles, the Bay Area has not expanded its rail network much in recent years (See **Figure 3-6**). After a spurt of building by Muni and VTA in the mid-2000s, the region saw no new rail miles added from 2007 until the opening of BART's Oakland Airport Connector in 2014 (Demery, 2011; VTA, 2019a; and BART, 2019d). Only recently did rail openings pick up again, with BART's Warm Springs/South Fremont extension in 2017 and the East Contra Costa "eBART" extension in 2018 (Demery, 2011 and BART, 2019d). These latter two openings coincide with the recent ridership decline, but given their small scale relative to the entire BART system, the timing appears to be a coincidence.

The relative dearth of new rail miles in the past decade suggests that the criticisms leveled against Los Angeles' rail expansions—that huge new investments starved buses of funds and riders—do not apply to the Bay Area. To be sure, the cost-effectiveness and marginal ridership effect of BART and VTA's earlier extensions (from the 1990s and 2000s) are not as high as was hoped or projected. However, within the timeframe of this report, active, new rail expansion does not appear to be behind ridership declines.

That said, regional rail ridership has increased as bus boardings have decreased (See **Figure 3-7**). Rail patronage has steadily risen over the past decade, save for a brief dip during the Great Recession and the drop in 2017. Overall, trains carried around 26 million more trips in 2018 than 2008. Bus boardings, meanwhile, have slid downward over the same period, at best flat-lining most years.

Figure 3-6. Rail Mileage Steady as Rail Boardings Rose and Fell



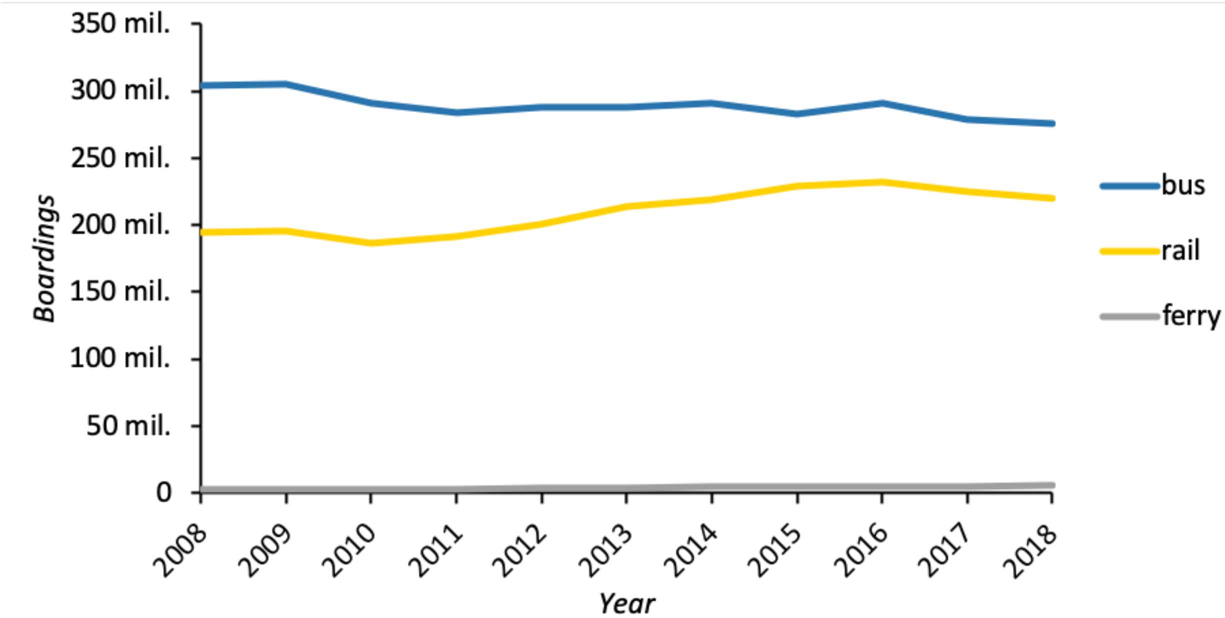
** geographic miles of rail lines, not revenue service miles (discussed below)*

Data source: FTA, 2019; Freemark, 2019; and Demery, 2011

Buses region-wide lost nearly 29 million trips between 2008 and 2018. To some degree, this difference between the two modes is due to ridership growth on BART, which carried 59 percent of the region's rail riders in 2018 and accounted for 53 percent of rail ridership growth since 2008. Nonetheless, rail boardings across agencies have grown since the Great Recession to a degree that more than offset losses on buses, until 2017. As the data presented above indicate, this does not appear to have occurred because new rail lines have taken ridership from buses—simply because there are few new rail lines, period—though some riders may be switching from buses to existing rail lines due to increased street congestion, changing job locations, or other factors. Worth noting, though, is the fact that rail and bus ridership finally did start moving in tandem in 2015, both rising the next year and falling the year after. While various pressures may have boosted rail ridership and dampened bus ridership before then, their parallel movements since suggest that a new or newly strengthened set of factors is now affecting both modes similarly.

All the while, ridership on public ferries in the Bay Area grew 63 percent between 2008 and 2018. Because ferries operate more like trains with a dedicated right of way than buses in mixed road traffic, the same commute-related factors behind increased rail ridership may also be boosting ferry use. However, some of ferries' ridership growth in the NTD is also due to public operators like Golden Gate Transit taking over previously private routes that did not report data. And despite the fact that ferries carried more trips in the Bay Area than all but two urbanized areas nationwide (with a share of total transit boardings higher than all but nine), ferries still only account for around one percent of annual Bay Area transit trips (FTA, 2019).

Figure 3-7. Boardings by Mode



Data source: FTA, 2019

All this comes as rail and bus service have increased at relatively similar rates. Bay Area agencies supply far more vehicle hours of bus service than rail service,[3] but both have increased markedly since 2014 (See **Figure 3-8**). Meanwhile, buses and trains have traveled nearly the same number of revenue service miles[4] over the past decade, with a slightly larger uptick for rail since 2014 (See **Figure 3-9**). In sum, since 2008, bus revenue service hours have gone up more than rail hours, but rail ridership has risen more than on buses. Again, this evidence does not support a story of rising rail investment (and patronage) occurring at the expense of buses; the story is one instead of increases in service on both modes. Despite this increased service, ridership fell faster than service was added, with productivity in terms of boardings per service hour falling on both modes since the end of 2014 (FTA, 2019).

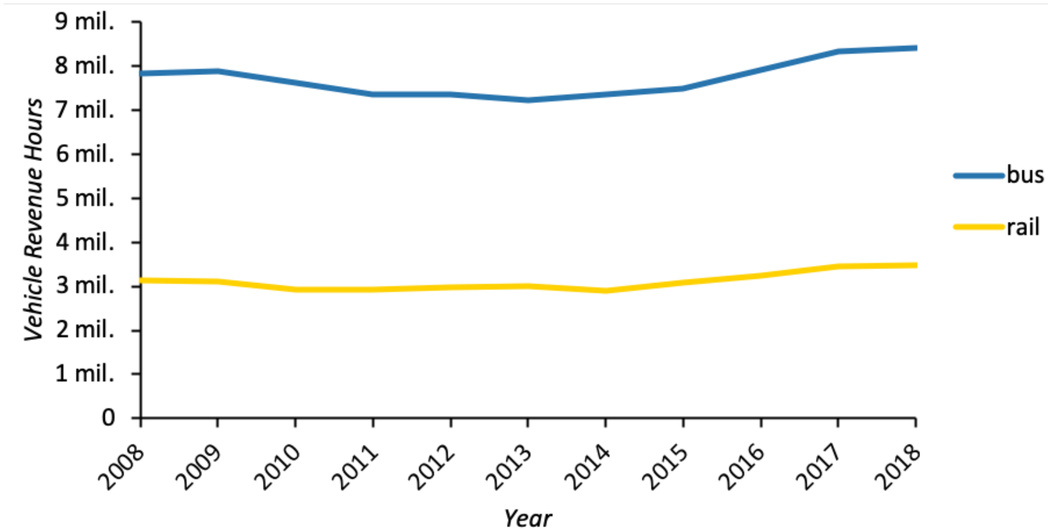
Nonetheless, the operating speeds of buses in the Bay Area have slowed in recent years, but not trains (See **Figure 3-10**). Dividing revenue miles by revenue hours, speeds on buses have dropped 0.9 miles per hour, or eight percent, since 2008 (over half of which occurred since 2017), while rail speeds have increased 0.6 miles per hour, or two percent. Stuck in gradually worsening traffic, with few dedicated lanes to bypass jams, slower buses, rather than fewer buses, may contribute to bus ridership declines.

However, worsening traffic is not the only possible cause of slower bus service. The relative spatial allocation of service among slow-moving central city areas, faster-moving suburbs, and free-flowing exurbs affects overall bus speeds as well. If service were reallocated from fast-moving but lightly-patronized outlying routes to slow-moving, but more heavily patronized central city

3. Though because trains typically accommodate many more passengers than buses, the differences in revenue service between the two modes are narrower if measured per seat-hour and per passenger-capacity-hour (Taylor, Garrett, and Iseki, 2000).

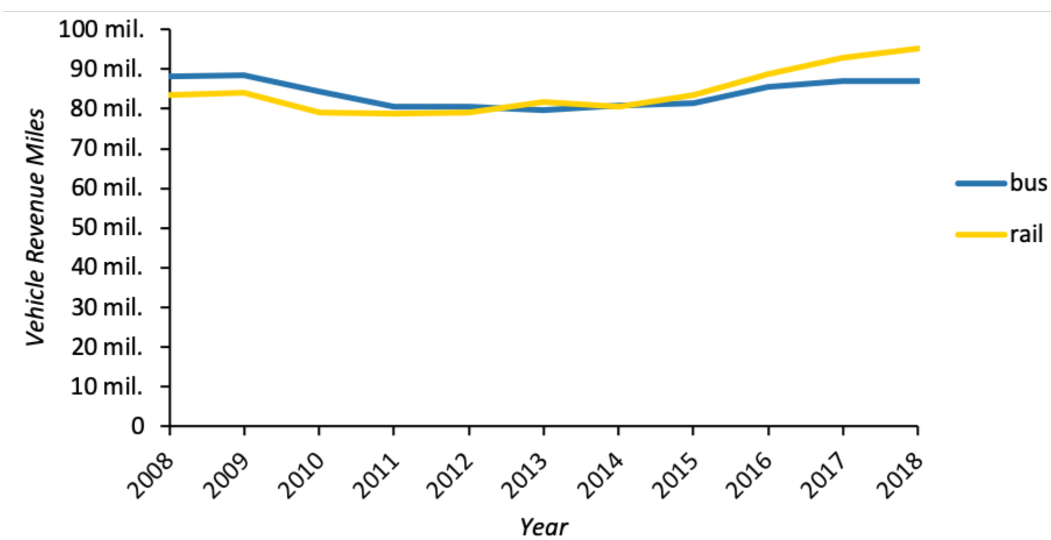
4. Not to be confused with geographic miles of rail lines, discussed above

Figure 3-8. Vehicle Revenue Hours of Service by Mode



Data source: FTA, 2019

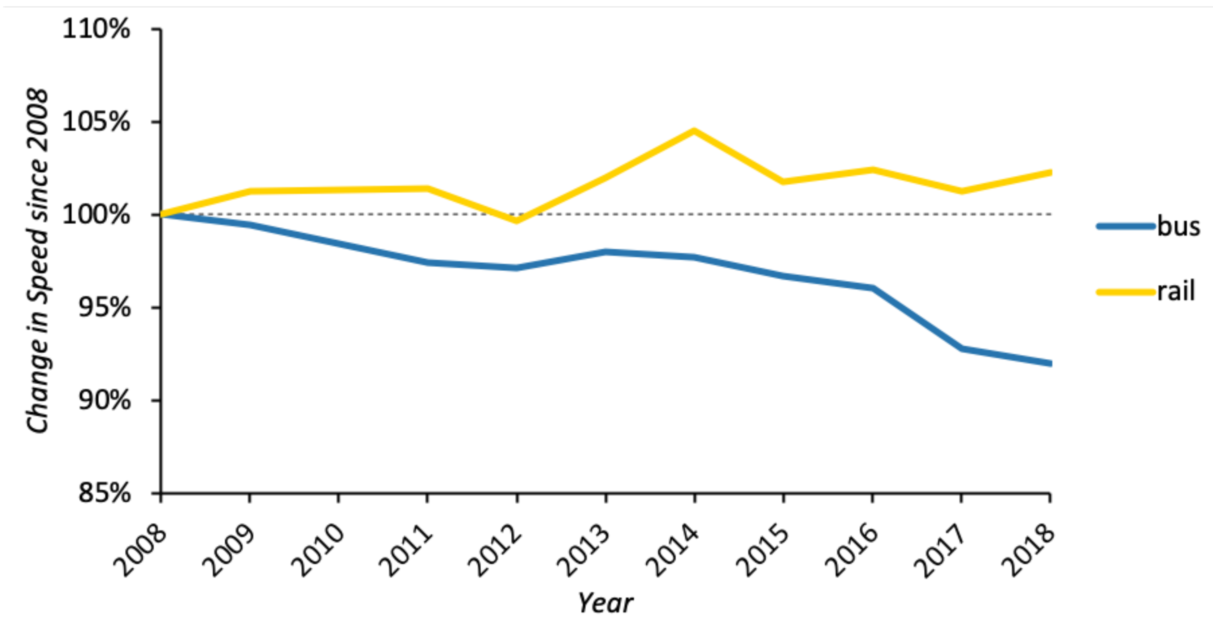
Figure 3-9. Vehicle Revenue Miles of Service by Mode



Data source: FTA, 2019

routes, falling bus speeds could be viewed in a positive light. But since the bulk of the speed drop occurred in just two years (2017 and 2018) and since we found no evidence of a substantial shift in the spatial distribution of service in recent years, worsening congestion on existing bus routes appears the more likely culprit. Still, slightly slower bus speeds alone cannot account for the scale of the region's ridership decline, especially absent data on bus reliability.

Figure 3-10. Slowing Speeds on Bay Area Buses



Data source: FTA, 2019

3.5. Conclusion

Across the Bay Area, transit operators are coping with troubling changes in the use of their services—troubling, but not dire. As we discuss in the rest of this report, the Bay Area's immense job growth has helped sustain ridership to a degree not seen in most other metropolitan areas. Still, even in this expanding regional economy and population boom, transit ridership is down. And prior to the recent downturn, portents like declining productivity in spite of service increases and falling per capita ridership presaged the short tenure of the region's post-Great Recession ridership growth.

Beneath the region-wide trends outlined above lie a host of nuanced differences across operators. Looking more closely at the Bay Area's overall patronage losses show them to be unevenly distributed across space, time, routes, and services. The next chapter, a summary of the detailed analyses in Volume II, details how these trends vary among the region's eight largest operators; as we will see, many of them are suffering from a growing peaking problem.

4. Transit Ridership Trends among Bay Area Operators

4.1. Introduction

While transit ridership in the Bay Area is falling as of late, some operators, areas, times, directions, routes, modes, and services have fared much better than others. Far from trivial distinctions, these differences help reveal the causes of the Bay Area's overall ridership slump, highlight the similarities and differences between the Bay Area and other American metropolitan areas, and inform policy and service decisions that aim to restore Bay Area transit use.

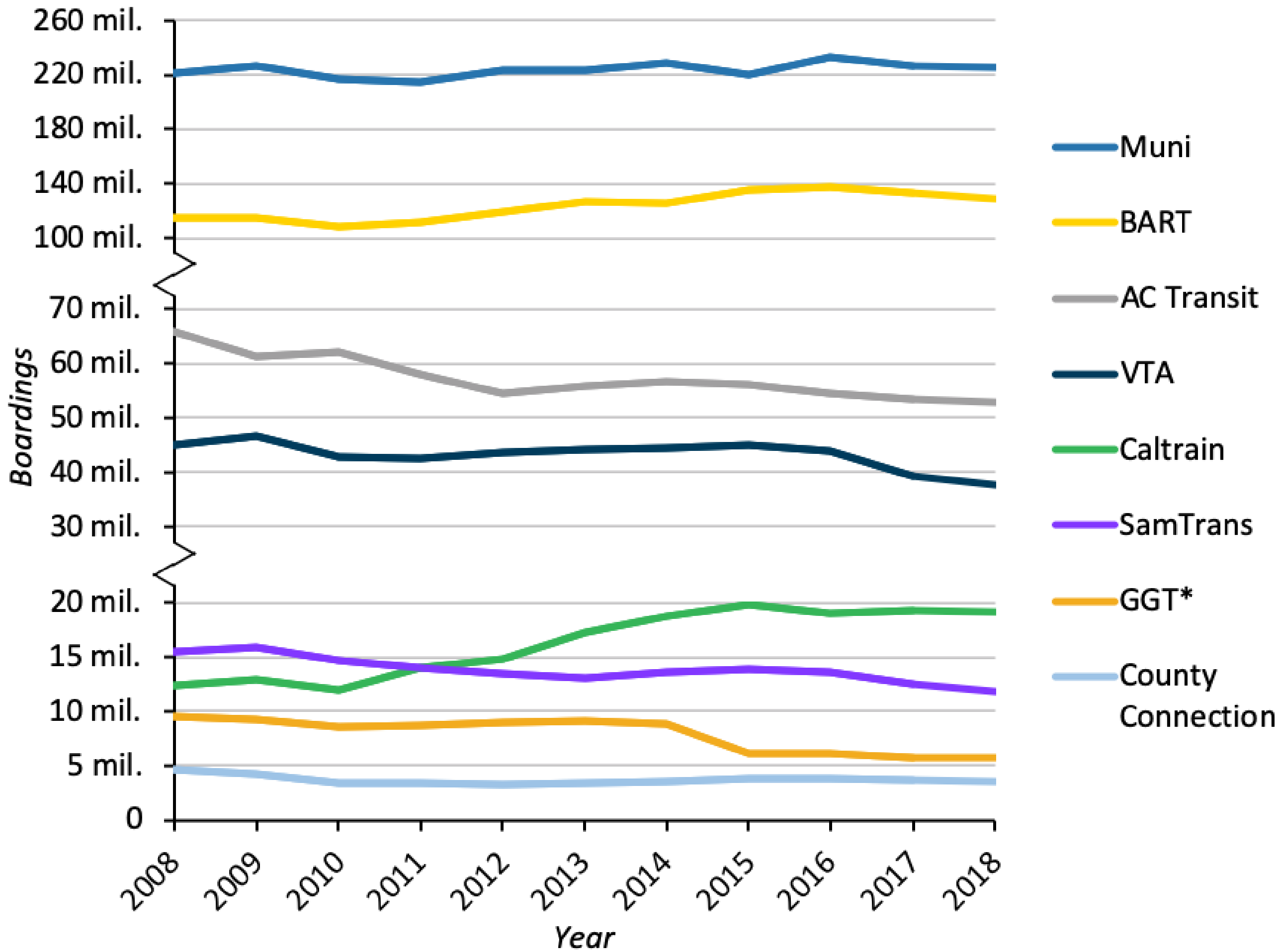
To investigate temporal and spatial similarities and differences in ridership, we analyze trends on the eight largest San Francisco Bay Area transit operators in considerable detail: Muni, BART, Alameda-Contra Costa Transit District (AC Transit), Santa Clara Valley Transportation Authority (VTA), Peninsula Corridor Joint Powers Board (Caltrain), San Mateo County Transit District (SamTrans), Golden Gate Bridge, Highway, and Transportation District (Golden Gate Transit or GGT), and Central Contra Costa Transit Authority (County Connection) Together, these top eight operators carried 96 percent of the region's transit trips in 2018 (FTA, 2019).

4.2. Operator Overview

As discussed in Chapter 3, the fundamentals of Bay Area ridership were weak long before it began to fall in absolute terms in 2017. Along with earlier flattening in per-capita trips and losses in productivity despite increased service, the other warning sign was ridership losses on smaller operators. Ridership gains on the region's two largest transit operators, Muni and BART, during most of the 2010s have in many ways masked longer-run patronage losses on the other Bay Area operators. The recent patronage decline may have drawn these contrasts to the fore, but ridership trends have systematically differed among Bay Area agencies for the past decade.

Figure 4-1 shows trends in annual boardings over the past decade; note the discontinuous axis to allow for comparison among larger and smaller operators on one graph. Since 2008, Muni ridership has remained at roughly the same level—albeit with some noticeable year-to-year jumps, and without overall growth despite San Francisco's expanding population. BART, meanwhile, grew its patronage significantly and steadily, gaining 22 million additional annual boardings between 2008 and its 2016 peak (subsequently falling more recently). Increases on BART over that period and on Muni between 2011 and 2015 account for essentially all of the region's ridership growth over the past decade. These gains have masked stagnant or slipping ridership on most other operators. Ridership on VTA, for instance, remained virtually flat for the past decade before falling in 2017. AC Transit, the region's third busiest operator, lost over 13 million annual trips since 2008, the most of any agency region-wide. Its ridership suffered severely from the Great Recession and never recovered. The exception is Caltrain, whose route on a key commute corridor between downtown San Francisco and Silicon Valley has seen major ridership growth.

Figure 4-1. Annual Boardings by Bay Area Operator



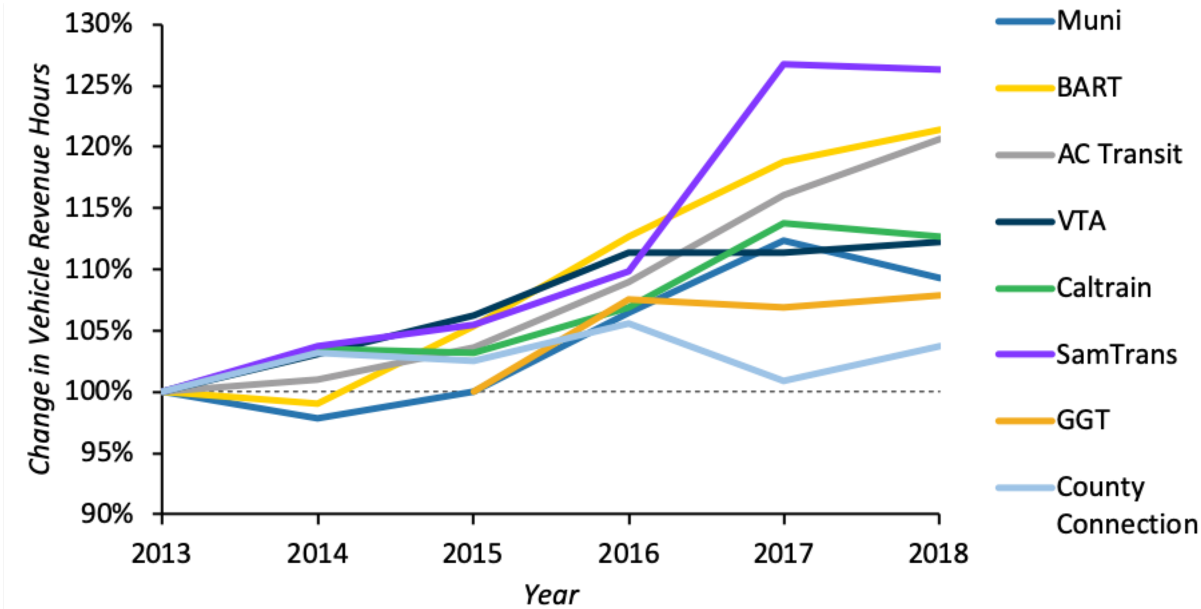
** In FY 2014-2015, Marin Transit began reporting a number of lines to the NTD that were previously counted under GGT (See Volume II, Chapter 8, Section 1) (Downing, 2020).*

Data source: FTA, 2019

Just as we rule out service cuts as an explanation for falling ridership region-wide (See Chapter 3), we also see little evidence that individual operators have reduced service across the board and in turn shed riders. **Figure 4-2** shows changes in vehicle revenue hours of service in the past six years;[5] vehicle revenue mile trends look similar. For all of the top eight operators, service is up, in SamTrans' case by over 25 percent. Ridership has stubbornly fallen all the same. Indeed, two of the top three operators by percentage service-hour increase, SamTrans and AC Transit, have seen sharp downwards ridership trends, steeper than the region overall. To be sure, operators have scaled back service on certain modes and routes, but agency-wide service cuts cannot be the cause of the recent ridership decline simply because they have not occurred on most operators.

5. The past four years for GGT, as a major service reclassification in FY14-15, discussed in Volume II, Chapter 8, Section 1, prevents apples-to-apples before-and-after comparison

Figure 4-2. Major Bay Area Operators Have Added Service Recently



Data source: FTA, 2019

What we do find evidence for is "peaking." Peaking refers to the concentration of riders at peak times, in core areas, in commute directions, etc. Peaking can occur because peak transit use is growing as off-peak use is flat, because peak transit use is flat as off-peak use is falling, or—as is the case on a number of Bay Area operators—both are declining, but off-peak use is falling faster than peak use. Peaking can be an expensive problem and can depress rider satisfaction.

Overall, we find a significant level of peaking on major Bay Area transit operators. In other words, ridership losses at off-peak hours, on weekends, on outlying routes, in non-commute directions, and on smaller operators account for a large and disproportionate share of the whole region's patronage decline (Wasserman, 2019). The most significant exceptions are operators in urban cores, like Muni and AC Transit, where residential and employment density throughout the network have blunted peaking, though not necessarily overall losses.

4.3. Muni Ridership Trends

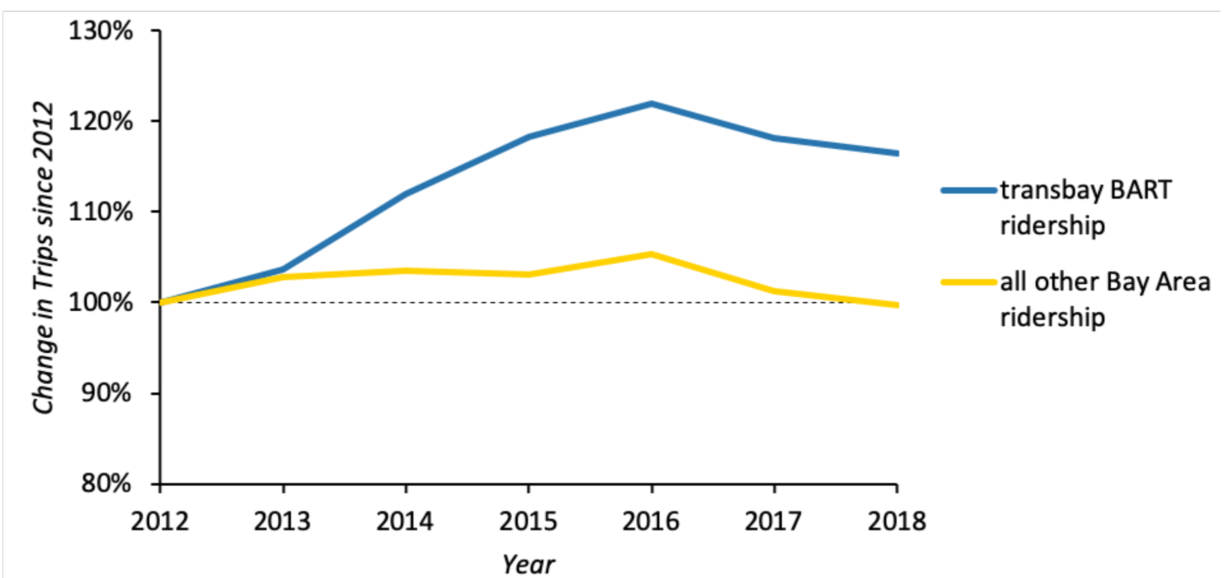
Muni, the region's largest transit agency, has simultaneously shed ridership in one of the most transit-favorable areas in America and has retained patronage better than most other national operators. Muni lost 7.8 million annual riders between 2016 and 2018—6.6 million in 2017 alone—with even steeper losses on a per capita basis (FTA, 2019). But unlike BART, AC Transit, and VTA, it gained significant ridership in 2016 and has generally had volatile ridership fluctuations from year to year. Recently, Muni has seen significant ridership shifts to lines with more frequent service and modes with more dedicated rights of way (SFMTA, 2018a). Between Fiscal Years 2015 and 2018, weekday local bus boardings fell three percent, while Rapid bus patronage rose 24 percent and light rail six percent. Indeed, many of the lines with the largest losses are the local routes along the same corridors as Rapids, which have seen some of the largest gains. Meanwhile, weekday ridership on lines with peak frequencies of ten minutes or less grew three percent, while less frequent routes carried two percent fewer trips. Overall, Muni has experienced some degree of peaking, especially by mode, but the high density of its entire operating environment has helped it avoid the acute peaking problems and sharp total losses of other agencies.

4.4. BART Ridership Trends

BART, the Bay Area's regional heavy-rail system and its second-most-ridden operator, has experienced a growing divergence between peak and off-peak ridership trends. But despite a recent decline in trips, BART's patronage growth also sustained the region's ridership in the years prior to the Bay Area's overall decline.

Between 2015 and 2018, trip counts at peak hours were almost identical, while trips at all other times fell 11 percent. Weekday ridership dropped four percent, compared to a 16 percent reduction on Saturdays and a 17 percent reduction on Sundays. Ridership into or out of downtown San Francisco, a huge job cluster, dipped only slightly, while trips to and from all other stations account for over half of the system's ridership losses over the same period, though they represent just 34 percent of all trips. Measured slightly differently, transbay trips between the relatively housing-rich East Bay and the relatively jobs-rich San Francisco Peninsula have remained healthy, while trips that did not cross San Francisco Bay account for 86 percent of system losses but less than half of system ridership. By any measure, BART's peaking problem is acute. But its peak trip growth has also propped up the whole Bay Area: BART transbay trips alone accounted for 43 percent of the *entire region's* ridership growth from 2012 to 2015, despite making up only 15 percent of 2015 patronage[6] (See **Figure 4-3**) (BART, 2019c and FTA, 2019).

Figure 4-3. Transbay BART Trips Accounted for Much of the Bay Area's Overall Ridership Growth



Data source: BART, 2019c and FTA, 2019

6. This is an estimate because internal BART data on transbay trips count linked trips, while the regional NTD data count unlinked trips.

To determine the most influential factors driving the trends above, we look at the determinants of BART ridership using a multivariate statistical model (See Volume II, Chapter 3, Section 4). We find that station-area jobs are, by far, the most important factor explaining BART ridership in both 2011 and 2015. Moreover, their influence has grown over time. The influence of employment even outweighs the headways at a station (as measured by the number of lines), which are often among the most important predictors of transit use. In an alternate set of models requiring more estimation, we could not establish that station cleanliness, police presence, or homeless counts, were having significant, independent effects on BART ridership, public debates about these issues notwithstanding.

4.5. AC Transit Ridership Trends

AC Transit has simultaneously lost a substantial share of its ridership but avoided the peaking problems of other agencies like BART. AC Transit has lost ridership across its route types, days of the week, and lines (AC Transit, 2018). Like Muni, AC Transit operates in a relatively dense service area; however, its Oakland service area lacks the explosive job growth of downtown San Francisco (U.S. Census Bureau, n.d.), likely contributing to AC Transit's deeper ridership drops. Indeed, AC Transit lost the third-most boardings of all Bay Area operators between 2015 and 2018 (FTA, 2019).

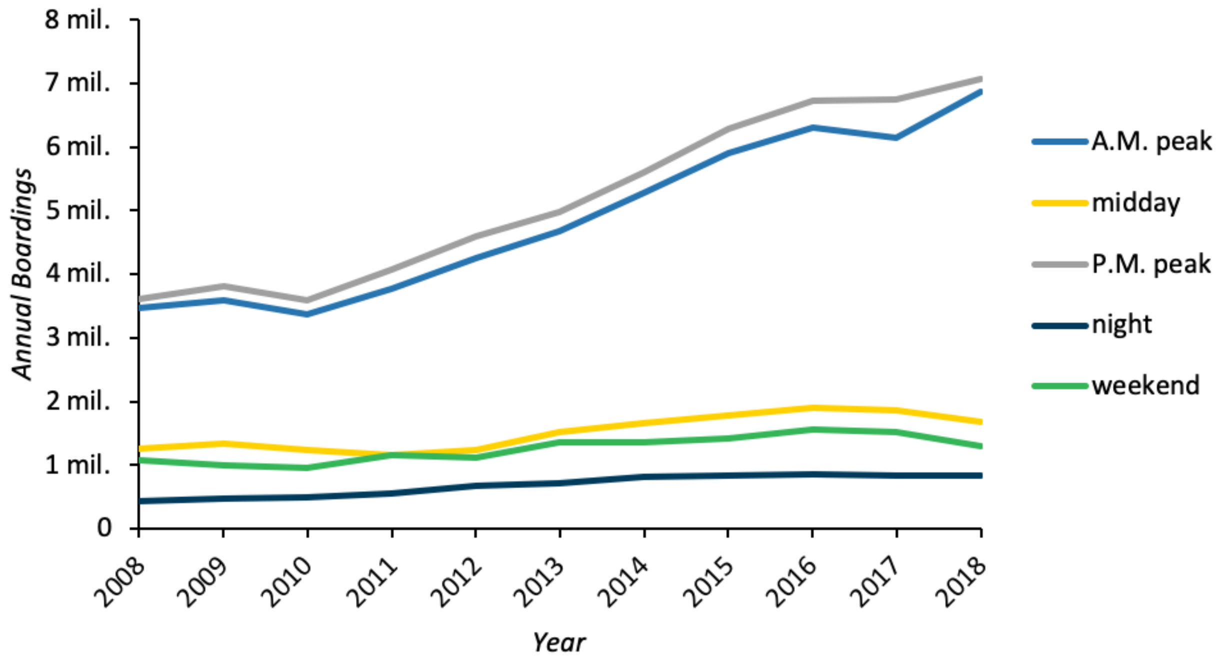
4.6. VTA Ridership Trends

VTA's ridership trajectory looks more like that of the U.S. than the Bay Area overall. VTA has experienced some ridership declines across modes and lines, but with particular losses off-peak (VTA, 2018). While rush-hour ridership jumped ten percent between April 2015 and April 2018, off-peak patronage dipped 18 percent—and dragged the agency's topline ridership number down with it. Light rail routes and outlying bus services have, respectively, suffered some of the agency's largest absolute and relative losses over the same period. Broadly, VTA's steepest losses come from its most-patronized lines.

4.7. Caltrain Ridership Trends

If any agency in the Bay Area represents a ridership success story, it is Caltrain. Coming off over a dozen years of nearly uninterrupted ridership growth, Caltrain connects the Bay Area's two largest cities, San Francisco and San José, and its two largest job centers, downtown San Francisco and Silicon Valley. Potentially for the same reasons as its ridership has grown, its peaking problem is acute: weekday ridership, and rush-hour patronage in particular (See **Figure 4-4**), each account for almost all of the agency's ridership growth (Caltrain, 2018). Meanwhile, trip counts are beginning to slide on local trains and in off-peak directions.

Figure 4-4. Annual Caltrain Ridership by Time of Day



Data source: Caltrain, 2018

4.8. SamTrans Ridership Trends

Ridership trends on SamTrans in some ways complicate the story we tell of other operators' patronage trends. SamTrans' service area has experienced substantial job growth (U.S. Census Bureau, n.d.), which, elsewhere, has sustained peak but not off-peak ridership on BART, GGT, and VTA. But on SamTrans, boardings have fallen across the board, dropping at similar rates across geographic sub-areas, route types, and days of the week (SamTrans, 2019). With housing growth failing to keep up with job growth in San Mateo County (U.S. Census Bureau, 2019, n.d.), the internal ridership data suggest that job growth alone has failed to support ridership on relatively short trips within the service area (SamTrans, 2019).

4.9. GGT Ridership Trends

Like BART and Caltrain, commute-oriented Golden Gate Transit's off-peak ridership trends have diverged starkly from its peak trends. Boardings on weekdays, at rush hour, on ferries, and on peak-only routes have declined only slightly, while trips on weekends, in the evening, on buses, and on all-day services have plunged (GGBHTD, 2019). But unlike BART and Caltrain, GGT's overall patronage has dropped as its peaking problems have sharpened. Yet, while GGT faces the same employment-driven peaking pressures as other large Bay Area operators, wildfires, service reclassifications, and competing transit options offer explanations for these trends unique to GGT.

4.10. County Connection Ridership Trends

County Connection, the eighth-largest operator in the Bay Area by 2018 boardings, was selected to represent the roughly dozen and a half smaller transit operators in the region. While the largest of these small operators, County Connection is likely emblematic: placing between the small operators that have gained patronage and those that have lost it, County Connection had nearly the same total ridership in 2017 as in 2014 (FTA, 2019). Serving largely suburban and exurban communities in Central Contra Costa County, County Connection is only one of the eight agencies profiled herein without any service in the three largest Bay Area cities (San José, San Francisco, and Oakland (U.S. Census Bureau, 2019)). Unlike the largely intra-urban operators like Muni and AC Transit, on which declines have occurred relatively evenly across the system, and commuter systems like BART and GGT, on which declines are focused at peak times and in commute directions, County Connection has seen moderate peaking (County Connection, 2019a).

4.11. Conclusion

Bay Area ridership faces two intertwined but distinct problems: absolute patronage losses and peaking. These issues are correlated, and many of the same causes, like changing residential locations, are behind both. Yet in surveying the ridership landscape of the top eight Bay Area transit agencies, we see cross-cutting divisions.

Caltrain, for instance, has experienced over the past decade both tremendous growth (56% growth, the highest relative growth of the operators profiled herein) and acute peaking. Despite some worrisome overall trip losses in the past two years, BART also falls into this category. Its patronage growth propped up the whole region in the years after the Great Recession, even as its ridership increasingly concentrated on weekday transbay commute trips.

Meanwhile, Muni, SamTrans, and AC Transit have experienced little peaking, with ridership trends on weekends and low-frequency lines tracking relatively closely. To be sure, even these operators have seen some peaking by various measures, but not nearly to the degree of BART or Caltrain. Yet their overall ridership trends differ dramatically. Muni's ridership is bumpy but high, as riders likely shifting within the agency from local services and slower modes to express services and faster modes. SamTrans ridership, though, has fallen, both recently and over the past decade; AC Transit's trip counts have dropped even more steeply.

Finally, VTA and GGT have experienced both peaking and ridership losses. Even here, though, there is nuance: VTA's ridership is growing at peak times, but not on its busiest lines. GGT, meanwhile, represents the only clear-cut case of an agency-wide decrease in revenue service hours and miles, as ridership has also plunged. Amidst all this, low-ridership operators like County Connection have seen only moderate peaking and only moderate ridership losses.

Job growth and its relation to urban form may explain these differences. While not a perfect classification, the three most clearly commute-oriented operators—the rail operators Caltrain and BART, along with GGT—have witnessed the most severe peaking. As other pressures depress off-peak trip-making on these operators, employment growth has sustained or even increased their ridership at their peak hours and on their faster services. Thanks to BART's rich origin-destination data, our statistical models show that station-area jobs do indeed have the greatest influence on ridership on BART, an influence that has grown over time (See Volume II, Chapter 3, Section 4).

Though they certainly also carry commuters, agencies like Muni and AC Transit also bear many short, non-work trips as well, given their location in the region's urban cores. This may explain why their peaking has been less acute. However, employment growth in San Francisco has outpaced growth in the parts of the East Bay that AC Transit serves—explaining in part why, despite neither having sharp peaking, AC Transit has lost a far greater share of its ridership than Muni. Lacking a clear commuter orientation and a large urban center, operators like County Connection have not experienced extremes of either peaking or ridership change.

Yet on all agencies, we see at least some evidence of peaking. All told, off-peak and non-commute trip types account for a large, disproportionate share of the region's losses. The resulting dependence on peak trips both incurs high costs—procuring vehicles and hiring workers needed only for peak periods is inefficient (Taylor, Garrett, and Iseki, 2000)—and depresses passenger satisfaction—due to overcrowding and other such issues. Expanding capacity to address the problems caused by peaking is also neither easy nor cheap. For instance, to better handle peak-hour crush loads, BART is presently working to upgrade capacity in the Transbay Tube, with the goal of increasing peak-period frequencies from the current 23 trains per hour to 30 trains per hour. Current detailed cost estimates peg the price of the project at $3.5 billion (Watry, 2019). In addition, longer-term plans are underway to add an additional tube under San Francisco Bay; preliminary estimates for this project range from $5 to $12 billion (MTC, 2017). Other operators may not be planning such large projects, but the same fiscal realities apply.

5. Transit User Trends

5.1. Introduction

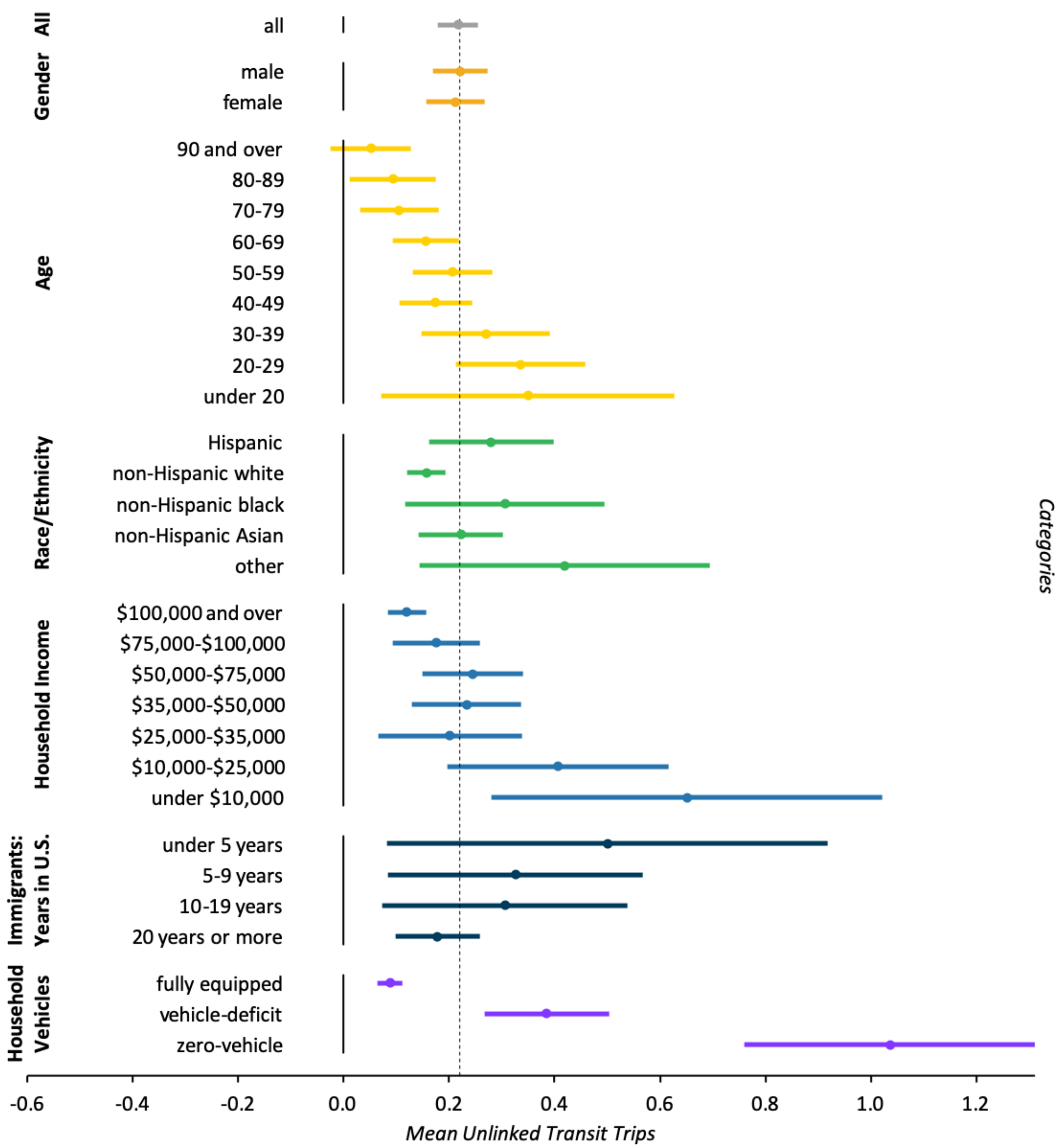
To better understand trends in transit use and among transit users in the Bay Area, we analyzed data on adults (18+ years) from the 2009 and 2017 National Household Travel Surveys (FHWA, 2009, 2017) (Appendix C, Section 1, Subsection 1 provides more detail on the NHTS.). In this chapter, we report on the findings of four different analyses: 1) descriptive statistics on changes in transit use among demographic groups traditionally likely to use transit, 2) statistical models to isolate key changes in the relationship between demographic groups and transit trips, 3) an analysis of transit user types, and 4) an overview of changes in trip-making by mode and purpose. Note that because the NHTS dataset is divided by metropolitan statistical area, not the whole nine-county Bay Area covered by the MTC, we only analyze the central Bay Area counties of Alameda, Contra Costa, Marin, San Francisco, and San Mateo in this chapter and the next (See Appendix A for further definitions).

Our results suggest important changes in transit use by individuals in several socio-demographic categories. Perhaps most interestingly, we find declining ridership among groups that are typically heavy users of transit, while at the same time finding increasing ridership among groups that are not traditionally frequent transit users. For example, the descriptive statistics highlight a drop in average daily person-trips by individuals in lower-income households, and an increase in trip-making among those living in households earning over $100,000 per year. Our multivariate models show a similar trend: ridership by those living in households with at least one vehicle per driver rose relative to those with limited vehicle access, while transit trip-making by residents of lower-density neighborhoods increased relative to their higher-density counterparts. Our analysis of transit user types also points to increasing transit use among relatively privileged individuals, as the proportion of higher-income, car-owning, long-distance transit users grew substantially between 2009 and 2017. Finally, we note that while trip-making declined during the study period, the average number of transit trips for work-related purposes increased dramatically in the central Bay Area counties, as did the number of non-work trips made by modes other than transit and private vehicle (e.g., via bike, foot, scooter, taxi, or ridehail).

5.2. Transit Use

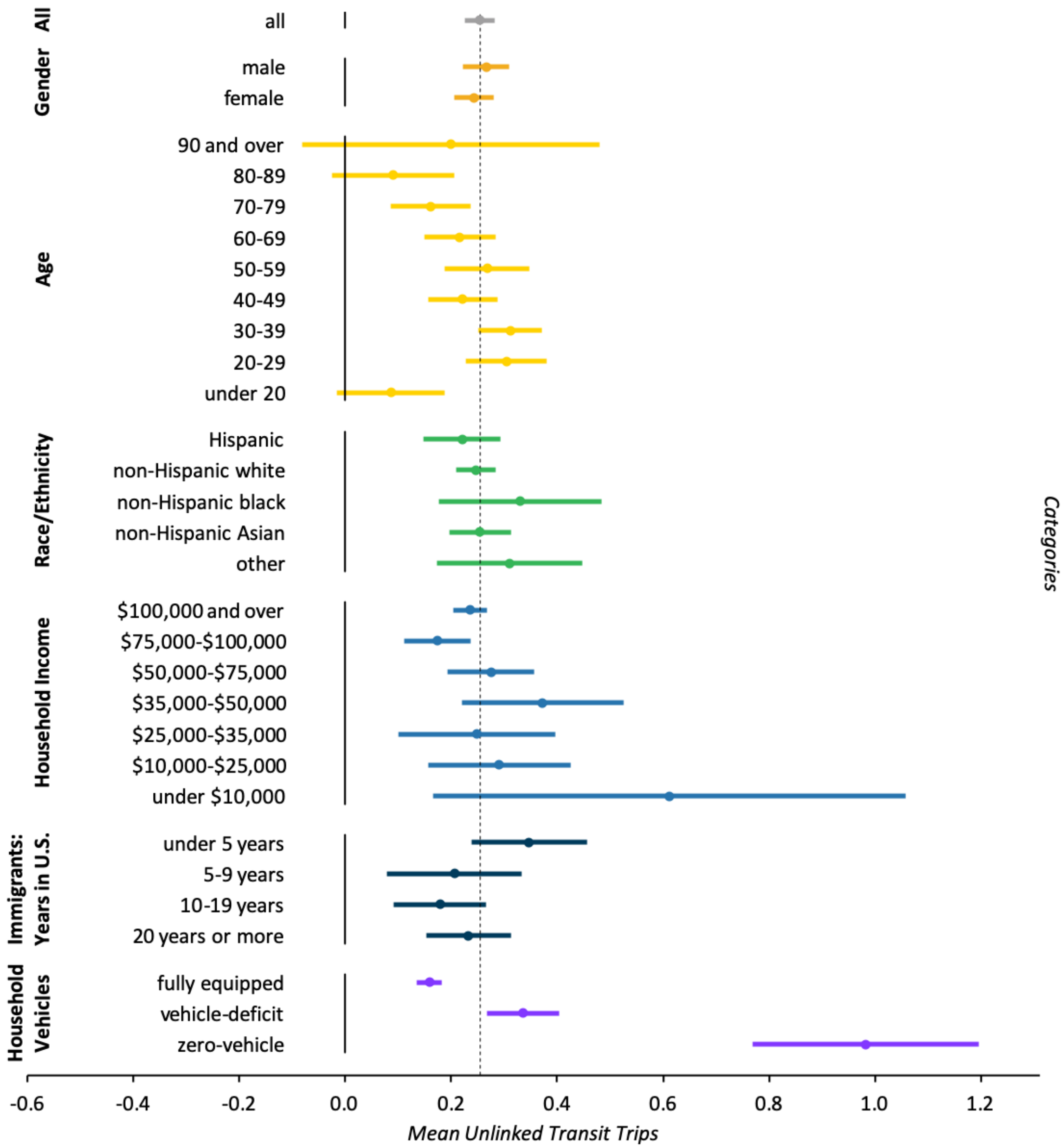
From the NHTS' travel data and household- and person-level characteristics, we are able to examine how transit use has changed among various socio-demographic groups. **Figures 5-1** and **5-2** includes mean daily transit trips in 2009 and 2017, respectively, broken down by seven categories: sex, age, race and ethnicity, income, length of time in the U.S. (for immigrants only), and vehicle ownership. These characteristics highlight trends among population groups that—at least historically—have had higher than average transit usage rates: women, young adults, minorities, low-income adults, recent immigrants, and individuals who live in households without automobiles (Anderson, 2016; Blumenberg and Evans, 2010; Maciag, 2014; and Rosenbloom, 1998). Overall, average daily transit trips per capita increased slightly from 2009 to 2017 in the central Bay Area counties (though, as described in Chapter 3 using a different dataset, not for the region as a whole).

