The Bay Area Rail System: A Sustainable Network or a Social Equity Phenomenon?

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The Bay Area Rail System: A Sustainable Network or a Social Equity Phenomenon?

By: Whitney Libunao

University of San Francisco

Final Master’s Project

MSEM | Fall 2020
Index

List of Tables 1
List of Figures 3
List of Acronyms and Abbreviations 4
Abstract 5

Introduction 6
   Sustainable Development 111
   Sustainable Transportation 133
   Transportation 166
   Rail Systems 200
   Displacement and Gentrification 244

Study Area 29

Methods 311
   Demographic Data 400
      Alameda 400
      Contra Costa 422
      Marin 433
      Napa 455
      San Francisco 455
      San Mateo 467
      Santa Clara 477
      Solano 49
      Sonoma 500
   Displacement Data 511
      Alameda 511
      Contra Costa 511
      Marin 511
      San Francisco 511
      San Mateo 522
      Santa Clara 522
      Solano 522
      Sonoma 522

Discussion 533

Recommendations 555
List of Tables

Table 1: Analyzed Bay Area Rail Systems and Types ..................................................9
Table 2: Adverse Impacts to Sustainable Transportation............................................15
Table 3: Bay Area Rail Systems ..................................................................................22
Table 4: Rail System Types........................................................................................23
Table 5: Generic Profile of a Bay Area Resident Living Within 1-Mile of a Railway Station Stop Location.........................................................................................53
List of Figures

Figure 1: California Emissions by Economic Sector ......................................................... 6
Figure 2: Greenhouse Gas Emissions by Primary Sources .............................................. 7
Figure 3: Per-Capita Greenhouse Gas Emissions from Primary Sources ....................... 8
Figure 4: The 17 Sustainable Development Goals .......................................................... 12
Figure 5: Three Pillars of Sustainability ........................................................................ 16
Figure 6: San Francisco Bay Area Commute Mode Choice for Cities and Neighborhoods .. 18
Figure 7: Historical Trend for Commute Mode Choice: Transit .................................... 19
Figure 8: Low-Income Households at Risk of Displacement and Total Low-Income Households in the San Francisco Bay Area ........................................................................ 28
Figure 9: San Francisco Bay Area, California with Rail Station Stops .............................. 30
Figure 10: Service Area Generation Geoprocessing Workflow ...................................... 33
Figure 11: 1-Mile Service Areas for Solano and Sonoma Counties ............................... 34
Figure 12: Low-Income Households at Risk of Displacement in Contra Costa and San Francisco Counties .................................................................................................................. 35
Figure 13: Alameda and Contra Costa Counties .............................................................. 36
Figure 14: Marin and Napa Counties ............................................................................. 37
Figure 15: San Francisco and San Mateo Counties ......................................................... 38
Figure 16: Santa Clara and Solano Counties ................................................................... 39
Figure 17: Sonoma County .............................................................................................. 40
Figure 18: Distance vs. Households at Risk of Displacement ......................................... 54
List of Acronyms and Abbreviations

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AASHTO</td>
<td>American Association of State Highway and Transportation Officials</td>
</tr>
<tr>
<td>ABAG</td>
<td>Association of Bay Area Governments</td>
</tr>
<tr>
<td>ACE</td>
<td>Altamont Commuter Express</td>
</tr>
<tr>
<td>BART</td>
<td>Bay Area Rapid Transit</td>
</tr>
<tr>
<td>CSD</td>
<td>Commission of Sustainable Development</td>
</tr>
<tr>
<td>EPA</td>
<td>Environmental Protection Agency</td>
</tr>
<tr>
<td>Mi</td>
<td>Mile(s)</td>
</tr>
<tr>
<td>MMT</td>
<td>Million Metric Tons</td>
</tr>
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<td>MT</td>
<td>Metric Tons</td>
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<tr>
<td>MTC</td>
<td>Metropolitan Transportation Commission</td>
</tr>
<tr>
<td>SDG(s)</td>
<td>Sustainable Development Goal(s)</td>
</tr>
<tr>
<td>SF Muni/Muni</td>
<td>San Francisco Municipal Railway</td>
</tr>
<tr>
<td>SFMTA</td>
<td>San Francisco Municipal Transportation Agency</td>
</tr>
<tr>
<td>SMART</td>
<td>Sonoma-Marin Area Rail Transit</td>
</tr>
<tr>
<td>TOD(s)</td>
<td>Transit-Oriented Development(s)</td>
</tr>
<tr>
<td>UN</td>
<td>United Nations</td>
</tr>
<tr>
<td>UNCED</td>
<td>United Nations Conference on Environment and Development</td>
</tr>
<tr>
<td>VTA</td>
<td>Santa Clara Valley Transportation Authority</td>
</tr>
</tbody>
</table>
WCED  World Commission on Environment and Development
Abstract

Sustainable transportation, as it relates to sustainable development, aims to achieve economic stability, social equity, and environmental preservation via transit projects. However, gentrification processes and transit-oriented developments or TODs have attracted more households inward toward reinvested transit-centric areas. The San Francisco Bay Area, California has continued to see positive economic growth, with that, higher-income households inhabiting more centralized locations. Native low-income residents have started to feel displacement pressures on both a social and economic scale. Over time, displacement risk inevitably leads to residential displacement where low-income families are forced to relocate to distant, more affordable neighborhoods. As more distance separates low-income residents from the region’s epicenter, transportation options grow increasingly scarce and the Bay Area transit network begins to cater to a smaller subset of people than what the service originally intended. Thus, potentially becoming more of a social equity phenomenon.

The primary objective of this project was to determine if the Bay Area rail system is a sustainable network or indicative of a social equity phenomenon. Using GIS, railway station stops were spatially analyzed to represent transit accessibility points within each of the 9 Bay Area counties. Demographic data including median household income, race, age range, sex, educational attainment, and transit mode preference were integrated to determine if the rail system satisfies the accessibility criteria of sustainable transportation and to construct a general profile of an individual that resides within 1-mile of a railway station stop. Displacement risk was analyzed to determine if residents living within the service area were susceptible to displacement and whether there is a noticeable disparity between the profile of a service area inhabitant and a displaced individual. Results indicated that the Bay Area railway station network does not satisfy the accessibility criteria of sustainable development, as generic profiles constructed for an individual living within the defined service area for all 9 counties exhibited similar characteristics - well paid, middle-aged white individuals that preferred to drive to work, had obtained a bachelor’s degree or equivalent. Alternatively, displaced individuals generally were low-income minority populations that either do not have access to a car or prioritize public transportation for the lower cost. Displacement risk across the region ranges from a low of 0% in North Bay counties to a high of 54% in San Francisco county.
Introduction

In 2018, California’s greenhouse gas emissions inventory totaled 425.3 million metric tons CO$_2$e - of which 41% were derived from transportation as shown in Figure 1 (California Air Resources Board, 2020). Collectively, the San Francisco Bay Area contributed approximately 23.2 MMT CO$_2$e into the environment via surface transportation in 2015 while GHG emissions per capita estimated 3.1 MT as shown in Figures 2 and 3 (MTC, 2017). According to the Metropolitan Transportation Commission (2017), despite the region’s commitment to protecting the environment, Bay Area residents generate GHGs at a rate substantially higher than the global average. To combat this, commuters across the Bay Area have transitioned to more sustainable transportation modes to get to work.

Adapted from California Air Resources Board (2020)

Figure 1: 2018 Greenhouse gas emissions inventory for California that include estimates of carbon dioxide (CO$_2$), methane (CH$_4$), nitrous oxide (N$_2$O), and fluorinated gases that have high global warming potential or high-GWP that include perfluorocarbons (PFCs), hydrofluorocarbons (HFCs), nitrogen trifluoride (NF$_3$), and sulfur hexafluoride (SF$_6$).
In 2018, the Bay Area ranked second in the nation after New York City for its efforts to shift commuters toward alternative transportation rather than motorized vehicles (MTC, 2020A). However, while 74% of Bay Area commuters chose to drive to work only 12% relied on public transportation (MTC, 2020A). Since 2000, 7% of commuters have shifted away from driving alone while the remaining three-quarters of the population chose otherwise.

Although the Bay Area is a leading example of alternative transportation use in a national context, transportation challenges in the region extend further than commute mode choices. The region’s economy has reached new heights in recent years with the growth of high-paying jobs in areas such as San Francisco and Silicon Valley, where displacement risk has become an increasingly regional problem (MTC, 2019). Rising housing costs and limited tenant protections in central affluent areas coupled with processes of gentrification via transportation-oriented development in disinvested areas can result in large numbers of Bay Area residents being forced to relocate to distant, more affordable communities. Households are pushed further
toward the region’s outskirts and forced to commute longer distances where positive growth in environmental restoration, alternative transportation usage, and social equity are jeopardized.

**Per-Capita Greenhouse Gas Emissions from Primary Sources**

Bay Area

![Graph showing per-capita greenhouse gas emissions from primary sources (natural gas, electricity, and surface transportation) from 1990 to 2015.](image)

Adapted from MTC (2017)

**Figure 3:** Data shown above was obtained from Vital Signs and illustrates greenhouse gas emissions by primary source - natural gas, electricity and surface transportation from 1990-2015.

