Title

Advancing Road User Charge (RUC) Models in California: Understanding Social Equity and Travel Behavior Impacts

Authors
Lazarus, Jessica
Broader, Jacquelyn
Cohen, Adam
et al.

Publication Date
2022-12-01

DOI
10.7922/G2FB518P

ADVANCING ROAD USER CHARGE (RUC) MODELS IN CALIFORNIA: UNDERSTANDING SOCIAL EQUITY AND TRAVEL BEHAVIOR IMPACTS

Jessica Lazarus

Jacquelyn Broader

Adam Cohen

Alexandre Bayen, Ph.D

Susan Shaheen, Ph.D

December 2022

doi:10.7922/G2FB518P

Contents

Acknowledgements

The authors would like to thank all of the experts interviewed for this study for their generous and thoughtful participation in this research. In addition, the authors thank Lauren Prehoda and Carolyn Plummer for their leadership and engagement throughout the study, Scott Williams and Tyler Monson for their invaluable support, and Suk Medeiros, Tory Rufus, and DMV staff that helped design and administer the paper survey distribution at DMV offices across California. The authors are additionally grateful to the members of the Road Charge Technical Advisory Committee for their invaluable feedback, particularly Richard Marcantonio and the late Professor Marty Wachs for their feedback on the study design. Finally, the authors thank Matthew Lin for his support in conducting the expert interviews as well as Juanwu Lu and Abhishrut Sinha for their contributions to the development of the data processing pipeline for this study.

Introduction

The State of California is currently moving forward with a road usage charge (RUC) demonstration program, creating promising research opportunities to examine the potential social equity implications of a shift from a gas tax to a RUC system in California. RUC . To this aim, this study investigates the relative burden of gas taxes and mileage-based RUC across various socio-demographic and geographic dimensions by examining key trends in road use, vehicle ownership, fuel consumption, use of RUC-related technologies, and attitudes/opinions related to RUC adoption. Expert interviews were conducted to increase understanding of the potential opportunities and challenges of a RUC system, particularly regarding social equity. The interviews included transportation industry professionals as well as representatives from community-based and other stakeholder organizations to understand best practices for RUC design and implementation, identify stakeholders' concerns and potential ways to address them, and inform the design and analysis of a survey of Californians.

A general population survey (N = 3,489; final N = 3,061) was distributed to a socio-demographically representative sample of residents in four regions of California including: Central California, Northern California, the San Francisco Bay Area, and Southern California. In addition to socio-demographic information, the survey captured respondents' revealed travel behavior, including the typical frequency, distance traveled, and travel modes used for various trip purposes as well as frequency of use of grocery, restaurant, and package delivery services. Respondents were also asked about their access to various financial services, the periodicity of their auto insurance payments, their awareness of transportation funding sources and their own transportation costs, and their level of comfort sharing location data with private and government entities. In addition to statistical analysis of key metrics of road use estimated from the survey data, a discrete choice model was estimated to further investigate discrepancies in Californians' sensitivity to RUC. Analysis of the model results develop a richer understanding of the potential impacts of RUCs on particular groups of Californians with the aim of understanding whether a RUC is likely to elicit a change in travel behavior.

This report contains six sections. A summary of the pertinent academic and grey literature is presented as background, followed by the approach for and key findings from expert interviews. Next, an overview of the methodological approach for the general population survey design and analysis, and discrete choice analysis (DCA) are presented, followed by the corresponding results and key takeaways. Finally, conclusions and recommendations are provided in the final section.

Literature Review

The literature suggests that RUC system accessibility may be impacted by a variety of factors including geographic and socio-demographic differences, such as:

- **Gender and Household:** Studies have revealed that people of different genders and household sizes have varying travel behaviors and incomes.
- **Rural Residents:** Residents in rural areas (i.e., places with populations between 2,500 to 50,000 people) may be concerned that their need to drive longer distances to reach goods and services may result in disproportionate impacts from a RUC system.
- **Un- and Under-banked Households:** Access to financial institutions for services, such as debit and credit cards, may be critical components to RUC system participation. Ensuring that all households, including those who do not have access to banking services, are included is an important consideration in the development of an equitable RUC system.
- **Low-income Households:** Similar to un- and under-banked households, ensuring that low-income households have access to financial resources and services is an important element in a RUC system.

The following subsections provide further information on these equity considerations that may need to be addressed in the development and deployment of RUC systems.

Gender and Household Differences

Research has shown that travel patterns may vary by characteristics, such as gender and age. A study by the National Academies of Sciences, Engineering, and Medicine (2006) found that travel behavior, such as the number of trips taken per day, may vary by age and gender. Men typically take less trips per day, which could be due to women typically completing more household sustaining trips (e.g., completing errands) (National Academies of Sciences, Engineering, and Medicine, 2006; McGuckin & Liss, 2005). In addition, according to statistics from the U.S. Bureau of Labor Statistics (2018), men's median salaries are approximately 20 percent more than women's salaries in similar roles. While women may spend a larger percentage of their income on travel, more investigation is needed to determine if a shift from the gas tax to RUC would have a disparate impact across genders or household structures.

Un- and Under-Banked Households

While travel patterns may vary by gender, access to transportation services may vary by financial institution access. A 2017 study by the Federal Deposit Insurance Corporation found that 6.5 percent of, or 8.4 million, households in the US were un-banked (i.e., they are not served by or do not have access to any financial institution or associated services) (Federal Deposit Insurance Corporation, 2017). The study also found that 18.7 percent of, or 24.2 million, US households were under-banked, meaning they have access to a checking or savings account but no other financial services (e.g., mortgages) (Federal Deposit Insurance Corporation, 2017). Un- or under-banked households may be dependent on alternative financing sources including cash, postal money orders, and payday loans (Kirk & Levinson, 2016).

Transportation services, such as a RUC system, that require a credit or debit card could exclude part of the population from accessing and using them. For example, the Oregon RUC program requires all participants to pay through a bank account, credit card, or debit card, which excludes un-banked households. In the initial California RUC research, payments were simulated so the impacts to participants from un- and under-banked households were not closely studied. In addition, these households may face challenges purchasing on board units (OBUs) or new vehicles equipped with usable OBUs (Kirk & Levinson, 2016). However, providing this integral part of a RUC system may increase administrative costs. In Minnesota's RUC program, the state Department of Transportation allocated resources to develop a specialized app for the program, rather than use funds to purchase and distribute OBUs or require participants to purchase OBUs themselves. However, this excluded populations of people who did not own, or could not afford, a smartphone. As RUC systems continue to develop, identifying ways to integrate un- and under-banked households is critical for the development of an equitable system with sustainable administrative costs.

Low-Income Households

Studies have found that higher-income households may produce more vehicle miles traveled (VMT) due to owning more vehicles and participating in more leisure activities (Cain & Jones, 2008; Bonsall & Kelly, 2005). However, low-income households are more likely to spend a higher percentage of their income on transportation and personal vehicle ownership to reach employment, such as manual labor (Cain & Jones, 2008). Low-income households are also more likely to be dependent on their vehicles to access necessities, such as grocery stores or medical facilities. As a result, low-income households may be less able to alter their travel patterns to travel less miles (Bonsall & Kelly, 2005). In addition, few public transit systems offer the convenience and speed of a personal vehicle, exacerbating the potential car-dependency of low-income households (Bonsall & Kelly, 2005). These factors likely result in a greater cost burden of road usage for low-income households compared to other travelers. Many of the studied RUC programs, including California's, have had difficulty recruiting participants from low-income households, resulting in a critical gap in understanding of how to address the potential impacts of a shift to RUC on this group.

Rural Residents

RUC system implementation could raise concerns that rural residents would pay a disproportionate number of RCs. This is due to rural residents' need to drive longer distances to access resources, such as retailers and employment opportunities (McMullen, Wang, Ke, Vogt, & Dong, 2016; Weatherford, 2011). This concern is supported by statistics that illustrate that the VMT by rural residents is typically 16 percent higher than the population average and 34 percent higher than urban residents (Weatherford, 2011; Atkinson, 2019). These higher-than-average VMT could be, in part, due to distances from resources, but may also be exacerbated by other factors. For example, roads connecting rural communities to denser areas may take longer due to more circuitous routing to navigate around natural landforms, such as mountain ranges. A lack of a robust number of roads that efficiently connect rural communities to other communities may increase the VMT per trip for rural drivers (McMullen, Wang, Ke, Vogt, & Dong, 2016). The larger amount of VMT by rural populations, potentially due to the geographic distribution of roads and resources rather than travel decisions, could result in rural drivers paying a large amount in RCs. However, research also clearly indicates that in a potential shift to a RUC system, rural drivers will, on average, pay less in taxes than under the current gas tax system, because they tend to drive less fuel-efficient vehicles (Weatherford, 2011; McMullen, Wang, Ke, Vogt, & Dong, 2016).

Rural households have also been difficult to recruit for RUC participation, potentially resulting in a lack of thorough understanding of this populations and concerns regarding a future RUC system.

Potential Strategies

Addressing the social equity concerns and risks may be the most important part of fostering public support for a RUC system and ensuring its sustainability. Addressing this risk can be done through a variety of strategies, such as those employed in other RUC systems including:

- **The Eastern Transportation Coalition:** Evaluated the demographic trends of the region and predicted the ways a RUC system could address the needs of a variety of demographic groups;
- **Colorado:** Conducted a survey of 500 demographically diverse residents to gain their opinion on a RUC system and what potential opportunities and challenges could result;
- **Hawaii:** Developed a targeted demographic focus of its RUC system to understand its impacts on visitors to the islands and residents who have long commutes or drives to access resources;
- **Minnesota:** Compiled a pool of participants that reflected the study area;
- **Oregon:** Conducted a survey that was representative of the demographic makeup of Oregon to understand different perspectives and potential opportunities and challenges; and
- **Washington:** Tracked the RUC system participants to identify different trends, opportunities, and challenges by demographic group.

These strategies, such as a zip code-based analysis and comparing participant demographics to the demographic makeup of the area, can be employed in the California RUC system to address potential equity concerns. Additional strategies to increase transportation equity in the California RC, and the demographic group-based challenges these strategies work to address, are summarized in Table 1 and further described below the table.

Table 1. Mitigation Strategies by Target Demographic Group

	Gender and Household	Un- and Under-Banked Households	Low-Income Households	Rural Residents
Alter RUC Rates	X	X	X	X
Charge Out-of-State Drivers	X	X	X	X
Conduct Zip Code Level Analysis				X
Educate Participants	X	X	X	X
Develop Cash-based Payment Options		X		
Differentiate Between Fuel Types			X	X
Disaggregate Data	X	X	X	X
Integrate into Existing Tax Systems	X		X	
Integrate with Existing Programs	X	X	X	X
Offer Tax Credits	X	X	X	X
Refine Mapping Systems	X	X	X	X
Support Purchasing More Efficient Vehicles			X	
Use Unique Funding Sources			X	

Strategies to improve the social equity outcomes of RUC include:

- **Alter RUC Rates:** Based on the findings of different analyses (e.g., zip code-based data), RUC rates may need to be altered to ensure that RUC participants pay a fair, equitable fee for their infrastructure impacts.
- **Charge Out-of-State Drivers:** The system administrators may need to develop a system to charge out-of-state drivers for their impacts on the states' public infrastructure through mechanisms, such as: a system similar to the HUB (a financial clearinghouse) used by Washington and Oregon, a tax on rental cars, and/or tolls administered at state borders.
- **Conduct Zip Code Level Analysis:** Similar to Hawaii, California can conduct a zip code-based analysis of RUC data, participant opinions, and travel patterns to better understand how a RUC system impacts may vary regionally.
- **Develop Cash-based Payment Options:** In order to allow un- and under-banked households to participate in RUC systems, payment systems and options that are not dependent on financial institutions will likely need to be developed.
- **Differentiate Between Fuel Types:** Establishing a fuel type-based rate structure to distinguish between fuel types (e.g., unleaded, super unleaded, diesel) can improve the accuracy of the correlation between RCs and environmental impacts. This may be important for populations that bear a disproportionate burden of negative environmental impacts (e.g., people of color), particularly if additional funds are targeted to directly mitigate for such impacts (Jenn & Fleming, 2020).
- **Disaggregate Data:** Disaggregating RUC participant data (e.g., annual miles driven) based on different demographic and/or vehicle characteristics (e.g., gender, income group, age group, race/ethnicity) can increase understanding of various travel patterns and disparate

impacts (e.g., on income) of RUC that may not be otherwise apparent. However, the collection of personal data should be carried out with caution, ensuring that participants' sense of privacy is not jeopardized, perhaps by allowing the provision of individual data to be voluntary and providing transparency about the intended use of the data (e.g., research efforts).

- **Educate Participants:** Educating participants on the opportunities and impacts of a RUC system could help foster support and explain how different population groups are impacted. Interactive tools, such as an online calculator that enables participants to estimate the change in taxes paid from the current fuel tax to the RUC system, may help to educate participants about the scale of payments and the actual impact they can expect to have on their own expenses.
- **Integrate into Existing Tax Systems:** Leveraging existing tax systems can allow agencies to use features of those programs (e.g., organizational models) to more efficiently allocate RUC funds to the locations in which miles are driven (Jenn & Fleming, 2020). This could decrease administrative costs by 1.7 percent (Atkinson, 2019).
- **Integrate with Existing Programs:** RCs can help fill transportation funding gaps and achieve other goals. Working with other agencies and programs in areas where goals overlap (e.g., decreasing vehicle miles traveled to improve the environmental impacts of transportation) can provide RUC programs with additional resources to strategically offer benefits (e.g., subsidized rates for low-income households) (Jenn, 2019).
- **Offer Tax Credits:** Tax credits could be used to address disproportionate payments in either a fuel tax or RUC system. This strategy, which is not unique to RUC, could leverage revenues to address existing disparities in road usage and the costs incurred across population groups.
- **Refine Mapping Systems:** By improving the level of detail on mapping systems (e.g., ability to differentiate between public and private roads) and vehicle location tracking technologies that are used in RUC systems, program administrators can better ensure that travelers are paying for their fair share of the maintenance for public roads and are not contributing more for driving on private roads. An option to exclude payments for private road usage will also likely need to be developed to accommodate drivers who used mileage reporting devices that are not location enabled.[1]
- **Support Purchasing More Efficient Vehicles:** Regardless of whether an RUC is structured with discounts for more fuel-efficient vehicles, the per-mile cost of driving primarily depends on the fuel type being consumed. Public agencies and non-profits could address prevailing equity concerns by reinvesting revenue in aid for low-income and rural households to purchase and operate (e.g., subsidized charging) more efficient vehicles. However, such strategies must be weighed against other key goals of an RUC system – primarily, revenue stabilization.

[1] Caltrans is launching the public/private roads project in 2023 to pilot this technology and improve understanding of the travel behavior and needs of rural and tribal drivers (California Department of Transportation, 2022).

- **Utilize Unique Funding Sources:** To assist low-income households unique funding sources or systems may need to be developed or utilized. For example, for households who may not be able to afford the initial cost of mileage reporting devices, such as OBUs, public agencies may need to engage in partnerships with organizations, such as manufacturers, to offer mileage reporting options that are less expensive because they are bought in bulk or are otherwise subsidized.

Expert Interviews

The research team conducted expert interviews to increase understanding of the potential opportunities and challenges, particularly regarding equity, of a RUC system. The interviews included transportation industry professionals as well as representatives from community-based and other stakeholder organizations. The goal of interviewing experts with a range of backgrounds was to understand transportation and best practices for RUC as well as identify stakeholders' concerns and potential ways to address them.

A total of 21 interviews were completed from October 2020 to January 2021. The organizations that the experts represent are listed in Table 2.

Table 2. Expert Organizations

RC Programs	Transportation and Research Organizations	Community-Based Organizations
Hawaii Road Use Charge	Center for Innovative Finance Support	American Automobile Association (AAA)
I-95 Coalition/Eastern Transportation Coalition	Greenlining Institute	American Transportation Research Institute
Minnesota Road Use Charge	Information Technology & Innovation	California Community Action Plan
OReGO	Public Advocates	California Independent Living Centers
Utah Road Use Charge	Reason Foundation	People Assisting the Homeless (PATH)
Washington Road Use Charge	United States Department of Transportation	Transform
Wyoming Road Use Charge	University of Texas - Austin	United Ways

The interviews were conducted virtually over video call, due to shelter-in-place orders from the COVID-19 pandemic, and typically lasted an hour. While the interview questions varied slightly based on the expert's background, they generally covered the topics of:

- **Program Participation:** Outreach efforts and potential strategies to increase program participation and adoption, particularly for underserved populations;
- **Program Impacts:** Possible impacts to different demographic groups and travel behaviors based on the RUC design,
- **Program Sustainability:** RUC design characteristics and strategies to help ensure the longevity of a RUC system, and
- **General Comments and Strategies:** Suggested areas of research or other general recommendations for a RUC system.

The expert interview protocols can be found in

Appendix A. Topical Expert Interview Protocol and Appendix B. Community Organization Expert Interview Protocol.

The following subsections summarize the expert interview findings on the topic areas of:

- **Program participation:** outreach efforts and potential strategies to increase program participation and adoption, particularly for underserved populations;
- **Program impacts:** possible impacts to different demographic groups,
- **Program design:** ways to design RUC programs to mitigate various impacts,
- **Program sustainability:** RUC design characteristics and strategies to help ensure the longevity of a RUC system, and
- **General comments and strategies:** suggested areas of research and other general recommendations for a RUC system.

The following subsections summarize findings from the expert interviews in each of these topic areas.

Program Participation

One of the biggest challenges to program participation that experts cited was public perception. Public perception regarding a RUC is generally negative as people view it as a fee that they are being charged for a resource they currently use for free. This negative perception can discourage program participation and decrease public support. A lack of understanding of how transportation resources are financed can fuel negative public perceptions of RCs. Experts, particularly those who manage a RUC system, stressed the importance of beginning public outreach efforts with an educational campaign that explains how roads are financed. Many transportation experts stated that without this knowledge it is difficult for people to understand why they have to pay an "additional fee" to use roads. Clarifying that a RUC is a replacement to a fuel tax, which drivers are already paying, is key.