Figure 5-1. Daily Transit Trips by Socioeconomic Categories, Central Bay Area Counties, 2009



Data source: FHWA, 2009

Figure 5-2. Daily Transit Trips by Socioeconomic Categories, Central Bay Area Counties, 2017



Data source: FHWA, 2017

Among the many group-level changes in transit patronage between 2009 and 2017, a few stand out as particularly noteworthy. In terms of race and ethnicity, the biggest shift in mean daily trips occurred among Hispanics, whose ridership dropped from an average of 0.28 trips per day in 2009 to 0.22 trips per day in 2017. Non-Hispanic whites, by contrast, increased their ridership rates, taking 0.16 daily trips in 2009 compared to 0.25 trips in 2017. Residents of high-income households—those making over $100,000 in yearly income—rode transit more in 2017 than in 2009, doubling their mean number of daily trips from 0.12 to 0.24. Middle-income households also increased their transit use. By contrast, individuals in households earning between $10,000 and $25,000 who made 0.41 trips per day in 2009, made only 0.29 daily trips in 2017.

More surprisingly, transit ridership decreased among residents of zero-vehicle and vehicle-deficit households (i.e., those with less than one vehicle per driver), dropping by about 0.05 daily person-trips for each group. Conversely, those living in "fully equipped" households (households with at least one vehicle for each driver), made just 0.09 trips per day on transit in 2009, but by 2017 this number had risen to 0.16. While this increase is rather small in magnitude, it is important to remember that nearly 80 percent of households in the central Bay Area counties owned at least one vehicle per driver in 2017 (FHWA, 2017). Therefore, even a small upturn in transit use by those households with automobiles can translate into a fairly substantial increase in overall transit ridership.

5.3. Determinants of Transit Use

Many of these characteristics are interrelated. For example, low-income households are more likely to live in zero-vehicle households than higher-income households. Therefore, to supplement these descriptive data, we also performed a statistical analysis using data from both the 2009 and 2017 NHTS to determine how much certain socioeconomic and demographic characteristics are related to transit use, in this case measured by the number of transit trips on the survey day. This allows us to identify socioeconomic and demographic characteristics that are associated with notable increases or decreases in the number of observed transit trips. For comparison purposes, we replicated this analysis for the central Bay Area counties, Los Angeles and Orange Counties, and the State of California. A more detailed description of our methodology is included in Appendix C, Section 1, Subsection 2.

In the central Bay Area counties, two characteristics stand out: vehicle ownership and residential density. Transit use by adults with limited automobile access (i.e., those living in either a zero-vehicle or a vehicle-deficit household) decreased between 2009 and 2017 from almost four times as many transit trips as their fully equipped counterparts to just 1.8 times as many. Similarly, the gap in transit trip-making between those living in zero-vehicle households and those living in fully equipped households shrank substantially, from almost 8.6 times as much in 2009 to just under five times in 2017. These trends were not restricted to the central Bay Area counties: transit ridership among those with limited vehicle access decreased in Los Angeles and Orange Counties and statewide similar to the central Bay Area counties.

Transit use by residents of high-density neighborhoods (between 10,000 and 24,999 residents per square mile) and very-high-density neighborhoods (25,000 or more residents per square mile) declined in the central Bay Area counties between 2009 and 2017. In 2009, residents of high- and very-high-density neighborhoods took 3.4 and 4.0 times more transit trips, respectively, than those living in low-density neighborhoods with fewer than 10,000 residents per square mile; by 2017, however, this gap had shrunk to 2.3 and 2.9 times respectively. Unlike vehicle ownership though, the relative decrease in transit use by residents of dense neighborhoods is unique to the central Bay Area counties, as statewide, the differences in transit ridership between those living in low density areas versus those who reside in high density neighborhoods remained stable between 2009 and 2017, while the gap actually grew in the Los Angeles and Orange Counties.

Finally, transit use trends in the central Bay Area counties also differ from those in Los Angeles and Orange Counties and the state as a whole with regard to race and ethnicity. In the central Bay Area counties, race and ethnicity stand out because they were *not* significant predictors of transit use frequency in either survey year. Statewide, relative to non-Hispanic whites, transit trips by African Americans increased dramatically between 2009 and 2017 as did transit trips for Asians, albeit somewhat more modestly. Conversely, modeled trip making decreased for Hispanics. While Hispanics were likely to take far more transit trips than non-Hispanic whites in 2009, by 2017, the modeled number of daily transit trips by Hispanic individuals was no different from their non-Hispanic white counterparts. Trends in Los Angeles and Orange Counties were similar to those statewide, with notable increases in transit trips among black residents and decreases among Hispanic individuals relative to non-Hispanic whites from 2009 to 2017. Transit use among Asians in Los Angeles and Orange Counties was not statistically different from non-Hispanic whites in either 2009 or 2017.

5.4. Transit User Types

In addition to the modeling approach above, we also use the NHTS data to identify three distinct types of transit users. To do this, we use latent profile analysis (LPA) in order to identify natural groupings of transit users. LPA is a technique that groups observations—in this case, transit users—into unobserved or "latent" classes (Muthén, 2001) (Appendix C, Section 1, Subsection 3 provides more detail on our LPA methodology.). These groupings help us to condense multiple socio-economic characteristics into three coherent classes to compare changes in transit use between them. **Table 5-1** shows the three resulting classes of transit users for the State of California as a whole, with data pooled from the NHTS's California add-on samples in 2009 and 2017 (FHWA, 2009, 2017) and names suggested by us.[7]

7 . We perform the LPA at the state-level due to the relatively small sample sizes of transit riders in individual metropolitan regions.

Table 5-1. Latent Classes of Transit Users in California, 2009 and 2017 (Pooled)

CHARACTERISTIC		OCCASIONAL TRANSIT RIDERS	TRANSIT DEPENDENTS	CHOICE RIDERS
Transportation/Travel Characteristics	Percent zero-vehicle	22.5%	40.2%	7.7%
	Percent vehicle-deficit	30.8%	25.5%	18.9%
	Percent fully equipped	46.8%	34.3%	73.3%
	Daily PMT (on transit)	8.1	16.2	68.9
	Daily PMT (total)	24.3	17.3	76.8
	Number of daily transit trips	1.4	2.4	2.1
	Total daily person trips	5.0	3.6	3.9
	Number of transit trips in past month	18.7	22.5	17.9
	Number of daily bus trips	1.06	1.89	0.84
	Number of daily rail trips	0.34	0.48	1.28
	Number of daily transit work trips	0.40	0.71	1.12
	Percent who commute on transit (among employed individuals only)	61.0%	83.3%	73.6%

CHARACTERISTIC		OCCASIONAL TRANSIT RIDERS	TRANSIT DEPENDENTS	CHOICE RIDERS
Socio-demographic Characteristics	Percent employed	64.8%	53.2%	81.6%
	Percent immigrant	40.5%	37.3%	36.3%
	Percent non-Hispanic white	33.7%	28.7%	36.5%
	Percent Hispanic	38.0%	41.2%	21.1%
	Percent non-Hispanic black	7.0%	10.8%	12.1%
	Percent non-Hispanic Asian	15.9%	12.6%	20.0%
	Percent non-Hispanic other	5.4%	6.6%	10.4%
	Percent income under $10,000	13.3%	18.7%	4.9%
	Percent income $10,000-$25,000	20.0%	27.7%	8.5%
	Percent income over $100,000	25.6%	17.5%	50.6%
	Percent living in very high density areas (25,000+ people per square mile)	23.9%	24.0%	8.6%
Percent of sample		32.7%	55.1%	12.2%

Data source: FHWA, 2009, 2017

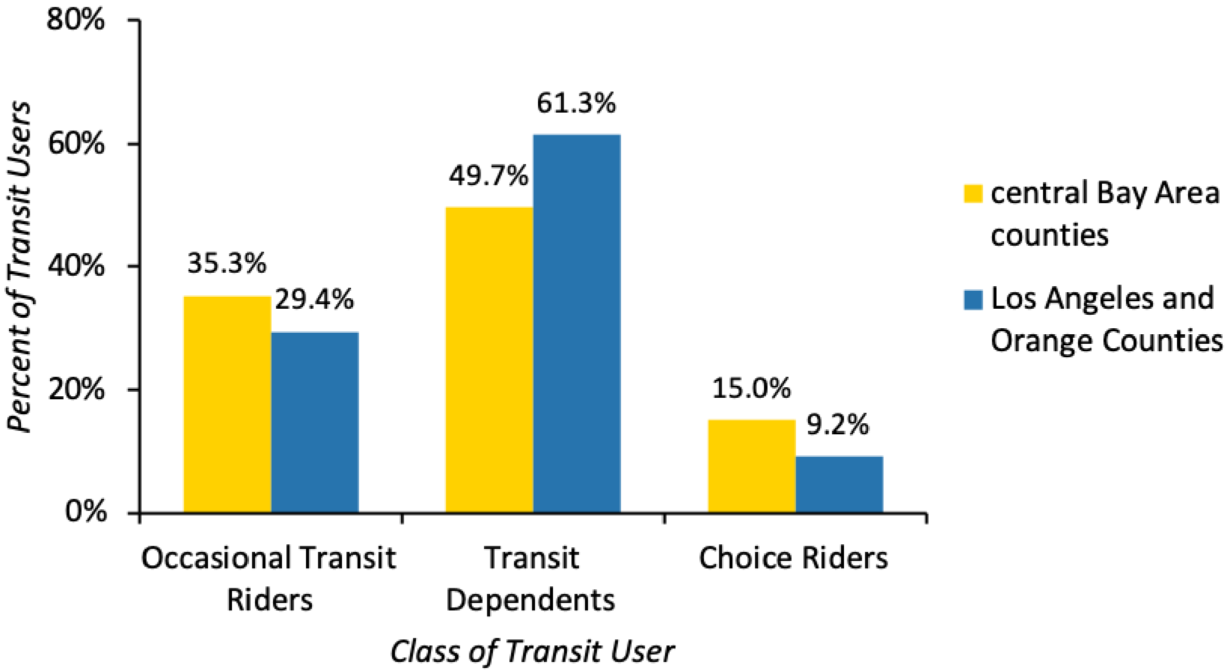
An examination of **Table 5-1** reveals clear distinctions across the three groups on a number of socioeconomic, demographic, and travel behavior factors. The first class is comprised of "Occasional Transit Riders"—a group of individuals who appear to use transit to supplement travel by other modes. This class uses transit to cover 30 percent of their daily person-miles traveled (PMT) and 28 percent of their daily trips, and represents about one-third of transit users in California. These Occasional Transit Riders tend to have moderate levels of vehicle access: just under half of the individuals in this group live in fully equipped households (with at least one vehicle per driver), while just over half live in a household where vehicle availability is limited. The income distribution of Occasional Transit Riders is quite varied, with one-third of these transit users residing in a household earning less than $25,000 per year, while over a quarter earn over $100,000 in yearly household income.

In contrast to Occasional Transit Riders, the second class of riders, "Transit Dependents," tend to have limited car access, with almost two-thirds living in zero-vehicle or vehicle-deficit households. They also have relatively low average levels of income, with 46.4 percent of Transit Dependents residing in households earning less than $25,000 per year. Given their combination of relatively poor automobile access and lack of financial resources, Transit Dependents likely have little choice but to rely on public transportation for most of their travel needs. Perhaps not surprisingly then, the trip-making and personal mobility of Transit Dependents is quite limited on average: these individuals make the fewest number of average daily trips (3.6), have the lowest average daily PMT (17.3) of all transit users, and rely on transit for almost all of their daily miles traveled (94%). Also of note is the fact that Transit Dependents make up a majority of transit users in California, comprising 55 percent of all riders during the period from 2009 to 2017.

Finally, the third class of transit riders, "Choice Riders," include individuals who use transit for a very high proportion—roughly 90 percent—of their overall miles of travel. However, in contrast to Transit Dependents, Choice Riders tend to have good automobile access (over 73% live in fully equipped households), relatively high incomes (more than half earn more than $100,000 in yearly household income), and live in relatively low-density communities (only 8.6% reside in a census tract with more than 25,000 inhabitants per square mile). While these characteristics traditionally predict low levels of transit use, Choice Riders have by far the highest transit PMT of the three latent classes of transit riders: they travel more than four-times farther on public transportation than Transit Dependents, and over 8.5 times farther than Occasional Riders. Choice Riders are also more likely than other transit users to ride rail, with well over half of their transit trips being made by train. Finally, for Choice Riders, there is a clear connection between work-related activity and transit ridership. Over 81 percent of Choice Riders are employed, and nearly three-quarters of these workers commute to their place of employment via transit. Not surprisingly then, Choice Riders take a considerable amount of work-related transit trips, averaging 1.12 trips to or from work per day, more than that of the other two classes combined.

In addition to identifying latent classes of transit riders in the State of California, we also assess the relative distribution of transit users in the central Bay Area counties and Los Angeles and Orange Counties. **Figure 5-3** provides these results. The percentages in **Figure 5-3** represent the proportion of all transit users within each region that fall into the three classes developed in the state-level model.

Figure 5-3. Latent Classes of Transit Users in the Central Bay Area Counties and Los Angeles and Orange Counties, 2009 and 2017(Pooled)



Data source: FHWA, 2009, 2017

Transit users in the central Bay Area counties are somewhat more evenly distributed relative to those in Los Angeles and Orange Counties (and relative to those in the state as a whole). Less than half of transit riders in the central Bay Area counties are included in the Transit Dependents category, while 35.3 percent are categorized as Occasional Transit Riders and 15 percent are classified as Choice Riders. In Los Angeles and Orange Counties, by contrast, a high proportion of riders are classified in the Transit Dependent category (61.3%), with only 29.4 percent categorized as Occasional Riders and 9.2 percent identified as Choice Riders.

In order to identify changes in transit use over time in the central Bay Area counties, the state, and Los Angeles and Orange Counties, we disaggregate the results of the pooled analysis by year. This allows us to examine the travel behavior, socioeconomic features, and population distribution of our three latent classes of transit users over the two survey periods. The results for the state as a whole, shown in **Table 5-2**, highlight several important trends. First, there was a the shift in the overall distribution of individuals across the three classes: while the percentage Transit Dependents stayed relatively stable, the proportion of Occasional users dropped from 37.9 percent to 29.6 percent and the share of Choice Riders more than doubled, rising from 7.1 percent to 15.3 percent of California's transit users. In other words, as the share of riders taking occasional, short transit trips is decreasing, the proportion of individuals making relatively long-distance trips, often by rail and often to or from work, is growing. In addition to its correlation with changes in travel behavior, the increasing proportion of Choice Riders is also associated with a geographic shift. In 2009, 17.2 percent of Choice Riders lived in very high-density neighborhoods (census tracts with more than 25,000 residents per square mile). While this was the lowest proportion of very high-density residents among the three types of riders, gaps in the residential location of members of the three classes were relatively small. By 2017, however, the share of Choice Riders living in very high-density neighborhoods dropped dramatically—to 5.8 percent—while the proportion of very high-density residents in the other classes remained relatively stable.

Trip-making on transit declined among all three categories during the study period. The number of daily transit trips made by Choice Riders decreased the most from 2.5 in 2009 to 2.0 in 2017. Occasional Riders dropped from 1.5 to 1.3; for Transit Dependents, daily trips decreased from 2.5 to 2.3. Clearly, transit users rode transit less on average between 2009 and 2017, regardless of transit rider type. In addition to this decrease in trip-making, there were also major shifts in the type of transit used by riders. While the number of bus trips by users in all three categories dropped dramatically during the study period, rail trips increased for transit riders in each class. This trend was especially pronounced among Choice Riders, whose bus-trip-making decreased by over one daily ride from 1.62 to 0.59 while their average number of rail trips increased by 0.59 rides per person per day.

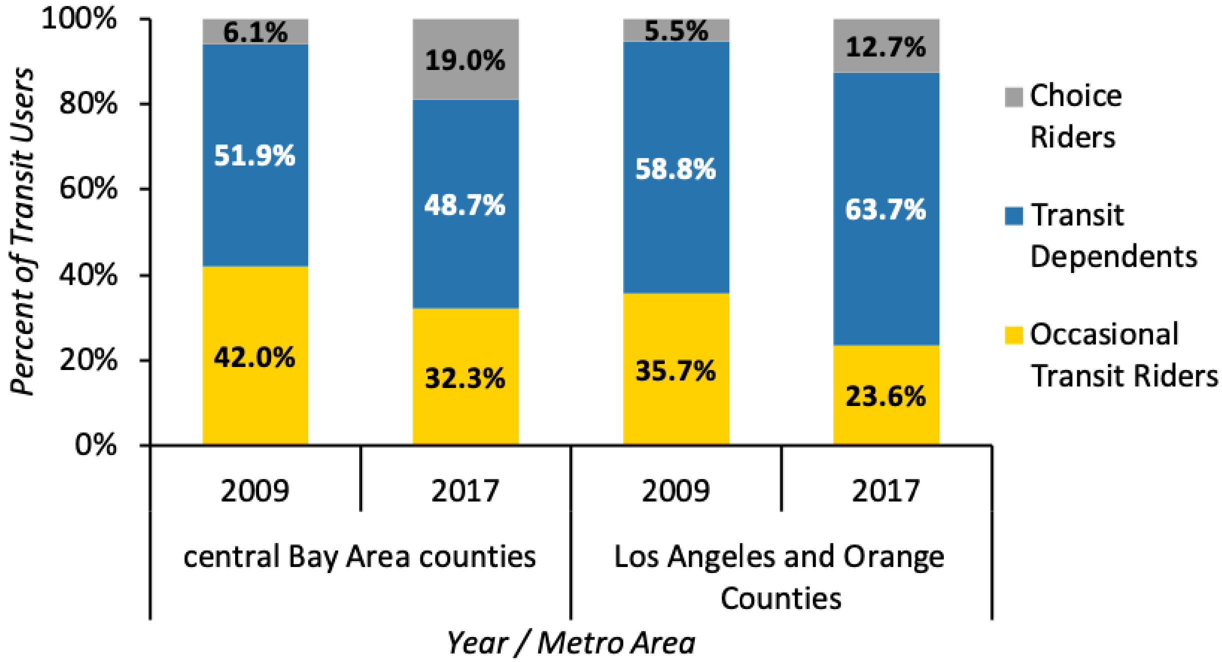
Table 5-2. Latent Classes of Transit Users in California, 2009 and 2017 (Pooled)

CHARACTERISTIC	2009			2017		
	OCCASIONAL TRANSIT RIDERS	TRANSIT DEPENDENTS	CHOICE RIDERS	OCCASIONAL TRANSIT RIDERS	TRANSIT DEPENDENTS	CHOICE RIDERS
Percent zero-vehicle	19.9%	38.2%	10.1%	24.9%	41.5%	7.0%
Percent vehicle-deficit	39.7%	38.9%	22.1%	22.5%	16.7%	17.9%
Percent fully equipped	40.4%	22.9%	67.8%	52.6%	41.8%	75.2%
PMT (on transit)	7.2	13.9	74.7	8.9	17.7	67.0
PMT (total)	23.8	15.0	82.0	24.8	18.8	75.1
Number of daily transit trips	1.5	2.5	2.5	1.3	2.3	2.0
Number of total daily trips	5.2	3.6	3.9	4.7	3.6	3.9
Number of transit trips in past month	21.3	28.3	23.7	16.2	18.7	16.1
Number of daily bus trips	1.22	2.20	1.62	0.92	1.68	0.59

CHARACTERISTIC	2009			2017		
	OCCASIONAL TRANSIT RIDERS	TRANSIT DEPENDENTS	CHOICE RIDERS	OCCASIONAL TRANSIT RIDERS	TRANSIT DEPENDENTS	CHOICE RIDERS
Number of daily rail trips	0.24	0.28	0.84	0.42	0.60	1.43
Percent employed	63.3%	56.2%	74.2%	66.1%	51.2%	84.0%
Number of daily transit work trips	0.40	0.75	1.11	0.40	0.67	1.12
Percent transit commuters (among employed individuals only)	56.6%	81.4%	77.0%	65.3%	84.7%	72.7%
Percent immigrant	45.2%	41.9%	50.1%	36.2%	34.3%	31.8%
Percent non-Hispanic white	30.8%	28.7%	39.3%	36.5%	28.7%	35.6%
Percent Hispanic	41.5%	46.9%	27.2%	34.8%	37.5%	19.1%
Percent non-Hispanic black	5.8%	9.9%	20.7%	8.1%	11.5%	9.2%
Percent non-Hispanic Asian	14.2%	7.7%	11.3%	17.4%	15.9%	22.8%
Percent non-Hispanic other	7.7%	6.9%	1.5%	3.2%	6.4%	13.3%
Percent income under $10,000	16.3%	16.7%	7.5%	10.6%	20.1%	4.0%
Percent income $10,000-$25,000	24.5%	38.7%	13.7%	15.8%	20.5%	6.8%
Percent income over $100,000	17.3%	9.6%	33.8%	33.3%	22.6%	56.0%
Percent living in very high-density areas (25,000+ people per square mile)	22.9%	25.5%	17.2%	24.8%	23.0%	5.8%
Percent of sample	37.9%	55.0%	7.1%	29.6%	55.2%	15.3%

Regional-level changes are also noteworthy. These results are highlighted in **Figure 5-4**. The proportion of Choice Riders grew substantially in both regions, with the share of riders in this category more than tripling in the central Bay Area counties and more than doubling in Los Angeles and Orange Counties. By contrast, the percentage of Occasional Transit Riders in both regions shrank, dropping 23 percent in the central Bay Area counties and 34 percent in Los Angeles and Orange Counties. Finally, the regions differed with regard to trends in the Transit Dependents class. In the central Bay Area counties, the proportion of Transit Dependents decreased from 51.9 percent of users to 48.7 percent. In Los Angeles and Orange Counties, conversely, the share of Transit Dependents increased, rising from 58.8 percent in 2009 to 63.7 percent in 2017.

Figure 5-4. Latent Classes of Transit Users in the Central Bay Area Counties and Los Angeles and Orange Counties, 2009 and 2017



Data source: FHWA, 2009, 2017

5.5. Trip-making by Mode and Purpose

Changes in transit ridership are, of course, related to changes in trip-making by other modes. Therefore, in order to understand how shifts in transit use are associated with trends in travel by other modes, we compare the average number of trips made by transit, in private vehicles, and by other modes (bike, foot, scooter, taxi, and ridehail) in the central Bay Area counties between 2009 and 2017. Additionally, because of the notable increase in peak-period transit use discussed in Chapter 4 of this report, we also examine how changes in trip frequency by each of these modes are related to trip purpose (i.e., work trips and non-work trips).

Table 5-3 shows the average number of daily trips by each mode in 2009 and 2017. We divide trips into two categories: those made to and from work and those made for non-work purposes. Results highlight a small overall drop (3.8%) in the total number of trips made per capita between 2009 and 2017. These declines were largely driven by a drop in automobile trips, both for work and non-work purposes, and by a decline in the number of daily transit trips for non-work purposes. Trip-making did increase, however, for some combinations of mode and purpose. In particular, the average number of trips to and from work by transit rose dramatically between 2009 and 2017, from 0.07 to 0.12 trips per day, an increase of 67.6 percent—which casts the recent transition of Bay Area transit use toward the journey-to-work in sharp relief.

In addition, trip-making by modes other than transit and private automobile (such as walk, bike, scooter, taxi, and ridehail) also increased during the study period by eight percent for work trips and 23 percent for non-work trips. While various forms of new mobility services are conflated with waking, biking, and taxis here, we can reasonably speculate that a substantial portion of these measured increases are due to ridehail and micromobility. We note as well that the growth in non-commute trips, where Bay Area transit operators have been losing passengers, is nearly three times higher than for commuting, where transit has been adding riders.

Table 5-3. Trips by Mode and Purpose, Central Bay Area Counties

	YEAR	2009		2017		PERCENT CHANGE
MODE	PURPOSE	DAILY TRIPS	SHARE OF DAILY TRIPS	DAILY TRIPS	SHARE OF DAILY TRIPS	
Transit	To/from work	0.07	1.6%	0.12	2.8%	+67.6%
	Non-work	0.14	3.2%	0.14	3.1%	-5.6%
Car	To/from work	0.63	14.1%	0.56	13.1%	-10.4%
	Non-work	2.74	61.3%	2.41	56.1%	-12.0%
Other (Walk, Bike, Scooter, Taxi, Ridehail)	To/from work	0.11	2.5%	0.12	2.8%	+8.0%
	Non-work	0.77	17.3%	0.95	22.1%	+23.0%
Total		4.47	100%	4.30	100%	-3.8%

Data source: FHWA, 2009, 2017

Trip data for the state as a whole (See **Table 5-4**) and for Los Angeles and Orange Counties (See **Table 5-5**) show somewhat different trends. Like the central Bay Area counties, the total number of average daily trips dropped in both California and Los Angeles and Orange Counties (by 6.8% and 6.7% respectively). However, in contrast to the large increases in transit trips for work purposes in the central Bay Area counties, work-related transit trips decreased in the other geographies that we analyzed, with the decline being especially dramatic in Los Angeles and Orange Counties (50%), where transit use has been falling at a much faster rate.

These geographic differences in trip making also diverge with regard to trip-making by automobile. Specifically, the number of work-related automobile trips increased in Los Angeles and Orange Counties, a result that differs from both the central Bay Area and the state, where trip-making by car decreased for all purposes. Finally, trends in non-transit, non-auto trip frequency also differ by geography. In contrast to the rise in "other" trips for both work and non-work purposes in the central Bay Area, the number of daily non-work trips not involving transit or a private automobile dropped by 15.4 percent in Los Angeles and Orange Counties, while the number of non-transit, non-car trips for work purposes remained relatively stable. Statewide, the average number of "other" work trips increased slightly (3.4%), while the number of non-work "other" trips dropped by 6.1 percent.

Table 5-4. Trips by Mode and Purpose, California

	YEAR	2009		2017		PERCENT CHANGE
MODE	PURPOSE	DAILY TRIPS	SHARE OF DAILY TRIPS	DAILY TRIPS	SHARE OF DAILY TRIPS	
Transit	To/from work	0.04	0.8%	0.04	0.8%	-2.8%
	Non-work	0.07	1.6%	0.07	1.7%	-1.4%
Car	To/from work	0.71	16.0%	0.71	17.1%	-0.7%
	Non-work	2.94	66.1%	2.68	64.7%	-8.8%
Other (Walk, Bike, Scooter, Taxi, Ridehail)	To/from work	0.06	1.3%	0.06	1.5%	+3.4%
	Non-work	0.63	14.1%	0.59	14.2%	-6.1%
Total		4.45	100%	4.14	100%	-6.8%

Table 5-5. Trips by Mode and Purpose, Los Angeles and Orange Counties

	YEAR	2009		2017		PERCENT CHANGE
MODE	PURPOSE	DAILY TRIPS	SHARE OF DAILY TRIPS	DAILY TRIPS	SHARE OF DAILY TRIPS	
Transit	To/from work	0.06	1.3%	0.03	0.7%	-50.0%
	Non-work	0.10	2.3%	0.08	2.0%	-19.6%
Car	To/from work	0.72	16.3%	0.74	18.0%	3.1%
	Non-work	2.76	62.9%	2.60	63.5%	-5.8%
Other (Walk, Bike, Scooter, Taxi, Ridehail)	To/from work	0.05	1.2%	0.05	1.3%	0.0%
	Non-work	0.70	16.0%	0.60	14.5%	-15.4%
Total		4.39	100%	4.10	100%	-6.7%

Data source: FHWA, 2009, 2017

5.6. Conclusion

Overall, our findings suggest a shift in the socio-demographics of transit users in thecentral Bay Area counties. The descriptive statistics highlight that as members of low-income households are using transit less frequently on average, those with higher incomes are taking more transit trips. The multivariate models illustrate a similar trend, as travelers with high levels of vehicle access and those living in low-density neighborhoods increased their ridership relative to those with low levels of vehicle access and residents in high-density neighborhoods. The LPA highlights the growing proportion of transit riders that fall into the "Choice Riders" class—riders who, on average, have higher incomes and good automobile access. Finally, in contrast to Los Angeles and Orange Counties and the state as a whole, we find a substantial increase in the number of commute-related transit trips in the central Bay Area counties. Taken together, we find that while traditional transit users (with lower incomes and less vehicle access) still ride frequently, the ridership gap between such travelers and those with higher incomes and better vehicle access is narrowing, due largely to increased journey-to-work trips by the latter group.

These changes do raise questions, however. First, if traditional users, who tend to have lower incomes, own no vehicles, and are more likely an immigrant, are tending to ride less over time, what are they doing instead, and are their mobility needs being adequately met? Second, if more transit riders are longer-distance transit commuters over time, is this by choice or because limited housing supply and high prices make it difficult to live nearer job centers? Answering these questions, which our data do not allow us to do, will be key to developing effective policies to both improve Bay Area transit and address the needs of (both current and former) riders.

Part III

Possible Explanations for Lagging Ridership

Part IIIA. Economic and Demographic Influences on Transit Use Trends

In Part IIIA, we focus on three possible explanations for lagging transit ridership in the Bay Area: changing demographics, the changing locations of workers relative to jobs, and the changing characteristics of individuals living in transit-friendly neighborhoods.

In Chapter 6, we examine the relationship between the region's demographics and aggregate transit ridership. We suggest that two factors have influenced transit patronage: "population effects," or changes in the population size of potential transit riders; and "usage effects," or changes in the frequency with which individuals in various socio-demographics use transit. Using data from the 2009 and 2017 California add-on to the NHTS (FHWA, 2009, 2017), we find that both population effects and usage effects have generally had a positive impact on total transit ridership in the central Bay Area counties. Unlike Los Angeles and Orange Counties and the state of California as a whole, where trends were largely negative, population growth and increasing ridership frequency among key demographics led to moderate aggregate increases in total transit trips in the central Bay Area counties.

In Chapter 7, we investigate associations between the location of workers, the location of jobs, and changes in transit ridership. We find that between 2002 and 2015, cities in the Bay Area have become less "self-contained," meaning the percentage of locally-residing workers has declined over time, and that average commute distance has lengthened. We also find that both workers and jobs are increasingly concentrated in neighborhoods with good access to employment via transit. This, combined with the decline in self-containment, may contribute to growth in transit use for commute trips. However, the results show that good access to jobs on transit is disproportionately concentrated among those with higher incomes. Higher-wage jobs and higher-wage workers are more likely to be located in such neighborhoods, and housing price increases in these neighborhoods have outstripped those in other areas. Taken together, these findings suggest that lower-wage workers—those most likely to be transit dependent—live in areas that are further from their place of employment than higher-wage workers, and may find it increasingly difficult to both live and work in neighborhoods with robust public transit employment access.

Finally, in Chapter 8, we assess the characteristics of residents living in transit-friendly neighborhoods. Broadly speaking, results show little evidence that gentrification is causing decreased access to transit among disadvantaged individuals. For example, we find that the percentage of residents below the poverty line, foreign-born residents, and zero-vehicle households that lived in transit-friendly neighborhoods was relatively stable between 2000 and 2017. Our results also show that while the percentage of "car-free" tracts in the Bay Area (i.e., those with a high proportion of zero-vehicle households who are relatively wealthy) has increased, this growth has not come at the expense of "car-less" tracts (i.e., those with a high proportion of zero-vehicle households who are poor). This suggests that while the number of wealthy residents living in neighborhoods with good transit may be rising, there is no clear evidence that such increases have led to lower-levels of transit access among poorer individuals.

6. Changing Riders versus Changing Travel Patterns among Those Riders

6.1. Introduction

In this section, we use the 2009 and 2017 NHTS to examine how changes in four demographics characteristics—car ownership, race and ethnicity, population density, and household income—affect transit ridership in the central Bay Area counties, Los Angeles and Orange Counties, and the state of California (See Chapter 2 for previous research detailing the relationship between these characteristics and transit ridership).

We first examine a "population effect." Traditionally, certain socio-demographic groups ride transit far more than others. Therefore, increases or decreases in the total population of these groups may lead to large changes in aggregate ridership, even if the frequency of use among individuals remains the same. Assuming each of these population groups were just as likely to ride transit in 2017 as they were in 2009, we calculated the number of trips that would have been taken on transit in 2017 based solely on changes in the population within each group (car owners, race/ethnic groups, number in dense urban areas, and by income) and compare that number to the actual number of observed trips in 2017. The percentage difference between these two numbers represents the population effect. In other words, the population effect represents the proportion of the actual change in ridership is due solely to population growth as opposed to changes in ridership habits.

Second, we assess a "usage effect." Here, we again use the same four determinants of transit use—car ownership, race and ethnicity, population density, and household income—to investigate how changes in ridership frequency have affected total transit patronage. We assume a constant population size (based on observed 2017 levels), and then calculate the difference in total ridership between 2009 and 2017 resulting from changes in the average ridership rate of our key groups of interest. Thus, the usage effect represents how much of the change in ridership is due to changing ridership habits as opposed to population change. A complete description of how we calculate population and usage effects is described in Appendix C, Section 2.

We find that in the central Bay Area counties, population and usage effects largely had positive effects on transit ridership during the period from 2009 to 2017. Generally speaking, both the population size of key demographic groups and the ridership frequency of these groups increased during the period. These trends contrast with those statewide and in Los Angeles and Orange Counties. Between 2009 and 2017, California as a whole and Los Angeles and Orange Counties experienced moderate negative population effects for some groups, while declining usage rates led to dramatic ridership losses in both geographies.

6.2. Population and Usage Effects in the Central Bay Area

Table 6-1 shows the results of our breakdown of these population effects and usage effects for the central Bay Area counties. The "Population Effects" column represents the change in regional transit trips that would have occurred if every group was just as likely to ride transit in 2009 as 2017, but the size of the groups grew as observed in the NHTS data. The "Usage Effects" column represents the change in regional transit trips that would have occurred if the population of every group had stayed the same between 2009 and 2017, but each group's transit use habits changed as observed. These percentages are not additive; they cannot be used to examine two different groups cumulatively.

Table 6-1. Changes in Transit Ridership Due to Changes in Population and Usage Effects in the Central Bay Area Counties between 2009 and 2017

CHARACTERISTIC		2009		2017		POPULATION EFFECT	USAGE EFFECT
		SHARE OF THE POPULATION	TRANSIT TRIPS PER YEAR	SHARE OF THE POPULATION	TRANSIT TRIPS PER YEAR		
Car Ownership	Zero-vehicle	7.7%	378.5	7.7%	358.4	+5.4%	-1.7%
	Vehicle-deficit	18.7%	140.5	18.0%	122.6	+3.6%	-3.5%
	Fully equipped	73.6%	32.1	74.3%	58.0	+9.0%	+20.7%
Race/ Ethnicity	Hispanic	18.7%	102.3	16.4%	80.4	+1.1%	-3.9%
Population Density	High population density	43.8%	142.3	45.5%	146.5	+15.5%	+2.0%
	Low population density	56.2%	29.9	54.5%	47.8	+4.5%	+10.5%
Income	Low-income	13.9%	179.1	9.3%	134.7	-3.0%	-4.5%
	Not low-income	81.3%	63.9	88.9%	88.7	+21.7%	+23.8%
All		N/A	79.1	N/A	92.7	+18.6%	+14.6%

The top panel of **Table 6-1** illustrates how the changing number of persons and the changing usage rates of individuals living in zero-vehicle, vehicle-deficit (i.e., fewer cars than drivers), and fully equipped (i.e., at least one car per driver) households affected transit patronage in the central Bay Area counties from 2009 to 2017. The first thing to note is that although there was a slight decline in the proportion of vehicle-deficit households and a slight increase in the proportion of fully equipped ones, the number of households in all three groups actually increased, leading to positive population effects for all of the vehicle ownership categories. If each of these groups were just as likely to take transit in 2017 as in 2009, the increase in the number of zero-vehicle households alone would have accounted for a 5.4 percent increase in transit use in the region. Similarly, vehicle-deficit households would be responsible for a 3.6 percent increase, while the growth in fully equipped households would have generated nine percent more transit trips across the region. These positive changes due to population increases were, however, partly offset by declining transit use among households with limited vehicle access.

Perhaps most notably, the frequency of transit use among individuals with limited vehicle access—typically the heaviest transit users—dropped between the two survey periods. Whereas zero-vehicle individuals made an average of over 378 trips per year in 2009, they made just over 358 trips per year in 2017. This decline was associated with a 1.7 percent drop in total transit ridership in the central Bay Area counties during the time period. The trend was slightly more pronounced among those living in vehicle-deficit households: the average number of yearly transit trips among these individuals dropped from 140.5 to 122.6 between 2009 and 2017, accounting for a 3.5 percent decrease in total regional transit patronage.

In contrast to the loss in ridership due to declining transit use among those living in households with limited car access, individuals living in fully equipped households actually rode transit more frequently in 2017 than in 2009. Not surprisingly, ridership among this group was relatively low in 2009, with a per capita observed rate of about 32 trips per year. By 2017, however, the frequency of use among those in the fully equipped category increased by over 80 percent to 58 trips per person per year. Because the fully equipped group comprises an extremely large proportion of the population—74.3 percent in 2017—these additional 26 rides per person translates into substantial growth in aggregate regional ridership. Holding population size constant, the increasing ridership frequency among those living in fully equipped households boosted total transit patronage by 20.7 percent in 2017 relative to 2009.

In the second panel we focus on trends among Hispanics. While changes in the ridership rates of other racial and ethnic groups shifted in important ways during the study period, and even though the percentage of Hispanic residents in the central Bay Area counties is somewhat lower than other areas of the state, the large size of California's Hispanic population combined with Hispanic travelers' high average transit use means that even small changes in ridership among this group can have outsized effects on aggregate patronage. In the central Bay Area counties, the Hispanic population increased slightly during the study period. This means that if usage rates had held constant, patronage by Hispanic residents would have increased by 1.1 percent in 2017 relative to 2009. As **Table 6-1** shows, however, transit use among Hispanics in the central Bay Area dropped substantially between 2009 and 2017. On average, Hispanics took about 22 fewer transit trips per capita per year in 2017 than in 2009, a drop of nearly 22 percent. This negative usage effect resulted in a loss of almost 4 percent of total ridership in the area.

There were also ridership changes due to the number of people living in high density areas compared to low density areas. High population-density neighborhoods are those census tracts with greater than 10,000 inhabitants per square mile; those that fall below this threshold are classified as low-density neighborhoods (though obviously there is considerable density variation among these tracts). During this same period the total population living in high-density neighborhoods grew by over 400,000 people, and accounted for a total ridership increase of 15.5 percent. Not surprisingly, individuals living in high-density areas take transit quite frequently compared to those in low-density areas, making an average of 142.3 transit trips per year in 2009. By 2017, this rate increased very slightly to 146.5 yearly trips. In total, this increasing trip rate led to a 2 percent gain in total transit trips. Thus, more people are living in high-density (and presumably more transit-friendly) neighborhoods over time, and the average number of transit trips taken by those high-density neighborhood residents is increasing slightly.

The total population of low-density neighborhoods, like that of high-density areas, also rose between 2009 and 2017: the number of low-density residents increased by roughly 380,000 individuals during the time period analyzed here, enough to produce a 4.5 percent increase in transit ridership when holding usage rates constant. In addition to growing in population size, the transit usage rates of those living in low-density neighborhoods also increased from 2009 to 2017. Compared to an average of 29.9 transit trips per year in 2009, residents of low-density areas took an average of 47.8 trips per year in 2017, and increase of about 60 percent. Holding population counts constant, this represents a 10.5 percent increase in total regional ridership.

Finally, we also examine the rate and composition effects for individuals living in lower- and higher-income households. We define low-income households as those earning less than $25,000 per year, and higher-income households as those whose incomes are above this threshold. With regard to population size, the total number of lower-income residents in the central Bay Area counties dropped considerably during the study period. Whereas residents of low-income households made up 13.9 percent of the population in 2009, they accounted for only 9.3 percent of the area's residents in 2017. This decline in the low-income population—likely the result of both a recovery from the Great Recession and a generally vibrant economy during the 2010s—had a negative impact on transit use, accounting for an estimated 3 percent fewer trips in 2017 than 2009. More importantly, usage rates of lower-income household residents, traditionally heavy transit users, dropped dramatically between 2009 and 2017. On average, those living in low-income households took almost 45 fewer trips per year, which was associated with a 4.5 percent decrease in overall transit ridership in the central Bay Area.

Total transit patronage among higher-income travelers sharply contrasted with their lower-income counterparts. First, an increase in population of nearly a million higher-income residents between 2009 and 2017 contributed to a 21.7 percent increase in total ridership when holding usage rates constant. In addition to these population gains, usage rates among higher-income residents also increased sharply, contributing to large increases in total regional ridership. Specifically, a 24.8 trip per year increase in transit use among middle- and higher-income individuals was associated with a 23.8 percent gain in total ridership in the central Bay Area counties.

Putting these findings together, the growth in the regional population contributed to an 18.6 percent growth in transit ridership between 2009 and 2017 in the central Bay Area, whereas collectively, changes in the rate of transit usage by central Bay Area residents produced a 14.6 percent increase.

6.3. Population and Usage Effects in California and in Los Angeles and Orange Counties

In comparison to the Bay Area, changes in population and transit usage produced somewhat different results in aggregate transit use at the state level and in Los Angeles and Orange Counties.

Table 6-2 highlights substantial differences in transit ridership trends between the central Bay Area counties and other areas in the state. In contrast to the generally positive outcomes in the central Bay Area counties, trends in California were somewhat mixed, while those in Los Angeles and Orange Counties a largely negative. Perhaps most notably, some of the biggest drops in aggregate ridership occurred among socio-demographic groups that are traditionally frequent transit users. The usage rates of individuals living in vehicle-deficit households, for example, fell dramatically. Decreased transit-use rates by vehicle-deficit residents led to a 17.9 percent decline in statewide ridership, and 27.1 percent drop in transit patronage in Los Angeles and Orange Counties. Similarly,

Table 6-2. Changes in Composition and Rate Effects in California and in Los Angeles and Orange Counties between 2009 and 2017

CHARACTERISTIC		CALIFORNIA		LOS ANGELES AND ORANGE COUNTIES	
		POPULATION EFFECT	USAGE EFFECT	POPULATION EFFECT	USAGE EFFECT
Car Ownership	Zero-vehicle	-1.2%	+2.1%	-14.5%	+0.7%
	Vehicle-deficit	+0.9%	-17.9%	-2.6%	-27.1%
	Fully equipped	+4.7%	+18.4%	+6.7%	+8.5%
Race/ Ethnicity	Hispanic	+5.6%	-26.7%	-0.1%	-48.2%
Population Density	High population density	+6.8%	-11.6%	+0.3%	-32.4%
	Low population density	+2.9%	+7.2%	+2.8%	-7.5%
Income	Low-income	-5.1%	-7.9%	-18.7%	-11.7%
	Not low-income	+10.0%	+13.2%	+9.0%	-5.8%
All		+8.6%	-2.7%	+5.7%	-44.2%

Data source: FHWA, 2009, 2017

those living in high-density census tracts used transit far less in 2017 than in 2009, both California-wide and in Los Angeles and Orange Counties. This resulted in declines in public transit use of 11.6 percent and 32.4 percent, respectively. Finally, in contrast to the central Bay Area counties, transit use by Hispanics in the state and in Los Angeles and Orange Counties plummeted between 2009 and 2017. Lower ridership rates among Hispanics resulted in over 300 million fewer trips being taken in California in 2017 compared to 2009, with almost 200 million of these "lost" trips occurring in Los Angeles and Orange Counties. In total, these declines resulted in ridership losses of 26.7 statewide and 48.2 percent in Los Angeles and Orange Counties. In general, these loses were compounded by, or only partly offset by, changes in population.

6.4. Conclusion

Changes in population size and transit usage rates clearly play an important role in aggregate transit patronage. In the central Bay Area counties, increases in population and more frequent transit use among key demographic groups generally resulted in moderate growth in regional transit ridership. The proportion of those with automobiles grew and also greatly increased their transit use. The same was true of higher income individuals. On the other hand, groups that typically make up a high proportion of transit riders, such as the poor, those without automobiles or in households with fewer cars than drivers, and minorities, especially Hispanics, either lost population in relation to other groups, or were less likely to ride transit, or both in 2017 compared to 2009. These shifts help explain the relative robustness of peak-period commute trips compared to other transit trips described in Part II.

Statewide, however, changes were far less positive, and population and usage effects were responsible for somewhat large drops in total transit use. Trends in Los Angeles and Orange Counties were often even more strongly negative. While individuals from households with at least one vehicle per driver increased their transit use somewhat, those with fewer cars than drivers actually cut back their transit use substantially, especially in Los Angeles and Orange Counties, which also saw a significant drop in the proportion of households without vehicles. Hispanics curtailed their transit use, dramatically in the case of Los Angeles and Orange County residents. The same was the case with those living in higher density areas. Low-income individuals also used transit less than they had been compared to higher income riders.

7. Changing Location of Workers Relative to Jobs

7.1. Introduction

Just as changes in demographics can affect transit ridership, so too can changes in the residential location of typical transit users. For example, if transit riders move away from expensive cities and neighborhoods to outlying areas where housing is more affordable but transit service is more limited, transit ridership will likely decline. In this section of the report, we examine this contention. We quantify changes in the spatial location of workers relative to jobs and public transit in Bay Area cities from 2002 to 2015. More specifically, we analyze the following:

1. Changes in the ratio between jobs and workers in Bay Area cities (jobs-housing balance);
2. Changes in the number of workers who both live and work within a Bay Area city relative to the number of workers who either travel into or out of a city (self-containment);
3. Changes in the average distance between home and work (commute distance);
4. Changes in the location of workers and jobs relative to neighborhoods with good transit access to jobs (job access by transit); and
5. High housing costs in neighborhoods with good transit access to jobs (housing costs)

Drawing on the U.S. Census Bureau's Longitudinal Employer-Household Dynamics Origin-Destination Employment Statistics (LODES), we find that a majority of Bay Area cities have more resident workers than jobs, while a majority of jobs are in cities with more jobs than resident workers. Further, the largest Bay Area cities are gaining more jobs over time relative to resident workers. Bay Area cities also are, indeed, becoming less self-contained over time. Although widespread, the downward trend is greatest in employment-rich cities. Meanwhile, the average linear commute distance for a Bay Area worker has increased almost 15 percent in 13 years. Finally, we find that both workers and jobs are increasingly concentrated in areas from which the number of jobs accessible in 30 minutes via transit is highest; however, jobs are concentrating at a much faster pace than workers.

The data suggest that increasing housing costs play a role in these trends. Areas with the best transit access to jobs tend to have higher median home values, a lower percentage of rent-burdened households, and a lower percentage of lower-wage households than other areas. By contributing to the growing separation between home and work, the Bay Area's affordable housing crisis likely has increased the number of lower-wage workers who live and/or work in outlying areas with limited transit access to jobs. The findings from this study suggest an important role for greater housing production in enabling lower-wage workers to live closer to their workplaces and, in so doing, increasing the viability of travel by modes other than the automobile.

7.2. Jobs-housing Balance in Bay Area Cities

We first explore jobs-housing balance trends across 89 Bay Area cities,[8] measured as the ratio between jobs and employed residents (For methodological details, see Appendix C, Section 3). **Table 7-1** summarizes these statistics, focusing on the median

8. Jobs and employed residents located in unincorporated areas count towards total Bay Area jobs and employed residents. City-level statistics consider only jobs and employed residents located within official city boundaries.

Table 7-1. Jobs-housing Balance in Bay Area Cities

MEDIANS	ALL (89 CITIES)			LARGEST 25 CITIES*			LARGEST 5 CITIES*		
	2002	2015	PERCENT CHANGE	2002	2015	PERCENT CHANGE	2002	2015	PERCENT CHANGE
Employed residents	13,861	14,879	+7.3%	33,794	39,969	+18.3%	167,619	185,435	+10.6%
Percent of Bay Area workers	100%	100%	N/A	67%	69%	+3.0%	38%	40%	+5.3%
Jobs	11,966	11,884	-0.7%	43,899	55,489	+26.4%	173,427	196,905	+13.5%
Percent of Bay Area jobs	100%	100%	N/A	77%	79%	+2.6%	45%	48%	+6.7%
Ratio of jobs to residents	0.86	0.80	-7.5%	1.30	1.39	+6.9%	1.03	1.06	+2.6%

** As measured by employment in 2015*

Data source: U.S. Census Bureau, n.d. and Caltrans, 2015

values across Bay Area cities.

In 2002, the median city in the Bay Area was home to approximately 14,000 employed residents and 12,000 jobs. In 2015, the median number of employed residents had risen to 15,000, a seven percent increase, and the median number of total jobs had declined slightly to around 11,900. Consequently, the ratio of jobs to residents in the region's median city declined slightly from 0.86 in 2002 to 0.80 in 2015.

Separate examination of the 25 largest Bay Area cities by employment in 2015 (which represent about two-thirds of all employed residents and close to 80% of all jobs) and then again of the five largest cities (which contain 40% of workers and nearly half of all jobs) show greater growth in population and particularly in the number of jobs in large cities (See **Table 7-1**). As a consequence, the ratio of jobs to residents increased in the region's largest cities, while it declined some across the region as a whole (including unincorporated areas).

Most Bay Area cities (60%) are home to more workers than jobs, while most jobs (60%) are found in cities with more jobs than employed residents. At the same time, the largest Bay Area cities—which generally have better transit access, especially access to rail—are gaining more jobs over time relative to resident workers while smaller cities are gaining more resident workers than jobs; the jobs-to-residents ratio in many smaller Bay Area cities declined from 2002 to 2015. Also, cities that started the period with a disproportionately large percentage of regional employment continued to attract more jobs than employed residents. Overall, these figures point to continued but uneven job creation and employment growth across the Bay Area.

Regardless of direction, however, trends away from a jobs-to-residents ratio of one imply a growing imbalance between where workers live and where they work. Jobs-to-residents ratios less than one suggest that some residents must commute to other locations to find employment, while jobs-to-residents ratios greater than one indicate that the number of jobs exceeds the number of available workers, thus requiring workers to commute into the city to fill some job vacancies. This may help to explain why transit commuting (especially for larger cities with strong transit connectivity) seems to be holding steady or growing while non-commute transit trips are in decline (See Chapter 4 and Volume II).

7.3. Self-containment

For a more nuanced view of commuting flows within and between cities, the data allow us to examine "self-containment"—the extent to which workers live in the same city in which they work ("locally-residing workers") and the related, but distinct, extent to which employed residents work in the same city in which they live ("locally-working residents"). We combine these two measures to calculate an independence index, the ratio of internal commutes to external commutes. For further information on this index, see Appendix C, Section 3.

Internal commutes consist of commutes for workers who both live and work in the same city, while external commutes are commutes where either home or work locations are outside of the city. We summarize the median values of these measures in **Table 7-2** to analyze whether Bay Area cities have become less "self-contained" over time.