The San Francisco Bay Area extends across 9 counties: Alameda, Contra Costa, Marin, Napa, San Francisco, San Mateo, Santa Clara, Solano, and Sonoma. These counties consist of 101 cities - 3 of which are major cities - San Francisco, Oakland, and San Jose (MTC, 2020B). In 2018, the Bay Area housed over 7.7 million people - a 53.1% increase in population from 1960 and a 12.8% increase since 2000 (MTC, 2020b). The region spans approximately 7,000 square miles and is a leading hub for high-tech innovation, high-paying jobs, community revitalization, and transportation-oriented developments or TODs. These attributes attract large quantities of people looking for advances in opportunity, convenience, aesthetic, and comfortability toward transit-centric hubs. Data derived from MTC (2019) suggests that middle- to upper-middle class residents (with a median household income greater than $73,000 to $116,000+) have gravitated toward gentrified areas that are in close proximity to the San Francisco Bay. Whereas, lower-income households (with a median household income between $12,000 and $73,000) primarily
reside in far, disinvested, underdeveloped areas that lack transportation options. Michelle Robertson of SF Gate (2018) concluded that to be considered low-income within San Francisco, San Mateo, and Marin counties, median household income for a family of four is $117,400. Very-low income is considered less than or equal to $73,300. Notably, in regard to median household income, the San Francisco Bay Area possesses figures that are the highest in the country and increase from year to year (Robertson, 2018). As transit options become scarce the further from the Bay’s epicenter one resides, accessibility to alternative transportation declines causing commuters to turn to more accessible yet unsustainable forms of transit.

In its densest and most developed areas, the Bay Area offers various sustainable transportation options that include buses, trains, ferries, light-rail fleets, cable cars, and street cars with a variety of modes and frequency of service from county-to-county. Railway station networks in particular were analyzed in this project. Specifically, light-rail, heavy- and rapid-rail, and commuter-rail system networks. The Bay Area railway networks that were analyzed in this project were the following:

Table 1: Analyzed Bay Area Rail Systems and Types

<table>
<thead>
<tr>
<th>Light Rails</th>
<th>Heavy and Rapid Rails</th>
<th>Commuter Rails</th>
</tr>
</thead>
<tbody>
<tr>
<td>San Francisco Muni Metro</td>
<td>Bay Area Rapid Transit</td>
<td>Altamont Corridor Express</td>
</tr>
<tr>
<td>Santa Clara Valley Transportation Authority</td>
<td></td>
<td>Caltrain</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Capitol Corridor</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sonoma-Marin Area Rail Transit</td>
</tr>
</tbody>
</table>

Notably, all counties in the region are serviced by at least one railway station network except Napa County.

Rail systems are the more sustainable transit option relative to single-occupancy vehicles. Seldom are the concepts of sustainable development and sustainable transportation addressed in empirical studies for alternatives that were intended to dissuade individuals from commuting in cars in the first place. Even less commonly analyzed is the relationship between sustainable transportation criteria and the communities they service - not in ridership but in proximity.
Sustainable development and transportation aim to harmonize social equity, economic vitality, and environmental sustainability. A primary criteria that must be satisfied within a sustainable network is catering to all communities equitably. However, in a region that consistently experiences rapid growth, measuring the Bay Area’s efficacy to measure up and continue to satisfy the framework of a sustainable network is at question; specifically, the Bay Area’s rail system. This project aims to determine if the region’s railway systems adequately service all communities. As the processes of gentrification and steady economic growth attract higher-income households inward, and the pressures of displacement risk weigh on lower-income households to move to outward, serviced populations near rail stations inevitably shift.

Using Geographic Information Systems or GIS, data reflecting the Bay Area census was manipulated to address four primary objectives. The goal of this project was to first determine if Bay Area railway accessibility caters to all communities equitably, including those with economic disadvantages. The second objective was to examine if a generic profile of an individual who lived within a 1-mile proximity of a railway station location could be generated. All current and operating station locations across the region were used as concentrated study areas to examine the demographic of individuals living within the same 1-mile distance from station locations. The third objective was to conclude if displacement risk within the service area was evident. To satisfy this objective, displacement risk data was gathered and integrated into the GIS to depict census tracts with low-income households at risk of displacement. Lastly, the fourth objective was to determine if there is a notable disparity between the generated demographic profile of an individual who lived within a 1-mile service area and the typical profile of a displaced resident.
**Sustainable Development**

The concept of sustainable development is derived from the U.S. government’s National Environmental Policy Act (NEPA) of 1969. As the first major environmental law in the United States, NEPA aims to create and maintain conditions where humans and the natural environment can coexist to achieve social, economic, and environmental harmony for future generations (NEPA, 2020). NEPA (2020) requires agencies to consider the environmental impacts of their proposed actions, identify adverse effects and alternatives, identify short-term and long-term effects of the proposal, and highlight any irreversible alterations of resources caused by the action. Because of its consideration of the relationship between man and the environment, countries and non-governmental agencies have adopted their own environmental impact assessment programs on a global scale.

In June 1972, the United Nations Conference on the Human Environment (Stockholm Conference) was held in Stockholm, Sweden and is known as the first major UN conference focused on environmental issues (United Nations, 1972). The conference brought together industrialized and developing nations to devise the Stockholm Declaration that prioritized 26 principles that placed environmentally related issues at the forefront of international concerns. The action plan determined that the main objective for the human family was to establish a harmonious relationship with a healthy, productive, and sustainable environment.

The oft-cited sustainable development term became popularized when its definition was formally introduced in a proposal for a world conservation strategy in 1987. The World Commission on Environment and Development (WCED) published *Our Common Future*, which later came to be known as *The Brundtland Report* after the commission’s chairwoman, Gro Harlem Brundtland (United Nations, 1987). The document pointed toward the critical global environmental disparities of extreme poverty in the South and the unsustainable practices and high rates of consumption habits in the North. The primary objective of the report was to link environmental stability and economic development to suggest a path toward sustainability for all nations - including developing ones.
In 1992, at the first United Nations Conference on Environment and Development in Rio De Janeiro, Brazil, Agenda 21 was adopted. Agenda 21 was generated as an action plan towards sustainable development and called for all States that have humans with the capability to impact the environment, to assume the responsibility of adopting a model aimed to achieve national sustainability (United Nations, 1992). To conduct follow-ups for the UNCED, the Commission of Sustainable Development or CSD was created to monitor and report on agenda implementation at the local, regional, national, and international levels (United Nations, 2020).

In September 2015, the General Assembly of the United Nations adopted the 2030 Agenda for sustainable development that idealizes a world fully inclusive of those with disabilities. The main objective of the UN agenda (2015) was to emphasize that “no man gets left behind” and implements a more holistic approach toward sustainable development for all. The Envision 2030 plan, as shown in Figure 4, prioritizes 17 Sustainable Development Goals (SDGs) to transform our world and devise a plan to strengthen universal peace (United Nations General Assembly, 2015).

Figure 4: The Sustainable Development Goals as proposed in the 2030 Agenda emphasize a plan of action for people, planet, and prosperity and highlights sustainable transportation under Goal 11 (United Nations General Assembly, 2015).
These 17 SDGs are a blueprint to achieve sustainable development and address the global challenges related to poverty, inequality, transportation, education, climate change, environmental degradation, peace and justice.

**Sustainable Transportation**

Under the Envision 2030 Agenda, goal 11 of the SDGs is to make cities and human settlements inclusive, safe, resilient and sustainable (United Nations, 2020A). Of the 10 primary targets under goal 11, one objective in particular focuses on transportation. By 2030, the agenda hopes to provide access to *safe, affordable, accessible*, and *sustainable* transportation systems for all. Improvements to road safety coupled with the expansion of public transportation options is integral to the success of goal 11. Additionally, consideration of the needs of those in special circumstances including women, children, people with disabilities, and elderly persons is pertinent (United Nations General Assembly, 2015).

Similar to sustainable development, sustainable transportation does not have a universally recognized definition. Stojanovski (2017) defines sustainable transportation as a process by which environmentally conscious and energy efficient transportation options are implemented through mobility management and sustainable mobility indicators. These indicators capture environmental, economic and social aspects, public participation, and future goals of a community. The American Association of State Highway and Transportation Officials (2012) scrutinizes sustainable transportation under the same criteria as sustainable development. The concept of sustainable transportation can be broken down by the triple bottom line framework to guide planning, policy, and implementation efforts. Agencies and companies should aim to satisfy the following criteria when considering transportation projects:

1. *Economically*, the transit project must support economic vitality and be cost-efficient. Transit costs must be within the ability of an individual or a household to pay without major financial burden.
2. *Socially*, the transit project must meet societal needs by creating transportation infrastructure that is accessible, safe, and secure. The project should offer sustainable transportation choices for all people (including those with economic disadvantages) and create transportation infrastructure that is an asset to its community.

3. *Environmentally*, the transit project must create solutions that will restore and enhance the natural environment, reduce emissions and material resources used in transportation development projects (AASHTO, 2012).

Alternatively, according to Sultana et al. (2017), to understand transportation sustainability, identifying what makes urban transport unsustainable is critical. Table 2 below highlights the primary and secondary sustainability impacts of urban transportation. Evidently, the prioritization of all variables has not been achieved across most transit projects and modern TODs. As noted in Campbell’s Planner Triangle (2016), inherent conflicts and tradeoffs arise when trying to satisfy all levels of sustainable transportation. As depicted in Figure 5 below, transportation projects aim to equally prioritize people, planet and profit; where the relationship between planet and people must be bearable; people and profit must be equitable; profit and planet must be viable; and across all three must be sustainable. Win-win-win solutions may be elusive, but the goal to achieve balance across all concepts remains. This project focused on the social equity and environmental aspect of the triple bottom line framework as it relates to transportation sustainability. Specifically, how TOD implementation in the Bay Area has satisfied accessibility standards under these conditions. Or, if the Bay Area transportation network is unable to satisfy this criteria, a larger social equity issue may be unveiled.
<table>
<thead>
<tr>
<th>Unsustainable Problem or Practice</th>
<th>Environmental</th>
<th>Social</th>
<th>Economic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carrying capacity and material throughput</td>
<td>air quality</td>
<td>health</td>
<td>oil prices</td>
</tr>
<tr>
<td>Oil (prices, supply, and reserves)</td>
<td>drilling in sensitive ecoregions</td>
<td>price variation effects on families and communities</td>
<td>oil prices</td>
</tr>
<tr>
<td>Climate change</td>
<td>biodiversity, precipitation, extreme weather conditions</td>
<td>health, occupations, food, safety, water, migration, etc.</td>
<td>impacts across all economic sectors</td>
</tr>
<tr>
<td>Traffic congestion</td>
<td>increased emissions</td>
<td>time constraints on households</td>
<td>time costs</td>
</tr>
<tr>
<td>Road safety</td>
<td>resources used in repairing and replacing parts</td>
<td>injuries and death</td>
<td>accident costs</td>
</tr>
<tr>
<td>Transportation affordability</td>
<td>increased emissions in older cars</td>
<td>household budgetary restrictions</td>
<td>accessibility to school, work, etc.</td>
</tr>
<tr>
<td>Equity</td>
<td>access to transportation alternatives</td>
<td>accessibility to school, work, etc.</td>
<td>exclusion of potential consumers and workers</td>
</tr>
<tr>
<td>Physical activities and health</td>
<td>emissions from motorized vehicles</td>
<td>health</td>
<td>medical costs</td>
</tr>
</tbody>
</table>
According to the Transit Oriented Development Institute (2020), TODs are a relatively new trend that create vibrant, livable, and sustainable communities. TODs incorporate a compact, walkable, pedestrian-oriented, and mixed-use design around transit hubs (Transit Oriented Development Institute, 2020) and aim to reduce stress on commuters and eliminate dependency on motorized vehicles. As a leading national example of transportation alternatives to the motorized vehicle, this project analyzed commuter transit preferences within a concentrated study area and the viability of TODs to successfully cater to the needs of communities across the region.