To support program participation and education, outreach has to be completed in various forms and on different platforms. This can help public agencies reach as much of the population as possible. For example, when experts from one RUC system were developing their program, they found that in their state people were accustomed to receiving information by mail. To leverage this, officials from that program printed and mailed out a RUC information sheet. The experts credit the relatively positive reaction to and widespread participation in their RUC system to this targeted approach. To achieve a similar effect in California various outreach and education campaigns need to be completed. Educational material that has already been developed by other organizations can support this.

Working with various community-based organizations can also be key for improving outreach for RUC programs. One community expert stated that outreach to lower-income individuals is best accomplished through frequently used social service providers. These providers are often able to tap into strong existing social networks, especially if they serve other purposes (e.g., a religious center which is both a social service provider and community organization). Similarly, the organizations that focus on the needs of select demographic groups may be particularly important outreach partners (e.g., Centers for Independent Living for building relationships with people with disabilities). Additionally, focus groups with community college students may be a way to target a diverse population that face many transportation challenges throughout the state.

Reaching a broad range of participants, particularly during early and piloting stages, can help program managers and other officials better understand and address challenges that may arise. Additionally, these efforts can help increase support for and adoption for RUC systems. For example, program managers may find that low-income households prefer to participate using app-based mileage tracking methods but pay RCs in person or via cash or check. These design considerations can help make a RUC system more accessible and easier to use. Understanding these individual-level decision-making factors can inform RUC program design and better accommodate a range of individuals.

Program Impacts

Experts, particularly those from community-based organizations, were able to offer insight on the potential challenges various underserved populations may face in a RUC system. The underserved populations discussed include lower-income households, older adults, people with disabilities, racial minorities, rural residents, undocumented individuals, and other historically underserved demographic groups. Many of the experts noted that the challenges these populations face frequently overlap (e.g., older adults may be more likely to have a disability and need an accessible, racial minorities tend to be lower income).

One prominent challenge that almost all of the experts noted was the lack of affordable housing options (e.g., for lower-income households, older adults) in urban areas. This may result in these demographic groups residing in exurban and suburban areas, subsequently requiring them to pay higher driving costs, including gas taxes and RUCs (e.g., for longer commutes). Additionally, these less dense areas may lack alternative transportation options (e.g., public transit, bikesharing), increasing the dependency on personal vehicles and the associated fuel taxes or RUCs. Four non-profit experts noted that lower-income households may be less able to change their travel patterns to avoid higher driving costs for various reasons including dependency on personal vehicles as a reliable transportation mode (e.g., when working two jobs or working night shifts), a lack of available affordable alternatives, and inability to secure a job that offers teleworking. People with disabilities may also be concerned about a change in driving costs since transportation alternatives (e.g., microtransit) are often not as accessible or reliable as personal vehicles. While issues related to car dependency may hold regardless of the tax mechanism - fuel tax or RUC - the heightened awareness of the differences in VMT across groups and its direct relationship with the amount of RUC paid is likely to affect the perception of fairness of an RUC system

Community experts representing particular demographic groups, including people with disabilities and racial minorities, noted a number of additional unique RUC challenges. Individuals who struggle with mental health challenges may also have concerns with mileage tracking, particularly regarding privacy and data sharing. Similarly, racial minorities, especially those who are undocumented, may be particularly hesitant to participate and share personal information in a RUC program due to various concerns (e.g., legal citizenship status, policing). Rural residents may lack consistent internet access, which may be critical for some mileage reporting options. . Additionally, while lower-income households may have smartphone access, they are less likely to have internet access at home. This can pose a challenge for RUC systems that are not designed to be smartphone compatible.

Program Design

Potential impacts from participation in a RUC program can be mitigated through program design that includes options for the various components of a RUC system (e.g., mileage reporting, payment). This allows participants to decide how a RUC will impact them. For example, letting participants choose how they record their mileage (e.g., pay-at-the-pump technologies, on-board device) gives them the opportunity to make decisions between different characteristics that are important to them. If a participant is concerned about data sharing and privacy, they could select a reporting option that is more manual and less technical to address that concern.

The experts offered various strategies to improve RUC accessibility and equity across various demographic groups. Approximately a quarter of the community experts described leveraging existing programs to address different challenges (e.g., smartphone and data plan access). For example, California LifeLine is a service from the state that offers discounted home and cell phone service to qualified individuals. Similarly, institutions, such as the Self-Help Credit Union, can provide individuals who have Social Security numbers with bank account access (e.g., for RUC payment). However, this may not be a viable solution for all individuals (e.g., those still going through the immigration process). Other existing programs, such as the Real Cost Measure, which factors in local costs to determine income-based aid, can be used when determining which individuals to offer benefits such as subsidized RCs to. These augmented calculations may be necessary, especially for California residents who face high rent burdens and housing costs.

Experts also stressed the importance of designing a RUC system that meets various needs. For example, offering different payment options (e.g., pay-as-you go, debit or credit card) can make a RUC system more accessible for low-income households who require different budgeting options (e.g., weekly, annually). Additionally, any technological component to a RUC system (e.g., mileage tracking through a smartphone app) should have a less technical alternative (e.g., manual reporting) to be more inclusive (e.g., for low-income household unable to afford these services or people who are not digitally fluent). One expert stated that simple programs that are less capital intensive tend to better meet the needs of underserved populations. These programs are also more likely to gain support from underserved populations.

Simplicity and clarity are also important when communicating about RCs and their respective benefits to underserved populations. Roughly half of the community experts said that it will be important to explain to the public how fraud and payment evasion will be mitigated and addressed to develop trust among community members that all participants pay their fair share. Similarly, an important RUC system consideration is how the funds generated will be spent, since public transit systems can benefit from infrastructure improvements (e.g., better maintained roads) and these modes may be critical mobility options for underserved populations. RUC programs could also be designed to support electric mode adoption (e.g., reduced RUC fees for EVs). This may help encourage participation by demographic groups that have already adopted more fuel-efficient vehicles in response to rising gas costs and to reduce environmental impacts.

RC programs may also need to have alternative mileage structures in place to address high vehicle ownership costs for different demographic groups. For example, accessible vehicles can be disproportionately expensive (e.g., an average of $70,000), potentially placing a higher financial burden on people with disabilities who require these vehicles for mobility. Similarly, while lower RCs for EVs can support increasing electrification, this may exclude lower-income households who are unable to afford these vehicle types. Lower RCs for EVs may also exclude households who do not have access to public vehicle charging infrastructure, at least in the short term.

A broader impact of an RUC system in California is the possibility of persuading original equipment manufacturers to develop standardized telematics in vehicles. This could allow vehicles to be more easily integrated into a RUC system and facilitate easier program participation. This would keep future RUC participants from needing to install a device, track their mileage, or use any other type of mileage reporting system. This opportunity is unique to California given the size of the state, its large population, and diverse vehicle markets.

Program Sustainability

To help support long-term program participation and sustainability, experts recommended maintaining a simple program and supportive online platforms and/or call center. A variety of RUC programs in other states have tried offering value-added services (e.g., vehicle maintenance reminders), but many of the experts stated that users did not find these additions as useful as anticipated and in some cases the options caused confusion. Having a simple program and intuitive platforms for users was more beneficial than offering additional services. For example, one RUC system had an easy-to-use website with a frequently asked questions (FAQ) section, including a video on how to install an on-board unit for mileage tracking. According to user surveys, the website, particularly the FAQ section, was helpful and positively impacted participants' satisfaction with the program.

Another key program feature for sustainability is privacy protection. Experts stated that it is important for participants to feel as if their privacy and information is being protected through strategies such as a third-party account manager for mileage reporting and payment. If data is misused or leaked and trust in the program is broken it will likely be difficult to regain. Privacy protection may be particularly important for demographic groups, such as racial minorities, who have greater concerns regarding government surveillance.

General Comments and Strategies

Generally, experts, including from organizations that are not transportation-focused, saw the value of a RUC system and thought that the design of California's system leverages a variety of best practices. However, one area that was recommended for further research was enforcement and compliance. Since the majority of the RUC systems in the United States are voluntary, there are few examples of proven enforcement and compliance strategies. Experts stated that developing a way to hold individuals accountable is key for all areas of a RUC program – participation, impacts, and sustainability. Unless people can be assured that everyone is participating equally and paying their share it would be difficult to encourage adoption and people to participate and record their mileage honestly. These two factors, adoption and honest participation, could alter the long-term sustainability of a RUC program.

Key Takeaways

A total of 21 interviews were conducted with experts from various organizations, October 2020 to January 2021, including current road use charge programs, transportation and research institutions, and community-based organizations. The interviews offered insight into various aspects of RUC programs including participation, impacts, design, and sustainability. The experts, particularly those involved directly with RUC programs, stated that addressing public perception challenges (e.g., that a RUC is an additional tax) is key for encouraging participation and adoption. Addressing these challenges can be accomplished through various outreach methods (e.g., mailing out information, distributing educational material). Community partners (e.g., religious centers) may also be critical stakeholders to conduct outreach with.

Proactive outreach and community communication can help identify potential impacts and challenges that RUC systems and their users may face. The experts described possible challenges, such as the lack of affordable housing. This can impact underserved populations (e.g., low-income households) who choose to move to more affordable areas with fewer viable (e.g., affordable, reliable) transportation alternatives. Underserved populations may also be impacted by other challenges, such as a lack of internet access and high vehicle ownership costs. However, RUC programs can be designed to address these challenges. For example, offering participants options (e.g., for mileage recording, payment) can allow them to tailor their participation to fit their needs and preferences. Additionally, outside resources can help address various challenges (e.g., California LifeLine for discounted cell phone service). Ensuring that a RUC system is designed with various options (e.g., low-technology alternatives) and clearly communicating about its design can help improve RUC equity and public perception. These design considerations can help with the long-term sustainability of a RUC system. In addition, ensuring that RUC programs (e.g., payment options) are easy to use and privacy is protected can help encourage long-term RUC viability. Going forward, further research on how to effectively enforce RUC participation can garner support.

General Population Survey Methodology

In addition to the expert interviews, this study includes analysis of a general population stated preference (SP) survey of residents of California. Insights gleaned from the expert interviews informed the design of the survey instrument, which was distributed in both paper and electronic formats from April 2021 to February 2022.

The methodology is designed to assess the relative burden of gas taxes and mileage-based RUC across various socio-demographic and geographic dimensions by examining key trends in road use, vehicle ownership, transportation expenditures, use of RC-related technologies, and attitudes/opinions related to RUC adoption. In addition to statistical analysis of key metrics of road use estimated from the survey data, a discrete choice model is estimated to further investigate discrepancies in Californians' sensitivity to RC. Analysis of model results develop a richer understanding of the potential impacts of RCs on particular groups of Californians with the aim of understanding whether RCs are likely to elicit a change in travel behavior.

The following subsections detail the methods used for data collection, survey analysis, and discrete choice analysis.

General Population Survey

The survey included questions about respondents' socio-demographic characteristics, travel profile, household structure, vehicle ownership, typical monthly expenses, opinions/attitudes regarding a series of four RC-related statements, and a series of stated preference experiments. The survey was distributed in both a paper and electronic format during two phases, in which the survey was distributed via:

1. California Department of Motor Vehicle (DMV) offices, and
2. The Qualtrics online survey platform.

In order to recruit a representative sample of the state population, the target sample size of 3,500 was divided into four study regions, including Northern California, the San Francisco Bay Area, Central California, and Southern California, as displayed in Figure 1below. The target sample size for each region (shown in the legend of Figure 1) was determined based on the distribution of the California population, as reported by the U.S. Census Bureau's 2019 American Community Survey (ACS) five-year estimates. In addition, target demographic distributions for each study region were based on the 2019 ACS five-year estimates of the distributions of gender, age, income, educational attainment, and race/ethnicity.

The eight DMV locations, shown with stars in Figure 1, were selected based on their proximity to lower income and rural communities in order to ensure that the sample included Californians least likely to be reached by the online survey distribution. These included the following DMV offices:

- Fort Bragg in Northern California,
- Oakland Coliseum in the San Francisco Bay Area,
- Fresno and Watsonville in Central California, and
- Blythe, Compton, Lincoln Park, and Lancaster in Southern California.

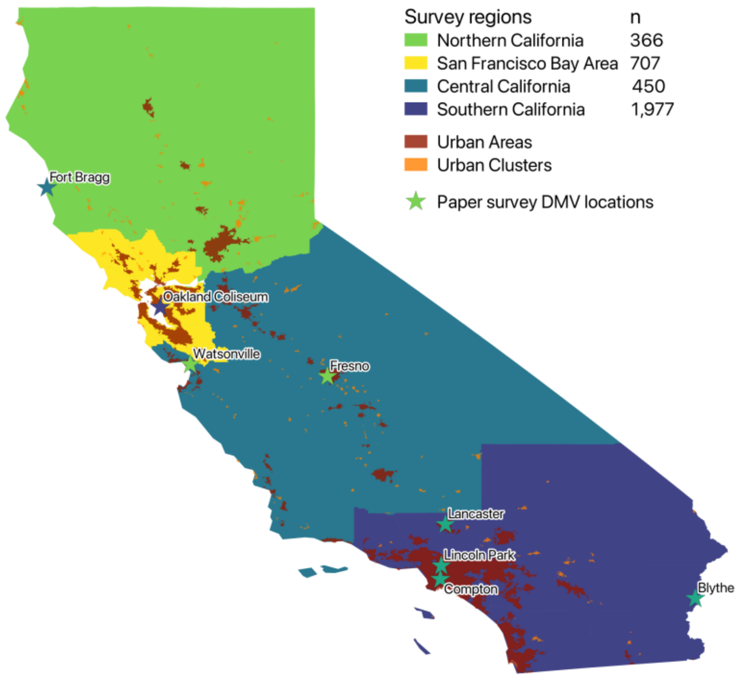


Figure 1. Survey Regions and Paper Survey Distribution Locations

From April 12 to May 14, 2021, visitors to the eight DMV offices were offered a single page tri-fold paper survey and pen during the check-in process for their scheduled visit to the DMV. Completed surveys were submitted to a locked drop box inside of the DMV office. In addition, the survey pamphlets included a flier with a QR code to access the survey in an online format hosted on the Qualtrics survey platform. At the end of this phase of distribution, the locked drop boxes were shipped back to the research team at UCB for data recording and processing.

A summary of the number of surveys distributed and responses collected from each DMV location is presented in Table 3 below. Response rates varied from 2% to 60% of the surveys distributed at each location, with an overall response rate of 14%. A total of 189 responses were collected via the paper version of the survey and an additional 48 responses were collected via the online version, 25 of which did not report a home zip code and thus have unknown distribution locations.

Table 3. DMV Survey Distribution

DMV Location	Target	N Distributed	N Submitted - Paper	N Submitted - Online	Response rate
Blythe	30	90	10	0	11%
Compton	110	360	8	1	3%
Lincoln Park	110	360	30	5	10%
Fort Bragg	50	180	9	1	6%
Fresno	40	250	67	2	28%
Lancaster	30	90	0	2	2%
Oakland Coliseum	100	330	12	11	7%
Watsonville	30	90	53	1	60%
Unknown	-	-	-	25	-
Total	**500**	**1660**	**189**	**48**	**14%**

The second phase of survey distribution launched in August, 2021 after the responses from the first phase were processed. The target demographic distributions in each study region were updated according to the socio-demographic distributions of the responses collected from phase 1 and coded into Qualtrics for targeted sampling in the second phase of distribution. The distributions of all the socio-demographic characteristics used for sample targeting as well as in the sample are presented in the Survey Demographics section (see Table 5 - Table 9 and Table 12).

Data Cleaning

A total of N=3,489 responses were collected across the two phases of survey distribution. An initial quality check for speedy responses was applied, removing 205 online responses that were completed in less than five minutes. An additional 169 responses were filtered out of the sample for incompleteness. Additional quality checks were applied, flagging responses with erroneous logic (e.g., employed/student that never commutes and never works from home) and cross-down responses in matrix-based questions. Survey responses flagged by more than one quality check were removed from the sample, resulting in a final sample size N=3,061. In each of the analyses included in this report, null responses for the questions pertaining to the analysis are omitted and the resulting sample sizes are reported in the accompanying figures.

Urban Classification

The 2010 U.S. Census Bureau urban-rural classification was used to classify respondents as either urban area, urban cluster, or rural residents. Any incorporated place or census designated place with at least 2,500 people is identified by the Census Bureau as an urban area, with two distinctions: urbanized areas (UAs) of 50,000 or more people, and urban clusters (UCs) of between 2,500 and 50,000 people. Any population, housing, or territory outside urban areas are identified as rural. As can be seen in Figure 1 above, UAs comprise of the most densely populated areas within the state's metropolitan and micropolitan areas, including suburban areas. UCs are primarily smaller, less densely populated areas that nonetheless comprise of clusters with at least 2,500 residents.

Respondents' self-reported home zip codes were classified as UA, UC, or rural by conducting a one-to-many zip code to census tract spatial join using the QGIS open-source geographic information system (GIS) software. Zip codes containing more than one type of urban-rural classification were classified with the densest urban classification (e.g., a zip code containing both UAs and UCs was classified as a UA.

Estimation of Weekly Person Miles Traveled and Vehicle Miles Traveled

Respondents were asked a series of questions to determine their typical travel profile and estimate their weekly person miles traveled (PMT) across various trip purposes and travel modes. Vehicle miles traveled (VMT) by driving alone or carpooling were examined to assess the relative cost burden of travel across various dimensions of the population. Respondents were asked to estimate how often (days per week) and how far (miles per trip) they typically travel to reach each of the following seven destinations[2]:

- Commute to work/school,
- Medical/dental care,
- Pickup/drop-off someone else (e.g., child, dependent),
- Grocery shopping,
- Other errands (e.g., going to the bank, shopping for household goods),
- Dining out (including picking up take out), and
- Other social/recreational activities (e.g., going to the movies, park, beach, etc.).