Table 7-2. Self-containment in Bay Area Cities

MEDIANS	ALL (89 CITIES)			LARGEST 25 CITIES*			LARGEST 5 CITIES*		
	2002	2015	PERCENT CHANGE	2002	2015	PERCENT CHANGE	2002	2015	PERCENT CHANGE
Locally-residing workers	12.0%	11.4%	-5.0%	13.3%	11.4%	-14.3%	28.8%	25.6%	-11.1%
Locally-working residents	11.4%	10.0%	-13.0%	15.9%	13.7%	-13.8%	29.8%	27.2%	-8.7%
Independence Index	6.0%	5.0%	-16.7%	8.0%	6.0%	-25.0%	21.0%	18.0%	-14.3%

** As measured by employment in 2015*

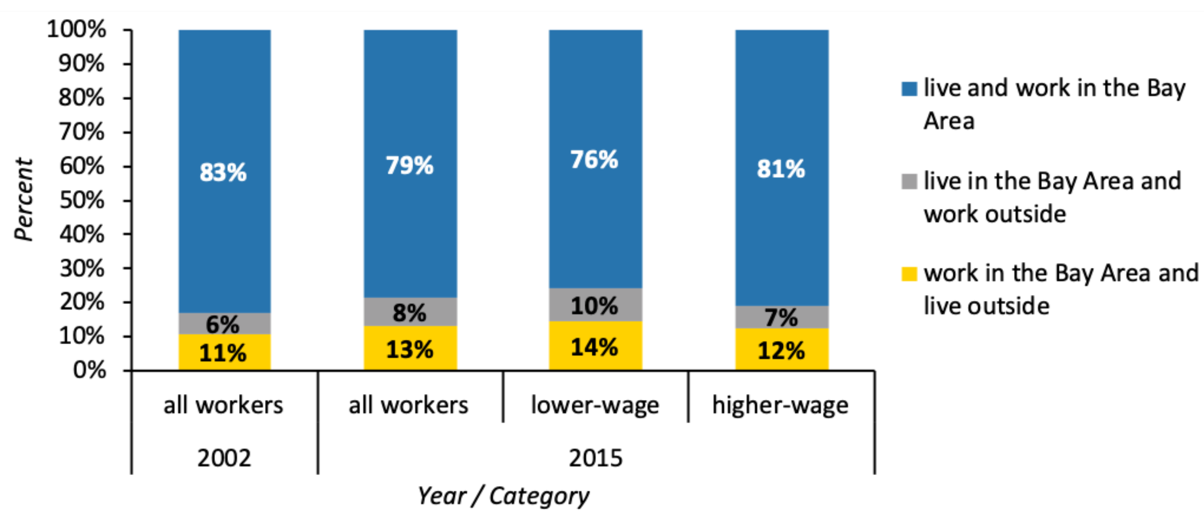
Data source: U.S. Census Bureau, n.d. and Caltrans, 2015

Across all Bay Area cities, the percent of locally-residing workers declined from 12.0 to 11.4 from 2002 to 2015. The percent of locally-working residents declined even more steeply, from 11.5 to 10.0. Finally, the independence index declined from 0.06 in 2002 to 0.05 in 2015. These trends complement the jobs-housing findings we report above and show a decline in the percentage of workers who are able to live and work in the same city.

Self-containment rates are positively related to city size. Larger municipalities provide substantial opportunities for workers to live and work in the same city. However, the data presented in **Table 7-2**, show that the decline in self-containment is widespread and has occurred even among the largest Bay Area cities. Among the 25 largest Bay Area cities, the independence index declined by 25% and among the largest five cities is declined by 14%.[9] These findings differ from analysis conducted in the 1980s showing a trend toward greater self-containment in Bay Area cities over time (Cervero, 1996).

Not only are cities within the Bay Area becoming less self-contained over time, but also, so too is the region as a whole. As shown in **Figure 7-1**, in 2002, 83 percent of employed workers who either live or are employed in the Bay Area both lived and worked in the Bay Area; by 2015 only 79 percent did. Six percent lived in the region but worked outside the region in 2002, while eight percent did so in 2015. Over the same period the percent of workers who lived outside the region increased from 17 to 22. Clearly, the Bay Area as a whole is becoming less self-contained over time.

Figure 7-1. Home and Work Locations inside/outside the Bay Area, 2002 and 2015



Data source: U.S. Census Bureau, n.d.

Thus, across all three measures (locally-residing, locally-working, and self-containment), we find that cities in the Bay Area are becoming less self-contained—further evidence of the growing spatial mismatch between jobs and housing. This finding holds even though the number of jobs and total employment is growing, albeit unevenly, across the region.

Moreover, self-containment patterns differ between lower- and higher-wage workers in 2015 (See Appendix C, Section 3 for

9. The correlation between size and change in the independence index is -0.27 for all Bay Area cities; -0.46 for the largest 25 cities; and -0.92 for the largest 5 cities. The correlation between size and the 2015 independence index is 0.81 for all cities, 0.90 for the 25 largest cities; and 0.99 for the largest 5 cities.

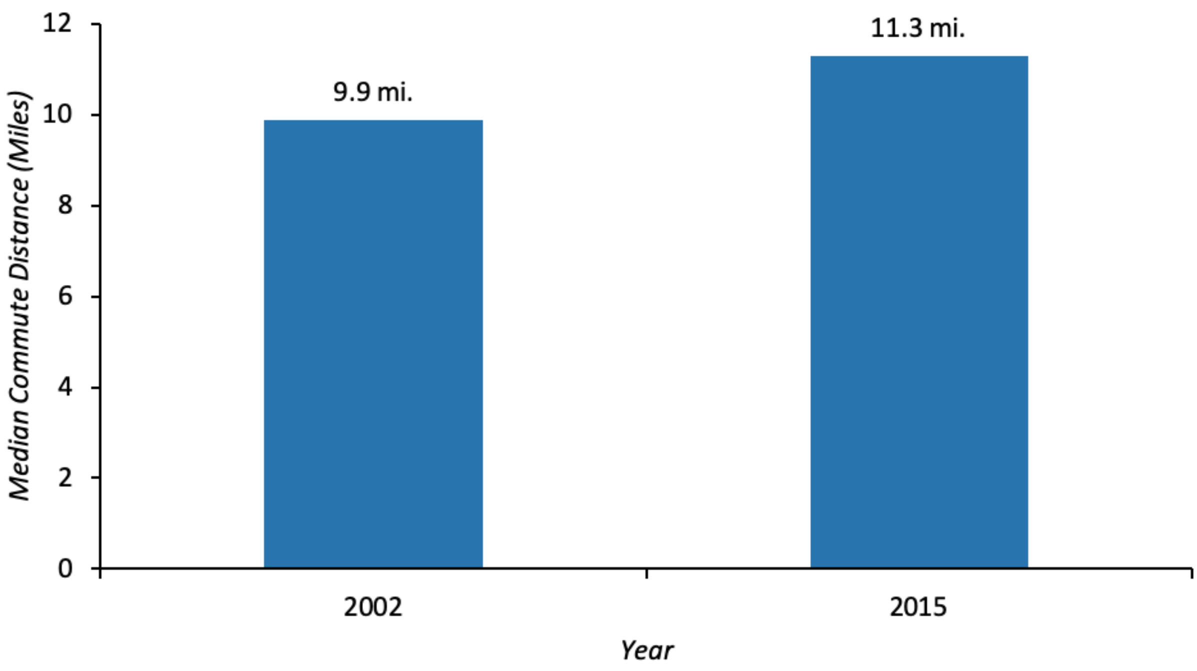
definitions and caveats about inflation). Lower-wage workers were less likely to both live and work both within cities in the region and in the region overall than higher-wage workers. Overall, these findings suggest that workers are living further from their job sites, which may help to explain both the decline in transit commute trips and, perhaps, the decline in transit trips serving local cities.

7.4. Commute Distances

As residential and employment locations evolve, commute distances in the Bay Area are lengthening. To quantify this, we calculate linear (Euclidean) commute distances based on the home and work addresses in the 2002 and 2015 LODES data. While these straight-line distances do not reflect the actual routes on the transportation network taken by commuters, our preliminary analysis shows significant correlation between Euclidean and transportation network distances in the region. Thus, the general trends in commute distances over time and between worker wage categories using Euclidean distances reported here should reliably represent—even if they consistently underrepresent—actual commute distances.

Commutes for all Bay Area workers have increased over time (See **Figure 7-2**). Workers in 2015 traveled approximately 1.4 miles further than in 2002—an increase of 14.3 percent over just thirteen years. In short, the time cost (and, likely, monetary cost) of the average commute has increased significantly for Bay Area commuters in the 2000s.

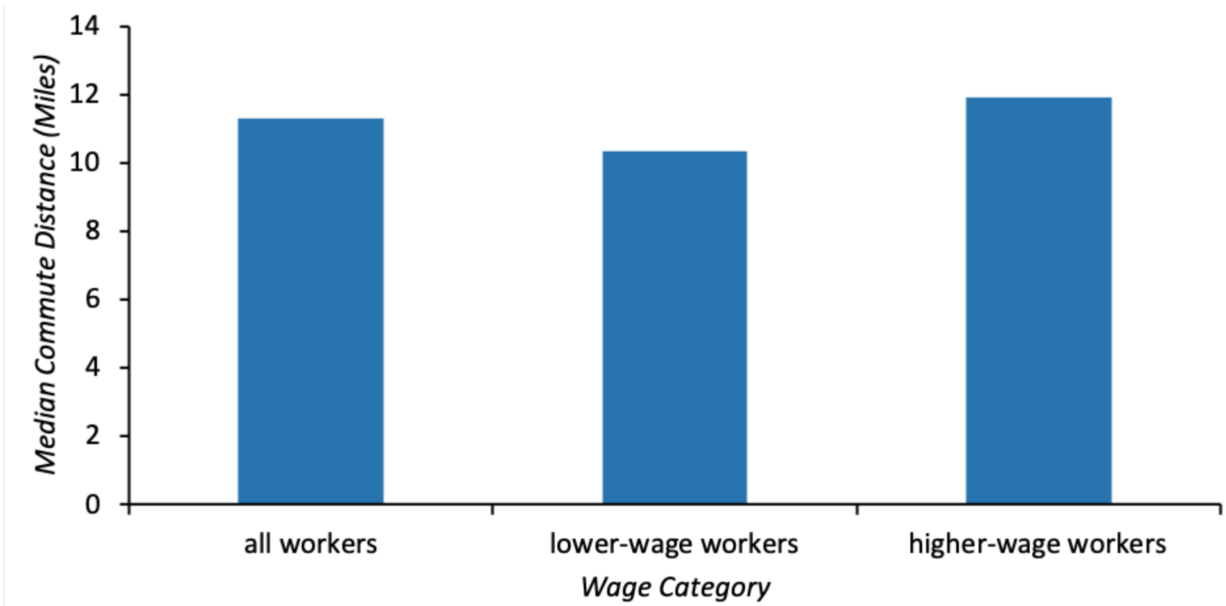
Figure 7-2. Commute Distances for Bay Area Workers over Time



Data source: U.S. Census Bureau, n.d.

Second, we find that lower-wage workers had shorter commutes (10.3 miles) than workers overall (11.3 miles), while higher-wage workers had longer commutes (11.9 miles) (See **Figure 7-3**). This finding accords with existing research showing that low-income workers generally tend to have shorter commutes than high-income workers (Blumenberg and King, 2019; Hu and Schneider, 2017; and Suárez, Murata, and Delgado Campos, 2016). In addition, lower-wage workers are more likely to use slower modes of transportation than higher-wage workers and, therefore, tend to live closer to their jobs. Employers are less likely to provide compensating wages to attract lower-wage workers, particularly if they can find local workers to fill job vacancies and, therefore, lower-wage workers may have difficulty with the out-of-pocket costs associated with longer-distance trips (Ong and Blumenberg, 1998).

Figure 7-3. Commute Distances for Bay Area Workers by Wage Category, 2015



Data source: U.S. Census Bureau, n.d.

Growing commute distances over time may reflect a mismatch between available housing and employment opportunities. Some workers may be increasingly unable or unwilling to pay for housing at locations closer to their workplaces, thereby requiring increasingly lengthy commutes. Longer commutes, likely to more dispersed locations less well-served by transit, may make travel via transit more expensive, time-consuming, and inconvenient.

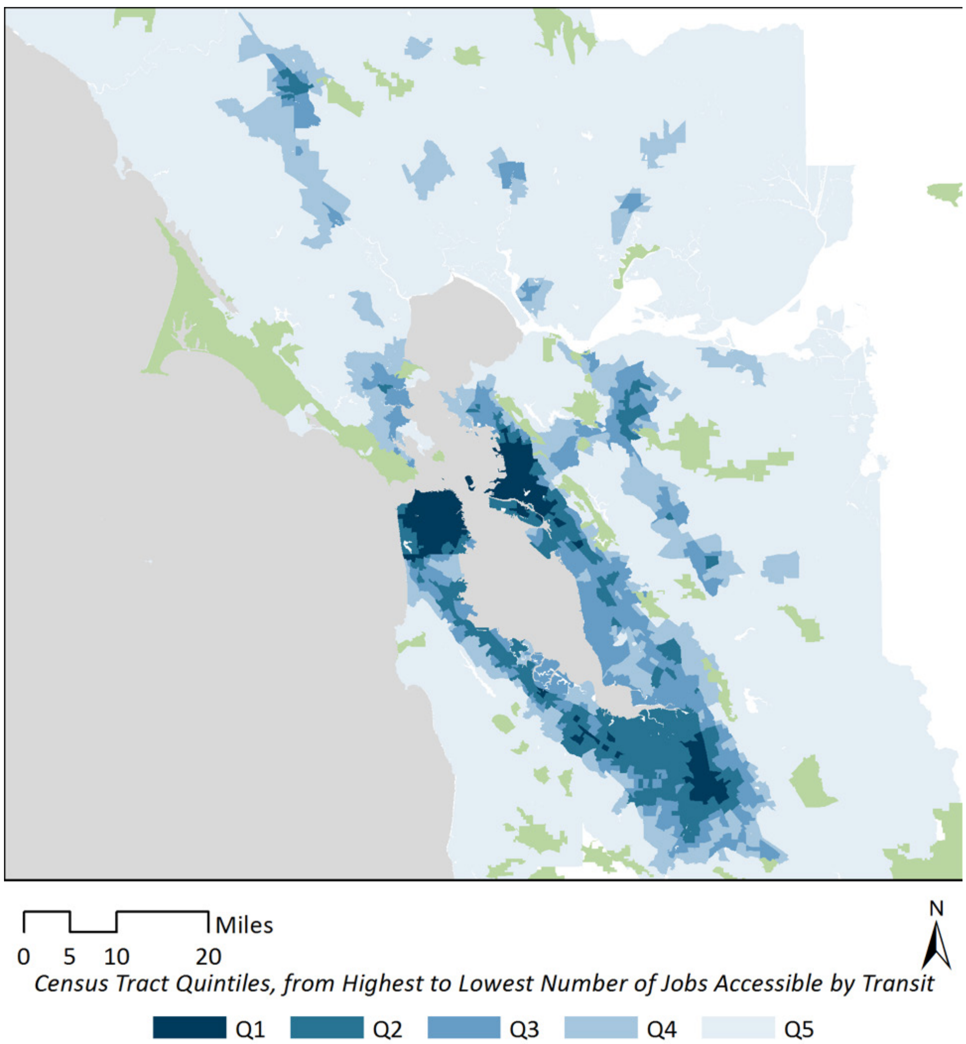
7.5. Jobs, Workers, and Transit

Our results above imply that jobs and workers are becoming increasingly dispersed throughout the Bay Area. Where jobs and workers are becoming more concentrated, however, it is in areas with greater transit access to jobs. Within such areas, jobs grew at a much faster pace than resident workers. These areas seem to be attracting higher-wage jobs and higher-income residents, suggesting that some lower-wage businesses and workers may be being pushed out. We deal with the issue of gentrification in the following section and in the next chapter.

Generally speaking, workers are more likely to use transit when they have good access to it at both their origins and destinations (Lund, Willson, and Cervero, 2006). However, many studies of transit use focus on the proximity of transit service to travelers' homes (Crowley and Shalaby, 2009; Dill, 2008; and Djurhuus et al., 2014). In contrast, evidence suggests that the proximity of transit to the workplace may be even more influential in whether commuters use transit (Kwoka, Boschmann, and Goetz, 2015). Decreasing self-containment, therefore, may have negative implications for transit use, particularly if workers are more likely over time to live and work in areas with poor transit access to jobs. If workers remain employed in areas with high job access by transit but increasingly live in the outer reaches of the region, they still may commute by transit but likely would use cars for many of their non-work trips.

To explore these relationships, we examine the changing distribution of workers and jobs relative to areas that provide good access to jobs on transit. We first examine changes in the location of workers and jobs relative to areas in which a relatively large number of jobs are accessible on transit. We then disaggregate these patterns further by analyzing changes in the percentage of Bay Area

Figure 7-4. Job Access by Neighborhood, 2015



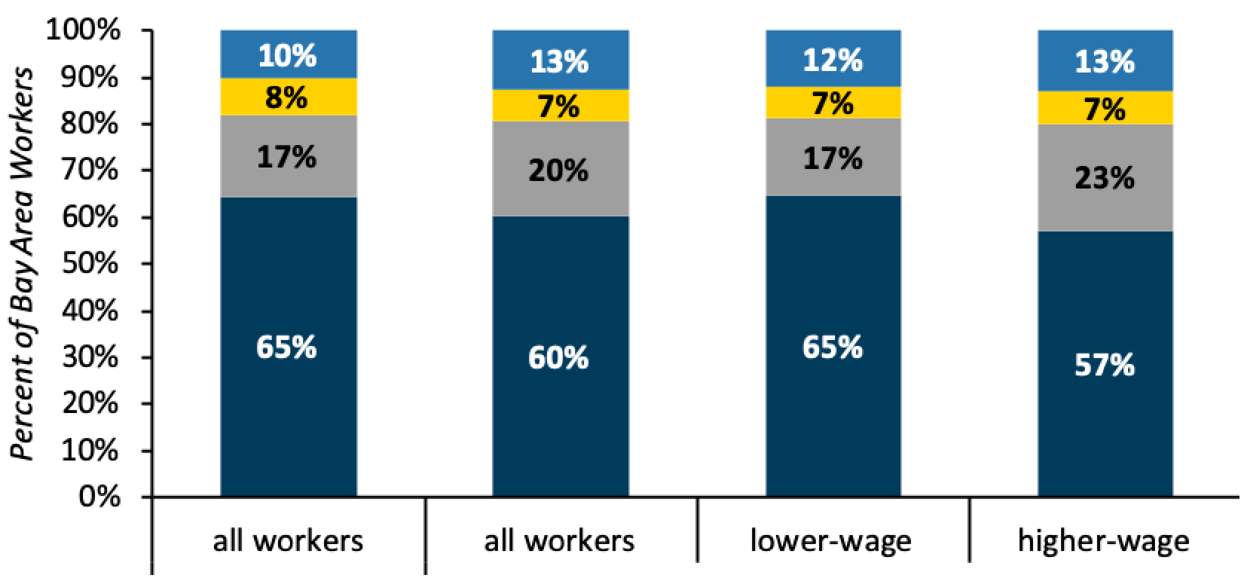
Data source: Owen and Murphy, 2018; CaliDetail, n.d.; and Esri, 2010 workers of their home and work neighborhoods combined. For this analysis, we draw on data from the University of Minnesota's Access across America program (Owen and Murphy, 2018), with tracts divided into five quintiles; tracts in the top quintile (Q1) are accessible to the most jobs by transit. As **Figure 7-4** shows, Q1 tracts (which have the highest access to jobs via transit) are primarily concentrated in downtown San Francisco, Oakland, and San José, which are well served by regional rail and by local bus lines. Q2 tracts (which have the next-best access to jobs via transit) are concentrated in developed areas, primarily surrounding the bay, and often abut Q1 tracts. Q3 and Q4 tracts, from which fewer jobs are accessible in 30 minutes via transit, are present in more suburban areas and subregional population centers. Finally, most Q5 tracts (which feature the fewest number of jobs accessible via transit) are located in rural and undeveloped land outside of populated areas.

Both jobs and workers are becoming increasingly concentrated in areas with superior access to jobs via transit over time, but jobs are concentrating at a faster rate in these areas. In 2002, Q1 tracts (those in the top accessibility quintile) contained 26 percent of regional jobs; this grew to 32 percent of regional jobs in 2015. Q2 tracts similarly contained 26 percent of regional jobs in 2002 and 28 percent of regional jobs in 2015. Conversely, the percent of regional employment concentrated in Q3, Q4, and Q5 tracts declined over this period.

Areas with high job access by transit also increased their share of employed residents but at a slower pace. In 2002, Q1 tracts contained 17 percent of employed Bay Area residents; by 2015, Q1 tracts contained 19 percent of employed residents. Similarly, Q2 tracts contained 18 percent of employed residents in 2002 and 20 percent of employed residents in 2015. If jobs are being better served by transit in both relative and absolute terms, the share of transit trips constituted by commute trips is likely to grow.

We also compare transit access to employmeny by wage group for 2015. Our data indicate that Q1 tracts contained 20 percent of employed higher-wage residents, 18 percent of employed lower-wage residents, 35 percent of higher-wage jobs, and 28 percent of lower-wage jobs. Similarly, Q2 tracts contained 20.4 percent of employed higher-wage residents, 19.6 percent of employed lower-

Figure 7-5. Relative Home and Work Locations of Workers in the Bay Area



Data source: U.S. Census Bureau, n.d.

wage residents, 20 percent of higher-wage jobs, and 25 percent of lower-wage jobs. These descriptive statistics imply that higher-wage workers have somewhat better access to both homes and jobs in areas with high transit employment access than lower-wage workers, even though we know that lower-wage workers are more likely to be dependent upon transit than higher-wage workers. These data indicate a spatial mismatch between areas of likely need for transit and areas with the best transit service to jobs, which may help explain declines in transit ridership, particularly outside of downtown San Francisco, into which significant numbers of higher-wage workers commute.

To better understand the changing relationships of work and home locations relative to areas in which a large number of jobs are accessible in 30 minutes via transit, we can separately analyze workers who both live and work in the Bay Area. Because our transit supply measure applies only to the Bay Area, we exclude workers who are either employed or live outside of the Bay Area.

As **Figure 7-5** shows,[10] between 2002 and 2015, the proportion of workers who both lived and worked in areas with the best access to jobs via transit (here, Q1 tracts) grew from ten percent to 13 percent. Those living in areas with good transit employment access but working in areas with poor transit employment access (here, tracts in all other quintiles) dropped from eight percent to seven percent (likely at least partially attributable to patterns of job growth), while those living in areas with poor access to jobs via transit and working in areas with good access to jobs via transit grew from 17 percent to 20 percent. Finally, the vast majority who both lived and worked in neighborhoods with poor transit employment access declined from 65 percent to 60 percent. Thus, a growing number of Bay Area residents work in areas that are well-connected to jobs by transit, and they are more likely to live there than in areas less well-connected. Even those in living in neighborhoods with poor transit employment access were more likely in 2015 to work in neighborhoods with good transit employment access than in 2002, which is not that surprising as overall jobs are shifting to such transit-connected areas. Certainly, these trends are consistent with the growing use of transit for the commute.

Figure 7-5 also shows wage-based differences in these trends. In 2015, lower-wage individuals (those earning under $3,333 per month, in nominal dollars) were less likely than higher-wage individuals to both live and work in neighborhoods with good access to jobs via transit, to live in neighborhoods with good access to jobs via transit and work in areas with poor access to jobs via transit, and to live in neighborhoods with poor access to jobs via transit and work in neighborhoods with good access to jobs via transit. Housing market conditions may be contributing to these wage-based differentials in workers residential location, as may be the tendency for higher-wage workers to have their places of employment be located in dense inner-city areas. Lower-wage workers were, however, more likely than higher-wage workers to both live and work in neighborhoods with relatively inferior access to jobs via transit (though some of these lower-wage workers are located in areas with reasonable, although not the highest, levels of job access via transit). This finding contrasts with previous research showing that lower-wage workers—particularly those without cars—self-select into transit-rich neighborhoods where they can rely on transit (Glaeser, Kahn, and Rappaport, 2008 and LeRoy and Sonstelie, 1983).

7.6. Housing Market Conditions in Neighborhoods with Good Transit Access to Jobs

Finally, we use tract-level data from the 2015 five-year American Community Survey (ACS) to examine housing market conditions in neighborhoods with the best access to jobs via transit (U.S. Census Bureau, 2019). We gathered data on median home values and the share of the population constituted by “rent burdened” households. Median home values increased across all neighborhoods from 2002 to 2015, but home value increases were highest in tracts with the best transit access to jobs. In Q1 tracts, median home values (in 2015 dollars) increased from $461,000 in 2002 to $800,000 in 2015; they similarly increased from $460,000 in Q2 tracts in

10. This graph includes workers who both live and work in the Bay Area.

2002 to $688,000 in 2015. These represent increases of 74 percent and 50 percent, respectively, while both Q4 and Q5 tracts saw median home values increase by approximately 40 percent. These patterns illustrate that increased home values in the Bay Area's booming housing market were greatest in neighborhoods with the highest transit access to employment.

This finding also is implied by trends in the percentage of "rent-burdened" households (households paying 30 percent or more of their household income in rent) by neighborhood type. In 2002, the distribution of rent-burdened households was relatively flat (between 27% and 29%) across all neighborhoods by transit access to jobs. In 2015, the percentage of rent-burdened households was lowest (43%) in Q1 tracts. Again, these numbers illustrate the significant rise in housing costs over the entire region. They also suggest, however, that lower-wage workers are less likely to live in neighborhoods with the best transit access to jobs. Together with observed trends in median housing prices, data on the distribution of rent-burdened households suggest that financial barriers to homeownership have become most severe in neighborhoods with high transit employment access and likely have started to price out some lower-wage workers from those areas. In short, the kinds of neighborhoods that have the potential to better serve the mobility needs of lower-wage workers have become increasingly inaccessible to exactly those same workers.

7.7. Conclusion

Bay Area cities, particularly employment-rich cities, are becoming increasingly less self-contained over time. At the same time, both workers and jobs have concentrated in areas of high transit access to jobs over time, even though jobs are concentrating at a much faster pace. Areas with the best access to jobs via transit tend to have higher median home values, a lower percentage of rent-burdened households, and a lower percentage of lower-wage households than other areas. All this may be contributing to higher transit use for commuting but less for other trip purposes. By contributing to the growing separation between home and work, California's affordable housing crisis likely has increased the number of workers who live and/or work in outlying areas with more limited transit service to employment opportunities. This is particularly problematic in the case of lower-wage workers who are disproportionately likely to be dependent upon transit to get to work.

8. Changes in Transit-friendly Neighborhoods

8.1. Overview

8.1.1. Introduction

In this chapter, we examine social and economic trends taking place in transit-friendly neighborhoods from 2000 to 2017. As housing costs have risen in the Bay Area, many surmise that gentrification may be reducing transit access for the poor and immigrants. However, and to our surprise, we do not find strong evidence of such changes in transit-friendly neighborhoods in the Bay Area. While the share of Latin-American immigrants living in transit-friendly neighborhoods has declined, the share of poor people and Asian immigrants has not. Additionally, while our previous study of Greater Los Angeles found steep declines in zero-vehicle households in its highest-quality transit neighborhoods (Manville, Taylor, and Blumenberg, 2018a), the same does not hold true for the Bay Area. We do, however, find small but steady increases in car-free neighborhoods—places with many zero-vehicle households but low levels of poverty—in the Bay Area's transit-friendly neighborhoods.

This may seem at odds with our jobs-housing balance findings in the previous chapter, but the prior analysis examined the home and work locations of *all* Bay Area workers and their access to jobs by transit. The transit measure used in the previous analysis incorporates both transit supply *and* proximate employment opportunities. Here, though, we focus on changes in household characteristics in areas with high transit supply or use—established measures of transit-induced gentrification.

8.1.2. Context

Building on the findings in the previous section, here we examine changes in the characteristics of residents in transit-friendly areas and the possible impact on transit ridership. Recently, many urban neighborhoods in the Bay Area have been experiencing soaring housing costs and gentrification, whereby more well-off newcomers displace incumbent low-income residents. The research literature on the problem of gentrification is vast and messy, and we will not visit it here. But in terms of travel behavior, gentrification implies replacing poorer residents who are more likely to ride transit with higher-propensity transit riders in transit-friendly neighborhoods with wealthier ones who are less likely to ride transit. So even if those gentrifying residents ride transit more than they did before their move to a transit-friendly neighborhood, they may ride considerably less than those they are replacing.

The issue of gentrification not only affects existing transit-friendly areas that are experiencing housing turnover but has increasingly been raised when local municipalities seek to concentrate housing and commercial development around major transit stops and stations—known as transit-oriented developments (TODs) (Hess and Lombardi, 2004). The issue is particularly salient in the Bay Area, since the MTC and Association of Bay Area Governments' (ABAG) *Plan Bay Area 2040* promotes "focused growth" in communities along the existing transportation network in nearly 200 designated Priority Development Areas (PDAs) with high-quality transportation access (MTC and ABAG, 2017, p. 43). While generally popular with transit and environmental advocates, some affordable housing scholars and activists have criticized these efforts for their unintended consequences, where the higher housing prices in TODs may potentially displace lower-income, transit-riding households to less transit-friendly areas (Rayle, 2015). Researchers have found that TODs are associated with somewhat higher levels of transit use, even controlling for other factors known to influence transit use, including self-selection into transit-oriented developments (Ewing and Cervero, 2010). As noted in an earlier chapter, a recent study in the Bay Area and Los Angeles found that neighborhood change (although not necessarily displacement) is associated with TODs, especially in core urban areas (Chapple et al., 2017). The authors concluded that, even if new wealthy residents replace intensive transit users in TODs, the higher densities associated with development should offset these losses and increase the number of potential transit users. However, while transit users might increase, transit trips may not. Dominie (2012) examined transit commuting before and after the development of new rail transit stations and station-area development in Los Angeles and found that overall transit commuting declined in most station areas, even if the overall station-area populations grew.

Aside from neighborhood gentrification (and its attendant effects on displacement, ethnic/racial change, and income disparity), the Bay Area's average housing costs have risen as the region experiences an affordability crisis; this might also push lower-income (and even middle income) residents to search for more affordable housing in outlying, less-transit friendly areas (Kimberlin, 2019). And gentrification is not the only way that neighborhoods change: poor neighborhoods can become poorer and blighted; already wealthy neighborhoods can become much wealthier; and so on.

In this chapter, we examine changes in the characteristics of residents in the Bay Area's most transit-friendly neighborhoods. In particular, we focus first on certain segments of the population that are far more likely to use transit than others, and as a result account for a relatively large share of transit trips. And second, we look at a relatively small share of places—both metropolitan areas and neighborhoods within metropolitan areas—that host a very large share of transit trips (Manville, Taylor, and Blumenberg, 2018b). Consequently, even small shifts in the composition of people living in certain neighborhoods—such as a decrease in the number of people lacking vehicles who live in the central part of a city—could have outsized effects on transit systems that depend on regular users for patronage (Manville, Taylor, and Blumenberg, 2018a).

Accordingly, the question we seek to answer is: has neighborhood change—due to gentrification, urban decline, decentralization, or otherwise—altered the demographics of transit-friendly neighborhoods in the Bay Area? To answer this question, we focus on three household characteristics—1) low incomes, 2) the presence/absence of motor vehicles, and 3) immigrant status—that have all been shown in the literature to significantly influence transit use.

8.2. Change in Transit-friendly Neighborhoods

8.2.1. Types of Transit-friendly Neighborhoods

In this section we investigate how changes in several key socioeconomic factors that have been shown to positively influence transit use are impacting transit-friendly neighborhoods in the Bay Area. For robustness, we identify such neighborhoods using three different methods (See **Figure 8-1** and **Table 8-1**), and compare the results (holding geographies as constant as possible over time, despite slight changes in tract boundaries):

1. "High-quality Transit Areas," a definition established in state law to encompass areas near high-frequency transit stops and corridors (Implementation of the Sustainable Communities Strategy, 2008).[11] In other words, these areas host high levels of transit supply, without regard per se to the degree to which nearby residents use it. This definition encompasses the widest area of the three (MTC, 2018).

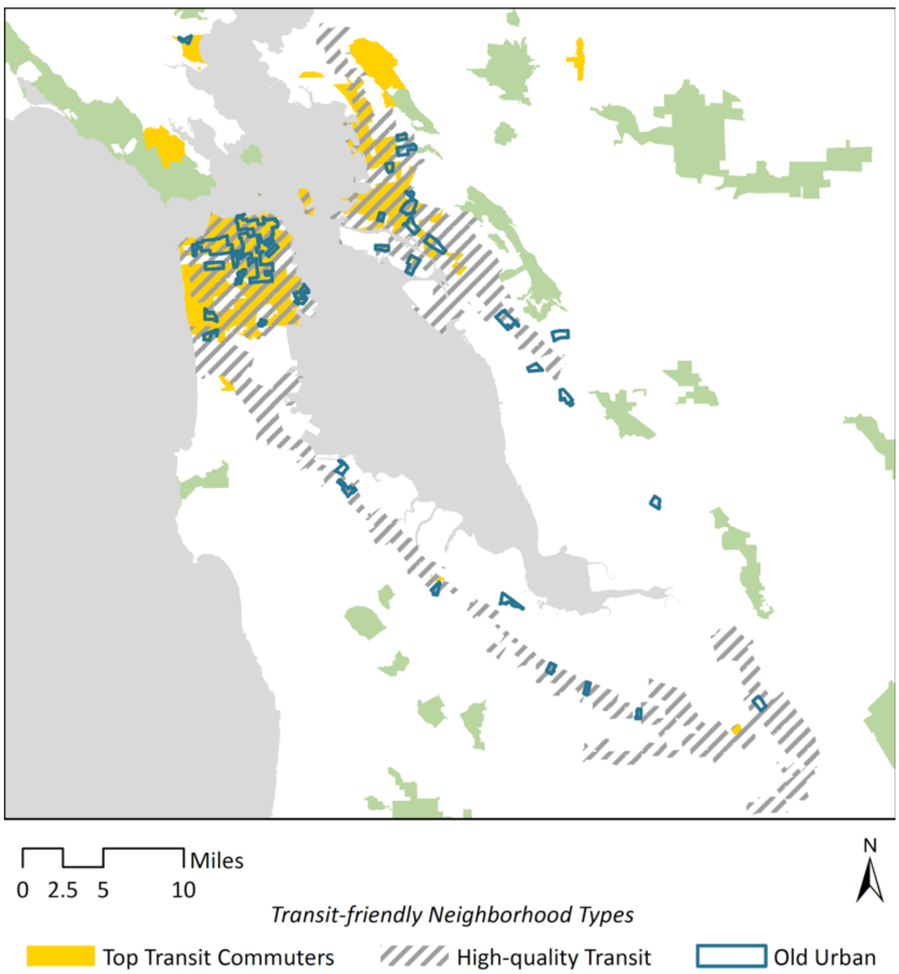
11. Specifically, the term "high-quality transit area" comes from California Senate Bill 375, which allows for streamlined environmental review processes for designated projects in high-priority growth areas (Barbour and Deakin, 2012). SB 375 allows metropolitan planning organizations to develop eligible projects that include tracts "within one-half mile of a major transit stop or high-quality transit corridor included in a regional transportation plan. A…high-quality transit corridor means a corridor with fixed route bus service with service intervals no longer than 15 minutes during peak commute hours" (Implementation of the Sustainable Communities Strategy, 2008).

2. "Old Urban" neighborhoods, one of seven types in the U.S. drawn from a land use/transportation system typology developed by Voulgaris et al. (2017) for the U.S. Federal Highway Administration. Old Urban residents typically display high use of transit, have low miles of personal travel, and take relatively few single occupancy vehicle trips. On average, Old Urban tracts have very high residential densities and are exceptionally transit-friendly. While just five percent of tracts nationally and home to only four percent of the U.S. population, residents of Old Urban census tracts make nearly a third (32%) of all transit trips (Voulgaris et al., 2017). In the Bay Area, most are located in San Francisco; this definition encompasses the least area of the three (Voulgaris et al., 2016).

3. "Top Transit Commuters," those census tracts that together contain half of all total transit commuters in the Bay Area. For consistency over time and with other work on falling ridership, we used Census data from 2000 to determine these tracts, but overall mode share of transit commuting has changed little since (U.S. Census Bureau, 2019).

See Appendix C, Section 4, Section 2 for caveats and limitations of this methodology.

Figure 8-1. Distribution of Transit-friendly Neighborhoods in the Bay Area



Data source: U.S. Census Bureau, 2018; MTC, 2018; Voulgaris et al., 2016; U.S. Census Bureau, 2019; CaliDetail, n.d.; and Esri, 2010

Table 8-1. Comparison of Transit-friendly Neighborhood Types

NEIGHBORHOOD TYPE	DEFINITION	NUMBER OF TRACTS	PERCENT OF ALL BAY AREA TRACTS
High-quality Transit areas	Tracts within one half-mile of a major transit stop or high-quality transit corridor	540	36.2%
Old Urban neighborhoods	Tracts with both high residential densities and transit access	112	7.5%
Top Transit Commuter tracts	Tracts that collectively host half of the region's transit commuters	270	18.1%

Data source: Implementation of the Sustainable Communities Strategy, 2008; MTC, 2018; Voulgaris et al., 2017, 2016; and U.S. Census Bureau, 2019

8.2.2. Change over Time

As a baseline, we first compare the Bay Area with respect to our three key socio-demographic categories and then focus on changes in these characteristics in our transit-friendly neighborhood types. As we discuss in Chapter 6, low-income households use transit at a much higher rate, all else considered. They also tend to live in transit-friendly neighborhoods and are less likely than others to own vehicles, which is also conducive to higher transit use. Finally, poorer neighborhoods usually have larger immigrant populations, which tend to take transit at even higher rates. In general, we should expect increasing rates of poverty, higher numbers of zero-vehicle households, and more immigrant households to be associated with greater transit use for commuting and other trips.

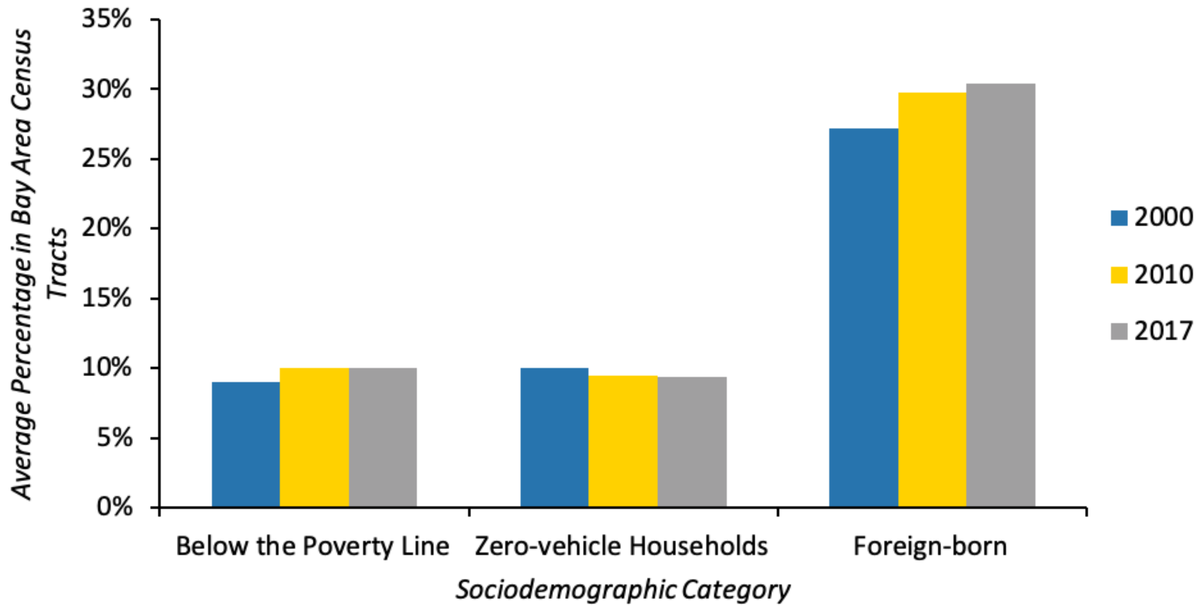
8.2.2.1. Baseline: All Bay Area Neighborhoods

Figure 8-2 shows how the three variables have changed over time in the Bay Area. First, poverty rates edged up slightly between 2000 and 2017. Second, as noted in Chapter 8, the share of zero-vehicle households has dropped only slightly, by less than one percentage point, which contrasts sharply from the findings in our previous study of Greater Los Angeles (Manville, Taylor, and Blumenberg, 2018a). Finally, the average neighborhood share of foreign-born residents is relatively high, and climbed from 27.2 percent in 2000 to 30.4 in 2017.

8.2.2.2. Socio-demographic Change in Transit-friendly Neighborhoods

Compared to the Bay Area overall, we find that transit-friendly neighborhoods, however defined, have larger shares of poor and foreign-born residents, as well as households without vehicles. Of greater interest, though, we find that transit-friendly neighborhoods have experienced little change in their shares of poor and zero-vehicle residents from 2010 to 2017, despite changes in the Bay Area regional economy and housing market. The most significant change has been a loss of Latin-American-

Figure 8-2. Change in the Bay Area Overall in Three Socio-demographic Categories with High Propensity to be Transit Users



Data source: U.S. Census Bureau, 2019

born immigrants in transit-friendly neighborhoods.

Figure 8-3 shows the share of residents living below the poverty line in each of the transit-friendly neighborhood types. The average transit-friendly neighborhood (across all three measures) is poorer than the total share of poverty for the entire Bay Area. From 2000 to 2010, poverty rates in transit-friendly neighborhoods in the Bay Area changed very little.

Figure 8-4 shows changes in the share of zero-vehicle households among the region's transit-friendly neighborhoods. Little change has occurred across all three neighborhood types, though the percentage of zero-vehicle households in Old Urban neighborhoods is almost double that of High-quality Transit areas.

The relative stability in the percentage of zero-vehicle households occupying transit-friendly neighborhoods in the Bay Area stands in stark contrast to the findings of our recent analysis of transit patronage in Greater Los Angeles (Manville, Taylor, and

Figure 8-3. Average Percentage of Residents Living in Poverty in the Bay Area's Transit-friendly Neighborhoods

Data source: MTC, 2018; Voulgaris et al., 2016; and U.S. Census Bureau, 2019

Blumenberg, 2018a). That report found increased private vehicle access across the Los Angeles Area, not just in transit-friendly neighborhoods. But in the Bay Area, the share of zero-vehicle households in transit-friendly neighborhoods increased relative to the region as a whole.

Figure 8-4. Average Percentage of Zero-vehicle Households in the Bay Area's Transit-friendly Neighborhoods

Data source: MTC, 2018; Voulgaris et al., 2016; and U.S. Census Bureau, 2019

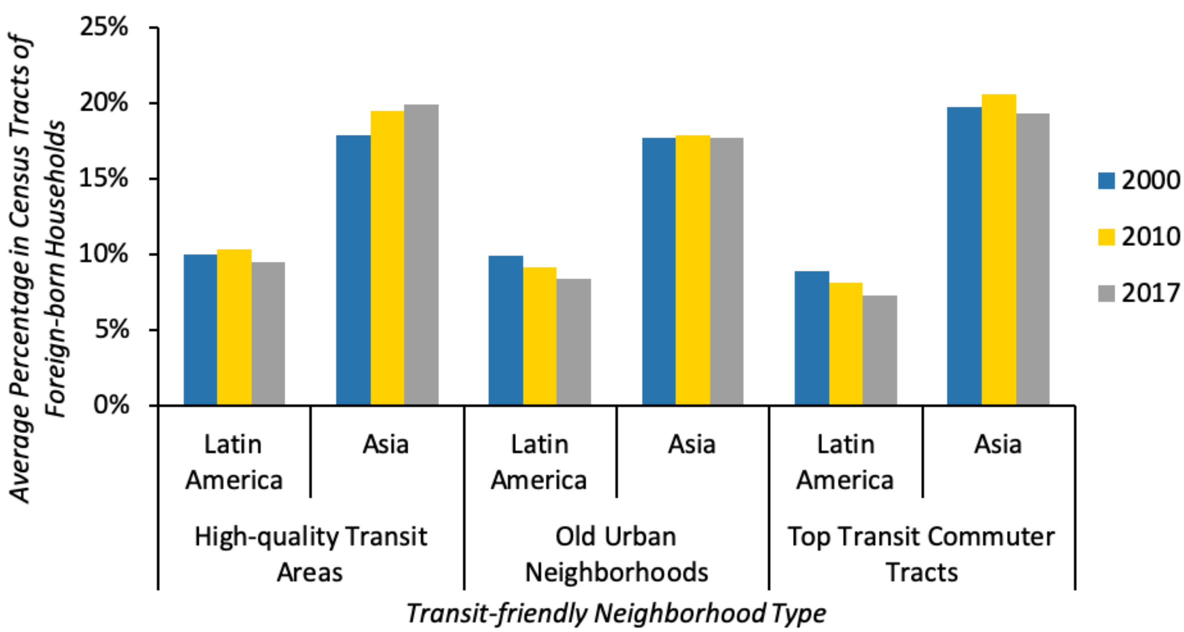
Finally, recall that, as shown in **Figure 8-2**, the Bay Area experienced a significant increase in the share of foreign-born residents among its population. However, the Bay Area's foreign-born population is split between Asian and Latin-American origin. From 2000 to 2017, the share of Asia-born residents increased, while the relative share of Latin-America-born residents declined, broadly consistent with national trends (Radford, 2019).

Figure 8-5 presents data on changes in the share of foreign-born residents by region of origin among the three transit-friendly neighborhood types. All transit-friendly neighborhoods held a smaller share of Latin-American immigrants (who in the past have been heavy transit users) in 2017 than in 2000. This perhaps represents the most significant socio-demographic change in areas near transit. In contrast, Asian-origin immigrants increased slightly from high-quality transit areas, and remained flat in Old Urban and Top Transit Commuter neighborhoods.

8.3. Car-less versus Car-free

The lack of significant change in the share of poor and zero-vehicle households in transit-friendly neighborhoods should, on the surface, imply that auto-access trends in these neighborhoods are not having much of an effect on ridership. However, the aggregate auto access trends described above mask considerable heterogeneity across neighborhoods. It is possible, for instance, that such neighborhoods are over time hosting fewer households with no vehicles due to financial constraints, and more households whose members have chosen to go without cars—while overall car-ownership statistics remain relatively stable. Given

Figure 8-5. Average Percentage of Foreign-born Residents, by Region of Birth, in the Bay Area's Transit-friendly Neighborhoods



Data source: MTC, 2018; Voulgaris et al., 2016; and U.S. Census Bureau, 2019 the widely varying circumstances, resources, travel patterns, and transit use between these two types of zero-vehicle households, any shifts in their relative share in transit-friendly neighborhoods could affect ridership.

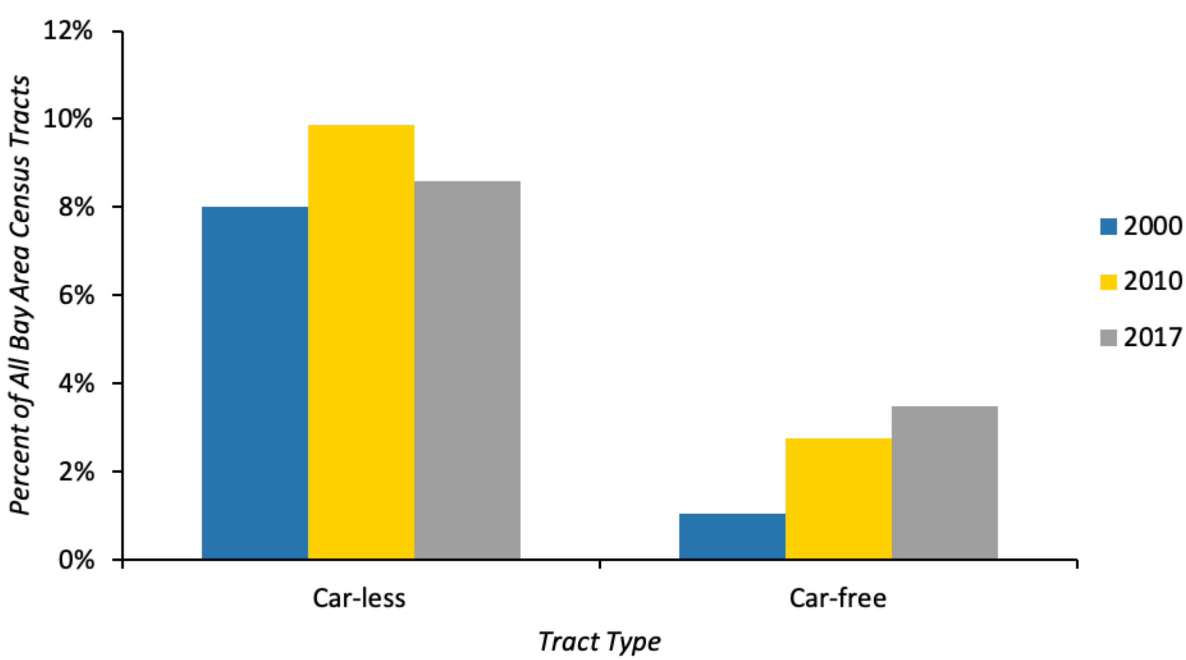
To examine these two types of zero-vehicle households, we draw on the recent study by Brown (2017) to create a simple (and admittedly imperfect) typology of census tracts: "car-less" neighborhoods, "car-free" neighborhoods, and other neighborhoods (See **Figure 8-6**). Car-less tracts host many poor people and many households with no vehicles. Together, this definition implies that many, though far from all, of residents of such areas likely do not own cars due to financial constraints. Car-free neighborhoods, in contrast, are home to few poor people but also many households with no vehicles—that is, households whose members are more likely to have chosen to forgo a car for reasons besides financial necessity. Our methodology is described in full in Appendix C, Section 4, Subsection 1.1.

Figure 8-6 shows the share of Bay Area census tracts that fall into these categories. car-less neighborhoods far outnumbered car-free neighborhoods in all years, but, of note, the share of car-free neighborhoods increased from 1.1 percent in 2000 to 3.5 percent in 2017.

To determine if transit-friendly neighborhoods (and their residents) are more likely car-free, as opposed to car-less, over time, we analyze changes in how car-free and car-less tracts overlap with the transit-friendly neighborhood categories established above (See **Figure 8-7**). In the Bay Area, the share of car-free tracts in every type of transit-friendly neighborhood increased from 2000 to 2017. Though car-less tracts continued to dominate transit-friendly neighborhoods, in some cases—especially Old Urban neighborhoods—the discrepancy between car-less and car-free tracts shrank.