From a regional perspective, mode shares in the Bay Area have shifted dramatically over the last decade as depicted in Figure 6. Commuters who chose to drive to work decreased 6.7% (from 80.9% in 2000 to 74.2% in 2018) (MTC, 2020A). This accelerated rate of reduction can be
partially attributed to the increased availability of public transit mode shares and rising
popularity of active forms of transit. And while public transportation options have expanded
across the region, so have its users. Public transit patrons increased to 12% in 2015 with
consistent participation through 2018. It should be noted that public transportation only
fluctuated 2% since 1970, rising and falling only fractions of a percent from year to year (MTC,
2020A). Stagnant public transportation participation can be attributed to restricted accessibility
in less-populated suburban neighborhoods; safety concerns on transit vehicles; lack of
comfortability on transit systems and; increased commute time due to infrequent or unreliable
transit service.

Moreover, MTC (2020A) noted that 3.7% of Bay Area commuters walked and biked to
work in 2018. Biking increased by 1.1% and walking had acquired a 0.3% increase in
participation since 2010. Development projects around the Bay Area are considering now more
than ever the prioritization of pedestrian and biking infrastructure. Integrating more car free
streets in neighborhoods and cities like San Francisco’s busiest corridor, Market Street, where on
January 29, 2020 a ban of all private vehicles traveling along the corridor was prohibited (SF
Bicycle Coalition, 2020). If more cities in the Bay Area adopted similar models, participation in
active mode shares should continue to see gradual increases in the near term.

Bay Area commuters who worked from home increased from 5.9% in 2010 to 6.4% in
2018. The share of individuals who have transitioned to remote work increased steadily since
1980 (MTC, 2020A). Commuters who have eliminated their time on the road contribute to the
reduction of single-occupancy vehicles on Bay Area thoroughfares.

Of the various transit options offered across the Bay Area, public transportation was
analyzed in this project. Because of its urban landscape, San Francisco is the regional leader of
commuters who chose to take public transportation to work (MTC, 2020A). During regular
commute hours, heavy and rapid rail service, light rail service, bus service, and employer-
supplied shuttle services operate through San Francisco. In 2018, 33.5% of commuters took
public transportation (MTC, 2020A).
Figure 6: The data shown here depicts Bay Area commute mode choice for cities and neighborhoods between the years 1960-2018. Indicators included all forms of automobiles, carpooling, driving alone, other (biking), public transit, walking, and working from home.

According to the Metropolitan Transportation Commission (2020A), walking and biking considered, 60% of San Francisco commuters traveled to work without an automobile.

Alameda county had the second highest rate of public transportation utilization. From 2010 to 2018, Alameda county experienced a 4.9% increase in usage. Contra Costa county increased by 0.9% from 2017 to 2018 and had the highest amount of public transportation users to date (11.2%)(MTC, 2020A). San Mateo county followed with 10.6% of its commuter population utilizing public transportation. Notably, San Mateo’s share of individuals who utilized public transportation decreased by 0.8% from 2017 to 2018 - the only one of the top four leading counties that experienced a decrease in recent years. In the North Bay, Marin County had shown a gradual reduction in public transportation usage from 2015 to 2018 (11.3% to 8.3%)(MTC, 2020A). However, Marin also experienced an increase in commuters that transitioned to working from home. From 2010 to 2018, Marin County had a 6.6% spike in remote workers. Therefore, it could be assumed that some individuals who once utilized public
transportation in Marin began to work from home in recent years. Alternatively, in the South Bay, Santa Clara county showed a 0.7% reduction in public transportation users between 2017 and 2018. Driving alone in Santa Clara county however, increased by 1.2% (0.74% to 0.75%) (MTC, 2020A).

In Solano County, public transportation usage increased to 1.2% from 2.1% in 2000 to 3.3% in 2018. Driving alone decreased by 0.8% while biking and other forms of public transportation increased by 2%. In Napa County, MTC (2020A) reported that public transportation also saw an increase in usage from 0% in 2011 to 2.2% in 2018 (a 1.6% increase from 2017 to 2018). Lastly, Sonoma County had the lowest share of public transportation users in the Bay Area overall. However, the county saw a gradual increase in participation over the span of nearly a decade. In 2010, 1.9% of commuters were utilizing public transportation and in 2018, 2.1% of commuters opted for public transit.

![Historical Trend for Commute Mode Choice](image)

Figure 7: Data shown here depicts each county’s historical public transportation usage trends from 1960 to 2018.
According to Dawkins and Moeckel (2016), between 2000 and 2009, the number of commuters who relied on public transportation increased by 18%. Population forecasts have suggested that demographics within the United States have changed that may enhance the popularity of living near transit as demographic groups such as older, nonfamily, nonwhite households have been growing most rapidly across the nation. These groups have historically relied on public transportation in large quantities to evade automobile use and high costs of transit. Lower-income households are also less likely to utilize motorized vehicles and in turn are more dependent on reliable access to public transit that should be prioritized in TOD planning (Dawkins and Moeckel, 2016).

TODs are a combination of regional planning, suburban renewal, city revitalization, and walkable communities that are centered around high quality train systems (Transit Oriented Development Institute, 2020). Rail implementation plays an integral role in channeling economic growth to station neighborhoods, reduces automobile dependency (Dawkins and Moeckel, 2016), and provides transit that grants accessibility to people and businesses that they can value with certainty. Within the Bay Area, seven rail systems operate in the region that cater to eight out of nine counties that offer fixed route and physical infrastructure that minimizes uncertainty and risk amongst commuters (Rayle, 2014).

**Rail Systems**

This project focused on light-rail, heavy- and rapid- rail, and commuter-rail systems that operate in eight out of nine Bay Area counties. The rail systems that were considered were San Francisco Muni Metro, Santa Clara Valley Transportation Authority, Bay Area Rapid Transit, Sonoma-Marin Area Rail Transit, Capitol Corridor, Caltrain, and Altamont Commuter Express as shown in Table 3. Light-rail systems are a form of urban rail public transportation that typically carry lower capacities and travel speeds than heavy rail systems but higher passenger capacities and travel speeds than street-running tram services (Rail System, 2015B). These networks are usually powered by overhead electrical wires and used primarily for local transit in metropolitan areas. Light-rail vehicles or LRVs are considered a technological overgrowth of streetcars and are more segregated from street traffic (Brittanica, 2020). Heavy and rapid-rails
are urban passenger transportation systems that operate in their own right of way independent of road and pedestrian thoroughfares (Rail System, 2015C). Heavy and rapid systems are used for local transit in metropolitan areas and may run underground (subway), above street level (elevated transit line), or at street level. Commuter rails, or suburban rails, are rail transport services that connect a city center to outer suburban areas, commuter towns, or other locations (RailSystem, 2015A). Commuter rails attract a large number of commuters on a daily basis and are typically made up of more seating and less space for amenities and storage. The differences and descriptions between the three types of rail systems analyzed in this paper are noted in Table 4.

San Francisco Muni Metro and Santa Clara Valley Transportation Authority were the light rail systems analyzed in this project. The SF Muni Metro light rail was first inaugurated on February 18, 1980 and is the United States’ third-busiest light rail system (SFMTA, 2013). The Muni operates 151 fleet vehicles with an average weekday ridership of 173,500 passengers. Spanning 71.5 miles, the Muni Metro system offers seven light rail lines - six regular lines and one peak-hour shuttle. The system operates using 3 tunnels, nine subway stations (below ground), 24 surface stations, and 87 surface stops. Station locations and stops span from the southwestern part of San Francisco (Stonestown and San Francisco State University) to the East (Embarcadero and onto Third Street) (SFMTA, 2013).

The VTA light rail system first opened on December 11, 1987 by the Santa Clara County Transit District Act and services San Jose and the Silicon Valley suburbs in Santa Clara county (VTA, 2019). The rail system spans 42.2 miles of Santa Clara county and operates three rail lines: Blue line (Baypointe-Santa Teresa); Green line (Old Ironsides-Winchester); and Orange line (Mountain View-Alum Rock) (VTA, 2019). Since its opening, the VTA has steadily expanded and currently services 60 light rail stations. In 2019, the system’s average weekday ridership was 26,700 passengers and total annual ridership was 8.3 million (VTA, 2019).

BART was the only heavy and rapid rails analyzed in this paper. The San Francisco Bay Area Rapid Transit District is a heavy-rail public transit system that first opened for service in 1972. BART connects the San Francisco Peninsula to some cities across the East Bay (BART,
The system currently serves five counties (San Francisco, San Mateo, Alameda, Contra Costa, and Santa Clara), spans 131-miles, services 50 stations and conducts 405,000 trips on an average weekday (BART, 2020B).