While paper survey respondents were able to fill in a numerical estimate, online survey respondents were asked to select an answer option from a list of intervals for each question (e.g., 1 to 2 days/week, 3 to 4 days/week, 1 to 2 miles/trip, 3 to 4 miles/trip, etc.). The online survey responses were translated into numerical values using the midpoints of each response.

Typical weekly PMT for each respondent *n* and trip purpose *t* was estimated as follows:

$$PMT_{n,t} = 2 \times freq_{n,t} \times distance_{n,t}$$

where $freq_{n,t}$ is the reported weekly trip frequency and $distance_{n,t}$ is the reported trip distance (in miles). Since respondents were asked to report the distance to travel *to* each destination, the product of the trip frequency and distance is multiplied by two to account for round-trip travel.

Next, respondents were asked to indicate which travel mode(s) they typically use for each of the same trip purposes. Several answer options were provided, including: Drive alone, Carpool (as a driver), Carpool (as a passenger), Walk, Bike, Uber/Lyft, Public Bus, Rail, and Other (please specify). Responses were classified into six mode categories: drive alone, carpool (as a passenger or a driver), active (walk and bike), public transit (public bus and rail), TNCs, and others. Since respondents could select more than one travel mode, respondents' typical mode share for each trip purpose was estimated by assuming a uniform distribution across the modes listed for each trip purpose (i.e., an even split), with one exception: responses that included both public transit and an

[2] Due to space constraints, the paper version of the survey included an abbreviated list of trip destinations: Commute to work/school, medical/dental care, pickup/drop-off someone else (e.g., child, dependent), grocery shopping, dining out (including picking up take out).

active mode were classified simply as public transit, with the assumption that the active mode served as an access/egress mode. We also note that responses in which walking was listed as a typical mode for a trip distance of five miles or more and no public transit mode was listed were flagged for poor response quality and not included in the PMT analysis.

The mode share of mode *m* for person *n* and trip purpose *t* was calculated as follows:

$$mode\ share_{n,t,m} = \frac{1_{m \in modes_{n,t}}}{\sum_{k \in modes} 1_{k \in modes_{n,t}}}$$

where $1_{m \in modes_{n,t}}$ is equal to 1 if mode *m* is one of the modes listed by person *n* for trip purpose *t* and equal to 0 otherwise. The PMT by any particular mode was estimated as the product of the overall PMT for a particular trip purpose, $PMT_{n,t}$, and the mode share as follows:

$$PMT_{n,t,m} = PMT_{n,t} \times mode\ share_{n,t,m}$$

VMT was estimated as the sum of the drive alone PMT and the carpool PMT.

Vehicle Classification and Estimation of Average Fuel Consumption Rate

Average fuel consumption rates for each driver were estimated based on respondents' self-reported vehicle characteristics. Respondents were asked to fill in the year, make, model, and estimated annual mileage for each of their two most frequently used vehicles. An answer option was also provided for respondents to indicate that they did not own or lease any vehicles. Respondents that provided vehicle information were also asked to indicate the fuel type of each vehicle by selecting one option from the following list for each vehicle: gasoline only, diesel only, hybrid electric, plug-in hybrid electric, battery electric, hydrogen fuel cell, and other.

Vehicle fuel economy data from the U.S. Environmental Protection Agency (EPA) was used to estimate the fuel consumption rate of respondents' personal vehicles. An algorithmic pipeline was developed to process raw responses and query the fueleconomy.gov web service for estimated combined city and highway fuel economy of each vehicle (miles per gallon (MPG) for internal combustion engine (ICE) and hybrid vehicles, miles gasoline-electricity combined (MPGe) for plug-in hybrid vehicles, and kw-hrs/100 miles for battery electric vehicles). Respondents' self-reported vehicle fuel types were used to refine queries to the fuel economy web service whenever possible (i.e., to distinguish between vehicle makes with multiple available fuel types).

The relative cost burden of road usage across Californians is investigated using an estimate of the average fuel consumption rate (gallons of gasoline or diesel per mile) of each driver in the sample. The inverse of the MPG fuel economy metric is used here in order to directly include battery electric vehicles, which consume 0 gas/diesel per mile, in summary statistics across various dimensions of analysis. For respondents with more than one vehicle, the average fuel consumption rate was estimated as a weighted average of the gas/diesel consumed per mile by each vehicle, as follows:

1. the average fuel consumption for each fuel type (gasoline and diesel) was calculated as the mileage-weighted average of the mpg of each gas-powered or diesel-powered vehicle, respectively, as follows:

$$average fuel\ consumption_{n,gas} = \frac{\sum_{v=1}^{2} 1_{type_v \in \{gas,HEV,PHEV\}} \times \frac{mileage_v}{mpg_v}}{\sum_{v=1}^{2} mileage_v}$$

$$average fuel\ consumption_{n,diesel} = \frac{\sum_{v=1}^{2} 1_{type_v \in \{diesel\}} \times \frac{mileage_v}{mpg_v}}{\sum_{v=1}^{2} mileage_v}$$

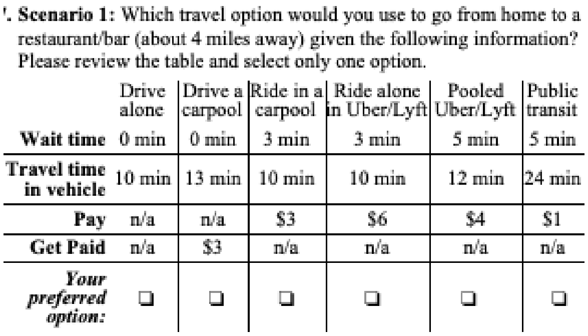
2. the overall gas/diesel fuel consumption rate was calculated as the sum of the gas and diesel consumption rates:

$$overall\ fuel\ consumption_n = fuel\ consumption_{n,gas} + fuel\ consumption_{n,diesel}$$

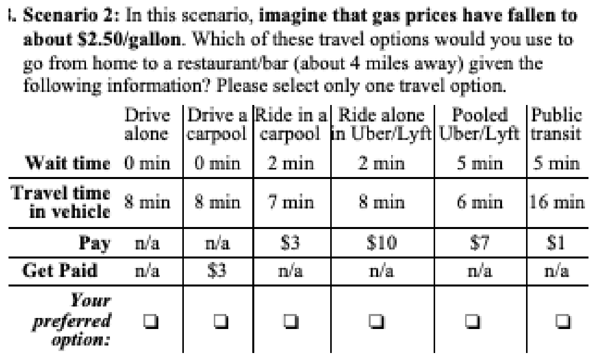
Stated Preference Experiment Design

A series of stated preference (SP) mode choice experiments were designed to measure the relative sensitivity of demand to fuel taxes and RUCs. Prior to the presentation of the choice experiments, respondents were instructed to imagine that they were making a trip of 4, 10, or 20 miles from their home to a specified location indicating a particular trip purpose (including work/school, grocery shopping, a medical/dental appointment, and restaurant/bar).

As shown in Figure 2 below, respondents were presented with an additional prompt in each of the three choice experiments and were asked to select the travel mode they would most likely choose based on the estimated wait time, in-vehicle travel time, and the amount to be received or paid that were presented in a table format. All three experiments included the following travel mode options: drive alone (presented to vehicle owners only), drive a carpool (presented to vehicle owners only), ride in a carpool, ride alone in a TNC, pooled ride in a TNC, and public transit. Half of the respondents were shown an estimated gas cost, displayed as a cost of driving alone and driving a carpool, and half of the respondents saw no driving costs. The first question (Scenario 1) provided no additional information. The second question (Scenario 2) stated that gas prices had either risen or fallen to a specified amount. Finally, the third question (Scenario 3) stated an average gas price at the time of the survey and asked respondents to imagine that there was a fee that charged some specified amount per mile driven.

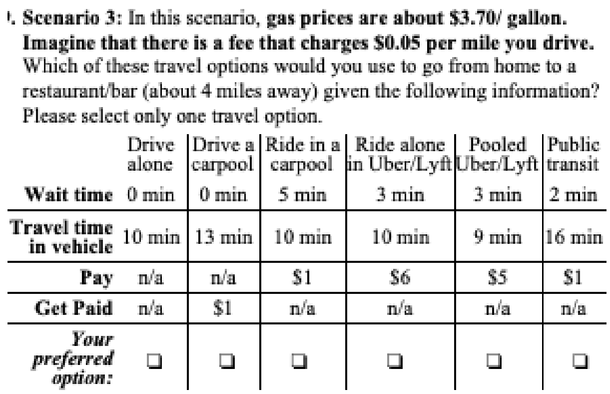

Scenario 1: Which travel option would you use to go from home to a restaurant/bar (about 4 miles away) given the following information? Please review the table and select only one option.

	Drive alone	Drive a carpool	Ride in a carpool	Ride alone in Uber/Lyft	Pooled Uber/Lyft	Public transit
Wait time	0 min	0 min	3 min	3 min	5 min	5 min
Travel time in vehicle	10 min	13 min	10 min	10 min	12 min	24 min
Pay	n/a	n/a	$3	$6	$4	$1
Get Paid	n/a	$3	n/a	n/a	n/a	n/a
Your preferred option:	❑	❑	❑	❑	❑	❑


Scenario 2: In this scenario, **imagine that gas prices have fallen to about $2.50/gallon.** Which of these travel options would you use to go from home to a restaurant/bar (about 4 miles away) given the following information? Please select only one travel option.

	Drive alone	Drive a carpool	Ride in a carpool	Ride alone in Uber/Lyft	Pooled Uber/Lyft	Public transit
Wait time	0 min	0 min	2 min	2 min	5 min	5 min
Travel time in vehicle	8 min	8 min	7 min	8 min	6 min	16 min
Pay	n/a	n/a	$3	$10	$7	$1
Get Paid	n/a	$3	n/a	n/a	n/a	n/a
Your preferred option:	❑	❑	❑	❑	❑	❑

a) Scenario 1: Neither tax stated **b) Scenario 2: Gas prices increase/decrease**


Scenario 3: In this scenario, **gas prices are about $3.70/ gallon. Imagine that there is a fee that charges $0.05 per mile you drive.** Which of these travel options would you use to go from home to a restaurant/bar (about 4 miles away) given the following information? Please select only one travel option.

	Drive alone	Drive a carpool	Ride in a carpool	Ride alone in Uber/Lyft	Pooled Uber/Lyft	Public transit
Wait time	0 min	0 min	5 min	3 min	3 min	2 min
Travel time in vehicle	10 min	13 min	10 min	10 min	9 min	16 min
Pay	n/a	n/a	$1	$6	$5	$1
Get Paid	n/a	$1	n/a	n/a	n/a	n/a
Your preferred option:	❑	❑	❑	❑	❑	❑

c) Scenario 3: Average gas prices and MBUF

Figure 2. Example Stated Preference Mode Choice Experiments (Paper Survey Format)

The values of each of the alternative-specific attributes, and trip context parameters (distance, purpose, gas prices, RUC rate) were randomized across all respondents. A set of levels were determined for each numerical attribute based on estimates of congested and uncongested travel times and travel costs in each of the four regions surveyed, collected from Google Maps. The range of each of the level sets were designed to encompass the range of possible values queried from Google Maps, allowing for the application of the resulting model for forecasting purposes across the state (i.e., by including values both above and below the prevailing levels of service of each mode).

An orthogonal design was generated for the paper survey using the SPSS software, producing 32 versions of the choice experiments. In the online survey, the values of each attribute were randomly generated from a uniform distribution, with constraints applied to avoid choice experiments with dominated alternatives (i.e., alternatives for which every attribute is considered worse than another alternative).

Discrete Choice Analysis

The SP data was applied in a discrete choice analysis (DCA) was conducted to investigate the heterogeneity in the sensitivity of demand to RUCs in California. DCA is a method used to model choices from an exhaustive, finite set of mutually exclusive alternatives, based on the principles of utility maximization (Ben-Akiva and Lerman, 1985; Train, 2009). The objective is to estimate a parameterized random utility model for each of the alternatives, composed of a deterministic component and a random component. As defined in the equation below, the utility of alternative j to individual n, denoted as U_{nm}, is the sum of the linear combination of observable independent variables, X_{nm}, multiplied by the corresponding coefficients, β_{nm}, (the deterministic component), plus a an independently and identically distributed random error term representing unknown factors, ε_{nm} (the random component).

$$U_{nm} = \beta_{nm}X_{nm} + \varepsilon_{nm}$$

The probability that a particular individual chooses any one of the alternatives is the probability that the chosen alternative provides that individual with the greatest utility across all available alternatives. The multinomial logit (MNL) model is presented in Equation 2 below.

$$P_{nm} = Prob(U_{nm} > max_{m\prime \in C_n, m \neq m\prime}(U_{nm\prime})) \; = \; \frac{e^{\mu\beta_{nm}X_{nm}}}{\Sigma_{m' \in C_n} e^{\mu\beta_{nm'}X_{nm'}}}$$

A mixed logit model is an advanced form of the MNL, in which a specified set of coefficient estimates are estimated as mixed variables with a specified distribution. The mixed logit model thus enables representation of within-subject variation in taste preferences, which is well-suited to a choice experiment with repeated observations, as in the present study.

A total of N = 8,049 observations from 2,683 individual respondents were included in the DCA to produce a mixed logit mode choice model that predicts the preferred mode option of a particular traveler in a given trip context. The model was specified using a forward stepping procedure in which variables were successively added to the model and tested for a significant improvement to model fit using the log-likelihood ratio test.

Table 1Table 4 below lists the parameters tested during this process. Responses with null values for the model parameters were filtered from the dataset used to estimate the model at each iteration of the specification process.

Table 4. Candidate Parameters for Discrete Choice Model

Contextual Variables	Alternative-Specific Attributes	Individual Characteristics
Destination (trip purpose) Distance (miles)	Estimated wait time Estimated in-vehicle time Estimated cost	Gender Age Income

	Estimated driving cost - Scenario 1 Estimated driving cost - Scenario 2 Estimated driving cost - Scenario 3 Estimated RUC cost - Scenario 3	Education Race/Ethnicity Region Urban classification Number of vehicles Vehicle fuel type Estimated mode share

Survey Results

The following sections present the results and analysis of the general population survey, starting with an overview of the survey demographics in comparison with the population in each of the four regions surveyed. Next, respondents' baseline travel behavior and transportation expenditures are presented and analyzed, followed by their use of RC-related technologies and their attitudes and opinions on RC-related statements.

Survey Demographics

The distributions of gender, age, income, educational attainment, race/ethnicity, and urban classification of the survey sample (n=3,061) are presented in Table 5 - Table 9 alongside those of the ACS 2019 five-year population estimates. The demographic distributions of the survey sample disaggregated by distribution method (i.e., distributed via DMV offices or the Qualtrics platform) are presented in Table 12 in Appendix C. Demographic Distributions of Survey Responses by Distribution Method On a regional level, the distribution of responses in each of the four regions is close to that of the population of California, with 483 responses (16% of the sample) from Central California, 384 (13%) from Northern California, 567 (19%) from the San Francisco Bay Area, and 1,627 (53%) from Southern California. This distribution mirrors that of the California population over the age of 18, which has about 13%, 10%, 20%, and 56% living in Central California, Northern California, the San Francisco Bay Area, and Southern California, respectively.

Females are slightly overrepresented in the survey sample, across all regions surveyed. The portions of female respondents in Central and Southern California are about 8 and 7% greater than those of the population, respectively, while those of Northern California and the San Francisco Bay Area are about 5% and 4% greater. In both the Central and Northern California regions, the gender distributions of the samples collected via distribution at DMV offices were slightly more representative than those of the samples collected via distribution by Qualtrics.

Table 5. Distribution of Gender in the Survey Sample and ACS 2019 Five-Year Population Estimate

	Central California		Northern California		San Francisco Bay Area		Southern California	
Gender	Survey n=479	Population N=3,891,926	Survey n=380	Population N=3,172,166	Survey n=559	Population N=6,119,501	Survey n=1614	Population N=17,077,758
Female	58%	50%	54%	49%	53%	49%	56%	49%
Male	41%	50%	46%	51%	47%	51%	44%	51%
Other	1%	-	0%	-	1%	-	0%	-

People over the age of 64 are underrepresented, particularly in Central and Southern California. In Central and Southern California, people under the age of 35 are slightly overrepresented. The samples collected via distribution at DMV offices in both of these regions have significantly greater portions of respondents under the age of 35 years compared to those of the samples collected via distribution by the Qualtrics platform. In Northern California, the sample collected via distribution at DMV offices is more skewed toward the two oldest age groups.

Table 6. Distribution of Age in the Survey Sample and ACS 2019 Five-Year Population Estimate

Age (years)	Central California		Northern California		San Francisco Bay Area		Southern California	
	Survey n=477	Population N=3,891,926	Survey n=373	Population N=3,172,166	Survey n=558	Population N=6,119,501	Survey n=1,577	Population N=17,077,758
18 to 24	20%	15%	12%	12%	12%	10%	17%	13%
25 to 34	26%	19%	20%	18%	20%	20%	23%	20%
35 to 44	18%	17%	17%	16%	19%	18%	20%	17%
45 to 54	15%	16%	18%	16%	18%	17%	18%	17%
55 to 64	13%	15%	17%	17%	17%	16%	12%	15%
65 and over	7%	18%	17%	21%	14%	19%	9%	17%

The response rate of annual income was the lowest across all demographic questions, with about 4% of the final sample preferring not to provide their annual income. Across all regions, the survey sample underrepresents the highest income groups and slightly over-represents the lowest income groups. A greater portion of lower income respondents make up the survey sample collected via distribution at DMV offices compared to the sample collected by Qualtrics, with about 30 to 35% of the DMV sample earning under $25,000 annually compared to about 12% to 24% of the Qualtrics sample. There were also higher rates of respondents opting not to report their income in the DMV sample than in the Qualtrics sample.