To us, this suggests a few possibilities. First, since the Bay Area has not seen a major drop in zero-vehicle households overall, maybe the distinction between car-less and car-free masks different motivations and mobility options for people who do not own

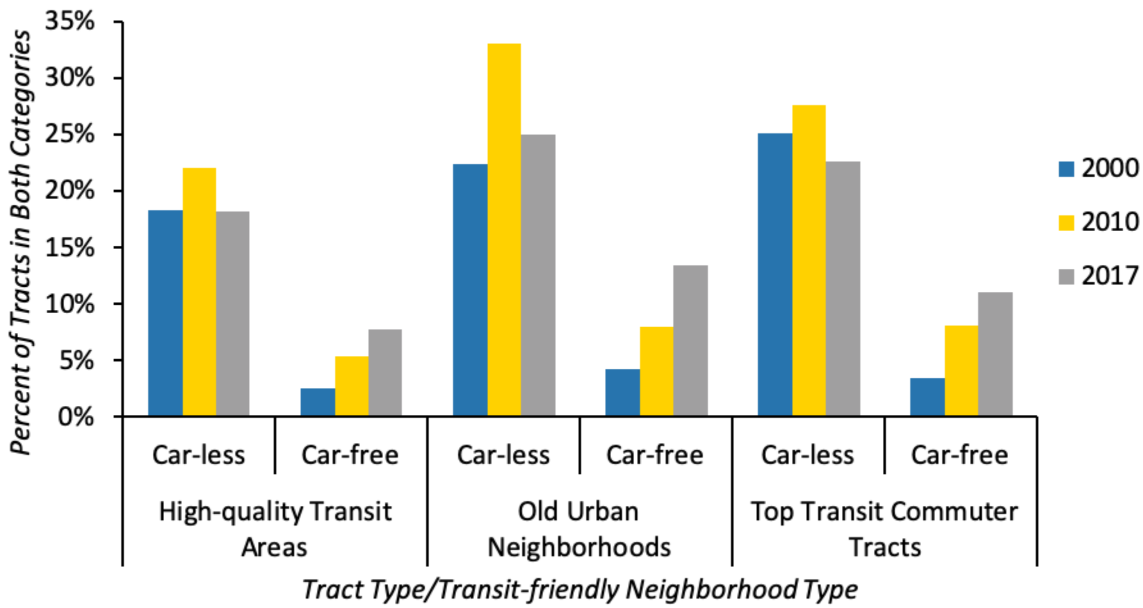
Figure 8-6. Share of Bay Area Census Tracts that Are Car-less and Car-free Neighborhoods



Data source: U.S. Census Bureau, 2019

vehicles. According to Brown's (2017) examination of the 2012 California House Travel Survey, car-free people took more trips than did the car-less, although they used transit at similar rates. This 2012 survey, however, occurred prior to the widespread use of ridehail and new mobility services like electric scooters, which may attract the car-free (or, for that matter, the car-less) at different rates. While the Bay Area's transit friendly neighborhoods still boast high number of zero-vehicle households, the changing motivations for eschewing vehicle ownership may affect transit use.

Figure 8-7. Percent of Transit-friendly Neighborhoods that Are Also Car-less and Car-free



Data source: MTC, 2018; Voulgaris et al., 2016; and U.S. Census Bureau, 2019

8.4. Models of Commuter Change

Of various socio-economic measures that predict propensity to use transit for commuting, many vary in concert. This makes it difficult to discern underlying relationships among these factors. For example, a variable like poverty can mask the effect of another variable of interest, such as automobile access, because the two are closely related. Thus, we estimated multivariate statistical models to simultaneously account for the many factors associated with changes in these neighborhoods over time. To help contextualize our results for the Bay Area, we also modeled data from Greater Los Angeles for comparison. Our full methodology and results are available in Appendix C, Section 4, Subsection 3.

The first set of models explains the number of transit commuters by neighborhood separately for each time period (2000, 2010, 2017) in terms of levels of poverty, zero-vehicle households, and foreign-born residents. While many of the predictors of transit change do not change dramatically over time, there are two exceptions. With respect to relative change over time, the share of people in the Bay Area living in poverty (controlling for other factors) is associated with a decrease in a census tract's transit commuters, and this relationship strengthened from 2000 to 2017. Meanwhile, in Greater Los Angeles, an increase in the share of foreign-born residents is associated with an increase in transit commuters, but this relationship weakened over time.

The second set of models explains the change in number of transit commuters by neighborhood from 2010 to 2017. In the Bay Area, the number of jobs accessible via transit in 2017 most determined the increase of transit commuters in a neighborhood. In Greater Los Angeles, the number of jobs accessible via transit in 2017 most determined a neighborhood's increase in transit commuters from 2010 to 2017, while its total number of transit commuters in 2010 most determined a decrease. This suggests that in the Bay Area, a neighborhood's level of access to jobs via transit remains an important determinant of transit commuting, and even growth, from 2010 to 2017.

8.5. Discussion and Conclusion

While we see some evidence of rising affluence in the Bay Area's most transit-friendly tracts, we do not find evidence that gentrification has displaced transit commuters. However, this analysis focused exclusively on transit commuting, which account for just over a third of all transit trips, and reflects a higher proportion of transit trips taken by wealthier transit riders.

We do not see evidence of displacement amid the rising affluence because the share of the region's poor housed in transit-friendly neighborhoods remained relatively steady from 2000 to 2017. Similarly, the shares of immigrants in transit-friendly tracts did not change much between those years either, though the shares of Latin-American-born immigrants (who tend to use transit more heavily) decreased while Asian-born immigrants increased.

Further, the proportion of zero-vehicle households in transit-friendly neighborhoods increased relative to the region as a whole. Our estimates of transit-friendly car-less neighborhoods far outnumber neighborhoods where by-choice car-free households predominate, although transit-friendly neighborhoods classified as car-free increased substantially (in percentage, if not absolute terms) between 2000 to 2017.

Among the factors analyzed in our statistical models, the best predictor of a change in the number of transit commuters between 2010 and 2017 was, intuitively, the number of jobs accessible within a 30-minute commute via transit in 2017. This suggests, unsurprisingly, that transit commuting grew most in transit-friendly neighborhoods where job access via transit was highest.

In California, the study of transit use and transit-friendly neighborhoods ridership inevitably leads to questions of housing affordability and regional economic change. Activists, policymakers, and researchers have all emphasized housing affordability as an enormous public policy issue, and the Bay Area boasts the highest housing costs of any large U.S. metropolitan area (Bureau of Economic Analysis, 2017). Gentrification and displacement of low-income minorities has garnered coverage in the media and prevalence in research, though the transportation effects are unclear. While we do not find large-scale evidence of displacement due to gentrification with respect to public transit commuting, some transit-friendly neighborhoods in the Bay Area are likely changing.

Part IIIB. Influences on Transit Use Trends in the Transportation System

In contrast to Part IIIA, Part IIIB looks at influences on transit use that are limited to the transportation system—things that affect the supply of transit and other transit options. Factors within the domain of transit operators include customer satisfaction, fare policies and evasion, and transit costs and subsidies. Competing mobility options we evaluate include trends in motor vehicle access, fuel prices, ridehail, and private employer shuttles. Finally, we examine the changing transportation policy environment in California, specifically (beginning in January 2015) the availability of driver licenses for undocumented people. Ultimately, while we lack the data to draw definitive conclusions, we surmise that ridehail service has likely had the largest negative effect on public transit use, though again we are not able to conclude this with any certainty. Most of these other factors analyzed are likely to have had only minor effects on transit use.

First, we examine factors largely or wholly within the control of transit managers, or public officials more broadly. We explore data on user perceptions of transit from customer satisfaction surveys on three of the region's largest operators. These surveys present mixed evidence on trends in customer satisfaction, which are not obviously related to trends in ridership. For example, BART's ridership satisfaction fell precipitously, yet it boasted the highest absolute growth in ridership of any transit agency in the region between 2013 and 2017 (FTA, 2019). We next present trends and transit fares and levels of fare evasion. When transit fares rise (as they have in the Bay Area), we should expect price sensitive riders to use transit less. However, from 2014 to 2017, agencies that increased fares collectively added riders, while agencies those that held the line on fare increases lost trips as a group. Trends of fare evasion, meanwhile, have a complex relationship with ridership but regardless cannot account for the scale of recent patronage losses.

The cost of providing transit service and subsidies across the region have both increased, leading to declining efficiency and effectiveness in transit service. But increasing costs do not explain declining transit patronage, as agencies have not (yet) cut service to balance their budgets in the face of rising costs—though this could change in the years ahead if transit system costs continue to outpace inflation.

Competing mobility options present a mixed picture. Although California has seen an uptick in vehicle access and driving, the Bay Area has seen only small increases in auto access. Additionally, the share of commutes via solo driving has actually decreased in the Bay Area; we thus conclude that increases in vehicle access and driving have not caused ridership declines. Similarly, we find no evidence of fuel prices pushing people on or off transit.

Next, we turn to travel options that have risen in popularity in the last decade. Lacking data from ridehail providers themselves, we use other methods to examine the effect of newer services like Uber and Lyft on travel behavior. As expected, we see large increases in livery "establishments" (which is the Census term used to describe independent contractor drivers for Lyft, Uber, taxis, and limousines) in the Bay Area after 2014, and especially in densely populated counties like San Francisco, San Mateo and Alameda. We also review studies of ridehail in the Bay Area and nationally and conclude that ridehail use is likely higher in the Bay Area than perhaps any other region in the U.S. In terms of Bay Area employee shuttle services, they are collectively quite large, increasing overall regional (*public and private*) transit ridership. Evidence suggests that these services replace more auto than public transit trips, and may encourage riders to live in more transit-friendly areas, like San Francisco.

Finally, we examine a significant change in state transportation policy that allows undocumented residents to secure driver's licenses. Since January 2015, Assembly Bill 60 allowed people who are unable to provide documentation of citizenship to apply for and receive drivers licenses from the California DMV; the evidence suggests that it leads to improvements in traffic safety (Lueders, Hainmueller, and Lawrence, 2017), and we find small associations between the implementation of AB 60 and increases in car commuting, increases solo driving to work, and decreases in transit commuting by undocumented workers.

9. Trends in Rider Satisfaction

9.1. Introduction

How travelers perceive and experience public transit varies across many dimensions and among individual travelers. Consider three travelers waiting at the same stop for a morning bus ride. The first is a regular commuter pleased by the short wait for his bus, as it will get him to his destination with time to stop for a coffee before heading to his downtown office. The second traveler, on her way to a job interview, arrives at the stop ten minutes earlier than the first passenger. She is frustrated by her 15-minute wait and uncertain that the bus will get to the interview on time. The third passenger is older than the first two and walks with a cane. She prefers not to ride during rush hour, but is on her way to a medical appointment. She worries about depending on strangers to give up their seats, and finds it increasingly difficult to stand on a moving vehicle.

So while the transit agency has provided the same bus, with the same operator, to carry three passengers from the same stop at the same time, their perceptions of the trip, and satisfaction with it, vary widely. Thus, operating data and associated performance measures alone tell us little about users' satisfaction with their service. To gather information about such perceptions, transit agencies regularly conduct surveys of their riders (and occasionally others to learn why they do not ride). These passenger surveys are an important indicator of the quality of transit service as perceived by riders. But because such surveys are not systematically implemented by Bay Area transit operators, detecting trends across transit agencies can be challenging; agencies take different approaches to surveying their passengers and do so at different frequencies. However, some comparison is possible, as we report below on the findings of passenger surveys of three of the largest transit systems in the region: BART, Muni, and VTA.

9.2. Passenger Satisfaction Trends

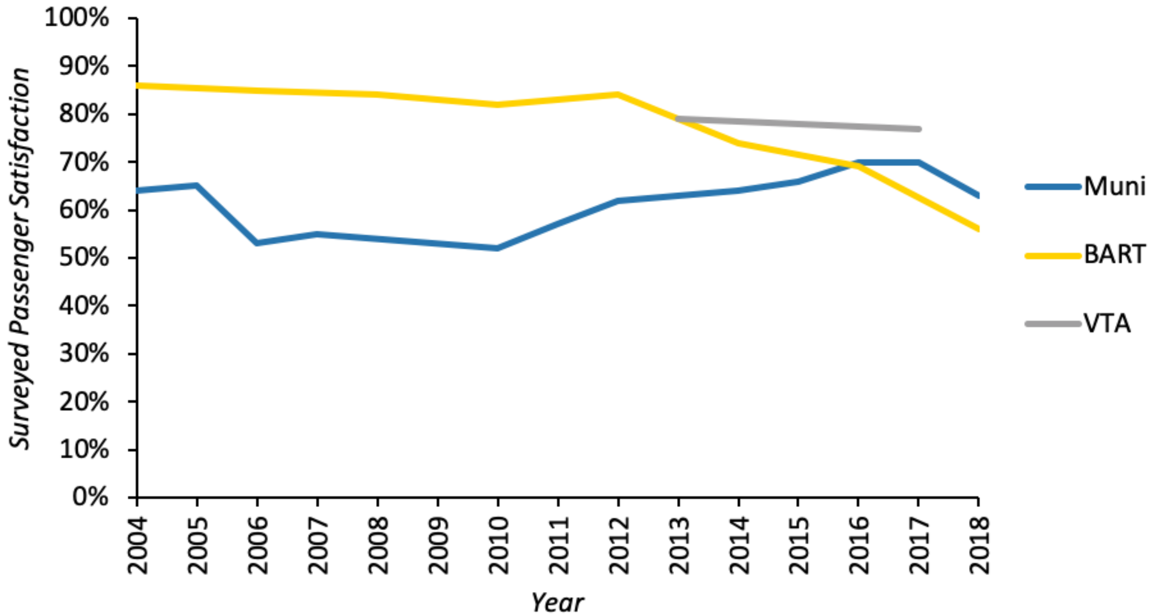
Overall, passenger satisfaction has varied over the past 15 years, but is now in decline on each of the three systems from which we have survey data (See **Figure 9-1**). Surveys identify service frequency and reliability, personal safety, system cleanliness, and crowding as key issues to riders, although concerns vary from agency to agency.

B ART riders expressed high levels of satisfaction with the service in 2004, but their satisfaction declined gradually from 2004 to 2012, and dramatically since then, when 84 percent of its passengers reported being satisfied with the service. By 2018, that figure fell to just over half (56%), a 33 percent decrease (BART and Corey, Canapary, and Galanis Research, 2019). But BART ridership mostly grew between 2012 and 2016, when passenger satisfaction levels were trending down most (perhaps explained in part by increased crowding due to the ridership surge, a commonly cited source of dissatisfaction in rider surveys).

Muni riders, by contrast, have been increasingly satisfied with their service, until 2017. Passenger satisfaction ratings on Muni gradually increased between 2010 and 2017, before declining in 2018. In 2017, Muni customer satisfaction was at 70 percent, an auspicious 35 percent increase from 2010. The 2018 survey, however, showed a 63 percent satisfaction rating, a ten percent decrease from the year before (Corey, Canapary, and Galanis Research, 2018).

VTA only has two recent years of passenger survey data, making trends more difficult to discern. Nevertheless, customer satisfaction has decreased slightly, from 79 percent in 2013 to 77 percent in 2017 (ETC Institute, Inc., 2017).

Figure 9-1. Passenger Satisfaction Ratings



Data source: BART and Corey, Canapary, and Galanis Research, 2019; Corey, Canapary, and Galanis Research, 2018; and ETC Institute, Inc., 2017

The relationship between passenger satisfaction and patronage is not a simple one. Safe, reliable, and affordable service can attract passengers, but if those added passengers increase crowding, reduce the odds of finding a seat, and add to boarding and alighting delays at stops and stations, passenger satisfaction can also decline because of increased ridership. So while poor service can drive away customers, resulting in lightly patronized buses and trains, oversubscribed service can discourage riding as well.

9.3. Key Concerns

Both BART and Muni's 2018 surveys identified issues that received low ratings and appeared to have large effects on overall satisfaction (BART and Corey, Canapary, and Galanis Research, 2019 and Corey, Canapary, and Galanis Research, 2018). Interestingly, these issues varied between the agencies, with BART's target issues mostly related to system cleanliness and personal safety, whereas Muni's low-rated but high-impact attributes centered on reliability/on-time performance and service frequency. On-time performance and train frequency were also correlated with overall satisfaction for BART riders, but passengers gave these attributes higher ratings. Crowding was a target issue for both agencies.

Of the aforementioned attributes, VTA's passengers gave service frequency and on-time performance the highest ratings and vehicle cleanliness the lowest (ETC Institute, Inc., 2017). All of these ratings were above 50 percent, however, and overall VTA's passengers rated their service higher than BART and Muni passengers did theirs.

Notably, many of BART's key issues are tied to factors outside of the agency's control, specifically the homelessness and drug/opioid addiction crises, which likely affect passengers' perceptions of personal security and system cleanliness. Muni's lower 2018 ratings in service reliability and frequency, meanwhile, probably reflect a summer with frequent service interruptions and a significant operator shortage (Fitzgerald Rodriguez, 2018).

9.4. The Waxing Role of Transportation Network Companies

The passenger surveys also show increased evidence of ridehail use. When asked what mode they would use were Muni not available, 44 percent of riders said they would take a ride hailing service in 2018, up from 34 percent in 2017 and 29 percent in 2016 (Corey, Canapary, and Galanis Research, 2018).

BART passengers, meanwhile, report increased use of ridehail service to reach BART stations, especially on weekends, among the times when BART ridership has fallen most steeply. Seven percent of BART weekend riders report taking ridehail to BART in 2018, an increase of six percentage points from 2014 (BART and Corey, Canapary, and Galanis Research, 2019).

9.5. Conclusion

Overall, passenger surveys at three of the largest Bay Area transit operators paint a varied picture of rider satisfaction over the past 15 years. Satisfaction on BART, which was relatively high in the 2000s and until very recently has been adding riders, has been sliding since 2012 (BART and Corey, Canapary, and Galanis Research, 2019). By contrast, rider satisfaction with Muni was much (>30 percentage points) lower in the 2000s, but climbed year-over-year in the 2010s through 2017, only to drop sharply in 2018 (Corey, Canapary, and Galanis Research, 2018). Finally, ridership satisfaction with VTA, with only two data points in 2013 and 2017, is the highest of the three operators, but down slightly (ETC Institute, Inc., 2017). But at all three agencies, ridership satisfaction is down coincident with the regional downturn in patronage since 2017.

While "quality of ride" concerns may be contributing to the ridership decline to some degree on some systems, we advise caution in overstating their influence. For one, satisfaction has fallen most sharply on BART, an operator with some of the Bay Area's most resilient ridership (See Chapter 4, Section 4 and Volume II, Chapter 3). And though BART ridership has fallen in the past two years, BART's customer satisfaction started falling during the district's 2012-2016 ridership boom. Indeed, a number of common rider concerns, like overcrowding and uncleanliness, are symptoms of ridership *gains* (at least at certain times of day), not losses. **Table 9-1** compares changes in rider satisfaction to changes in ridership across operators—showing only loose correlation between the two at best. On the whole, both are down recently, but the data do not support any stronger relationship than that. In fact, our statistical model of BART ridership in Volume II, Chapter 3, Section 4 could not establish an independent ridership effect of station cleanliness, police presence, and homeless counts on ridership.

Finally, the socio-demographics of survey respondents may be changing. As we note in Chapter 5, the population of transit users is changing, and as we note in Chapter 4 and Volume II, these riders are increasingly taking transit for commutes instead of other trip purposes. These more well-off commuters may have higher expectations than reflected in earlier survey pools. We lack evidence to test this hypothesis directly, but the possibility bears mentioning to temper the region's nonetheless concerning passenger satisfaction trends.

Table 9-1. Changes in Ridership versus Changes in Passenger Satisfaction

OPERATOR	CHANGE IN RIDERSHIP, 2012-2018	CHANGE IN SURVEYED SATISFACTION, 2012-2018*
Muni	+1%	+2%
BART	+9%	-33%
VTA	-14%	-3%

** VTA satisfaction: 2013-2017*

Data source: BART and Corey, Canapary, and Galanis Research, 2019; Corey, Canapary, and Galanis Research, 2018; ETC Institute, Inc., 2017; and FTA, 2019

10. Trends in Transit Fares and Fare Evasion

10.1. Overview

10.1.1. Introduction

While fares are the most outwardly noticeable cost of riding transit for most travelers, changes in fares do not appear to be causing changes in ridership, or even correlated with them. Adjusted for inflation, fares per boarding are rising at the same steady rate as the past decade, and fares per passenger-mile are flat, all as ridership fell, rose, and is falling again. The operators with increasing average fares are faring no worse than their counterparts with flat or decreasing fares. And from what limited evidence we could gather, we see no link between rates of fare evasion and ridership trends.

10.1.2. Background

When riders decide whether to take transit, they weigh many perceived costs, like the cost of time and the cost of discomfort. But of course, most riders pay an actual monetary cost: the fare. Despite fares' undoubted influence on transit use, this most visible cost of transit does not appear to be significantly influencing recent changes in Bay Area transit ridership.

Fare increases and decreases do not affect transit ridership the same way, nor do fare changes have the same effect on different groups of travelers. In general fare increases drive travelers away from transit, although low-income patrons tend to be less sensitive to fare increases since they often lack auto access and therefore must accept higher fares for lack of alternatives. Conversely, fare cuts are likely to attract more trips (and disproportionately among already frequent transit users) than a fare hike of the same size drives away (Litman, 2004).

More broadly, fare changes at off-peak times and for non-commute purposes have twice as large an effect on transit use as at peak times and for commuting, respectively, since peak period commuters may have fewer travel options. Fare changes in large cities have a greater effect than in small cities and suburbs (Litman, 2004; Cervero, 1990; and Schimek, 2015).

To investigate the potential relationship between fares and recent changes in ridership in the Bay Area, we examine the average fare paid per boarding and per passenger-mile traveled based on data for each agency as reported to the NTD. The average fare is not the "sticker price" fare listed on fareboxes, though. Most transit operators offer discounts for certain riders—students, seniors, youth, people with disabilities, etc.—or for purchasing trips in bulk, like daily, weekly, and monthly passes (Yoh, Taylor, and Gahbauer, 2016); thus, the fare paid per boarding and per mile traveled can vary substantially across riders and trips.

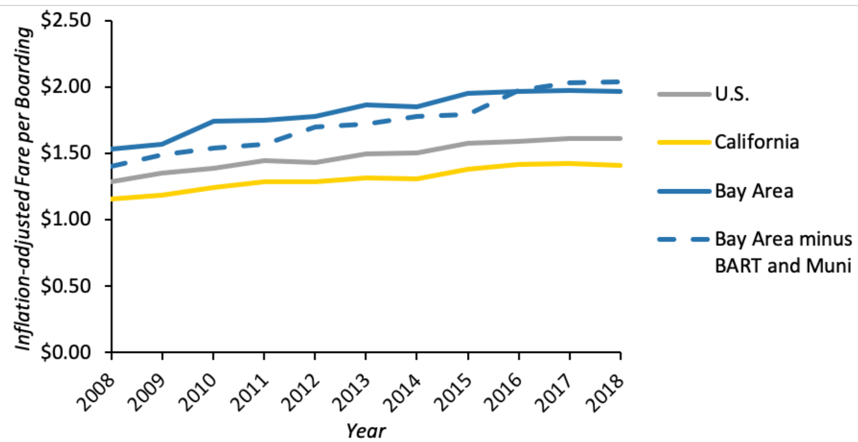
10.2. Fare Changes: Almost Certainly Not behind Regional Ridership Losses

Across the region, fares are up and ridership is down, but it does not appear that higher fares are causing ridership loses. The average inflation-adjusted fare per boarding has increased steadily, albeit modestly, for the past decade (See **Figure 10-1**) as ridership also increased. Fares did not rise any faster before ridership recently went down, nor when patronage fell during the Great Recession. In other words, ridership trends appear largely independent of steadily rising fares.

But not all boardings are created equal. One can board a TriDelta bus for a three-quarter mile ride from Meadowbrook Park to the Antioch BART station, and then take BART for a 46-mile ride to the San Francisco Civic Center. Each of these transit trips entails a boarding, but the trips they commence are vastly different. Thus, when measured per passenger-mile, the average inflation-adjusted fare has actually remained flat in the Bay Area over the past decade, other than a modest rise in 2010 after a 50¢ fare increase on Muni (See **Figure 10-2**) (SFMTA, 2009). This means that transit trips in the Bay Area are growing longer over time. While inflation-adjusted fares per passenger-mile have risen nationwide, they have remained near $0.28 or $0.29 per passenger-mile in the Bay Area since 2010. But by either fare metric, fares are not rising at a rate that would explain falling ridership since 2016.

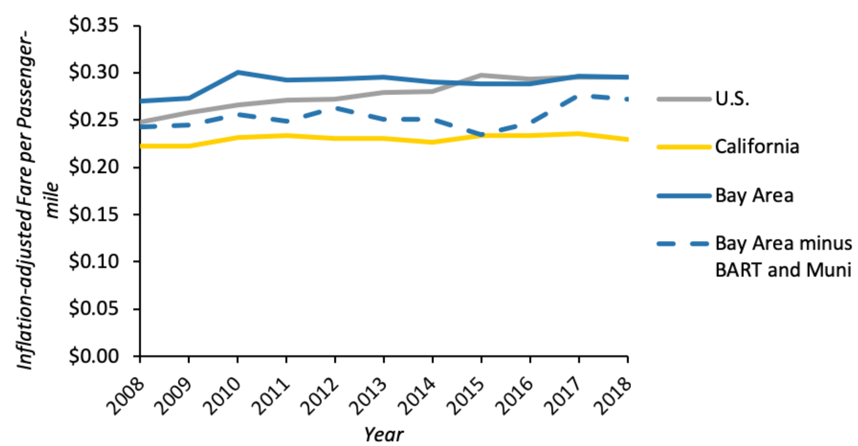
As described in Chapter 4 and Volume II, transit ridership has fallen more deeply at off-peak hours and in non-commute directions, while peak ridership has remained steady. While it is possible that gradually rising fares may have had more impact on off-peak trip taking, this does not explain the sudden drops in ridership many Bay Area agencies have recently experienced.

Figure 10-1. The Average Bay Area Fare per Boarding Is Higher than the U.S., but Its Rate of Increase Has Remained Steady for the Past Decade.



Data source: FTA, 2019 and Bureau of Labor Statistics, 2019

Figure 10-2. Average Fares per Passenger-mile in the Bay Area Have Remained Flat.

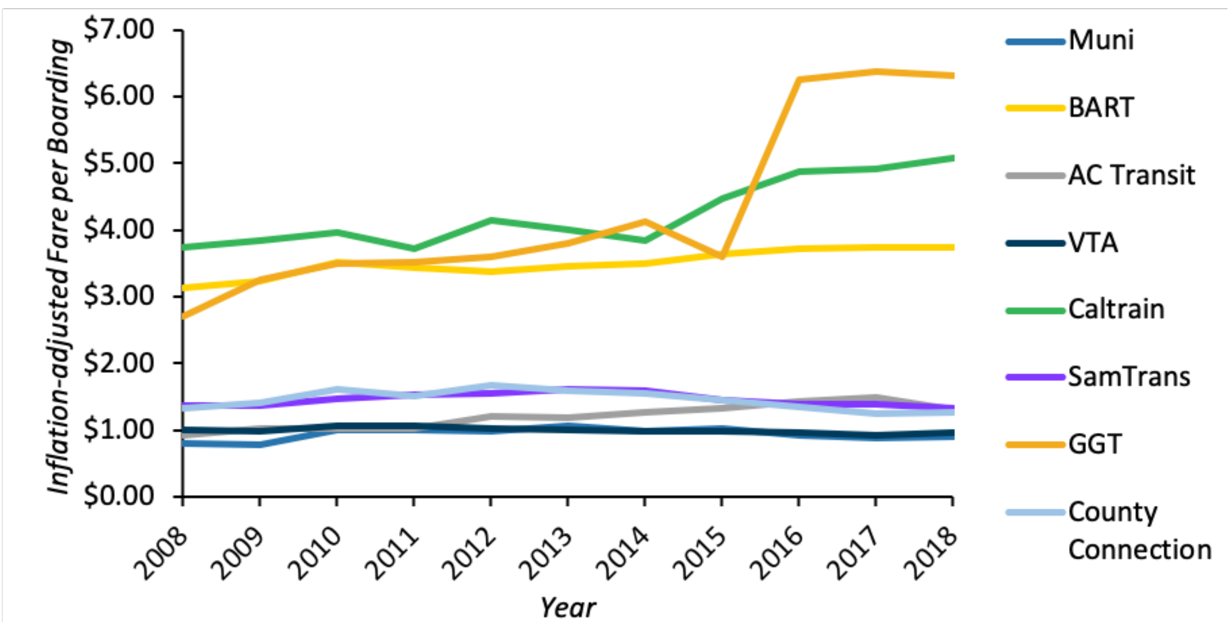


Data source: FTA, 2019 and Bureau of Labor Statistics, 2019

10.3. Fares Trends by Operator

Although the average regional fare has not changed much, fare changes for individual operators might be having an effect of local ridership (See **Figures 10-3** and **10-4**). Per boarding, BART, Caltrain, and GGT have substantially higher fares than the other top operators in the region. However, as noted above with the example for BART, these agencies have long routes spanning much of the entire region. As a result, BART and Caltrain's fares per passenger-mile are among the lowest, and Muni the highest. Since the start of the recent ridership decline, VTA fares have not changed substantively, and BART fares have increased at a similar rate to before. But Caltrain, AC Transit, and GGT have all seen a spike in fares per boarding and per passenger-mile. Conversely, SamTrans and County Connection have had their fares per boarding fall, and Muni and County Connection have seen their fares per passenger-mile drop. Failure to keep pace with inflation, rather than actual cuts in nominal fare product prices, is likely behind these drops.

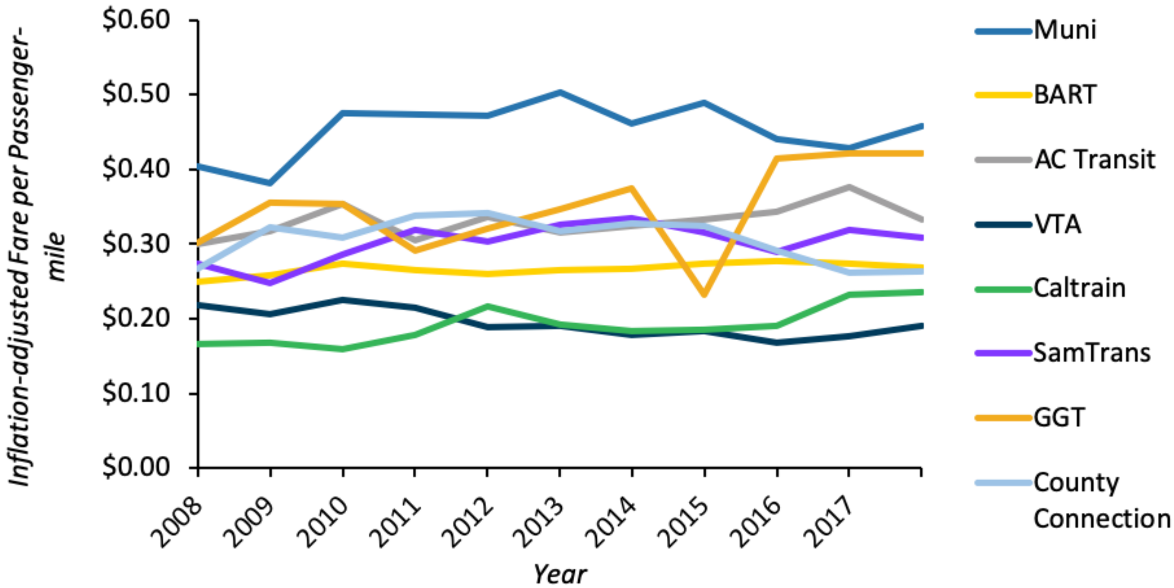
Figure 10-3. Fares per Boarding Vary by Operator but Are Not Correlated with Ridership Trends.



Data source: FTA, 2019 and Bureau of Labor Statistics, 2019

All told, however, trends in fares by operator do not correlate with changes in ridership. Between 2014 and 2017, the R^2 value (See Appendix A for definition) between change in boardings and change in average fare per boarding was only 0.07, among all Bay Area operators. The R^2 value between change in passenger-miles and change in average fare per passenger-mile was less than one-hundredth of one percent. In fact, summed together, the agencies with increasing fares per boarding gained trips from 2014 to 2017, and those with falling fares per boarding lost trips. The same is true for fares per passenger-mile and passenger-miles. We do not mean to suggest that raising fares somehow increases transit ridership, but rather that fares do not appear to be driving ridership changes.

Figure 10-4. Fares per Passenger-mile Vary by Operator but Are Not Correlated with Ridership Trends.



Data source: FTA, 2019 and Bureau of Labor Statistics, 2019

10.4. Fare Evasion

It is possible that ridership losses due to increasing fares could be masked by fare evasion. In other words, some riders may react to fare increases simply by not paying, while others might choose another mode. Indeed, fare evasion and underpayment have received much media attention in the Bay Area, particularly on BART (Cabanatuan, 2017). However, the relationship between fare evasion and ridership trends is not a simple one.

Two possible links between fare evasion and transit patronage may exist. First, fare evasion may correlate with other violations or behaviors that discomfort fellow riders, potentially depressing ridership. Riders have grown increasingly concerned with issues of safety, cleanliness, and other such issues that decrease rider satisfaction, as discussed in Chapter 9. However, we lack the data to test the connection between these consequences and fare evasion. But if there is a correlation, its effects on ridership are small, as explained below.

Second, if fare evasion rates are increasing, ridership may actually be higher on certain transit agencies than reported. Some operators, like Muni, count their ridership from automated passenger counters (APCs) on vehicles, which tally fare-payers and fare-evaders alike (J. Lee, 2019). Other operators, like BART, determine and report their ridership based on fare gate data (Monaghan, 2019). These systems do not capture people who ride but do not pay. If fare evasion is rising, BART's ridership could be higher than reported.

In either direction, the limited evidence available suggests that fare evasion has had an insubstantial effect on ridership. For all the ink spilled over BART's fare evasion problem, its estimated fare evasion rate, four to five percent, is around half of Muni's (Cabanatuan, 2017 and SFMTA, 2014b). Its estimated annual lost fare revenue in 2017—$15 to $25 million (Monaghan, 2019; BART, 2019b; and Cabanatuan, 2017)—represents only one to two percent of the agency's costs that year (and, of course, even a perfect fare enforcement system would not recoup all of this lost fare revenue, as some people would stop riding rather than pay). On Muni, fare evasion fell from 9.5 percent in 2009 to 7.9 percent in 2014, even though the agency implemented all-door boarding in 2012 (SFMTA, 2014b). While preliminary results from a 2019 survey show that fare evasion is back on the rise (J. Lee, 2019), the problem is still not at a scale to plausibly explain ridership changes. The benefits and tradeoffs of increased fare enforcement for agency budgets, rider satisfaction, and equity goals are multifaceted and beyond the scope of this report, but transit patronage trends are largely unrelated.

10.5. Conclusion

While changes in fares and fare evasion appear unrelated to recent ridership trends, losses in revenues, from fares and otherwise, may reduce agencies' overall ability to provide service in a high-cost region like the Bay Area (See Chapter 11). On the other hand, transit in America often serves as a social safety net for low-income travelers (Taylor and Morris, 2015), and high fares and heightened enforcement constrict that safety net. How agencies balance those two priorities is not the subject of this report. However, we can rule out fare-related factors as a significant cause of the recent ridership downturn.

11. Transit Costs and Subsidies

11.1. Introduction

In this chapter, we discuss changes in agency finances both as a potential cause of the recent ridership decline and a potential consequence thereof. To explore these facets of the ridership decline, we discuss two key financial metrics: cost-efficiency and cost-effectiveness. A system operates efficiently when inputs like spending translate into high levels of outputs supplied to the public, like hours of service. A system operates effectively when those inputs and outputs in turn lead to high levels of transit consumption—i.e., high ridership.

The relationship between transit expenses and transit ridership is a two-way street (or, in this case, a two-way route). An operator that spends its funds effectively will increase its ridership, and a system with high ridership may take in more fare and advertising revenues and have better effectiveness metrics. On the other hand, if transit expenditures fail to increase ridership (or fail to produce enough additional revenue to cover added costs) it may lead to financial strains that could affect future service.

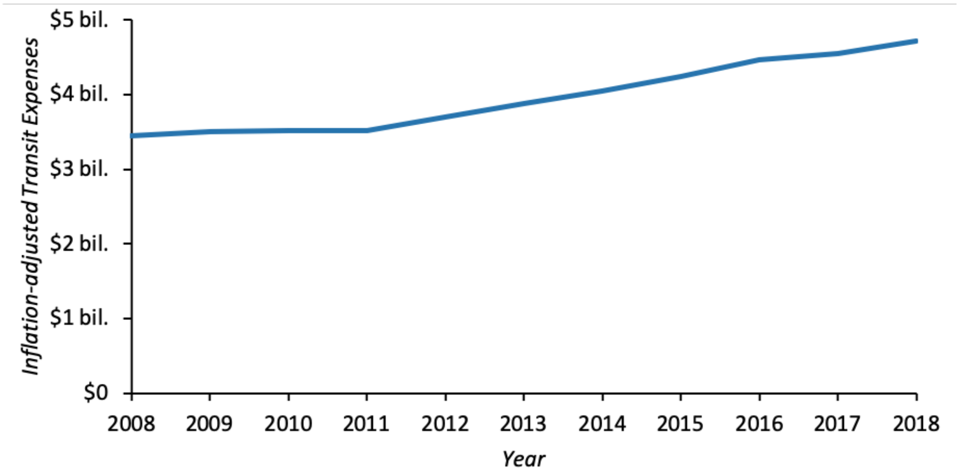
Given these potential relationships between transit expenditures and use, we find first that the Bay Area's investment is increasing; second, that the cost-efficiency of transit service is declining; and third, that this declining cost-efficiency is not responsible for losses in ridership. Nonetheless, recent ridership declines are beginning to negatively affect agency revenues and subsidies, though this varies by operator and in many cases only slightly. Some operators have shown improvement in financial performance metrics by following strategic plans under the MTC's Transit Sustainability Project, though the Transit Sustainability Project uses the height of the Great Recession as their baseline for comparison (Pierlott and Associates, 2018 and MTC, 2019d).

11.2. Investment and Inefficiency: Not Causes of the Ridership Decline

Bay Area operators are spending more on transit than ever before, even adjusting for inflation, but are becoming less cost-efficient at providing service. On the surface, the fact that "spending on transit is up" may hearten advocates of greater investment in public transportation. As **Figure 11-1** shows, the sum of Bay Area operators' annual costs (combining operating expenses and a rolling average of capital expenses, as defined in Appendix A) has risen every year since 2011. But this spending is unevenly distributed. **Figure 11-2** breaks down expenses by mode, revealing that post-Great-Recession, investment in rail has grown faster than investment in buses (though not as starkly as in, say, Greater Los Angeles).

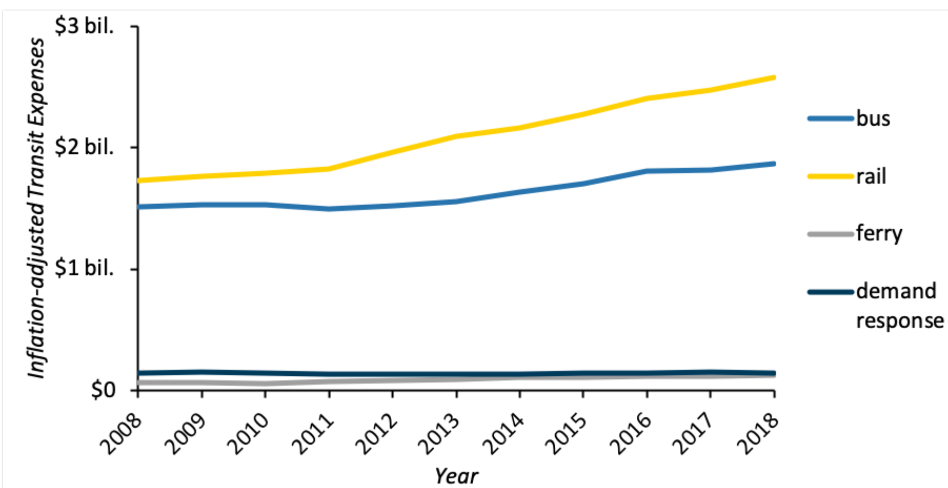
Beyond the difference in overall modal expenditures, this additional transit spending is delivering service less cost-efficiently, especially for rail. Except for a slight dip in 2017, the average cost per hour of vehicle revenue service has increased annually for the past decade (See **Figure 11-3**). In 2008, a vehicle revenue hour in the Bay Area already cost $271, $75 above the national average, but by 2018, the cost rose to $348, fully $123 above the national average. While hours of revenue service have risen in the region since the end of the Great Recession (See Chapter 3, Section 3), spending more on existing levels of service accounts for much of the increase in regional transit funding. Many reasons explain the Bay Area's rising and higher-than-average costs: land, equipment, and labor expenses all likely contribute. However, while the cost of a vehicle hour of bus service has stayed nearly flat the past decade, growth in spending on rail accounts for most of the average per-vehicle-hour cost increases (See **Figure 11-4**).

Figure 11-1. Bay Area Transit Expenses



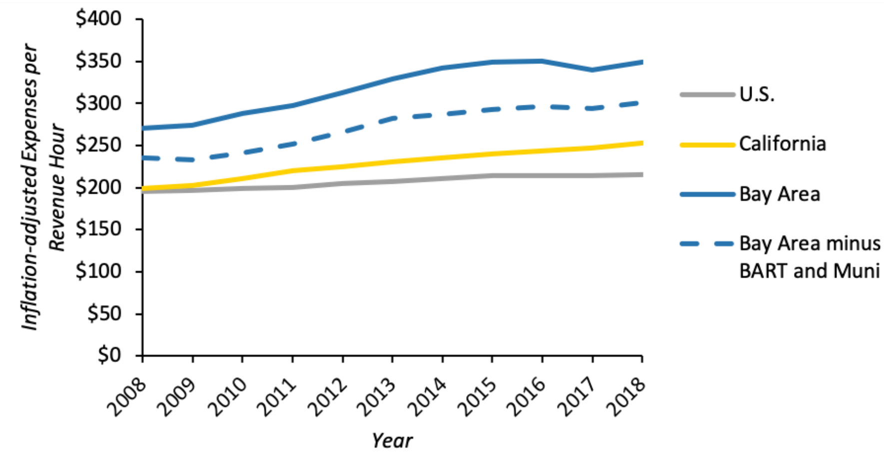
Data source: FTA, 2019 and Bureau of Labor Statistics, 2019

Figure 11-2. Bay Area Transit Expenses by Mode



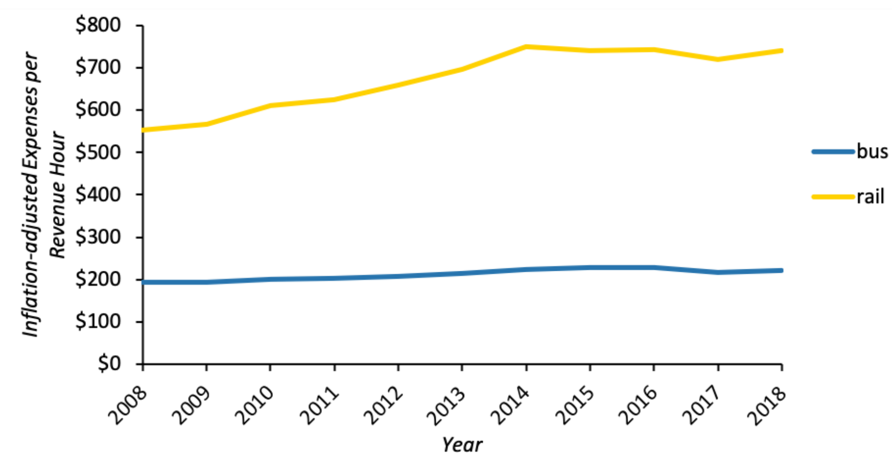
Data source: FTA, 2019 and Bureau of Labor Statistics, 2019

Figure 11-3. Cost-efficiency



Data source: FTA, 2019 and Bureau of Labor Statistics, 2019

Figure 11-4. Bay Area Cost-efficiency by Mode



Data source: FTA, 2019 and Bureau of Labor Statistics, 2019

While such cost-inefficiencies present a fiscal sustainability challenge for Bay Area operators, neither declining cost-efficiency nor total spending patterns explain the recent ridership downturn. The supply of transit service is growing in the region, even if it is increasingly costly. Cost-efficiency problems have not (yet) set off a vicious cycle of service cuts and ridership losses, known as the reverse Mohring effect (Mohring, 1972), as has happened elsewhere.

Meanwhile, the fact that transit spending has continued to increase suggests that overall investment levels are not behind recent ridership changes. If they were, we would expect to see cuts in investment, but that is not the case. As total service has increased due to funding increases, rather than decreased due to cuts, we can conclude that changes in transit spending have not caused ridership losses. While the steady rise in total transit investment may be one reason that regional ridership recovered after the Great Recession, it has not contributed to today's patronage declines. Still, increasingly inefficient operations may eventually begin to tax agency resources, and this could result in service cutbacks which would adversely affect future ridership.

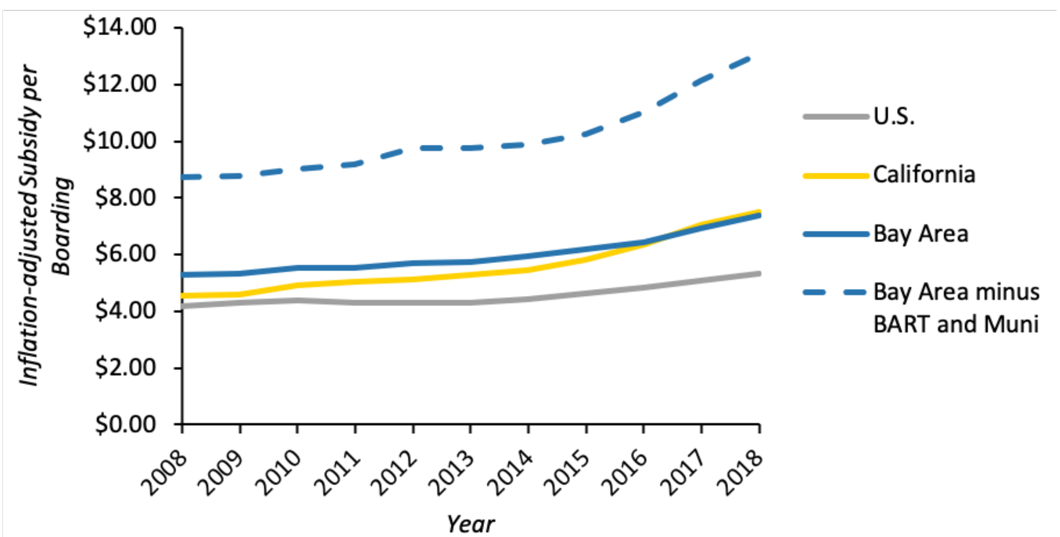
11.3. Financial Consequences of Falling Ridership

But if spending and service cuts are not behind the recent ridership decline, patronage losses are nonetheless lessening operators' revenues. Total regional fare revenues fell three percent from 2016 to 2017 and two percent from 2017 to 2018 (FTA, 2019)—modest decreases, but the first annual drops since 2003 (For more on fares, see Chapter 10.). Likewise, the ridership decline in the face of rising service means transit service has become less effective. Though investment is rising, boardings are falling faster; by definition, this has worsened the region's transit cost-effectiveness, though only gradually. In 2017 and 2018, both average subsidy per boarding (See **Figure 11-5**) and average subsidy per passenger-mile climbed (See **Figure 11-6**).

Average subsidies per rail boarding are higher than for the average bus boarding,[12] but the recent ridership decline appears to have affected both modes about equally. Per-boarding subsidies began to rise as each mode's ridership started to fall (See **Figure 11-7**).