Table 3: Bay Area Rail Systems

<table>
<thead>
<tr>
<th>Rail System</th>
<th>Alias</th>
<th>Year Began</th>
<th>Type</th>
<th>Counties Serviced (in Bay Area)</th>
<th>Total Mileage in Network</th>
<th>Number of Stations in Network</th>
</tr>
</thead>
<tbody>
<tr>
<td>Altamont Corridor Express</td>
<td>ACE</td>
<td>1988</td>
<td>Commuter</td>
<td>Alameda Santa Clara</td>
<td>86</td>
<td>10</td>
</tr>
<tr>
<td>Bay Area Rapid Transit</td>
<td>BART</td>
<td>1972</td>
<td>Heavy/Rapid</td>
<td>Alameda Contra Costa San Francisco San Mateo Santa Clara</td>
<td>131.4</td>
<td>50</td>
</tr>
<tr>
<td>Caltrain</td>
<td></td>
<td>1992</td>
<td>Commuter</td>
<td>San Francisco Santa Clara</td>
<td>51</td>
<td>31</td>
</tr>
<tr>
<td>Capitol Corridor</td>
<td>Amtrak</td>
<td>1991</td>
<td>Commuter</td>
<td>Alameda Contra Costa San Francisco Santa Clara Solano</td>
<td>170</td>
<td>18</td>
</tr>
<tr>
<td>San Francisco Muni Metro</td>
<td>SF Muni Muni</td>
<td>1980</td>
<td>Light</td>
<td>San Francisco</td>
<td>71.5</td>
<td>24</td>
</tr>
<tr>
<td>Santa Clara Valley Transportation Authority</td>
<td>VTA</td>
<td>1987</td>
<td>Light</td>
<td>Santa Clara</td>
<td>42.2</td>
<td>60</td>
</tr>
<tr>
<td>Sonoma-Marin Area Rail Transit</td>
<td>SMART</td>
<td>2017</td>
<td>Commuter</td>
<td>Marin Sonoma</td>
<td>45</td>
<td>11</td>
</tr>
</tbody>
</table>

ACE, BART, Caltrain, Capitol Corridor, SFMTA, SMART, VTA

Capitol Corridor, Caltrain, SMART, and ACE were the commuter trains analyzed in this project. Amtrak, as a national rail operator, services the Bay Area via the Capitol Corridor (CCJPA). The Capitol Corridor is an intercity passenger train system offering a sustainable alternative to commuters traveling along I-80, I-680, and I-880. Full service of the Capitol Corridor spans 180-miles with 18 station stops and serves 5 Bay Area counties - San Francisco, Solano, Contra Costa, Alameda, and Santa Clara (Capitol Corridor, 2019). Lastly, SMART is the
Bay Area’s newest passenger rail system and bicycle-pedestrian pathway project that services Marin and Sonoma county. The system currently spans 45-miles and has stops in Rohnert Park, Cotati, Petaluma, San Rafael, Larkspur, Santa Rosa, and Novato (SMART, 2020). At completion, the railway is projected to span 70-miles that extends from Cloverdale in northern Sonoma county to Larkspur Landing in Marin county.

Table 4: Rail System Types

<table>
<thead>
<tr>
<th>Rail Type</th>
<th>Capacity</th>
<th>Frequency</th>
<th>Schedule (Interval or Scheduled Time(s))</th>
<th>Areas Serviced</th>
<th>Thoroughfare(s)</th>
<th>Powered Via</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light</td>
<td>Medium</td>
<td>High</td>
<td>Interval</td>
<td>local; metropolitan areas</td>
<td>partially segregated from street traffic</td>
<td>overhead electrical wires</td>
</tr>
<tr>
<td>Heavy/Rapid</td>
<td>High</td>
<td>High</td>
<td>Interval</td>
<td>urban; metropolitan areas</td>
<td>underground (subway); above street level (elevated transit line); or at street level; exclusive right-of-way</td>
<td>electrical</td>
</tr>
<tr>
<td>Commuter</td>
<td>High</td>
<td>Low</td>
<td>Scheduled Time</td>
<td>city centers; suburban areas; commuter towns</td>
<td>shared right-of-way with intercity and freight trains</td>
<td>electrical or diesel trains</td>
</tr>
</tbody>
</table>

Caltrain began operation in 1992 and offers rail service along the San Francisco Peninsula, through the South Bay and into San Jose and Gilroy (Caltrain, 2020). The northern tip of the service line begins in San Francisco at 4th and King Street and extends south to San Jose at Diridon station with rush hour service running to Gilroy.

Lastly, ACE began service in October 1988 and is an 86-mile route that connects Stockton and San Jose during peak hours only. Total travel time from end-to-end is 2 hours and 12 minutes servicing 10 stops (ACE, 2020). The system operates on four weekday round trips.
and just integrated Saturday service in September 2019; average weekday ridership was 5,900 passengers.

Rail transit has been historically known to accommodate white and higher-income riders - sometimes, exclusively (Rayle, 2014). While rail transit could be an effective tool for accomplishing redevelopment, TODs have been associated with gentrification in terms of demographic change. As noted by Rayle (2014), neighborhoods near existing or planned transit may be susceptible to gentrification because they generally have above-average populations of renters, blacks, hispanics, and low-income households. TOD designs target the middle class, especially nonfamily households and younger, college-educated professionals that lead to a disparity between those native to the neighborhood, and those looking to inhabit the neighborhood. This project explored if neighborhoods within the Bay Area show evidence of gentrification and displacement via the analysis of railway systems.

**Displacement and Gentrification**

The most oft-cited definition of displacement is derived from George and Eunice Grier:

Displacement occurs when any household is forced to move from its residence by conditions that affect the dwelling or its immediate surroundings, and that:

“1) are beyond the household’s reasonable ability to control or prevent; 2) occur despite the household’s having met all previously imposed conditions of occupancy; and 3) make continued occupancy by that household impossible, hazardous, or unaffordable” (Grier and Grier, 1978).

The definition offered by the Griers’ addresses two types of direct displacement - physical and economic displacement. Physical and economic displacement signify situations of involuntary residential dislocation but should be supplemented with concepts related to exclusionary and pressure displacement.
While the processes of displacement have been identified largely through direct and visible forms, over recent years, displacement has shifted towards more diffused, indirect, and less obvious scenarios. Indirect displacement deals mostly with gradual economic pressure or the slow erosion of residents’ sense of belonging in social networks, community resources, and political power (Rayle, 2014). Whether direct or indirect displacement occurs, the result often remains the same where permanent displacement is inevitable.

Alternatively, gentrification aims to improve the quality of housing (via an increase in property values prompting an increase in housing demand); contribute to the overall tax base; and restore landmarks within the neighborhood, community, city or region via private initiatives (Marcuse, 1985). Over the years, gentrification has evolved its meaning to include:

1. a transformation of class and racial composition of a neighborhood;
2. an increase of financial investment in a neighborhood that once experienced disinvestment;
3. a rehabilitation of structures and the built environment;
4. a class- or race-based conflict over territory; and
5. a displacement of original residents (Rayle, 2014)

According to Peter Marcuse (1985), German-American lawyer and professor emeritus of urban planning, gentrification is the process of new residents replacing older ones in previously dilapidated and poorly-aged inner-city housing in a spatially concentrated area. Invasions from new residents mixed with pressures placed on old residents to leave stimulates a radical demographic shift in gentrified areas. New residents are often disproportionately young, white, professional workers with higher educational attainment and income. Residents who are typically pushed out are poor, working-class minorities or elderly peoples.

The relationship between gentrification and displacement is a complicated one. The debate of how the two processes coexist are argued to be either closely related, dependent on each other, or exist independent of the other. For some scholars, gentrification does not necessarily imply displacement as several empirical studies have failed to provide substantial
evidence of displacement in areas where gentrification has occurred. In some cases, studies have shown that gentrification benefitted the neighborhood substantially while displacement derived minimal results (Rayle, 2014). Circumstances like these suggest that where sufficient housing space can be found on former industrial land or depopulated residential areas, planners and developers could theoretically accommodate new dwelling units for incoming residents without displacing existing ones.

According to Lisa Rayle (2014), middle ground scholars do not believe that the two concepts *must* be married. This mindset is hyper focused on the different forms gentrification takes in various contexts. Due to the guise that gentrification has adopted over time and across communities, centrist scholars maintain the belief that gentrification cannot be described as a singular universal process (Rayle, 2014). Forces such as capitalist markets, economic restructuring, and demographic changes in communities should all be considered separate gentrified processes that manifest themselves at different points of time.

Arguably, other scholars believe displacement is a defining feature of gentrification (Elliott-Cooper et al., 2019). One [gentrification] cannot exist without the other [displacement]. Ruth Glass, a Marxist urban geographer, supported this theory. She first coined the term *gentrification* to describe the state of London neighborhoods in the mid 1960s (Glass, 1964). Glass defined gentrification as the process by which middle- and upper-middle income households moved into disinvested working-class neighborhoods (Comey et al., 2006). The general invasion of higher income households into historically lower income areas led to the improvement of the housing market but the displacement of native residents. Transformation of the culture and social dynamics of the neighborhood were also compromised. Those that could not hold their own like lower-income people, small businesses, and those alike were pushed out of London neighborhoods (Elliott-Cooper et al., 2019). In this regard, gentrification becomes a class struggle over urban territory driven by the critical agenda of a capitalist market (Rayle, 2014).

The negative implications associated with gentrification, especially in the context of displacement, complicate and outweigh the benefits that gentrification originally sought to
provide (Ahajazin, 2017). For some, the risk of potential displacement is worth the benefits that new and renovated development, TODs, and increased job opportunities bring to the community.