Table 7. Distribution of Annual Income in the Survey Sample and ACS 2019 Five-Year Population Estimate

Income	Central California		Northern California		San Francisco Bay Area		Southern California	
	Survey n=460	Population N=1,666,772	Survey n=362	Population N=1,490,705	Survey n=546	Population N=2,730,920	Survey n=1,555	Population N=71,57,485
Under $25,000	27%	20%	21%	19%	14%	12%	13%	17%
$25,000 to $50,000	26%	22%	22%	21%	16%	13%	28%	19%
$50,000 to $100,000	32%	30%	35%	30%	24%	23%	34%	29%
$100,000 to $200,000	12%	22%	16%	23%	33%	30%	22%	25%
$200,000 or above	3%	7%	6%	7%	12%	22%	4%	11%

The survey sample slightly over-represents the lowest level of educational attainment and slightly underrepresents people with some college or associate's degree. In all regions except for Northern California, respondents with a high school diploma or less education made up greater portions of the DMV survey samples than of the Qualtrics samples. In contrast, respondents with a Bachelor's degree or higher made up a greater portion of the Northern California DMV sample than of the Qualtrics sample in that region.

Table 8. Distribution of Educational Attainment in the Survey Sample and ACS 2019 Five-Year Population Estimate

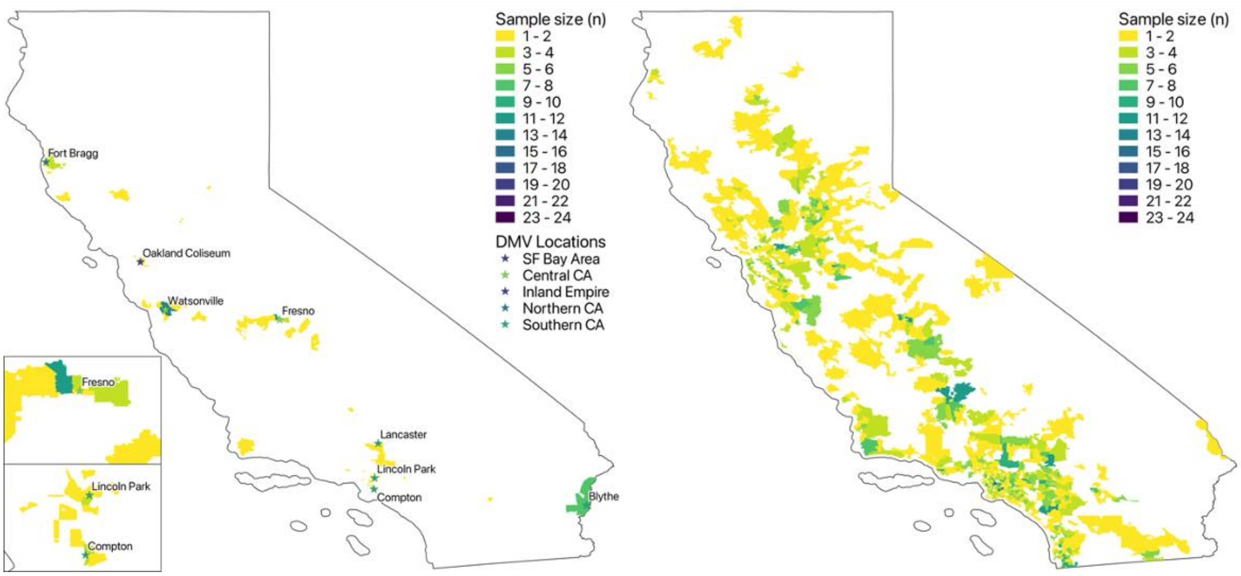
	Central California		Northern California		San Francisco Bay Area		Southern California	
Educational attainment	Survey n=466	Population N=3,891,926	Survey n=374	Population N=3,172,166	Survey n=557	Population N=6,119,501	Survey n=1,592	Population N=17,077,758
High school graduate or less	51%	46%	37%	37%	31%	28%	41%	39%
Some college or associate's degree	27%	34%	36%	37%	23%	27%	26%	31%
Bachelor's degree	15%	13%	19%	17%	27%	27%	23%	19%
Graduate or professional degree	7%	7%	9%	9%	20%	18%	9%	10%

The survey sample slightly underrepresents Californians that identify only as White, across all regions. The sample in Southern California also slightly over-represents Hispanics. The DMV samples in all regions except Northern California had significantly greater portions of Hispanics and smaller portions of Whites than did the Qualtrics samples. In all regions except for Central California the DMV samples also had significantly smaller portions of Asian respondents than did the Qualtrics samples.

Table 9. Distribution of Race/Ethnicity in the Survey Sample and ACS 2019 Five-Year Population Estimate

	Central California		Northern California		San Francisco Bay Area		Southern California	
Race/ Ethnicity	Survey n=475	Population N=5,299,216	Survey n=373	Population N=4,120,134	Survey n=563	Population N=7,710,026	Survey n=1,609	Population N=22,154,121
Hispanic	49%	49%	25%	24%	25%	24%	49%	45%
White alone	34%	37%	53%	56%	36%	39%	28%	33%
Black/ African American alone	5%	4%	5%	5%	7%	6%	6%	6%
Asian alone	7%	7%	10%	9%	27%	26%	12%	13%
Two/ more	2%	2%	5%	4%	3%	4%	3%	3%
Other	2%	1%	2%	2%	1%	1%	2%	1%

Note: the total population distributions are presented instead of only the population over 18 years.



a. DMV Sample (n=129) **b. Qualtrics Sample (n=2,879)**

Figure 3. Distribution of Respondents by Home Zip Code and Distribution Method

Figure 3 displays the distribution of respondents in the a) DMV and b) Qualtrics survey samples aggregated by home zip code, as reported in the survey. About 99% of respondents provided the zip code of their home address. The distribution of the survey sample across urban classifications is very similar to that of the 2019 ACS five-year population estimates (see Table 10 below). Across all regions except southern California, people in urban areas are slightly overrepresented while those in urban clusters are slightly underrepresented.

Table 10. Distribution of Urban Classification in the Survey Sample and ACS 2019 Five-Year Population Estimate

	Central California		**Northern California**		**San Francisco Bay Area**		**Southern California**	
Urban classification	Survey N=461	Population N=3,882,441	Survey N=376	Population N=3,176,467	Survey N=563	Population N=6,122,978	Survey N=1,608	Population N=17,071,481
Urban area	82%	79%	78%	74%	99%	98%	98%	98%
Urban cluster	15%	18%	16%	20%	1%	2%	2%	2%
Rural	3%	3%	5%	5%	0%	0%	0%	0%

Baseline Travel Behavior

This section characterizes a baseline of travel behavior in California in order to better understand the disparities in the existing cost burdens of road use as well as the potential impacts from the adoption of a mileage-based RC. Geographic and demographic trends were analyzed using respondents' self-reported travel profiles including the frequency, distance, and typical mode(s) used for each of seven common trip purposes. The frequency of use of delivery services and work from home rates before and during the COVID-19 pandemic were also analyzed to better understand the potential impacts of emerging trends in mobility on the cost burden of road users fees across the state. The average trip frequencies and distances by region and trip purpose are presented first, followed by a presentation of the key insights drawn from in-depth analyses of the distributions of total weekly VMT by trip purpose.

Intensity and Composition of Road Use

The following subsections describe different road use intensities and compositions by: trip frequency, travel distances, PMT, PMT by travel mode, and VMT.

Trip Frequency

The average weekly trip frequencies for each trip purpose and region surveyed are presented in Figure 4 below. Central and Southern Californians tend to travel more often than the other two regions surveyed. Most notably, Central and Southern Californians dine out (including pickup food) significantly more often than residents of Northern California and the San Francisco Bay Area. Northern Californians and Bay Area residents also make fewer trips to pick up/drop-off other people, go grocery shopping, and do other errands.

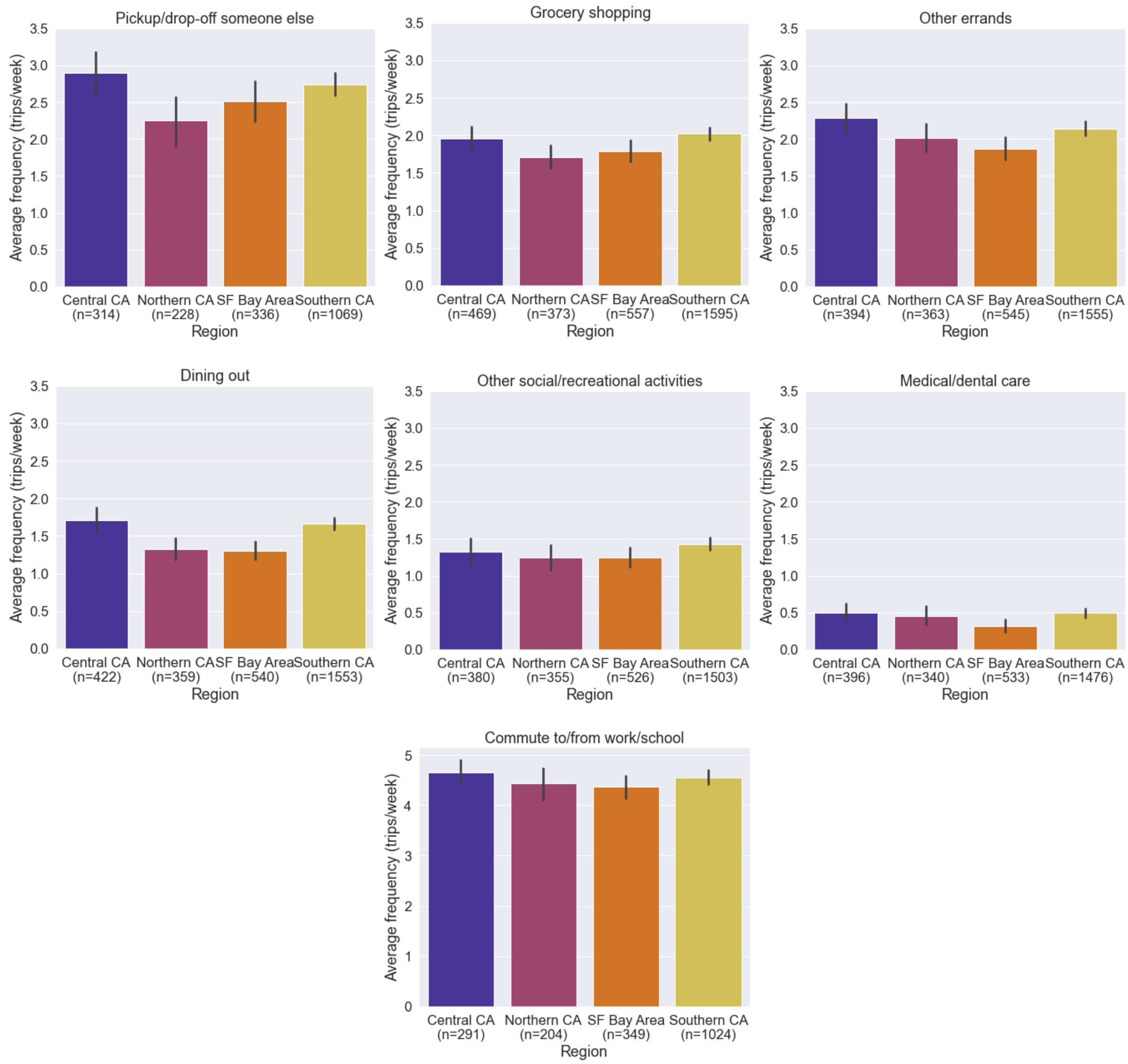


Figure 4. Average Weekly Trip Frequencies by Region and Trip Purpose

Note: The lines on each bar represent the 95th confidence intervals of the average.

Travel Distances

The average round-trip distances traveled for each trip purpose in each region, presented in Figure 5 below, reflect the differences in land use and urban form across the four regions surveyed. Residents of the two more heavily urban regions (SF Bay Area and Southern California) travel shorter distances, on average, than residents of the other two regions. In addition to traveling more often, Central Californians tend to travel farther distances, on average, than residents of the other three regions. However, residents of Northern California tend to travel similar distances as Central Californians for groceries, errands, dining out, and medical/dental care. However, when it comes to commuting to/from work/school, the average commute distances in Northern California are more similar to those of the SF Bay Area and Southern California than Central California.

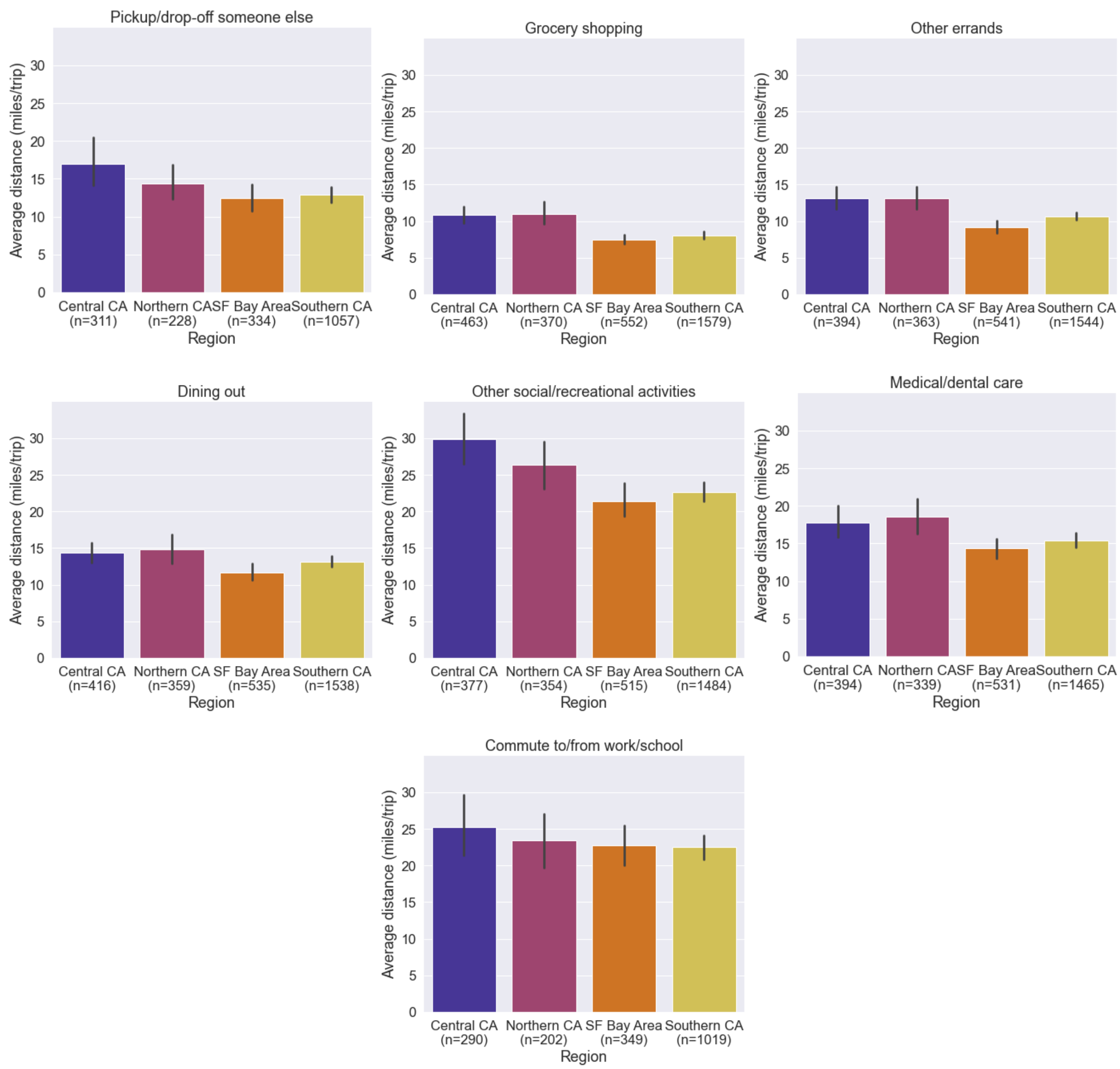
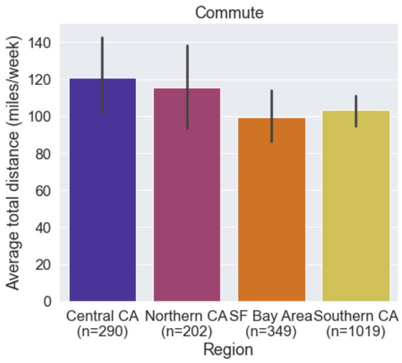


Figure 5. Average Trip Distances by Region and Trip Purpose

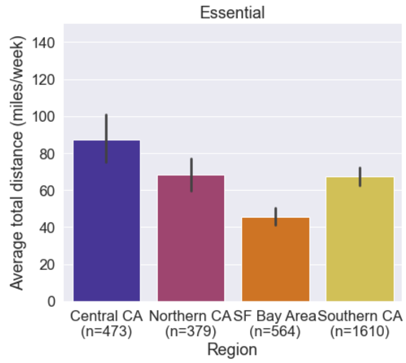
Note: The lines on each bar represent the 95th confidence intervals of the average.

Person Miles Traveled

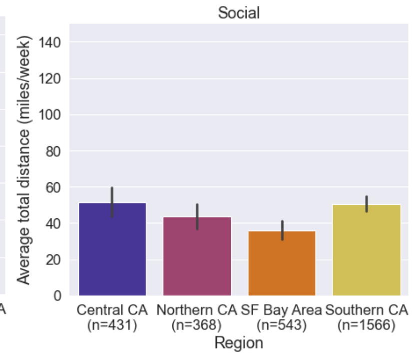
Figure 6 displays the average estimated total weekly PMT in each region for each of three groups of trip purposes: 1) Commute (commute to/from work/school), 2) Essential (pickup/drop-off someone else, grocery shopping, other errands, medical/dental care), and Social (dining out, other social/recreational activities). The average estimated total weekly PMT in each region across all trip purposes is also presented in the last subfigure. Among commuters, Central and Northern Californians have the greatest average PMT for work/school on a weekly basis. The average weekly PMT for essential and social trip purposes of residents of Central California and the San Francisco Bay Area are the greatest and least of all regions, respectively. In total across all trip purposes, including both commuters and non-commuters, Central Californians travel about 204 miles per week, on average, while Northern and Southern Californians travel about 173 and 180 miles per week, respectively, on average. Finally, residents of the San Francisco Bay Area travel a total of about 140 miles per week, on average.



