Post-Covid Transportation Scenarios: Evaluating the Impact of Policies

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Abstract

The COVID-19 pandemic caused changes in how people travel. Whether these changes will persist, return to pre-COVID trends, or move in other directions is uncertain, creating an unprecedented challenge for transportation planners. This project explores several possible scenarios for transportation after the COVID-19 pandemic and assesses possible policies to improve outcomes. We develop four post-COVID scenarios for California: COVID trends persist, return to pre-COVID trends, urbanism returns, and urbanism bounces ahead. The scenarios are defined by assumptions for five key modalities: telecommuting, e-shopping, ride-hailing, public transit, and active travel. We use outputs from the state's travel demand model and implement a post-processing approach to model these scenarios. The results show increases in trips and vehicle miles traveled (VMT) compared to the pre-COVID forecast across the first three scenarios but a small decrease in VMT for the fourth scenario, which assumes the strongest shift toward alternatives to driving. An equity analysis of the model results provides additional insights. A wide array of policies could help the state to minimize the negative impacts while maximizing the positive impacts of post-COVID trends from the standpoint of both reducing GHG emissions and enhancing transportation equity. The analysis presented here shows that the effects of the pandemic will likely set the state behind on their progress toward achieving its VMT goals and demonstrates that achieving those goals will take aggressive and multi-faceted action on the part of the state, as well as local, regional, and federal agencies.

Executive Summary

Background

The COVID-19 pandemic has had significant impacts on society globally, drastically changing travel patterns. The state of California has been no exception. As the pandemic has become an increasingly "normalized" condition, the question arises as to how and whether COVID-19 can be expected to alter travel patterns on a long-term basis. While shorter-term impacts have been well documented, these long-term impacts remain highly uncertain. A related question, given pressing concerns about impacts of climate change and sustainable development, is how and whether the pandemic will alter travel patterns, either increasing or reducing driving. The answer to this question will have major implications for policies targeting future pollution and carbon emission mitigation goals. For example, the pandemic has increased much of the public's aversion to shared spaces, which may have future implications for shared transportation and other sustainable modes. It is critical to consider possible future scenarios to inform policymakers and adequately plan for future needs.

Objectives and Methods

The goal of this project was to explore several possible scenarios for transportation during and after the COVID-19 pandemic, to evaluate their implications for equity, and to assess possible policies to improve transportation system outcomes from the standpoint of sustainability and equity using a blend of quantitative and qualitative methods.

We developed four future scenarios that aim to capture differing post-COVID travel possibilities: COVID trends persist, return to pre-COVID trends, urbanism returns, and urbanism bounces ahead. These scenarios are defined by assumptions about five key modalities: telecommuting, e-shopping, ride-hailing, public transit, and active travel. The assumptions are based on an extensive review of the literature on pre-COVID trends, during-COVID changes, and post-COVID forecasts for each of these modalities.

- **Scenario 1: COVID trends persist.** This scenario assumes that the travel patterns associated with the COVID levels and associated restrictions from around June 2021 persist into 2030 and 2050.
- **Scenario 2: Return to pre-COVID.** This scenario assumes that travel patterns gradually return to pre-COVID 2019 levels by the year 2030 then continue to follow pre-COVID trends from 2030 to 2050.
- **Scenario 3: Urbanism bounces back.** This scenario assumes that the pandemic's shift away from urbanism reverses, where urbanism is defined as higher levels of transit, ride-hailing, bike, and pedestrian mode shares with a smaller driving share.
- **Scenario 4: Urbanism bounces ahead.** This scenario assumes that urbanism returns as in the urbanism bounces back scenario, but with even more optimistic assumptions regarding transit ridership and active travel, with less of a non-work travel rebound from telecommuting.

To model these scenarios, we use outputs from the California Statewide Travel Demand Model (CSTDM) for 2030 and 2050, provided by Caltrans, and apply a post-processing approach that adjusts these outputs to reflect the specific assumptions of each scenario with respect to the five modalities. For each scenario, we start with the CSTDM baseline projections at the Traffic Analysis Zone (TAZ) level for 2030 and 2050, which were developed before the COVID pandemic. We call this a business-as-usual (BAU) scenario. The post-processing uses the trip tables produced by the CSTDM and adjusts trips by mode and trip purpose according to the assumptions for the scenario. We examine numbers of trips, vehicle miles of travel (VMT), and mode shares for each scenario as a way to assess their implications for sustainability. In particular, more VMT and a higher share of travel by automobile, both of which contribute to greenhouse gas (GHG) emissions and other environmental impacts, are assumed to be an undesirable outcome from the standpoint of sustainability.

We also analyze the equity implications of each of the scenarios described earlier. We compare the travel outcomes of VMT, trip length, and mode share aggregated by three socioeconomic characteristics: neighborhood designation using equity priority area definitions at the traffic analysis zone level, and household income and household car ownership at the trip level. We examine outputs by region where appropriate to understand the spatial distribution of transportation equity considerations. Although higher numbers of vehicle trips and VMT can reflect a positive outcome for some disadvantaged households (e.g. if the additional driving helps low-income workers reach higher paying jobs), we assume that more driving is generally a burden for disadvantaged households because: 1. Driving imposes a financial burden on these households, 2. It may reflect poor accessibility to jobs and other activities by more affordable modes, 3. The environmental impacts of driving are especially acute in disadvantaged communities. The Transportation Equity and Environmental Justice Advisory Group (TEEJAG) reviewed and provided input to the development of the scenarios and methods for analyzing the equity implications.

We explore a variety of policies the state could consider as a way to minimize the negative impacts while maximizing the positive impacts of post-COVID trends from the standpoint of both reducing GHG emissions and enhancing transportation equity.

Results

A key finding is that trips and VMT increase compared to the pre-COVID forecast across the first three scenarios, though results differ with respect to patterns of mode use and trip purpose. The fourth scenario, which assumes the strongest shift toward alternatives to driving, results in a small decrease in VMT relative to the pre-COVID forecast.

Results from the scenario analysis show that disadvantaged groups would continue to face burdens under some model assumptions. While the model predicts that disadvantaged groups (by geography, income, and car ownership status) will drive less and for shorter cumulative distance than advantaged groups in all scenarios, their driving is highest in the scenario where COVID-19 pandemic trends persist into the future, suggesting a high degree of burden compared to other scenarios.

Conclusions

Although these scenarios are hypothetical, the results provide useful insights into future travel patterns as well as a baseline against which to compare other possible post-COVID scenarios. The estimates of increases in VMT and total trips for three of the four scenarios is discouraging from the standpoint of meeting California’s goals for emissions reductions, but the differences between scenarios point to the importance of state, regional, and local policy in the state’s efforts. It is unclear which of the four scenarios the post-COVID future in California will most closely resemble. It is also possible that the future will reflect a combination of the scenarios – or will look very different than both the CSTDM and the assumptions these scenarios suggest.

1 Introduction

The COVID-19 pandemic has had significant impacts on society globally, drastically changing travel patterns. The state of California has been no exception. As the pandemic has become an increasingly "normalized" condition, the question arises as to how and whether COVID-19 can be expected to alter travel patterns on a long-term basis. While shorter-term impacts have been well documented, as summarized in Section 2, these long-term impacts remain highly uncertain. A related question, given pressing concerns about impacts of climate change and sustainable development, is how and whether the pandemic will alter travel patterns either increase or reduce driving. The answer to this question will have large implications for policies targeting future pollution and carbon emission mitigation goals. For example, the pandemic may have increased the public's aversion to shared spaces, which may have future implications for shared transportation and other sustainable modes. It is critical to consider possible future scenarios to inform policymakers and adequately plan for future needs.

This study addresses these questions by examining changes in travel behavior and mobility patterns in California pre-COVID, during the early onset stages of COVID, and projections for post-COVID trends. We use a blend of quantitative and qualitative analysis to explore several possible scenarios for transportation during and after the COVID-19 pandemic, and to analyze possible policies to improve outcomes with respect to sustainability and equity. We focus on five key surface transportation modalities significantly affected by COVID: telecommuting, e-shopping, ride-hailing, public transit, and active travel. To explore the range of possible futures, we define four future transportation scenarios for the state of California which vary across these five modalities. We use outputs from the California Statewide Travel Demand Model (CSTDM) with a post-processing approach to model these scenarios. We then compare projections of vehicle-miles traveled (VMT) and travel pattern changes across the four scenarios and compare them to the baseline pre-COVID projections from the CSTDM.

The results indicate that policy makers should expect increases in VMT in the future. Vehicle trips and VMT, both associated with greenhouse gas (GHG) emissions, increase to varying degrees of intensity across three of the scenarios, though the scenarios differ with respect to patterns of mode use and trip purpose. In the fourth scenario, which assumes high shares of transit and active travel and a small rebound in non-work travel for telecommuters, VMT declines somewhat relative to the baseline projections. These possible post-COVID futures all have important implications for transportation equity and environmental justice, as our analysis shows. In some cases, particularly in a future in which COVID trends continue, disadvantaged communities and households may be made worse off with respect to travel outcomes. However, trends toward less auto-dominated transportation could reduce inequitable travel burdens. A deeper dive into the topic of on-line shopping, likely to be one of the most enduring of the impacts of COVID on travel behavior, also points to the uncertainties about the long-term effects. Although e-commerce grew very rapidly during 2020 and 2021 fueled by various factors such as temporary retail closures and economic incentives, resulting in a significant shift in shopping behaviors from in-store to online, this trend has not continued, at least not at the pace of change experienced during the peak of the pandemic.

Based on our analyses, we explore a variety of policies the state could consider as a way to minimize the negative impacts while maximizing the positive impacts of post-COVID trends from the standpoint of both reducing GHG emissions and enhancing transportation equity. The scenario analyses provide a valuable picture of possible transportation futures that can guide policy makers in a post-COVID transportation world.

2 COVID-Induced Changes in Travel Behavior

Numerous studies have sought to determine the impact of the COVID pandemic upon travel patterns and behavior and to consider long-term implications of these changes. Impacts have been investigated for travel mode choice, work and leisure travel patterns, and trip substitution. We focused on understanding impacts for mode choice and travel (e.g., trip lengths, trip purpose) for five key surface transportation modalities[1] significantly affected by the COVID pandemic: telecommuting, e-shopping, ride-hailing, transit and, active travel. We investigated impacts during 2020 and 2021, and looked for research findings that could assist in predicting post-COVID travel patterns, for example, considering employer and employee surveys on telecommuting patterns with predictions for telecommuting post-COVID. We employed the research findings in defining scenarios based on COVID-induced shifts in the use of these five modalities.

The imperative for social distancing brought about by the COVID pandemic has enhanced the value of private space, whether for mobility purposes or for residential and work space *(1)*. Thus, the travel modes most negatively affected by COVID have been shared modes, such as transit and ride-hailing (including use of Uber or Lyft). Similarly, the need for social distancing during the COVID pandemic prompted a sudden and substantial increase in telecommuting, a pattern that is predicted to persist to some degree moving forward. However, the question of how and whether the mobility patterns observed at the height of the pandemic will persist in the coming years, if COVID becomes “normalized,” is not simple or straightforward to determine.

Research suggests that when it comes to overall effects on VMT in the US, the trend in telecommuting prompted by COVID exerted the greatest influence among the modalities we studied, and it may continue to do so. The share of US employees working at home at least once a week more than doubled from 2.97% to 6.18% from 2001 to 2017 (*2, citing FHWA, 2004, 2011, 2019*), but after COVID appeared, the rate increased dramatically. The share of full-time US workers who reported working entirely from home in September 2020 was 33% *(3, citing Gallup).* By October 2021, the full-time work-at-home rate had declined to 25%, but an additional 20% were working from home part-time *(4)*. Of those working at least some hours remotely, 91% indicated they hoped to continue working remotely, and 75% indicated that their employer would allow remote work *(4).* Various other studies suggest that a permanent increase in telecommuting will occur as a result of the pandemic, though to what degree remains in question. Barrero et al. *(5)* found, as of June 2021, surveyed employers plan for their employees to spend 1.2 full days per week (20% of work time) working from home after the pandemic ends, about four times the pre-pandemic level. Other studies also predict that, moving forward, a plurality of workers are likely to work 1-3 days remotely. Based on two-wave panel survey data of 3,000 US workers in 2020 and 2021, weighted to be representative of the full population using various demographic variables, Javadinasr et al. *(6)* found that workers expect to commute to work 3.4 days per week on average post-pandemic.

Estimating the impact of increased telecommuting on VMT is not simple. It depends on which travel mode commuters would have used and the effect of telecommuting on trip-making patterns for purposes other than work, as well as potential changes in housing location. Various researchers predict that less frequent commuting post-COVID will reduce car commute VMT *(e.g., 7)*. However, other scholars are less sanguine, especially when considering effects of telecommuting on overall VMT, accounting for trips taken for purposes other than work. Assessing 39 published research studies on the subject of telecommuting impacts on travel, Hook et al. *(8)* concluded that the more methodologically rigorous among them (e.g., accounting for non-work as well as commute-only trips) have been less likely to estimate energy savings from teleworking. O'Brien and Aliabadi *(9)* reached a similar conclusion after reviewing 30 papers on the subject, noting that more recent studies have tended to conclude that teleworking is associated with, at best, small travel reductions. Reasons for this

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[1] We use “modalities” rather than “modes” because of the inclusion of telecommuting, which does not involve physical travel.

outcome include telecommuters' average longer commute trip distances (as they tend to live farther from the job than others), and their propensity to take more non-work-related trips than non-telecommuters *(9, 10)*. A recent study points to the possibility that telecommuting could lead to an increase in VMT. Using the California sample of the 2017 National Household Travel Survey (NHTS), Su et al *(11)* found that telecommuters who had at least one trip during their workday accrued more VMT and a higher number of trips than their commuter counterparts. On average, telecommuters generated 1.37 times more VMT in a day compared to commuters and 1.53 times more trips. The impact of telecommuting on VMT also depends on the share of workers who telecommute. It is important to note that the industries in which in-person working is required are often those that employ lower-wage workers, including the retail, services, agriculture, and transportation sectors. Overall, the evidence suggests that a sustained increase in telecommuting is unlikely to help the state achieve its goals for VMT reduction – and may exacerbate social inequities – unless strong policies are implemented to dampen the indirect increase in VMT that telecommuting generates.

Another travel modality significantly affected by the COVID pandemic has been shopping behavior, with stay-at-home orders during the early phase of COVID, and ongoing concerns about the need for social distancing prompting many shoppers to substitute on-line shopping for in-person trips. According to the US Census Bureau, e-commerce comprised 11% of all retail sales in the first quarter of 2020, up from 5% in the first quarter of 2011 *(12).* The share of all retail sales then rose to 15.5% by the second quarter of 2020, but dropped to 13.5% by the second quarter of 2021, still an increase of 2.5 percentage points, or 23% increase in share, since 11% pre-COVID *(12).* In March of 2020, 42% of the US population was shopping for groceries online at least once a week, nearly double the share (22%) in 2018 *(13).*

The predicted ongoing impacts of e-commerce on VMT are inconclusive. Some observers project positive impacts; for example, the consulting firm KPMG estimated that e-commerce may reduce total VMT because delivery trucks substitute for personal shopping trips and generate 30 times less travel *(14).* KPMG estimated that the growth of on-line shopping and delivery could reduce shopping trips by 10% to 30% in the future, which is equal to up to 5% of all personal VMT *(14).* However, other studies predict rising vehicular congestion as the result of more goods delivery substituting for in-person shopping trips. One study projects that rising e-commerce may increase the number of delivery vehicles (and thus delivery VMT and associated emissions) on the road by 36% between 2019 and 2030 *(15).* The impacts of rush deliveries, basket size, and consolidation levels affect the outcomes in question, confirming the importance of managing the urban freight system *(16).* The potential to reduce VMT and emissions are therefore less a question of online versus in-store shopping, and more about the efficiencies in manner and practices involved in each *(16).* E-commerce has the potential to be energy-reducing if personal VMT decreases and delivery services help consolidate package deliveries. The outlook for e-commerce is discussed in more detail in the Appendix.

Public transit was the travel mode most negatively affected by COVID, and transit ridership is expected to remain lower than pre-COVID levels, at least in the short term, moving forward. Public transit ridership was already experiencing declines before COVID in many locations. After ridership climbed from 2011 to 2014 (upon recovering from the earlier recession), California lost more than 165 million annual transit boardings by 2018 — a drop of over 11%, nearly double the rest of the nation *(17).* However, this overall pattern masked significant variation by region, mode, and operator. For example, transit trips in the San Francisco Bay Area and on rail grew significantly over the 2010s and started to decline only recently. The transit commute mode share in the Bay Area increased from 10% in 2010 to 12% in 2018 *(18)*. Meanwhile, by contrast, ridership in the Greater Los Angeles (LA) area and on buses throughout the state experienced longer-term declines that grew steeper recently *(17).* In LA County, transit commute modes share decreased from 7.7% in 2011 to 6.1% in 2017 *(19).* With over two-thirds of transit boardings in California taking place in the Bay Area and LA County, these contrasting ridership patterns underscore the message that transit patterns are not uniform. Nevertheless, transit patronage has failed to keep pace with population growth in most regions of California for more than a decade *(17)*.

Transit ridership plummeted with the onset of COVID, and by January 2021, it was still down by approximately 63% nationally, compared to pre-COVID levels *(20).* This decline in transit ridership led to significant cutbacks in transit service that contributed to further declines in transit ridership. Based on a survey of 7,613 US adults between July and October 2020, and with results weighted to be representative of all US adults, Salon et al *(7)* predicted that transit commute trips will decline by 40% post-COVID. Results were similar in the research conducted by Javadinasr et al *(6),* based on their longitudinal two-wave panel survey of 3000 US adults conducted in 2020 and 2021, also weighted to be representative of the full population. These authors predicted that transit commute trips would remain at 32% below pre-pandemic levels after the pandemic is over. Transit agencies have restored many of the services cut at the beginning of the pandemic, but declines in ridership mean declines in fare revenues that further threaten transit services.

Another mode that has suffered during COVID has been use of ride-hailing services provided by transportation network companies (TNC) such as Uber and Lyft. In California, the mode share of trips composed of ride-hailing/taxi trips was 0.73 percent in 2017, having grown rapidly (eight-fold) up from 0.09 percent in 2009 *(17)*. The NHTS data on which these estimates are based combined taxi and TNC use, but with research showing that taxi use has declined with the rise of TNCs, the recent growth in ride-hailing/taxi trips likely can be attributed to TNCs *(17).* In the San Francisco Bay area in 2018, Uber and Lyft rides comprised 3% of all VMT, and 13% in San Francisco County/City; in the LA metro region, these rides comprised 2% of all VMT, and 3% in LA County *(21).* COVID stay-at-home orders caused demand for ride-hailing services to plummet, as in April 2020, TNCs reported declines in bookings of 75% to 80% compared to a year before *(20).* As pandemic restrictions were lifted, ride-hailing demand began to recover; as of June 2021, sales measured in dollars were back to 65% of pre-pandemic levels *(22).*

The effect of ride-hailing on VMT can vary. Ride-hailing vehicles and taxis have among the highest energy and GHG emission impacts per passenger kilometer of all urban mobility options, when considered on a full lifecycle basis; while this is especially true for internal combustion engine vehicles, it is also true for EVs *(23).* The high VMT of ride-hailing is partly because empty miles make up 20% to 40% of all ride-hailing VMT *(24).* Pooled rides can help in reducing VMT from ride-hailing. In 2017, pooled rides made up 20-40% of all Uber and Lyft trips in cities in which pooling programs were implemented *(25).* However, during the height of COVID concerns, TNCs canceled ride-sharing programs such as UberPool *(26).* Consumer preference for shared rides was down, as demonstrated by a before- and during-pandemic survey that reported that ride-hailing customers were less likely to share a ride, even if it saved them money *(27)*. If the trend disfavoring pooled rides persists, the VMT impacts of ride-hailing will increase.

The impact of COVID upon our fifth modality investigated, active travel (bicycling and walking), was mixed. Pre-COVID, walking comprised 13.0% of trips in California in 2017, down from 16.2% of trips in 2012 (based on data from the 2012 California Household Travel Survey and the 2017 NHTS) *(28)*. Meanwhile, bicycling comprised 1.3% of trips in 2017, down from 1.5% in 2012 *(28).* The pandemic lockdowns led to a 70% drop in walking trips, which recovered by July 2020 to 33% below regular levels, considered across ten US metropolitan areas *(28).* COVID significantly impacted utilitarian walking (−72.3% in distance traveled, directly after the declaration of a national emergency, and still down −39.2% in May 2020, compared to pre-pandemic levels) *(29).* Leisure walking was not affected as much and has surpassed pre-pandemic levels in higher-income areas.

Meanwhile, bicycling increased during the pandemic, with 16% growth in bicycle trips overall from 2019 to 2020, with higher growth on weekends (+29%) than on weekdays (+10%) *(29).* As with leisure walking, much of the increase in biking has been for non-transportation reasons, including mental health, exercise, socializing, and relaxation *(30; 31).* However, while Streetlight reported that bicycling ("bike ridership") increased 11% from September 2019 to September 2020 across the US, this source found that the rate declined in some metropolitan areas, including in San Francisco, San Jose, Los Angeles, and San Diego *(32).* In the years preceding the onset of COVID, so-called micro-mobility services were gaining in popularity, including shared bikes and e-bikes, and docked and dockless e-scooters. However, micro-mobility services suffered severe losses in ridership in the first year of the pandemic, when many services were suspended, at least temporarily. Analysts concluded that ridership declined by 60-70% during the early months of the pandemic, based on iPhone mobility data in the US and Europe *(33).* A consumer survey revealed "risk of infection" as the primary concern when choosing shared micro-mobility options *(33).* Nevertheless, in 2020, Americans bought about a half million e-bikes, more than double the number of electric vehicles purchased *(34).* The growth in e-bike sales has not been slowing, with projections for 130 million e-bikes to be sold world-wide between 2020 and 2023 *(34).* E-scooter ridership in the US has also bounced back and was reportedly back to pre-COVID levels by October 2021 *(35).* Even so, the micro-mobility industry has continued to experience volatility, with some service operators withdrawing from selected markets or going out of business entirely.