Gentrification-induced displacement or GID forces residents to leave their homes due to increased housing costs, evictions, or ownership transfers of rental units - a process that was once known to be violent, sudden, and highly publicized (Ahajazin, 2017). However, the implementation of TODs, mixed income policies, and a slower affordability crisis, has made the process of gentrification less visible and more ambiguous (Rayle, 2014). The life cycle of GID typically implies increased housing opportunities coupled with an increased population of middle- to upper-middle class renters, and the steady decline of lower-income residents (Ahajazin, 2017). Thus, displaced households are forced to secure living in the less expensive neighborhoods that are likely underdeveloped and disinvested.

Displacement in this sense impedes on the basic human rights of those coerced out of their original dwelling units and neighborhoods. According to the Universal Declaration of Human Rights and the International Covenant on Economic, Social and Cultural Rights, everyone is entitled to an adequate standard of living that supports the well-being of themselves and their families including food, clothing, housing, social services, medical care and security (United Nations General Assembly, 1948)(United Nations General Assembly, 1966). From a global standpoint, the process of gentrification discriminates against, targets, and marginalizes minorities and the lower-income populations of society. Those that make up this population lack the political and economic power to defend and protect their families, communities, and lifestyle from displacement. GID compounds these issues of marginalization and exacerbates the effects of structural violence on vulnerable populations. GID in this regard, is both a human rights violation and an environmental justice issue.

In the Bay Area, the issue of displacement has been a growing regional concern over the last several decades. In 1990, San Francisco was the only county that had 30% of its lower-income household population at risk of displacement (MTC, 2019). However, 2008 prompted a slight increase in displacement risk for most Bay Area counties due to the Great Recession and the negative implications brought on by the mortgage lending crisis. By 2017, all Bay Area
counties had displacement risk levels within a comparable range as shown in Figure 8 (MTC, 2019).

![Figure 8: The graph here shows displacement risk in the San Francisco Bay Area from 1990-2017.](image)

Rising housing costs, limited affordable housing and tenant protections all contribute to the increase in displacement risk and pressures that lower-income households face throughout the region. While urban neighborhoods have been susceptible to displacement risk via gentrification for some time, signs of potential risk are just as apparent in suburban communities across the Bay like Concord, El Cerrito, Santa Clara, and Santa Rosa (MTC, 2019). Conversely, communities that are known to provide affordable housing options to those displaced - like Antioch and Vallejo - contain relatively low numbers of at risk households even with a consistent increase in poverty over time. And, as more individuals are pushed out of urban neighborhoods like San Francisco’s Mission District and West Berkeley and suburban neighborhoods like East San Mateo and Concord, periphery communities and counties - especially in the North Bay (who have been seemingly untouched by the adverse effects of displacement) - are burdened with the spillover of housing demand.
This project analyzed if existing Bay Area neighborhoods have been made susceptible to the processes of gentrification and displacement risk via TOD design and transit inequity. Displacement risk refers to the share of lower-income households living in neighborhoods that lose its lower-income residents over time. Households that are designated “at risk” may not necessarily result in residential displacement in the short- or long-term however, those who do represent the at risk population signify the pressures felt from the decline of lower-income households within the area (who are presumed to secure more affordable dwelling spaces in periphery communities) (MTC, 2019). Transit inequity refers to the lack of cost and transit benefits offered by a city’s land use system that affords various levels of access to different demographic groups (Sultana et al., 2017). This leads to a feeling of social exclusion and results in the inability of certain groups to participate in the economic or social dynamics of their community. As low-income residents eventually get outbid by higher income households attracted to revitalized, transit proximate areas with rising living costs, displaced households may choose to relocate to parts of the urban and suburban fringe to afford housing (Sultana et al., 2017).

**Study Area**

The area analyzed in this project was the San Francisco Bay Area, California as shown in Figure 9. The Bay Area extends from Wine Country in the North Bay, down to Silicon Valley in the South Bay, from the edge of Central Valley in the East, and borders along the Pacific Ocean. The Bay Area consists of 9 counties, 101 cities, 7.7 million inhabitants, and approximately 7,000 square miles of land (MTC, 2020B). The counties that make up the Bay Area include: Alameda, Contra Contra, Marin, Napa, San Francisco, San Mateo, Santa Clara, Solano, and Sonoma.
Figure 9: The map depicted here is the San Francisco Bay Area, California - the study area for this project. All rail systems with station stops that service the Bay Area are shown here.
Within each county, census tracts were included. The U.S. Census Bureau (2015) defines a census tract as a small, relatively permanent, statistical subdivision of a county that typically averages around 4,000 residents (minimum population of 1,200 and a maximum of 8,000). Census tracts are an official geographic entity that the U.S. Census Bureau (U.S. Census Bureau, 2015) publishes data for and was integral to this study to analyze and depict data in a spatially concentrated area.

Regional roadways for the Bay Area were incorporated into the study area to examine access points to railway station stops. Roads included primary, secondary, local neighborhood, rural, and private roads, city streets, vehicular trails, ramps, service drives, walkways, stairways, and alleys (MTC, 2019B). Rail station locations were also added for all light, heavy and rapid, and commuter networks offered in the Bay Area: BART, SMART, Santa Clara VTA, Capitol Corridor, Caltrain, ACE, and SF Muni Metro.

**Methods**

The methodology for this project was executed using GIS. GIS, according to the Environmental Systems Research Institute (ESRI, 2020) is a digital framework that gathers, manages, and analyzes data. GIS is rooted in the science of geography and compiles data to analyze spatial location and organize layers of information to produce map visualizations and three dimensional images. This analysis was conducted using ArcGIS Pro software, the industry standard for conducting spatial analyses.

This project required data collection and manipulation prior to GIS integration. California’s county boundary shapefile was collected from the United States Census Bureau’s 2016 Master Address File and TIGER spatial Database (CA Open Data Portal, 2019). To summarize data to more concentrated areas, a 2018 California TIGER/Line shapefile was gathered that contained all current California census tracts (U.S. Census Bureau, 2019). Next, a census tract-level comma separated values or CSV file was downloaded from the U.S. census bureau that contained statistics on population, density, and socio-economic status (SES) indicators. SES indicators included in this CSV were median household income, % below
poverty, education level, race, sex, and unemployment rate. Separately, data was also obtained from the U.S. Census Bureau on age range distribution across the Bay Area. Lastly, a displacement risk dataset was collected via Vital Signs - the Bay Area’s monitoring initiative that tracks trends related to transportation (MTC, 2020C).

In regard to map generation, world topographic and a dark human geography base map were added to show map features like city and county names, water boundaries, street names, highways, green development, and major locations. To define the study area, a California county shapefile (CA Open Data Portal, 2019) was added to the map frame to show edges of the San Francisco Bay region and the boundaries of all 9 Bay Area counties. A census tract shapefile (U.S. Census Bureau, 2019) was integrated into the map to show tract boundaries within each county and to better diversify and visualize data. Next, a regional roadway vector file was added that depicted all road, street, trail, and alley networks (MTC, 2019B). Then, a data layer containing coordinates of railway station stops for all light, heavy/rapid, and commuter systems that serviced the Bay Area were added and clipped to the extent of the region for any systems that serviced counties outside of the study area (MTC, 2020D).

After, the regional roadway data file was converted to a network dataset in order to use the network analyst tool, Build a Network. Building a network in ArcGIS Pro reconstructs the attribute and network connectivity information of a network dataset as shown in the modelbuilder in Figure 9. Once the network was built, a new service area was created using the Network Analyst. Populated service areas then appeared in the map design as a composite layer. It should be noted that the service area layer automatically generates six network analysis classes that appeared as sub-layers to the service area layers (facilities, polygons, lines, point barriers, line barriers, and polygon barriers), but only facilities and polygons were used in this project. Then, locations for all railway station networks were imported into the facilities sub-layer of the service area. This displayed another layer of railway station stops onto the map display. The first layer that was added of regional roadways was then removed out of the map layout. Then, to configure the service area properties, default breaks were set at 0.25 miles (5 minute walk), 0.50 miles (10 minute walk), 0.75 miles (15 minute walk), and 1-mile (20 minute walk) with direction of traffic flowing toward each facility and avoided all streets that traveled away from it.
Figure 10: The workflow shown here details the geoprocessing steps used to generate a service area via modelbuilder in ArcGIS Pro.

As noted by Davis et al. (1998), the Integrated Regional Transportation Plan for South East Queensland, Australia specifies a policy goal for public transportation that has 90% total population coverage within 400 meters of any bus, rail or ferry stop. This 400 m threshold represents a comfortable walk for most people under normal conditions (Davis et al., 1998). This project took this standard into consideration and expanded the scope four times that distance to analyze changes in behavior and demographic trends between mileage.

U-turns at junctions and pedestrian access within the service area was allowed. For polygon generation, detailed, trimmed, overlapping disks were created that merged by break value if multiple facilities were in close proximity to each other. Figure 11 shows service areas in Solano and Sonoma counties where one service area stands alone and another merges by break value between two stations.

After, demographic data for race, sex, educational attainment, age, median household income, commute mode choice, and displacement risk were added to the map layout with each layer clipped to the Bay Area’s region displayed with various symbology. Figure 12 shows two counties - San Francisco and Contra Costa - that are depicted with displacement risk symbology turned on. Displacement risk indicates the number of low-income households at risk of displacement relative to total low-income households within a census tract. Parts of San Francisco’s Market Street, the city or Richmond and the suburban neighborhood of El Cerrito all have displacement risk indicators for some low-income household populations in each county.
Figure 11: The maps shown here depict 1-mile service areas in Solano and Sonoma counties with default breaks at 0.25-miles, 0.50-miles, 0.75-miles, and 1-mile.