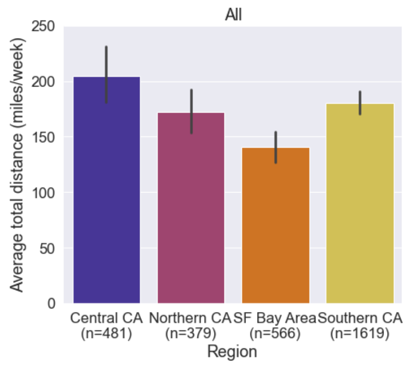
a) Commute trips



b) Essential trips



c) Social trips



d) All trips

Figure 6. Average Estimated Total Weekly Person Miles Traveled (PMT) by Region and Trip Purpose

Note: The lines on each bar represent the 95th confidence intervals of the average.

PMT by Travel Mode

Figure 7 presents the average total weekly PMT by trip purpose and typical modes of travel, as reported by respondents in each region. Driving alone and carpooling account for about 90% of total average PMT, across all regions, and about 94% of total average PMT in both Central and Northern CA, about 90% in Southern CA, and about 86% in the San Francisco Bay Area. Across all trip purposes, the total average miles driven (including carpools) is about 183, 154, 117, and 158 miles per week in Central California, Northern California, the San Francisco Bay Area, and Southern California, respectively. The average weekly VMT by driving and carpooling by residents of the San Francisco Bay Area is significantly lower than that of the other three regions for both essential ($p<0.0001$) and social trip purposes ($p<0.03$), while it is only slightly lower for commuting. Residents of Central California have the highest average weekly VMT across all trip purposes, although the differences with Northern and Southern California are not significant ($p=0.1$).

On average, about 2.8% of total weekly PMT is completed using TNCs (e.g., Uber, Lyft). Residents of the San Francisco Bay Area and Southern California have the highest rates of TNC use as a portion of total PMT, making up about 3.1% and 2.7% of total average weekly PMT in these regions, respectively. Although the average weekly PMT by TNCs is similar in Northern California (about

3.2%), there was a higher degree of variation across respondents from this region. Across all regions, there is a higher rate of TNC use as a percent of total PMT for *social* trip purposes (about 3.7%) compared to essential trip purposes (about 2.5%) and commuting (about 2.4%), which is generally supported by prior research. Active (i.e., walk, bike) modes of transportation make up about one to two percent of the total weekly average PMT across all regions, with San Francisco Bay Area residents exhibiting slightly greater rates of active transportation for essential and social trip purposes than all other regions. Finally, public transit modes (e.g., public bus, rail) make up about 2% to 3% percent of total average weekly PMT in Central and Northern California, about 5% in Southern California, and about 9% in the San Francisco Bay Area. Key differences are reflected in the significantly greater PMT by public transit for commuting in both Southern California and the San Francisco Bay Area as well as slightly higher VMT by public transit for social trip purposes in both of these regions.

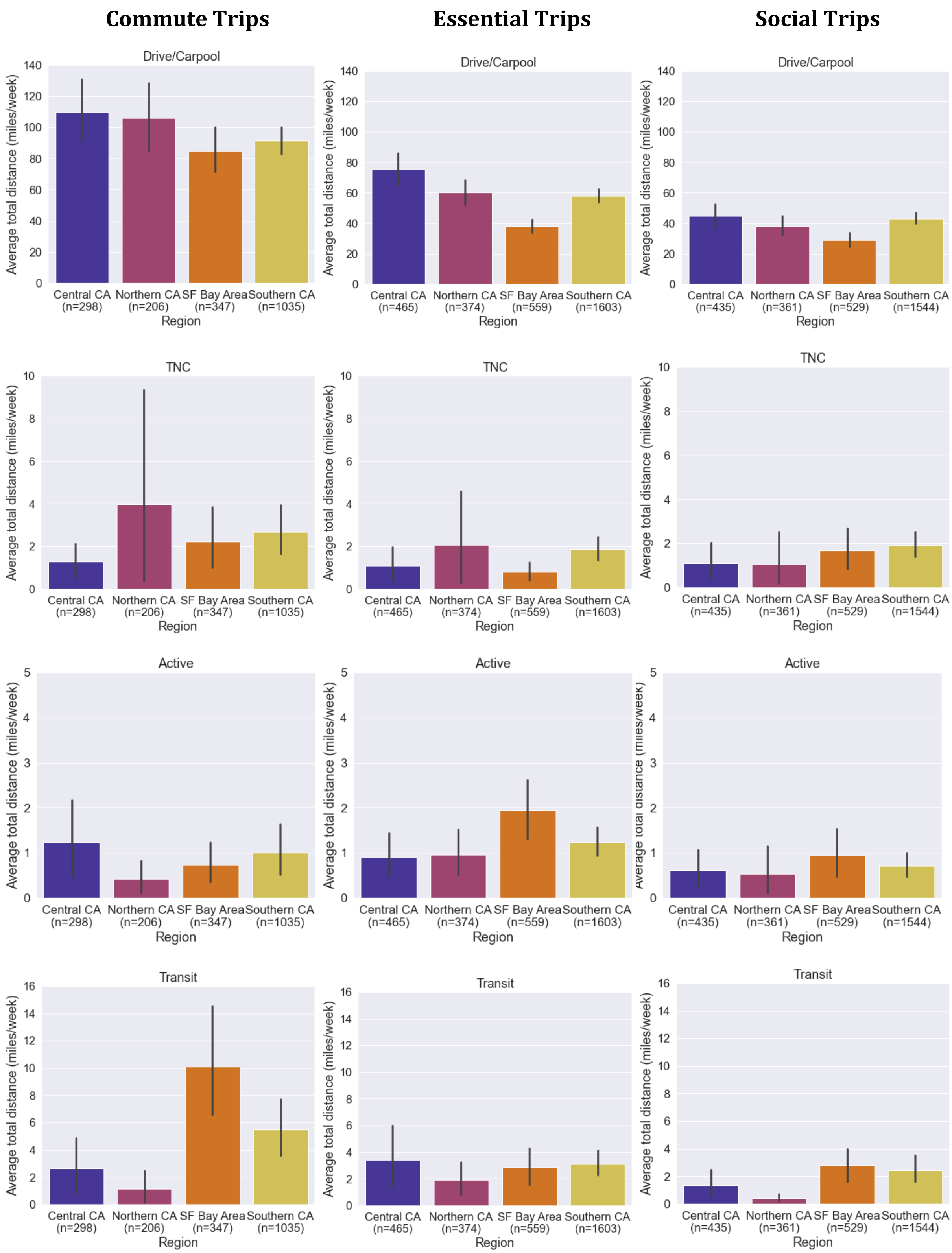


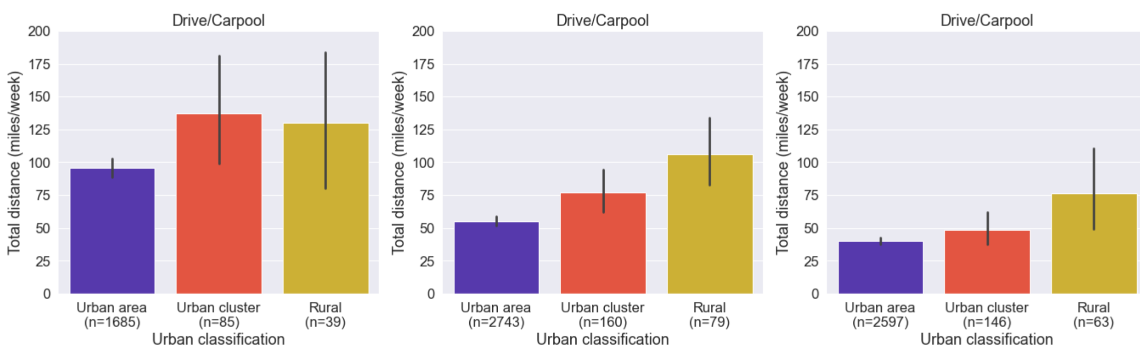
Figure 7. Average Estimated Total Weekly Person Miles Traveled (PMT) by Region, Mode, and Trip Purpose

Note: The lines on each bar represent the 95th confidence intervals of the average.

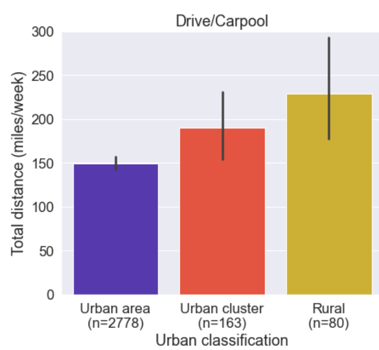
Vehicle Miles Traveled

The following discussion of results builds upon the regional characterization of the intensity and composition of road use with an examination of other key distinguishing factors, including urban form (i.e., urban area, urban cluster, rural) and key demographics (i.e., age, income, race/ethnicity, medical condition/mobility impairment, vehicle ownership, vehicle characteristics, etc.).

We begin the deep dive with an examination of the trends in average weekly VMT by driving and carpooling per resident by urban classification. The total average weekly VMT from drive/carpool among urban area residents (about 150 miles/week) is significantly less than that of urban cluster residents (about 190 miles/week; p=0.035) and of rural residents (about 229 miles/week; p=0.014), reflecting shorter travel distances in more densely populated areas of California. Although residents of rural areas have greater total average weekly VMT by driving/carpooling, the difference is not significant at the 90% confidence interval due to a relatively small sample size and high variance in the reported travel profiles of rural residents. The discrepancy is particularly notable for essential trip purposes, for which the average weekly VMT of rural residents is significantly greater than that of urban area residents (p=0.0003) and of urban cluster residents (p=0.062).



a) Commute trips **b) Essential trips** **c) Social trips**



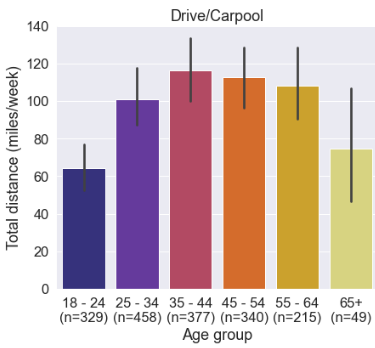
d) All trips

Figure 8. Average Estimated Total Weekly Drive/Carpool Vehicle Miles Traveled by Urban Classification and Trip Purpose

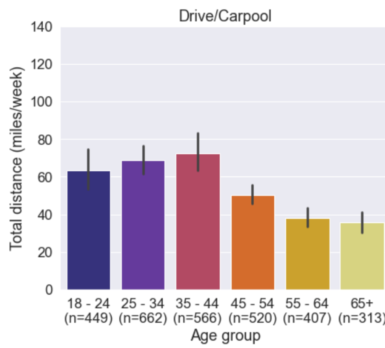
Note: The lines on each bar represent the 95th confidence intervals of the average.

While total average weekly VMT by driving/carpooling decreases with population density from rural to urban area, the total average weekly VMT by TNCs increases significantly from an average of about one mile per week among urban cluster and rural residents to about five miles per week among urban area residents.

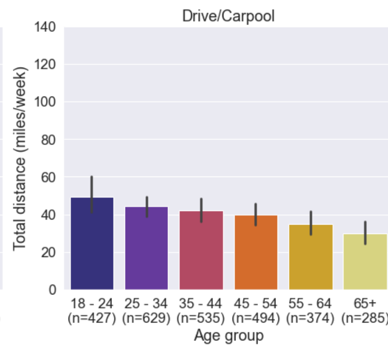
Age and household structure play an important role in determining the intensity of vehicle usage across Californians. The average drive/carpool VMT for commuting increases significantly with age, from about 64 miles/week among the youngest age group to about 116 miles/week among commuters aged 35 to 44 years. Average drive/carpool VMT for essential trip purposes increases slightly with age up to travelers aged 45 years (from about 63 to 73 miles/week) but decreases significantly (p<0.001) between the 35 to 44 and 45 to 55 age groups and continues decreasing among older age groups. Finally, average drive/carpool VMT for social trip purposes decreases slightly with age, though the differences in the average weekly VMT drive/carpool VMT across successive age groups are not statistically significant. Taking all trip purposes into account, average total drive/carpool VMT increases significantly with age from 18 to 44 and decreases significantly with age from 45 years and older.



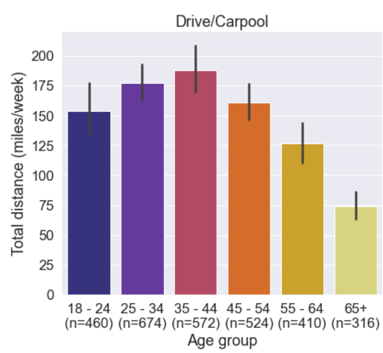
a) Commute trips



b) Essential trips



c) Social trips



d) All trips

Figure 9. Average Estimated Total Weekly Drive/Carpool Vehicle Miles Traveled by Age Group and Trip Purpose

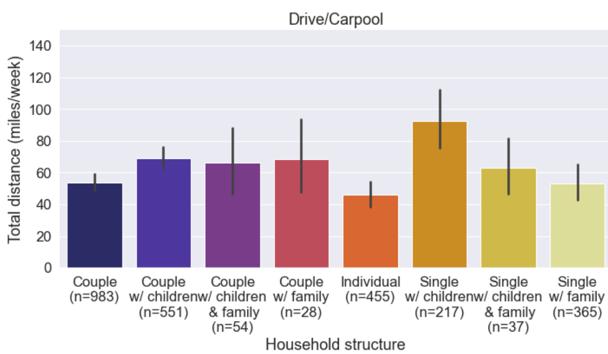
Note: The lines on each bar represent the 95th confidence intervals of the average.

Across all trip purposes, the average TNC VMT is highest among 25 to 34 year olds (average total of about 7 miles/week) and generally declines with age among subsequent age groups. While the rate of TNC use for commuting decreases steadily with age,[3] the differences in average commute VMT by

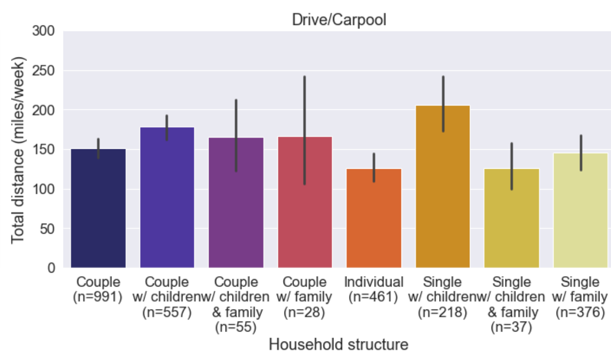
[3] About 7% of all respondents aged 18 to 24 reported using TNCs as a typical commute mode; about 6% of respondents aged 35 to 44, and 1% of respondents aged 55 to 64 did so.

TNCs across age groups are not statistically significant. TNC VMT for both essential and social trip purposes is significantly lower among travelers aged 55 years and older (about 0.6 and 0.8 miles/week for essential and social trips, respectively) compared to younger age groups (about 2.3 miles/week for each of essential and social trips).

Household structure is most strongly correlated with the total average weekly drive/carpool VMT for essential trip purposes, which include grocery shopping, other errands, and pickup/dropping off others. On average, single-parent households travel significantly greater distances by drive/carpool for essential trip purposes (about 92 miles/week) than every other household structure, with the exception of couples living with other family members (e.g., elderly, other relatives) (about 68 miles/week[4]). Households with some degree of co-parenting have the second-highest average weekly drive/carpool VMT, including couples with children (about 69 miles/week) and both single parents living with other family members and couples with children living with other family members (63 and 66 miles/week, respectively). The differences in average total VMT by drive/carpool across all trip purposes is displayed below. Single parent households drive/carpool the greatest total distance, with an average of about 206 miles/week. Couples living with children and/or family, all of which had higher than average employment rates, travel the next greatest distance (165 to 178 miles/week).



a) Essential trips



b) All trips

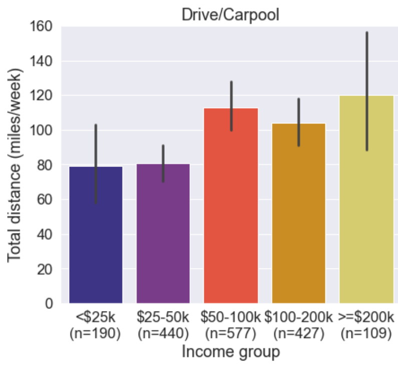
Figure 10. Average Estimated Total Weekly Drive/Carpool Vehicle Miles Traveled by Household Structure and Trip Purpose

Note: The lines on each bar represent the 95th confidence intervals of the average.

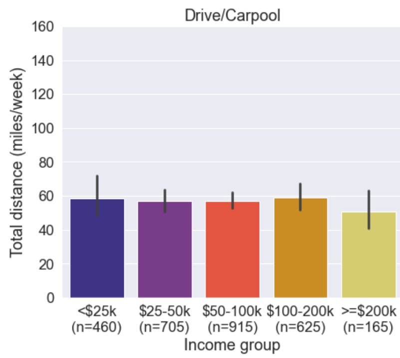
Average weekly VMT by drive/carpool increases slightly with annual income (see Figure 11 below), primarily due to significantly greater average weekly commute VMT by drive/carpool among higher income groups: about 110 miles/week among commuters earning $50,000 or greater compared to about 80 miles/week among those earning less than $50,000. On average, VMT by drive/carpool for essential trip purposes is slightly lower for the highest income group (earning $200,000 or more per year) while that of social trip purposes is slightly higher among the two highest income groups (earning $100,000 or more per year). However, these differences are not significant at the 90% confidence level. The discrepancies between income groups in the average total VMT by drive/carpool across all trip purposes are exacerbated by the employment rates across groups, with only about 41% of the lowest income group traveling for work/school

[4] The difference in average weekly VMT by drive/carpool between single parent households and couples with family is not significant (p=0.12).