3 Materials and Methods

To explore possible post-COVID transportation futures, we define four future transportation scenarios for the state of California that vary across the five modalities of telecommuting, e-shopping, ride-hailing, public transit, and active travel. To model these scenarios, we use outputs from Version 3 of the California Statewide Travel Demand Model (CSTDM) for 2030 and 2050, provided by Caltrans, and apply a post-processing approach that adjusts these outputs to reflect the specific assumptions of each scenario with respect to the five modalities. Version 3 of the CSTDM has 2015 as a base year and was calibrated using data from the 2012 California Household Travel Survey.[2]

3.1 Scenario Development and Modeling Approach

The scenarios are defined as follows:

- **Scenario 1: COVID trends persist.** This scenario assumes that the travel patterns associated with the COVID levels and associated restrictions from around June 2021 persist into 2030 and 2050.
- **Scenario 2: Return to pre-COVID.** This scenario assumes that travel patterns gradually return to pre-COVID 2019 levels by the year 2030 then continue to follow pre-COVID trends from 2030 to 2050.
- **Scenario 3: Urbanism bounces back.** This scenario assumes that the pandemic's shift away from urbanism reverses, where urbanism is defined as higher levels of transit, ride-hailing, bike, and pedestrian mode shares with a smaller driving share.
- **Scenario 4: Urbanism bounces ahead.** This scenario assumes that urbanism returns as in the urbanism bounces back scenario, but with even more optimistic assumptions regarding transit ridership and active travel, with less of a non-work travel rebound from telecommuting.

For each scenario, we start with the CSTDM baseline projections for 2030 and 2050, which were developed before the COVID pandemic. We call this a business-as-usual (BAU) scenario. The CSTDM is a tour/activity-based travel demand model operated by the California Department of Transportation (Caltrans) used to forecast travel by California residents, with datasets for 2015, 2020, 2030, 2040, and 2050. Caltrans has run the model completely for each of these years for the BAU scenario. For this study, we do not re-run the model with new assumptions but instead adjust intermediate and final model outputs to reflect the assumptions of each scenario to produce estimates of the outcomes for each. Because we use the same CSTDM outputs as the starting point for all four scenarios, auto ownership and land use patterns are assumed to be the same across all four scenarios; adjusting these assumptions would require separate runs of the CSTDM.

Figure 3.1 illustrates the CSTDM structure. The post-processing uses the trip tables produced by the CSTDM as an intermediate output. The trip tables show the number of trips between each pair of traffic analysis zones (TAZs) in the state by both trip mode (Item 1 in Figure 3.1) and trip purpose (Item 2 in Figure 3.1). We focus on short-distance trips (< 100 miles), given that these trips contribute to more than 95% of intra-state travel (according to the CSTDM baseline results) and because the COVID-related changes for long-distance travel may depend on factors other than those that affect daily travel. For the remainder of the report, "trips" refers to these short-distance trips unless otherwise specified. The detailed categories of travel mode and trip purpose enable additional customizability in developing the scenarios. For trip mode, the options are single occupancy vehicle (SOV), high occupancy vehicle with 2 people in total (HOV2) and 3+ people in total (HOV3+), transit with

[2] Information about the CSTDM is available at https://dot.ca.gov/programs/transportation-planning/division-of-transportation-planning/data-analytics-services/statewide-modeling/california-statewide-modeling-freight-forecasting-travel-demand-model

walking to station, transit with driving to station, walk, and bike. Trip purposes include home, work, school, shopping, eating, escorting for households with and without kids, recreation, social, personal business, and others. These categories enable more specific assumptions and targeted adjustments for each of the scenarios. Note that the analysis is of trips rather than trip chains; a simple work trip chain – to work, then back home – consists of two trips.

The scenario assumptions, based on our background research, are summarized in Table 3.1, Table 3.2, Table 3.3, and Table 3.4 (more detail about the basis for the assumptions is provided in Appendix A). Table 3.5 provides a comparison across the scenarios as to the assumptions. The post-processing for each modality was done in the following ways:

- *Telecommuting*: We change the number of trips with work as their purpose by an amount unique to each scenario as indicated. We then reallocate a proportion of these trips to all other non-work-related trips in the output to account for potential increased personal time availability when working from home. This is what we call the rebound effect from telecommuting. We do not account for potential changes in residential location resulting from telecommuting.
- *E-shopping*: We decrease the number of trips with shopping as the purpose to reflect the surge in e-shopping during the pandemic according to the assumptions. Because our focus is on household travel, we do not account for an increase in delivery trips. This means that the results overstate the benefits of e-shopping from the standpoint of VMT reduction.
- *Transit*: We directly change the number of walk-access and drive-access transit trips according to the assumptions for each scenario. We redistribute these trips to non-transit trips, i.e., change mode share, where applicable.
- *Ride-hailing*: One limitation of the data used in this analysis is that the version of the CSTDM that produced these data does not account for ride-hailing as a travel mode. In order to model ride-hailing, we first created a ride-hailing mode from the other trips by assuming that ride-hailing trips replace trips by other modes in the following proportions: SOV 38%, HOV2 and 3+, 28%, transit 22%, bike-walk 12% *(36;37;38;39;40;41)*. Based on each scenario's assumptions, we alter the percentage of ride-hailing trips and redistribute these trips to or from other modes.
- *Active travel*: We directly change the percentage of walk and bike trips, removing trips or increasing trips, substituting away from auto-based trips where needed.

We use a post-processing procedure to model these scenarios rather than running the CSTDM for each scenario for two reasons. First, running the model is a substantial undertaking beyond the scope of this relatively modest project. Second, the CSTDM does not include ride-hailing or telecommuting. These modes would necessitate post-processing even if we had run the CSTDM for each scenario.

The post-processing procedure was programmed in the Python platform. We first obtain trip table results from CSTDM baseline scenarios for the 2030 and 2050 forecasting years. The trip tables include all trips made by the synthetic population in California for the forecasting years. For each trip, the model generates: 1) location information: home zone of the traveler, origin and destination zones; 2) trip characteristics: tour and trip mode, tour and trip purpose, trip distance, time of day when the trip happens; 3) sociodemographics of traveler: vehicle ownership, income group, household size, sex and age. We modify the trip tables based on the scenario assumptions by drawing a sample of trips from the trip table and reducing and/or reassigning them by mode and/or purpose according to the assumptions for each scenario. For example, we create a ride-hailing mode through reassigning a sample of trips originally made using SOV, HOV, transit, walk and bike to the new ride-hailing mode. To account for increases in e-shopping, we randomly remove a number of shopping trips from the original table based on the scenario assumptions. For telecommuting, based on the scenario assumptions, we randomly select a certain number of working trips and reassign them to work-from-home "non-travel-trips." This reassignment does not affect the total amount of work activity in the region, but it does reduce the amount of work-related travel. In addition, to account for the increase in non-work trips for telecommuters, we draw a random sample of the work-from-home trips, randomly assign them to other non-working purposes, and add them back to the modified trip table. Because of the massive size of the trip tables for the state of California, the machine runtime on a windows machine with 2.60GHz CPU and 16 GB memory is approximately 3 hours for each scenario.

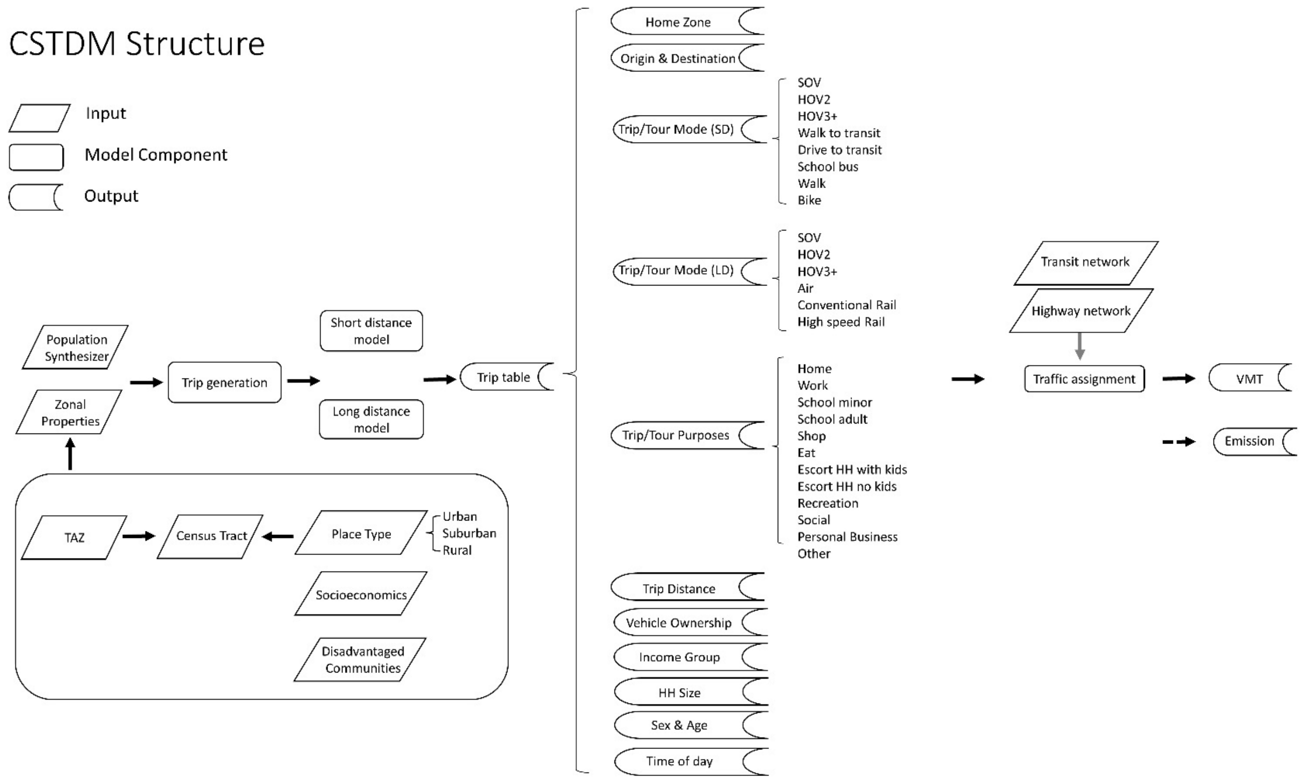

Figure 3.1: California Statewide Travel Demand Model Structure

Table 3.1: Scenario 1: COVID Trends Persist

	Explanation/Assumptions	Proposed Changes
Telecommuting	Pandemic telecommute levels persist. Assume 45% of full-time workers telecommute, with 25% full-time, and 20% part-time *(4)*. Average number of commute days per week predicted to be 1-3 days. For teleworking, this comes to 33% (i.e., 25% full-time + 20% * 2/5 for part-time workers = 33% overall). However, the CSTDM was estimated and calibrated with actual data that already included (we assume the model from Caltrans properly replicates behaviors pre-pandemic) the average of 5-6% of workers that work from home on a given day. With the first 6% of trips replaced by work from home (WFH) already accounted for in the baseline CSTDM assumptions, we use 33%-6%= 27% reduction in short distance working trips. On average, telecommuters make 0.53 more trips in a day than commuters *(11)*. Therefore, we choose to redistribute the removed short distance working trips at a factor of 1.53, to all other purposes.	2030 and 2050: Reduce short distance working trips by 27% and redistribute the number of reduced trips by a factor of 1.53 to all other purpose trips
E-shopping	Online sales increased by 40% during the first year of COVID, but by the second quarter of 2021, the e-commerce share was 13.5%, an increase of 2.5 percent points, or 23% increase in share, since 11% pre-COVID *(12)*.	2030 and 2050: Reduce short-distance shopping trips by 2.5%
Transit	There were significant drops in transit use during the pandemic; transit ridership nationally was 63% below pre-COVID levels in January 2021 *(20)*. Remove 63% of short-distance transit trips, replace these removed trips with auto trips at the rate of SOV 55%, HOV2+ 26%, HOV3+ 19%, per the Caltrans intermediate model output.	2030 and 2050: Reduce Short-distance transit trips by 63%. Reassign these transit trips to auto trips at specified rate.

	Explanation/Assumptions	Proposed Changes
Ride-hailing	Ride-hailing remains at COVID levels, which were 65% less than pre-COVID levels as of June 2021 *(22)*. As of 2017, ride-hailing comprised 0.73% *(17)* of California trips and between 2% and 3% of VMT in the San Francisco and Los Angeles metro areas *(21)*. Assuming less use statewide, we use 1%. Since no ride-hailing mode exists in CSTDM, create it, substituting from existing modes at the rate of SOV 48%, HOV2 +16% and 3+, 12%, transit 12%, bike-walk 12% *(36;37;38;39;40;41)*.	2030 and 2050: Create ride-hailing mode, assuming 1% ride-hailing trips from existing CSTDM trips, substituted from other modes at specified rate. Reduce those ride-hailing trips by 65% in urban and suburban areas and allocate those trips back to other CSTDM modes.
Active Travel	Bike use increased during the pandemic, but much of this new biking was for non-transportation purposes *(31)*. Bike ridership increased nationally, but decreased in many California metro areas *(32)*, hence we do not change bike trips. By mid-May 2020, utilitarian walking was down 39.2% in distance traveled compared to pre-pandemic *(29)*. In July 2020, walking trips were 33% below regular levels *(29)*. Use average of 36% and reduce walk trips by this amount.	2030 and 2050: Reduce walk trips by 36%.

Table 3.2: Scenario 2: Return to pre-COVID

	Explanation/Assumptions	Proposed Changes
Telecommuting	People slowly decrease telecommuting from COVID-era highs, but not all the way to 2019 levels, since that would be unrealistic. We can assume that auto commute trips will decrease by 9% post-pandemic compared to pre-pandemic levels *(6)* providing a benchmark estimate assuming most workers drive to work. Since the CSTDM already accounts for 5-6% workers working from home on a given, day, we choose a 2% reduction for 2030 and a 6% reduction for 2050, applying the same trend line as for the pre-COVID period. We then redistribute the removed short distance work trips, by a factor of 1.53 to all other purposes, by the same rationale from scenario 1.	2030: Reduce short distance working trips by 2%, and redistribute the number of reduced trips by a factor of 1.53 to all other purposes 2050: Reduce short distance working trips by 6%, and redistribute the number of reduced trips by a factor of 1.53 to all other purposes
E-shopping	It is unrealistic to assume e-commerce reduces back to pre-COVID levels by 2030, since e-commerce would likely not decrease so drastically. Nevertheless, for this scenario, we assume BAU levels for 2030 using the pre-COVID CSTDM data. For 2050, assume 26% e-shopping trips by applying the pre-COVID trendline in e-shopping growth rates from 2030 to 2050 (pre-COVID data from *(12)*). This translates to a decrease in driving shopping trips of 15%. Assume all shopping trips are short distance trips, and that shopping trips are a perfect substitute for e-shopping "trips".	2030: BAU, no change 2050: Reduce short-distance shopping trips by 15%
Transit	Transit rates return to pre-COVID levels by 2030, then transit rates proceed as projected pre-COVID. Hence, we use the 2030 and 2050 projections.	2030: BAU, no change 2050: BAU, no change

	Explanation/Assumptions	Proposed Changes
Ride-hailing	Ride-hailing returns to pre-COVID levels by 2030, then proceeds as per pre-COVID trendline to 2050. No ride-hailing mode exists in CSTDM, so we substituted from existing modes at the rate described in scenario 1. We assume the 1% for 2030 using the same rationale as in scenario 1 and 3.2% for 2050, based on the pre-COVID trendline.	2030: Create a ride-hailing mode, assuming 1% are ride-hailing trips, from existing CSTDM trips, substituted from other modes at specified rate. 2050: Create a ride-hailing mode, assuming 3.2% are ride-hailing trips, from existing CSTDM trips, substituted from other modes at specified rate.
Active Travel	We assume active travel returns to pre-COVID levels by 2030, then continues as projected in 2050. Hence we keep the BAU 2030 and 2050 projections.	2030: BAU, no change 2050: BAU, no change

Table 3.3: Scenario 3: Urbanism Bounces Back

	Explanation/Assumptions	Proposed Changes
Telecommuting	Assume more people are telecommuting than before the pandemic, but not as many as during peak COVID levels. According to *(4)* 30% of workers may be expected to telecommute at least partially, assuming 2/3rds part-time and 1/3 full-time. Various studies estimate that telecommuters will work at home on average 1-3 days per week *(6;5)*. Computing from these data translates to about 18% teleworking. Accounting for the pre-pandemic 6% in the CSTDM, 18%-6%= 12% decrease in short distance working trips for both years. We then redistribute the removed short distance work trips, by a factor of 1.53 to all other purposes, by the same rationale for scenario 1.	2030 and 2050: Reduce short distance working trips by 12%, and redistribute the number of reduced trips *1.53 to all other purposes
E-shopping	Assume efforts are made to improve deliveries and create urban pick-up hubs. We assume this will reduce shopping trips, particularly car trips. KPMG estimated that the growth of online shopping and delivery could reduce shopping trips by 10-30% in the future *(14)*. Hence, we reduce in-person shopping trips by car by 15% for 2030 and 2050.	2030 and 2050: Reduce short-distance auto shopping trips by 15%
Transit	Assume transit ridership increases, despite projections that transit use will stay low post-pandemic *(6; 7)* The highest levels of work trip transit mode shares during the 2010 decade were 8% in LA County and 12% in the Bay Area. Assuming we return to and surpass these levels statewide in this scenario, we substitute away from auto work trips, increasing transit work trips by 10% in 2030 and by 15% for 2050.	2030: Increase working transit trips to 10% (move trips from auto to transit) 2050: Increase working transit trips to 15% (move trips from auto to transit)

	Explanation/Assumptions	Proposed Changes
Ride-hailing	We assume that a return to urbanism will bring dramatically higher ride-hailing in this scenario. Hence, we make ride-hailing trips 3% of all trips in 2030, roughly doubling the pre-COVID share, and 9% of all trips in 2050. No ride-hailing mode exists in CSTDM, so we substituted from existing modes as in scenarios 1 and 2.	2030: Create a ride-hailing mode, assuming 3% are ride-hailing trips from existing CSTDM trips, substituted from other modes at specified rate. 2050: Create a ride-hailing mode, assuming 9% are ride-hailing trips from existing CSTDM trips, substituted from other modes at specified rate.
Active Travel	Assume an increase in bike and walking trips, returning to the highest (2012) bike and walk trip mode shares *(28)*. Hence walking comprises 16.2% of trips and bicycling comprises 1.5% of trips. We substitute away from auto trips to arrive at these levels.	2030 and 2050: Substituting away from auto trips, replace trips to reflect 16.2% walking and 1.5% biking mode share for all trips.

Table 3.4: Scenario 4: Urbanism Bounces Ahead

	Explanation/Assumptions	Proposed Changes
Telecommuting	Assume more people are telecommuting than before the pandemic, but not as many as during peak COVID levels. According to *(4)* 30% of workers may be expected to telecommute at least partially, assuming 2/3rds part-time and 1/3 full-time. Various studies estimate that telecommuters will work at home on average 1-3 days per week *(6;5)*. Computing from these data translates to about 18% teleworking. Accounting for the pre-pandemic 6% in the CSTDM, 18%-6% = 12% decrease in short distance working trips for both years. We then redistribute the removed short distance work trips, by a factor of 1.2 to trips of all other purposes, which is more optimistic, since it results in less rebounding trips, than the 1.53 used in the previous scenarios.	2030 and 2050: Reduce short distance working trips by 12%, and redistribute the number of reduced trips *1.2 to all other purposes, doubling the trips using walking and biking as modes.
E-shopping	Assume efforts are made to improve deliveries and create urban pick-up hubs. We assume this will reduce shopping trips, particularly car trips. KPMG estimated that the growth of online shopping and delivery could reduce shopping trips by 10-30% in the future *(14)*. Hence, we reduce in-person shopping trips by car by 15% for 2030 and 2050 (same as scenario 3).	2030 and 2050: Reduce short-distance auto shopping trips by 15% (same as scenario 3).
Transit	Assume transit ridership increases, despite projections that transit use will stay low post-pandemic *(6; 7)* The highest levels of work trip transit mode shares during the 2010 decade were 8% in LA County and 12% in the Bay Area. Assuming we return to and surpass these levels statewide in this scenario, we substitute away from auto work trips, increasing transit work trips optimistically by 15% in 2030 and by 20% for 2050.	2030: Increase working transit trips to 15% (move trips from auto to transit) 2050: Increase working transit trips to 20% (move trips from auto to transit).

	Explanation/Assumptions	Proposed Changes
Ride-hailing	We assume that a return to urbanism will bring dramatically higher ride-hailing in this scenario. Hence, we make ride-hailing trips 3% of all trips in 2030, roughly doubling the pre-COVID share, and 9% of all trips in 2050. No ride-hailing mode exists in CSTDM, so we substituted from existing modes as in scenarios 1 and 2 (same as scenario 3).	2030: Create a ride-hailing mode, assuming 3% are ride-hailing trips from existing CSTDM trips, substituted from other modes at specified rate. 2050: Create a ride-hailing mode, assuming 9% are ride-hailing trips from existing CSTDM trips, substituted from other modes at specified rate (same as scenario 3).
Active Travel	Assume an increase in bike and walking trips to beyond highest 2012 mode shares used in scenario 3 (16.2% and 1.5%) *(28)*. Hence walking comprises 20% of trips and bicycling comprises 5% of trips. We substitute away from auto trips to arrive at these levels.	2030 and 2050: Substituting away from auto trips, replace trips to reflect 20% walking and 5% biking mode share for all trips.

Table 3.5: Summary of Scenario Assumptions - Adjustments to CSTDM Outputs

	COVID trends persist	Hybrid	Urbanism bounces back	Urbanism bounces ahead
Telecommuting	Reduce short distance working trips by 27% and redistribute the number of reduced trips* 1.53 to all other purpose trips	2030: Reduce short distance working trips by 2% and redistribute the number of reduced trips* 1.53 to all other purposes 2050: Reduce short distance working trips by 6% and redistribute the number of reduced trips* 1.53 to all other purposes	Reduce short distance working trips by 12%, and redistribute the number of reduced trips *1.53 to all other purposes	Reduce short distance working trips by 12%, and redistribute the number of reduced trips *1.2 to all other purposes, doubling the trips using walking and biking as modes.
E-Shopping	Reduce short-distance shopping trips by 2.5%	2030: No change 2050: Reduce short-distance shopping trips by 15%	Reduce short-distance auto shopping trips by 15%	Reduce short-distance auto shopping trips by 15%
Transit	Reduce Short-distance transit trips by 63%, reassign to auto trips at specified rate.	No change	2030: Increase working transit trips to 10% (move trips from auto to transit) 2050: Increase working transit trips to 15% (move trips from auto to transit)	2030: Increase working transit trips to 15% (move trips from auto to transit) 2050: Increase working transit trips to 20% (move trips from auto to transit).