Using the geoprocessing tool, *Summarize Within*, data was summarized by default breaks (0.25-miles, 0.50-miles, 0.75-miles, and 1-mile distances) showing the number of individuals that reside at each of the four distances within the service area for demographic variables. Once this process was completed for the region as a whole, the same steps were executed for each independent county to determine if results differ across county boundaries.
Figure 12: Low-income households at risk of displacement within 1-mile service areas in San Francisco and Contra Costa counties

Results
Figure 13: The maps depicted here show Alameda and Contra Costa counties with all railway station stops and 1-mile service areas.
Figure 14: The maps shown here are Marin and Napa counties. Railway station stops and 1-mile service areas are depicted for Marin county. Napa county is the only county not serviced by any rail system.
Figure 15: San Francisco county and San Mateo county are depicted here that include 1-mile service areas from station stops with default breaks at 0.25-miles, 0.50-miles, 0.75-miles, and 1-mile.
Figure 16: The maps shown here are Santa Clara and Solano counties. Each county is serviced by at least 1 railway system and station stops and 1-mile service areas were included here.
Sonoma County

Figure 17: Sonoma county is depicted here. Railway station stops and 1-mile service areas with 0.25-mile default breaks were added to the map layout.

Demographic Data

Alameda

BART, Capitol Corridor, and ACE operate in Alameda county. BART services 22 stations, Capitol Corridor serves 6, and ACE serves 4 locations. Within the service area, the most preferred mode of transit was driving alone followed by public transportation and carpooling. Walking, biking, and working from home were the three most underutilized modes of transit in the county. Of a sample size of 272,912 commuters within a 1-mile distance from transit stations, 49% of commuters chose to drive, 21% took public transportation, and 9% carpooled. No data was listed for commuter preferences at the 0.25-mi distances for any mode. At 0.50-mi, 5.1% of commuters drove alone, 2.7% took public transportation, 1.3% walked, 1.1% carpooled, 0.08%
worked from home, and 0.07% biked. At 0.75-mi, 15.7% of commuters drove alone, 7.1% chose public transit, 2.7% carpooled, 2.7% walked, 2.1% biked, and 2.1% worked from home. Notably, at a 0.75- mi distance, carpooling and walking shared the same number of participants as did biking and working from home. At a 1-mi distance, 28.3% of commuters drove, 11.3% took public transit, 5.0% carpooled, 4.4% walked, 3.4% worked from home, and 3.3% biked.

Commuters who chose to drive to work at a 1-mi distance were nearly three times the amount of individuals who took public transit from the same distance.

Of a sample size of 566,205 individuals, the most populous age ranges within the service area were 25 to 29 years (10.8%), 30 to 34 years (9.9%), and 20 to 24 year olds (9.2%). The least likely individuals to inhabit a service area within a 1-mi distance were 80 to 84 year olds with 1.3%, 85 years and older with 1.7%, and 75 to 79 year olds with 1.9%. Other age ranges inhabiting the service area were generally evenly distributed across other groups with middle-aged individuals between 35 to 44 having the slightly higher percentage (7.9% between 35 to 39 and 6.9% between 40 to 44 years old).

Overall, women were more likely to inhabit the service areas within Alameda county 49.6% male versus 50.4% female). However, males were more likely to reside within 0.25-mi (7,126 males or 1.3% versus 6,875 females or 1.2%) and 0.50-mi distances (35,823 males or 6.32% versus 35,673 females or 6.3%) from station locations. At 0.75-mi (87,188 females or 15.4% versus 85,833 men or 15.2%) and 1-mi distances (155,758 women or 27.5% versus 152,199 males or 26.9%) from service stations, females were more likely to inhabit Alameda service areas.

More individuals were likely to possess a bachelor’s degree as opposed to solely having a high school diploma within Alameda service areas. At 0.25-mi, 1.6% of residents have their bachelor’s degree while 1.2% of residents have their high school diploma. At a 0.50-mi distance, the gap between levels of education widened with 6.6% of inhabitants obtaining a bachelor’s degree while 4.7% only went to high school. At 0.75-mi, the gap narrows with 13.1% of individuals going to college and 11.5% only attending high school. Then, at 1-mi, 34.1% of
individuals went to college and 27.3% completed high school. Ultimately, 55% of the service area completed a higher level of education, while 45% did not.

White individuals were more likely to inhabit the Alameda county service area followed by Blacks and Hispanics. Hawaiian/Pacific Islander, multiracial, and “other” races were the least likely to inhabit the Alameda service areas. White individuals made up 36.2%, Blacks made up 21.0% and Hispanics made up 19.9%. Notably, more Asians lived in the service area at 0.25 and 0.50-mi compared to Hispanics. However, at 0.75 and 1-m distances, Hispanics (6.5% at 0.75-miles and 11.7%) who lived in the service areas were more than double the amount of Asians (3.1% at 0.75-miles and 5.4% at 1-mile) inhabiting the same space.

Median household income within the service area was greatest at the 0.25-mi and 1-mi distances ($76,843.58 and $104,419.22) but lowest at the 0.5-mi and 0.75-mi distances ($70,487.83 and $67,561.25).

Contra Costa

BART and Capitol Corridor operate in Contra Costa county. BART has 12 stations and Capitol Corridor has 3. Driving alone was the most utilized mode of transit followed by public transportation and carpooling. The least utilized modes of transit were biking, walking, then working from home. At 0.25-mi, 1.0% drove to work, 0.06% took public transit, and 0.009% chose to carpool. At 0.50-mi, 3.6% drove to work while 2.4% took public transit and 1.6% carpooled. At 0.75-mi, driving to work increased nearly three times the amount of users at 12.8%, public transit increased to 5.6% and carpooling doubled to 3.4%. Lastly, at 1-mi, driving was 35.2% utilized while public transportation and carpooling were 11.8% and 10.3% utilized.

Twenty-five to 29, 30 to 34, and 35 to 39 were the most common age groups found within the Contra Costa service areas. The least populous age groups within the service areas were 75 to 79 years, 80 to 84 years, and 85 years and older. The remaining age ranges were spread relatively evenly with higher values under 5 years old, between 20 to 24 years old, and 40 to 49 years of age.
Similar to Alameda county, females who lived within Contra Costa service areas were slightly more populous over males. At 0.25-mi, men and women both occupied the service area at 2.4%. At 0.50-mi, 9.5% of women lived within the service area while men consisted of only 7.4%. At 0.75-mi, 10.5% of men and 12.5% of women inhabited the service area. This differentiation was almost identical between 0.50 and 0.75-mi. Then, at 1-mi, 29.1% of women and 26.4% of men inhabited the area.

White (36%), Hispanic (18%), and Asian (16%) individuals were the most populous within the service areas. The least populous groups were American Indian (0%), two or more races (0%), and multiracial (5%). It should be noted that Blacks (14%) and “other” races (11%) also had individuals distributed across the service areas. In regards to education, 50% of individuals completed a higher level of education while 50% completed high school.

Like Alameda county, median household income within the service area was greatest at 0.25-mi and 1-mi distances ($82,043.72 and $82,233.47) and lowest at 0.50-mi and 0.75-mi distances ($75,446.71 and $78,722.24).

Marin

SMART is the only rail system that operates in Marin county and has 4 stations. Driving alone was the most utilized commute mode choice within Marin service areas followed by working from home and carpooling. Public transportation, biking, and walking were the three most underutilized modes of transit within the county. There was no differentiation in values for any commute mode between 0.25 and 0.50-mi. However, of a 24,056 sample, 8.3% of commuters chose to drive alone, 1.6% worked from home, 0.9% carpooled, 0.8% took public transportation, 0.7% walked and 0.1% biked. At 0.75-mi, 16.4% chose to drive alone, 2.9% worked from home, while 2.1% carpooled. Only 1.4% of commuters took public transportation, 1.0% walked, and 0.4% biked. At a 1-mi distance, 33.4% of commuters chose to drive alone while 4.2% worked from home and 5.9% carpooled. At the same distance, 4.6% took public transit, 2.1% walked, and 1.1% biked.
In Marin county service areas, individuals were slightly more likely to have their high school diploma over their bachelor’s degree. At 0.25-mi, 3.4% of residents had their high school diploma while 3.9% had their bachelor’s degree. At 0.50-mi, 7.1% of individuals had their diploma versus 6.8% who had their bachelor’s. At 0.75-mi, 11.9% of residents solely had their high school diploma, while 12.2% had their bachelor’s. Lastly, at 1-mi, 28.2% of individuals who lived in the service area had their high school diploma and 26.5% had their bachelor’s. Notably, only at 0.75-mi did more individuals have a higher level of education than at any other distance.

In regard to race, White individuals were the most populous group within the service area followed by Hispanics and “Other” races. The least populated groups were Hawaiian/Pacific Islander, American Indian, and Black. At 0.25-mi, 2.7% of individuals were White and 2.6% were Asian (all other races at this distance had less than 1.0% representation). At 0.50-mi, 9.0% were White, 1.8% were Hispanic, and 1.4% were Asian. Then, at 0.75-mi, 22.3% were White, 4.27% were Hispanic, and 1.9% were “Other” races. Lastly, at a 1-mi distance, 38.9% were White, 7.1% were Hispanic and 3.1% were “Other” races. All other races had less than 1.0% representation at a 1-mi distance.

Insufficient data was collected for age ranges between 0.25 and 0.75-mi. However, at a 1-mi distance from station locations, the most populous age ranges were under 5, 5 to 9, 10 to 14, 15 to 19, 25 to 29, and 35 to 39 years old. Each of these age ranges made up 11.1% of the service area. Conversely, between the ages 60 to 64, 65 to 69, 70 to 74, 75 to 79, 80 to 84, and 85 and over - no data was derived for any distance within the service area.

In terms of gender, data did not contain values for women between 0.25 and 0.75-mi. Of the total sample size, 3.9% of men occupied the service area between 0.25 and 0.75-mi. At a 1-mi distance, 50% were men and 38.5% were women. Median household income within the service area was lowest at the 0.25-mi range ($81,659.52) and highest at 0.5-mi ($87,867.19). At 0.75-mi, median household income within the service area decreased to $86,194.24 and increased slightly at a 1-mi distance to $86,907.17.
Napa

Napa county was the only county that was not serviced by any rail station network in the region and therefore was not considered in the service area demographic analysis.