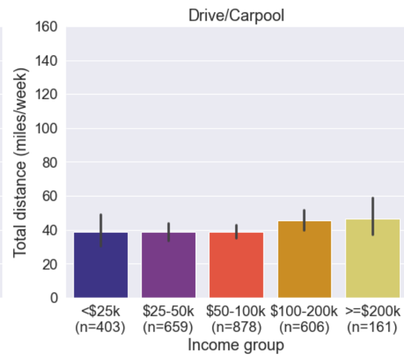
compared to about 62% and 67% of those earning between $25,000 and $100,000 and $100,000 or more, respectively.



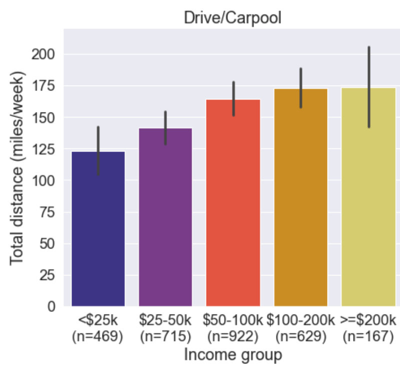
a) Commute trips



b) Essential trips



c) Social trips



d) All trips

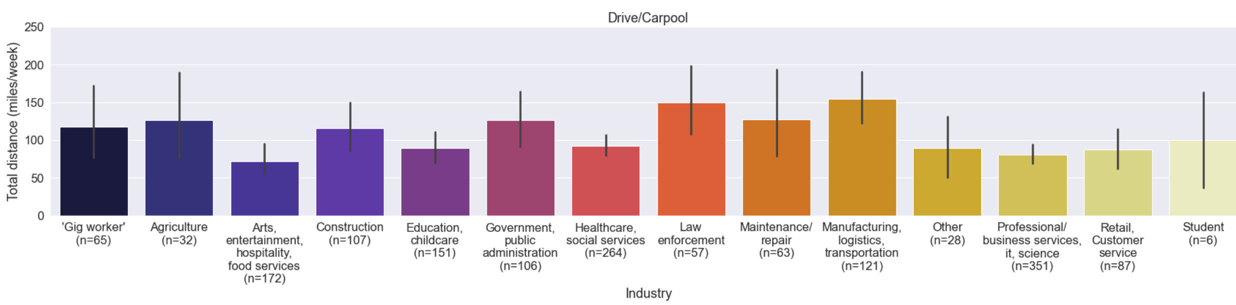
Figure 11. Average Estimated Total Weekly Drive/Carpool Vehicle Miles Traveled by Annual Income and Trip Purpose

Note: The lines on each bar represent the 95th confidence intervals of the average.

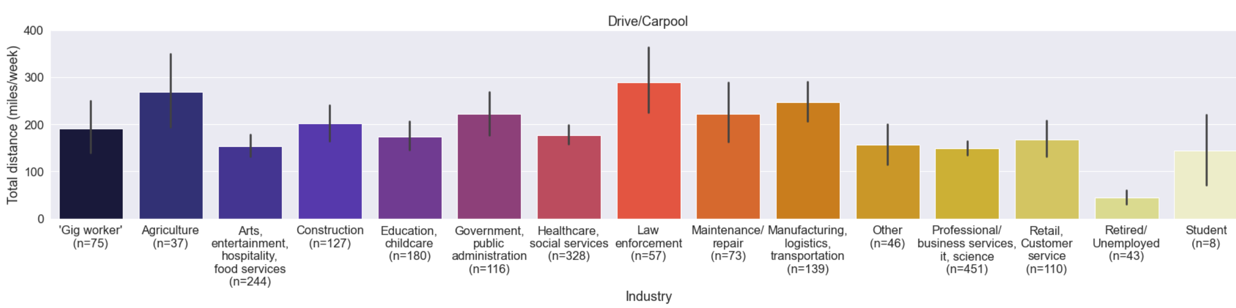
While the portion of each income group living in urban areas increases with income level, from 88% of those earning less than $25,000 living in urban areas to about 95% of those earning $200,000 or greater living in urban areas, the same trend of increasing VMT by drive/carpool with increasing income levels holds across urban classifications. Moreover, the differences in total average VMT by drive/carpool between urban areas and urban clusters/rural areas tend to increase with income level. On average, residents of urban clusters and rural areas earning $100,000 or more per year drive/carpool about 120 miles more per week than residents of urban areas earning as much. On the other hand, residents of urban clusters and rural areas earning less than $50,000 per year drive/carpool only about 34 miles more per week, on average, than residents of urban areas earning as much.

TNC VMT does not vary significantly across income groups in the survey sample, although there are a few notable trends. Across all trip purposes, the $25,000 to 50,000 income group has the greatest average TNC VMT (about six miles per week) while the highest income group has the lowest (about three miles per week). The lowest income group (earning less than $25,000 per year) has significantly lower average TNC VMT compared to the next group (earning $25,000 to 50,000 per year) for commuting and social trip purposes. However, for essential trip purposes, the two lowest income groups have about the same total average TNC VMT (about two miles/week), which is about one mile more than the average across higher income groups. This finding is consistent with prior research indicating that lower income groups are more likely to be heavy TNC users that use TNC for essential trip purposes (Lazarus, et al., 2021).

Californian's drive/carpool VMT varies notably across employment sectors (see Figure 12 below). Commuters employed in the manufacturing/logistics/transportation, law enforcement, and government/public administration sectors have significantly greater average weekly drive/carpool VMT (about 154, 149, and 126 miles per week, respectively) than commuters employed in arts/entertainment/hospitality/food services (about 72 miles per week; $p<0.02$), professional/business services/IT/sciences (about 81 miles per week; $p<0.03$), education/childcare (about 89 miles per week; $p<0.09$), healthcare/social services (about 92 miles per week; $p<0.09$), and retail/customer services (about 88 miles per week; $p<0.1$). This discrepancy is due to these sectors having both the longest commute distances (about 60 to 66 miles per day compared to the average of about 46 miles per day) and the highest commute frequencies, all of which averaged about five days per week or greater while the average across all Californians was about 4.5 days per week. On average, workers in the maintenance/repair sector also have similarly high commute distances (about 52 miles per day) and frequencies (about five days per week). However, the total average weekly commute drive/carpool VMT is not significantly greater than other sectors due to greater variance in the data for this group.



a) Commute trips



b) All trips

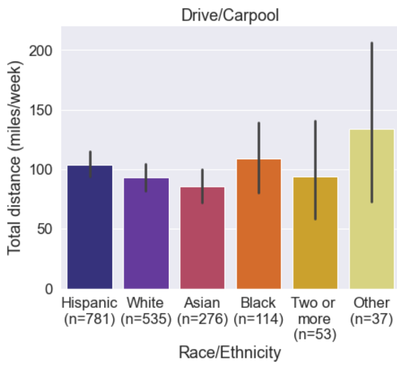
Figure 12. Average Estimated Total Weekly Drive/Carpool Vehicle Miles Traveled by Employment Industry and Trip Purpose

Note: The lines on each bar represent the 95th confidence intervals of the average.

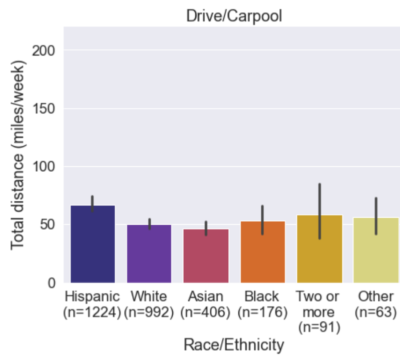
'Gig workers' (e.g., Uber and Lyft drivers), construction, and agriculture sector workers also had higher than average commute frequencies (about 5.1, 4.9 and 4.8 commute days per week, respectively). However, the average commute distances of these sectors were lower (about 47, 46, and 46 miles per week, respectively), resulting in middle-range average weekly drive/carpool commute VMT. The remaining sectors considered ‘essential’ during the COVID-19 pandemic, including education/childcare, healthcare/social services, and retail/customer service all had higher than average commute frequencies (about 4.8, 4.6, and 5.0 days per week, respectively), as expected. However, workers in these sectors tend to live closer to work, as reflected by shorter than average commute distances (about 37, 43, and 37 miles per week).

The differences across sectors in average drive/carpool commute VMT are generally reflected in the differences in average total drive/carpool VMT (including all trip purposes). Firstly, retired/unemployed drivers have significantly lower drive/carpool VMT due to the lack of commuting, as would be expected. Individuals employed in the arts/entertainment/hospitality/food services, education/childcare, healthcare/social services, professional/business services/IT/science, and retail/customer service sectors all travel significantly less distance by drive/carpool, on average, compared to those working in the agriculture ($p<0.05$), government/public administration ($p<0.1$), law enforcement ($p<0.005$), and manufacturing/logistics/transportation ($p<0.009$) sectors.

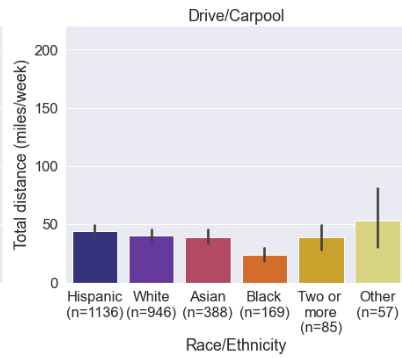
The relationship between race/ethnicity and drive/carpool VMT is relatively weak, although there are some notable discrepancies (see Figure 13 below). In general, Hispanic residents tend to travel greater VMT by drive/carpool (about 173 total miles per week), on average, compared to most other racial/ethnic groups. Of note, the average drive/carpool VMT by Hispanics for essential trip purposes (about 67 miles per week) is significantly greater than that of Asian (about 46 miles per week; $p<0.0001$), black (about 53 miles per week; $p=0.06$), and white (about 50 miles per week; $p<0.0001$) residents. Residents that identify as black have greater average drive/carpool VMT for commuting (about 109 miles per week), although the differences with other racial/ethnic groups are not statistically significant. Black residents have significantly less drive/carpool VMT for social trip purposes (about 23 miles per week), on average, compared to all other racial/ethnic groups ($p<0.04$).



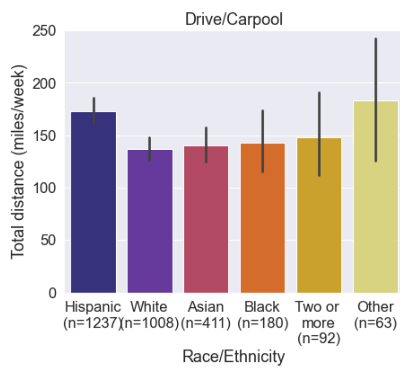
a) Commute trips



b) Essential trips



c) Social trips



d) All trips

Figure 13. Average Estimated Total Weekly Drive/Carpool Vehicle Miles Traveled by Race/Ethnicity and Trip Purpose

Note: The lines on each bar represent the 95th confidence intervals of the average.

Black and Hispanic residents travel the greatest distances by TNCs, on average, across all trip purposes. On average, black and Hispanic residents travel about 12 and six miles per week by TNCs, which is significantly more than the average weekly TNC VMT of white (about three miles per week; p<0.04) and Asian (about two miles per week; p<0.004) residents.

Developing Trends Shifting VMT

Next, we examine two developing trends in travel behavior: working from home and the use of delivery services (including grocery, restaurant, and package deliveries). Both behaviors represent potentially significant shifts in not only the quantity of VMT via personal vehicles but also the distribution of VMT across the population.

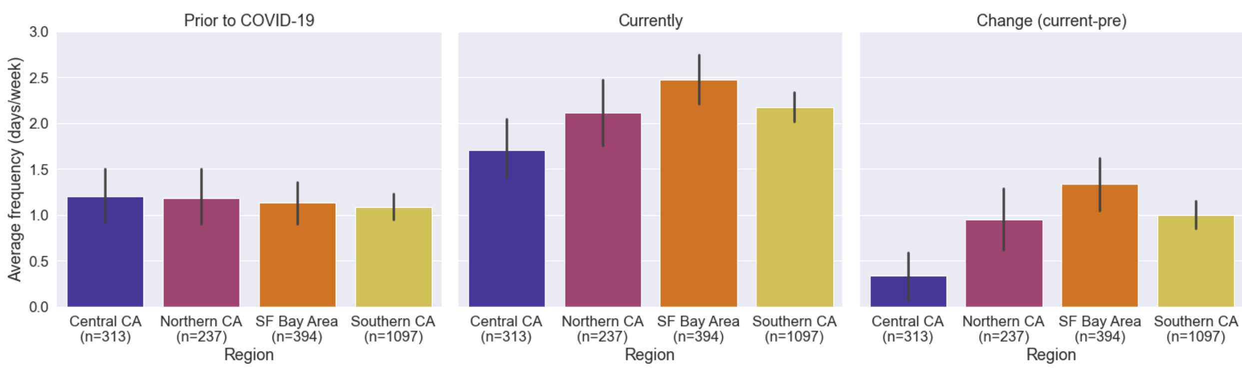
Work from Home Rates

Prior to the COVID-19 pandemic, about 29% of Californians worked from home one or more days per week: about 16% worked from home one to four days per week; about 14% worked from home five or more days per week. At the time of the survey, the portion of Californians working from home increased to about 51%, with about 23% working from home one to four days per week and about 28% working from home five or more days per week. These findings are supported by recent research that found that about half of Californians had worked from home in the period from

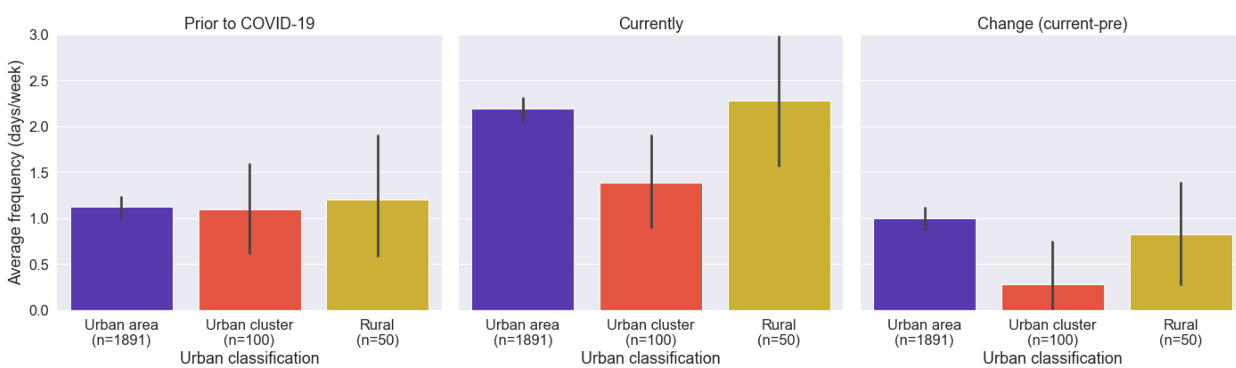
October 2020 to October 2021. The following figures present average work from home rates (in days per week) by various geographic and demographic groupings. The overall average work from rates prior to the pandemic and "currently" (at the time of the survey) were about 1.1 and 2.2 days per week, respectively.

The impact of the COVID-19 pandemic on work from home rates varies significantly by geography (see Figure 14 below). On average, work from home rates changed the least in Central California (+0.3 days/week) and in urban clusters (+0.3 days/week). Work from home rates during the pandemic were significantly higher, on average, in the San Francisco Bay Area (about 2.5 days/week; p=0.0005), Southern California (about 2.2 days/week; p=0.012), and Northern California (about 2.1 days/week; p=0.097) than in Central California (about 1.7 days/week). While Bay Area workers were most likely to have a fully remote work schedule with about 38% working from home five or more days per week and about 19% working from home one to four days per week, Southern Californians had the highest rate of partial work from home schedules, with about half of the 53% of respondents that were working from home doing so less than five days per week.

Employed residents of urban areas and rural areas had similar average work from home rates during the pandemic (about 2.2 and 2.3 days per week, respectively), resulting in average increases of about 1 and 0.8 days working from home per week, respectively. Urban area residents were the most likely to be working fully remote, with about 29% working from home five or more days per week.



a) Region



b) Urban classification

Figure 14. Average Work from Home Rates by Region and Urban Classification

Note: The lines on each bar represent the 95th confidence intervals of the average.

While there was no significant difference across age groups prior to the pandemic, work from home rates at the time of the survey generally increased with age, from an average of about 1.7 days per week among 18-24 year olds to about 2.4 days per week among those aged 55 or older (see Figure 15 below). This likely reflects the elevated risk factors in exposure to COVID among older workers. Work from home rates also increased significantly with income, from an average of about 1.9 days per week among the lowest income group (earning less than $25,000 annually) to about 3.1 days per week among the highest income group. While only about 38% of those in the lowest income group worked from home one or more days per week at the time of the survey, about 75% of those in the highest income group were doing so.

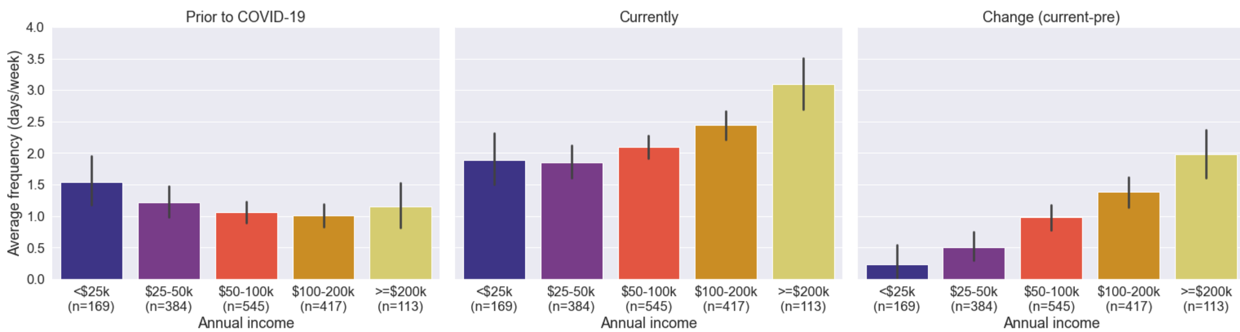


Figure 15. Average Work from Home Rates by Income

Note: The lines on each bar represent the 95th confidence intervals of the average.