	COVID trends persist	Hybrid	Urbanism bounces back	Urbanism bounces ahead
Ride-hailing	Assume 1% ride-hailing trips, substituted from other modes at specified rate. Reduce those ride-hailing trips by 65% in urban and suburban areas and allocate those trips back to other CSTDM modes.	Assume 1% ride-hailing trips, substituted from other modes at specified rate. Assume 3.2% ride-hailing trips, substituted from other modes at specified rate.	2030: Assume 3% ride-hailing trips, substituted from other modes at specified rate. 2050: Assume 9% ride-hailing trips, substituted from other modes at specified rate.	2030: Assume 3% are ride-hailing trips, substituted from other modes at specified rate. 2050: Assume 9% ride-hailing trips, substituted from other modes at specified rate
Active travel	Reduce walk trips by 36%.	No change	Replace auto trips to reflect 16.2% walking and 1.5% biking mode share for all trips.	Replace auto trips to reflect 20% walking and 5% biking mode share for all trips.

3.2 Equity Analysis of Scenarios

We also analyze the equity implications of each of the scenarios described earlier. We compare the travel outcomes of VMT, trip length, and mode share aggregated by three socioeconomic characteristics: neighborhood designation using equity priority area definitions at the traffic analysis zone level, and household income and household car ownership at the trip level. We also examine outputs by region where appropriate to understand the spatial distribution of transportation equity considerations. While an analysis by race and ethnicity would be important to assess for equity, the travel demand models used for this analysis do not include race as an input or output variable (as is the case for most travel demand models). Equity priority neighborhoods serve as an imperfect proxy for analysis by race.

We used two definitions to create the equity priority areas. First, we used the SB 535 characterization of disadvantaged communities based on the CalEnviroScreen 3.0 definition from 2017. Under this definition, a census tract is considered disadvantaged if its CalEnviroScreen score falls into the top 25% of scores across the state or if it is in the 5% highest pollution burden with a low population *(42)*. We obtained the list of disadvantaged census tracts from the California Environmental Protection Agency. This equity definition encompasses communities with environmental justice concerns.

Second, we adapted the definition of equity priority communities (EPC) developed by the Metropolitan Transportation Commission (MTC), the metropolitan planning organization for the San Francisco Bay Area. EPCs are based on population thresholds relative to the regional population. A census tract is defined as an EPC if it has a high concentration of both people of color and low-income households, or if it has a high concentration of low-income households and three of the following: people with limited English proficiency, zero vehicle households, adults 75 years and older, people with disabilities, single parent families, or households with rent burdens. A high concentration is defined as a population share more than a half standard deviation above the regional share. Low-income households are defined as those less than 200% of the Federal Poverty Level. Rent-burdened is defined as households paying at least 50% of their income toward rent. We computed the population thresholds for six regions: the big four Metropolitan Planning Organizations (MPOs), consisting of the San Francisco Bay Area (MTC), San Diego County (SANDAG), the Sacramento region (SACOG), and southern California (SCAG); the Central Valley, which consists of Fresno, Kern, Kings, Madera, Merced, San Joaquin, Stanislaus, and Tulare Counties; the Central Coast, which consists of Monterey, San Benito, San Luis Obispo, Santa Barbara, and Santa Cruz Counties; and rural California, which consists of the remainder of the state. Data to create the definitions come from the 2011–2015 five-year American Community Survey to match the base year of the CSTDM population. This equity definition prioritizes communities with housing and transportation burdens.

We identified census tracts as an equity priority area if they met either of the two definitions (see Figure 3.2). The unit of analysis for the CSTDM is the traffic analysis zone (TAZ). We defined a TAZ as an equity priority area based on the classification of the largest census tract contained within that TAZ. (Many, but not all, TAZs are coterminous with census tracts.)

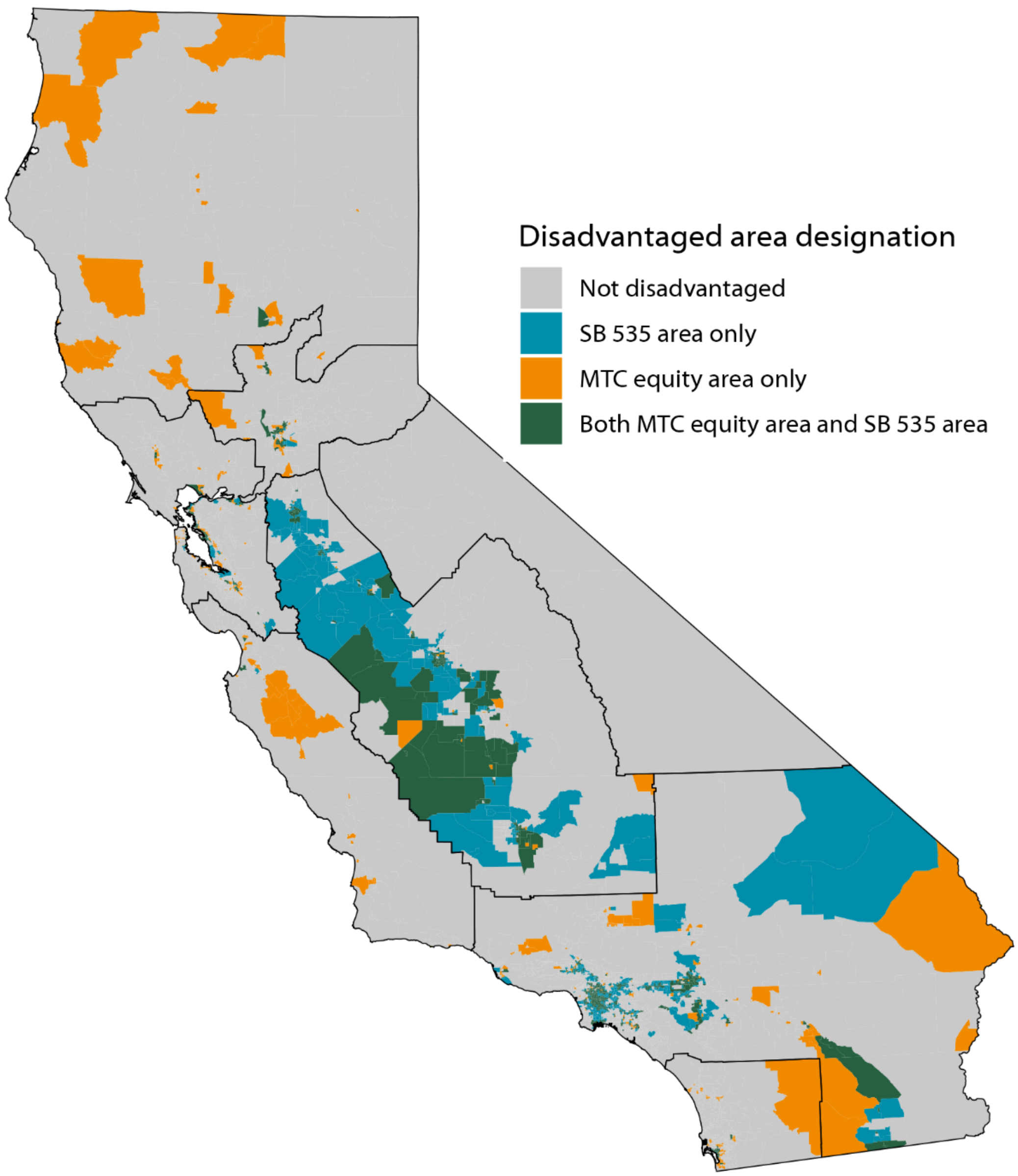

Figure 3.2: Equity priority areas with analysis regions

We then compared scenario outputs between equity priority areas and non-disadvantaged communities statewide and within the six analysis regions. We examined model outputs for differences in VMT and mode share between equity priority areas and non-disadvantaged communities, by income, and by car ownership status.

The Transportation Equity and Environmental Justice Advisory Group (TEEJAG) reviewed and provided input to the development of the scenarios and methods for analyzing the equity implications.

4 Results of Scenario Modeling

4.1 Scenario Modeling Results

The four scenarios are compared to the CSTDM BAU, reflecting pre-COVID assumptions about both travel behavior and transportation policies over time. The BAU is the state's best guess, prior to COVID, about future travel patterns in the state. Figure 4.1 compares the number of trips across scenarios to the CSTDM BAU projections for 2030 and 2050. The largest increase in trips occurs for Scenario 1, with increases of 30% and 29% for 2030 and 2050, respectively. Scenario 3 has smaller increases, with 11% for 2030 and 11% for 2050. Scenario 4 has moderate increases, with 7% for both 2030 and 2050. Minimal increases occur for Scenario 2, with 3% for 2030 and 4% for 2050.

The patterns are similar for auto VMT across scenarios (Figure 4.2), including SOV, HOV and ride-hailing. The largest increase in VMT occurs in Scenario 1 (COVID trends persist) for both 2030 and 2050, with each year increasing by 30% and 31% from the BAU projection, respectively. Scenarios 2 and 3 have minimal increases in VMT. Changes in both trips and VMT are consistent with our scenario assumptions. Scenario 1 brings the largest increase in trips, mostly due to remote working and more time availability for leisure trips. There is less change compared to BAU for Scenario 2 since we assume the travel patterns and trends return to pre-pandemic levels, and the modeled trips and VMT should be close to the Caltrans' baseline for which COVID was not considered. Scenario 3 has moderate increases in auto VMT mainly due to less car travel and more transit, walk and bike trips. Scenario 4 generates a small decrease in VMT as a result of more transit and active transport trips.

VMT per capita for the scenarios is presented in Figure 4.3. The patterns are consistent with total VMT across the scenarios. However, VMT per capita results for Scenario 2 and Scenario 3 are closer to the BAU case than they are for total VMT.

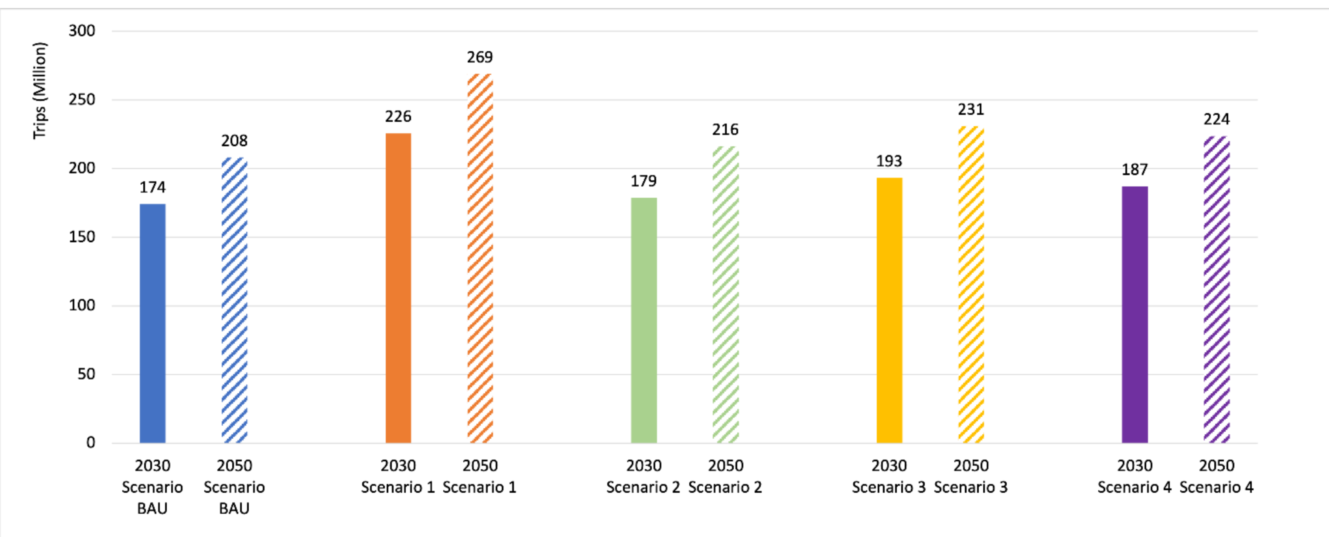

Figure 4.1: Total trips 2030 and 2050

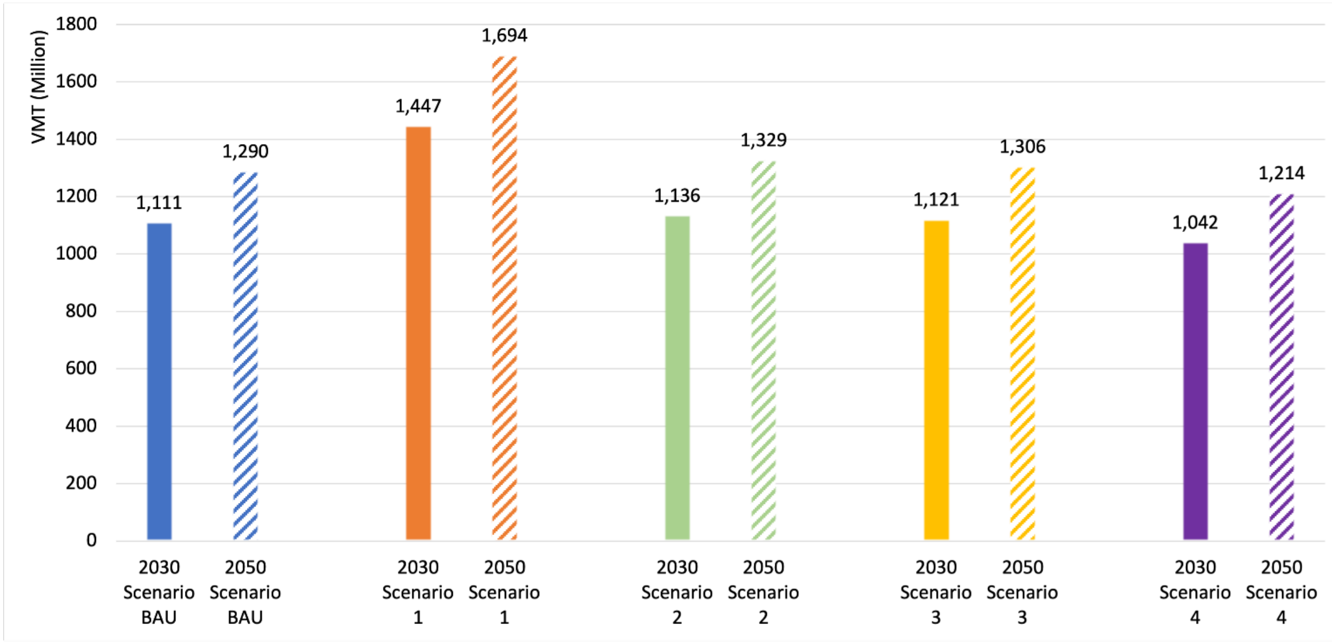

Figure 4.2: Auto VMT 2030 and 2050

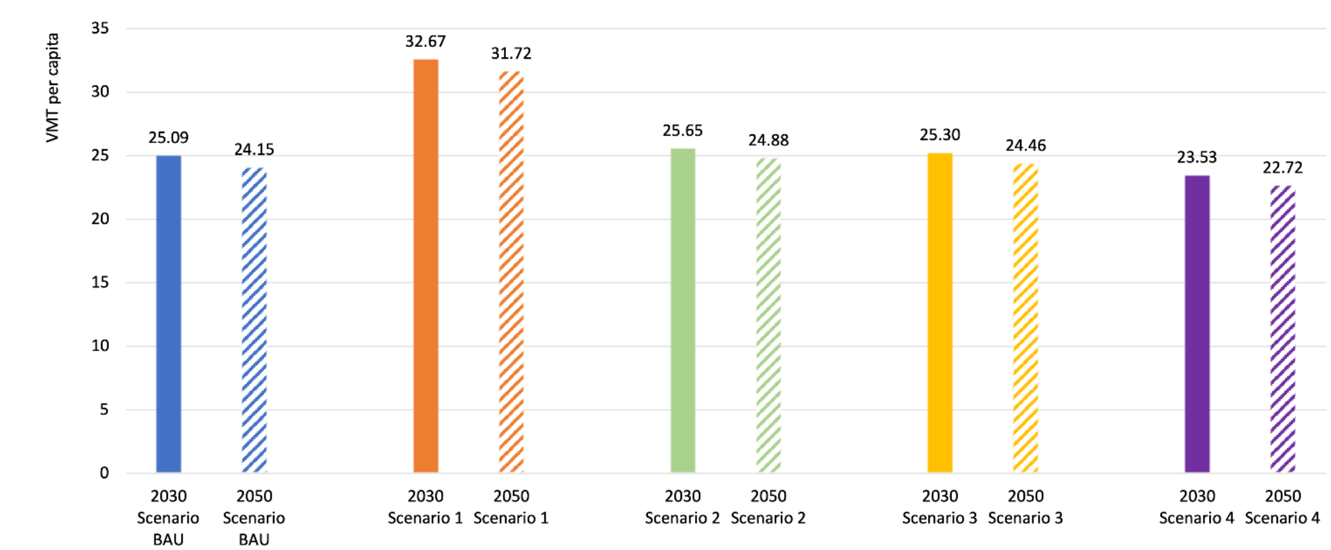

Figure 4.3: Auto VMT per capita 2030 and 2050

The analysis of the changes in mode use across scenarios in 2030 (Figure 4.4) shows large increases in single occupancy vehicle (SOV) and high occupancy vehicle (HOV) use for Scenario 1. Scenario 2 has smaller increases across these modes, and Scenario 3 shows decreases in these modes. In comparison, walking trips increase by a negligible amount in Scenario 2 and by 181% in Scenario 3. Scenario 3 also has a large increase in bike trips, by 756%. More aggressive increases in active transport happen in Scenario 4, with the largest decrease in auto trips. For 2050, we see similar results; Scenario 1 has large increases in SOV and HOV of 29% and 49%, respectively, while Scenario 3 has decreases of 27% and 18%. Scenario 3 has increases in walk, and bike by 147%, and 808%, respectively, as shown in Figure 4.5. Again, consistent with the urbanism assumption, Scenarios 3 and 4 have large increases in ride-hailing, walk, and bike, along with a decrease in auto trips.

The breakdown of trips by trip purpose is shown in Figure 4.6 and Figure 4.7. Note that home trips refer to staying at home, so they do not translate to vehicle trips on the road. If COVID trends persist, as in Scenario 1, work-from-home would gradually evolve into a regular work option, so that stay-at-home behaviors increase by 31% and 30% for 2030 and 2050 respectively. For Scenario 1, work trips decreased by 28% and 28% for 2030 and 2050 compared to BAU 2030 and 2050.

Although e-shopping became more popular during the pandemic, the reduction in shopping trips due to e-shopping seems to be offset by more flexible working schedules and locations, producing a net increase in shopping trips for Scenario 1. The increases are similar for leisure, personal business, escort and school trips, due to more personal time availability. And unsurprisingly, work trips decrease less for Scenario 2, Scenario 3, and Scenario 4 compared to Scenario 1. For Scenario 2, compared with BAU, work trips decrease by 2% and 7% for 2030 and 2050, respectively. For Scenario 3, work trips decrease by 13% for both years.

Figure 4.8 shows the changes in total trips spatially at the TAZ level, where darker purple represents larger increases from the CSTDM BAU, and yellow indicates larger decreases. Scenario 1 has the largest increases in total trips across the state with few TAZ’s with a decrease in total trips. However, the pattern varies across TAZ’s, as indicated by lighter color, especially in the Central Valley. The maps for Scenario 2 show minimal changes in total number of trips across TAZ’s with little to no variation across the state. The maps for Scenario 3 indicate larger increases than Scenario 2 but smaller increases than Scenario 1, with noticeable variation across TAZ’s in the state, again especially in the Central Valley region.