However, some Bay Area transit agencies have performed better than others. As **Figures 11-5** and **11-6** show, when we exclude Muni and BART from the calculations, the rest of the region has much higher per-boarding and per-passenger-mile subsidies and decidedly sharper recent increases. Indeed, BART was the only agency to meet all three of the MTC's Transit Sustainability Project cost performance metrics in Fiscal Year 2017 (Pierlott and Associates, 2018). On both a per-boarding and per-passenger-mile basis,

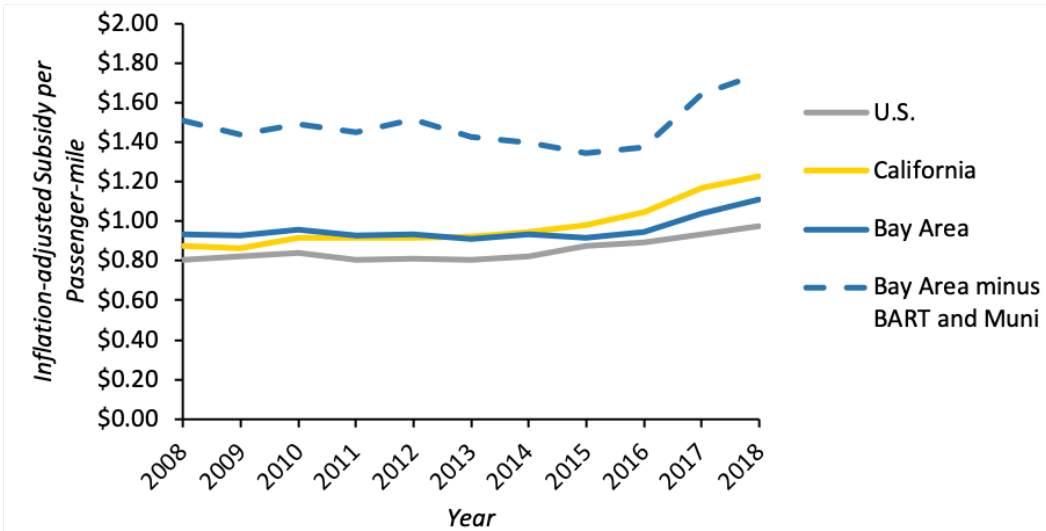
Figure 11-5. Subsidies per Boarding



Data source: FTA, 2019 and Bureau of Labor Statistics, 2019

12. The higher rail costs are largely due to the higher annualized capital costs per boarding.

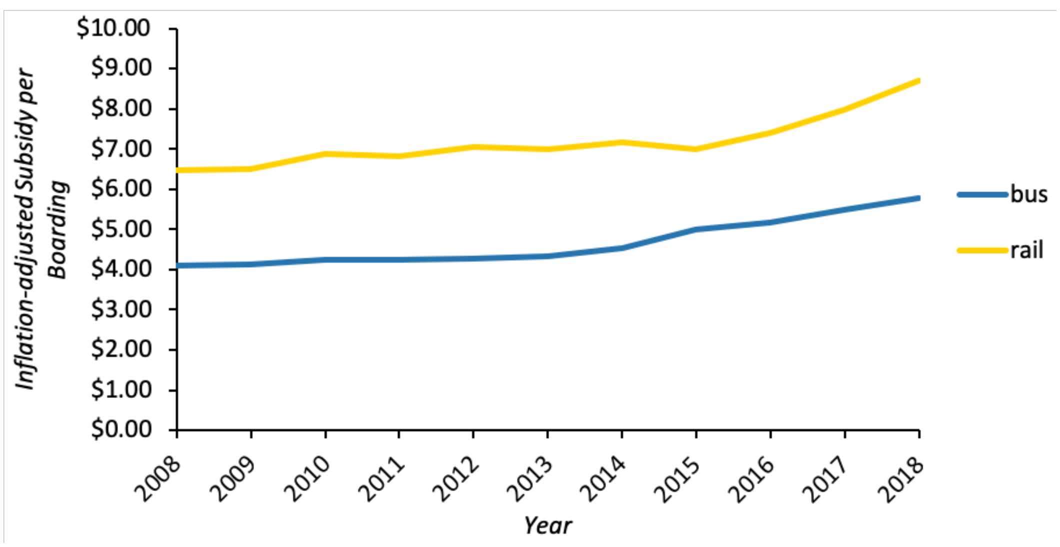
Figure 11-6. Subsidies per Passenger-mile



Data source: FTA, 2019 and Bureau of Labor Statistics, 2019

VTA has the highest subsidies of the region's eight largest operators, with a spike in per boarding and per passenger-mile subsidies in 2017 (See **Figure 11-8** and **11-9**). Lower-ridership agencies like SamTrans and County Connection also have high ridership

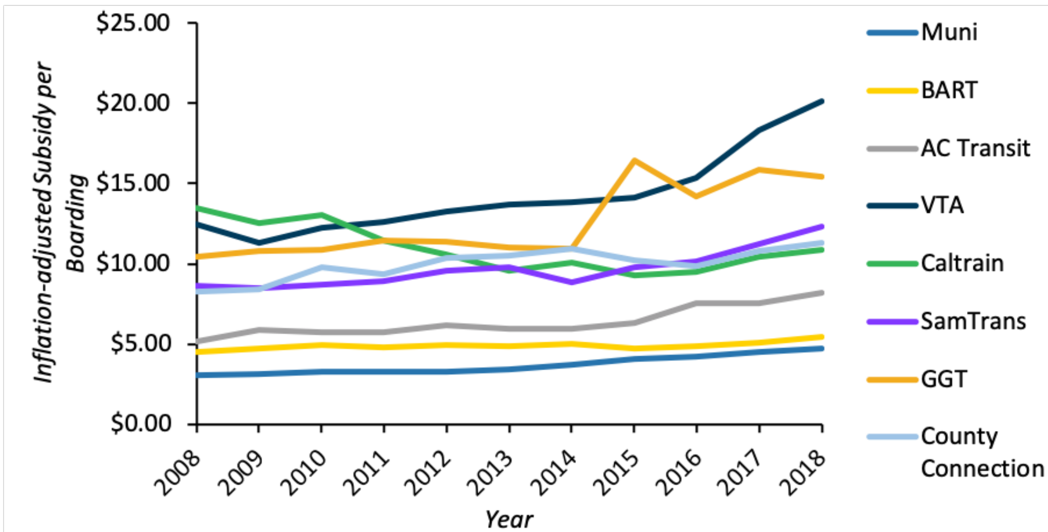
Figure 11-7. Bay Area Subsidies per Boarding by Mode



Data source: FTA, 2019 and Bureau of Labor Statistics, 2019

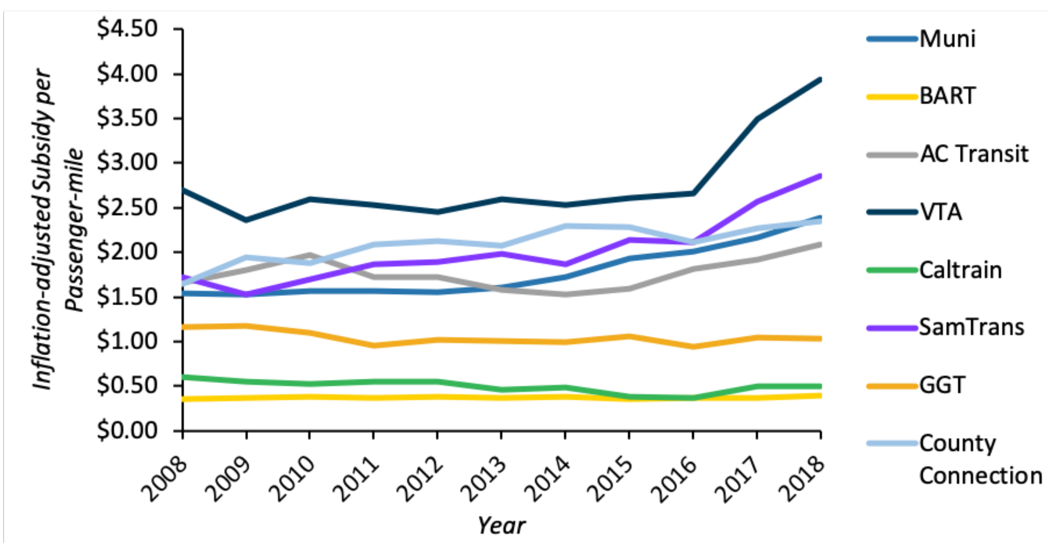
subsidies, but without the clear recent uptick. Meanwhile, Caltrain is the region's only operator with unambiguously falling per boarding and per passenger-mile subsidies over the past decade. Even as regional ridership falters, Caltrain is growing its ridership and providing service more effectively, with spending relatively constant but boardings on the rise. Employment growth in the region's job centers in San Francisco and Silicon Valley is spurring patronage on systems like Caltrain (See Chapter 4 and Volume II), which keeps costs per boarding down.

Figure 11-8. Bay Area Subsidies per Boarding by Operator



Data source: FTA, 2019 and Bureau of Labor Statistics, 2019

Figure 11-9. Bay Area Subsidies per Passenger-mile by Operator



Data source: FTA, 2019 and Bureau of Labor Statistics, 2019

In this vein, by adopting strategic improvement plans, Caltrain, BART, AC Transit, and SamTrans each met at least one of the MTC's Transit Sustainability Project cost performance metrics in Fiscal Year 2017, and every large operator has met at least one metric in at least two years since the start of the Project (Pierlott and Associates, 2018 and MTC, 2019d). Without minimizing these successes, we reach our assessment of agency performance for a few reasons: 1) the Transit Sustainability Project uses the height of the Great Recession as its baseline year of comparison, 2) it includes only operating costs, while we add in the region's large capital investments, and 3) it processes and analyzes operators' financial data in far more detail than our admittedly high-level analysis.

11.4. Conclusion

While declining efficiency and effectiveness in Bay Area transit service should cause concern, neither spending cuts nor rising costs appear to be behind recent patronage losses (to date). So far, the Bay Area appears to have avoided the so-called transit "death spiral" of falling revenues, service cuts, and ridership losses. More concerning is the high cost of accommodating increased demand for peak service, especially on rail systems. As detailed in Chapter 4 and Volume II, many Bay Area operators have seen significant off-peak patronage losses, while ridership at peak times, in peak directions, and in central areas is steady or even growing. But peak service is usually more expensive to provide (Taylor, Garrett, and Iseki, 2000), since transit agencies must build and maintain routes, stops/stations, fleets, and yards that may sit idle the rest of the day. Agencies must also hire, pay, and schedule additional vehicle operators and expose riders to the discomfort of overcrowding. We discuss this and other consequences of the Bay Area's peaking problem further in the conclusion (Chapter 17).

12. Trends in Motor Vehicle Access and Use

12.1. Introduction

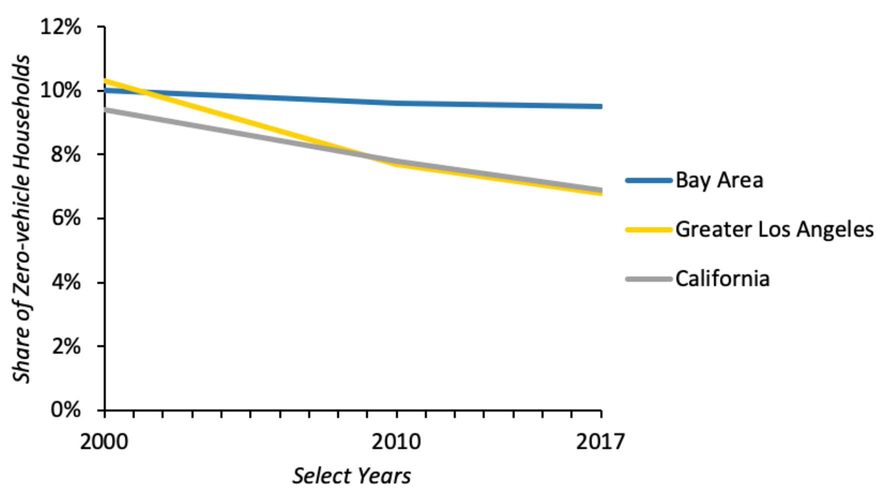
Transit ridership is often tied to lack of vehicle access, with zero-vehicle households making approximately 46 percent of all transit trips in the United States (FHWA, 2017). Data from the microdata samples of the U.S. Census and the American Community Survey—from which the rest of this chapter draw—show that in keeping with national trends, vehicle access in California increased between 2000 and 2017 (Ruggles et al., 2019). Trends vary across regions, however, and the data show that changes in the Bay Area are less dramatic than elsewhere in the state. In the Bay Area, the number of zero-vehicle households declined slightly and solo driving for the commute also decreased, indicating that increasing vehicle access is not a major culprit in falling transit ridership.

12.2. Zero-vehicle Households and Vehicles per Capita

Figure 12-1 tracks changes in the percentage of zero-vehicle households in California, the Bay Area Region, and Greater Los Angeles. Between 2000 and 2017, the number of zero-vehicle households dropped by 27 percent in California, while vehicles per capita increased 6 percent. Most of the vehicle growth took place between 2000 and 2010, with California adding nearly 3 million vehicles in that decade and another 1.4 million vehicles between 2010 and 2017.

In contrast, the Bay Area has a greater proportion of zero-vehicle households, and vehicle ownership numbers grew at a much slower pace. Between 2000 and 2017, zero-vehicle households declined by only 5 percent and the Bay Area added only 636,000 new automobiles, despite a population increase of 845,000. Over this same time period, Greater Los Angeles saw a dramatic 35 percent decrease in zero-vehicle households, from 10.3 percent to 6.8 percent, and a large increase in vehicle ownership, adding 2.1 million vehicles and 2.5 million people. The number of vehicles per capita in the Los Angeles Area jumped from 0.56 in 2000 to 0.60 in 2017.

Figure 12-1. Share of Zero-vehicle Households in the Bay Area, Greater Los Angeles, and California

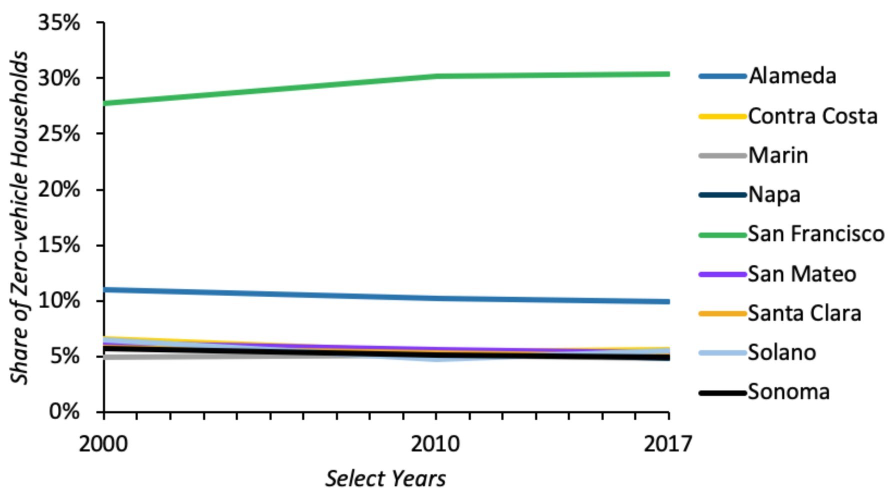


Data source: Ruggles et al., 2019

As a wealthier region, the Bay Area boasts more vehicles per capita than the Los Angeles Area, but the rate of growth has been much slower. In other words, while increased vehicle access was a major factor in declining ridership for Greater Los Angeles, the same does not appear true for the Bay Area.

Figure 12-2 shows that, among the Bay Area counties, San Francisco has by far the largest proportion of zero-vehicle households, followed by Alameda, and then the remaining seven counties. In San Francisco, 30 percent of all households lacked a vehicle in 2017, a slight increase from 28 percent of households in 2000. In Alameda County, meanwhile, ten percent of households did not own a car in 2017, down from 11 percent in 2000. Between 2000 and 2017, all other Bay Area counties saw slight declines in zero-vehicle households, but none greater than one percentage point.

Figure 12-2. Share of Zero-Vehicle Households in the Bay Area



Data source: Ruggles et al., 2019

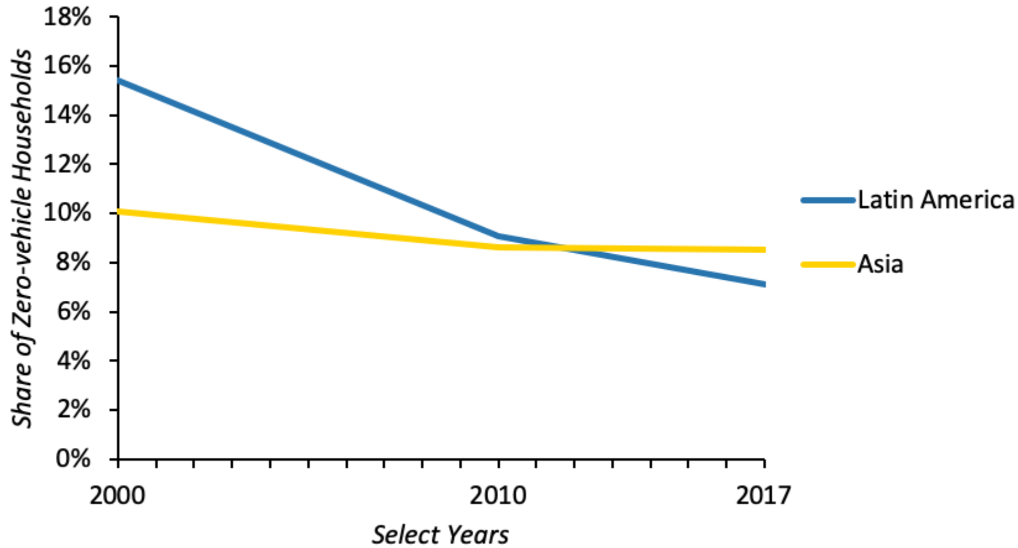
12.3. Immigrants and Zero-vehicle Households

In keeping with longstanding trends, immigrants today are more likely than native-born households to live in zero-vehicle households and take transit. Car ownership among California immigrant households, however, has been increasing, and the share of zero-vehicle immigrant households dropped 38 percent between 2000 and 2017. As **Figure 12-3** shows, this decrease was dramatic among immigrants born in Latin America. In 2000, 15.4 percent of California immigrant-headed households from Latin America lacked a vehicle, but by 2017 that share had declined to only 7.1 percent, a 54 percent drop. In the Bay Area, the decline was 55 percent, leaving just 6.8 percent of Latin American immigrant households with no vehicles by 2017.

Immigrants from Asian countries, however, only experienced a 16 percent drop in the share of zero-vehicle households during this time, less than the decrease among the overall population. The decrease in the Bay Area was also 16 percent, such that by 2017 10.5 percent of Asian immigrant households lacked cars.

These trends are fairly consistent across the state, with a large decrease in zero-vehicle immigrant households from Latin America between 2000 and 2010 and then a smaller decrease between 2010 and 2017. Hispanic immigrants are more likely to use transit, so any decline in the number of zero-vehicle households among this group may be more significant than losses among other groups. Since the Bay Area has a higher proportion of Asian immigrants, rising auto ownership may have a smaller impact on the region than other parts of California.

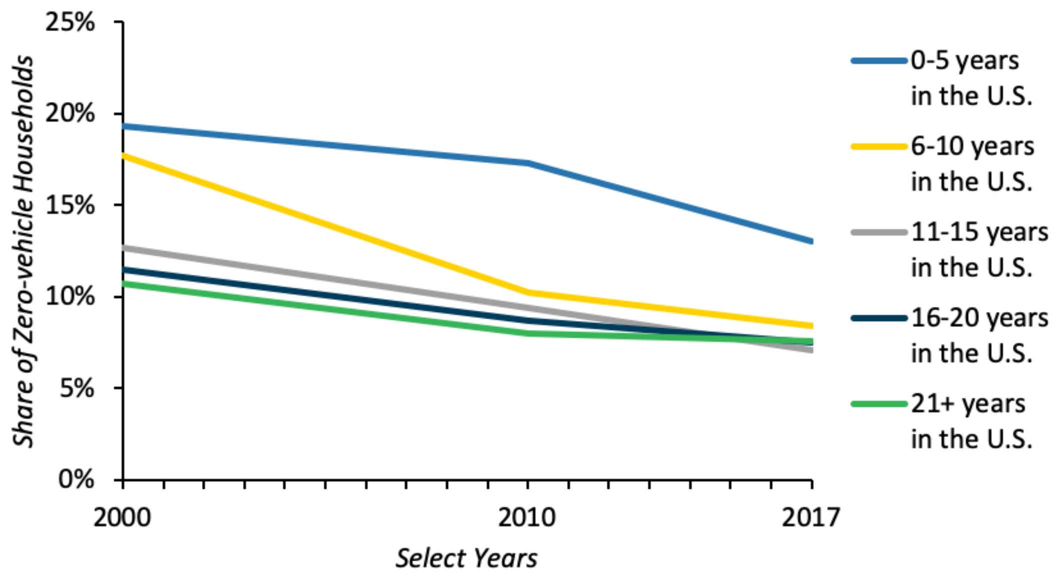
Figure 12-3. Share of Zero-Vehicle Immigrant Households in California from Latin America and Asia



Data source: Ruggles et al., 2019

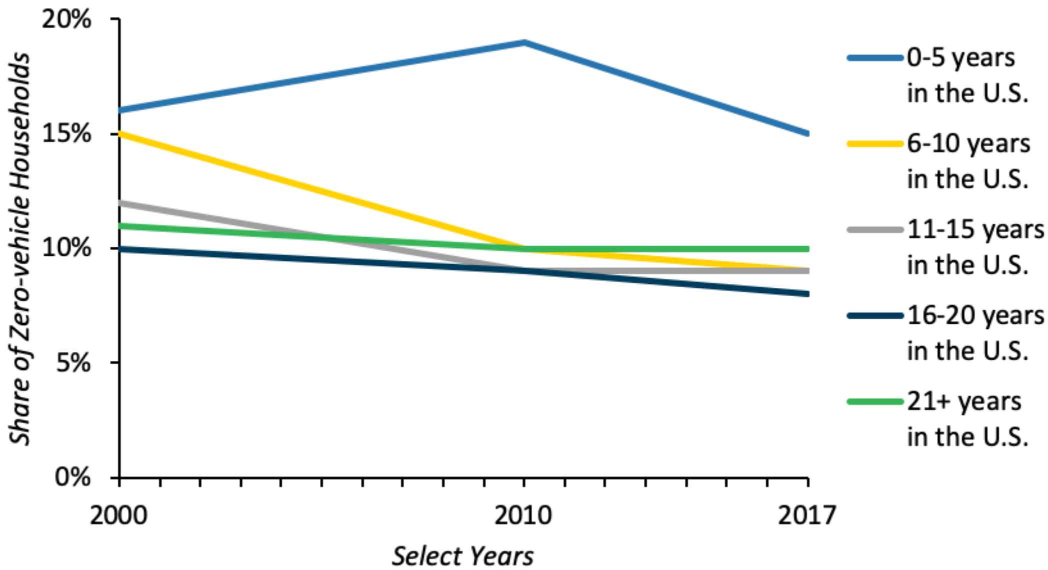
Another notable trend is the higher rate of vehicle ownership among recently arrived immigrants (See **Figure 12-4**). While those who have immigrated in the past five years are still more likely to live in zero-vehicle households, the share of zero-vehicle households among recent arrivals is dropping. In 2000, nearly 20 percent of immigrants in California who had been in the United States for five years or less lived in zero-vehicle households, a share that only dropped by eight percent for those who had arrived between six and ten years prior. By 2017, only 13 percent of those who had arrived within the last five years lived in zero-vehicle households, and the share dropped 35 percent for those who immigrated between six and ten years before. In other words, recent immigrants are more likely to own cars today and are more likely to purchase them soon after arrival.

Figure 12-4. Share of Zero-Vehicle Households among Immigrants in California by Years in the United States



Data source: Ruggles et al., 2019

Figure 12-5. Share of Zero-Vehicle Households among Immigrants in the Bay Area by Years in the United States



Data source: Ruggles et al., 2019

In the Bay Area, assimilation to automobile ownership is less dramatic than elsewhere in the state, but still notable (See **Figure 12-5**). The increase in ownership is especially pronounced for those who have lived in the United States between six and ten years; among this group there were 40 percent fewer zero-vehicle households in 2017 than in 2000.

12.4. Single-occupancy Vehicle Commuting

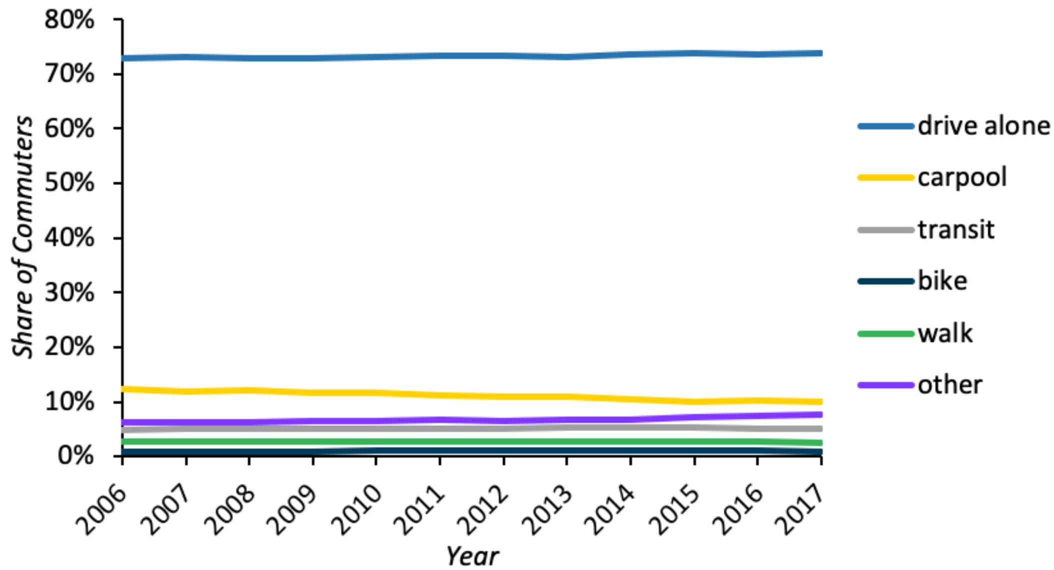
The microdata of the U.S. Census and the American Community Survey include data on commute mode (Ruggles et al., 2019). We thus evaluate the share of commutes taken via transit over time. Most commute trips take place during peak travel periods (even though a growing number of workers travel during off-peak hours). Therefore, if transit mode share for the commute has not declined, this suggests that declining transit ridership results from the loss of non-commute, likely non-peak-period, trips.

Figure 12-6 shows that across California, the share of workers driving alone for their commute has increased by one percentage point since 2006, while carpooling has declined slightly. Notably, transit use for commuting remains steady at a mode share of five percent.

In the Bay Area, solo driving for the commute actually decreased six percent between 2006 and 2017, and transit use increased 25 percent (See **Figure 12-7**). Since then, as overall transit use in the region declined, transit use for commuting held steady.

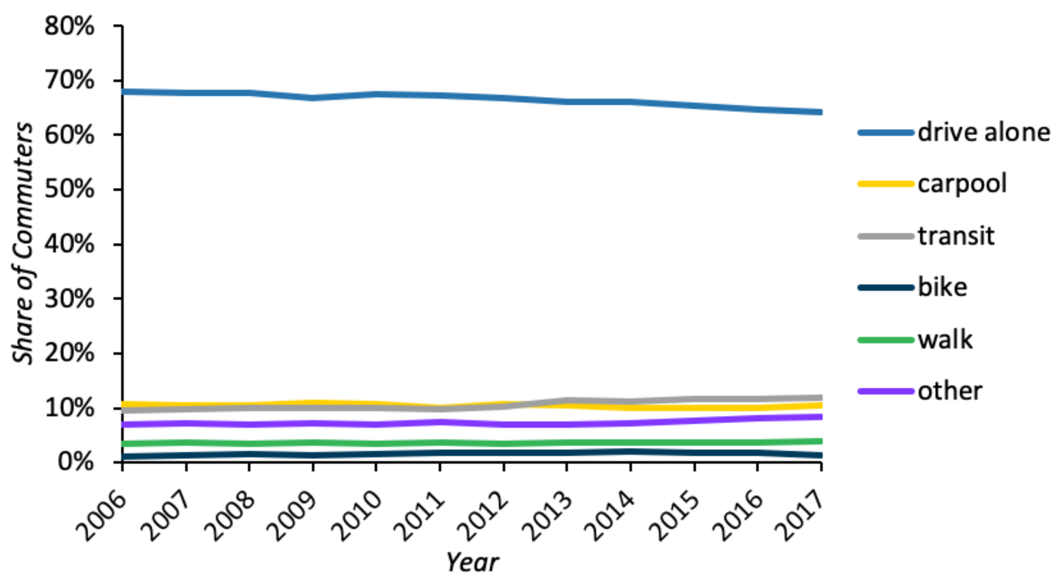
Ultimately, neither the minor increases in vehicle access nor expanded automobile commuting explain declining transit ridership. While the rest of the state saw a large increase in vehicle access between 2000 and 2017, the Bay Area has only seen a slight uptick, and solo driving for the commute actually declined.

Figure 12-6. Commute Mode in California, 2006 to 2017



Data source: Ruggles et al., 2019

Figure 12-7. Commute Mode in the Bay Area, 2006 to 2017



Data source: Ruggles et al., 2019

13. Trends in Fuel Prices

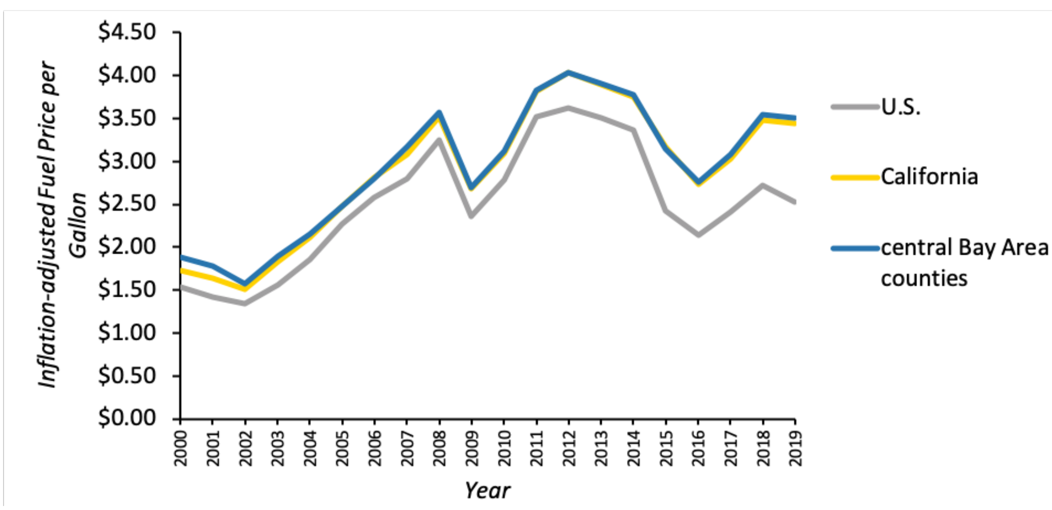
In this section, we analyze the relationship fluctuating fuel prices may have with transit use. When the price of fuel increases, so does the cost of driving; while taking transit is almost always less costly than driving, very high gasoline prices could cause people to take transit to save on travel costs. We test for such a relationship, and find none between the relative cost of transit to the price of fuel with the number of transit trips taken by Bay Area residents. In examining declining transit ridership, then, lower fuel prices do not appear to be the culprit in the Bay Area.

Much of the cost of owning and operating a motor vehicle is unrelated or at best loosely related to driving. Cars and trucks are expensive to purchase before a mile is ever driven. Insurance and maintenance costs are related to miles driven, but indirectly. The auto insurance bill is typically presented annually, while repair costs can seemingly strike at random. By contrast, filling up one's fuel tank every few days or weeks is much more visibly related to driving than other costs. Further, there is no other commodity where daily price fluctuations are posted on large signs at major urban and rural intersections for all to see.

As a result, fuel prices may influence transit ridership because they so visibly affect the cost of driving. When gasoline prices increase, driving becomes more expensive, and transit may become more attractive by comparison. However, most people do not use private vehicles and public transit interchangeably; not only do many car owners never take transit, but many regular transit users do not own cars (Pucher and Renne, 2003). Fuel prices could influence rates of car ownership, if a prospective car owner decides that high or rising fuel prices make auto ownership and use too expensive.

Fuel prices are volatile, which affects the larger economy in ways indirectly related to transportation behavior (Sawhill, 2012). Fuel prices may also have varying effects on individual transit modes. For instance, light rail ridership appears more sensitive to fuel price changes than heavy rail and buses, presumably because more "choice" riders who own automobiles ride light rail (Currie and

Figure 13-1. Average Price of Gasoline per Gallon, in 2018 Dollars

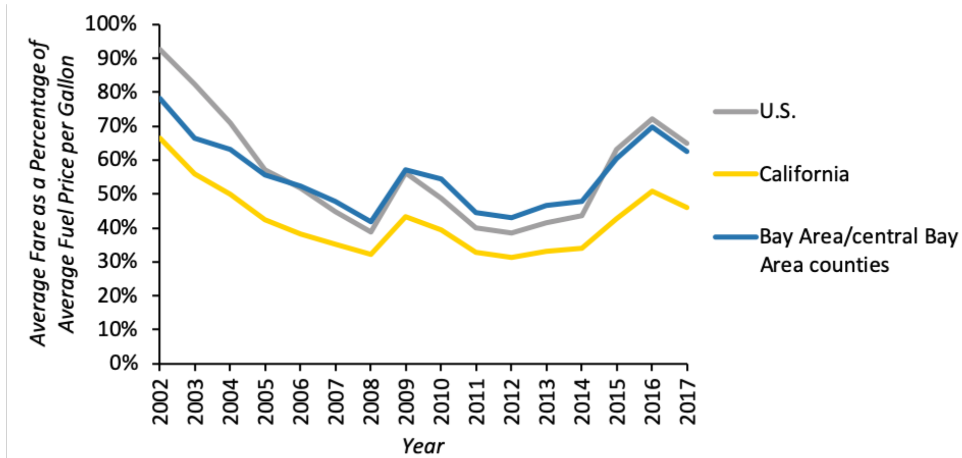


Data source: EIA, 2019 and Bureau of Labor Statistics, 2019

Phung, 2007) (See Appendix D, Section 1 for a summary of past research on the relationships between fuel prices and transit use.). **Figure 13-1** shows the average inflation-adjusted price for a gallon of gasoline from 2000 to 2019 for the United States, California, and the central Bay Area counties (EIA, 2019). The graph shows that inflation-adjusted gasoline prices have gradually, albeit unevenly, increased since 2000, with notable price downturns between 2008 and 2010 (during the Great Recession) and between 2014 and 2016. Significantly, California and central Bay Area gasoline prices have always stood higher than national prices, but usually by less than 50¢ per gallon.

Figure 13-2 compares the average fare paid per transit trip to the price for a gallon of gasoline over time for California, the central Bay Area counties, and nationally from 2002 to 2017. While not entirely comparable, the average transit fare paid has consistently been less than the price of a gallon of gasoline. Between 2002 to 2017, the average transit fare paid as a percentage of the cost of a gallon of gas fell from 78 to 63 percent in the Bay Area.[13] If travelers are highly price sensitive (to both fuel and fares), we would expect that Bay Area transit ridership per capita should have increased over the period; however, as noted in Chapter 3, it has not. Indeed, the relationship between transit trips per person in the Bay Area and the fare-to-gas ratio is not statistically significant ($t = 1.44$, $p = 0.171$).

Figure 13-2. Average Fare as a Percent of Region's Average Gas Price per Gallon



Data source: EIA, 2019; FTA, 2019; and Bureau of Labor Statistics, 2019

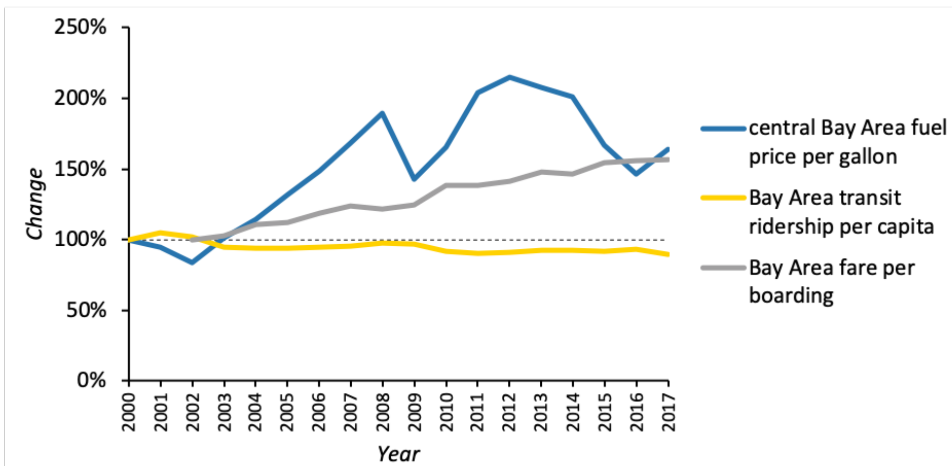
Finally, **Figure 13-3** shows the percentage changes in fuel price, transit fares, and transit ridership per capita. Fuel prices increased significantly from 2000 to 2012, while transit fares also increased (with less volatility than fuel prices but with similar long-term results). Ridership remained fairly stable despite the relatively favorable position of transit fares. From 2015 to 2017, transit fares and fuel price change since the early 2000s crossed; however, as noted above, the average Bay Area transit fare paid remained lower than the price of a gallon of gasoline.

In contrast to transit fares, motor vehicle fuel prices have proven far more volatile since 2000. The relationship between transit trips per person in the Bay Area and the price of fuel is statistically significant and negative ($t = -3.82$, $p = 0.002$); each $1 increase

13. While fares and ridership represent the entire Bay Area, the fuel price data are for the central Bay Area counties; we assume that these fuel prices are broadly representative of the region as a whole.

in the price of fuel is associated with a 2.67 decrease in transit trips per person. This is precisely the opposite of what we would observe should high fuel prices encourage Bay Area residents to switch to transit. Both this finding and the statistically insignificant relationship between the fare-to-gas ratio suggest that fuel prices are not driving changes in transit use in the Bay Area.

Figure 13-3. Change in Central Bay Area Gas Prices, Bay Area Transit Ridership per Capita, and Bay Area Transit Fares per Boarding



Data source: EIA, 2019; FTA, 2019; and Bureau of Labor Statistics, 2019

14. The Effect of Ridehail on Transit Ridership in the Bay Area

14.1. Overview

14.1.1. Introduction

In this section, we consider the effect of ridehail services—provided by companies like Uber and Lyft—on transit ridership. Without data from the companies themselves, we analyze data regarding private transportation establishments and synthesize evidence from previous surveys and studies. We find a major spike in taxi/limousine establishments in the Bay Area, especially in the denser, urban counties like San Francisco, Alameda, and San Mateo. National studies of transit ridership suggest that should ridehail indeed replace transit trips, it would be most likely to do so in regions which boast high transit ridership, are early adopters of services, and report high rates of ridehail use. The Bay Area, and especially San Francisco, has all three characteristics. However, ridehail could also complement certain kinds of transit trips, for example providing first/last-mile connections to commuter rail stations (though we have at best limited evidence of this in the Bay Area). Lacking actual ridehail trip data, we cannot quantify its effect on transit ridership; however, circumstantial evidence strongly suggests that ridehail replaces some transit trips, especially those taking place at night and on weekends.

14.1.2. Context

The Bay Area is ground zero for the rise of ridehail. Ridehail is a relatively new and increasingly popular mobility option provided by firms called "transportation network companies" (or TNCs). Both Lyft and Uber, now global mobility behemoths, were born in San Francisco (Hartmans and Leskin, 2019), and use of these services is higher in the region than any other (Conway, Salon, and King, 2018).

Nominally, the companies provide a service which connects travelers with drivers. The traveler uses the company's application interface ("app") on a mobile phone or other device and requests a ride. This alerts the driver to travel to the pick-up location. The driver then takes the user to the predetermined drop-off location. Payment, including tipping, is handled electronically. TNCs offer similar services to those of taxis, but with greater technological integration, faster average response times, no exchange of cash, lower fares, and opportunities to reduce costs further by sharing rides with other users going in similar directions. Drivers typically ferry passengers in their personal vehicles, or those that they lease.[14]

TNCs have grown dramatically since Uber began service in San Francisco in 2010. Uber delivered its 10 billionth ride in July 2018, while its competitor Lyft carried its one billionth in September 2018 (Dickey, 2018). Uber and Lyft dominate the U.S. ridehail market, together capturing 98 percent of trips: Uber provides approximately seven out of ten U.S. TNC trips, and Lyft the other three

14. The relationship between the TNCs and their drivers is frequently contested, with the TNCs holding that they are not employers of the drivers, but are merely for-profit ride-matching platforms that link travelers with independent contractor drivers. On the other hand, many drivers and their advocates have argued drivers are employees of TNCs and not independent contractors. This latter view prevailed in September 2019 when California passed a law (AB 5) which reclassifies most TNC drivers as employees (Myers, Bhuiyan, and Roosevelt, 2019).

(Zaveri, 2018). By early 2019, Uber and Lyft operated in nearly every major U.S. city and internationally, with Uber servicing more than 60 countries and 600 cities (Uber, 2019 and Lyft, 2019).

While these private, and frequently lightly regulated firms, occasionally release top line data on cities, drivers, and rides, detailed data on the geography and timing of use is mostly unavailable to the public. Unfortunately, the lack of comprehensive public ridehail data by city and region greatly limits our ability to understand, and plan for, these new services.[15] This makes analyzing the effect of these new services on public transit use especially challenging. This lack of data is increasingly problematic as these services have continued to expand.

14.2. The Ridehail Market

Lyft and Uber have generated enormous value for investors. At the time of the companies' IPOs in 2019, Wall Street valued Lyft and Uber, neither of which existed 15 years ago, at $24.3 billion and $82.4 billion respectively (O'Donnell and Franklin, 2019 and de la Merced and Conger, 2019). While the two companies have generated substantial support from venture capitalists, concerns about the financial viability of their business models are waxing, leading to weaker-than-anticipated public offerings. Lyft reported $911 million in net losses in 2018 (Clark, 2019), and Uber $1.8 billion (O'Brien, 2019).

Meanwhile, these two companies, and a host of smaller ones, have begun to diversify their services by offering electric scooters, bicycle share, and food delivery, among others (Jasinski, 2018). Uber and Lyft have also invested in and developed autonomous vehicle technology (Hawkins, 2018). Given their substantial market valuations, pools of users, expanding array of mobility services, and technology development, Lyft and Uber have emerged as key private actors in the rapid expansion and deployment of technology-enabled mobility.

With respect to public transit generally, and in the Bay Area in particular, the effect of ridehail services on ridership is theoretically ambiguous (Hall, Palsson, and Price, 2018). Ridehail use could:

1. replace transit trips, if travelers use ridehail instead of taking transit, thereby decreasing transit use;
2. complement transit trips, if travelers use ridehail to extend the reach of traditional transit lines, either by using it to travel to a transit stop or station, or from a transit stop/station to a destination, thereby increasing transit use; or
3. have no effect on transit use, if travelers use ridehail instead of driving, taking taxis, or traveling via some other non-transit mode, or if they make trips that would not otherwise have occurred without TNC service.

In additional to these potential direct impacts, there may also be indirect effects of ridehail services on public transit. For example, increased congestion produced by added TNCs in a central city district could lead to slower bus speeds and discourage transit use. On the other hand, if reliable, affordable ridehail access motivates some households to reduce their motor vehicle ownership, then lower levels of private vehicle access could encourage more transit use as a collateral benefit.

As ridehail use has expanded over the last few years, researchers have struggled to answer the question of ridehail effects on transit use, due in no small part to the lack of available data. This has motivated scholars to come up with a variety of creative methods to estimate and analyze ridehail use, as summarized below.

15. While many governments, like California's, require reporting of TNC data, these are most often limited to monitoring regulatory compliance only and are not available for planning (or research) purposes.

14.3. Taxi and TNC Establishments in the Bay Area

While we do not have direct access to comprehensive information regarding TNC trips in the Bay Area, the U.S. Census Bureau provides data on the number of people who register as taxi or limousine drivers (i.e., set up a "taxi and limousine establishment") (U.S. Census Bureau, 2019)—a category which also includes people who drive for TNCs (Sandusky, 2018). These data may provide an approximation of TNC activity in the Bay Area. However, such estimates should be viewed with caution for a few reasons:

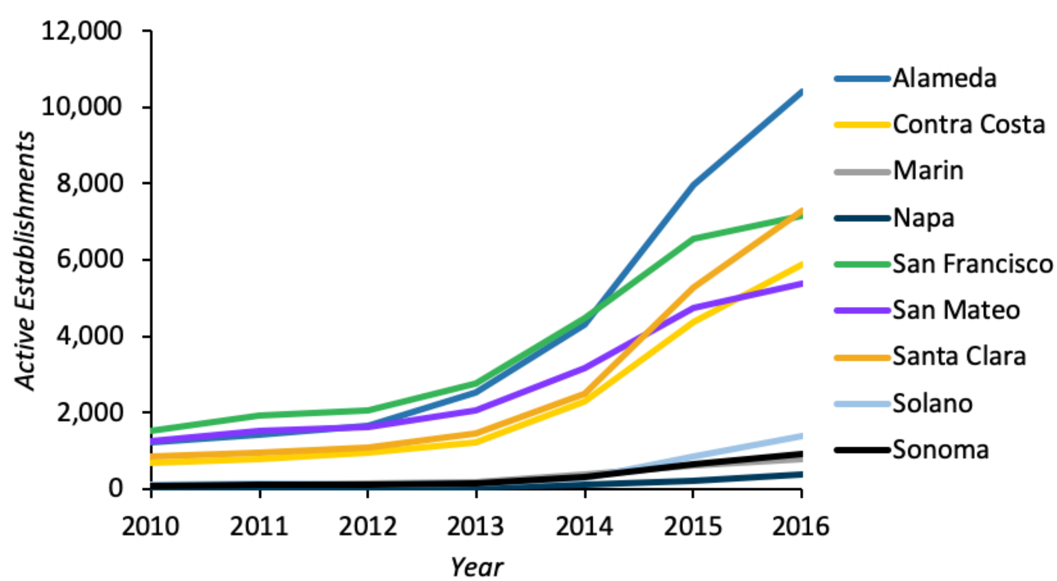
- The number of establishments may overstate the level of ridehail service provided. First, establishments are not linearly related to levels of service, as some Uber and Lyft drivers may work 40 hours per week, while others drive only occasionally. Further, research shows that only four percent of Uber drivers were driving a year later (Efrati, 2017). So the number of establishments recorded for tax purposes in a given year likely overstates the number of drivers working at a single point in time.

- Where drivers live does not necessarily reflect where they drive. Although drivers who live in Iowa are not likely traveling to San Francisco to drive for Lyft, journalists have interviewed TNC drivers who live in cities like Modesto and travel several hours to drive in San Francisco (Paul, 2019). This would suggest that the number of TNC drivers working in San Francisco is likely undercounted in these data, while the number active in Modesto is likely overcounted.

- Finally, measures of establishments do not directly capture the numbers of trips completed (and thus potential transit trips displaced or complemented). For example, perhaps people in Sonoma County registered as taxi and limousine drivers regularly complete 500 trips per month, while the comparable figure for San Mateo is 30 trips. If both counties reported 1,000 taxi and limousine establishments, TNC intensity would still differ greatly between them.

Figure 14-1 shows the total number of driver establishments registered in each year by county. The enormous jump after 2012 almost certainly reflects the increase in individuals registered to drive for Lyft, Uber, or another ridehail service. Alameda, San Francisco, and Santa Clara report the largest number of establishments in the Bay Area, with Alameda surpassing 10,000 establishments in 2016.

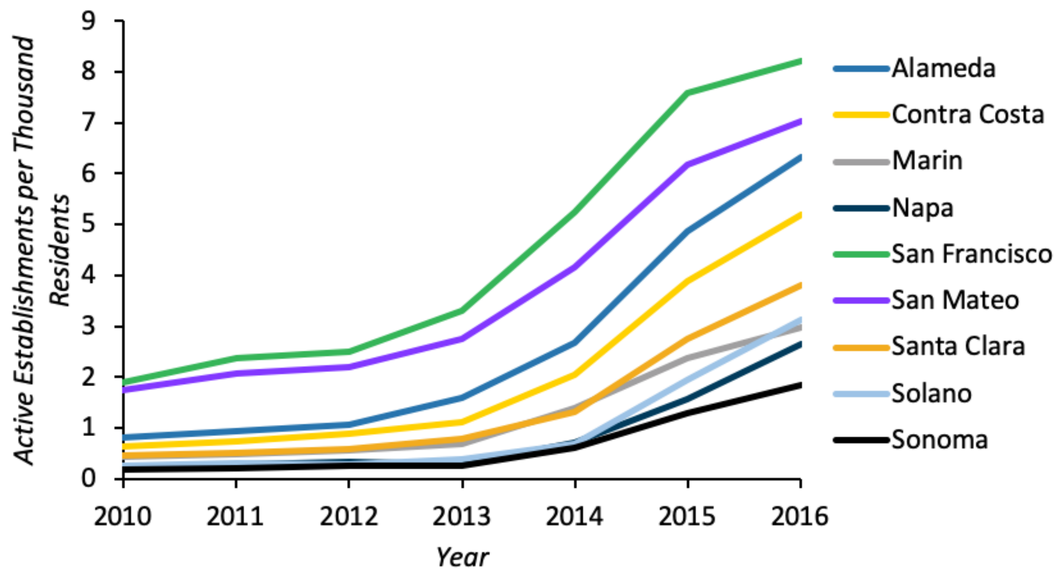
Figure 14-1. Active Taxi and Limousine (Including TNC) Establishments by County



Data source: U.S. Census Bureau, 2019

However, **Figure 14-1** masks the density of establishments in the counties, because some counties have much larger populations than others. In **Figure 14-2**, we control for total population in each county.

Figure 14-2. Active Taxi and Limousine (Including TNC) Establishments per Thousand Residents by County



Data source: U.S. Census Bureau, 2019

In **Figure 14-2**, the per capita number of establishments tracks closely with the residential density of each county. San Francisco, San Mateo, and Alameda have the highest per capita establishments, respectively, again showing a substantial spike after 2012. Meanwhile, more suburban and rural counties like Solano and Sonoma have about one fourth as many establishments per capita as San Francisco. Taken together, these business establishment data suggest a large and rapid increase in the number of taxi/limousine/TNC workers in the Bay Area, which we assume are confined mostly to TNC drivers and which are most prevalent (even in per capita terms) in the most urbanized counties.

14.4. Studies of Ridehail and Transit Use

Studies measuring the effect of TNC use on general travel behavior have exploded in the last few years, in concert with the steep rise of ridehail use. While not yet conclusive, these studies collectively suggest that as ridehail services mature and expand, increasing numbers of travelers opt for these services rather than public transit. Many of the Bay Area-specific studies focus on the City of San Francisco. In 2016, the San Francisco County Transportation Authority sought to understand the effect of ridehail on congestion in the city, but could not gain access to Uber or Lyft's data. To work around the lack of direct operator data, researchers accessed the public user interface and examined where and when drivers and vehicles in San Francisco appeared on the app interface in order to estimate the approximate frequency and location of trips. Using these collected data they attributed almost half of congestion increases from 2010 to 2016 to TNCs (Castiglione et al., 2017). Relatedly, Graehler, et al. in measuring effects of ridehail on regional transit markets, estimated that specifically for early adopter San Francisco, all else equal, bus ridership would be expected to drop by 12.7 percent, and that transit agencies serving The City would need to increase service by about 25 percent in order to offset this loss (Graehler, Mucci, and Erhardt, 2019).

In terms of Bay Area survey data, results from the 2017 NHTS indicate that the central Bay Area counties have the highest rates of ridehail among all metropolitan statistical areas (MSAs), with 31 percent of its resident respondents reporting use of ridehail in the prior 30 days (Conway, Salon, and King, 2018). Finally, Rayle et al.'s (2016) survey of 320 ridehail users in San Francisco found that they were younger and better-educated than other travelers, that two-thirds of trips were taken for social and leisure purposes, and that one-third of ridehail trips surveyed replaced transit trips. The implications of these findings for public transit are substantial, given that nearly two-thirds of Bay Area transit trips pass through San Francisco on Muni and BART alone (FTA, 2019 and BART, 2019c).

Table 14-1 presents a summary of findings from several recently ridehail studies, including the Bay Area-specific ones noted above. See Appendix D, Section 2 for descriptions of the methodologies, analyses, and results of these studies.

Table 14-1. Summary of Findings from Studies of Ridehail and Transit Use

STUDY	GEOGRAPHY	SAMPLE SIZE	PROPORTION OF ESTIMATED TRANSIT TRIPS REPLACED BY RIDEHAIL	METHODOLOGY
Babar and Burtch, 2017	356 urbanized areas in the U.S.	1,066 transit agencies	N/A	statistical analysis of transit agency ridership and estimated Uber market entrance/ penetration
For each year of Uber operation in a region, bus ridership decreases by 1.1%, subway increases by 2.6%, and commuter rail increases by 7.2%.				
Brown, 2018	Los Angeles County	6.3 million Lyft trips	N/A	geographic analysis of Lyft data
Data suggest wide geographic availability of ridehail service in Los Angeles County and price sensitivity in low-income neighborhoods.				
Castiglione et al., 2017	San Francisco	62 million trips	N/A	estimate of Uber/Lyft trips via API
San Francisco County Transportation Authority study; finds half of increased congestion from 2010 to 2016 due to TNCs; suggests replacement of transit/active transportation mode use by TNCs				
Circella et al., 2018	California	482 respondents	24%	survey
Using latent class analysis, researchers divided users into three groups, with almost 69% of those in the "Urban Travelers" group reporting using transit less with the advent of ridehail.				