The sectors that experienced the greatest change in work from home rates compared to before the pandemic include professional/business services/it/science (+2.0 days per week) and government/public administration (+1.4 days per week) (see Figure 16 below). While the former already had significantly higher average work from home rates compared to most other sectors prior to the pandemic (about 1.4 days per week; about 40% working from home 1+ days per week), the latter had one of the lowest work from home rates (about 0.7 days per week; about 20% working from home 1+ days per week). At the time of the survey about 79% of professional/business services/it/science workers were working from home one or more days per week and about 48% were doing so five days or more per week.

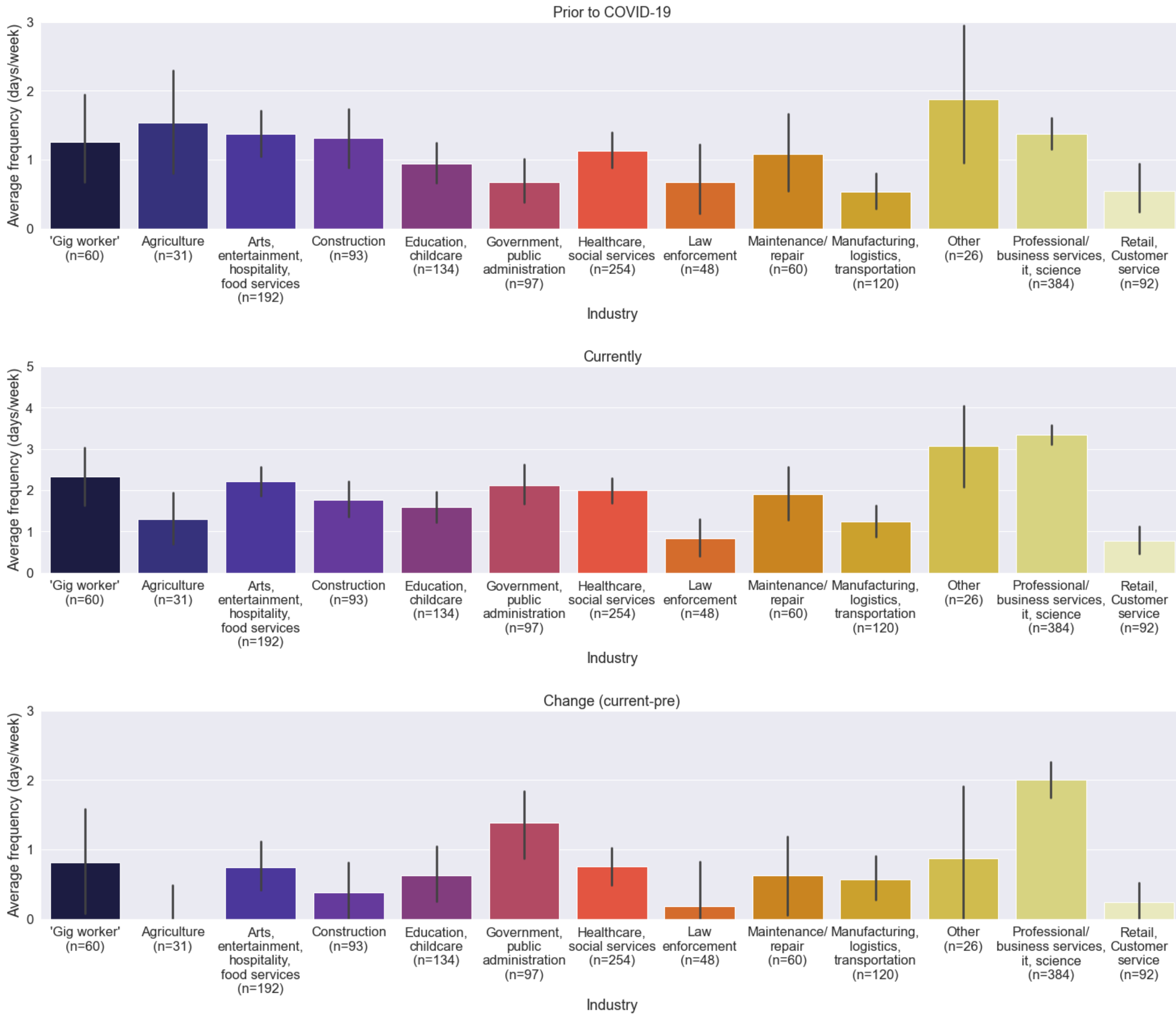


Figure 16. Average Work from Home Rates by Sector

Note: The lines on each bar represent the 95th confidence intervals of the average.

Unsurprisingly, work from home rates have a significant impact on total drive/carpool VMT, primarily due to the decrease in commute VMT (see Figure 17 below). People working from home three or more days per week drive/carpool a total of about 86 miles per week less, on average, compared to those working from home two or fewer days per week ($p<0.001$). People who work from home five or more days per week have slightly less drive/carpool VMT for essential (about 59 miles per week) and social (about 41 miles per week) trip purposes, on average, compared to those with lower work from home rates, but the differences are not statistically significant at the 90% confidence level.

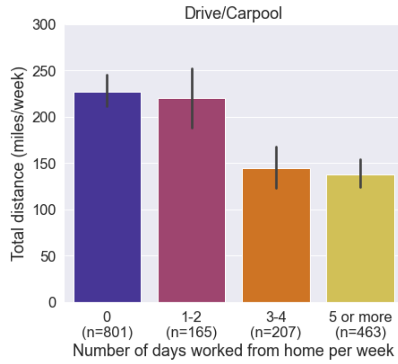
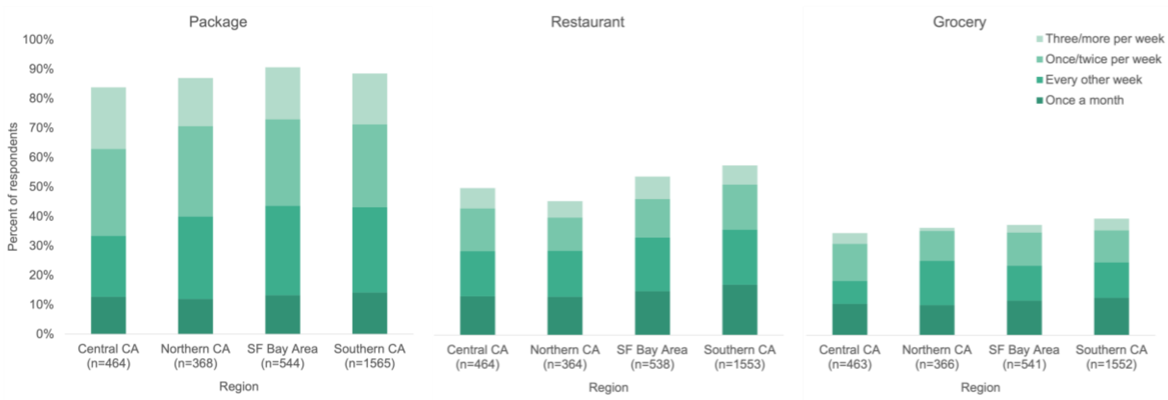


Figure 17. Average Estimated Total Weekly Drive/Carpool Vehicle Miles Traveled by Work from Home Rate

Note: The lines on each bar represent the 95th confidence intervals of the average.

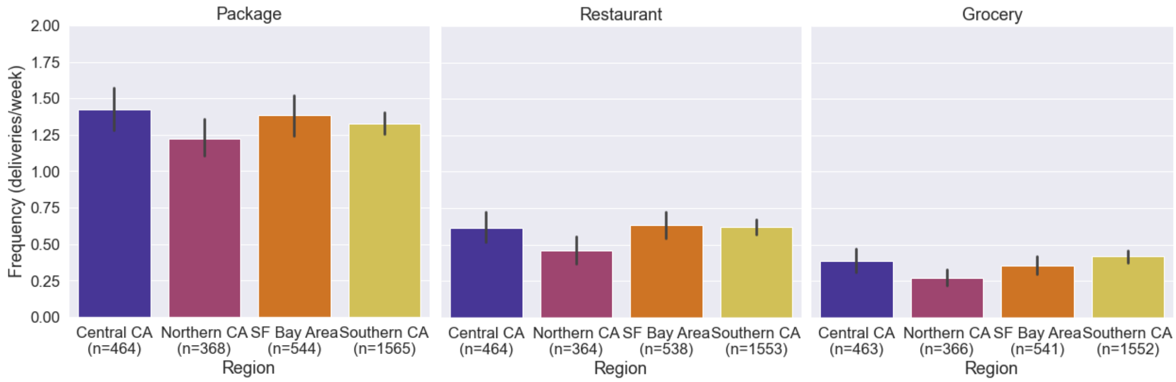
Delivery Services

At the time of the survey, about 38% and 54% of Californians were ordering grocery and restaurant delivery once a month or more, respectively. Package deliveries were far more common, with about 88% of Californians ordering package deliveries at least once a month and about 47% ordering package deliveries one or more times per week. The figures below present the distributions of delivery frequencies of these three types (package, restaurant, and grocery) by various geographic and demographic dimensions. As displayed in Figure 18 below, there is not a lot of variation in the frequency of use of delivery services across regions. Across all three types of delivery services, the San Francisco Bay Area and Southern California have slightly higher proportions of residents getting one or more deliveries per month compared to the other two regions. In average terms, Northern CA residents receive significantly fewer deliveries per week, across all delivery types, as displayed in Figure 19 below.



a) Package delivery **b) Restaurant delivery** **c) Grocery delivery**

Figure 18. Distribution of Delivery Frequency by Delivery Type and Region

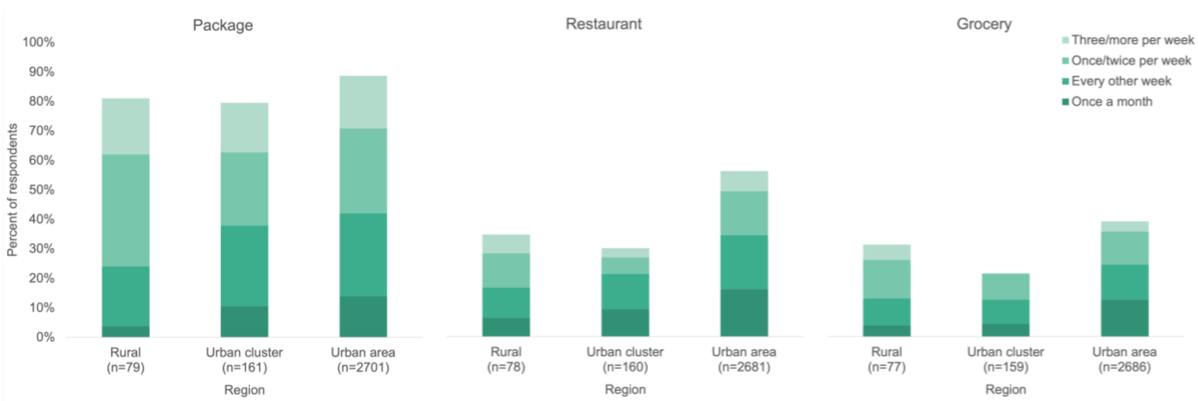


a) Package delivery **b) Restaurant delivery** **c) Grocery delivery**

Figure 19. Average Delivery Frequency by Delivery Type and Region

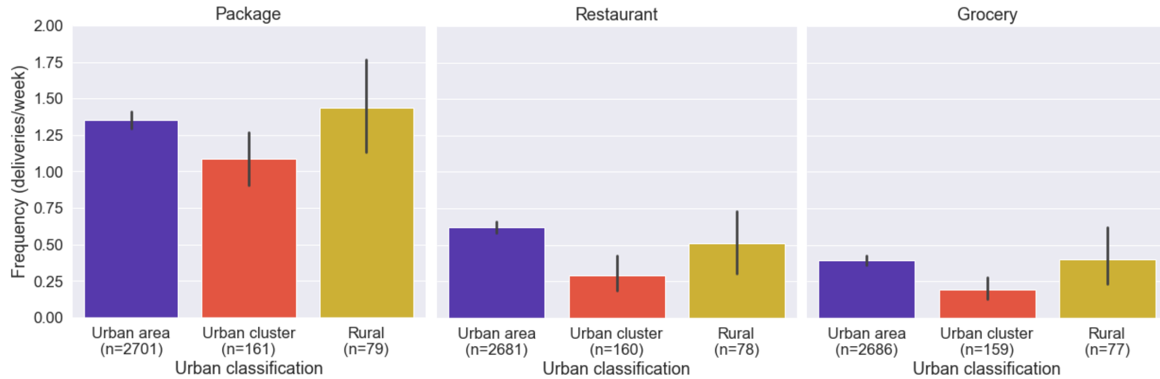
Note: The lines on each bar represent the 95th confidence intervals of the average.

Geographic differences in the use of delivery services are more notable across urban classification, as displayed in Figure 20 below. While urban areas have the greatest portion of residents using package delivery services once a month or more (about 89%), rural areas actually have the greatest portion of weekly package deliveries, with about 57% of rural residents receiving one or more package deliveries per week compared to about 42% and 47% of urban cluster and urban area residents, respectively. On average, urban clusters have significantly lower frequencies of deliveries across all three service types. Urban cluster residents get grocery and restaurant deliveries about half as often as urban area and rural residents, on average.



a) Package delivery **b) Restaurant delivery** **c) Grocery delivery**

Figure 20. Distribution of Delivery Frequency by Delivery Type and Urban Classification

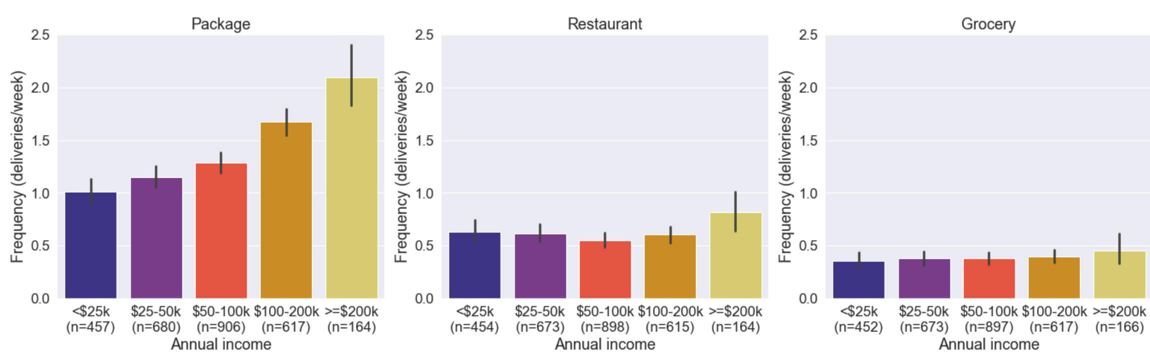


a) Package delivery **b) Restaurant delivery** **c) Grocery delivery**

Figure 21. Average Delivery Frequency by Delivery Type and Region

Note: The lines on each bar represent the 95th confidence intervals of the average.

Across socio-demographic variables, the frequency of use of delivery services is most strongly related to income and age. In particular, the portion of people receiving one or more packages per week increases significantly with increasing income levels, from about 36% of the lowest income group to about 68% of the highest income group. This is reflected in the significant increases in the average number of package deliveries per week with increasing income levels displayed in Figure 22 below. There is little difference in the frequency of restaurant deliveries across the four lowest income groups, all of which average about 0.6 deliveries per week, or about one restaurant delivery every other week. The average frequency of restaurant deliveries among the highest income group is significantly higher, though slightly so, at about 0.8 deliveries per week, or about three restaurant deliveries per month. While there is no significant difference in the average frequency of grocery deliveries across income groups, the highest income group has a slightly higher portion of people ordering grocery deliveries every other week or one to two times per week compared to the lower income groups.



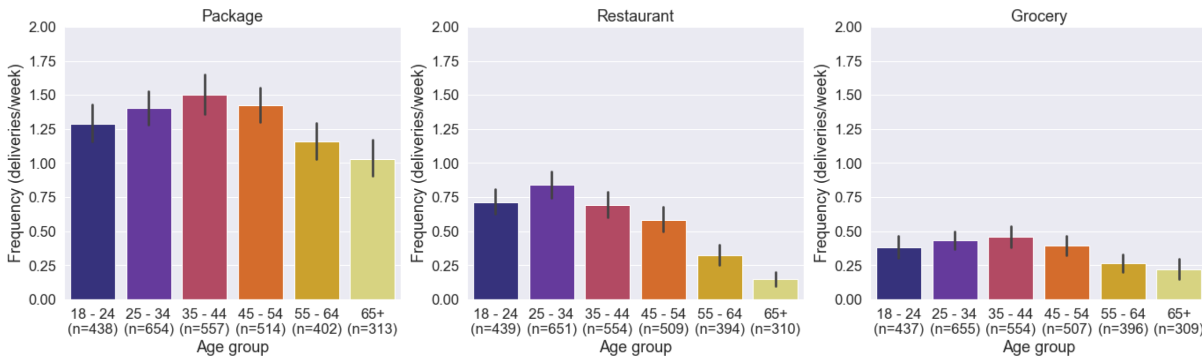
a) Package delivery **b) Restaurant delivery** **c) Grocery delivery**

Figure 22. Average Delivery Frequency by Delivery Type and Annual Income

Note: The lines on each bar represent the 95th confidence intervals of the average.

Across all delivery types, the eldest two age groups (55 and older) have the lowest delivery frequencies while the middle age groups (from 25 to 54 years old) tend to have the highest. About half of people aged 25 to 54 years order package deliveries once or more per week, compared to about 45% of and 42% of people aged 18 to 24 years and 55 to 64 years, respectively, and about

36% of people aged 65 years or older. Grocery delivery frequencies were highest among 25 to 44 year olds, about 31% of whom order two or more grocery deliveries per month while about 28% and 25% of 18 to 24 and 45 to 54 year olds, respectively, and about 16% of people 55 years or older order grocery deliveries as often. The trends in restaurant delivery skew a bit younger, with 25 to 34 year olds having the greatest restaurant delivery frequencies. About 30% of 25 to 34 year olds get one or more restaurant deliveries per week, compared to about 26% and 24% of 18 to 24 and 35 to 44 year olds, respectively, 20% of 45 to 44 years olds and just 8% of people 55 years or older.



a) Package delivery **b) Restaurant delivery** **c) Grocery delivery**

Figure 23. Average Delivery Frequency by Delivery Type and Age Group

Note: The lines on each bar represent the 95th confidence intervals of the average.