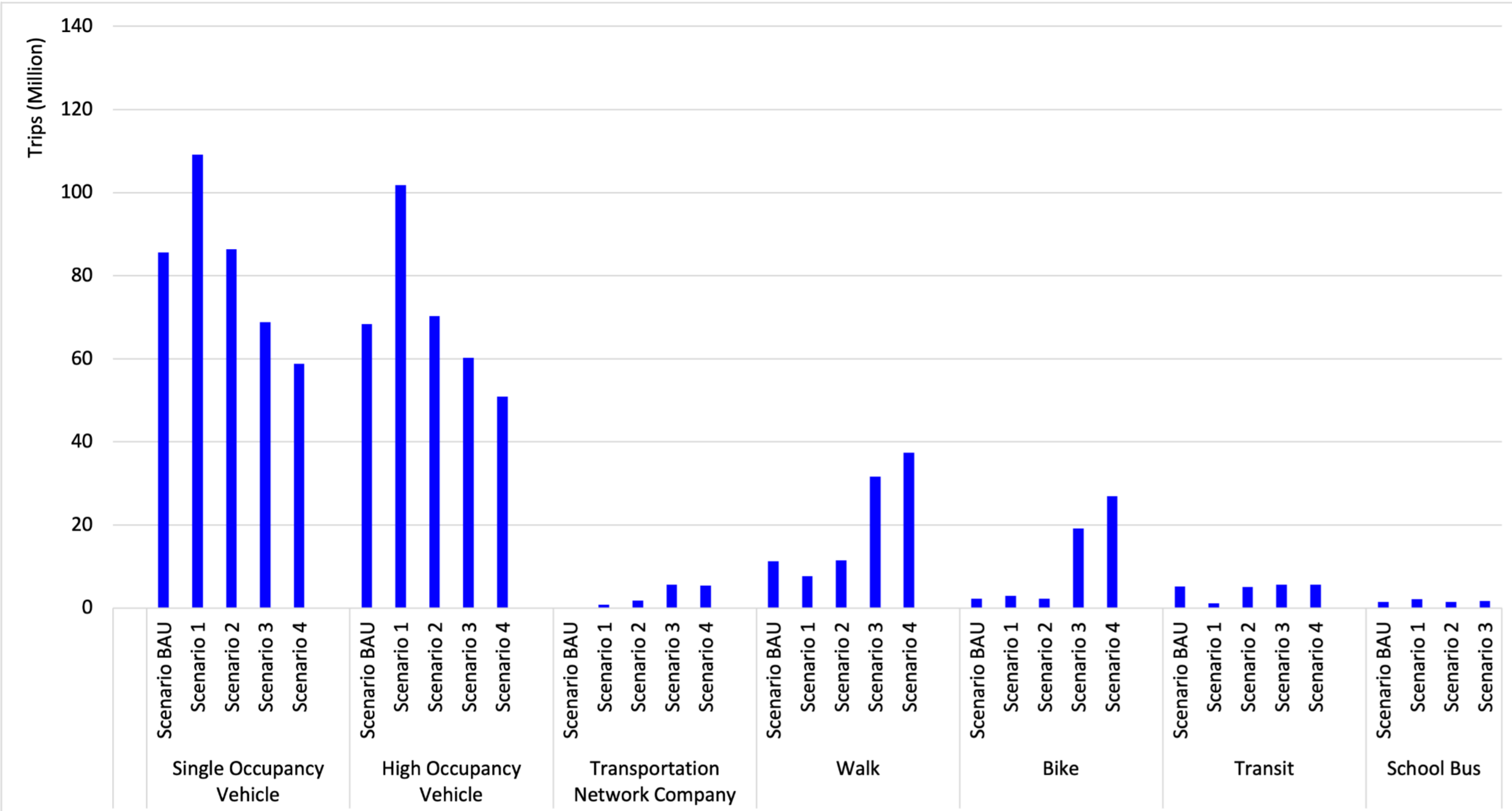

Figure 4.4: Trips by mode 2030

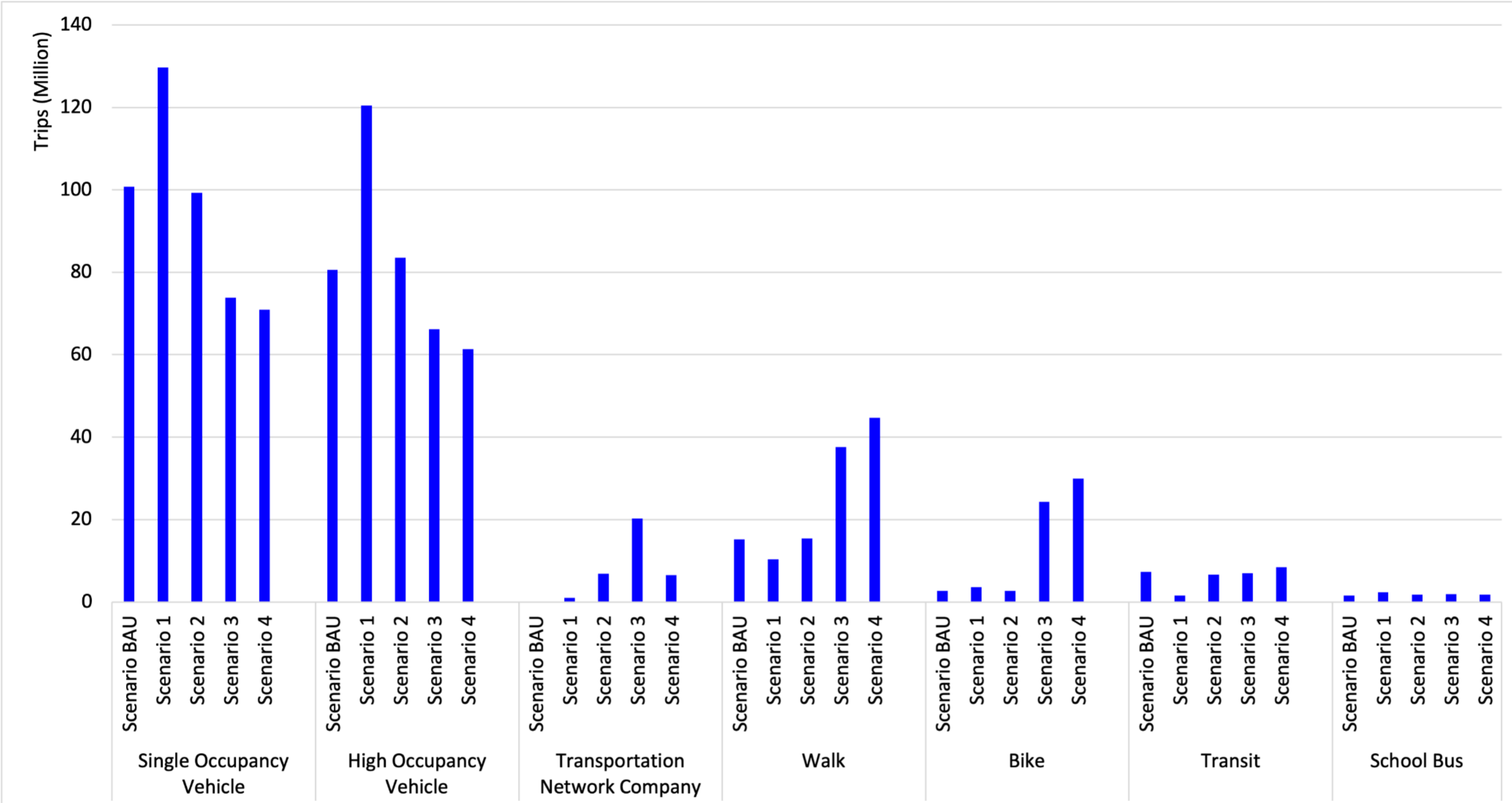

Figure 4.5: Trip by mode 2050

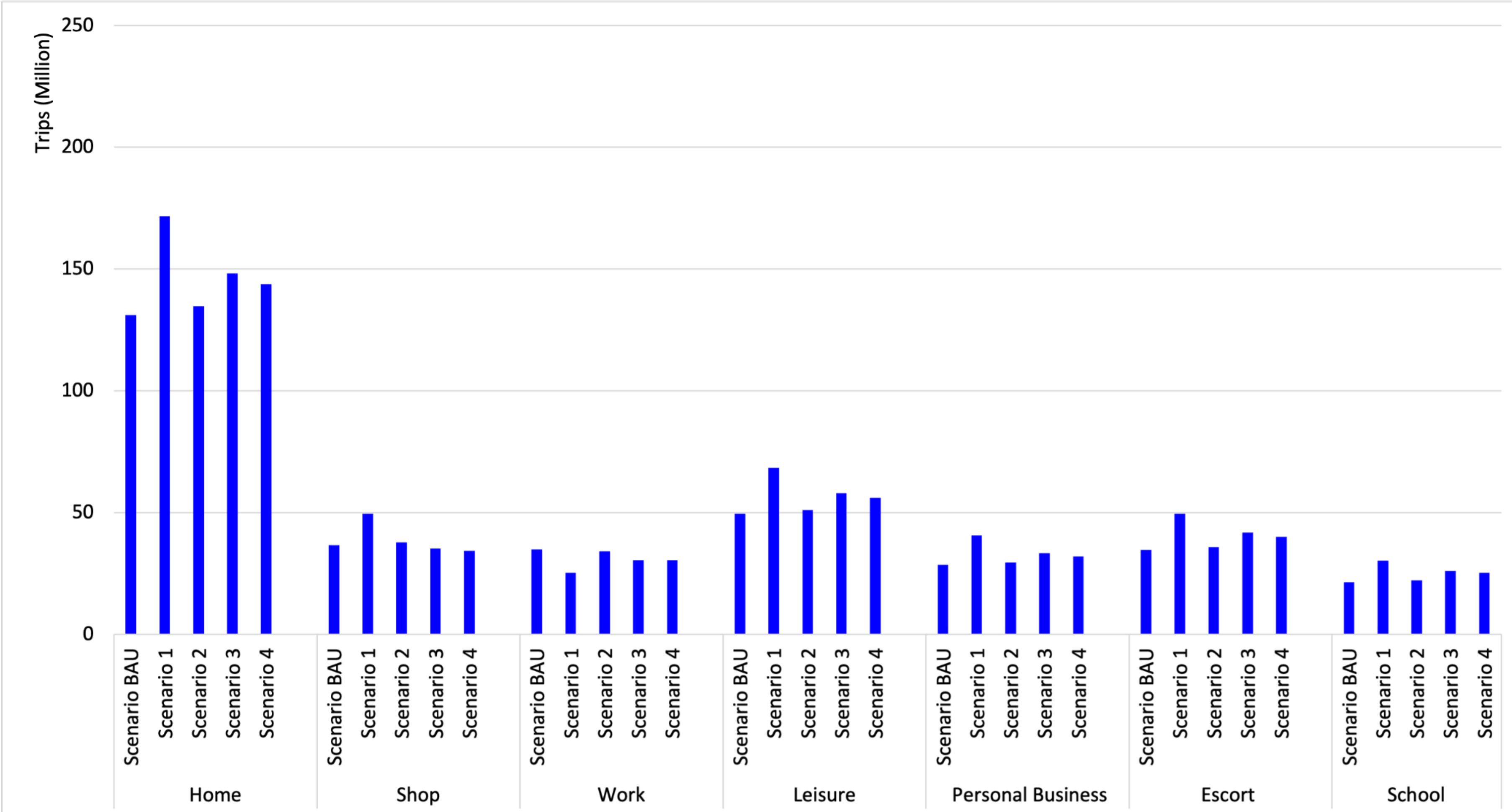

Figure 4.6: Trip by purpose 2030

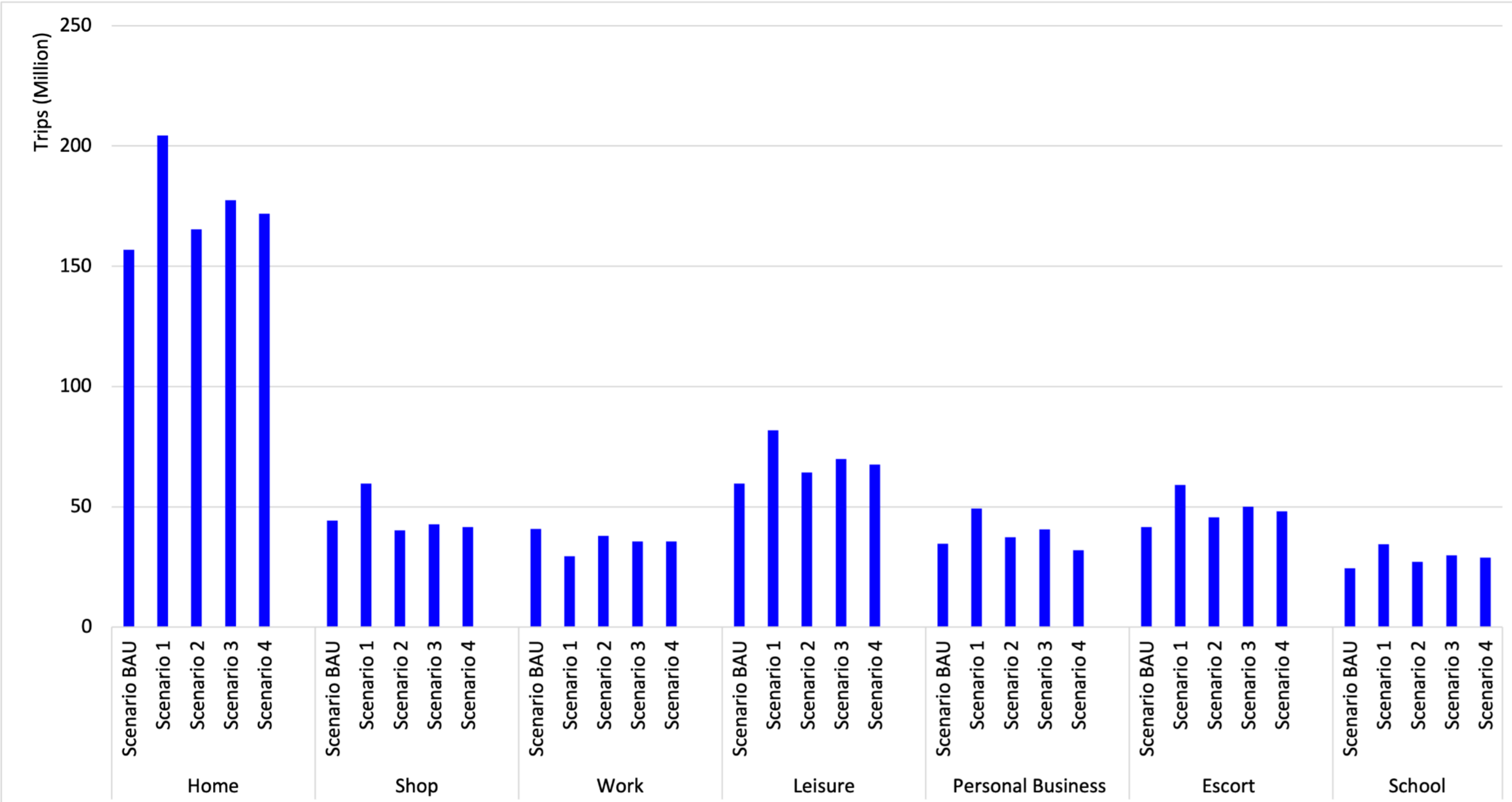

Figure 4.7: Trip by purpose 2050

Figure 4.8: Percentage change for total trips for all four scenarios in 2030 and 2050

4.2 Summary of Scenario Modeling Results

The previous section presented estimates of the potential outcomes from different post-COVID futures at a state-wide scale. A key finding across the scenarios is that certain increases in both trips and VMT associated with current COVID trends (with the most drastic increases for Scenario 1) will likely persist in 2030 and 2050. This is counterintuitive since more telecommuting is often associated, in the general media discussion and also in some of the scientific literature, with lower VMT. However, our study accounts for the well-documented phenomenon that work trips eliminated by telecommuting are often replaced with trips for other purposes, which are often made with private vehicles. Because of the increase in non-work trips, remote work does not necessarily result in a net decrease in VMT. It should also be noted that our model does not account for changes in residential location that might result from telecommuting that are likely to lead to further increases in VMT.

While it is not yet clear how people will adapt to working from home or working hybrid schedules in the long run, the available evidence suggests that telecommuters may increase rather than decrease their total travel. These increases will have large policy implications for future transportation planning in terms of transportation demand and vehicle emissions. Especially in Scenario 1, which shows large increases in SOV and HOV modes, reaching emission reduction goals will depend on changes in vehicle technology. The VMT results for Scenarios 2, 3 and 4 are surprisingly similar, though Scenario 4 has large increases in the walk, bike, and ride-hailing modes (the last of which is not included in the BAU scenario), and decreases in auto modes, with transit remaining roughly constant.

It is unclear which of these four scenarios the post-COVID future in California will most closely resemble. It is also possible that the future will reflect a combination of the scenarios, such as one in which teleworkers do not replace their work trips with trips for other purposes, or one in which urbanism eventually bounces back after returning to BAU in 2030. Although these scenarios are hypothetical, the results provide useful insights into future travel patterns as well as a baseline against which to compare other possible post-COVID scenarios.

The estimates of increases in VMT and total trips for three of the four scenarios is discouraging from the standpoint of meeting California's goals for emissions reductions, but the differences between scenarios point to the importance of state, regional, and local policy in the state's efforts, as discussed in Section 7. There are many possibilities for further work on this topic. Analysis of different regions within California can provide important insights into community-level effects of these scenarios, helping these communities better prepare for their future needs. Another path forward could be to refine the scenarios using different factors and modalities. This would allow for more nuance within the model and provide more detailed results. For example, some elements we did not directly address in the model are land use and place type. Further iterations of the model would enable scenario definitions based on TAZ-level attributes like urban/rural place type, or other socio-economic factors.

5 Results of Equity Analysis of Post-COVID Scenarios

In this section, we analyze the equity implications of each of the scenarios described earlier. We compare the travel outcomes of VMT, trip length, and mode share aggregated by three socioeconomic characteristics: neighborhood designation using equity priority area definitions at the traffic analysis zone level, and household income and household car ownership at the trip level. Although higher numbers of vehicle trips and VMT can reflect a positive outcome for some disadvantaged households (e.g. if the additional driving helps low-income workers reach higher paying jobs), we assume that more driving is generally a burden for disadvantaged households because: 1. Driving imposes a financial burden on these households, 2. It may reflect poor accessibility to jobs and other activities by more affordable modes, 3. The environment impacts of driving are especially acute in disadvantaged communities. We also examine outputs by region where appropriate to understand the spatial distribution of transportation equity considerations. While an analysis by race and ethnicity would be important to assess for equity, the travel demand models used for this analysis do not include race as an input or output variable (as is the case for most travel demand models). Equity priority neighborhoods serve as an imperfect proxy for analysis by race.

5.1 Equity Results for VMT

Across the state, the models predict that non-disadvantaged areas will generate substantially higher VMT than equity priority areas (Figure 5.1). In both cases, the scenario where peak COVID trends persist (Scenario 1) will produce the highest VMT out of all the modeled scenarios and the business-as-usual scenario. Scenario 1 estimates over 1.1 billion vehicle miles traveled in non-disadvantaged areas compared to 543 million in equity priority areas by 2050. As in the overall analysis, Scenarios 2 and 3 indicate an increase in VMT while Scenario 4 shows lower VMT across all groups compared to a business-as-usual scenario for both equity priority areas and non-disadvantaged areas. While non-disadvantaged areas generate a greater total VMT in all scenarios and model years, VMT growth between 2030 and 2050 is larger in equity priority areas by a small degree (Table 5.1). For example, Scenario 1 produces a 16.2% increase in VMT for non-disadvantaged communities between 2030 and 2050, while equity priority areas generate a 19.2% increase in VMT. Percentage changes in VMT by area are similar across all four scenarios, with the smallest increases in VMT in scenario 4 for both equity priority areas (18.3%) and non-disadvantaged areas (15.6%).

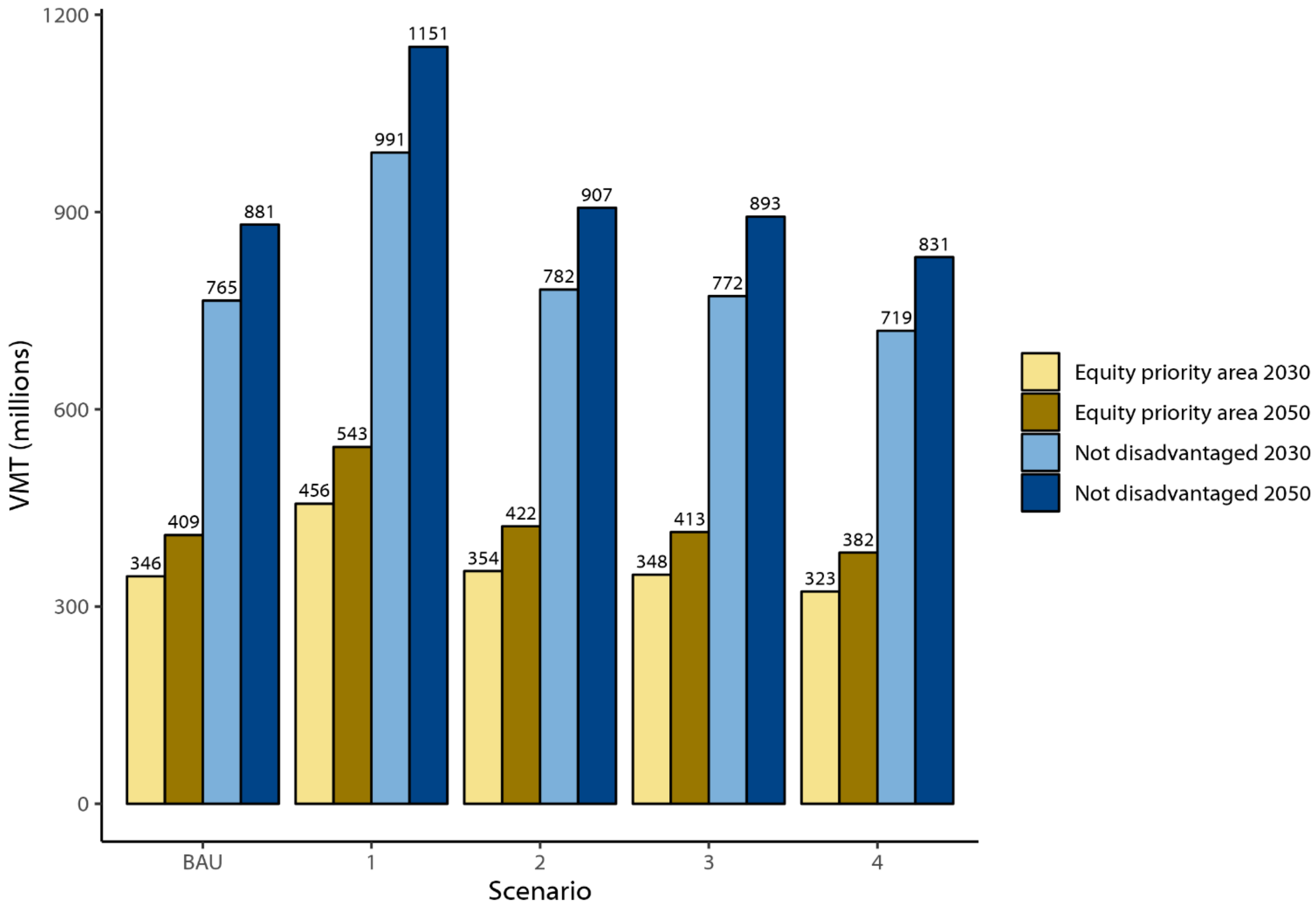

Figure 5.1: Total VMT by equity priority area, year, and model scenario

Table 5.1: Percent change in total VMT by equity priority area, year, and model scenario

Scenario	Equity priority area	Not disadvantaged
BAU	18.1	15.1
1	18.9	16.2
2	19.2	15.9
3	18.6	15.6
4	18.3	15.6

VMT per capita is shown in Figure 5.2. Across all scenarios, VMT per capita is lowest in equity priority areas and decreases by a small amount between 2030 and 2050. Scenario 1 predicts the most car travel per person, with 33.2 miles per person by 2050 in non-disadvantaged areas and 29.1 miles per person in equity priority areas. VMT per capita is slightly greater than business-as-usual in Scenarios 2 and 3, while it is the lowest in Scenario 4. The relative difference in VMT per capita between equity priority areas and non-disadvantaged areas is similar across all three scenarios and both model years.