STUDY	GEOGRAPHY	SAMPLE SIZE	PROPORTION OF ESTIMATED TRANSIT TRIPS REPLACED BY RIDEHAIL	METHODOLOGY
Clewlow and Mishra, 2017	Boston, Chicago, Los Angeles, New York City, San Francisco / Bay Area, Seattle, Washington DC	4,094 total respondents (not exclusively ridehail users)	15%	survey
15% of respondents, which include urban and suburban residents from metropolitan areas of noted cities, used transit for the trips made using Uber or Lyft; the speed of service is the primary reason cited for choosing TNCs over transit.				
Feigon and Murphy, 2016	Austin, Boston, Chicago, Los Angeles, San Francisco, Seattle, and Washington, D.C.	4,500 respondents	14%	survey
APTA-sponsored survey; respondents reported relatively low proportions of shared mode trips replacing transit trips, which suggests that new modes (including shared modes such as bikeshare and carshare in additional to ridehail) more often complement public transit.				
FHWA, 2017	nationally representative sample	~130,000 households	N/A	survey/travel diary
2017 National Household Travel Survey; nationally, 0.5% of all person-trips were taken via ridehail/taxi.				
Gehrke, Felix, and Reardon, 2018	Boston	933 respondents	42%	intercept survey administered during ridehail trip
Study by the Metropolitan Area Planning Council estimates that for every ridehail trip taken, the Massachusetts Bay Transportation Authority (MBTA) loses 35 cents in fare revenue.				

STUDY	GEOGRAPHY	SAMPLE SIZE	PROPORTION OF ESTIMATED TRANSIT TRIPS REPLACED BY RIDEHAIL	METHODOLOGY
Graehler, Mucci, and Erhardt, 2019	22 large MSAs in the U.S.	51 entities (cities and/or agencies)	N/A	statistical analysis of MSA transit ridership and estimated Uber market entrance/ penetration
For each year of Uber operation in a region, heavy rail ridership decreases by 1.3%, commuter rail increases by 1.9%, light rail decreases by 0.4%, and bus decreases by 1.7%.				
Hall, Palsson, and Price, 2018	196 Metropolitan Statistical Areas in the U.S.	296 agencies	variable, depending on mode, MSA size, and agency size	statistical analysis of transit agency ridership and estimated Uber market entrance/ penetration
Uber's entrance varies from 5.9% decrease in ridership (for small cities) to 6.0% increase in ridership (for small transit agencies).				
Hampshire et al., 2017	Austin	1,840 respondents	3% of disrupted riders	survey
Non-random survey distributed to ridehail users during service disruption finds that only 3% reported switching to transit after ridehail's temporary departure.				
Henao, 2017	Denver	311 respondents	22%	intercept survey administered during ridehail trip
Finds that only one percent of riders surveyed were taking ridehail to connect to transit				
New York City Department of Transportation, 2018	New York City	616 respondents	50%	travel diary
50% of respondents reported that the ridehail trip replaced a transit trip.				
Rayle et al., 2016	San Francisco	321 respondents	33%	intercept survey
Ridehail trips are highest for social trips on weekends and in the evenings.				

Ridehail continues to expand in most U.S. cities, so the findings from these analyses are moving targets. In addition, the studies reviewed here vary substantially across geography, year, sampling frame, methodology, sample size, phrasing of questions, and basis of comparison. The surveys conducted for these studies collectively suggest that ridehail services may replace anywhere from 14 to 50 percent of transit trips, depending on the circumstances of the operating environment and trip. While virtually all studies directed questions toward urban travelers, the findings from Boston and New York City suggest that very dense metropolitan areas with established, well-patronized transit systems may be more vulnerable to transit ridership losses than other places where transit use is much lower (and, presumably, ridehail response times are lower as well). Bus service also appears more vulnerable to replacement than rail, and several studies show that the transit-to-ridehail substitution effects may increase over time as more people begin using ridehail.

In the larger context of personal travel, the role of ridehail remains relatively modest. The 2017 NHTS indicates that ridehail and taxi trips comprised 0.5 percent of all person trips nationwide, while public transit accounted for 2.5 percent of all person trips (FHWA, 2017); personal travel remains overwhelmingly dominated by travel in private vehicles. But like public transit, ridehail use tends to be concentrated in areas of dense development and activity, like in San Francisco. And because the public transit share of overall personal travel is already relatively modest, if TNCs are beginning to draw a significant share of their trips from regular transit users, as several of the studies reported here suggest, continued growth in TNC use could have significant effects on transit system patronage—particularly in places where transit use is already high and where TNCs services are long-established, as in San Francisco.[16]

14.5. Conclusion

Without data from TNCs themselves, we unfortunately cannot draw firm conclusions as to the net effect of ridehail on transit use. However, from the limited data we do have available and our review of prior research, we see strong circumstantial evidence that ridehail in the Bay Area is subtracting more transit riders (who are substituting ridehail for transit trips) than it adds (through better first-/last-mile connections to transit stops and stations). First, the Bay Area, particularly in the central cities of San Francisco and Oakland/Berkeley, is a dense, transit-rich region, and research has shown that ridehail use is highest precisely where transit service is best (Brown, 2018). Second, a greater share of people drives for ridehail in the Bay Area than anywhere else (Farrell, Greig, and Hamoudi, 2019), and in addition, TNC/taxi/limousine drivers per capita in San Francisco, San Mateo, and Alameda Counties are the highest in California. Third, ridehail services began in the Bay Area and have operated there longer than anywhere else (Hartmans and Leskin, 2019); studies find that TNC-for-transit substitution tends to increase the longer that ridehail operates in a city (Graehler, Mucci, and Erhardt, 2019 and Babar and Burtch, 2017).

While strongly suggestive, the case here is not an open and shut one. Several studies find that public transit and ridehail tend to serve two very different travel markets. Ridehail use tends to be highest in the evening and on weekends, which are not peak times for transit (but are the times and days when we have observed the largest loss of transit riders). In addition, ridehail passengers tend to be higher-income, better educated, and somewhat younger than the average traveler, as well as much more likely to use the service to go out in the evening or to an airport than ride to work (Rayle et al., 2016 and Feigon and Murphy, 2016).

16. While our focus here is on what's behind recent declines in transit use, we should note that travelers who switch from transit to TNCs choose to do so, often paying higher fares in the process. TNCs mimic the door-to-door service that makes driving so attractive to the vast majority of travelers, and can offer personal safety benefits over public transit as well. While the consequences of growing TNC use (and of course driving personal vehicles) pose significant challenges for policy makers in general, and transit operators in particular, they may entail significant personal benefits for travelers as well.

However, the Bay Area may present a unique case. First, our analyses in Chapter 4 and Volume II show that off-peak-hour trips and non-commute trip purposes account for the vast majority of net ridership losses on major Bay Area operators. It is precisely in those travel markets where ridehail use tends to be highest. Second, even if ridehail and transit initially served different travel markets, more mature and ubiquitous ridehail networks have the potential to substitute for transit's core trips—especially in markets served longest by Lyft and Uber. Finally, although per-capita transit ridership was already faltering, absolute ridership in the Bay Area only began falling after 2016, as ridehail was continuing to expand (See Chapter 3). Thus, the rise of ridehail and fall of transit use align—in terms of timing, location, and trip purpose—relatively well in the Bay Area.

15. Private Shuttle Services

In this section, we review transportation effects of private shuttle services (so-called "Google buses") in the Bay Area. Data collected by regional providers show a rapid rise in shuttle users, especially among commuters traveling between San Francisco and the Silicon Valley. If shuttle trips replace transit trips, the effect is significant, as regional census of shuttle services found that if they comprised a single transit agency, it would be the seventh largest in the region (Bay Area Council and MTC, 2016). But while shuttle services carried about 9.6 million people in 2014, they may also indirectly affect the choices people make about where to live and work. By allowing people who work in suburban Silicon Valley to live in urban San Francisco (for example), shuttles may encourage gentrification by making it easier for higher-paid workers to live in densely developed areas with high-quality transit access. However, private shuttles also could introduce a new population to the benefits of transit travel, and take many private vehicles off roads, reducing congestion (Rentschler and Goodwin, 2018).

15.1. Introduction

Most legacy public transit systems began as private, for-profit services a century or more ago, only to later shift into public ownership and operation when they ran into financial troubles.[17] Since the early 2000s, the Bay Area has seen a dramatic increase in private shuttles, colloquially referred to as "Google buses." However, these shuttles differ from most early private transit services in that they are for employees and contractors only, and not open to the fare-paying public.

Google's program began in 2004 with fewer than 200 users (O. Thomas, 2012); by 2007, 1,200 Google employees regularly used the shuttles, representing almost a quarter of the company's then-workforce (Helft, 2007). Other major Bay Area companies like Apple, Cisco, Genentech, Facebook, and Yahoo also offer long-distance private transportation services to employees (Bay Area Council and MTC, 2016). Beyond the Bay Area, other similar services have developed as companies on large suburban campuses employ urban dwellers. Since 2007, Microsoft has offered a shuttle service—the Microsoft Connector—to employees traveling from urban Seattle to the campus in suburban Redmond (Long, 2009).

While Google buses and similar shuttles have operated for at least 15 years, they began to garner national attention in 2013 as local activists organized protests associating the buses with young tech workers gentrifying San Francisco and Oakland (Gumbel, 2014). During one protest in 2013, protesters reportedly smashed the windows of a Google shuttle as employees boarded in West Oakland (A. Lee, 2013). Many activists have criticized the fact that the buses used public space to provide private services without paying and blocked curb space regularly used by public transit buses (Hollister, 2014). Residents and travelers have also complained about traffic and regular curb conflict with municipal buses, leading to regulation in the City of San Francisco beginning in 2014 (detailed further below).

17. SFMTA is a notable exception to this rule, as it was a public entity since its inception in 1912 (SFMTA, 2019a). However, many of Muni's routes today were originally operated privately before shifting into public ownership and operation (Market Street Railway, 2019).

Research on these private employer shuttles has evaluated both their potential positive and negative effects. Shuttle users experience benefits including increased mobility and choice, comfort, (often) shorter trip times than with traditional public transit, and the enhanced ability to work while traveling due to wi-fi access (Helft, 2007). Meanwhile, positive external effects include the benefits of decreased single-occupancy vehicle use: lower greenhouse gas emissions and reduced congestion (Brooks, 2014). According to an SFMTA report, shuttles boarding from San Francisco in 2015 reduced monthly regional vehicle miles traveled by 4.3 million (SFMTA, 2015). In a region where congestion increased 80 percent from 2010 to 2017, reductions in single-occupancy use of roads have positive implications for region-wide mobility (Rentschler and Goodwin, 2018).

However, shuttles may also negatively affect the Bay Area. Prominent criticisms have associated these private shuttle services with issues of housing affordability and neighborhood change (Crucchiola, 2016). Some research on private shuttles in the Bay Area has focused on neighborhood effects, particularly the relationship between shuttle use and gentrification (McNeill, 2016). One report found a strong association between the location of shuttle stops and increasing rents (Goldman, 2013). Another study identified an association between no-fault evictions and proximity to San Francisco shuttle stops from 2011 to 2013 (Maharawal and McElroy, 2017).

Other aspects of private shuttles have led to operational concerns. The lack of dedicated zones for loading and unloading passengers can lead to safety issues for pedestrians and bicyclists, conflicts with municipal buses in bus-loading zones, and increased congestion on small residential streets, especially in San Francisco (San Francisco Board of Supervisors, 2014). And as private operators, shuttle services offer services only to their employees, and not to the public at large; this raises equity concerns when these buses compete for curb and streetspace with public transit (O'Brien and Guyn, 2014).

By all estimates, ridership on private shuttles in the Bay Area has increased over the last decade. However, the magnitude of these gains, and the relationship to transit ridership, remain unclear due to data limitations. While we are not aware of any studies that have directly examined the relationship between private shuttle services and changes in transit system ridership, we discuss here those that have looked at shuttle policy, ridership estimates, and rider surveys.

15.2. Policy

In response to complaints from residents of several San Francisco neighborhoods, SFMTA began regulating private shuttle use of city streets. Beginning in 2014 with the Commuter Shuttle Pilot Program, the agency designated specific zones to reduce conflicts between city buses, private vehicles, shuttles, and other street users. SFMTA also requires that shuttle operators register with the city and pay fees. After the 18-month pilot program, the agency expanded the scope of the program. San Francisco currently has 125 shuttle stop locations that allow loading and unloading, concentrated in the eastern part of the city (SFMTA, 2018b). SFMTA also charges a fee for each "event" (shuttle stop), which stood at $7.65 in 2019. The fees collected through the program (totaling $5.7 million in 2017) cover costs associated with its administration (SFMTA, 2018b).[18]

18. While many streets in San Francisco charge drivers to store their private vehicles at the curb, most do not. Curb parking pricing is mostly confined to commercial districts, while a substantial majority of the curb space in residential neighborhoods is designated for free parking of privately owned vehicles. By contrast, only a tiny minority of the city's curb space is designated for either public transit or private shuttle stops. Thus, most drivers in San Francisco's residential neighborhoods are not charged by the city for parking events at the substantial majority of public curb space that the city designates for private vehicle storage.

In contrast to SFMTA, regional agencies do not have the same capability to regulate shuttles. In the State of California, for-hire carriers and TNCs must register with the California Public Utilities Commission (CPUC) (CPUC, 2019b). The CPUC collects information related to safety and consumer complaints, but does not publish data on private shuttle operation, location of stops, or number of passengers traveling in private passenger transportation vehicles (CPUC, 2019a). Presently, no framework exists for regulating curb use by shuttles in Bay Area counties outside San Francisco. The best source of information for ridership and vehicle operation thus far has been a study produced by the MTC and the Bay Area Council, detailed below.

15.3. Shuttles by the Numbers

15.3.1. SFMTA's Commuter Shuttle Program

Given its regulatory capacity, SFMTA collects the most detailed data regarding shuttle activity among all Bay Area counties. Through their program, SFMTA collects ridership information directly from shuttle operators, which is summarized in the table below for 2014 to 2017 (years of the shuttle program's operation). The methodology of ridership counts changed slightly from 2015 to 2016, correcting some operator data and eliminating ridership associated with stops outside of the shuttle network (SFMTA, 2018b). After the agency controlled for these changes in measurement, SFMTA estimated that ridership increased approximately ten percent year-to-year over the 2014 to 2017 period (SFMTA, 2018b).

Table 15-1. Shuttle Passengers Traveling from San Francisco, 2014-2017

YEAR	ESTIMATED DAILY SHUTTLE PASSENGERS TRAVELING TO/FROM SAN FRANCISCO
2014-2015	17,000
2016	16,200
2017	17,800

Data source: SFMTA, 2015, 2018b

In 2017, 92 percent of passenger trips occurred on intercity routes, mostly to Silicon Valley, while eight percent of shuttle passengers traveled within San Francisco. In 2015, only 76 percent of shuttle passengers traveled on intercity routes while 24 percent traveled within San Francisco (SFMTA, 2018b). Since the average length of an intercity shuttle trip was 47 miles, while the average length of a within-San Francisco trip was approximately two miles (SFMTA, 2015), the increase in passenger ridership has likely produced a significant increase in total passenger miles traveled.

15.3.2. Bay Area Shuttle Census

In 2016 and 2019, the Metropolitan Transportation Commission and the Bay Area Council compiled information on shuttle counts throughout the region, defining shuttle service as "regularly scheduled transportation services in large multi-passenger vehicles operating as either 'last mile' connections or serving longer routes between more distant parts of the Bay Area" (2016, p. 1). This definition of shuttle service includes both private and public operators, although none of the participants listed in the report are public transit agencies. The data were collected from shuttle sponsors and operators through a voluntary online survey, but the collective results were reported anonymously. While the data do not cover all operating shuttles in the Bay Area, they offer a snapshot of ridership from 2012 to 2018 (Bay Area Council and MTC, 2016 and Bacon, 2019).

The Bay Area Shuttle Census does not report passenger ridership by county, but does report the number of fleets traveling between counties (or within one county); this represents the best source of information regarding regional shuttle activity (Bay Area Council and MTC, 2016 and Bacon, 2019). The top six county origin-destination pairs account for over 85 percent of total shuttle routes in the Bay Area in 2014 and 87 percent in 2018.

Table 15-2. Shuttle Routes by County Origin-destination Pair, 2014 and 2018

COUNTY OF ORIGIN/DESTINATION	SHUTTLES PER DAY, 2014	SHUTTLES PER DAY, 2018
San-Francisco - Santa Clara	308	380
Alameda - Santa Clara	119	220
Santa Clara - Santa Clara	81	419
San Mateo - San Mateo	77	94
San Francisco - San Mateo	65	184
San Mateo - Santa Clara	44	197
Others	110	221
Total	**804**	**1715**

Data source: Bay Area Council and MTC, 2016 and Bacon, 2019

Aggregate annual boardings increased over 200 percent over a six-year period, from 6.6 million in 2012 to 20.1 million in 2018. In 2014, these private shuttles carried 34,000 Bay Area passengers on an average weekday (Bay Area Council and MTC, 2016); passenger counts are not yet available for 2018 (Bacon, 2019). Using these 2014 numbers, if shuttles were an independent transit agency, they would be the seventh-largest transit agency in the region by passengers served, ranking just ahead of Golden Gate Transit and just behind SamTrans (FTA, 2019). According to the survey data, about half of all private shuttle passengers traveled to or from San Francisco in 2014.

15.4. Shuttle Users and Travel Behavior

A handful of studies have looked at the travel behavior and preferences of shuttle riders, although most studies feature very small sample sizes. However, the 2015 SFMTA pilot program surveyed 546 shuttle riders (SFMTA, 2015). Seventy-two percent of respondents reported riding the shuttle to work every day, 45 percent did not own a car, and 20 percent reported that shuttle service availability was the main reason they did not own a car. Without access to a private shuttle, 47 percent of respondents stated that they would drive alone to work, 29 percent would use public transit, 14 percent would get a job closer to home, five percent would carpool, and five percent would move closer to work (SFMTA, 2015). This suggests that these shuttles do likely affect public transit use, though effects on driving are even larger.

In 2013, a UC Berkeley Institute of Transportation Studies project surveyed 130 riders (all of whom worked in "tech") boarding shuttles in San Francisco headed for San Mateo and Santa Clara counties. The findings of this study with respect to the alternatives riders would use in the absence of shuttle services were similar to the 2015 study cited above: 48 percent said that they would drive alone, 20 percent would take transit, 15 percent would carpool, ten percent would change jobs, and two percent would bicycle. The study also asked respondents about their primary reasons for using the shuttles. With multiple responses allowed, the top five responses were that that the shuttle is: free (57%), allows for en-route work productivity (44%), avoids dealing with traffic (33%), provides amenities and comfort (33%), and has environmental benefits (29%) (Dai and Weinzimmer, 2014).

Both the SFMTA and UC Berkeley ITS surveys found that while many shuttle users would drive to work, the majority would either take transit, carpool, or change their place of employment or residence (SFMTA, 2015 and Dai and Weinzimmer, 2014). Notably, both surveys only collected information about boardings and alightings from San Francisco.

15.5. Conclusion

While the aggregate numbers of private shuttle commuters appear to be large in the Bay Area, the diversion of transit riders from public to private services is likely small—based on the two surveys cited above, this amounts to about 11,000 daily public transit trips throughout the Bay Area (30% of 36,000 rides). These commuters are a kind of transit rider, but on closed, private systems rather than open public ones.

However, other changes in behavior associated with shuttle infrastructure—lower rates of car ownership and/or allowance of long-distance commuting across the Bay Area—could have indirect positive or negative effects on public transit ridership. Decreased car ownership might mean that transit users take transit more often (particularly in San Francisco) for non-commute trips. However, if shuttles allow for higher-income residents to live in transit-rich urban areas distant from their place of work, they may displace other, poorer urban dwellers who tend to ride public transit at even higher rates.

16. Effect of Driver's Licensing for Undocumented Immigrants

16.1. Introduction

Changes in local or state policies may influence transit ridership. For example, some states, including California, have made it easier for undocumented immigrants to acquire driver licenses and, therefore, to drive legally. In 2013, California passed AB 60, the Safe and Responsible Drivers Act. Starting on January 2, 2015, AB 60 requires the DMV to issue "an original [driver's] license to an applicant who is unable to submit satisfactory proof of legal presence in the United States." AB 60 was responsible for 605,000 driver licenses in its first year (California DMV, 2016). As of spring 2018, the DMV had issued an additional 400,000 driver licenses for a total of more than one million licenses issued under the program (California DMV, 2018).

Immigrants, particularly recent immigrants, are more likely to use transit than native-born travelers (Blumenberg and Evans, 2007; Chatman and Klein, 2009; Kim, 2009; and Manville, Taylor, and Blumenberg, 2018a). However, like native-born adults, most immigrants travel via automobile. Further, studies in California show that prior to AB 60 many undocumented immigrants traveled by car (Lovejoy and Handy, 2008). However, assuming that at least some of the new AB 60 license holders previously relied on transit, changing state driver's licensing regulations may have contributed to declining transit use. Preliminary analyses suggest that AB 60 reduced the number of undocumented immigrants in California without a car by 21 percent and potentially contributed to a decline in use of public transit, though this latter finding is more speculative (Lueders, 2019).

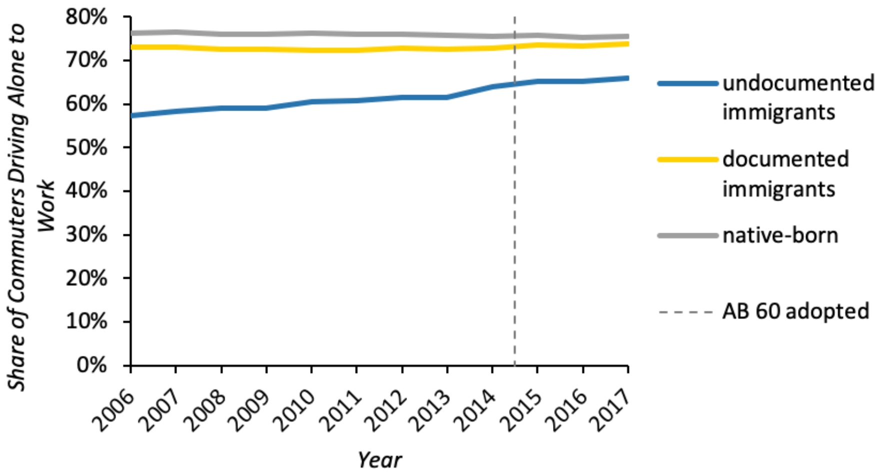
Unfortunately, we know of no available data source that allows us to answer this question directly. California DMV rules prohibit the release of individuals' data from this new program, and there is no longer a requirement to provide proof of citizenship in order to secure a license. As such, we must address this issue indirectly.

16.2. Vehicle Use by Nativity

Like Lueders, we use data from the microdata of the American Community Survey (Ruggles et al., 2019) to examine trends in the percentage of immigrants (documented and undocumented) that travel to work by car, that drive alone to work by car, and that travel to work by transit. In our analysis, we estimate undocumented immigrants by adopting the methodology used by Borjas (2017). We categorize foreign-born respondents as documented if they arrived before 1982, are a citizen, have Social Security income, are a veteran, are currently in the armed forces, work in the public sector, were born in Cuba, or are employed in an occupation that requires licensing.

As **Figure 16-1** shows, across California, native-born residents have the highest rates of solo driving for the commute, followed by documented immigrants, and then by undocumented immigrants. Over time, solo driving among undocumented immigrants has increased. Surprisingly, most of the growth occurred prior to the implementation of AB 60. Between 2006 and 2014, solo driving among undocumented immigrants in California increased by 12 percent, and only increased one percent between 2015 and 2017.

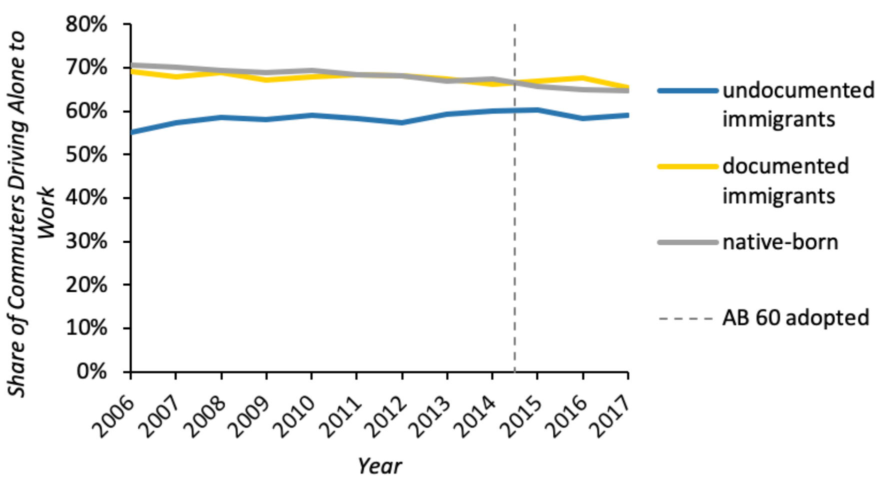
Figure 16-1. Solo Driving to Work by Nativity Status, California



Data source: Ruggles et al., 2019

In the Bay Area, solo driving among native-born and documented immigrants declined slightly over time (See **Figure 16-2**). In contrast, solo driving to work among undocumented immigrants increased, though its rate decreased by two percent between 2015 and 2017, exactly when we would expect to see increases if driver's licensing were a major factor in transit ridership decline.

Figure 16-2. Solo Driving to Work by Nativity Status, Bay Area



Data source: Ruggles et al., 2019

In order to better interpret these somewhat inconclusive descriptive statistics, we specify a set of regression discontinuity models to assess the relationship between the implementation of AB 60 and the travel behavior of immigrants in California. This type of model allows us to control for the effects of numerous characteristics that are not related to AB 60 but that may affect commute mode (such as income, age, marital status, number of years in the U.S., and county of residence), while also isolating the impact of an immigrant's documentation status on his or her travel behavior. Since Mexican immigrants are both the largest undocumented immigrant group in the state as well as traditionally relatively heavy users of transit, we focus our analysis on this demographic.

Results of the regression discontinuity models show small but consistent associations between the commute mode share of undocumented workers and the availability of AB 60 licenses. For example, findings suggest that for undocumented Mexican immigrants, the predicted percentage of car commuters increased by 1.7 percentage points following the enactment of AB 60. In other words, having access to a driver's license means that undocumented Mexican workers were slightly more likely to commute to their jobs via automobile.

Like car commuting, AB 60 also appears to have had a moderate effect on the proportion of undocumented workers that drive alone to their place of employment. All else equal, the predicted proportion of undocumented Mexican immigrants that drove alone to work increased by three percentage points in the first year after AB 60 licenses became available. These findings suggest that access to driver's licenses has made it easier for undocumented immigrants to drive alone to their workplace.

Finally, like the automobile commute models, our transit commute model suggests a small but significant association between the implementation of AB 60 and changes in travel behavior. Specifically, the predicted proportion of undocumented Mexican workers that commuted by transit dropped by one percentage point—from 8.1 percent to 7.1 percent—following AB 60's implementation. While this decline is somewhat modest, it does highlight a potential relationship between changes in the policy environment and changes in the transit use of undocumented immigrants.

Despite the associations discussed above, our ability to draw strong conclusions about the relationship between the availability of AB 60 licenses and overall transit use in the Bay Area is somewhat limited. Small sample sizes preclude us from focusing solely on the Bay Area, meaning that our results apply only to the state as a whole. Furthermore, due to our reliance on census data, we are only able to examine commute-related trips, which represent a relatively small proportion of daily travel. Consequently, the way in which the implementation of AB 60 has affected the non-work travel of undocumented immigrants remains unclear, and the impact that AB 60 has had on total transit patronage in the Bay Area is difficult to determine.

Part IV

Conclusion

17. Conclusion: Light at the End of the Tunnel?

17.1. Findings

This study has examined transit use trends in the San Francisco Bay Area during the 2010s, with a focus on the recent patronage downturn and its possible causes. In a nutshell, we find that transit patronage has been relatively robust for some trip types, but waning for many others. We conclude that the most likely causes of the recent downturn lie mostly outside the control of most transit systems.

Public transit in the 2000s captures two primary travel markets: 1) people who, because of age, income, or inability, do not drive an automobile, and 2) trips bound for destinations where parking is difficult to find, expensive, or both. In serving the first of these markets transit is best characterized as a social service; and in serving the second, it allows dense economic and cultural agglomerations to function and thrive. Members of zero-vehicle households perhaps best epitomize the first travel market, and downtown commuters the second.

The booming regional economy and attendant employment growth, high housing prices (particularly near job centers), and job growth in downtown San Francisco have combined to make Bay Area transit riders more well-off and more likely to 1) commute on transit than ride for other purposes, 2) ride on trains, and 3) begin or end trips in downtown San Francisco. Correspondingly, Bay Area transit riders are less likely to 1) be transit dependent, 2) travel outside of the peak periods, 3) ride on buses, and 4) make suburb-to-suburb trips.

Regional transit ridership in the Bay Area has risen for most of the past decade, but 2018 was the second consecutive year of regional ridership losses. While a two-year downturn is not yet a definitive trend, key indicators like ridership per capita and productivity have been on the wane for a longer time. For most of the past decade, ridership gains on BART and generally high ridership on Muni obscured worrying patronage losses among other operators across the region. Bus ridership in particular has seen a slow but deepening decline for the past decade. While the details of the patronage changes at each of the region's eight largest transit operators vary, as detailed in Volume II, they share a common thread: peak ridership is either rising or falling only slightly, while off-peak ridership is dropping moderately to precipitously.

If a booming regional economy and job growth in downtown San Francisco explain the resilience of peak ridership, the causes of the sharp passenger losses in the off-peak and on non-CBD routes are less clear. To understand what might be behind this ridership shifts, we examined in this research ten possible causes, which are summarized below.

1. **Changes among likely transit users**

   As noted above, transit use tends to vary systematically by the socio-economic characteristics of travelers. For example, immigrants are more likely to ride than native-born residents, those with motor vehicles tend to ride less than those without them, and so on. Over time in the Bay Area, the share of high- and low-propensity transit users has changed, as has the frequency with which members of a given group ride.

   Overall, changes in transit demographics have broken largely positively in the Bay Area. Between 2009 and 2017, when transit use was mostly climbing in the central Bay Area counties of Alameda, Contra Costa, Marin, San Francisco, and San

Mateo, population growth and increasing ridership frequency among certain rider groups—especially higher-income and vehicle-owning households, who make up an increasing share of ridership—combined to cause moderate aggregate increases in transit trips there. These results contrast sharply with the State of California as a whole and, especially, with Los Angeles and Orange Counties, where trends were largely negative, indicating that the share of high-propensity transit users decreased as did that average rate that such population groups rode transit.

2. Changing location of workers relative to jobs

The arrangement of jobs and housing in a region can have multiple effects on transit use. Densely developed areas can make driving and parking more of a challenge, support frequent transit service, push origins and destinations close together, including houses and jobs, and encourage transit use for all manner of trips. Transit is well-suited to serve and link these concentrated centers of high-density housing and employment. Conversely, transit tends to play a much smaller role in linking suburban residents to dispersed job sites, where driving is often easy and parking free. Finally, dispersed development patterns where jobs are concentrated but located far from housing can increase longer distance transit *commuting* into major employment hubs (particularly when the transit service can avoid getting stuck in traffic), but travelers are less likely to use transit for non-work trips. In this case, the directional peaking of demand can prove an expensive challenge to accommodate. So the relative balance of jobs and housing in a region can importantly shape transit demand and use.

From 2002 to 2015, the largest Bay Area cities gained more jobs than resident workers, as did the Bay Area municipalities that already had the highest share of regional employment. Meanwhile smaller cities collectively gained more resident workers than jobs. Regardless of whether a given Bay Area municipality is jobs-rich or housing-rich, the jobs-to-residents ratio grew more unbalanced across the region and in most cities over time. These patterns may help to explain why transit commuting (especially for larger cities with job growth and strong transit connectivity) held steady or grew between 2002 and 2015, while non-commute transit trips have been in decline (as some people move to smaller cities with low transit access).

In 2015, three out of five Bay Area workers both lived and worked in areas with poor job access by transit, likely making it difficult for them to commute by transit. But compared to 2002, both workers and jobs concentrated to some degree in areas with relatively high transit access to jobs. This trend might bode well for transit use in these areas.[19] Nonetheless, jobs in these areas grew at a much faster pace than resident workers. Indeed, cities in the Bay Area, especially large ones, became less "self-contained": fewer workers lived in the same city as their job, and even fewer residents worked in the city where they lived. These trends are consistent with the growing use of transit for commuting, and declining use for other trips, that we observe in the Bay Area.

As cities became less self-contained, the average commute distance for Bay Area workers accordingly increased almost 15 percent in 13 years. Although lower-wage workers had shorter commutes (10.3 miles) than higher-wage workers (11.9 miles), the former workers were *less likely* to live and work in the same city. In concert, these trends help to explain both the increase in transit commuting to job centers, especially downtown San Francisco, and the growth in long-distance transit commuters.

Moreover, in 2015 higher-wage jobs and workers were more likely to be located in areas with good transit access to jobs

19. However, jobs and residents in these areas were more likely to be higher-wage workers, who ride transit less, on average, than lower-income residents.

than lower-wage jobs and workers. Higher-wage workers were more likely to both live *and* work in these areas, while lower-wage workers were more likely to both live and work in areas with poor transit access to jobs.

Data show that areas with the best transit access to jobs tend to have higher median home values, a lower percentage of rent-burdened households, and a lower percentage of low-wage households compared with other areas. Housing prices have grown faster in these areas than in other parts of the region. Lower-wage workers may find it increasingly difficult to both live and work in neighborhoods with robust public transit access to jobs, a conclusion consistent with data from other parts of our analysis showing that Bay Area transit commuters are becoming more well-off over time.

3. Changes in transit-friendly neighborhoods

As housing costs have risen in the Bay Area, many surmise that gentrification has reduced transit access for poor people and immigrants. There is concern that efforts to encourage TODs along high-speed transit networks to increase ridership may displace lower-income, transit-riding households in these areas. However, and to our surprise, we do not find strong evidence of such changes in transit-friendly neighborhoods in the Bay Area.

We examined this issue by analyzing three different measures of transit-friendly Bay Area neighborhoods. Across all three of these definitions of neighborhood transit-friendliness, the percent of the households in poverty declined only slightly from 2000 to 2017 (to about 15%), while across the region the percent of households below the federal poverty line rose just slightly (to about 10%). So while there was some decline in households in poverty in transit-friendly neighborhoods between 2000 and 2017 relative to the Bay Area as a whole, the shifts were slight.

We also examined trends in the share of immigrant households in these neighborhoods, as well as the trend in zero-vehicle households, as, noted above, both are strong predictors of transit use. With respect to immigrant households, we do observe a moderate decline in immigrants from Latin America (from 9% to 7% by one of our neighborhood definitions) between 2000 and 2017, while the share of immigrants from Asia was largely unchanged. With respect to zero-vehicle households, we observe a modest increase in neighborhoods with our strictest definition of transit-friendliness, but slight decreases in the larger number of less-restrictively-defined transit neighborhoods.

To explore this latter finding a bit further, we differentiated "car-less" from "car-free" transit-friendly neighborhoods. In a nutshell, car-free neighborhoods are those with low rates of auto ownership *and* low rates of poverty. Car-free neighborhoods are far less common than car-less neighborhoods (which have relatively high rates of poverty), but more than tripled (from 1.1% to 3.5% of all Bay Area census tracts) between 2000 and 2017, while the share of car-less neighborhoods changed little.

How do we reconcile these findings with data presented above showing that workers are traveling farther and farther from home to their jobs in the Bay Area over time? First, we do see declines in Latin American immigrants and very slight declines in the shares of poverty households in transit-friendly Bay Area neighborhoods over time, though admittedly these modest changes do not square with popular narratives of wholesale gentrification-driven displacement. Second, this particular analysis focused on changes in the most transit-friendly neighborhoods with respect to poor residents, immigrants, and zero-vehicle households, while the previous jobs-housing analysis examined all workers across all Bay Area neighborhoods. Most Bay Area workers are not poor, and most do not live in transit-friendly neighborhoods. Increasing housing prices affect all workers, not just poor ones. It may be that lower-wage (but not poor) workers who do not qualify for income or housing subsidies may be particularly affected by rising Bay Area housing prices.

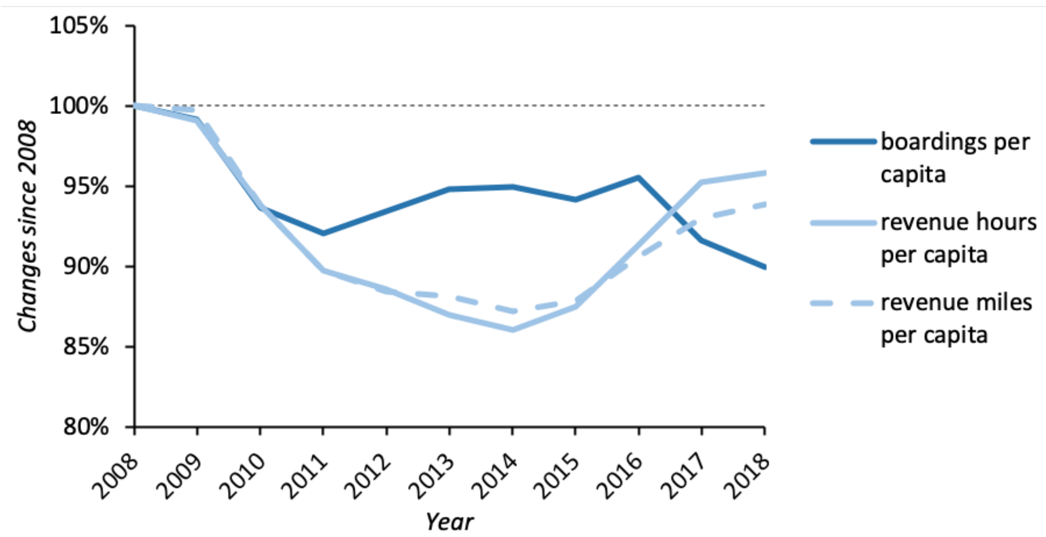
4. **Changes in supply of transit service and rider satisfaction**

We see no evidence that falling ridership is due to falling transit service levels in the Bay Area. While total population-adjusted service levels in the Bay Area have yet to fully return to pre-recession levels, **Figure 17-1** shows that the region mostly added riders between 2011 and 2014 when per capita service levels were falling, and mostly lost riders (though with considerable year-to-year variation) since 2014 when service levels were climbing. As such, it is not possible to attribute declining regional ridership to cuts in transit service.

Nor can we attribute regional ridership declines to service changes on ridership-losing transit agencies alone, since while those Bay Area operators whose 2014-2016 ridership rose did add slightly more service than those whose 2014-2016 ridership fell, both groups added service since 2014 at roughly the same rate, and neither has actually cut service.

Data on changing rider satisfaction for three major Bay Area transit operators—BART, Muni, and VTA—are more mixed. Over the past 15 years, passenger satisfaction has varied, but it is now generally in decline. Bay Area riders typically name frequency. reliability, safety, cleanliness, and crowding as major issues, though concerns vary across operators. While passenger satisfaction on these three systems have all been trending downward in their most recent rider surveys, the link between falling rider satisfaction and falling ridership over the past two years is far from conclusive. Satisfaction fell deeply on BART, for instance, but its ridership has fared better than other major operators. Indeed, its satisfaction started falling as its patronage was booming, given that many common concerns, such as uncleanliness and overcrowding,[20] often result from ridership *gains*, not losses. We note that as ridership has become increasingly peak-period commute oriented, crowding is likely increasing into and out of major job centers, and in addition the increasingly well-off Bay Area transit commuters may have higher expectations than prior survey respondents.

Figure 17-1. Bay Area Boardings per Capita versus Service per Capita



Data source: FTA, 2019 and U.S. Census Bureau, 2011, 2019

20. The degree to which passenger dissatisfaction with crowding affects transit use depends on the alternatives available to passengers. With no or few viable alternatives passengers are likely to continue riding, albeit less happily, while those with other choices—driving, carpooling, switching to express bus service, or relocating their home or workplace to change their commute—are increasingly likely to opt out of riding as crowding worsens.

5. **Trends in transit fares and fare evasion**

Though rising transit fares should, all else equal, lead to less transit use, from 2014 to 2017, changes in fares do not appear to be behind the recent patronage downturn. Accounting for inflation, Bay Area fares per boarding increased at a steady rate for a decade, and Bay Area fares per passenger-mile remained flat due to increasing average trip lengths. During this time, Bay Area transit patronage dropped, lifted, and is dropping again. In the recent patronage downturn, transit operators with increasing average fares fared no worse than their counterparts with flat or decreasing fares. Based on our admittedly limited evidence, we also find no link between fare evasion and ridership patterns.

6. **Changes to costs and subsidies**

A transit system operates efficiently when inputs like spending translate into high levels of outputs supplied to the public, like hours of service. A system operates effectively when those inputs and outputs in turn lead to high ridership. Subsidies are public funds that fill the gap between fare revenues and total expenditures. Subsidy and spending cuts, which were common during the Great Recession, frequently lead to service cuts, particularly if costs are rising.

But in recent post-Great-Recession years, Bay Area transit operators are spending more on transit than ever before, even accounting for inflation, while the overall cost-efficiency of transit service has been declining. Thus, the average cost per hour of vehicle revenue service has increased annually for the past decade. While some large operators have met the MTC's Transit Sustainability Project cost performance metrics, as compared to a baseline at the height of the Great Recession (Pierlott and Associates, 2018 and MTC, 2019d), our analysis considers different time scales and a rolling average of capital costs as well. In spite of this, we do not see evidence that falling cost-efficiency has led to service cuts and falling ridership, as has happened in some other metropolitan areas. Still, increasingly cost-inefficient operations may eventually begin to tax agency resources that could result in service cutbacks that could, in turn, adversely affect future ridership.

7. **Competing mobility options: private automobiles and fuel prices**

Competing mobility options present a mixed picture. In contrast to statewide trends, and in dramatic contrast to Greater Los Angeles, the number of zero-vehicle households in the entire Bay Area declined only slightly, and solo driving for the commute also decreased. We thus conclude that increases in vehicle access and driving have not caused ridership declines. Similarly, we find no evidence of fluctuating fuel prices pushing people on or off transit.

8. **Competing mobility options: ridehail**

Unfortunately, the lack of geographically-refined public ridehail data greatly limits our ability to analyze and understand the effects of ridehailing on transit use. However, the available data for the Bay Area, as well as a growing body of research (that draws data from many different sources around the country) provide waxing circumstantial evidence that ridehail services in the Bay Area are subtracting more transit riders (who substitute ridehail for transit trips) than they add (through better first-/last-mile connections to transit stops and stations).

While this evidence is strongly suggestive, the magnitude of the effect on transit ridership remains ambiguous. Studies show that transit and ridehail tend to serve different travel markets. In addition, ridehail passengers systematically differ socio-economically and with respect to trip purpose from transit travelers. However, ridehail may particularly substitute for transit in the Bay Area. The Bay Area is both dense and transit-rich, and its transit ridership losses have come at off-peak times and from non-work trips. These are each the very travel markets where ridehail use tends to be highest. Moreover, the Bay Area, home of Uber and Lyft, has a greater share of people are ridehail drivers than anywhere else, particularly in San Francisco and adjoining counties. As studies show, the longer ridehail operates in an area, the more it substitutes for transit. Finally, although there were earlier warning signs, transit ridership began falling later in the Bay Area than elsewhere, just as ridehail use ballooned.

9. Competing mobility options: employer shuttles

There has been a rapid increase in employer shuttle commuters in the Bay Area. These shuttle services are collectively quite large, increasing overall regional (*public and private*) transit ridership, but they may pose a particular challenge for *public* transit. Despite this growth, evidence suggests that these services divert relatively few riders from public transit and replace more trips on private vehicles than public transit. In addition, shuttle services may cause other behavioral changes—such as lower rates of car ownership and/or longer-distance commuting—that could have secondary effects on transit ridership. Decreased car ownership might mean that travelers take transit more often (particularly for those living in San Francisco) for non-commute trips. On the other hand, if shuttles allow higher-income workers to live in cities far from their jobs, they may displace other residents who tend to ride transit at even higher rates.

10. Public policy change: driver's licensing for undocumented immigrants

In 2013, California passed AB 60, the Safe and Responsible Drivers Act. Since January 2015, AB 60 has required the DMV to issue driver licenses to applicants who are unable to submit satisfactory proof of legal presence in the United States. By the spring of 2018, the DMV had issued one million licenses under this program. Assuming that at least some of the new AB 60 license holders previously were reliant on transit, changing state driver's licensing regulations may have contributed to declining transit use since 2015.

Unfortunately, there are no available data to analyze this question directly. However, data on changes in commute mode by nativity and legal status do show an increase in driving for the commute among undocumented immigrants over time, and particularly between 2014 and 2016.[21] Furthermore, our multivariate analysis of census data highlights small but noteworthy changes in work-related travel by undocumented immigrants statewide. Specifically, undocumented Mexican immigrants—the largest undocumented population in the state—were slightly more likely to commute by car, slightly more likely to drive to work alone, and slightly less likely to take transit to work after the implementation of AB 60. Unfortunately, data limitations do not allow us to examine non-work travel, and small sample sizes preclude us from focusing specifically on undocumented immigrants in the Bay Area. Thus, while we are able to highlight general trends in the work-related travel of undocumented immigrants statewide, we are unable to draw clear conclusions regarding the impact of AB 60 on Bay Area transit ridership.

21. The region's most significant transit ridership losses have come outside of peak commute times and directions, but we cannot even indirectly analyze the relationship between this and AB 60, as we do not have access to temporal data, nor do we have data on non-commute travel by undocumented immigrants.

17.2. Policy Framework

While our primary foci in this research were on what is happening to transit ridership in the Bay Area and what may be behind these changes, we consider the public policy implications of our findings as well. First, and as noted at the outset, many of the factors affecting transit use lie beyond the direct control of transit agencies, including parking policy, road pricing, housing affordability, regional land use policy, international migration and trade, and global economic expansion or contraction (Taylor and Fink, 2013). Changes in the shares of poor, immigrant, and zero-vehicle households in transit-friendly neighborhoods also make this list. But while all of these factors lie largely beyond the control of transit managers, not all are outside the reach of local and regional policymakers. Thus, stemming recent declines in transit use may require action by policymakers outside of transit agencies to ensure that the region's substantial transit investments pay off. We outline some of these actions below.

Table 17-1. Policy Framework

POLICY CATEGORY	RELATED FINDINGS AND EVIDENCE	CURRENT POLICIES AND PROPOSALS	RECOMMENDATION
TRANSIT OPERATOR POLICIES			
Transit service improvements	*Report Volume II*: Transit ridership has fallen most at off-peak times, in counter-commute directions, and in outlying areas; the most significant determinants of ridership are beyond the control of transit operators	Transit Performance Initiative, Muni Forward, East Bay Bus Rapid Transit, service and network realignment at other operators	Invest in rapid bus/rail services in dense areas with exclusive or semi-exclusive rights-of-way; invest in fleet and operational improvements to increase effective service capacity, reduce crowding, and enhance customer experience; look for ways to improve off-peak services to attract new riders; carefully evaluate proposed transit capital projects on their ability to effectively generate ridership by connecting concentrations of housing and employment, considering land use and development changes as both complements and alternatives
Demand-based fares	*Report Volume I and other research*: Fares increases are not driving recent ridership changes; peak capacity constraints limit the ability of some systems to accommodate increased peak demand; off-peak ridership is declining on many systems	Only a few Bay Area transit systems, notably BART and Caltrain, vary fares by distance	Investigate off-peak incentives to reduce peak crowding, shift some riders to the "shoulders" of peaks, and encourage off-peak ridership
REGIONAL TRANSPORTATION POLICIES			
Regional integration and seamless mobility	*Other research:* Research shows that better information, easier transfers, and more seamless fare payment systems reduce the burdens of transit travel	MTC Connected Transportation/Seamless Mobility effort	Better integrate trip planning and fare payment across jurisdictions and service providers; investigate new mobility pilots to improve first-last mile access to transit and transportation services in areas and times of day with limited transit service

Data on private-sector transportation	*Report Volume I:* General lack of systematic data on private-sector shared mobility, especially ridehail; suggestive evidence of ridehail substitution for public transit	Bay Area Shuttle Census, data-sharing agreements with micromobility companies, Mobility Data Specification	Establish systems to obtain and maintain robust data from private new mobility and micromobility operators on an ongoing basis for public policymaking and planning purposes
Management of private vehicle travel	*Report Volumes I and II and other research*: Auto access and use is strongly and negatively associated with transit use	Express lane network expansion, congestion pricing studies, local performance-priced parking programs	Investigate and pilot-test road- and parking-pricing programs and projects to reduce congestion and increase the relative attractiveness of transit because traffic congestion makes transit less time-competitive and increases operating costs
REGIONAL LAND USE AND HOUSING POLICIES WITH TRANSIT IMPLICATIONS			
Land use near transit	*Report Volume I:* Three out of five Bay Area workers live *and* work in neighborhoods with poor transit access to employment	*Plan Bay Area 2040, Plan Bay Area 2050* development, MTC Resolution 3434	Broaden the focus of TOD to include land-use planning strategies that increase employment and housing densities near one another; consider financial incentives to promote such strategies
Affordable housing and transit	*Report Volume I:* Housing prices are associated with a decline in locally-residing workers, which may be depressing transit use in some areas	*Plan Bay Area 2040, Plan Bay Area 2050* development, CASA Compact	Continue and strengthen involvement in housing-related planning efforts, with the goal of increasing the supply of affordable housing near jobs

17.3. Transit Service Improvements

17.3.1. Findings

Transit ridership in the Bay Area has declined, falling most steeply outside of peak hours and beyond employment clusters, especially downtown San Francisco. While the quantity of transit service and the factors behind rider satisfaction certainly matter a great deal to ridership, the largest determinants of both transit use and peaking are beyond the control of operators. Still, how transit agencies respond to peaking and ridership decline will help determine whether the Bay Area continues to lose riders or whether it returns to its recent upward path.

Even during this period of decline, certain frequent and reliable trunk or Rapid services in dense areas have outperformed other routes. The prime example, SFMTA's Rapid lines, have notably increased their boardings, though as we discuss in Volume II, Chapter , much of their ridership gains likely come from riders shifting from local services on the same corridor. Caltrain's increased service too has paid off with a heartening ridership boom (See Volume II, Chapter 2, Section 3). Broadly, while factors internal to transit systems and their service have only so much influence on ridership, efforts like creating a Rapid network or increasing service to serve new commute patterns have met with success.

17.3.2. Current Initiatives

Seeking to improve transit performance through its Transit Sustainability Project, the MTC has invested $82 million in the Transit Performance Initiative to fund projects targeted at improving transit speed, reliability, and customer service. The Initiative has funded signal priority and stop consolidation projects on a number of large operators: for example, SFMTA's Muni Rapid network, with colored lanes to reduce travel time, and AC Transit's travel-time-savings projects for Line 51 and the San Pablo and Telegraph Corridors (MTC, 2019c). Meanwhile, operators like VTA and County Connection have recently reallocated service and restructured their networks or will do so soon (VTA, 2019b and County Connection, 2019b). SFMTA and AC Transit have continued to invest in their Muni Forward and East Bay Bus Rapid Transit initiatives as well (Rhodes, 2014 and AC Transit, 2019).