San Francisco

BART, Caltrain, and SF Muni Metro operate in San Francisco County. BART services 8 stations, Capitol Corridor services 3, and SF Muni Metro services 419. Driving alone and public transportation had equal participation within the service area followed by walking. Carpooling, biking, and working from home were the three most underutilized modes of transit within the county. At 0.25-mi, public transportation had 38,912 participants (3.8%) while driving alone had 36,157 (3.6%) and walking had 17,483 (1.7%). At 0.50-mi, 7.9% used public transit, 7.3% drove alone, and 3.1% walked. At 0.75-mi, 10.5% of commuters drove, 10.4% took public transit, and 3.6% drove. Lastly, at 1-mi, 12.2% drove to work, 11.9% took public transit, and 3.8% walked. Notably, commuters were more likely to take public transportation at 0.25- and 0.50-mi whereas commuters preferred to drive alone at 0.75- and 1-mi.

Twenty-five to 29 years, 30 to 34 years, and 35 to 39 year olds were the most densely populated age groups within the San Francisco service areas. Seventy-five to 79, 80 to 84, and 85 years and older were the least likely to occupy a San Francisco service area. Other age ranges were distributed across service areas with middle-aged individuals more likely to inhabit the area over adolescents, teens, and the elderly.

Males were only 2% more likely to occupy a San Francisco service area over women (51% versus 49%). At 0.25-mi, 5.9% of men and 5.5% of women lived in the area. At 0.50-mi, men were slightly more populous with 11.5% men and 11.3% women. At 0.75-mi, 14.7% were men and 14.4% were women. Then, at a 1-mi distance, men consisted of 18.6% and women were 18.2%.
White was the most populous race (46.6%) followed by Asian (21%) and Hispanic (13.2%). American Indian (0.02%), Hawaiian/Pacific Islander (0.02%), and two or more races (3.0%) were the least likely to inhabit a San Francisco service area. At 0.25-mi, 7.7% were White, 4.0% were Asian, and 1.4% were Hispanic. At 0.50-mi, 10% were White, 4.0% were Asian, and 2.7% were Hispanic. Notably, Hawaiian/Pacific Islander was the only race in San Francisco that had no representation at the 0.25- and 0.50-mi distances. At 0.75-mi, 12.2% of Whites inhabited the service area followed by 6.4% of Asians, and 3.6% of Hispanics. Lastly, at 1-mi, 16.6% were White, 5.6% were Asian, and 5.6% were Hispanic.

Individuals who lived in the service area were twice as likely to obtain a higher education and receive their bachelor’s degree as opposed to solely having their high school diploma. At 0.25-mi, 9.9% of individuals had their degree while 5.2% only went to high school. At 0.50-mi, 13.6% had their degree as opposed to the 7.6% who had their diploma. Next, at 0.75-mi, 10.6% had their high school diploma while 17.2% completed more schooling. Then, at 1-mi, 21.4% received their degree while 14.1% did not.

Median household income within the service area was lowest at 0.25-mi ($86,938.47) and highest at 0.50-mi ($92,231.30). At 0.75-mi, household income declined to $89,906.94 and continued to drop at a 1-mi distance with a median household income of $87,783.03.

_San Mateo_

BART and Caltrain operate in San Mateo county. BART has 6 stations and Caltrain operates with 13. Preferred commute mode within the San Mateo service area was driving alone (64.6%) followed by public transportation (14.7%) and carpooling (91.4%). The least utilized modes were walking (3.8%), biking (3.5%), and working from home (4.4%). Insufficient data was offered for commute mode preference at the 0.25-mi distance, however, 6.5% chose to drive, 1.7% took public transit, and 0.08% carpooled at the 0.50-mi distance. At 0.75-mi, 22.1% drove, 5.2% took public transit, and 3.2% carpooled. Then, at 1-mi, 35.9% drove while 7.7% chose public transportation and 5.1% carpooled.
In the service area, more individuals were likely to obtain a higher education than solely earning a high school diploma. Nearly two times the amount of individuals received their bachelor’s degree (63.9%) as compared to those who completed high school (36.1%). Moreover, women (51.6%) were more likely to live within the service area as opposed to men (48.4%). At 0.25-mi, there was equal representation of men and women (0.02%). Between 0.50-mi and 0.75-mi, differences in the amount of men and women were miniscule with less than a percent separating each of the values. However, at 1-mi, a greater disparity was evident with 43.8% male and 46.2% female who lived in the service area.

Individuals between the ages of 25 to 29, 30 to 34, and 35 to 39 were the most populous groups with 8.6%, 10.6%, and 9.1% representation within the San Mateo service areas. Residents between the ages of 80 to 84 (2.1%), and 85 and over (1.6%) were least likely to inhabit dwelling spaces within a 1-mi distance from station stops. Median household income was lowest at 0.50-mi ($60,302.08) and highest at a 1-mi distance ($96,183.68) - a difference greater than $30,000 within 0.50-mi. At 0.25-mi, median household income was $79,058.43 and $78,747.62 at 0.75-mi.

Santa Clara

ACE, Capitol Corridor, Caltrain, and Santa Clara VTA operate in Santa Clara county. ACE has 4 station locations, Capitol Corridor has 2, Caltrain has 15, and Santa Cara VTA has 125. Driving alone (71.4%) was the most utilized transit mode within the service followed by carpooling (10.5%) and public transportation (6.7%) whereas, walking (3.4%), biking (3.9%), and working from home (41.6%) were not as popular. At 0.25-mi, 0.09% chose to drive, 0.01% chose to carpool, and 0.008% chose public transportation. At 0.50-mi, driving increased to 9.4% participation, carpooling grew to 1.2% while public transportation only increased to 0.08%. Then, at 0.75-mi, driving alone almost tripled in commuters within a quarter mile (24.6%) while carpooling did the same with 3.6% participation. Public transportation increased to 2.5% at this distance. Lastly, at a 1-mi distance, 36.4% drove alone, 5.5% carpooled, and 3.3% took public transit.
Twenty-five to 29 (11.9%) and 30 to 34 year olds (10.8%) are the most common age groups within the Santa Clara service area whereas, 80 to 84 year olds (1.4%) and 85 years and over (1.5%) were the least common. Other age ranges were sprinkled throughout the service area with the highest populations belonging to middle aged groups between 20 and 44 (ranging from 7.0% to 8.2%) and the lowest populations belonging to elderly residents 65 and older (the range is between 1.4% for 85 and over and 3.4% for those 65 to 69 years old).

White individuals were more likely to reside within the service area followed by Hispanics and Asians. The least populated groups within Santa Clara service areas were Black (0.004%), multiracial (0.008%), and two or more races (1.5%). At 0.25-mi, Asian individuals accounted for 1.2%, Whites made up 0.07%, and Hispanics made up 0.04%. At 0.50-mi, Whites and Hispanics both accounted for 1.9% while Asian representation was 1.5%. Then, at 0.75-mi, 5% were White, 4.6% were Hispanic, and 2.7% were Asian. Finally, at a 1-mi distance, Whites were 36.1% of the service area, Asians were 14.2%, and Hispanics were 13.1%.

Individuals were 13.6% more likely to obtain their bachelor’s degree as opposed to only attending high school within a Santa Clara service area (56.8% with a BS and 43.2% with a high school diploma). Between 0.25- and 0.75-mi, the number of individuals with a bachelor’s versus an individual with a high school diploma were comparable ranging from 0.15% to 3%. However, at a 1-mi distance, 32.9% of individuals went to high school and 47.5% pursued higher education.

In Santa Clara, more men were likely to inhabit the service areas as opposed to women (51.8% versus 48.2%). At 0.25-mi, 1.8% were male and 1.6% were female. Then, at 0.50-mi, 7.7% were male and 7.1% were female. At 0.75-mi, 16.0% were male while 14.9% were female - the most substantial difference between sexes at all four distances. At 1-mi, 26.2% were male and 24.6% were female. Median household income ranged from $93,662.76 to $104,287.43. At 0.25 and 1-mile distances, household income was the highest at $103,251.32 and $104,287.43. At the 0.5 and 0.75-mile distances, income was $97,443.96 and $93,662.76.
Capitol Corridor is the only rail system that operates in Solano county and has 2 stops. No data was retrieved for individual commute mode preference for those who lived within 0.75-mi of a Solano county service area however, at a 1-mile distance, driving alone (62.3%), carpooling (22.9%), and walking (5.5%) were the most utilized modes of transit within the service area. Whereas, public transportation only accounted for 2.8% of commuters while biking was 3.0% and working from home was 3.5%.

In terms of race, Whites (72.9%) were the most densely populated group that lived within a 1-mi distance of Solano rail stations followed by Hispanics (13.7%) and “other” races (6.1%). Hawaiian/Pacific Islander (0.03%), American Indian (0.05%), and Black (1.7%) were the least populated groups within the service area.

Similar to Santa Clara, men (61.5%) were more likely to reside within the service area as compared to women (38.5%). However, it should be considered that between 0.25- and 0.50-mi, no data was obtained for women that lived within these distances.

Solano county possessed one of two service areas where individuals were more likely to have a high school diploma over a bachelor’s degree. No data was derived for individuals who lived within 0.25-mi of a service area however, at 0.50-mi, 0.4% completed high school while 0.2% went to college. At 0.75-mi, 15.6% of residents had their bachelor’s while 32.2% had their high school diploma. Lastly, at a 1-mi distance, 16.5% graduated from college while 35.2% completed high school.

For median household income, insufficient data was collected at 0.25-mi however, income ranged from $109,327.11 to $112,25.00. At 0.50-mi, income was largest at $112,250.00 and lowest at a 1-mi distance with $109,327.11.
Sonoma

SMART is the only rail network that operates in Sonoma county with 7 station locations. Driving alone was the most utilized mode of transit (72.0%) followed by carpooling (13.5%) and walking (6.1%). The modes less utilized in Sonoma service areas were working from home (4.8%), public transportation (2.5%), and biking (1.2%). At 0.25- to 0.50-mi, values did not change in mode utilization however, 6.4% of commuters chose to drive alone while 1.3% carpooled and 0.8% walked. At 0.75-mi, 16.0% drove, 3.1% carpooled, and 1.28% worked from home. Then, at 1-mi, 43.2% of commuters drove, 7.7% carpooled, and 3.23% walked.