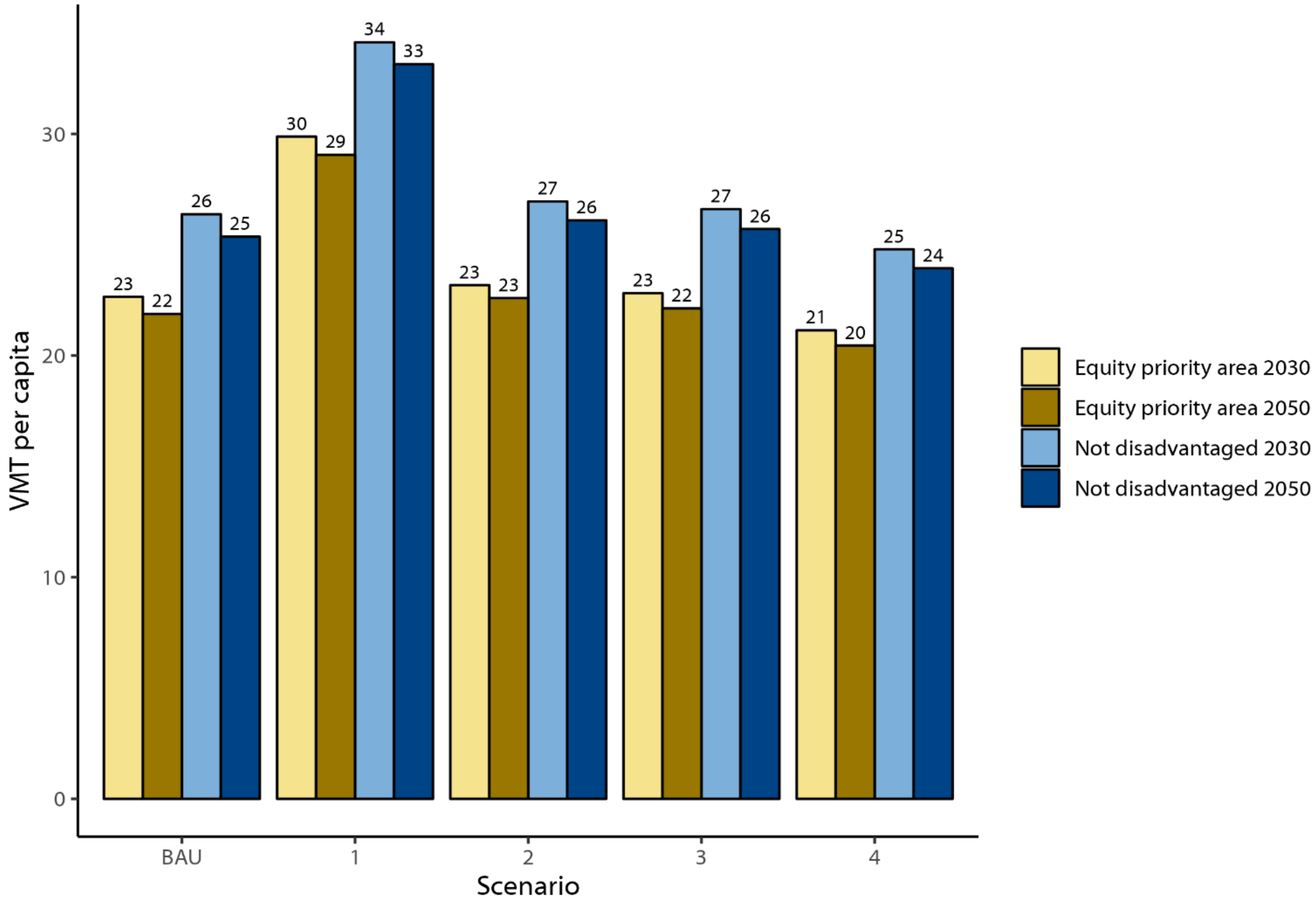

Figure 5.2: VMT per capita by equity priority area

Differences within regions show similar patterns as the statewide patterns with one significant exception (Figure 5.3). Across all regions, Scenario 1 generates the most VMT in both 2030 and 2050, Scenarios 2 and 3 tracks close to, but slightly greater than, the business-as-usual scenario by 2050, and Scenario 4 generates the least VMT. The SCAG region has the largest VMT outputs across all scenarios, while both rural California and the Central Coast generate the least, depending on which year or population group is analyzed. While equity priority areas typically generate less VMT than non-disadvantaged areas in the analysis, they generate more VMT in the Central Valley. This is likely because most of the TAZs in the Central Valley fall within disadvantaged areas, more than any other region due to high CalEnviroScreen scores (see Figure 3.2).

Changes between 2030 and 2050 and between disadvantaged and advantaged areas also show differences across regions and scenarios (Figure 5.4). In the baseline business-as-usual scenario, regional VMT shows increases between 7% and 40%. In three of the seven regions, VMT increases are higher among non-disadvantaged communities by a negligible amount. In two regions—MTC and SANDAG—increases in VMT in equity priority areas are more than double than in non-disadvantaged communities. These relative patterns are consistent across all scenarios, with the largest VMT forecast increases shown in the SACOG region in Scenario 1. In the urbanism-bounces-back scenario (Scenario 3), the change in VMT for non-disadvantaged communities compared to equity priority areas in the Central Coast is notably higher than in any other scenario. Similarly, non-disadvantaged areas in rural California have higher changes in VMT than equity priority areas under Scenario 4, unlike the other four scenarios.

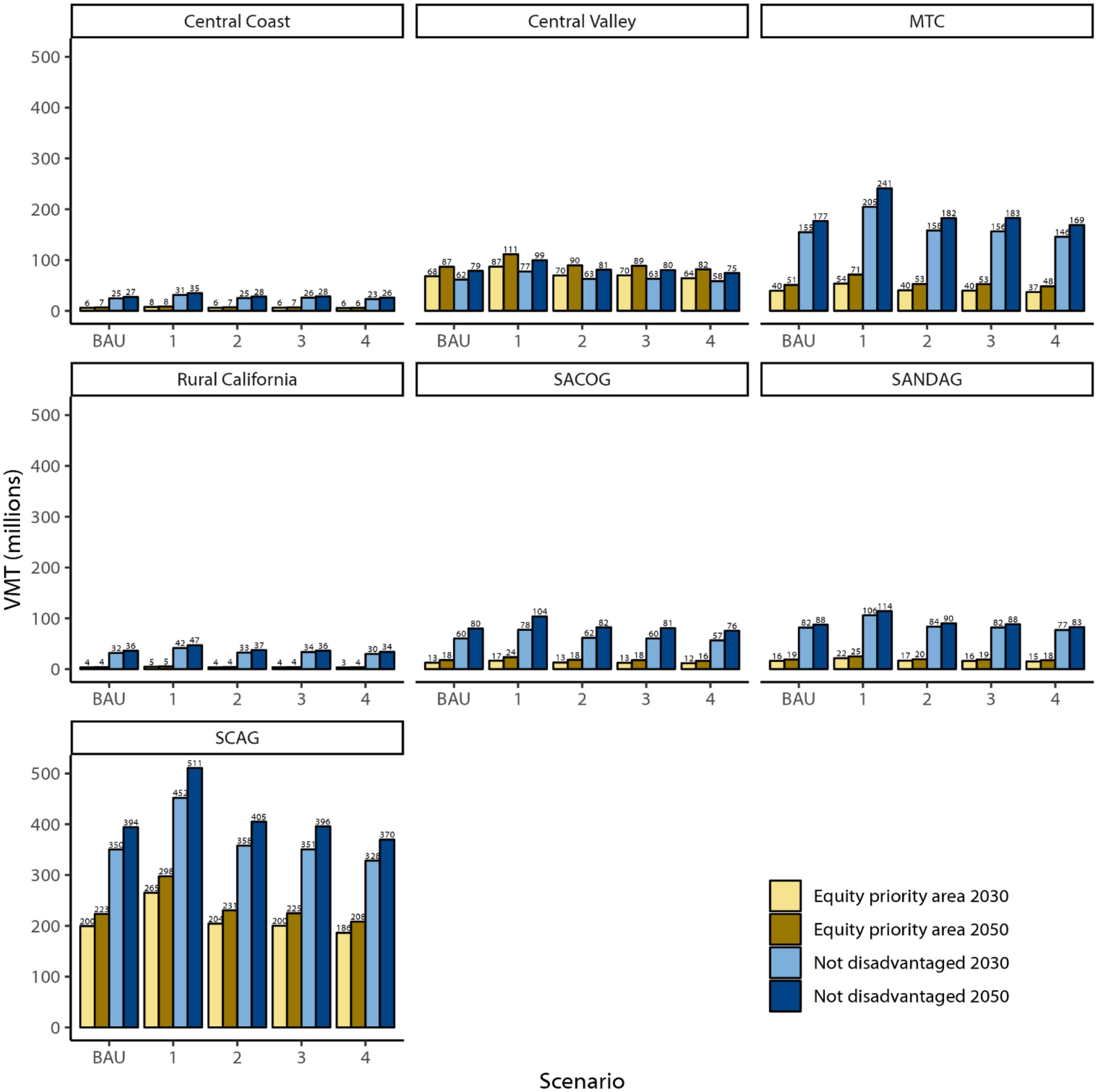

Figure 5.3: VMT by region

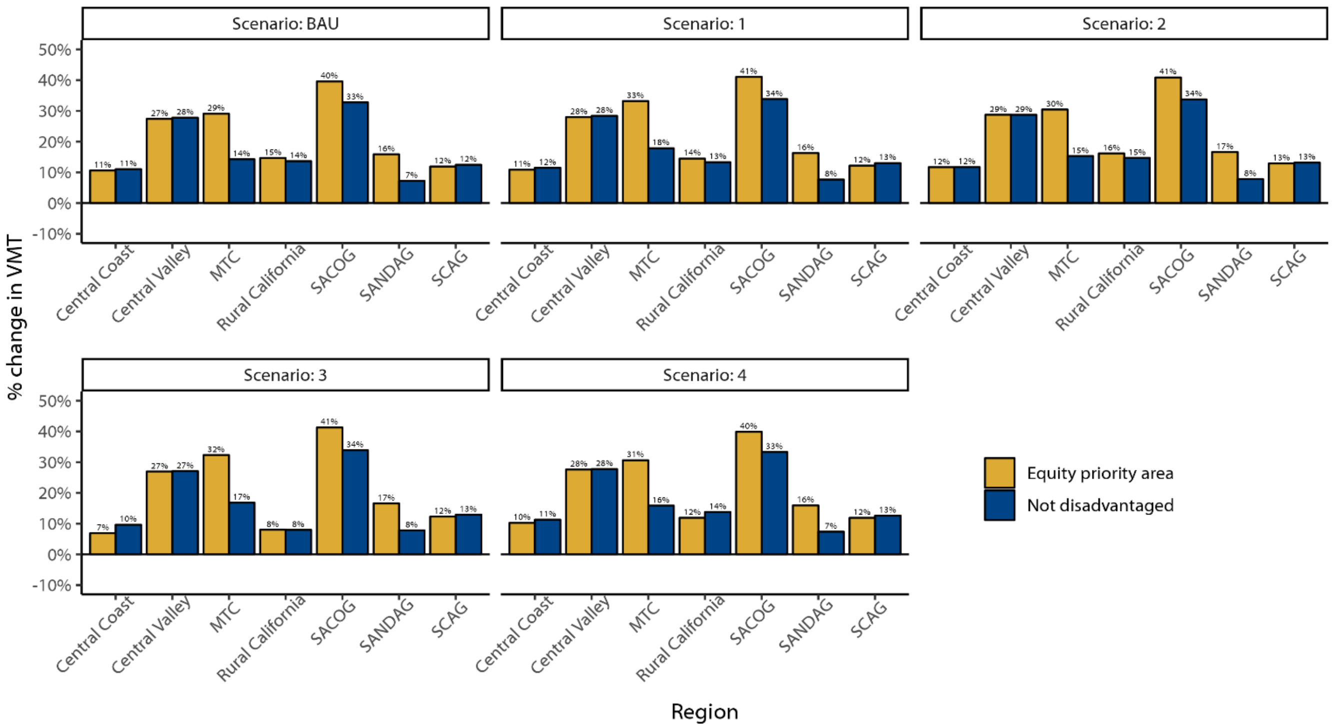

Figure 5.4: Change in VMT, 2030-2050 by equity priority area

Total VMT by income category is shown in Figure 5.5. The shape of the VMT distribution across income categories roughly approximates a normal distribution for all scenarios in both model years. The highest levels of VMT are generated by individuals in the $25k to $50k category (a high share of the population) with the lowest total VMT generated by those earning less than $10k (a small share of the population). Patterns are consistent with respect to relative VMT generation by income group across the scenarios.

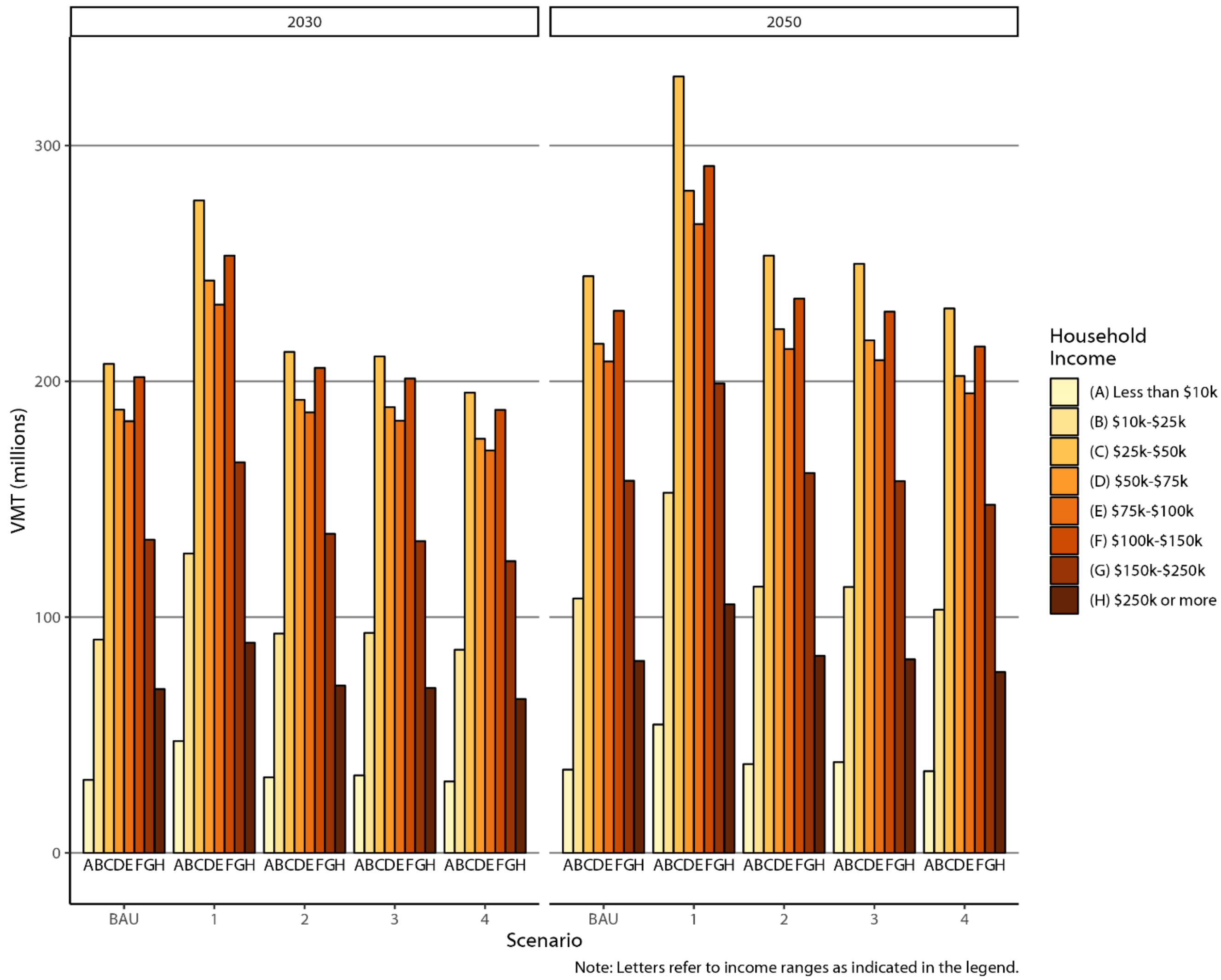

Figure 5.5: VMT by income category

Average vehicle trip length for car travel by income is shown in Figure 5.6. In general, across all scenarios, trip length increases as incomes increase. However, car trip lengths are slightly higher for those earning less than $10k compared to those earning between $10k and $25k and car trip lengths are slightly lower for those earning more than $250k compared to those earning $150k. Notably, average car trip lengths are highest in Scenario 4, the urbanism-bounces-ahead scenario, with small decreases between 2030 and 2050. Because total VMT is lower in this scenario and fewer trips are made by car, it suggests drivers are forecast to be more judicious in their car use, using vehicles primarily for longer trips when alternative modes may not be readily available.

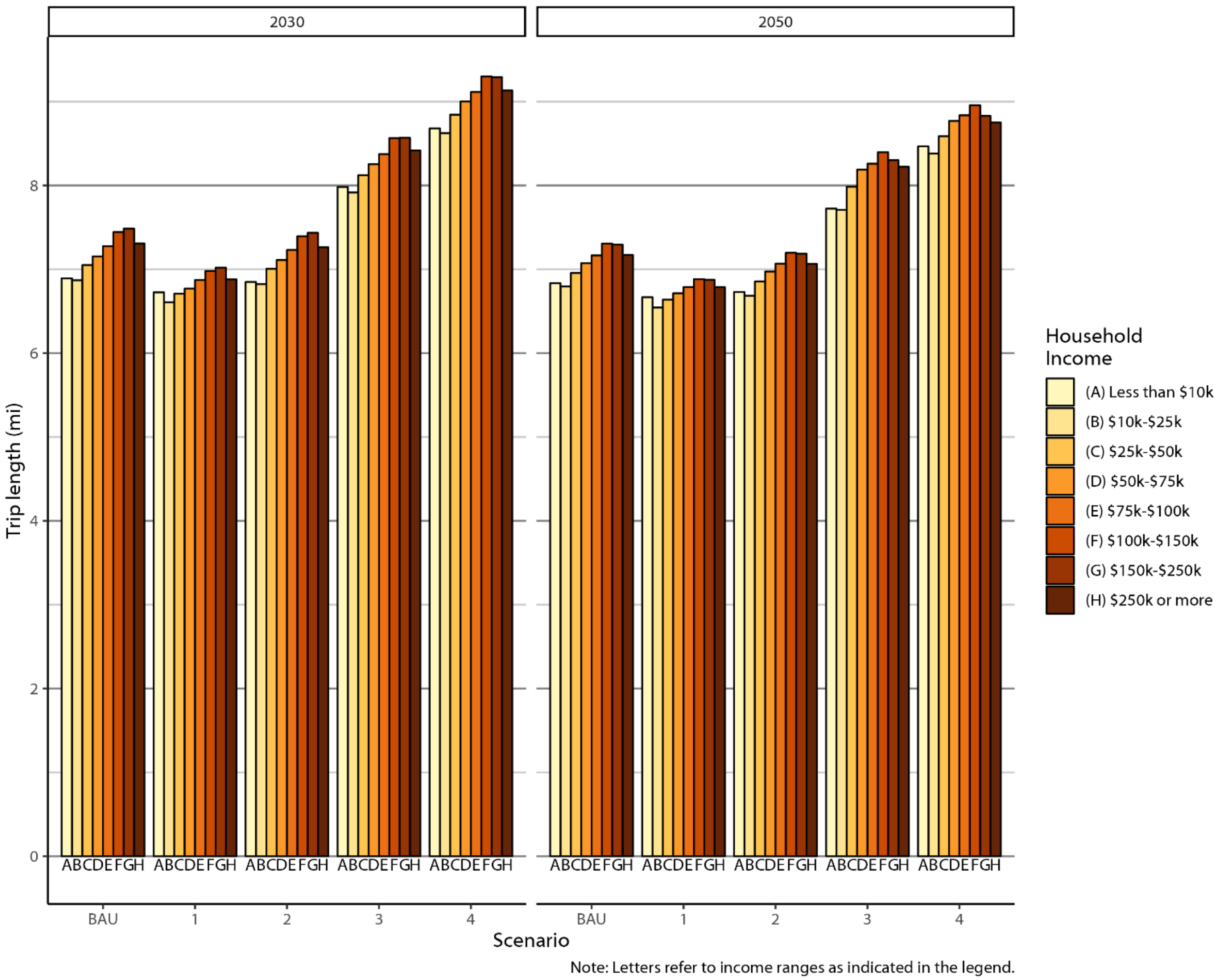

Figure 5.6: Mean vehicle trip length by income category

VMT per capita by income group is shown in Figure 5.7. The results show that across all scenarios and in both years, the lowest income groups generate the least VMT per capita, though the relative amount varies slightly by scenario. VMT per capita is forecast to decrease between 2030 and 2050 across all income groups and within all scenarios. Scenario 2 has substantially higher VMT per capita for each income group compared to other scenarios, while scenario 4 again has the lowest. The differences in VMT per capita by income category are illustrated in Figure 5.8. The largest decreases in VMT per capita between 2030 and 2050 occur in the lowest income group (less than $10,000) in the business-as-usual scenario and in Scenarios 1 and 4. In Scenarios 2 and 3, however, the largest decreases are in the upper income groups. This suggests that merely moderate changes toward sustainable travel may put low-income groups at a disadvantage as their decreases in car travel will be far lower than a more aggressive sustainable travel scenario.