17.3.3. Recommendations

Reviving off-peak transit use presents a dilemma for planners. On one hand, policies targeted at increasing non-commute, reverse direction, evening, and weekend trips are of great importance for addressing the most significant declining trip types. On the other, the most significant factors that influence transit use—such as household auto access and free parking at trip ends—tend to be beyond transit agencies' control. Policymakers must therefore decide whether to channel resources towards the most crowded peak-period, peak-direction trips to alleviate crowding and double down on their strongest market, or to improve off-peak, off-direction services where demand is slumping.

There are a number of strategies for restoring off-peak ridership: reducing midday, evening, and weekend headways; adding more service in counter-commute directions; and regulating or working with ridehail companies to make them better complements to transit. Each of these approaches entails both cost and risk, and their individual effects may be small or slow to manifest, though the success of such efforts in other cities, notably Houston, Texas, are promising. Still, increasing reliance on peak trips is very expensive, so a suite of off-peak investments may be worth pursuing.

The more expensive path to expanding ridership is currently being pursued in the Bay Area: increasing peak capacity on systems and routes struggling with peak-period crush loads. Examples here include lengthening trains at rush hour, adding more service in commute directions, creating more transit-only lanes, adding more core capacity at the center of the BART and Muni Metro networks, and eventually constructing a second Transbay Tube. Such strategies will help retain, and may grow peak-hour and peak-direction ridership, although they may do as much or more to improve trip satisfaction and speed for existing riders as to attract new ones.

In isolation, each of these improvements may be worth pursuing, with research and evidence to support their effectiveness, and peak-focused and off-peak focused strategies are not mutually exclusive. But policymakers should recognize that they may still be at odds in a world of limited resources. Moreover, agencies should shape every strategy, as best they can, around the factors that are the most influential determinants of ridership, like job and population density. Service increases, for instance, will do little good if they do not serve major job or activity centers.

Regardless of how operators strike this balance, certain improvements may address the particular contours of the Bay Area's ridership decline. For instance, programs to incentivize travelers to shift their trip-making from peak to off-peak times will both relieve crowding at rush hour and fill underutilized capacity off peak. We discuss below one way to do this: reducing or eliminating fares at off-peak times. Likewise, at both peak and off-peak times, reliable transit service with dedicated rights-of-way will attract riders, better compete with driving, and avoid street congestion, as evidenced by, for instance, SFMTA's Rapid lines. These frequent and separated services can be implemented cheaply and quickly through improvements like tactical transit lanes (Gahbauer and Matute, 2019).

Finally, we suggest a thorough assessment or reassessment of proposed transit capital projects outside of the region's core in light of the findings of this report. Historically, such rail investments have enabled decentralization in the Bay Area (Webber, 1976), and evidence in this report and other studies (Guerra and Cervero, 2011) show that rail stations far from downtown Oakland and San Francisco typically serve relatively few riders and reduce system and line productivity in terms of boardings per service hour. In light of our findings that transit services in outlying parts of the region today have, on average, experienced proportionally larger ridership losses than services in denser areas (See Volume II), we recommend that performance analyses of transit capital projects 1) include specific evaluations of how effectively the project connects *concentrations* of housing to workplaces and 2) consider the development of more housing in job-rich areas as either an alternative or complement to the project.

17.4. Demand-based Fares

17.4.1. Findings

While many of the causes of increased peak ridership, such as continued job growth in major employment agglomerations, are beyond the control of transit managers, transit agencies do have some policy tools to manage peaking and the high costs associated with it. While we do not see evidence in our analysis that rising fares have depressed ridership much, this does not mean that there is no role for pricing transit to increase ridership and without substantially increasing subsidies.

Long distance, peak-hour, peak-direction rail trips tend to cost much more to provide than shorter-distance, off-peak, bus trips (Taylor, Garrett, and Iseki, 2000). Yet most (though not all) transit fares do not account for these differences in marginal costs. On many systems, long peak-hour trips and short off-peak trips are priced similarly. Even on BART and Caltrain, which vary fares by distance traveled, research on transit costs suggests that these variable fares do not fully account for peak-hour or peak-direction differences in costs.

17.4.2. Current Initiatives

To our knowledge, there are no current demand-based fare pilots or programs in the Bay Area based on time of day, day of the week, or direction. Minneapolis-St. Paul, heavy rail in Washington, D.C., and commuter rail in Philadelphia and New York, among others, charge a surcharge at peak periods, variously defined (or offer an off-peak discount, for those who see the glass half full) (Smith, 2009 and MTA, n.d., 2019). D.C.'s WMATA varies fares by both distance and time of day and even experimented with an extra "peak-of-the-peak" surcharge (Tyson and Rein, 2010).

17.4.3. Recommendation

A strategy long favored by transportation economists on both efficiency and equity grounds entails having fares reflect (if not fully cover) the marginal cost of transit trips. Doing so may well increase fares on long-distance, peak-period, peak-direction transit trips that most tax system capacity, but substantially lower fares on shorter, mid-day, evening, and weekend trips where the cost of accommodating such trips is low. Accordingly, we recommend that the MTC work with Bay Area transit operators to explore the potential of variable pricing as part of its regional fare integration efforts.

Technology now allows fine-tuned adjustment of fares based on the time and location of boarding and alighting buses and trains; simpler applications are possible as well. For example, systems could charge somewhat higher fares for peak-hour service but steeply discount fares for off-peak service, which would provide more revenues to support the high cost of accommodating peak-hour trips. Low (or even free) off-peak fares would encourage travelers to take inexpensive-to-accommodate off-peak trips. One way to implement such fares on buses might be to charge the highest base fare on boarding, but reduce the ultimate fare paid based on distance traveled and time if the passenger voluntarily "taps out" as they alight (while those who choose not tap out would be charged the full base fare).

Such pricing can encourage more riders but at little additional cost because systems typically have vehicles and operators available to carry additional off-peak trips (Yoh, Taylor, and Gahbauer, 2016). Most forms of demand-based variable fares are also a more equitable pricing method. According to Walker (2010), "To insist that peak service be priced equally to midday or weekend service is to argue that the riders of those off-peak services should subsidize the peak….As the average peak-period traveler usually has a higher income than an average midday traveler…insisting on flat fares all day could actually be seen as regressive."

17.5. Regional Integration and Seamless Mobility

17.5.1. Findings

While the Bay Area transportation is delivered by a wide array of organizations—the state, counties, cities, special purpose districts, joint planning authorities, and private companies as well—travelers make trips from origins to destinations mostly without regard administrative and jurisdictional boundaries. Thus, how these various actors coordinate—or fail to coordinate—their infrastructure and services can have a substantial effect on public transit use.

For example, we find in this research strong suggestive evidence that transportation network companies like Lyft and Uber both complement and, especially, compete with public transit services. While (as we discuss below) public sector planners currently lack sufficient information to fully understand these complementary and competing effects on transit use, there is no doubt that coordination among the transportation network companies and public transit operators is often lacking or in its infancy. This lack of coordination may inhibit movement across these modes, and create other disruptions at transit stations not designed with substantial ridehail boarding and alighting in mind.

Further, the private actors in this realm are not confined to transportation service providers. Private sector information providers, like Google, now offer navigation apps that allow travelers to compare routes and modes in trip planning. Other apps, developed both privately and under the auspices of public agencies, seek to promote "mobility as a service" (MaaS), whereby users can more easily plan, book, and pay for trips that involve multiple modes.

17.5.2. Current Initiatives

Building on the success of regional cooperative efforts like Clipper cards, FasTrak, the Regional Transit Connection Discount ID Card for transit users with disabilities, the MTC has launched a new Connected Transportation/Seamless Mobility effort under the auspices of the Bay Area Partnership Board (Bay Area Partnership Board, 2019). As broadly defined currently, the goals of this effort include investing in local pilots and regional efforts to foster a more connected transportation system. Examples of programs being explored and pursued include regional fare integration, pilots with new mobility providers to provide first-/last-mile connections to transit, and a unified transportation demand management strategy. Specific initiatives of note include BART's multimodal trip planner, Muni's real-time information and service announcements, and VTA's service redesign and micromobility programs.

17.5.3. Recommendations

As the Bay Area, a global leader in information and communications technology innovation, moves increasingly toward integrated public/private trip planning and payment services, known as "Mobility as a Service" business models, traditional public transit services—some of which have been operating for better than a century—need to be fully integrated into them. Accordingly, we recommend that the Bay Area Partnership Board initiate a customer-oriented transportation program, with near-term actions focused in three areas. First, they should work to advance technology platforms that integrate trip planning and fare payment across jurisdictions and service providers. Travelers should be able to seamlessly pay for a ride on any transit operator (or combination of operators) the way they pay for anything else—by credit card, by mobile app, or by cash for the unbanked—instead of having separate, non-fungible accounts and applications for each operator. Second, they should explore and evaluate new mobility pilots, either in partnership with private sector mobility providers of various stripes or operated publicly, to improve first-last mile access to and from transit stations as a potential alternative to traditional fixed-route transit service in suburban parts of the region, where subsidies of traditional transit service are high and the utility of this service is low. And third, they should work to develop regional support for policy standards, such as standards for data-sharing with private ridehail and other shared mobility operators, discussed below.

17.6. Data on Private-sector Transportation

17.6.1. Findings

Most Bay Area mobility planning—and indeed the policy analysis and recommendations above—suffer from a blindspot: a lack of systematically collected data on private-sector transportation. Between corporate shuttles, transportation network companies, new mobility enterprises like scooter-share, informal economy jitney and bus services, and private ferries, for-profit shared mobility has perhaps a greater market share in the Bay Area than any other American metropolitan area. Yet a full picture of the scale and reach of those operations is not known. With some small exceptions, policy makers, planners, and researchers—much less the public—do not have access to data on how many trips are taken by such modes, where these trips begin and end, at what times and on what days these trips occur, how many people share each ride, how much operators charge, and how operators compensate their drivers.

These data are especially necessary in light of the findings of this report. What limited data we have suggest that ridehail is net substituting for public transit, and increasingly so. At the least, we can say that if ridehail is eating into transit's market share anywhere in the U.S., it is in the Bay Area, where it began and where it has the most drivers per capita. Moreover, the dramatic off-peak losses in transit patronage line up with the trip markets in which ridehail is most concentrated. Any steps to help ridehail complement transit rather than substitute for it must begin with a better understanding of when, where, and how ridehail and other private shared mobility services operate.

To be sure, private personal mobility—individually owned cars—account for far more trips than private shared mobility, and we do not wish to exaggerate the role of the latter at the expense of the former. But without good data, the role of the private shared mobility, whatever its size, cannot truly be explored.

17.6.2. Current Initiatives

The Bay Area is not entirely bereft of information on private mobility. As detailed in Chapter 15, the Bay Area Shuttle Census, SFMTA's commuter shuttle permit program, and various surveys have given some definition to the private shuttle landscape (Bay Area Council and MTC, 2016; SFMTA, 2015, 2018; and Dai and Weinzimmer, 2014). Meanwhile, the innovative methods by the

SFCTA to measure ridehail in San Francisco produced a revealing dataset of Uber and Lyft trips within San Francisco (See Appendix D, Section 2, Subsection 3.2) (Castiglione et al., 2017). But ridehail companies have closed off SFCTA's data collection approach, leaving this one rich snapshot unreplicatable. Still, the SFCTA has used these data to estimate the congestion effects of ridehail in recent years (Castiglione et al., 2018).

Learning lessons from the rapid rise of ridehail, Bay Area municipalities have better managed to establish data-sharing agreements with and collect and disseminate data from new mobility services. For instance, San Francisco's scooter-share pilot program includes a real-time data-sharing requirement for participating operators, utilizing the Mobility Data Specification (MDS) (Leung, 2018 and SFMTA, 2019b). Such efforts are not without pushback: Uber, as of writing, is threatening to sue Los Angeles over MDS (Hawkins, 2019). But the more systemic and more proactive approach cities have taken to scooter-share and dockless bikeshare will enable better planning outcomes through better data.

17.6.3. Recommendations

To implement many of the policies above effectively requires not just comprehensive data on private shared mobility services but also a robust data framework to enable ongoing evaluations and support myriad planning efforts. Through voluntary agreements, permitting programs, or changes in laws and regulations, the MTC and its local government partners should ensure a continuous, real-time, and perpetual stream of data from private new mobility and micromobility operators. These data should be provided in a common format like the Mobility Data Specification. Obtaining such data may have benefits in many areas of planning and policy, but it is particularly necessary to understand the current dip in public transit use.

Other than Uber's Movement tool (Uber Technologies, 2019)—which does not cover the entire Bay Area and does not provide trip data at levels disaggregated enough to be useful in mobility planning (Marshall, 2019)—ridehail companies only regularly share their data at scale with the California Public Utilities Commission (CPUC) (SFCTA, 2017). Accordingly, we suggest that the MTC and other stakeholders work through the CPUC rulemaking process or other mechanisms so that these data become widely available for policy, planning, research, and regulatory purposes. New York City, for instance, systematically collects data on ridehail trip pickup and drop-off locations and times (New York City Taxi and Limousine Commission, 2019), with new information on fares, wages, and wheelchair-accessibility and more detailed GPS positions on the way (Marshall, 2019). New York offers a model for the robust collection and sharing of data, which has enabled numerous analyses to date (New York City Department of Transportation, 2019; Bialik et al., 2015; Silver and Fischer-Baum, 2015; Fischer-Baum and Bialik, 2015; and Bialik, Fischer-Baum, and Mehta, 2015).

In the nearer term, cities, counties, and transit agencies do have opportunities to secure data from private shared mobility operators at least on a smaller scale. For instance, some California cities and transit operators currently contract with ridehail firms to supplement transit service and provide paratransit. Where they do, the public agency should stipulate robust data-sharing procedures. Likewise, cities should mandate comprehensive data-sharing as a key provision of any micromobility permitting program, as municipalities like San Francisco have already begun to do. We suggest that the MTC work with local governments in the region to develop systematic and compatible reporting protocols to insure the collection of useful and comparable data.

17.7. Management of Private Vehicle Travel

17.7.1. Findings

Even in relatively transit-rich regions like the San Francisco Bay Area, private vehicles dominate personal travel. While the region is home to the population- and employment-dense central cities of San Francisco and Oakland, new development in the region for most of the past century has occurred in outlying areas at relatively low densities that are much friendlier to driving than riding public transit. These driving-friendly areas have been supported by public policies like single-family residential zoning, minimum parking requirements, and wide, divided boulevards and arterials.

We show in this report that auto access is strongly and negatively related to transit use. Members of zero-vehicle households use public transit much more than those in vehicle-deficit households, while those in vehicle-deficit households use transit more than those in fully equipped households. Put simply, those with vehicles tend to drive more and ride transit less.

The ubiquity of driving generates numerous well-documented problems, including chronic traffic congestion, air pollution and greenhouse gas emissions, safety concerns for pedestrians and cyclists, parking demand that often exceeds supply, and isolation for those unable to drive. But while the problems arising from the use of private vehicles for most trips are unpopular, and public officials are often lobbied by their constituents to address them, driving remains very popular with most travelers. This paradox has caused most regions in the U.S. to focus more on encouraging alternatives to driving—such as carpooling, public transit use, and cycling—and less on managing driving. So even in the most densely developed and congested parts of the Bay Area, like downtown San Francisco, private vehicle owners can consume scarce road space as much as they want anytime they want.

The result of all of this unmanaged driving is chronic traffic congestion that slows everyone down, including public transit; it also increases emissions and makes places less attractive to walk or cycle. While such congestion can increase the use of public transit services that operate in their own rights of way, like BART, most Bay Area transit, including almost buses and much of its rail service, operate in or across mixed traffic. On these lines, worsening congestion discourages transit use because transit travel times tend to be longer than driving, particularly in congested conditions.

17.7.2. Current Initiatives

In a state where we call our highways "freeways," tolled roads are few and dynamically tolled roads even fewer. The bridges over San Francisco and Suisun Bays have long been tolled, most with flat rates and the Bay Bridge with a $2 upcharge during peak hours (FasTrak, 2019 and Bay Area Toll Authority, 2019). More recently, dynamically priced "express lanes" have opened on a few major highways in the region, with more under construction (MTC Geographic Information Systems, n.d.). The MTC plans to operate 600 miles of express lanes by 2035 (MTC, 2019a).

Bay Area policymakers have mulled a comprehensive congestion pricing mechanism for at least the past decade. San Francisco's peninsular geography makes the city a natural candidate for a cordon or gateway pricing model. In 2010, the San Francisco County Transportation Authority (SFCTA) (2010) studied various models of congestion pricing; their mobility effects; and their financial, technological, and institutional requirements. In the past two years, this work has been renewed with a fresh study and outreach effort (SFCTA, 2019 and Dentel-Post, n.d.).

While less often discussed at the regional level and more often at the local scale, performance-priced parking has had wider implementation to date in the Bay Area. San Francisco, Oakland, and Berkeley, for example, each operate branded demand-responsive parking programs in parts of their municipalities (SFpark, Park Oakland, and goBerkeley, respectively) (SFMTA, 2019c; Oakland, 2019; and Berkeley, 2019). SFpark, for one, has expanded citywide (Jose, 2017). Though not without issues—evaluations have faulted its reactive price-setting, the low visibility of its prices (Pierce and Shoup, 2013), and political missteps in its rollout (Manville, 2018)—SFpark has successfully increased parking availability and turnover and reduced VMT and congestion (SFMTA, 2014a).

17.7.3. Recommendations

Recent drops in Bay Area transit ridership are occurring amidst increasing private vehicle use, worsening traffic congestion, and increasing concerns about vehicle emissions. Better management of the road network would increase economic efficiency, reduce delays, and make traveling by means other than solo driving (including riding public transit) more attractive. While motorists have long been wary of any efforts to meter road use, public outcry over worsening chronic congestion has motivated road- and parking-pricing programs and pilots in the Bay Area and around the U.S. to manage traffic congestion and generate needed revenues for transportation improvements.

These programs and pilots can significantly benefit transit by encouraging drivers to consider less costly alternatives to driving, including taking transit, and by making transit more attractive, particularly for short trips, by reducing street traffic and cruising for parking that slows down buses and streetcars. For these reasons, current regional pricing plans, programs, and pilots should be viewed and evaluated as important pro-transit policies.

17.8. Land Use near Transit

17.8.1. Findings

Traditional fixed-route, fixed-schedule public transit works best in densely developed, mixed-use environments where destinations (and stops and stations) are easy to reach by foot, large numbers of people travel in the same direction at the same time, and parking is scarce and expensive. In the Bay Area, much of San Francisco, particularly the northeast quadrant of the city, fits this description. Moreover, transit works best when both the origin and destination of a transit trip are in transit-rich environments.

Even if a trip ends at a dense, walkable downtown, it is unlikely to be made by transit if there is no convenient stop near the trip origin. Research suggests that adding housing around other transit nodes outside of central cities may have only minor effects on ridership, as residents may use transit occasionally but drive for most trips in otherwise suburban settings. Even in densely populated areas, a TOD may actually reduce ridership absent strong affordability protections or requirements. People who move into new TODs may use transit more than they used to, but may replace or displace lower-income residents who rode transit much more than the new arrivals (Dominie, 2012).

While the percentage of Bay Area workers and jobs located in high-density areas that have high transit access to employment has increased in recent years, as of 2015, more than three out of five Bay Area workers both lived and worked in what we classify as neighborhoods with poor transit access to jobs, likely making it difficult for them to commute to work by transit. Moreover, higher-wage jobs and workers are more likely to be located in areas with high transit employment access than lower-wage jobs and workers—even though lower-wage workers are more likely to rely on transit than higher-wage workers.

17.8.2. Current Initiatives

Recognizing that fostering jobs and housing concentrations in the region can significantly affect transit ridership, among other benefits, the MTC and many municipalities have encouraged transit-oriented development. *Plan Bay Area 2040*, for instance, the MTC and ABAG's (2017) long-range Sustainable Communities Strategy, calls for substantial employment and housing growth near transit. The plan anticipates that over two-thirds of new housing and jobs will occur in Priority Development Areas around high-quality transit stops. Earlier, MTC Resolution 3434 (2005) set thresholds for housing density around transit capital expansions that must either be met by existing or permitted development as a condition of funding. The policy also station-area land-use and circulation plans and creates corridor working groups of stakeholders.

17.8.3. Recommendations

While we applaud existing efforts to promote equitable transit-oriented development in the Bay Area, we suggest broadening the TOD concept beyond primarily locating residences adjacent to rail transit lines. First, long-range plans to build transit ridership should not only put housing near transit but also *jobs* near transit, as our research suggests that transit-adjacent jobs are increasingly powerful generators of transit use. A study of Bay Area employment by the MTC's Horizon Initiative—which, like our study, finds that jobs are generally decentralizing even as there is some new concentration near transit (See Chapter 7) (MTC and ABAG, 2019, p. 47)—also recommends building jobs near transit hubs. "Due to the longstanding Bay Area housing crisis, urgency has centered on getting housing built," the report states." However, jobs may be at least as suitable a focus for strategic near-station areas" (MTC and ABAG, 2019, p. 54).

Better yet, policies to locate more housing near job centers generally, will likely encourage transit ridership growth because transit use (in the Bay Area and elsewhere) is highest in relatively dense agglomerations of employment and housing. Land-use planning strategies to increase employment and housing density together, with well-designed affordability and anti-displacement policies, can restore demand for off-peak transit use and still retain peak transit riders across the region.

Transit-oriented development should be planned with more than just station-adjacent considerations in mind; it should encompass a variety of higher density, mixed use districts served by multiple types of transit service, including high-quality bus service. This broader perspective could entail efforts to increase the production of higher-density multi-unit housing in already built-up job centers to enable shorter commutes and to increase the relative attractiveness of transit (which is typically slower than driving). While such land use decisions are largely the domain of local governments, the MTC could motivate more transit-friendly development by increasing the housing and employment thresholds in its TOD policy , as recommended in the development of *Plan Bay Area 2050* (MTC, 2019b). The Horizon Initiative report, for instance, calls for financial incentives to densify employment in PDAs near transit (MTC and ABAG, 2019, p. 71). The MTC could also expand its TOD policy by tying more funding sources, beyond transit capital expansion dollars, to TOD thresholds; this could involve stipulating rezoning near existing stops and stations or more generally zoning to better connect employment and housing as a funding condition. This updated policy could also consider transit access, including the use of new mobility services and other first- and last-mile connections, for both employment and residential development when updating guidelines for transportation and land-use planning programs such as the Priority Development Areas Planning and Technical Assistance and OneBayArea Grant programs.

17.9. Affordable Housing and Transit

17.9.1. Findings

Bay Area cities are growing less self-contained over time as measured by the percentage of workers who work and live in a city relative to all other residents and workers. This trend is associated with increased housing prices, suggesting that at least some workers have difficulty finding affordable housing in close proximity to their jobs.

17.9.2. Current Initiatives

As we note above, *Plan Bay Area 2040* anticipates growth in housing and jobs in priority development areas located near public transit (MTC and ABAG, 2017). In addition, the MTC recently convened the Committee to House the Bay Area (CASA). The CASA Compact (2019) is a 15-year set of policies to address the Bay Area housing crisis. It includes specific policy reforms to increase housing production at all levels of affordability, preserve existing affordable housing, and protect vulnerable populations from housing instability and displacement. The effort involves the MTC and leaders from the region's private, philanthropic, governmental, and nonprofit sectors.

17.9.3. Recommendations

Employment in the Bay Area has been growing faster than housing, particularly in the central, transit-rich parts of the region. This chronic undersupply of housing, particularly near burgeoning job centers, has dramatically increased housing prices across all segments of the Bay Area housing market and is almost certainly behind the substantial increases in commute distances. Policies to enable more housing supply, particularly in job-rich, transit-friendly parts of the region will help ease upward pressure on both housing prices and commute lengths.

Further, transit use in the Bay Area remains highest among individuals living in low-income households, even as the average income of transit riders has been increasing. Therefore, a policy focus on increasing housing and employment in transit-rich areas (both inside and outside PDAs) must include efforts to ensure that low-income households can continue to live in and move into these neighborhoods. The California Department of Housing and Community (HCD) Development mandates that local governments plan for the housing needs of their residents through the Regional Housing Needs Allocation process. HCD determines the total number of new units required in each region, including the number of affordable units. ABAG then develops a methodology to distribute these new housing units across jurisdictions in the region. Unfortunately, this process tends to result in the allocation of much affordable housing to far-off areas with lots of developable land, but does little to encourage housing production in cities like San Francisco where housing is most expensive and demand is highest (Monkkonen, Manville, and Friedman, 2019).

Neither the MTC nor Bay Area transit agencies are responsible for housing policy; however, given the important relationship between housing and transit use, we recommend that the MTC continue and strengthen its involvement in housing-related planning efforts in the region, specifically by advocating for more housing, including affordable housing, near jobs. Increasing housing production, especially affordable housing, in already built-up areas is both challenging and expensive. But increasing housing density in transit-rich areas will help restore and grow transit ridership, particularly if it enables low-income families to live closer to jobs.

Additional affordable housing also may indirectly improve rider satisfaction. While we find little evidence that the presence of people experiencing homelessness on transit and other "quality of ride" concerns are discouraging patronage, such factors are depressing surveyed passenger satisfaction. More affordable housing can help house at least some of those now experiencing homelessness and can reduce the number of people literally forced underground into transit stations and onto transit vehicles in search of shelter. This is not a short-term solution, to be sure, but it is a far more equitable than sweeping unhoused people out of stations in the name of restoring ridership or passenger satisfaction.

Appendices

Appendix A. Key Terms

Boardings:

Unlinked passenger trips

Because the NTD (FTA, 2019) and most operator datasets do not track intra-operator transfers—let alone inter-operator transfers—a transfer therefore counts as two boardings. BART's origin-destination matrices, discussed further in Volume II, Chapter 3, are an exception (BART, 2019c).

Car-free neighborhood:

Census tracts with many zero-vehicle households but low levels of poverty; areas with many zero-vehicle households by choice (See Appendix C, Section 4, Subsection 1.1 for classification methodology)

Car-less neighborhood:

Census tracts with many zero-vehicle households but high levels of poverty; areas with many zero-vehicle households due to financial constraints (See Appendix C, Section 4, Subsection 1.1 for classification methodology)

Central Bay Area Counties or Central Bay Area:

The San Francisco-Oakland-Berkeley Metropolitan Statistical Area, defined by the U.S. Census Bureau, including Alameda, Contra Costa, Marin, San Francisco, and San Mateo Counties

For a few data sources in which we lack available data to conduct an analysis at the level of the full Bay Area, we consider only the central Bay Area —i.e, the San Francisco-Oakland-Berkeley Metropolitan Statistical Area, formerly known as the San Francisco-Oakland-Fremont Metropolitan Statistical Area and the San Francisco-Oakland-Hayward Metropolitan Statistical Area.

Costs or expenses:

Sum of annual operating expenses and a ten-year rolling average of capital expenses (five years prior to four years after, as available)

Since capital costs often rise and fall dramatically as agencies incur one-time expenses for large projects every few years, a rolling average smooths out costs for fairer comparisons. In our analyses and figures, we converted all monetary values to 2018 dollars, except where noted (Bureau of Labor Statistics, 2019).

Fully equipped household:

A household that owns at least one vehicle per household driver

Greater Los Angeles or the Los Angeles Area:

The six counties covered by the Southern California Association of Governments: Imperial, Los Angeles, Orange, Riverside, San Bernardino, and Ventura (but notably not San Diego)

Based on the UCLA Institute of Transportation Studies' prior work on falling transit ridership in Greater Los Angeles (Manville, Taylor, and Blumenberg, 2018a), we use Greater Los Angeles as a comparison to the San Francisco Bay Area at a number of points throughout this report.

Los Angeles and Orange Counties:

The Los Angeles-Long Beach-Anaheim Metropolitan Statistical Area, defined by the U.S. Census Bureau, including Los Angeles and Orange Counties

PMT:

Person-miles traveled (in the context of individual and household travel behavior) or, equivalently, passenger-miles traveled (in the context of transit operators)

R^2 value:

The share of the variation in one factor explained by the variation in another factor or set of factors; also called the coefficient of determination

San Francisco Bay Area or the Bay Area:

The nine counties covered by the Metropolitan Transportation Commission (MTC): Alameda, Contra Costa, Marin, Napa, San Francisco, San Mateo, Santa Clara, Solano, and Sonoma

Self-containment:

The share of an area's internal work trips (work and live inside a city) relative to external work trips (work outside the city or live outside the city); extent to which workers find housing and employment in the same spatial area

Subsidies:

Costs less fare revenues; the net public funds spent on transit

In other circumstances, we would also subtract other revenue sources like advertising from costs in calculating subsidies, but the NTD does not break down other revenues by mode (FTA, 2019). Since much of our examination of subsidy trends compares between modes, we therefore left out these (relatively small) miscellaneous revenue sources from all analyses, for consistency.

Transit-friendly neighborhood:

An area with a high supply or use of transit, as specifically defined three ways in Chapter 8, Section 2, Subsection 1

Transportation Network Companies (TNCs), ridehail, or ridehailing:

Transportation Network Companies (TNCs) include major companies like Uber and Lyft, which provide ridehail services. Similar to taxi companies, Uber and Lyft offer transportation with greater technological integration. The companies operate smartphone applications, in which a user selects a starting and end point. After summoning the ride, a driver (also using the application) picks up and then delivers the rider to the destination. The fare is paid entirely through the computer application, and the TNCs take some portion of the fare as a fee.

In the exchange, the TNCs set prices, often through dynamic pricing systems based on passenger demand. More recently, Uber and Lyft have offered services that allow for riders with different destinations, who usually do not know each other, to travel in the same vehicle. These services—called UberPool and Lyft Line—charge lower fares.

Vehicle-deficit household:

A car-owning household that owns less than one vehicle per household driver

Zero-vehicle household:

A household that no vehicles, for whatever reason

Appendix B. Data Sources

Table B-1. Major Data Sources

DATA SOURCE		YEARS	CHARACTERISTICS	CITATION
National Household Travel Survey (with California oversample)		2009, 2017	Characteristics of transit users and their transit travel (income, poverty, nativity, mode, race/ethnicity, vehicle availability, commute mode, miles travelled per day, share of daily trips by transit)	FHWA, 2009, 2017
National Transit Database		2000-2016	Annual absolute and per capita boardings, passenger miles traveled, vehicle revenue hours, vehicle revenue miles, operating expenses, capital expenses, and fare revenues by operator, urbanized area, MPO, mode, and whether the service was directly operated or contracted out under a purchased transportation agreement	FTA, 2018
Operator Data	SFMTA/Muni internal data	FY98-FY18	Boardings by mode and route	SFMTA, 2018a
	BART internal data	2001-2018	Origin-destination matrix of trips by station pair, day of the week and time of day	BART, 2019c
	AC Transit internal data	FY15-FY18	Boardings, trips, and revenue hours by day of the week, time of day, route, route type, and headways	AC Transit, 2018
	VTA internal data	2015-2018	Boardings, trips, revenue hours, and revenue miles by day of the week, time of day, mode, and route	VTA, 2018
	Caltrain internal data	2008-2018	Boardings and alightings by day of the week, train, and station	Caltrain, 2018
	SamTrans internal data	2011-2018	Boardings by day of the week and route	SamTrans, 2019
	GGT internal data	FY15-FY19	Boardings by day of the week, time of day, route, and direction	GGBHTD, 2019
	County Connection internal data	FY10-FY19	Boardings, trips, revenue hours, and revenue miles by day of the week, time of day, and route	County Connection, 2019a

DATA SOURCE		YEARS	CHARACTERISTICS	CITATION
Passenger Surveys	SFMTA ridership survey	2001-2018	Customer satisfaction and passenger survey reports	Corey, Canapary, and Galanis Research, 2018
	BART customer satisfaction survey	1996-2018	Customer satisfaction and passenger survey reports	BART and Corey, Canapary, and Galanis Research, 2019
	VTA on-board transit passenger survey	2013, 2017	Customer satisfaction and passenger survey reports	ETC Institute, Inc., 2017
Public Use Microdata Sample (PUMS)		2000-2017	Age, race, ethnicity, disability status, educational attainment, income, nativity, year of entry for foreign born, poverty status, income, vehicle availability, commute mode, central city/suburban status	Ruggles et al., 2019
American Community Survey, Five-year Estimates		2000-2017	Transit commuters, race, ethnicity, income, housing costs, housing tenure	U.S. Census Bureau, 2019
Longitudinal Employer-Household Dynamics Origin-Destination Employment Statistics (LODES)		2002, 2015	Counts of workers by commute, wage, and spatial location	U.S. Census Bureau, n.d.
Access Across America: Transit		2015	Transit access to jobs by census block	Owen and Murphy, 2018
U.S. Energy Information Administration (EIA) Weekly Retail Gasoline Price Estimates		2000-2019	Gasoline prices by state and major metropolitan statistical areas	EIA, 2019
Nonemployer Statistics		2010-2016	Number of taxi and limousine (Including TNC) establishments	U.S. Census Bureau, 2019

Appendix C. Methodology

C.1. Methodology: Transit User Trends

The following describes the methodology used for the analysis in Chapter 5.

C.1.1. National Household Travel Survey

While data from the NTD is useful for tracking ridership trends, the data are not associated with the characteristics of the travelers themselves (FTA, 2019). Therefore, for the analysis of transit user trends, we rely on data from the National Household Travel Survey (FHWA, 2009, 2017). Each iteration of the NHTS collects a single-day travel diary from households and individuals across the U.S. While the NHTS is national in scope, both the 2009 and 2017 surveys include a special California add-on sample that allows us to specifically focus on statewide transit usage trends in the time period between these two survey years. The 2009 California add-on contains data from just over 21,000 households and nearly 45,000 individuals statewide, including 2,239 households and 3,975 adults in the central Bay Area counties; the 2017 NHTS California sample includes over 26,000 households and 56,000 people, with 2,309 of these households and 4,106 adults residing in the central Bay Area counties. The data contain a wealth of household- and person-level characteristics in addition to travel data.

C.1.2. Determinants of Transit Use

To supplement the descriptive data in Chapter 5, Section 2, we also performed a multivariate analysis in which we control for a number of confounding factors in order to isolate associations between socioeconomic variables and transit ridership. We specify separate negative binomial regressions for each of the NHTS survey years (2009 and 2017), and for three geographies (the central Bay Area counties, the state of California, and Los Angeles and Orange Counties). The number of trips taken on the survey day functions as the dependent variable. Most often, this type of modeling exercise serves as a means of isolating the relationship between a predictor variable and an outcome variable at a single point in time. Here, however, we take advantage of the fact that we have survey data from both 2009 and 2017, and use these models as a way to identify features associated with temporal changes in transit use frequency. Specifically, we compare coefficients from the 2009 models to those of the 2017 models. This comparison allows us to identify socioeconomic and demographic characteristics that are associated with notable increases or decreases in the number of expected transit trips. **Table C-1** provides the results of six negative binomial regressions: central Bay Area models for 2009 and 2017; all-California models for 2009 and 2017; and Los Angeles and Orange County models for 2009 and 2017.

Table C-1. Determinants of Transit Trips—Multivariate Model Results

	DEPENDENT VARIABLE: UNLINKED TRANSIT TRIPS (SURVEY DAY)					
	CALIFORNIA		CENTRAL BAY AREA COUNTIES		LOS ANGELES AND ORANGE COUNTIES	
	2009	2017	2009	2017	2009	2017
Race/Ethnicity (Base: Non-Hispanic White)						
Non-Hispanic black	0.268	0.964***	0.028	0.318	0.136	0.815**
	(0.194)	(0.153)	(0.346)	(0.254)	(0.317)	(0.308)
Non-Hispanic Asian	0.345*	0.576***	0.029	0.024	0.065	0.363
	(0.153)	(0.112)	(0.241)	(0.150)	(0.279)	(0.247)
Hispanic	0.304**	0.162	0.054	-0.125	0.616***	0.498*
	(0.112)	(0.098)	(0.260)	(0.205)	(0.185)	(0.206)
Non-Hispanic other	-0.106	0.373**	-0.030	0.013	0.501	0.462
	(0.201)	(0.134)	(0.364)	(0.227)	(0.335)	(0.351)
Household Income (Base: under $10,000)						
$10,000-$25,000	-0.064	-0.259	-0.074	-0.107	0.004	-0.159
	(0.169)	(0.167)	(0.418)	(0.429)	(0.267)	(0.369)
$25,000-$35,000	-0.575**	-0.226	-0.606	0.090	-0.040	-0.085
	(0.199)	(0.183)	(0.481)	(0.457)	(0.306)	(0.406)
$35,000-$50,000	-0.577**	-0.480**	-0.312	0.476	-0.533	-0.827
	(0.187)	(0.181)	(0.412)	(0.431)	(0.309)	(0.431)

$50,000-$75,000	-0.472*	-0.353*	0.149	0.562	-0.827*	-0.494
	(0.187)	(0.169)	(0.397)	(0.407)	(0.328)	(0.379)
$75,000-$100,000	-0.339	-0.486**	0.202	0.184	-0.469	-0.393
	(0.191)	(0.175)	(0.402)	(0.412)	(0.327)	(0.385)
$100,000+	-0.376*	-0.031	0.077	0.561	-1.003**	-0.741*
	(0.178)	(0.156)	(0.380)	(0.388)	(0.318)	(0.356)
Nativity (Base: U.S.-born)						
Foreign-born	0.312**	0.239**	0.311	0.032	0.383*	-0.010
	(0.104)	(0.091)	(0.196)	(0.135)	(0.170)	(0.191)
Automobile Ownership (Base: Fully Equipped)						
Vehicle-deficit	1.712***	0.796***	1.383***	0.608***	1.579***	0.635**
	(0.096)	(0.092)	(0.190)	(0.135)	(0.168)	(0.230)
Zero-vehicle	2.782***	2.542***	2.150***	1.600***	2.507***	2.035***
	(0.142)	(0.133)	(0.271)	(0.194)	(0.229)	(0.313)
Population Density (Base: Low Density)						
High Density	1.100***	1.108***	1.212***	0.834***	0.473**	0.638***
	(0.090)	(0.078)	(0.175)	(0.118)	(0.159)	(0.170)
Very High Density	1.728***	1.827***	1.396***	1.059***	0.893***	0.976***
	(0.157)	(0.145)	(0.222)	(0.151)	(0.228)	(0.254)

Constant	-4.061***	-3.677***	-3.463***	-2.748***	-3.703***	-3.110***
	(0.170)	(0.154)	(0.388)	(0.393)	(0.291)	(0.363)
Observations	35,494	45,726	3,705	4,007	7,802	5,637
Log Likelihood	-4,995.02	-7,537.39	-1,083.60	-2,058.15	-1,455.71	-1,223.29
Theta	0.067***	0.058***	0.142***	0.208***	0.101***	0.073***
	(0.004)	(0.003)	(0.019)	(0.019)	(0.011)	(0.009)
AIC	10,022.040	15,106.770	2,199.207	4,148.292	2,943.425	2,478.583

** significant at a 95 percent confidence level*
*** significant at a 99 percent confidence level*
**** significant at a 99.9 percent confidence level*
Standard errors are in parentheses.

Data source: FHWA, 2009, 2017

C.1.3. Transit User Types: Latent Profile Analysis

Along with this traditional multivariate modeling approach, we also perform a latent profile analysis. With LPA, we can use a latent variable mixture model to group observations—here, transit users—into unobserved classes (Muthén, 2001). Scholars often differentiate between latent profile analyses, which often use only continuous independent variables, and latent class analyses, which use categorical variables. In practice, however, the differentiation is unnecessary, as LPA and LCA use the same model structure, which can accommodate both variable types (Muthén, 2001; Muthén and Muthén, 2002; and Pastor et al., 2007).

Performing an LPA first requires us to determine the travel-behavior characteristics that differentiate one group of transit users from another. For example, a wealthy suburbanite who uses rail transit to commute into a central business district represents a very different type of transit user from a poor urban resident who relies on bus transit to carry out his or her daily errands. Because we want to identify the underlying groups that these types of travelers belong to as well as track the relative size of these groups over time, we must select as many meaningful travel behavior indicators as possible to function as independent variables in our LPA.

To this end, we include four types of variables that the literature suggests might distinguish various “classes” of transit users: the extent to which an individual rides transit; an individual’s relative dependence on public transportation; the availability of alternative modes of travel; and the type of transit an individual uses. Unfortunately, our analysis is somewhat limited by the fact that we only have data for a single travel day, meaning that we are not able to categorize all transit users—instead, we can only assess the travel behavior of individuals who used transit on the survey day. **Table C-2** provides a description of the variables included in the LPA.

Table C-2. Independent Variables for Latent Profile Analysis

VARIABLE		TYPE	RANGE
Extent of Transit Use	Number of transit trips (survey day)	continuous	1-7
	Transit PMT (survey day)	continuous	0.1-150
	Number of transit trips (past month)	continuous	1-150
Relative Transit Dependence	Percent of trips on transit	continuous	7-100
	Percent of PMT on transit	continuous	0.2-100
Availability of Alternatives	Driver’s license	categorical	yes; no
	Household vehicle ownership	categorical	zero-vehicle; vehicle-deficit; fully equipped
Transit Type	Mode of transit used	categorical	bus only; rail only; mix

Data source: FHWA, 2009, 2017

The models used in LPA do not specify an optimal number of latent classes; instead, analysts generally estimate models for a range of class solutions, and use one or more fit statistics to determine the ideal number of classes. In our analysis, we test solutions ranging from two to eight classes, and use the Bayesian Information Criterion (BIC) to determine the relative quality of each model fit (Nylund, Asparouhov, and Muthén, 2007). While the BIC improves with each increasing number of classes, we find that class sizes become extremely small beyond a three-class solution (often under 3% or 4% of the sample), making interpretation of the outcomes somewhat more difficult and less meaningful, and reducing the number of individuals in these classes to a level that would inhibit further statistical analysis. Therefore, we choose a three-class solution, following a recommendation for non-trivially-sized classes that are identifiable and interpretable.

After conducting our LPA at the statewide level, as a robustness check, we also performed region-level LPAs in which we reclassify transit riders using one model that includes only individuals from the central Bay Area and another model that includes only individuals from Los Angeles and Orange Counties. The resulting class distributions are very similar to those from the statewide model. Given the similarity of these results, and given the much larger sample sizes available at the state level, we present our results from the all-California model (including results that disaggregate the statewide model by year and region) in Chapter 5.

C.2. Methodology: Transit Use Decomposition

The usage rate effect evaluates how—given a static population—changes in per capita transit use are associated with changes in aggregate ridership. To operationalize this effect, we calculate the mean ridership rates in 2009 and 2017 among population groups within each of the four variables of interest. We then multiply these rates by the population size of these groups in 2017. This produces two aggregate values: a group's total estimated ridership in 2009 assuming 2017 population levels; and a group's total observed ridership in 2017. The difference in these two values represents the rate effect (See **Equation C-1**); in other words, the usage effect is the increase or decrease in total ridership that would have occurred between 2009 and 2017 if the population size in 2009 was the same as 2017 levels. Finally, in order to obtain the percentage difference in aggregate ridership due to changing transit usage rates in a given group, we subtract the rate effect from the total number of region-wide trips and divide by the total number of region-wide trips; this value is then subtracted from 1 (See **Equation C-2**).

Equation C-1.

$$rate\ effect_{group\ A} = (2017\ rate_{group\ A} *\ 2017\ pop_{group\ A}) - (\ 2009\ rate_{group\ A} *\ 2017\ pop_{group\ A})$$

Equation C-2.

$$\%\ change\ in\ regional\ ridership,\quad rate\ effect\ _{group\ A,\ region\ X} = 1 - \left(\frac{tot\ trips_{region\ X} -\ rate\ effect_{group\ A}}{tot\ trips_{region\ X}}\right)$$

In addition to examining how changing rates of transit use affect aggregate ridership, we also assess how changes in population composition influence overall transit patronage. As we note above, traditionally, certain socio-demographic groups ride transit far more than others. As such, increases or decreases in the total population of these groups may lead to large changes in aggregate ridership, even if the frequency of use among individuals remains the same. Therefore, we examine a "population effect." Like the usage effect calculation described above, we focus on key socio-demographic groups that showed changes in their propensity to use transit between 2009 and 2017. In this case, however, rather than holding their population size constant, we instead assume a constant rate of per capita use, based on observed 2017 levels. Using these rates, we then calculate total ridership in 2009 and 2017. Once again, this produces two values for each group: first, its total estimated ridership in 2009 assuming 2017 transit usage rates; and second, its total observed ridership in 2017. The difference in these two values represents the population effect (See **Equation C-3**); in other words, the population effect is the increase or decrease in total ridership that would have occurred between 2009 and 2017 if transit trip-making rates were constant at 2017 levels. Finally, in order to obtain the percentage difference in aggregate ridership due to changing population sizes in a given group, we subtract the composition effect from the total number of region-wide trips, divide by the total number of region-wide trips, and subtract this value from 1 (See **Equation C-4**).

Equation C-3.

$$comp\ effect_{group\ A} = (2017\ rate_{group\ A} * 2017\ pop_{group\ A}) - (2017\ rate_{group\ A} * 2009\ pop_{group\ A})$$

Equation C-4.

$$\%\ change\ in\ regional\ ridership,\ \ comp\ effect_{\ group\ A,\ region\ X} = 1 - \left(\frac{tot\ trips_{region\ X} - comp\ effect_{group\ A}}{tot\ trips_{region\ X}}\right)$$

C.3. Methodology: Changing Location of Workers Relative to Jobs

The following describes the methodology used for the analysis in Chapter 7.

We first examine the ratio between jobs and resident workers in Bay Area cities. We then analyze whether Bay Area cities have become less "self-contained" over time. To measure "self-containment," we use an independence index, developed by Thomas (1969) and used in earlier studies by Cervero (1989). The index takes the following form:

Equation C-5.

$$Independence\ Index = \frac{Internal\ Work\ Trips\ (work\ and\ live\ inside\ city)}{External\ Work\ Trips\ (work\ outside\ city\ +\ live\ outside\ city)}$$

To conduct this analysis, we draw on data from the 2002 and 2015 LODES (U.S. Census Bureau, n.d.). These data provide information on the location of workers, jobs, and the location of workers relative to their jobs. The data distinguish between three wage categories of jobs and workers. For part of our analysis, we collapsed these categories into two: jobs in which earnings are either less or more than $3,333 per month. Unfortunately, the wage categories in the publicly-available data are not adjusted for inflation, making it impossible to accurately track work-residential location changes over time by wage group. However, we make some comparisons between lower- and higher-wage workers using the most recent year for which we have data, 2015.

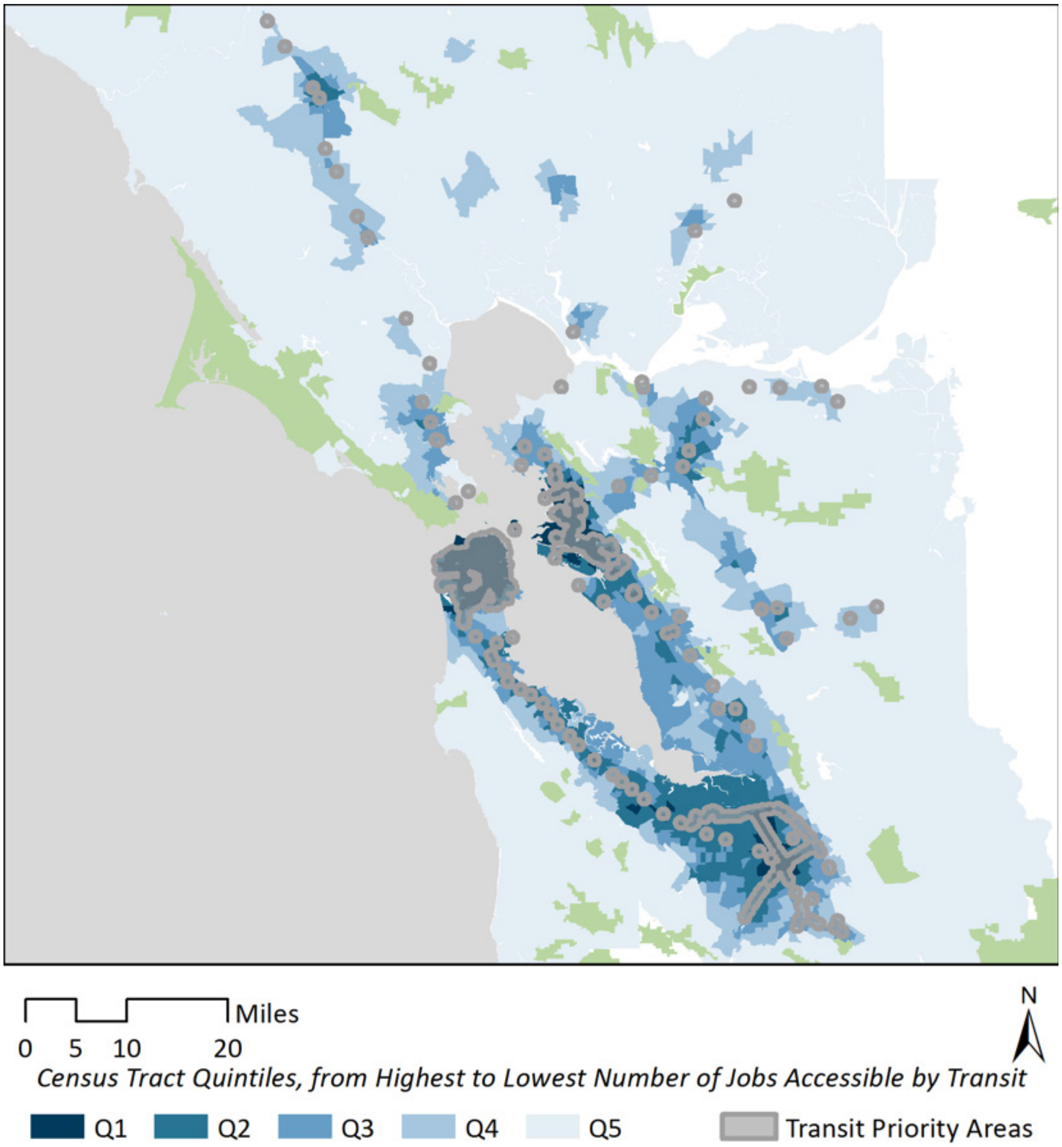
We use two primary spatial units of analysis: cities and the entire region. For the city analysis, our sample includes 89 cities for which administrative boundaries and employment/demographic data was available for both years. Cities are politically incorporated and, therefore, analysis of their self-containment—while important for municipal housing policy and economic development (Palm and Niemeier, 2017)—may not precisely measure commute patterns. To assemble data by city, we used geoprocessing tools (primarily the computation of geometric intersections) in Geographic Information Systems (GIS) software (ArcMap) to assign all tracts in California to cities using a shapefile created by Caltrans using California Board of Equalization parcel data (Caltrans, 2015). We then aggregated LODES Origin-Destination (OD) data for 2002 and 2015 from the block level to individual sample cities or to unincorporated areas based on worker origins and destinations from the block-level to the tract-level using a custom R script. For the portion of our analysis focusing on the region as a whole unit, we used LODES data aggregated (U.S. Census Bureau, n.d.) and ACS data reported at the tract level (U.S. Census Bureau, 2019).