Twenty to 24 (8.3%), 25 to 29 (8.5%), and 30 to 34 (8.3%) were the most populated age groups within the Sonoma service areas. Similar to other counties, 75 to 79 (1.5%), 80 to 84 (1.1%), and 85 and over (1.4%) were the least populated age ranges found in the service areas. Other age ranges were distributed sporadically with the highest percentages in adolescents (under 5 to 19) and middle aged individuals (35 to 54 years old).

Females (56.2%) were slightly more likely to occupy a Sonoma service area over men (52.1%). The amount of men and women that lived between 0.25- and 0.75-mi from a transit station were identical (0.8% at 0.25-mi, 1.7% at 0.50-mi, and 5.8% at 0.75-mi). However, at a 1-mi distance, 43.8% were male and 47.9% were female. Similar to Solano county, individuals were more likely to have a high school diploma (73.3%) over a bachelor’s degree (26.7%). This indicated the largest disparity between those who did continue on to higher learning and those that did not.

Median household income within this area was the lowest in the Bay Area with $51,163.33 at 0.25-mi, $51,158.34 at 0.50-mi, $53,802.47 at 0.75-mi, and $56,202.69 at a 1-mi distance. Despite the $4.99 difference between median household income at the 0.25- and 0.50-mi range, Sonoma is the only county that had median income increase as distance from rail stations increased. Additionally, Sonoma’s service area was also the only area that had the smallest range of income values across the region.
**Displacement Data**

**Alameda**

In Alameda county’s service area, 1,301 households were designated low-income households. Of the 1,301 total households, 355 were at risk of displacement. At 0.25-mi, 41.9% of households were at risk, followed by 33.3% at 0.50-mi, 32.5% at 0.75-mi, and 23.1% at a 1-mi distance. As distance from rail stations increased, the total amount of low-income households increased while those at risk of displacement decreased.

**Contra Costa**

Of the 173 total low-income households that lived within a Contra Costa service area, 60 were at risk of displacement. At 0.25-mi, 87.5% low-income households were at risk of displacement. At 0.50-mi, 21.2% of households were at risk of displacement. At 0.75-mi, 26.3% were at risk and at 1-mi, 38.3% were considered at risk of displacement. Notably, at 0.25-mi, displacement risk was placed on all low-income households who lived within the service area except one.

**Marin**

Marin did not possess any low-income households (or those at risk of displacement) within 0.25- to 0.75-mi. However, at a 1-mi distance, 6 households were considered low-income and 50% were at risk of displacement.

**San Francisco**

San Francisco had the highest number of low-income households within the service area (7,017 households) and thus, the highest number of households at risk of displacement (3,765 households). At 0.25-mi, 53.7% were at risk of displacement (486 of 905 low-income households). At 0.50-mi, 59.2% of households were at risk of being displaced (906 of 1,530 low-income households). At 0.75-mi, of 1,933 total low-income households, 1,138 were at risk of
displacement or 58.9%. Lastly, at a 1-mi distance, 1,235 out of 2,649 - or 46.6% - households were at risk of displacement.

_San Mateo_

Within San Mateo, 383 households were considered low-income households and 119 were at risk of displacement. No households were at risk at a 0.25-mi distance however, 80.0% were at risk at 0.50-mi (12 of 15 low-income households). At 0.75-mi, 54.5% of households were at risk of displacement (12 of 22 low-income households) with 27.5% at a 1-mi distance (95 of 346 low-income households).

_Santa Clara_

Santa Clara’s service areas contained 566 total low-income households where 135 or 23.9% were at risk of displacement. At its closest distance, nine low-income households were identified and 100% of those households were at risk of displacement. At 0.50-mi, 80.0% were at risk of being displaced with twenty-eight of its thirty-five households experiencing displacement pressures. Then, at 0.75-mi, 62.7% (42 of 67 low-income households) were considered at risk while 12.3% (56 of 455 low-income households) were at risk at a 1-mi distance.

_Solano_

Solano was the only county that possessed no low-income households and no households at risk of displacement within the service area.

_Sonoma_

Finally, in Sonoma county, 97 (0 at 0.25-mi, 2 at 0.50-mi, 7 at 0.75-mi, and 88 at a 1-mi distance) households were considered low-income within the defined service area however, no households were considered at risk of displacement.
Discussion

The overall goal of this project was to determine if (1) accessibility - as it relates to the social equity pillar of sustainable development - caters to all communities *equitably*, including those with economic disadvantages; (2) a generic and simplified profile of an individual could be generated based on their proximity to a railway transit hub; (3) there is evidence of displacement [risk] within the service area and; (4) there is a strong disparity between demographic profile and those displaced. From a regional perspective, this project’s results show that within a 1-mi distance of Bay Area railway transit stops that a generic profile of a typical individual in a service area could be generated based on demographic data. Regardless of county, the typical profile has the following characteristics summarized in Table 5.

<table>
<thead>
<tr>
<th>Profile</th>
<th>Commute Mode Preference</th>
<th>Age Range</th>
<th>Race</th>
<th>Sex</th>
<th>Educational Attainment</th>
<th>Median Household Income</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Drove Alone</td>
<td>25 to 29</td>
<td>White</td>
<td>Male</td>
<td>Bachelor's Degree or Higher</td>
<td>$83,778.11 - $85,164.30</td>
</tr>
<tr>
<td>Percentage Within Service Area</td>
<td>46.8%</td>
<td>11.2%, 10.9%</td>
<td>41.20%</td>
<td>70%</td>
<td>56.30%</td>
<td></td>
</tr>
</tbody>
</table>

The information depicted in Table 5 was constructed based on which commute mode, age range, race, sex, educational achievement, and income derived the highest percentages within all service areas regionwide. This profile is not indicative of *all* residents who occupied service areas across the Bay, only ones that derived the greatest results. Nevertheless, this generic profile satisfied the second objective of this project.

Total low-income households across the region was 2.03 million in 2017. According to MTC (2020B), the Bay Area was home to 7.75 million people in 2018. Overall, 26.3% of Bay Area households were considered low-income. Of the 3.1 million low-income households, 1.02 million households were at risk of displacement - 13.2% of the total San Francisco Bay Area population. And, as distance from rail stations increased, displacement risk increased. At 0.25-
mi, displacement risk within the service area was 58.8%. At 0.50-mi, 52.4% of households were at risk of being displaced and 49.6% at 0.75-mi. Lastly, displacement risk equated 48.1% at a 1-mi distance as highlighted in Figure 18.

The data shown in Figure 18 addresses objective 3 of this project - results indicated that displacement risk was present within the defined service areas. Most notably, San Francisco, (which possesses the most urban landscape within the Bay Area and has historically had high levels of displacement) showed that displacement risk within the county’s service area remained the highest in the region with 53.7% of low-income households at risk of displacement. Conversely, Solano county, which is located in the North Bay (and has typically seen the spillover of displacement across other parts of the region), not only had no low-income households and no displacement risk but also had the highest median household income in the
Bay Area. This data could be indicative of TOD initiatives already in place that have driven low-income households toward the region’s outer fringe.

Ultimately, based on these findings, the Bay Area rail system does not satisfy the accessibility criteria of the social equity pillar of sustainable transportation. This project determined that a generic profile of an individual living within a 1-mi distance of a railway station location is not necessarily typical of the population of individuals who could most benefit from having close access to this form of transportation. Bay Area rail systems predominantly cater to white, middle-aged, highly paid, and well educated males who prefer to drive to work and live within 1-mi of transit proximate areas. This profile is consistent with the targeted demographic of TODs. While transit centric areas are generally home to the same profiled individual as derived from this project, results indicate that the fourth objective of this project is true - there is a strong disparity between constructed demographic profiles within service areas and those displaced. As TOD initiatives and gentrification processes are executed, low-income households feel displacement pressures that inevitably lead to residential displacement away from accessible and sustainable modes of transit. Thus, low-income minority populations have declined dramatically in county service areas such as San Francisco. As TOD projects become normalized, and processes of gentrification and displacement continue to take a toll on Bay Area residents, the region’s rail system becomes less of a sustainable network and more indicative of a social equity phenomenon.

**Recommendations**

This project demonstrates further research is necessary to examine displacement risk and the role transportation plays in communities. Displacement, as noted by Elliott-Cooper et al. (2019), is much harder to detect than gentrification. Displacement cannot be measured from year-to-year, data must be collected over time and compared. Distinguishing between forced and voluntary mobility is also another obstacle in measuring displacement. However, collecting more regional data on displacement trends to track lower-income households that move from at risk to displaced should be considered. Census tract data for areas that have been reinvested in coupled with evidence of transit-oriented design should be cross-examined. Then, integrating additional
demographic variables to conduct a more detailed analysis of the profile of an individual living with increased or restricted accessibility to rail station networks is advised. Other variables such as marital status, average members per household, occupation, average distance traveled to work, etc. should be considered. While some variables are accessible through open data portals like the United States Census Bureau and the MTC Open Data Portal, data collection via survey distribution for more complex variables is recommended within service areas.

Additionally, the COVID-19 pandemic has brought great uncertainty to the lives of Bay Area residents. Analyzing shifts in transportation utilization due to transitions in the work environment and shelter-in-place guidelines are recommended. And, incorporating the share of those unemployed caused by the pandemic and how those numbers play a role in displacement pressures could be indicative of another social equity phenomenon occurring simultaneously within a concentrated service area.

Moreover, future studies should consider incorporating expansion projects into the study area to examine the full extent of the Bay Area rail system at completion and determine if serviced populations in new projects are more inclusive. It should be considered that expansion projects designated to alleviate congestion on our busiest freeways may in fact be exacerbating the displacement problem. Ultimately, planning and transportation agencies should be taking the necessary steps toward becoming a sustainable transportation network that services all its communities equitably.
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