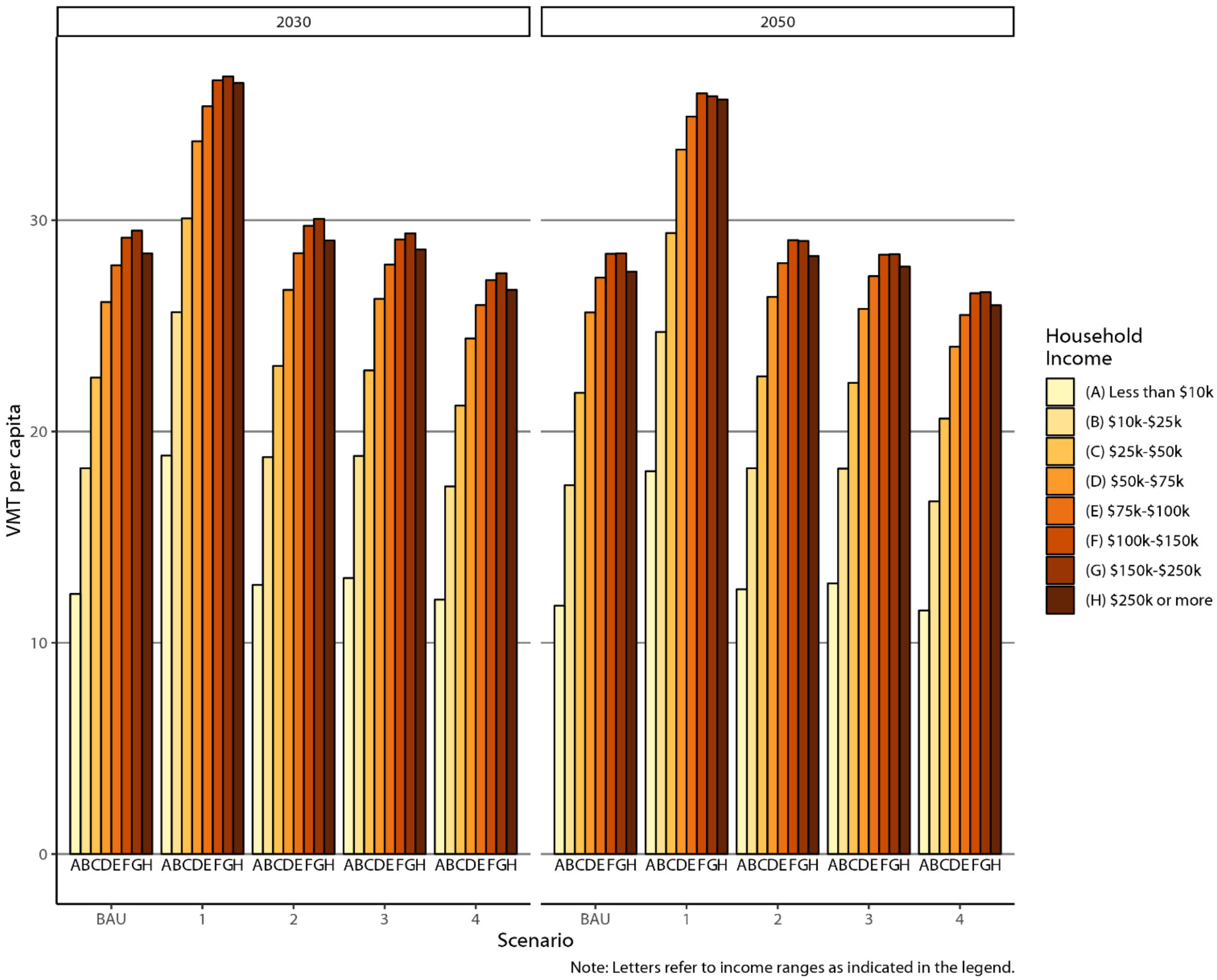

Figure 5.7: VMT per capita by income category

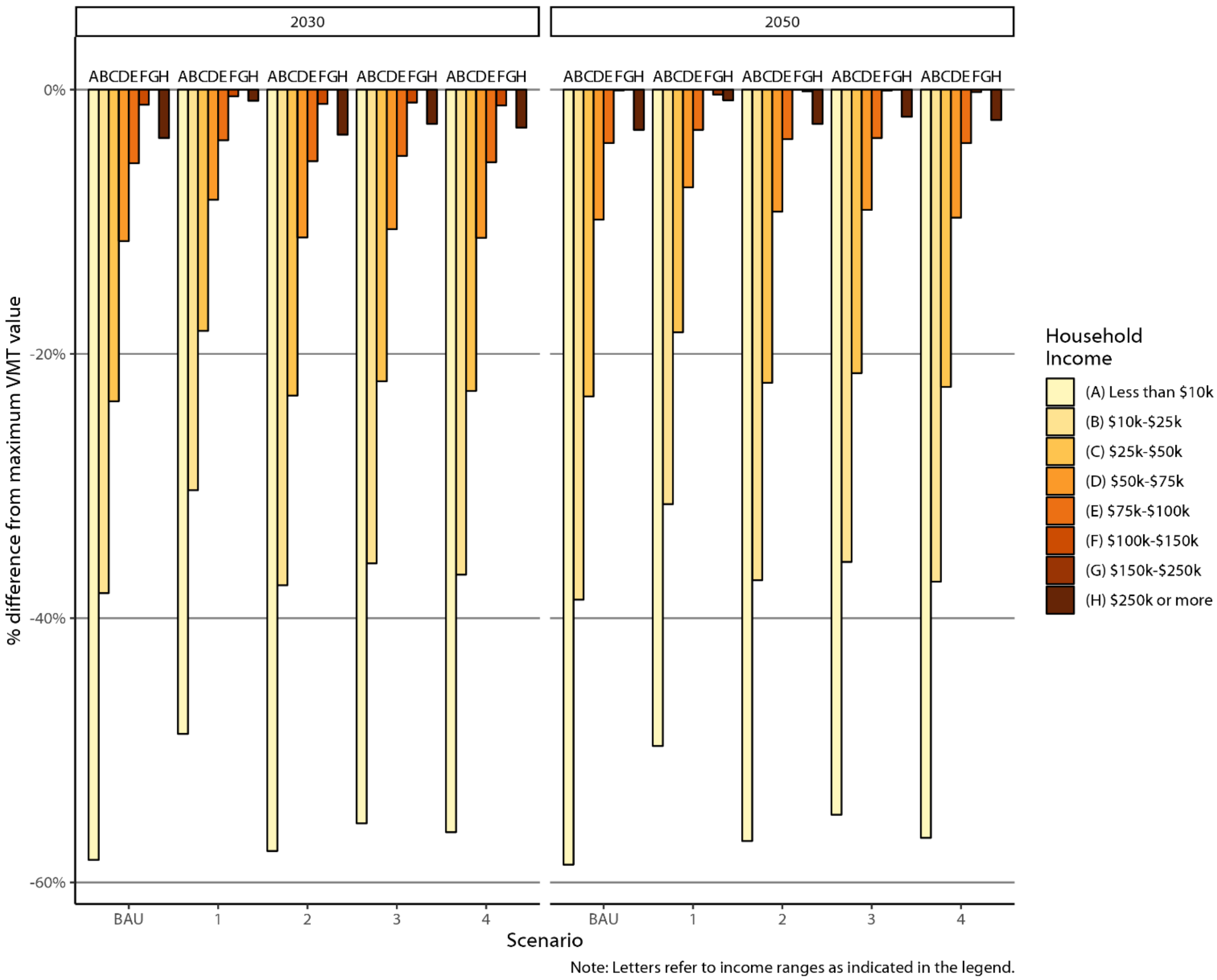

Figure 5.8: Difference in VMT per capita by income category from the maximum category

VMT by car ownership status[3] is shown in Figure 5.9. Not surprisingly, "fully-equipped" households (with as many vehicles as drivers) generate the most VMT in all scenarios while zero-car households generate the least (zero-car households can generate VMT from car-pooling, ride-hailing, and borrowing cars). Zero-car households have the largest increases in VMT between 2030 and 2050 compared to the two other car ownership categories. This is true across all scenarios; Scenario 1 shows the largest increase at 31%, while Scenario 3 is the smallest at 20%. The two other car ownership categories have similar increases in VMT within scenarios across the two years. Note that VMT in zero-car households is largely generated via carpooling; about 90% in Scenarios 3 and 4 and about 96% Scenario 2. The models predict no drive-alone travel for Scenarios 2, 3, and 4, but roughly 20% of VMT generated in Scenario 1 is via driving alone for zero-car households. (This is likely to come from extensive car sharing or car borrowing.) These patterns again illustrate the potential for significant travel burdens associated with COVID trends.

[3] CSTDM categorizes car ownership as "car sufficiency" in three categories: zero-car households, or households without cars; insufficient (renamed "car deficient"), or households with fewer vehicles than drivers; and sufficient (renamed "fully equipped"), or households with at least as many vehicles as drivers. We assume car ownership status to remain the same across the scenarios.

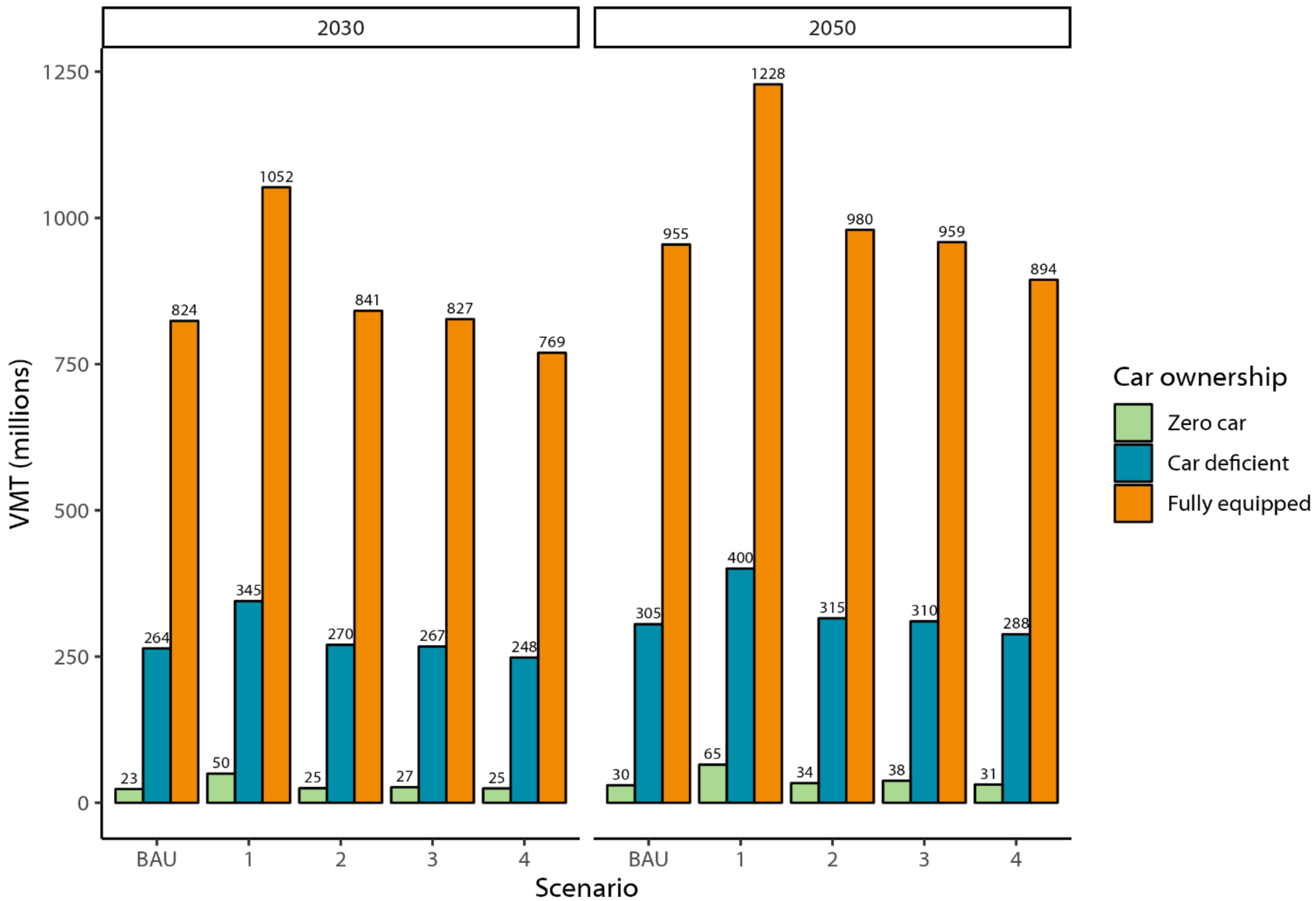

Figure 5.9: VMT by car ownership status

VMT per capita by ownership status is shown in Figure 5.10. Here again, zero-car households generate the least VMT per capita compared to the other car ownership categories. The Scenario 1 results suggest the highest level of burden for zero-car households; VMT per capita is roughly double that of the other two scenarios. All scenarios show modest decreases in per capita VMT between 2030 and 2050 for all car-ownership categories (except Scenario 3, where there is a slight *increase* in VMT per capita for zero-car households between 2030 and 2050).

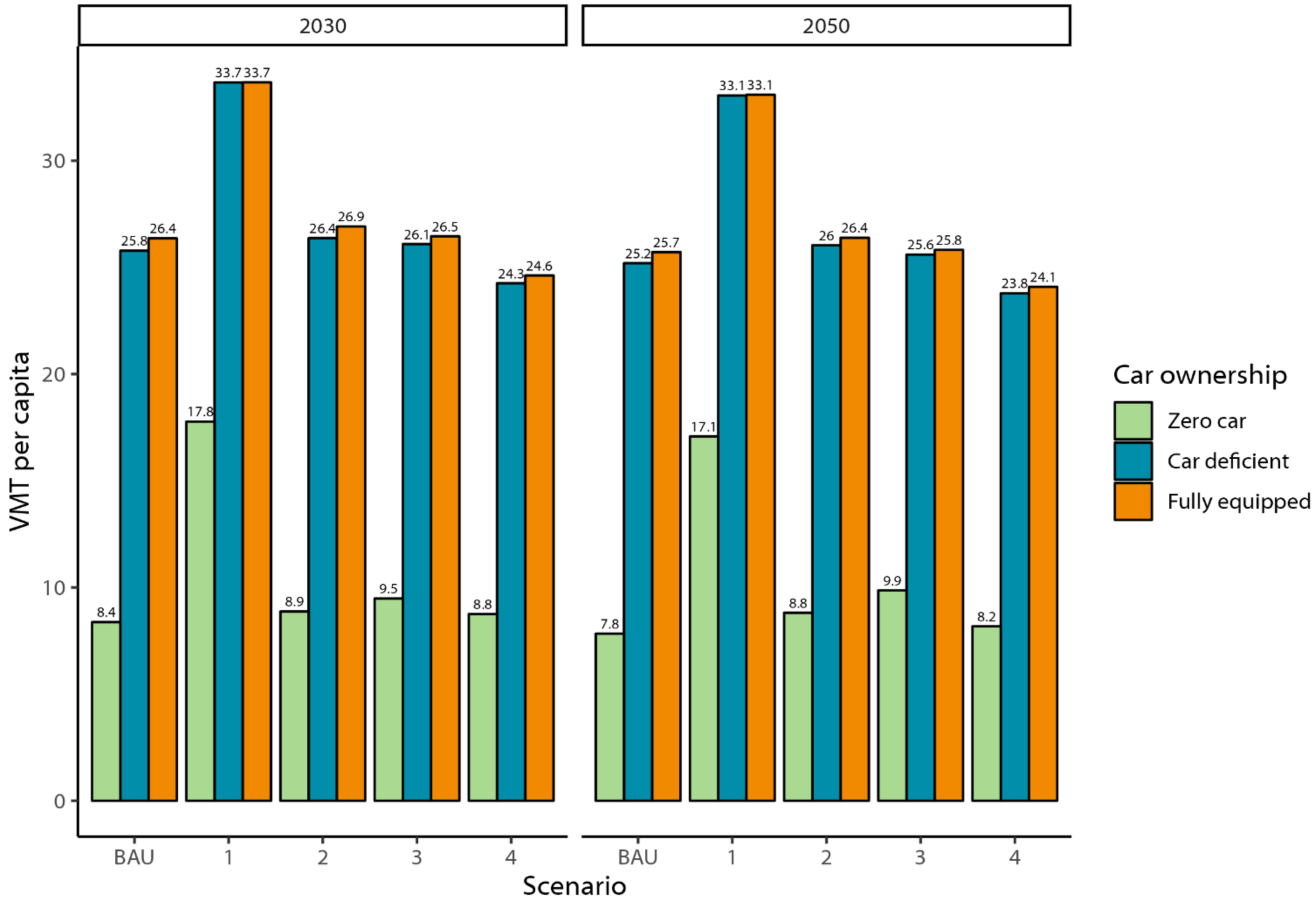

Figure 5.10: VMT per capita by car ownership status

5.2 Equity Analysis Results — Mode Choice

Trip making by mode is shown in Figure 5.11. In general, residents of equity priority areas are taking many fewer trips than residents of non-disadvantaged areas. As expected, most trips are forecast to be taken by automobile—both single-occupancy vehicle and carpool—with more car trips in Scenario 1, a similar number in Scenario 2, and fewer car trips in Scenarios 3 and 4 compared to the baseline scenario. Residents of equity priority areas are forecast to take fewer car trips than non-disadvantaged areas. The relative gap in car trips between equity priority areas and non-disadvantaged areas across all scenarios are similar, but equity priority areas have the smallest relative share of solo car trips in Scenario 4. Trips by carpooling are more similar between the two area categories.

For both groups, the number of non-motorized trips is highest in Scenario 4, while the number of ride-hailing trips is the highest in Scenario 3, with relative gaps between equity priority areas and non-disadvantaged areas staying close for both forecast years. The story for transit trips is more complex. Scenario 1, where COVID trends persist, has the smallest number of transit trips by far at less than one-quarter the total in the business-as-usual scenario. In the 2030 scenario, transit trips match the BAU scenario in Scenario 2 and exceed them in Scenarios 3 and 4 for both groups. But by 2050, transit trips for both groups fall below business as usual in Scenarios 2 and 3. Yet in Scenario 4, transit grows to the largest number of trips across groups and scenarios. In other words, long term trends for transit use show a negative trend except in the most optimistic scenario.

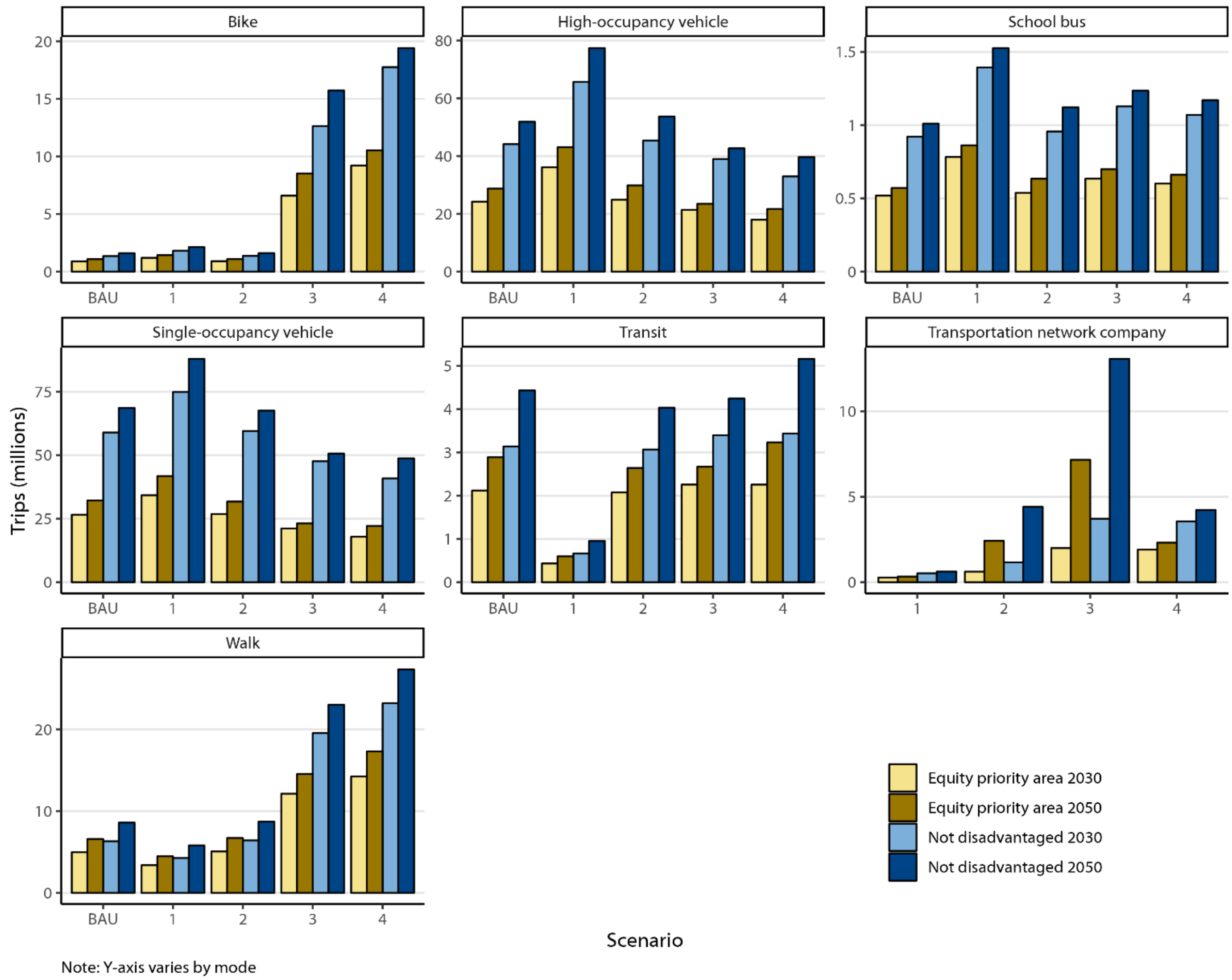

Figure 5.11: Trips by mode

Mode share by scenario and population category is illustrated in Figure 5.12 as an alternative visualization. In Scenario 1, car trips by single occupancy vehicle remain similar to the business-as-usual scenario, making up about half of all trips in non-disadvantaged communities and 45% of trips in equity priority areas in both model years. However, carpooling is substantially higher, making up 44% of trips in non-disadvantaged areas and 47% of trips in equity priority areas in both model years, compared to 38% and about 40% for business as usual, respectively. Mode shares for both driving alone and with two or more people remain about the same in 2030 and 2050. These carpooling trips appear to be making up for fewer transit trips, which make up less than 1% of trips in Scenario 1 in both equity priority areas and other communities. Walking trips decrease in Scenario 1 again by about half for both community types. Mode shares in Scenario 2 are similar to the business-as-usual scenario, with slightly fewer drive-alone trips in 2030 and a larger, but still small, difference in drive-alone trips in 2050. ride-hailing trips make up the difference in this scenario, making up 1% of trips for both groups in 2030 and 3% of trips in 2050. (Note that the business-as-usual scenario does not have ride-hailing trips because they are not included in the CSTDM.) Scenarios 3 and 4 show the biggest differences from business as usual. In Scenario 3, both equity priority areas and non-disadvantaged areas have a substantially smaller drive-alone and high-occupancy vehicle share, decreasing between 2030 and 2050. In this scenario, both groups bicycle and walk more. Walking is higher in equity priority areas than non-disadvantaged areas. Mode share for cycling is roughly the same across both groups and years (10%), though there is a small increase in cycling for equity priority areas in 2050 (11%). In Scenario 4, driving alone and carpooling have the smallest mode shares across all scenarios. Walking and cycling are the highest in this scenario as well, with 36% of trips in equity priority areas and about 33% of trips in non-disadvantaged areas done by non-motorized modes in both 2030 and 2050.