There are several limitations of the data (U.S. Census Bureau, n.d.). First, the LODES data include only workers who both live and work in the state of California. It, therefore, excludes workers who live in California but work elsewhere or workers who are employed in California but live elsewhere. This limitation is probably most severe for the San Diego region, which features a non-trivial number of cross-border commutes. Second, LODES data provide information about wages rather than household income. Third, a known limitation of LODES data is that workers employed by large institutions may be assigned workplaces based on corporate headquarters rather than satellite facilities where workers physically work. This is the result of LODES data being derived from administrative employment records. Fourth, we combine 2000 housing data from the U.S. Census (2019) with 2002 LODES employment data because 5-year ACS vintages are not available prior to 2008. Fifth, we assign both 2002 and 2015 tracts to cities based on 2015 city boundaries. This analytical choice has the advantage of maintaining spatial continuity over time but does not allow us to examine the effect of administrative boundary changes. Given that there are only 13 years between our two observation years, however, it is likely that boundary changes were minimal.

In the second part of our analysis, we examine how the locations of jobs and workers in the Bay Area have changed relative to transit employment access and housing affordability. Here we draw on data from the University of Minnesota's Access across America program to define geographic areas by their level of transit access to jobs, measured as the total number of jobs reachable from each block by transit within 30 minutes (Owen and Murphy, 2018).[22] We aggregate these block-level data to the tract level by calculating the mean number of jobs reachable within 30 minutes on transit for all blocks in a given tract. We then divided all Bay Area tracts into five accessibility quintiles, with tracts in the top quintile (Q1) having the highest mean number of jobs accessible by transit and tracts in the bottom quintile (Q5) having the lowest. As shown in **Figure C-1**, our definition of transit access closely corresponds to the MTC's Transit Priority Areas (TPAs) (MTC, 2019e), with the majority of the area classified as TPAs falling into our Q1 and Q2 tracts; at the same time, some of these Q1 and Q2 tracts are located outside of the MTC's PDAs. As *Plan Bay Area 2050* is developed, the PDA definition may need expansion to attract development into these areas with good access to jobs via transit.

22. Using General Transit Feed Specification (GTFS) schedule data from transit operators, the researchers first calculated the travel time to all other census blocks within 60 kilometers for each departure time at one-minute intervals between 7-9 A.M. They then determined the cumulative opportunity accessibility to jobs for each block and departure time by time threshold combining the travel time data with employment data from LODES. The final access estimate is an average for each block over the two-hour period (Owen and Murphy, 2018).

Figure C-1. Transit Priority Areas versus Job Access by Transit



Data source: Owen and Murphy, 2018; MTC, 2019e; CaliDetail, n.d.; and Esri, 2010

For the purposes of our study, the transit employment access measure has some limitations. It does not incorporate access to other types of destinations; this is particularly notable given that recent losses in transit use have been concentrated in off-peak periods (See Chapter 4 and Volume II). Our access measure also does not consider differences in access across job type (e.g., wages, sector), or competition for available jobs. Our measure is derived from data for one year, 2015; we do not have comparable data for 2002. However, given the short time period covered by our analysis, the temporal changes in transit service likely have little impact on the final results. Finally, we use tract-level housing data from the five-year 2013-2017 American Community Survey (U.S. Census Bureau, 2019).

C.4. Methodology: Changes in Transit-friendly Neighborhoods

The following describes the methodology used for the analysis in Chapter 8.

C.4.1. Zero-vehicle Households

C.4.1.1. Car-less versus Car-free Tracts

We define car-less neighborhoods as any tract whose:

1. Share of zero-vehicle households is above the 75th percentile of the share of zero-vehicle households among all tracts and
2. Share of people living below the poverty line is above the 75th percentile of individuals below the poverty line among all tracts.

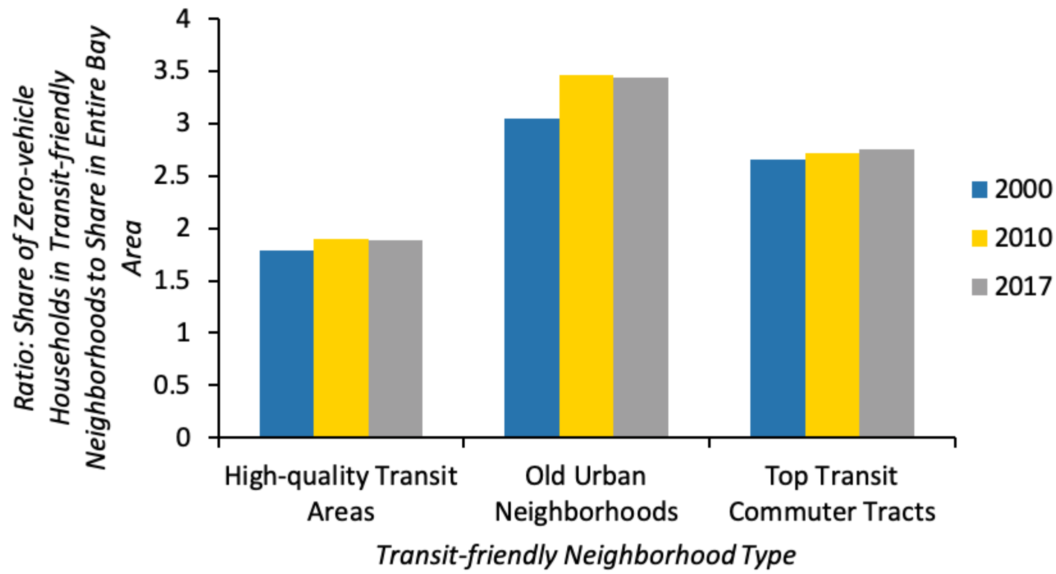
We define car-free neighborhoods as tracts whose:

1. Share of zero-vehicle households is above the 75th percentile of the share of zero-vehicle households among all tracts and
2. Share of people living below the poverty line is below the 25th percentile of individuals below the poverty line among all tracts.

C.4.1.2. How Is the Concentration of Zero-vehicle Households in Transit-friendly Neighborhoods Changing over Time?

In Chapter 8, Section 2, Subsection 2, we examine the distribution of zero-vehicle households in different types of transit-friendly neighborhoods. **Figure C-2** shows, over time, the ratio of the share of zero-vehicle households in transit-friendly neighborhoods to the share in all Bay Area tracts. The higher the bar, the more concentrated zero-vehicle households are in transit-friendly neighborhoods, relative to the entire Bay Area. The figure demonstrates that the share of zero-vehicle households in transit-friendly neighborhoods increased relative to the region as a whole.

Figure C-2. How Concentrated Are Zero-vehicle Households in Transit-friendly Neighborhoods, Relative to the Entire Bay Area



Data source: MTC, 2018; Voulgaris et al., 2016; and U.S. Census Bureau, 2019

C.4.2. Caveats and Limitations

Our methodology throughout Chapter 8 has limitations. First, because we use Census information aggregated to the tract level, we cannot follow individuals, only tract averages. These averages do not capture the demographics of actual transit users in tracts. So, for example, a tract's foreign-born population may decline by only two percent, but if 40 percent of the foreign-born regular transit users depart the neighborhood; the Census would capture the two percent decline, not the demographic change directly influencing ridership.

Related, we use demographic characteristics as proxies for high-propensity transit users, but they are imperfect. As we note above, not all low-income people take transit; the departure of a low-income resident from a High-quality Transit Area is not necessarily associated with a decline in transit ridership. While these demographic groups capture users with high propensities to use transit, they fail to isolate our actual variable of interest—transit riders (However, these proxies are helpful in other ways. Policymakers may have special interest in low-income transit riders if their focus is equity and employment access.).

Similarly, some people who may want to drive do not own cars or drive, not because of income constraints, but because of physical impairments (such as visual impairments, seizure disorders, and so on) or because they have lost the right to drive (due to traffic violations or other legal issues). People in this category residing in non-poor neighborhoods would be classified in our schema as car-free, when they might more accurately be classified as car-less. This could lead us to overestimate the number of car-free households.

Third, the three different transit-friendly neighborhood types are based on data from different years: High-quality Transit Areas from 2017 (MTC, 2018), Old Urban neighborhoods from 2010 to 2013 (Voulgaris et al., 2016), and Top Transit Commuters from 2000 (U.S. Census Bureau, 2019). Also, for many of these analyses, we group together neighborhood types that may otherwise differ substantially. Old Urban areas in San Francisco's financial district differ from the Old Urban areas of downtown Berkeley; however, we average the demographics of these neighborhoods to analyze Old Urban neighborhoods.

Finally, our Top Transit Commuter neighborhood type overemphasizes the work commute. The U.S. Census only asks about the trip-to-work and does not report trips taken for other purposes. Only 36.4 percent of all transit trips are journey-to-work trips (FHWA, 2017). Therefore, the Top Transit Commuter typology may miss neighborhoods whose residents take a high proportion of transit trips for non-commuting purposes.

Even with these limitations, we see great value in examining residential change using data with high geographic specificity.

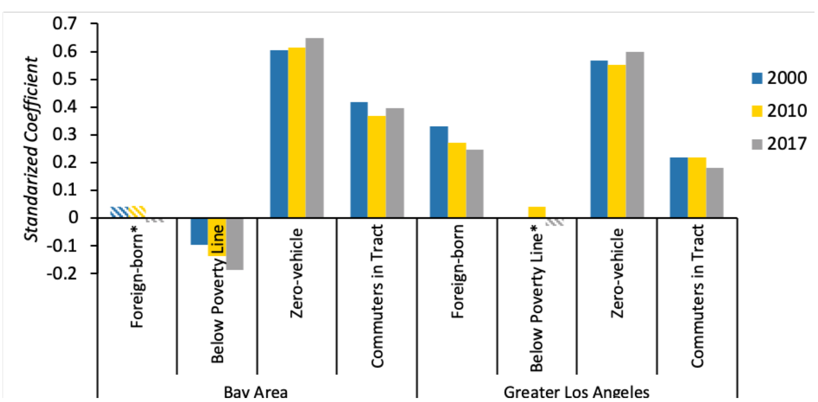
C.4.3. Models of Commuter Change

C.4.3.1. First Set of Models

First, we develop six models, each of which represents a different year—2000, 2010, and 2017—and a different region—the Bay Area and Greater Los Angeles—and models the total number of transit commuters in the region's census tracts. We use the three socio-demographic categories identified above as explanatory variables and also use one control variable for the number of all commuters—including those who drive— in each tract.

Figure C-3 depicts the outputs of these models. It graphs the standardized coefficient of each factor—a measure of the relative effect of each factor. The higher each bar is above zero, the more that factor contributed to increasing the number of transit commuters in the given year (and the lower each bar is below zero, the more that factor contributed to decreasing the number of transit commuters). The height of the bars therefore shows how influential each factor is on transit commuting; zero-vehicle households, for instance, contribute more to transit commuting by tract than foreign-born residents. But for our purposes, more important than comparing the heights of bars across factors is comparing change over time within each factor. Shrinking bar heights mean that a factor is becoming less influential on transit commuting over time, and the reverse for growing heights.

Figure C-3. Standardized Coefficients for Regressions Modeling the Number of Transit Commuters



** Striped bars indicate factors that are not statistically significant at a 95 percent confidence level; all others are statistically significant.*

Data source: U.S. Census Bureau, 2019

C.4.3.2. Second Set of Models

While the first set of models modeled the number of commuters by year, we can also study predictors of change in transit commuters over a specified period. In this second set of models, the dependent variable is the change in an individual tract's in the number of transit commuters between 2010 and 2017. The average Bay Area census tract added 66.4 transit commuters between 2010 and 2017. By comparison, the average Los Angeles Area tract lost 6.4 transit commuters over the same period. In addition, we include new variables that capture residential density and job access by transit. **Table C-3** shows the results of these models modeling change in number of transit commuters by census tract.

From these two models, we note the following for both Bay Area and Greater Los Angeles census tracts, controlling for other factors. First, the change in the percentage of foreign-born residents is not a significant predictor of transit commuting in either region. Second, an increase in people living below the poverty line in Los Angeles Area tracts is associated with a decline in transit commuters from 2010 to 2017, and is statistically significant. The relationship is not statistically significant for the Bay Area. This suggests that the poor are commuting less by using transit less over time in Greater Los Angeles. (controlling for other factors mentioned above).

Third, an increase in zero-vehicle households is associated with an increase in transit commuters. This relationship is statistically significant in both regions, but almost twice as strong for the Bay Area as it is for the Los Angeles Area. This suggests that zero-vehicle households are increasingly important determinants of transit commuting in both regions, but especially so in the Bay Area (controlling for other factors mentioned above).

Fourth, an increase in population density is associated, somewhat surprisingly, with a decline in transit commuters from 2010 to 2017. This relationship is statistically significant in both regions, at a similar magnitude. This suggests that population density increases do not results in increased transit commuting in both regions (controlling for other factors mentioned above).

Fifth, a tract having more commuters in 2010 is associated with a decline in transit commuters over the 2010 to 2017 period. This relationship is statistically significant in both regions, but is over six times as strong for Greater Los Angeles as for the Bay Area. This suggests that the growth in transit commuting occurs in places with lower levels of transit commuting in 2010 in both regions; especially for Los Angeles, the losses are greatest in neighborhoods which previously hosted a lot of transit commuting (even controlling for other factors mentioned above).

Finally, greater access to jobs via transit in 2017 is associated with an increase in transit commuters from 2010 to 2017. This relationship is statistically significant in both regions, at a similar magnitude. This suggests that the growth in transit commuting is driven by job access in both regions; neighborhoods with high job access via transit in 2017 gained more transit commuters (controlling for other factors mentioned above).

These six factors explain about 10% of the variance for the Bay Area, while they explain about 29% of the variance for Greater Los Angeles Los Angeles (However, the Bay Area contains fewer tracts, providing half the sample size of the Los Angeles Area.). This suggests that the demographic and built environment factors we measured more systematically explain transit commuter change for Greater Los Angeles than for the Bay Area.

Finally, the best predictor of transit commute change in the Bay Area is the number of jobs accessible via transit in 2017. For the Los Angeles Area, the best predictors of transit commuter change are the number of jobs accessible via transit in 2017 as well as total number of transit commuters in 2010. This suggests that the Bay Area's transit commuter increases are explained best by job access, while for Greater Los Angeles increases are explained by both job access and lower levels of commuting in 2010.

Table C-3. Full Model of Predictors of Transit Commuter Change (by Census Tract), 2010 to 2017

REGION	BAY AREA		GREATER LOS ANGELES	
FACTOR	COEFFICIENT	STANDARDIZED COEFFICIENT	COEFFICIENT	STANDARDIZED COEFFICIENT
Change in share of foreign-born residents, 2010 to 2017	1.094 (1.87)	0.0469	0.254 (1.41)	0.0196
Change in share of residents below the poverty line, 2010 to 2017	-0.0108 (-0.02)	-0.000435	-0.393*** (-2.68)	-0.0363
Change in share of zero-vehicle households, 2010 to 2017	1.469* (2.09)	0.0520	0.814*** (3.60)	0.0496
Change in population density, 2010 to 2017	-0.0125*** (-7.04)	-0.176	-0.0102*** (-11.60)	-0.161
Total number of transit commuters, 2010	-0.0691*** (-3.90)	-0.128	-0.391*** (-36.86)	-0.655
Total number of jobs available within a 30 minute transit commute, 2017	0.000360*** (9.60)	0.311	0.000391*** (20.75)	0.363
Intercept	51.675*** (10.57)	N/A	15.43*** (11.27)	N/A
Number of observations	1,482		3,918	
R^2	0.0999		0.287	

** significant at a 95 percent confidence level*
*** significant at a 99 percent confidence level*
**** significant at a 99.9 percent confidence level*
Standard errors are in parentheses.

Data source: U.S. Census Bureau, 2019 and Owen and Murphy, 2018

Appendix D. Summary of Prior Research

D.1. Overview of Past Research on Fuel Prices and Transit Use

This chapter details findings of prior studies on the relationship between fuel prices and transit use, a topic discussed in Chapter 13.

Previous research has found different levels of transit rider sensitivity to fuel price changes. These estimates vary by geography, time, and mode. Iseki and Ali (2014) found a 0.61-0.63 percent short-term increase in transit ridership accompanying a ten percent increase in gasoline prices. Other researchers in Chicago found elasticities as high as 37 percent for commuter rail in Chicago when gasoline exceeded $4 per gallon (Nowak and Savage, 2013). Currie and Phung (2007) estimate an ordering of elasticity by mode, with light rail having the most responsiveness to fuel price changes, followed by heavy rail and finally bus. They hypothesize that this ranking reflects the greater use of light rail by "choice" riders who own automobiles. Of course, Bay Area likely differ from residents of other areas. Blanchard (2009) found cross-price elasticities in San Francisco of 0.098 for commuter rail and 0.099 for heavy rail, and 0.0299 for light rail in San José. In sum, the literature suggests a relationship between fuel price and transit patronage is a present but often weak one; the relationship also differs based on mode and the starting price of gasoline.

D.2. Overview of Past Research on Ridehail and Public Transit

This chapter details findings of prior studies on the relationship between ridehail and transit use, a topic discussed in Chapter 14. For a summary of major studies, see **Table 14-1** in Chapter 14.

D.2.1. Introduction

This review summarizes research on ridehail use in the United States, focusing on its effects on public transit use. This still nascent literature is growing at a remarkable pace, matching the rapid increase in ridehail use in the last decade.

After describing issues with data access and methodological solutions to these challenges, we organize this review into four sections with different general approaches and findings: 1) studies using data from ridehail companies, 2) studies that have relied on national transit ridership data and use market entry as a proxy for ridehail service, 3) surveys of general travel behavior change, and 4) surveys reporting levels of transit trip replacement.

D.2.2. Data Access and Methodologies

The lack of data about TNC use is a significant barrier to analyzing the relationships between ridehail and transit use. Lyft and Uber routinely decline requests from public agencies and researchers for information about trips and users, citing both economic competition and privacy issues (Said, 2017). As Lyft and Uber only recently became publicly traded companies, they have not uniformly reported ridership information to the public (Marshall and Thrum, 2019). However, data availability has changed in recent years, as cities like New York and Boston have signed agreements with the companies as conditions of operation in their cities (D. Morris, 2017). Additionally, Uber and Lyft committed in 2018 to sharing data with cities via the National Association of City Transportation Officials' (NACTO) SharedStreets platform (Mosquera and Engel, 2018). However, the level of data detail and access to it for regions remains unclear, as SharedStreets data for cities other than Washington, D.C. were not publicly available at the time of the writing of this report (SharedStreets, 2019).

Researchers and policymakers need accurate and timely ridehail ridership data to analyze frequency, location, and timing of ridehail trips for a wide range of research and policy questions, including their effects on public transit systems. In the absence of such data, researchers have used several methods to estimate and approximate for ridehail trips. One major exception is a recent study of Lyft in Los Angeles County, which used data provided by Lyft to examine the distribution of Lyft service across different neighborhoods (Brown, 2018). Other research has used approximations of ridership, including when TNCs entered a local market or surveys of respondents reporting the use of ridehail services. Therefore, the sections below are organized around how researchers approximate TNC data and compare it to national transit ridership, which are available publicly.

Finally, the rapid growth of ridehail presents another major analytical challenge. The major national survey of personal travel, the NHTS, is only administered every few years, with the three most recent iterations in 2001 and 2009—before the rise of ridehail—and in 2017, after the rise of ridehail. Unfortunately, this survey combines taxi and TNC use, making it difficult to isolate the growth of ridehail. Given the rapid evolution of ridehail, data from as recently as 2017 may soon become outdated, as the percentage of U.S. adults who have used a ridehail service has doubled since late 2015, according to Pew Research Center (Jiang, 2019). Additionally, as users become more comfortable with technology and the availability of these services continues to expand, travel behavior may be evolving in yet unforeseen ways. In attempting to overcome these many issues, the studies described below use different approaches to investigate the effect of ridehail on transit use. Unfortunately, several of the studies are plagued by some glaring limitations, which prevent generalizing their findings.

D.2.3. Studies Using or Modeling the Spatial Distribution of Ridehail Ridership

D.2.3.1. Lyft Service in Los Angeles County

Brown (2018) uses 2016 Lyft data to explore the geographic equity of ridehail service. Specifically, she analyzes data on 6.3 million trips in Los Angeles County from September to November 2016, which is the most comprehensive set of TNC data analyzed by researchers to date. The trip data were aggregated to the census tract level and includes little about individual rider characteristics (beyond their billing zip code). While the analysis does not focus on the relationship between ridehail and transit use, it does offer insight on the availability and use of ridehail across Los Angeles County neighborhoods, which are operationalized as census tracts.

Brown finds that access to ridehail is virtually universal across all census tracts, although use varies depending on socioeconomic and built environment characteristics. Hispanic neighborhoods generate fewer rides compared to predominantly non-Hispanic and African-American neighborhoods. In addition, higher income tracts have higher trip rates than lower income tracts, while shared Lyft Line trips are more common in lower-income neighborhoods take more, which offer lower fares (Brown, 2018).

Brown finds a clear relationship between higher density land uses and higher Lyft use, and notes that the strongest built environment predictor of high per capita Lyft rides is the number of transits stops per square mile; a ten percent increase in the number of transit stops per square mile is associated with a 2.5 percent increase in Lyft rides. This suggests a major overlap between those who have regular and high-quality access to transit and those who take ridehail trips at high rates. Brown also analyzes fares, and finds that median Lyft trip prices are $6.25, which is over 3.5 times the cost of a single trip on Los Angeles Metro. That the lower cost Lyft Line use is higher in low-income neighborhoods suggest that lower-income riders are indeed more price sensitive, as expected. Because car ownership is inversely related to transit use (Taylor and Morris, 2015), increased car access via Lyft and Uber may reduce transit use as well. However, the fact that Lyft is most frequently used in the most densely developed, transit-friendly neighborhoods may mean that as least some trips are enhancing transit use by increasing access to high-quality transit service (Brown, 2018).

D.2.3.2. SFCTA Congestion Study

In 2018, the SFCTA released a report analyzing the effect of TNC growth on rising traffic congestion in San Francisco between 2010 and 2016. Using its SF-CHAMP travel demand model, SFCTA estimated scenarios with and without ridehail, population, and employment changes in the City. The report attributes half of congestion growth over this six-year period to the proliferation of TNC use and the other half to employment and population growth. The growth in traffic delays related to ridehail suggest that TNC trips are not only replacing taxi and driving trips, but walking, bicycling, and transit trips as well. The authors conclude that ridehail use increases vehicle travel and trip times, especially in the central business district and during peak morning and afternoon commute hours (Castiglione et al., 2018).

The SFCTA requested from Uber and Lyft, but did not receive, the data used for this analysis. The SFCTA also requested ridehail data from the California Public Utilities Commission (CPUC), which collects data from TNCs as a regulatory body for the state (Castiglione et al., 2017). Given the dearth of data, the SFCTA worked with computer scientists from Northeastern University to monitor vehicle availability on Uber and Lyft platforms at five second intervals in to estimate locations of passenger origin and destination. SFCTA then used SF-CHAMP to simulate scenarios in which TNCs did not come to San Francisco to estimate the proportion of traffic growth attributable to ridehail, employment, and population growth. The SFCTA study only examined intra-San Francisco TNC trips and their effect on congestion, and so did not estimate the effects on transit ridership directly; however, these findings suggest that the effects of TNCs in the birthplace of the mode are substantial and growing (Castiglione et al., 2018).

D.2.4. Modeling TNC Market Entrance Effects

Given the scarcity of ridehail data, discussed above, many researchers have used indirect methods to estimate ridehail availability and use in cities and regions, which in some cases they compare with changes in transit system patronage. Two studies below use market entry and per-capita TNC employment to examine the effects of ridehail on public transit. In using these data and methods of analysis, researchers have not been able to examine the causal nature of these relationships, as these studies lack enough information to discern how riders choose among modes. Limitations notwithstanding, these studies attempt to capture trends in transit and ridehail use in large U.S. cities but reach different conclusions about how ridehail use is affecting transit ridership.

D.2.4.1. Transit Agencies and Ridehail

Transit agency managers have good reason to question the effect of ridehail use on their systems, and a study by Hall et al. (2018) take the transit agency as the unit of analysis in evaluating the relationship between transit ridership and Uber use.[23] They use a difference-in-differences approach across 196 Metropolitan Statistical Areas in the U.S., comparing transit agency ridership and ridehail market entrance. They also use Google Trends searches for "Uber" to approximate the number of drivers per capita and compare this with data received from Uber about driver supply, finding a strong correlation. By creating dummy variables for cities and agencies below and above median population and ridership, Hall et al. conclude that transit agencies in higher-than-median population cities with lower-than-median ridership benefit from Uber entry into a metropolitan market, but that transit agencies with higher-than-median ridership show the largest decreases with the entrance of Uber. For agencies in higher-than-median population cities, Uber's arrival results in a 0.8 percent increase in ridership, but for agencies in lower-than median population cities ridership decreases by 5.9 percent. For higher-than-median ridership agencies, Uber's arrival decreases ridership by 2.1 percent, while for lower-than-median transit agencies ridership increases by 6.0 percent. These dummy variables combine in

23. Hall et al. (2018) do not analyze the effects of Lyft market entry on transit use, likely due to preexisting research relationships and access to data about Uber drivers.

different ways; a small transit agency in a big city will experience different combinations than a large transit agency in a small city. Hall et al. also find differing effects by mode, predicting that Uber will have a positive effect on bus patronage and a negative effect on rail, though these differences vary by size of agency. These potential shifts in riders switching from rail systems to bus systems conflict with findings from stated preference surveys discussed below (See Section 2.5) (Hall, Palsson, and Price, 2018).

Hall et al. note that their findings of ridehail effects vary across different types of U.S. cities. For the Bay Area, the study's findings suggest that ridehail would reduce rather than increase transit ridership because of the higher-than-median levels of ridership among transit agencies and Uber's very early market penetration. For the Bay Area, this could suggest different effects of ridehail use between, for example, BART and TriDelta, as well as for Muni light rail service versus Muni bus service. The authors also find that for a one standard-deviation increase in Uber market penetration, commute times increase by 0.9 percent (controlling for employment, population, and fuel prices). However, while private vehicle commutes lengthen, transit commutes shorten; the authors hypothesize that these changing commute times result from riders switching to transit or ridehail vehicles, increasing congestion. While the authors' findings vary by agency and region, this study offers one of the strongest pieces of evidence that Uber increases transit ridership for certain agencies (small ones) and regions (populous ones) (Hall, Palsson, and Price, 2018).

Similarly, Babar and Burtch (2017) model effects of ridehail by transit agency, and find differences emerging by mode and prior service quality. Using transit agency data from the NTD and Uber's entry into a region's market, the researchers employ a difference-in-differences approach to compare ridership between different transit agencies. They find, among other things, that Uber's presence is associated with increases in ridership for commuter rail (7.24%) and subway (2.59%), suggesting a complementary relationship between these modes and ridehail. Conversely, Uber's presence is associated with a decrease in ridership for city bus (1.05%), suggesting a substitution relationship. The authors also find that regions with more robust transit systems stand to benefit from Uber's presence, exhibiting more complementary effects, than do regions with less frequent transit service and coverage (Babar and Burtch, 2017).

D.2.4.2. Ridehail Use and Metro Area Transit Ridership

Other researchers have used regional transit ridership rather than agency ridership as the unit of analysis, and have produced different results. Graehler, Mucci, and Erhardt (2019) model the effects of Uber market entry on transit ridership in 22 MSAs in the U.S. and compare the effects of service changes with ridehail use to explain transit ridership change. Controlling for population, economic, and service supply variables, they find statistically significant negative effects of ridehail (measured as years since TNC entry into a given market) on heavy rail and bus ridership, and negative, but not statistically significant effects on light and commuter rail. According to the model, for each year Uber operates in a region heavy rail ridership decreases by 1.3 percent, commuter rail increases by 1.9 percent, light rail decreases by 0.4 percent, and bus decreases by 1.7 percent. As Graehler, Mucci, and Erhardt observe an increasing effect of ridership changes with each year of TNC operation, this suggests that as riders establish greater familiarity with the services, they forego transit at higher rates. The researchers also note a small but positive effect of bikeshare on light and heavy rail ridership, but a negative effect on bus ridership (Graehler, Mucci, and Erhardt, 2019).

Given these observed additive chronological effects, Graehler et al. state that a city like San Francisco, where Uber began service in 2010, would experience substantial decreases in transit ridership. They estimate that from 2010 to 2019, SFMTA would experience a 12.7 percent decrease in bus ridership, assuming no changes to service provision, population, employment, and car ownership. They conclude that SFMTA would have needed to increase service by more than 25 percent to maintain the 2010 bus ridership in this scenario; this also implies that SFMTA service has become less productive over time. However, this analysis is limited to large MSAs, and agencies in small or medium-sized MSAs could experience other effects. Additionally, the researchers include SFMTA service changes in the San Francisco analysis, but not those of other regional transit agencies like BART or Golden Gate Transit that move substantial numbers of transit passengers within the City and County of San Francisco; this may overlook the effect of changes in service availability (Graehler, Mucci, and Erhardt, 2019). For example, from 2001 to 2018, 17 percent of all BART trips ended and began in San Francisco.

D.2.5. Surveys of Travel Behavior Change

Finally, several researchers have utilized surveys to explore how ridehail trips may affect travel behavior by conducting surveys asking respondents about decision-making between ridehail and other forms of travel. Such surveys have been employed to address a variety of questions about ridehail beyond transit use; as a result, findings vary widely, likely due to differences in geography, year of completion, survey instrument, and sampling method. Additionally, many studies feature small numbers of respondents and both revealed- and stated-preference questions; these latter questions do not necessarily capture the future of behavior of travelers (Fujii and Gärling, 2003). In contrast to the causal modeling studies described above, these survey-based studies are most explicit about putting ridehail and transit use and tradeoffs in perceptional and behavioral frameworks, both in terms of previous trip-making and stated modal preferences.

D.2.5.1. National Household Travel Survey

The most recent National Household Travel Survey, in 2017, shows growth in TNC and taxi use, although these two services accounts for a very small portion of total trips (0.5%) nationally (FHWA, 2017). NHTS data are based on travel diaries of a representative sample of respondents, and the 2017 version contains data on over 250,000 respondents' travel activity, mostly over the previous 24-hours but in a few cases over longer periods, and include extensive economic, social, and demographic data as well. In the NHTS, taxis and TNCs are aggregated to the same question, so parsing out trends that apply to ridehail and not taxis is challenging. For-hire vehicle use (both taxi and ridehail) as a share of total trips doubled from 2009 to 2016, almost certainly reflecting the remarkable growth of ridehail. While the share (0.5%) share of person trips via ridehail (and taxi) remains relatively small, the use of ridehail, like public transit, varies substantially between the centers of large cities (where use is common) to rural areas (where it is rare). Further, a much larger share of the population uses ridehail occasionally, if not regularly; almost ten percent of respondents report having used ridehail (excluding taxi) at least once (Conway, Salon, and King, 2018).

With respect to the relationship between for-hire (taxi and TNC) vehicle use and public transit, analyses show that use of the two modes is closely correlated. In the previous NHTS survey year, 2009, ridehail services did not yet exist (FHWA, 2009). Among other noteworthy findings, respondents from the central Bay Area report the highest levels of ridehail use (in the previous 30 days prior to survey administration) among all Core-Based Statistical Areas (CBSAs) in the U.S. Conway et al. (2018) find a strong positive association between use of for-hire vehicles and use of public transit and active travel modes, such as bicycling and walking. However, the researchers suggest that the nature and direction of these relationships are unclear. Evidence from the NHTS indicates that a ridehail user is more likely to use transit, but before the advent of ridehail, that same user may have ridden transit less, more, or an equal amount (Conway, Salon, and King, 2018).

D.2.5.2. Natural Experiment in Austin

In an innovative study, Hampshire et al. (2017) administered a survey in 2016, when Uber and Lyft left the Austin, Texas market rather than comply with a local regulation requiring more extensive driver background checks. Although the companies later returned to the Texas capital, other ridehail services sprang up in Uber and Lyft's absence. Following the withdrawal of Uber and Lyft, researchers surveyed 1,840 ridehail users in Austin. Hampshire et al. administered the survey online and acknowledge that the methodology was non-random, although the socio-demographic profiles appeared to match previous studies of Austin ridehail users. In the study 45 percent of users switched to using personal vehicles when ridehail service was disrupted, while only three percent reported switching to transit. Perhaps most surprisingly, 8.9 percent of respondents reported purchasing a vehicle in response to the departure of Uber and Lyft. Taken together, this suggests that ridehail use and private vehicles serve similar functions for travelers, while transit is not a viable substitute for the typical TNC trip in Austin. Although few users reported switching from ridehail to transit, this does not necessarily mean that prior to TNCs entering Austin, respondents did not regularly use transit. However, it does suggest that, for the Austin respondents, once they have accessed ridehail services, only a small percentage of people would shift to public transit if ridehail services ceased operations (Hampshire et al., 2017).

D.2.6. Surveys Reporting Transit Trip Replacement

D.2.6.1. National Transit Usage

Some survey studies have shown that ridehail trips either replace or complement transit depending on the transit modes available for the trip. A 2015-2016 survey of 4,094 residents of major metropolitan areas in the U.S. finds that, while the majority of respondents reported no change in transit use, an average of six percent of users reported reduced transit use due to ridehail (Clewlow and Mishra, 2017). Travelers were surveyed in seven major U.S. metropolitan areas;[24] 21 percent of respondents reported regularly using ridehail services, which is slightly more than double the levels reported in the 2017 NHTS discussed above. When asked how they would have completed their trip in the absence of ridehail, 39 percent of respondents reported that they would have made the ridehail trip via private automobile, while 15 percent reported that they would have made the trip via transit. Nearly half (46%) reported that they would not have made the trip, or would have traveled by bicycling, walking, carpooling, or taxi. Clewlow and Mishra also find that ridehail draws riders from bus service and light rail at the highest rates (reducing bus use by 6% and light rail by 3%), while ridehail was found to increase increases heavy rail ridership (by 3%). Finally—in a finding often misstated by commentators—the researchers find that ridehail users who now take transit less often outnumber those who take it more often by six percentage points (Clewlow and Mishra, 2017).

D.2.6.2. Transit Replacement by City and Region

A 2015 survey of California travelers by Circella et al. (2018) finds different rates of ridehail substitution for transit based on the type of rider, which the authors divide into frequent and non-frequent users of ridehail. About 13 percent of non-frequent ridehail users reported substituting ridehail for public transportation for their most recent trip; however, the comparable figure for frequent ridehail users was 34 percent. Further, as the top ten percent of Lyft users in Los Angeles took more than half of all ridehail trips, the habits of frequent ridehail users may produce outsized effects on transit use (Brown, 2018). In response to a question about how the most recent ridehail trip affected their travel by other means, more than 40 percent of non-frequent ridehail users reported a decrease in public transit use, while more than 50 percent of frequent users reported the same (multiple answers were allowed). The study also estimates a latent-class choice model based on self-reported behavioral changes associated with the emergence of ridehail, dividing respondents into three classes (termed "urban travelers," "car users," and "transit and TNC users") based on individual and household characteristics, lifestyle, and stage of life. The study then asked respondents to describe how ridehail access had generally affected their travel behavior. A total of 53 percent of the sample was in the urban travelers class, and 69 percent of these travelers reported a decrease in transit use. In the car users class (37% of total sample), 1.7 percent reported a decrease in transit use, and 0.1 percent reported an increase. Finally, just ten percent of respondents were classified as transit and TNC users, and 93.6 percent of these travelers reported an increase in transit use. The survey allowed multiple responses for how ridehail access changed respondent travel behavior (Circella et al., 2018).

24. Boston, Chicago, Los Angeles, New York, San Francisco, Seattle, and Washington, D.C.; data were weighted by gender, income and age to match ACS data for each metro area.

Surveys of ridehail use in Denver, Boston, and New York City reveal very different patterns. A 2016 study in Denver examines the relationship between ridehail use and vehicle travel and finds that 22 percent of ridehail trips replaced transit trips. For the trip surveyed, only one percent of riders reported using the ridehail trip to replace driving to connect to transit. Four percent of riders reported that public transit was not an option for their ridehail trip (Henao, 2017). A 2017 survey by the Metropolitan Area Planning Council found that 42 percent of Boston passengers surveyed during a ridehail trip were replacing a transit trip. The study estimates that for every ridehail trip taken, the Massachusetts Bay Transportation Authority (MBTA) loses 35 cents in fare revenue (Gehrke, Felix, and Reardon, 2018). And in a survey by the New York City Department of Transportation (2018), 50 percent of respondents reported replacing a transit trip with the current ridehail trip (with multiple options allowed for mode replaced).

D.2.6.3. Transit and Shared Modes

Finally, a 2016 survey from the American Public Transportation Association (APTA) surveyed over 4,500 people living in seven large U.S. cities[25] about use of "shared modes," a term that includes include ridehail, carshare, and bikeshare systems (Feigon and Murphy, 2016). Survey respondents reported relatively low proportions of shared mode trips replacing transit trips, which suggests that these new modes (which, again, include shared modes more broadly, and not just ridehail) more often complement public transit. Fourteen percent of respondents reported that their shared mode trip would have been by transit were ridehail not available, while 34 percent reported they would have driven alone or with a friend. Ten percent of "supersharers" (defined by APTA as people who had used non-transit shared modes such as bikeshare and ridehail for commuting, errands, and recreation over the last three months) reported using public transit more since they began using shared services. However, bikeshare and carshare offer very different experiences for users than ridehail. The grouping of these decidedly distinct shared mobility options makes it difficult to draw any conclusions about the relationship between ridehail and transit use (Feigon and Murphy, 2016).

D.2.6.4. Summary of Survey Findings

Together, these surveys show little agreement on the effect of ridehail on transit use. Ridehail continues to expand in most U.S. cities, so these analyses are a moving target. In addition, the studies reviewed here vary substantially across geography, year, sampling frame, methodology, sample size, phrasing of questions, and basis of comparison. The findings of transit replacement range from 14 to 50 percent, depending on the respondent. While virtually all studies directed questions toward urban travelers, the findings from Boston and New York City suggest that very dense metropolitan areas with established, well-patronized transit systems may be more vulnerable to transit ridership losses. Bus service also appears more vulnerable to replacement than rail, and several studies show that effects may increase over time as users adopt ridehail in a region. As noted in Section 2, Subsection 5.1 above, ridehail and taxi trips comprised 0.5 percent of person trips in the 2017 NHTS. But as only 2.5 percent of trips were transit trips, a potential overlap between the two modes (as suggested in some of these studies) could cause steep declines in public transit ridership.

25. Austin, Boston, Chicago, Los Angeles, San Francisco, Seattle, and Washington, D.C.

Appendix E. Jobs and Housing in Bay Area Cities

Table E-1. Change in Residents and Jobs over Time in the Bay Area

CITY	EMPLOYED RESIDENTS			JOBS			RATIO OF JOBS TO RESIDENTS		
	2002	2015	CHANGE, 2002 to 2015	2002	2015	CHANGE, 2002 to 2015	2002	2015	CHANGE, 2002 to 2015
Alameda	35,614	39,000	+9.51%	21,887	27,687	+26.50%	0.61	0.71	+15.52%
Albany	7,344	8,010	+9.07%	3,450	4,201	+21.77%	0.47	0.52	+11.64%
American Canyon	3,256	6,579	+102.06%	6,916	925	-86.63%	2.12	0.14	-93.38%
Antioch	34,038	43,678	+28.32%	17,947	24,134	+34.47%	0.53	0.55	+4.79%
Belmont	12,213	13,175	+7.88%	7,752	7,320	-5.57%	0.63	0.56	-12.47%
Benicia	10,562	14,011	+32.65%	4,490	12,580	+180.18%	0.43	0.90	+111.21%
Berkeley	44,484	45,655	+2.63%	72,666	65,799	-9.45%	1.63	1.44	-11.77%
Brentwood	10,081	12,526	+24.25%	1,830	4,527	+147.38%	0.18	0.36	+99.09%
Brisbane	2,125	2,711	+27.58%	8,456	6,465	-23.55%	3.98	2.38	-40.07%
Burlingame	13,413	14,290	+6.54%	43,215	40,280	-6.79%	3.22	2.82	-12.51%
Calistoga	2,786	2,484	-10.84%	2,260	2,153	-4.73%	0.81	0.87	+6.85%

CITY	EMPLOYED RESIDENTS			JOBS			RATIO OF JOBS TO RESIDENTS		
	2002	2015	CHANGE, 2002 to 2015	2002	2015	CHANGE, 2002 to 2015	2002	2015	CHANGE, 2002 to 2015
Campbell	18,574	21,037	+13.26%	22,578	25,560	+13.21%	1.22	1.22	-0.05%
Clayton	5,847	3,683	-37.01%	1,358	1,218	-10.31%	0.23	0.33	+42.39%
Colma	1,105	1,648	+49.14%	4,690	4,093	-12.73%	4.24	2.48	-41.48%
Concord	51,839	54,627	+5.38%	30,433	27,655	-9.13%	0.59	0.51	-13.77%
Corte Madera	4,407	4,521	+2.59%	8,787	11,884	+35.25%	1.99	2.63	+31.83%
Cotati	7,202	7,354	+2.11%	7,972	10,194	+27.87%	1.11	1.39	+25.23%
Cupertino	21,733	26,424	+21.58%	30,806	45,799	+48.67%	1.42	1.73	+22.28%
Daly City	48,363	49,452	+2.25%	16,564	17,129	+3.41%	0.34	0.35	+1.13%
Danville	15,820	16,128	+1.95%	8,742	8,066	-7.73%	0.55	0.50	-9.49%
Dixon	7,367	8,729	+18.49%	6,619	5,001	-24.44%	0.90	0.57	-36.23%
Dublin	9,720	20,056	+106.34%	13,922	20,720	+48.83%	1.43	1.03	-27.87%
East Palo Alto	9,920	11,795	+18.90%	6,353	8,373	+31.80%	0.64	0.71	+10.84%

CITY	EMPLOYED RESIDENTS			JOBS			RATIO OF JOBS TO RESIDENTS		
	2002	2015	CHANGE, 2002 to 2015	2002	2015	CHANGE, 2002 to 2015	2002	2015	CHANGE, 2002 to 2015
El Cerrito	12,172	13,065	+7.34%	4,696	5,246	+11.71%	0.39	0.40	+4.08%
Emeryville	3,201	5,915	+84.79%	18,907	22,711	+20.12%	5.91	3.84	-35.00%
Fairfax	4,016	3,993	-0.57%	1,429	1,594	+11.55%	0.36	0.40	+12.19%
Fairfield	23,924	33,145	+38.54%	25,112	23,755	-5.40%	1.05	0.72	-31.72%
Foster City	14,879	17,423	+17.10%	15,846	20,333	+28.32%	1.06	1.17	+9.58%
Fremont	94,004	106,347	+13.13%	36,540	43,449	+18.91%	0.39	0.41	+5.11%
Gilroy	14,230	16,310	+14.62%	9,157	9,075	-0.90%	0.64	0.56	-13.53%
Hayward	66,956	70,378	+5.11%	72,645	68,774	-5.33%	1.08	0.98	-9.93%
Healdsburg	3,991	3,751	-6.01%	4,372	5,448	+24.61%	1.10	1.45	+32.58%
Hercules	10,243	10,666	+4.13%	2,974	4,430	+48.96%	0.29	0.42	+43.05%
Lafayette	9,151	9,004	-1.61%	8,956	10,191	+13.79%	0.98	1.13	+15.65%
Larkspur	2,503	5,295	+111.55%	2,069	5,678	+174.43%	0.83	1.07	+29.73%
Livermore	30,367	37,149	+22.33%	14,471	21,162	+46.24%	0.48	0.57	+19.54%
Los Altos	13,140	15,415	+17.31%	10,838	10,639	-1.84%	0.82	0.69	-16.32%

CITY	EMPLOYED RESIDENTS			JOBS			RATIO OF JOBS TO RESIDENTS		
	2002	2015	CHANGE, 2002 to 2015	2002	2015	CHANGE, 2002 to 2015	2002	2015	CHANGE, 2002 to 2015
Los Gatos	9,403	10,722	+14.03%	8,031	9,734	+21.21%	0.85	0.91	+6.29%
Martinez	10,603	10,983	+3.58%	8,420	10,151	+20.56%	0.79	0.92	+16.39%
Menlo Park	12,191	14,879	+22.05%	23,704	36,406	+53.59%	1.94	2.45	+25.84%
Mill Valley	5,517	5,551	+0.62%	5,297	5,782	+9.16%	0.96	1.04	+8.49%
Millbrae	8,847	10,064	+13.76%	5,379	5,559	+3.35%	0.61	0.55	-9.15%
Milpitas	27,366	33,520	+22.49%	31,084	29,293	-5.76%	1.14	0.87	-23.06%
Moraga	3,544	3,708	+4.63%	2,383	2,825	+18.55%	0.67	0.76	+13.30%
Morgan Hill	8,774	8,186	-6.70%	11,966	11,327	-5.34%	1.36	1.38	+1.46%
Mountain View	29,755	35,532	+19.42%	36,753	50,853	+38.36%	1.24	1.43	+15.87%
Napa	30,059	29,529	-1.76%	24,701	24,866	+0.67%	0.82	0.84	+2.47%
Newark	26,862	25,873	-3.68%	75,114	82,704	+10.10%	2.80	3.20	+14.31%
Novato	20,798	23,653	+13.73%	19,225	19,390	+0.86%	0.92	0.82	-11.32%
Oakland	167,619	185,435	+10.63%	173,427	196,905	+13.54%	1.03	1.06	+2.63%
Oakley	13,861	14,096	+1.70%	2,720	3,535	+29.96%	0.20	0.25	+27.80%

CITY	EMPLOYED RESIDENTS			JOBS			RATIO OF JOBS TO RESIDENTS		
	2002	2015	CHANGE, 2002 to 2015	2002	2015	CHANGE, 2002 to 2015	2002	2015	CHANGE, 2002 to 2015
Orinda	6,077	6,387	+5.10%	3,575	3,411	-4.59%	0.59	0.53	-9.22%
Pacifica	17,267	20,576	+19.16%	2,982	4,782	+60.36%	0.17	0.23	+34.57%
Palo Alto	24,099	28,436	+18.00%	40,540	57,586	+42.05%	1.68	2.03	+20.38%
Petaluma	19,333	17,138	-11.35%	17,553	13,530	-22.92%	0.91	0.79	-13.05%
Piedmont	4,593	4,630	+0.81%	1,863	1,534	-17.66%	0.41	0.33	-18.32%
Pinole	5,577	8,087	+45.01%	1,312	2,299	+75.23%	0.24	0.28	+20.84%
Pittsburg	16,540	16,825	+1.72%	9,013	10,756	+19.34%	0.54	0.64	+17.32%
Pleasant Hill	16,484	14,140	-14.22%	14,193	11,824	-16.69%	0.86	0.84	-2.88%
Pleasanton	21,841	26,668	+22.10%	60,574	57,881	-4.45%	2.77	2.17	-21.74%
Redwood City	33,794	36,547	+8.15%	44,604	59,321	+32.99%	1.32	1.62	+22.98%
Richmond	48,433	49,242	+1.67%	32,992	34,643	+5.00%	0.68	0.70	+3.28%
Rohnert Park	17,420	14,523	-16.63%	8,892	7,672	-13.72%	0.51	0.53	+3.49%
Saint Helena	2,641	2,693	+1.97%	8,355	5,527	-33.85%	3.16	2.05	-35.13%
San Anselmo	3,229	3,336	+3.31%	2,717	2,336	-14.02%	0.84	0.70	-16.78%

CITY	EMPLOYED RESIDENTS			JOBS			RATIO OF JOBS TO RESIDENTS		
	2002	2015	CHANGE, 2002 to 2015	2002	2015	CHANGE, 2002 to 2015	2002	2015	CHANGE, 2002 to 2015
San Bruno	20,450	20,198	-1.23%	16,038	13,557	-15.47%	0.78	0.67	-14.41%
San Carlos	13,489	14,086	+4.43%	16,861	16,682	-1.06%	1.25	1.18	-5.25%
San Francisco	367,188	446,298	+21.54%	515,790	689,271	+33.63%	1.40	1.54	+9.95%
San Jose	379,730	449,026	+18.25%	379,030	445,642	+17.57%	1.00	0.99	-0.57%
San Leandro	39,088	47,193	+20.74%	41,789	46,686	+11.72%	1.07	0.99	-7.47%
San Mateo	43,174	50,825	+17.72%	38,958	49,660	+27.47%	0.90	0.98	+8.28%
San Pablo	11,722	11,429	-2.50%	3,983	4,589	+15.21%	0.34	0.40	+18.17%
San Rafael	21,360	21,937	+2.70%	32,853	29,522	-10.14%	1.54	1.35	-12.50%
San Ramon	14,602	30,300	+107.51%	20,792	38,551	+85.41%	1.42	1.27	-10.65%
Santa Clara	45,384	59,853	+31.88%	104,591	104,190	-0.38%	2.30	1.74	-24.46%
Santa Rosa	53,324	54,004	+1.28%	61,730	57,331	-7.13%	1.16	1.06	-8.30%
Saratoga	10,904	11,774	+7.98%	5,558	6,710	+20.73%	0.51	0.57	+11.81%
Sausalito	3,360	3,357	-0.09%	5,417	5,433	+0.30%	1.61	1.62	+0.38%
Sonoma	2,842	3,232	+13.72%	4,648	4,282	-7.87%	1.64	1.32	-18.99%

CITY	EMPLOYED RESIDENTS			JOBS			RATIO OF JOBS TO RESIDENTS		
	2002	2015	CHANGE, 2002 to 2015	2002	2015	CHANGE, 2002 to 2015	2002	2015	CHANGE, 2002 to 2015
South San Francisco	30,150	34,815	+15.47%	43,899	50,161	+14.26%	1.46	1.44	-1.05%
Suisun City	6,381	6,721	+5.33%	2,503	1,097	-56.17%	0.39	0.16	-58.39%
Sunnyvale	65,356	76,147	+16.51%	71,053	66,065	-7.02%	1.09	0.87	-20.20%
Tiburon	3,695	3,884	+5.12%	2,338	2,178	-6.84%	0.63	0.56	-11.38%
Union City	32,100	35,944	+11.98%	20,016	30,489	+52.32%	0.62	0.85	+36.03%
Vacaville	30,416	39,969	+31.41%	22,343	32,351	+44.79%	0.73	0.81	+10.19%
Vallejo	47,936	49,897	+4.09%	27,584	27,670	+0.31%	0.58	0.55	-3.63%
Walnut Creek	25,950	30,447	+17.33%	57,899	55,489	-4.16%	2.23	1.82	-18.32%
Windsor	3,742	5,174	+38.27%	2,419	3,473	+43.57%	0.65	0.67	+3.84%
Yountville	1,012	1,113	+9.98%	1,175	2,787	+137.19%	1.16	2.50	+115.67%

Data source: U.S. Census Bureau, n.d.; Caltrans, 2015

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