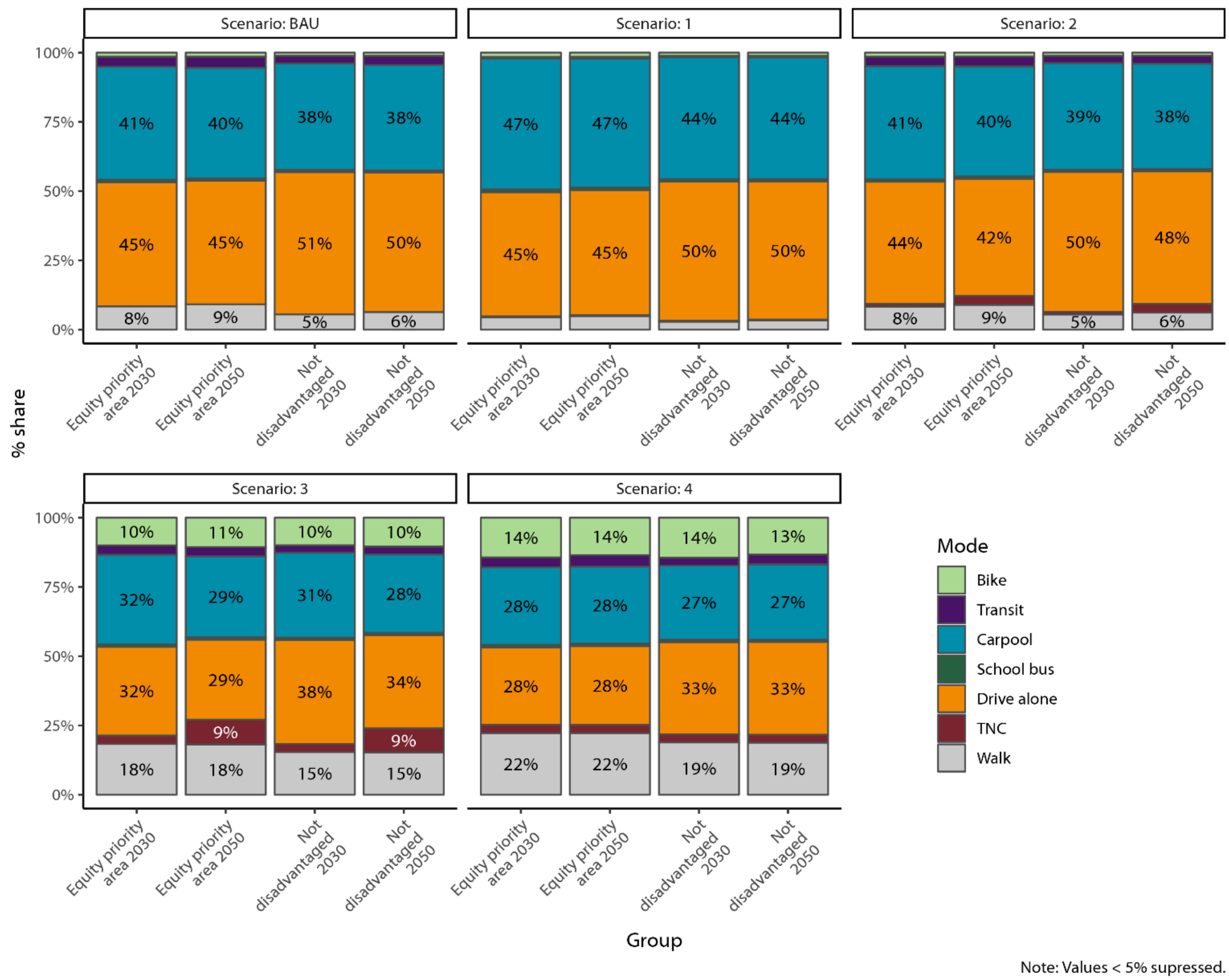

Figure 5.12: Mode share by equity priority area

Mode share by income category is shown in Figure 5.13. In all scenarios, people in lower income households drive less and walk, bike, and take transit more than higher income households. The scenario where the lowest income households drive the most is in Scenario 1; households earning less than $10,000 are forecast to drive for about 83% of their trips in 2030, with a small decrease to 82% in 2050. However, this is far less than households earning more than $100,000, who drive for 96% of their trips in Scenario 1 and have the highest driving mode share. Low-income households drive the least in Scenario 4. Scenarios 3 and 4 are the only scenarios in which less than half of trips for any income group are made by driving or where any other mode has a higher share of trips. In Scenario 3, the lowest income households make about a quarter of their trips by walking, an additional 10% by cycling, and 7% by transit. In scenario 4, nearly 30% of trips are done by walking, an additional 12% by cycling, and 9% by transit. Driving mode share among other income groups in Scenarios 3 and 4 is also smaller than in other scenarios. In Scenario 3, there are small decreases in both driving alone and carpooling between 2030 and 2050 but in Scenario 4, there are very small increases in driving among most income groups. Transit use is highest among low-income groups as well, though slightly lower than in the business-as-usual scenario. Walking share generally declines as incomes increase, while cycling shares remain about the same and change little between the two scenario years.

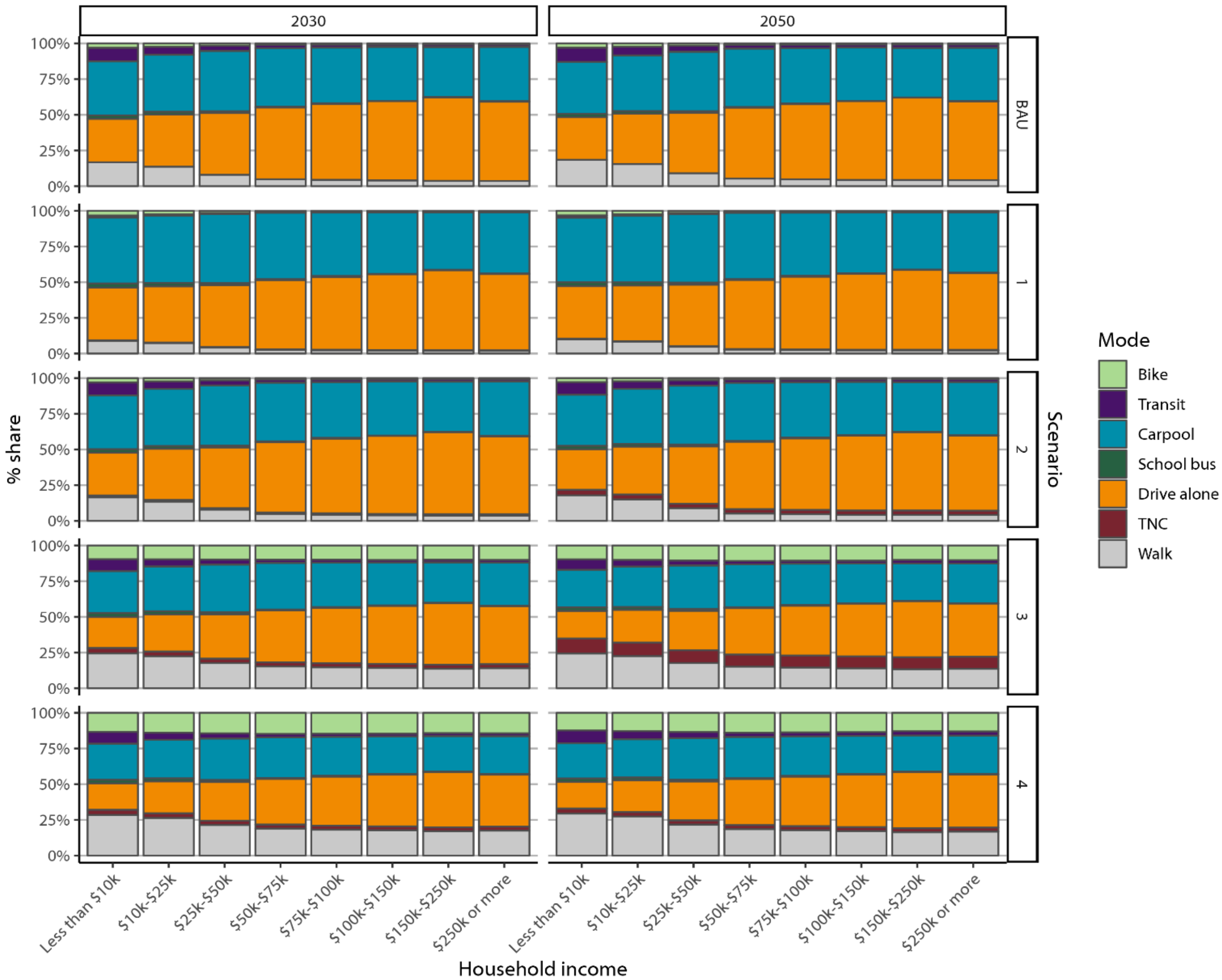

Figure 5.13: Mode share by income

Mode share by car ownership status is shown in Figure 5.14. Across all scenarios, zero-car households are the least likely to drive. Zero-car households drive the most in Scenario 1, where about 58% of trips are made via carpooling in both model years—more than car-deficient and car fully-equipped households. This is also substantially more than the business-as-usual scenario, where 41% carpool in 2030 and 39% carpool in 2050. Scenario 1 is also the only scenario where zero-car households drive alone at all; about 15% of trips are forecast to be made in single-occupancy vehicles. Scenario 2 is most like the business-as-usual scenario. Over a quarter of zero-car household trips are made by walking in 2050, compared to 8% of car-deficient households and 5% of fully-equipped households, slightly more than in 2030. Transit use is also high for zero-car households in this scenario, with just under one quarter of trips made by transit. In Scenario 3, zero-car households are the most multimodal by 2050, with roughly equal shares of households walking (29%) and carpooling (28%), a smaller share (19%) taking transit, and a significant amount of ride-hailing use (13%) and cycling (8%). Scenario 3 is the only scenario where there are substantial changes in mode share between 2030 and 2050, with a more-than-doubling in ride-hailing use for zero-car households, a tripling for car-deficient households, and nearly tripling for car fully-equipped households. Like for Scenario 3, zero-car households are predominantly multimodal by 2050 in Scenario 4, with the plurality of trips done on foot (34%), followed by carpooling (27%), transit (23%), and cycling (10%). Car-deficient and fully-equipped households also walk and cycle the most in Scenario 4 compared to the other scenarios; driving alone makes up the plurality—but not the majority—of trips.

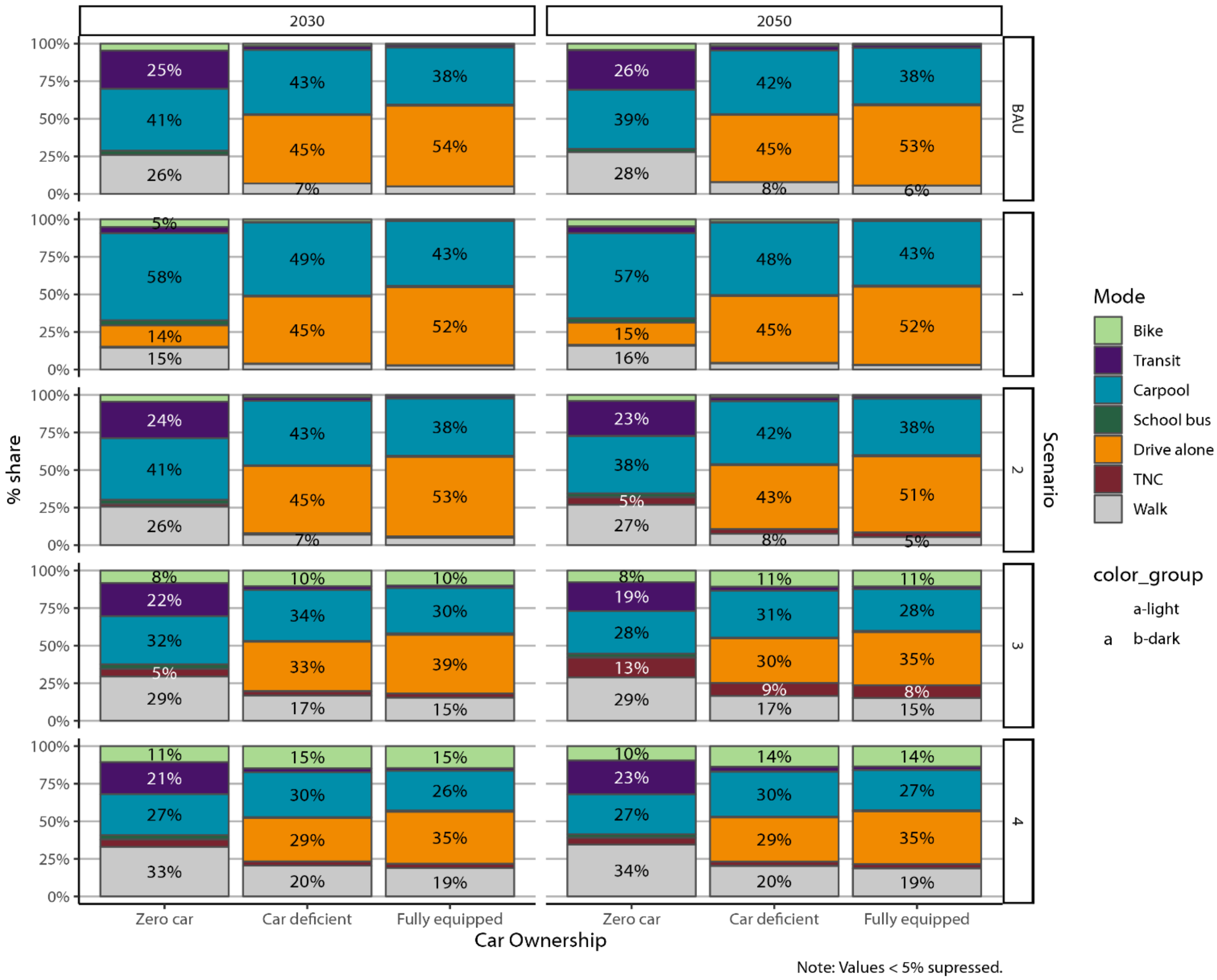

Figure 5.14: Mode share by car ownership

5.3 Summary of Equity Analysis

Results from the model outputs show that disadvantaged communities and population groups would continue to face travel burdens, defined here as a high level of auto use, under some model assumptions. While the model predicts that disadvantaged groups (by geography, income, and car ownership status) will drive less and for shorter cumulative distance than advantaged groups in all scenarios, VMT, per capita VMT, and mode share is highest for disadvantaged groups in the scenario where COVID-19 pandemic trends persist into the future. The relative difference in travel outcomes between disadvantaged and advantaged groups also tends to be the smallest in this scenario, while driving is most prevalent, suggesting a particularly high degree of burden compared to other scenarios given that driving is less sustainable and relatively more expensive for the lowest income households compared to other modes of travel. Of particular note, equity priority areas in the Central Valley appear to face the highest burdens given the higher relative amount of driving they do compared to non-disadvantaged communities and other regions in the state (except southern California).

On the other hand, the urbanism scenarios predict significantly more multimodal travel behavior and more judicious use of household vehicles for both advantaged and disadvantaged groups. VMT and driving mode share is the smallest in these scenarios, suggesting travel burdens may be eased by using alternative modes.

6 Recommendations

The state of California is undertaking many concurrent efforts to reduce solo-occupancy driving and encourage transit-oriented development through "smart growth" legislation like Senate Bill 375 *(42)* of 2008 and the subsequent Senate Bill 743 of 2013, which codified VMT as a metric for evaluating the environmental impacts of public and private projects *(43)*. These policies require MPOs and other planning agencies to leverage long-term planning efforts towards the goal of reducing VMT. Several new policies will take effect in 2023 that support the state's efforts to reduce car travel. These include a new statute that will remove parking minimums for development near transit (Assembly Bill 2097) *(44)*, as well as several streamlining laws aiming to make it easier to build bike lanes and pedestrian projects (Senate Bill 922) and set timelines for local agencies to issue entitlement permits (Assembly Bill 2234).

The pandemic was a shock to the travel and transportation markets, one that changed travel patterns overnight with potentially lasting effects for many California residents. Public agencies responded quickly to the changed transportation situation. Many cities, for example, implemented neighborhood slow streets during the pandemic. The state took notice, and legislators passed AB 773, which allows local authorities to advance slow streets programs that may encourage active modes in place of driving. Other COVID-related transportation changes may, even in the waning days of the pandemic, offer further opportunities for the state to take actions that would nudge California residents towards more sustainable travel patterns. The state can seize these opportunities by leveraging available policy tools, identifying new programmatic solutions, and applying incentives and punitive levers. These solutions, as cities discovered from with the implementation of their slow streets programs *(45),* must be rooted in equitable processes that learn from and address community needs first.

The 2022 CARB Scoping Plan reiterates the state's commitment to VMT reduction in stating, "Managing total demand for transportation energy by reducing the miles people need to drive on a daily basis is also critical as the state aims for a sustainable transportation sector in a carbon neutral economy" *(46).* The Scoping Plan aims to reduce VMT per capita to **more than 25% below 2019 levels by 2030, and 30 percent below 2019 levels by 2045.** However, the analysis in this report demonstrates that the pandemic has made the achievement of the VMT goals more challenging. To achieve the goals set out in the Scoping Plan, the state must pursue a more aggressive set of policies derived from more expansive thinking about the possibilities. In this section, we aim to identify policy gaps necessary to achieve VMT reductions that go beyond even the *Urbanism Bounces Forward Scenario.*

Addressing the barriers (e.g., fiscal, institutional, or political) that the state would face in implementing the policy recommendations listed here is beyond the scope of this study. In the four hypothetical scenarios analyzed here, some outcomes could conceivably occur in the absence of changes in public policy, while other outcomes would require concerted government intervention. While more research is necessary to quantitatively estimate the potential impacts of the proposed policies, understand the impacts across population groups, and map a comprehensive strategy that achieves the Scoping Plan goals, the discussion presented here can be used as the conceptual basis for a more robust analysis to compare the merits of different policy alternatives.

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6.1 Telework Policy

The complete shift to remote working for certain segments of the workforce coupled with lockdowns for non-work activities led to a dramatic decline in VMT in the early days of the pandemic. But the contribution of telecommuting post-pandemic to the achievement of the state's VMT reduction goals is uncertain. Although evidence suggests that telecommuting will continue at notably higher rates than before the pandemic, this will be true for only certain segments of the workforce; it is not an option for lower-wage workers in retail, service, agriculture, and other sectors. In addition, work-based trips do not generate the majority of vehicle miles traveled in the state, and research shows that telecommuters travel more for non-work purposes than non-telecommuters do. Evidence also suggests that some telecommuters relocate to lower density areas where VMT is likely to be higher for non-work purposes and where even commute VMT might increase for part-time telecommuters (if the increase in the distance to work more than offsets the decrease in the number of work trips). Policies to encourage telework must take these issues into account in order to maximize its potential to reduce VMT in an equitable way. They will be most effective if implemented in conjunction with complementary policies that enable and encourage travel by modes other than driving.

Should the state conclude that telecommuting would be a net benefit for the state, a starting point would simply be to set a statewide benchmark for increased telecommuting without an increase in VMT, and then establish performance standards for each. These standards might be applied to employers in the form of a target VMT per employee or total vehicle trips per employee, as in employer-based trip reduction programs, once common in California. Vehicle trips may or may not be an accurate proxy for VMT, so a well-crafted policy would work to collect better data on commute patterns to inform ongoing assessments of VMT and GHG reduction strategies with respect to telework.

Telework policy mechanisms might include:

1. **Establishing a statewide benchmark for teleworking** (e.g., 45% by 2035): An amendment to state statutes to identify a statewide goal for telecommuting to accompany other climate goals would empower state regulators to establish regulations that help achieve the benchmarks. The regulations could include strategies like those listed below. This approach would need to be coupled with other strategies for reducing VMT and for increasing the use of alternative modes in order to ensure a net reduction in VMT.
2. **Setting employer-targeted policies:** Once a state goal for telecommuting is established then state policy must be aligned with this goal. Currently the state requires that large employers provide commute benefits, with local and state policies augmenting these requirements *(47)*. These benefits include telework as an option, in addition to other offerings, such as tax-free transit fares. This statute could be amended to include a direct tax rebate or credits for employers if they could demonstrate that they have, for example, 50% or more telework employees, or more stringently, more than the average share of remote workers for their sector.

   Driver-targeted policies: To ensure that telework policies encourage a net reduction in VMT over time, the state can continue to expand piloting and eventually implement state mileage-based road charges. This strategy would help to discourage non-work travel for remote workers but could also generate revenues that the state could use to improve commute alternatives. Equity impacts of mileage-based road charges can be addressed with subsidies to lower-wage workers with long distance commutes, for example, through the implementation of "mobility wallets."

Complex Equity and High-Road Jobs Considerations for Telework Policy

Telework policies raise fairness questions involving difficult tradeoffs. First, worker disparities might be exacerbated by telework policies. Much lower-wage work, such as retail, service work, agriculture, and logistics, cannot be done by telework. If, for example, transit agencies respond to the decreased demand for transit by cutting routes, service hours, or frequency, lower-income workers who have fewer alternatives may be disproportionately burdened by the reduction in transit service. More research is needed to support an equity evaluation of a potentially widening gap between white collar and blue-collar work that can yield savings for home-based work, and additional burdens for in-person work (e.g., commuting costs, risk burdens).

A second concern is the complex community-wide effects of telework. Under the right conditions, telework can reduce VMT but it might have a chilling effect, directly and indirectly, on investments for in-person essential businesses and other market sectors. For example, the loss of office workers in downtown areas has meant a loss of customers for businesses and services in the area. Retail businesses already struggle to balance online and in-person brand presence, and a telework policy that indirectly pushes retailers online might have ripple effects beyond even the downtown area. Small businesses, often minority-owned, have been especially impacted. Programs to support such businesses would be important for ensuring that these indirect equity effects are minimized.

Given the complexities of these effects, it is critical that telework policies strike a balance between these tradeoffs that does not widen economic and social disparities. To promote telework in a way that does not worsen inequities and inefficiencies in the labor market, policy makers might follow a *high-road jobs framework,* first recognized by Governor Newsom in an Executive Order released in 2020 *(48)* and codified in several bills since then, including AB 794 *(49)*. This framework is a suite of public policies that support the creation of high-quality jobs and protect workers from labor abuses. High-road jobs can be created through a number of pathways, including market-based incentive programs and/or industry training partnerships to ensure that job access is available for historically disadvantaged populations and for workers in at-risk jobs or sectors. Applying a high-roads job framework to telework policy would help the state identify strategies to ensure that both home-based and in-person jobs in the future follow the high-road, leading to a more equitable workforce.

Land Use Impacts of Teleworking

Whether pandemic-induced increases in teleworking will lead to an increase in housing demand in lower density areas will not be clear for several years. If teleworking does lead to a shift in where workers choose to live, these relocations could offset reductions in VMT. At the same time, the emptying of office buildings in central business districts as employers have shifted to remote work represents an opportunity to increase housing in urban cores, helping to offset the decentralizing effect of teleworking. The near-term role for California's policymakers is to continue the ongoing effort to promote higher-density infill development as a way to reduce VMT, energy use, and greenhouse gas emissions throughout the state and to adopt policies that take advantage of opportunities created by shifting work patterns.

Specific land use policy mechanisms include:

- **Strengthen smart growth requirements for regional planning.** California MPOs develop detailed plans for reducing VMT in their Sustainable Communities Strategies but more support from local authorities and state agencies would help regions to move these plans forward *(50)*. Implementation of SCSs is hampered by the fact that land use authority belongs to local governments and by the limited control that MPOs have over state and federal funding allocations as well as local-option sales taxes.
- **Strengthen state laws to streamline the approval process for projects that increase housing density, particularly in transit corridors.** Recent laws mentioned above should streamline the approval process thereby encouraging higher-density development in transit-rich areas, but additional enabling legislation and further incentives may be needed.
- **Strengthen home electricity requirements for greenfield development** to prepare for an electrified vehicle fleet. New development is the lowest hanging fruit for vehicle charging installation.

6.2 E-shopping

The pandemic led to a dramatic increase in e-shopping, as discussed in Section 2 (and discussed further in the Appendix) and while the rate of increase has now returned to pre-pandemic levels, e-shopping is likely to continue to grow. To ensure that this trend does not lead to a net increase in greenhouse gas emissions, policy must address two challenges: how to make the distribution (e.g., operations, facilities, vehicles, services) of the goods sustainable, and how to foster a conscious consumer behavior that takes into account the impacts of shopping choices and purchases.

Although e-commerce, under specific conditions, may bring about VMT savings, research shows that fast deliveries, if not supported by the appropriate distribution infrastructure and because of the lack of neighborhood-based delivery consolidation, are the least sustainable *(51)*. This effect may be most pronounced in low-density areas where customers are more widely dispersed.

One particular category of e-shopping that experienced growth during the pandemic was e-groceries, and although time spent at grocery stores has almost returned to pre-pandemic levels, e-grocery shopping is still up *(52)*. E-grocery delivery services have proliferated, as have options for at-store pick-up shopping, the impacts of which, including potential reductions in travel, are not yet well understood.

A suite of last mile delivery options can help mitigate the potential impact of increased e-commerce shopping, *(53)* including cargo consolidation and the use of alternate delivery and pick-up locations, the use of cleaner delivery vehicles (e.g., electric trucks or delivery vans), the use of alternate delivery modes such as cargo bikes or new technologies including autonomous delivery robots, and more importantly, good land use planning that considers freight movements in general and last mile distribution in particular.

Potential e-shopping policy mechanisms include:

- **Require transparency in the footprint of delivery choices.** To address some of the issues associated with e-commerce it will be necessary to increase transparency of the potential environmental impacts from the delivery choices offered by retailers. Delivery footprint is not homogeneous across retailers and companies, and it will be important to understand how efficient these deliveries are. Transparency can also be a tool to incentivize sustainable consumption as it will help inform customers about the impact of their purchase decisions and their delivery choices (e.g., fast shipping). The information, to be effective, should be provided in a form that is easily understood by the public for both the total overall impact of their choice as well as the relative impact across choices.
- **Set state requirements for freight planning at the local level**. From the logistical point of view, the topology of the distribution network, the location of logistics facilities, and the density of consumers are key drivers for efficiency. In the same way that they consider the location of transit terminals, local plans must consider the needs of the distribution system in order to reduce its externalities. Planning for the distribution system should involve a holistic approach so that locations do not cause disproportionate burden to any community. Land use plans must consider rapid changes in the freight system because of the growth of e-commerce. Local, regional, and state plans must be consistent in their treatment of freight (e.g., as contributor to positive and negative externalities), and should guarantee multi-jurisdictional coordination.
- **Establish state guidelines that promote the use of urban pick-up and delivery hubs, and alternative delivery modes in local planning**. Micro-hubs or other types of urban consolidation facilities can help to reduce delivery miles and enable the use of alternative delivery modes such as cargo bikes, which have a lower delivery footprint (*53*).
- **Require the use of zero emission vehicles for last mile deliveries, especially for food, groceries, and parcels**. Although state regulations are pushing faster adoption of cleaner vehicles in freight, these regulations do not necessarily apply to all types and sizes of delivery vehicles. Cleaner technologies

already exist that satisfy the needs of these delivery segments, and these technologies can be pushed in a more aggressive way *(54)*.

- **Establish efficiency metrics for managing public assets such as curb space**. E-commerce deliveries fight for curbside access with other users such as ride hailing, public transit, taxis, pedestrians, bicyclists, and others *(55)*. An efficient management of the curb will benefit the various users, improve their efficiency, and lower their carbon footprint.

6.3 Transit

The pandemic caused a severe decline in transit ridership and, along with it, service. Although an infusion of federal funding helped to keep transit running throughout the pandemic, and many of the services cut have now been restored, the end of the emergency funding coupled with the sustained decline in ridership and thus fare revenues has brought many transit agencies to the edge of a financial cliff. Providing sufficient funding for transit is essential to its long-term viability as an alternative to driving that helps to meet both equity and sustainability goals. Funding would help to convert the vicious cycle of ridership cuts followed by service cuts followed by ridership cuts to a virtuous cycle of service improvements followed by ridership increases followed by further service improvements.

Beyond the issue of funding, transit agencies, with help from the state, can take several steps to foster a rebound in ridership and growth beyond 2020 levels. The pandemic also brought on a severe driver shortage, and efforts to streamline hiring will be important. Increased teleworking has also depressed transit ridership and will remain an on-going challenge for transit agencies. The pandemic accelerated innovations surrounding touchless entry and payment for reasons of health safety and may have boosted broader efforts to streamline fare payment that could help to grow ridership.

Potential policy mechanisms for transit include *(56)*:

- **Provide operational funding support.** With operational funding support beyond the CARES Act, transit agencies can improve fixed route transit frequency and coverage. This is likely to require reforms to current funding mechanisms, such as the Transportation Development Act (*57*).
- **Enable greater flexibility in state funding streams to enable increased spending on operations.** This flexibility should include funding for public-private partnerships with shared mobility providers (e.g., microtransit, and shared TNC operators), where such services can offer affordable solutions for improving access.
- **Address driver shortages.** The state can provide incentives to transit agencies for streamlining new hiring and take steps to shorten the timeline for commercial driver license approvals. The state can invest in workforce training to increase the pool of potential drivers (and the pool of potential workers with the skill sets needed for sustainable transportation modes more generally).
- **Support efforts by transit agencies to streamline fare payment systems**. Streamlined fare payment systems offer many benefits, including seamless transfers between transit systems, targeted discounting of fares, and equitable payment options. Research on free-fare programs could help in identifying where such programs would yield net benefits.

6.4 Transportation Network Companies

The regulation of TNCs is under the purview of the Public Utility Commission (CPUC). The oldest rulemaking (R1212011) on TNCs established the original requirements for TNC operation, data sharing, etc. More recently the CPUC has opened rulemakings to address TNC wheelchair accessibility and the Clean Miles Standard (CMS). The CMS will require that between 90-100% of each TNC fleet is electric by 2030, provides incentives for increasing persons per vehicle, and makes credits available to the TNCs for increasing connectivity to active modes and transit. While these strategies do not guarantee that ride-hailing will reduce VMT on a per trip basis, given the associated deadheading miles for a ride-hailing trip, the CMS will help to reduce emissions for high-mileage vehicles. Additional policy will be necessary to also address VMT. Policies to support the drivers, many of whom are low-income, are also needed.

Potential TNC policy mechanisms include:

- **Invest in charging access to meet the fast charging needs of TNC fleets.** Targeting TNC charging needs through implementation of the Clean Miles Standard program will be an essential strategy to target high-mileage vehicles for emission reductions. Policies should ensure adequate access to charging in low-income and disadvantaged communities.
- **Strengthen incentives for riders to take transit as a portion of their total ride-hailing trips (after 2030 goals achieved).** The Clean Miles Standard allows TNCs to meet the standard with as much as 10% of their miles associated with transfers to transit and other non-car modes. To ensure this is possible, more work is necessary to expand ticketing and payment integration that ensures seamless travel between these modes and ensures that the transit service connections can be audited. The California Integrated Travel Project (Cal-ITP), for example, which addresses critical barriers such as income verification and eligibility, could be expanded statewide.

Encourage local governments to innovate in making curb spaces dedicated to pick up and drop off. Innovating curb access is a critical VMT reduction strategy, and cities must continue to align curb access prioritization with their climate and VMT priorities. Policies must minimize conflicts with bike lane and pedestrian facilities as well as bus stop access. Ensuring that pick-up and drop offs can be seamless will reduce pinch points that result in congestion, and reduce desirability of shared mobility. Curb access reform may be able to target reductions in deadheading, which offer TNCs staging solutions, that discourage drivers from circling downtown areas.

6.5 Active Modes

The increase in walking and bicycling that occurred during the pandemic, though mostly for recreational purposes, represents an opportunity to increase the use of these modes for transportation purposes. During the pandemic, many California cities expanded safe spaces for active modes by implementing slow streets programs in residential and commercial areas. Many cities took advantage of lighter vehicle traffic to install new bicycle lanes, helped by an influx of emergency funding. Bicycle purchases, especially purchases of electric-assist bicycles, skyrocketed during the pandemic, sometimes encouraged by financial incentives. Several state programs provided funding for efforts to promote active modes well before the pandemic, including the California Department of Transportation (Caltrans) Active Transportation Program and CARB's Sustainable Transportation Equity Project. More action is needed to fully leverage the pandemic-fueled momentum in active modes, especially biking.

Strategies for promoting active modes include:

- **Increase investment in slow streets.** Policies like AB 773 make implementing slow streets initiatives easier for cities by normalizing the reclamation of street space for active modes. Political as well as financial barriers to expanding car-free/car-light residential and commercial spaces remain.
- **Increase investments in infrastructure for active modes.** While recent policies make bike lanes easier to build in transit-rich areas, many barriers to expanding bike-infrastructure throughout California's diverse communities remain (e.g., insufficient funding), and more aggressive efforts are necessary to make biking safe, convenient, and accessible to populations across the state.
- **Implement and promote e-bike purchase incentives.** CARB's Electric Bicycle Incentives Project is poised to launch in 2023. Efforts are needed to ensure that Californians are aware of these and other incentives

available. If the program is successful, increased funding for the program would expand its reach to more consumers statewide and reinforce the upward trend in bicycling as a mode of transportation.

6.6 Policy Conclusions

The effects of the pandemic will likely set the state behind on their progress toward achieving its VMT goals. The analysis presented here demonstrates that achieving those goals will take aggressive and multi-faceted action on the part of the state. Action on the part of local and regional agencies is also essential, while federal support primarily in the form of funding for infrastructure has an important role to play as well. Potential policy mechanisms for achieving the ambitious VMT reduction goals set by the state include driver-targeted policies, employer-targeted policies, land-use changes, transit investments, further regulation of TNCs, and investments in bike and pedestrian infrastructure. The policies outlined here are a starting point for discussion; more research is needed to identify the best alternatives and evaluate these options for cost effectiveness, equity, and feasibility.

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8 Appendix: E-Shopping Discussion

The evolution of information and communication technologies has transformed many facets of modern life. For example, with about 90.8% internet penetration in the U.S. *(58)*. e-commerce has grown further into the retail sector, and generated structural changes to supply chains, and the way goods move through them, until reaching the consumers (mostly at their homes).

Before the pandemic, about 80% of all shopping activities were influenced by e-commerce either in the search process or for final purchase *(60, 61).* New devices and interfaces, as well as delivery services, facilitate the interactions and improve the (seamless omni-channel) experience for shopping online *(61).* At the macro level, before the pandemic, e-retail sales had been growing rapidly (at double digit growth rates year over year) for over a decade. In the US, the e-retail sale share of total retail sales had grown from 5% at the end of 2013 to about 11% at the end of 2019 *(60).* These rapid changes led researchers and practitioners to consider the impacts of e-commerce on travel demand and whether substitution, complementarity, modification, or inducement dominates; the associated logistics processes also became a subject of study. Today, the research community has still not reached a consensus about the net effect, though most of the literature indicates that complementarity is prevalent *(63-68).* Evaluating the impacts of e-commerce is complex because shopping-related travel is also affected by a person's schedule, lifestyle, location, and preferences towards different shopping modes and services (e.g., expedited deliveries).

Adding to this complexity, the COVID-19 pandemic and the mitigation measures adopted to address it impacted other facets of daily lives that may have significantly affected those factors (e.g., location, preferences, lifestyles). When the pandemic hit in 2020, statewide and city lockdowns prevented people from leaving their homes to stay safe and minimize the spread of the Coronavirus. Compared to the 22% of the U.S. population that purchased their groceries online in 2018, in March of 2020, 42% did so at least once a week, showing that the pandemic contributed to a near doubling of online grocery sales *(69).* In terms of overall retail sales, e-retail shares peaked at more than 16% in the third quarter of 2020. This was a significant change as it took e-retail sales only about 2 quarters to achieve the same gain in share as over the last almost 10 years. Moreover, the U.S Census Bureau reported a 39% increase in the first quarter of e-commerce sales in 2021 compared to retail e-commerce sales pre-COVID *(60).*

During this period, there was uncertainty and anticipation about the future growth of e-commerce, with studies and reports suggesting that, for example, e-commerce sales will account for 18.1% of retail sales worldwide and by 2023 for 22% of retail sales worldwide *(70)*, more than doubling from the 10% worldwide in 2019 *(71)*. Additionally, retail e-commerce sales were expected to reach $6.5 trillion by 2023, with projected grocery sales for 2025 (in billions) at $1,164 trillion and the projected grocery e-commerce sales share post-COVID at 13.5%.

Other uncertainties were associated with the changes in travel patterns. In the initial months of the pandemic, VMT declined to 2008 levels in the US, and some areas in coastal California experienced travel reductions of more than 75% *(72).* Some research investigated correlations between these reductions, the implemented measures, and the demographics of the populations. For example, reductions were most prevalent in areas with larger employment in higher education industries, information, finance and insurance, real estate rental and leasing, and professional, scientific, and technical services *(73).* And with the temporary closure of retail stores, and the surge of e-commerce, shopping related VMT also decreased. Figure 8.1 shows a percent change in time spent at grocery stores and retail stores (compared to January 2020) in the US. The aggregate behavior shows a reduction of almost 50% for retail and about 20-25% for groceries during March and April, though almost reverting to pre-COVID levels by sometime in May for groceries, and within the -10% in June and July. At the same time, e-commerce transactions showed a peak around a 60% increase in May and then declining.

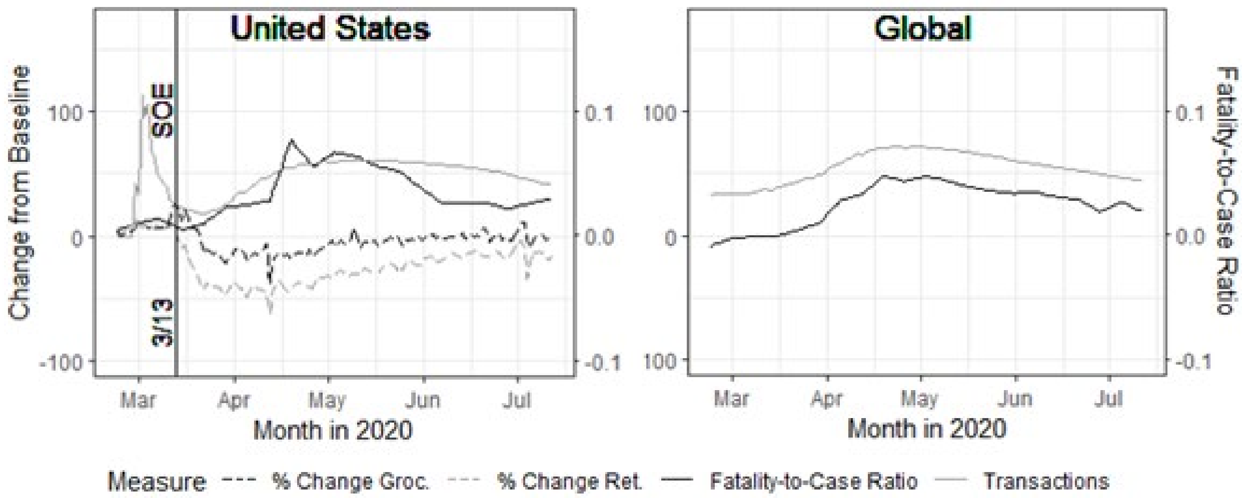

Figure 8.1: Change in time spent in retail and grocery locations, and trends in e-commerce transactions and fatality-to-case ratios. Adapted from *(74)*

Two years later, travel (by most modes) had come back to pre-pandemic levels, and while e-retail sales continued to grow, this growth reverted to the pre-pandemic levels, with some of the latest information showing a slight deceleration of growth (see Figure 8.2).

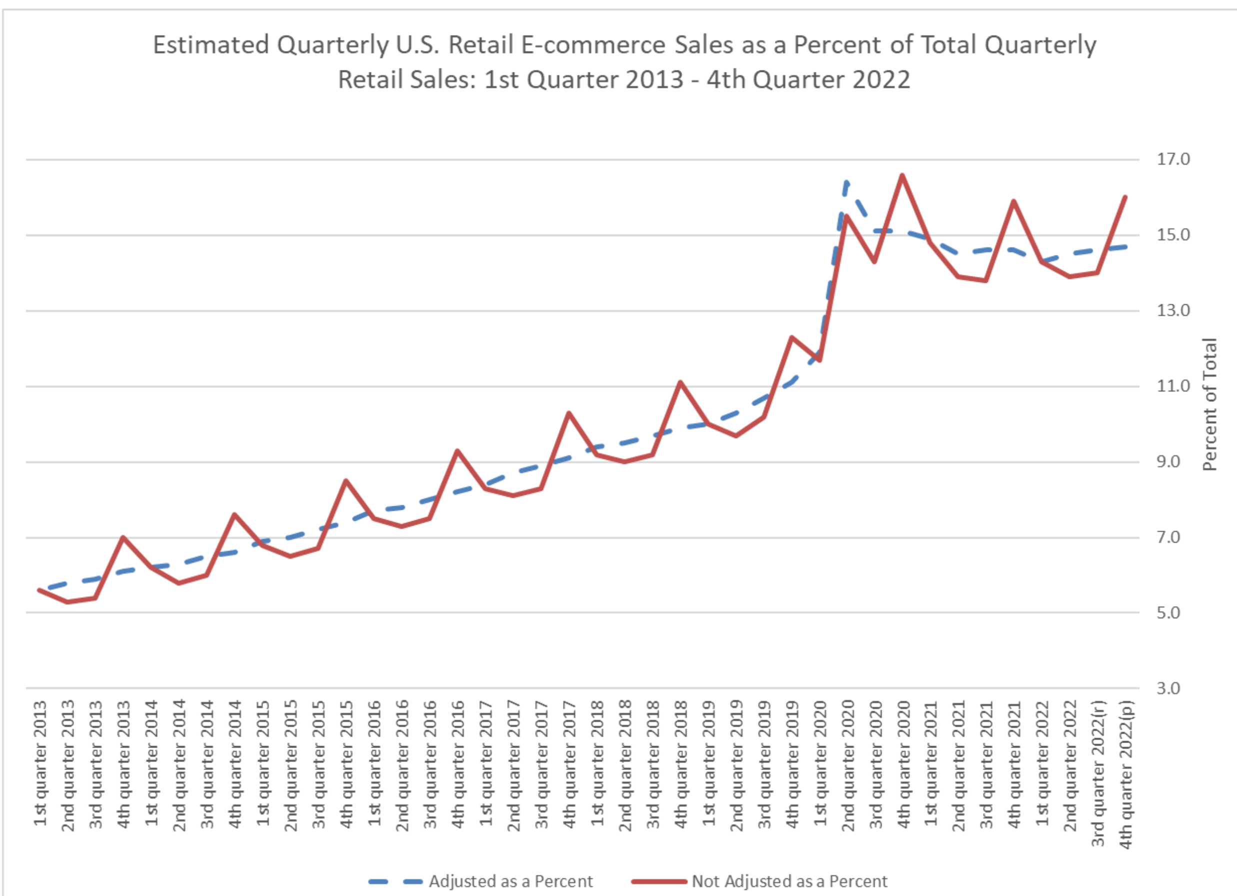

Figure 8.2: US retail e-commerce sales as a percent of total quarterly retail sales *(69)*

The early projections for future shopping associated travel seem to have not materialized and it remains unclear whether long-term post-Covid shopping patterns will reduce or increase VMT. For example, a 2020 survey by McKinsey & Co. found that nearly 70% of consumers intend to continue to shop online post-COVID *(75).* Another study found that about a fifth of Americans will visit shopping centers and indoor malls less frequently than they did before the pandemic *(76)*. Contrasting those results, a 2021 survey found that 70% of respondents are planning to visit stores as much or more than pre-pandemic after the pandemic because they are excited to get back in stores *(77).*

Overall, delivery services are also projected to increase compared to pre-COVID, although projected effects are uncertain. In 2020, CommerceHub surveyed consumers of various age groups across the U.S. and found that 69% of respondents would be more willing to subscribe to a delivery service following the pandemic *(78).* This was evident in the growth of e-retailers' sales and the associated delivery travel. Residential deliveries are significantly higher today than ever before. But the explosive growth experienced in 2020 and 2021 was not sustainable.

To summarize, although many factors resulting from the pandemic have affected e-commerce growth, the associated shopping travel, and the intensity of the last mile delivery market, VMT impacts are likely to revert to the pre-pandemic trends (with some potential slight reduction of shopping travel). These trends, if left unmanaged, will most likely translate into increased traffic congestion *(79)*. In the long-term, potential impacts on the overall retail market and the availability of new delivery services could mean that shopping-related travel eventually declines, and empirical analyses suggest that this reduction could be as much as 15%. Whether reductions will be offset by increases commercial traffic remains to be seen.