While zero-vehicle households have higher frequencies of restaurant and grocery deliveries than households with one or more vehicles, package delivery frequencies increase significantly with increasing numbers of household vehicles. The latter trend is likely a reflection of the correlation between income and vehicle ownership (Pearson's r = 0.34). Finally, we observe that people with a medical condition/handicap have significantly greater grocery delivery frequencies (p=0.008) compared to those who do not. However, there are no significant differences in the frequencies of restaurant or package deliveries across people with and without a medical condition/handicap.

Baseline Transportation Expenditure

This section begins by noting the distributions of vehicle ownership across the survey sample. About 97% of respondents responded to questions about the vehicle(s) they own/lease, or lack thereof. Following the analysis of vehicle ownership trends, the distribution of fuel efficiency and the combustion type of vehicles in the sample will be discussed, noting key disparities in gas and diesel consumption and the cost burden of fuel excise taxes across Californians.

Vehicle Ownership

About 86% of respondents reported owning or leasing one or more vehicles, with some variation in vehicle ownership rates across geographies. The San Francisco Bay Area and Northern California had slightly lower vehicle ownership rates, at 83% and 85%, respectively, compared to Southern and Central California, in which about 87% and 88% of residents own/lease one/more vehicles. Vehicle ownership rates also varied across the degree of urbanization where respondents lived, with urban cluster residents having the highest vehicle ownership rates, at 89% (about 47% owned/leased one vehicle and about 43% owned/lease two or more vehicles), and rural residents having the lowest vehicle ownership rates, at 80% (about 38% owned/leased one vehicle and about 43% owned/lease two or more vehicles). While about 53% of urban area residents owned/leased one vehicle, only 33% owned/leased two or more.

Vehicle ownership rates increase with income and age, as do the rates of ownership of two/more vehicles per household. Only about two-thirds of respondents earning less than $25,000 annually own/lease one or more vehicles (13% own/lease two or more). The vehicle ownership rate increases significantly to 84% owning/leasing one or more vehicles (24% own/lease two or more) in the next income group and continues to increase steadily with increasing income, with about 91%, 96%, and 99% of respondents earning $50,000 to $100,000, $100,000 to $200,000, and $200,000 or more, respectively, owning one or more vehicles (about 36%, 51%, and 61% earn two or more, respectively). Similarly, only about 69% of respondents aged 18 to 24 years own/lease one or more vehicles (20% own/lease two or more) - significantly less than 25 to 34 year olds, 86% of which own/lease one or more vehicles (about 25% own/lease two or more). Vehicle ownership rates continue to increase with age, up to 95% of respondents aged 65 years or older (42% own/lease two or more vehicles).

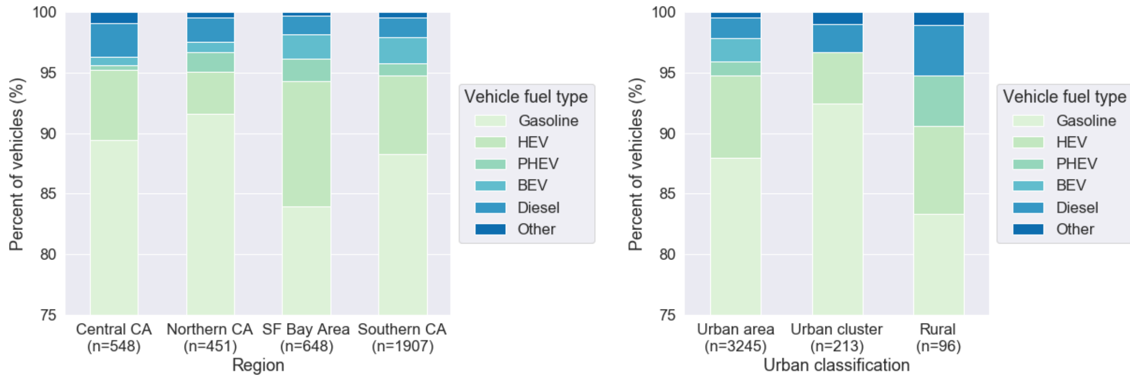
Across race/ethnicity, vehicle ownership is highest among white and Asian residents, about 89% and 90% of whom own one or more vehicles, respectively. Black and Hispanic residents have significantly lower vehicle ownership rates, at about 78% and 83%, respectively. Moreover, black and Hispanic residents are significantly less likely than white and Asian residents to own two or more vehicles, with about 20% and 29% owning two or more vehicles, respectively, compared to 37% of Asian residents and 39% of white residents.

Finally, as may be expected, vehicle ownership is significantly higher among households with children (about 96% of couples with children and about 87% of singles with children) than in those without (about 91% of couples without children and about 77% of individuals).

Vehicle Fuel Type and Fuel Consumption

Next, we turn our attention to the distribution of vehicle combustion types and fuel economy across California vehicle owners. Overall, about 90% of the vehicles reported in the survey were internal combustion engine (ICE) vehicles, with about 88% being fueled by gasoline and 2% by diesel. About 10% of vehicles were hybrid electric or fully electric, with about 7% being hybrid electric (HEV), 1% being plug-in hybrid electric (PHEV), and about 2% being fully battery-powered electric vehicles (BEV). We note here that respondents were only asked to report the two most frequently used vehicles in their household. Thus, the following analysis of the distribution of vehicle fuel types and average vehicle fuel consumption rates across the California fleet is slightly skewed toward households' two primary vehicles.

Figure 24 a) below displays the distribution of vehicle fuel types by region, showing that the San Francisco Bay Area had a significantly lower portion of ICE vehicles (about 84% of vehicles reported were gasoline-powered and about 2% were diesel-powered) compared to the other three regions in California. Central and Northern California had the highest portions of diesel-powered vehicles, at about 3% and 2% of the vehicles reported in those regions, respectively. Hybrid vehicles were most prevalent in the San Francisco Bay Area where HEVs and PHEVs made up about 10% and 2%, respectively, of the vehicles reported. Finally, BEVs were most prevalent in the San Francisco Bay Area and Southern California, at about 2% of the vehicles reported, whereas only about 1% of the vehicles reported in Central and Southern California were BEVs.

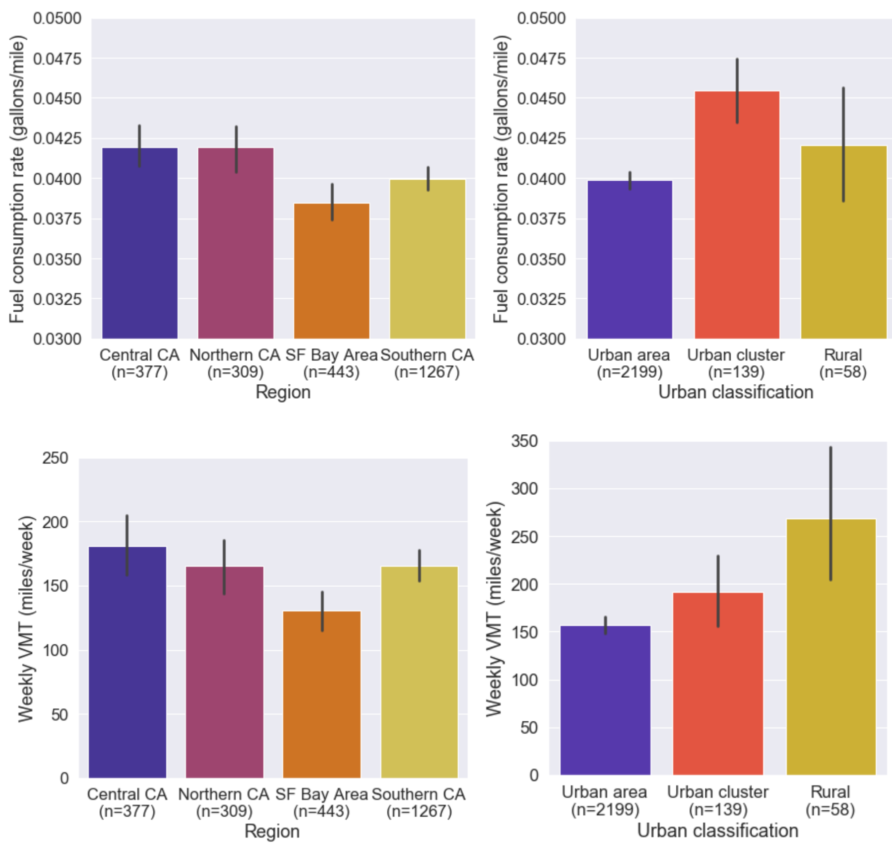


a) Region **b) Urban classification**

Figure 24. Distribution of vehicle fuel type by geography

In Figure 24 b), the distribution of vehicle fuel types by urban classification of respondents' home zip codes is displayed, revealing that the portion of ICE vehicles among urban cluster residents' vehicles is the greatest across urban classification, with about gasoline- and diesel-powered vehicles making up about 92% and 2% of urban cluster vehicles, respectively. Only about 4% of vehicles owned/leased by urban residents are HEV, and no PHEVs or BEVs were reported among those respondents. On the other hand, rural residents have the greatest portion of vehicles owned/leased that are HEV or PHEV, with about 7% and 4% of vehicles, respectively. About 7% of vehicles owned by urban area residents were HEVs, 1% were PHEVs, and 2% were BEVs. All the BEVs reported in this survey belonged to urban area residents.

The resulting average fuel consumption rates by region and urban classification are displayed in the top row of Figure 25 below, where we observe that San Francisco Bay Area and urban area drivers have lower fuel consumption rates, on average, compared to other drivers in the state. Southern California residents have lower fuel consumption rates, on average, compared to Central and Northern California residents, where average fuel consumption rates are about the same. Across regions, urban cluster residents have significantly higher fuel consumption rates than either rural or urban area residents, reflecting the relatively high ownership rates of ICE vehicles in urban clusters. The majority of urban cluster vehicle owners reside in the Central and Northern CA regions, making up about 15% and 17% of the vehicle owners in those regions, respectively. As is true of the overall population, the rural residents in these two regions have lower fuel consumption rates compared to their urban cluster counterparts, at about 0.044 and 0.042 gallons per mile, respectively, among rural residents in Central and Northern CA and about 0.045 and 0.046 gallons per mile, respectively, among urban cluster residents. Across all regions except for Southern California, urban area residents have the lowest fuel consumption rates, at about 0.041 gallons per mile among those living in Central and Northern CA, about 0.038 and 0.040 miles per gallon among those living in the San Francisco Bay Area and Southern CA, respectively. Notably, the 1% of Southern Californian vehicle owners living in rural areas have the lowest fuel consumption rates of the region, at about 0.037 gallons per mile.



a) Region **b) Urban classification**

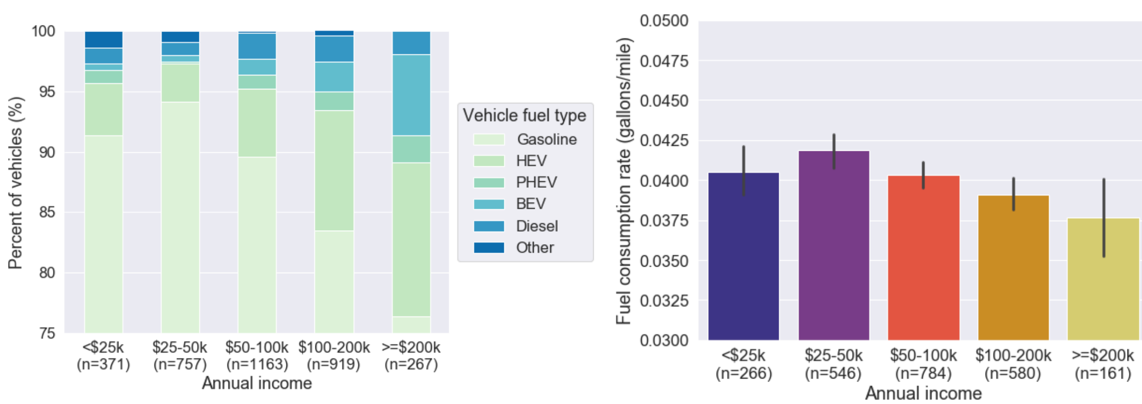
Figure 25. Average Gasoline/Diesel Consumption Rates and Weekly VMT per Driver by Geography

Note: lines on graphs represent the 95% confidence interval of the estimated means

While urban cluster road users may have the greatest per-mile fuel tax costs, on average, due to significantly worse fuel economy, rural road users are traveling significantly greater distances on a regular basis, as displayed in the bottom row of Figure 25 above. Thus, while they may pay less fuel taxes per mile driven, rural road users are paying significantly greater sums of fuel taxes, as they consume an average of about 14.5 gallons per week, on average, compared to about 9.9 and 7.5 gallons per week consumed by the average urban cluster and urban area road user, respectively. At the current gas excise tax rate of $0.539/gallon, rural road users are paying an average of $7.80 per week in gas taxes while urban cluster and area residents are paying about $4.07 and $5.35 per week, respectively. While a RUC may reduce the amount paid by drivers of less fuel efficient vehicles relative to the amount paid under the fuel tax, drivers in rural areas and urban clusters will continue to pay more per capita due to land use and overall transportation network design factors that lead not only to a greater reliance on private vehicles, but also greater trip distances in comparison to urban areas in the state.

Next, we consider vertical equity concerns by examining the distributions of fuel consumption rates and weekly VMT across socio-demographic characteristics both across the state and within specific geographies.

Vehicle fuel economy generally increases with income, with the exception of the lowest income group, which has about the same fuel economy, on average, as those earning $50,000 to $100,000 annually. Figure 26 below displays the distributions of vehicle type and average fuel consumption rates by income groups. People earning annual income between $25,000 and $50,000 have the worst fuel economy at about 0.042 gallons per mile on average (equivalent to about 24 miles per gallon), as well as the highest rate of ICE ownership at about 94% and 1.1% of vehicles being gas- and diesel-powered, respectively. The rate of hybrid and electric vehicle ownership increases with income from the $25,000 to $50,000 income group onward, resulting in significantly lower fuel consumption rates in successive income groups. The highest two income groups (earning $100,000 to $200,000 and $200,000 or more annually) have significantly higher rates of BEV ownership, at about 3% and 7% of vehicles, respectively, compared to all other income groups, as well as the highest rates of HEV (about 10% and 13%, respectively) and PHEV (about 1.5% and 2.2%, respectively) ownership. This results in significantly lower fuel consumption rates, on average, at about 0.039 and 0.038 gallons per mile, respectively (equivalent to about 26 and 27 miles per gallon, respectively).

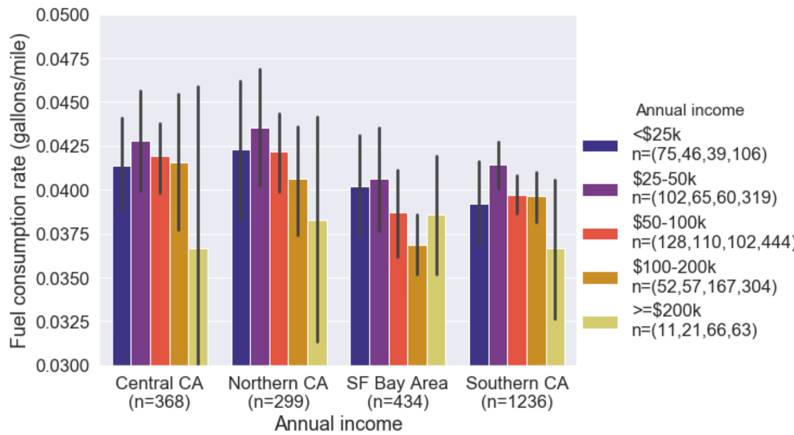


a) Vehicle fuel type **b) Fuel consumption rate**

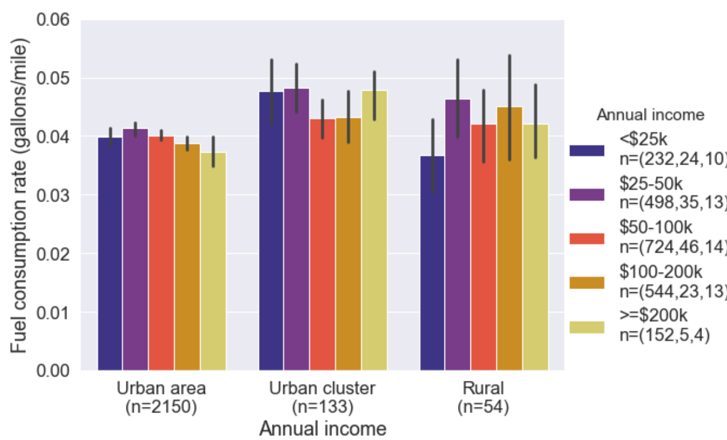
Figure 26. Distributions of Vehicle Fuel Type and Average Gasoline/Diesel Consumption Rates by Annual Income

Note: lines on graphs represent the 95% confidence interval of the estimated means

The observed overall trend in vehicle fuel efficiency across income groups is primarily influenced by vehicle ownership in urban areas, where over 90% of the sample lives. Figure 27 below displays the distributions of average fuel consumption rates by and annual income. The small sample sizes of urban cluster and rural residents in any particular income group are relatively small, resulting in insignificant differences in the mean fuel consumption rates. However, we observe that in urban clusters, the average fuel consumption rate of the highest income group is more similar to that of the lowest income groups. In addition, as displayed in Figure 27 a), the highest income group in the San Francisco Bay Area actually has a slightly higher average fuel consumption rate than the preceding income group, whereas the highest income groups in all other regions have the lowest average fuel consumption rates.



a) Region

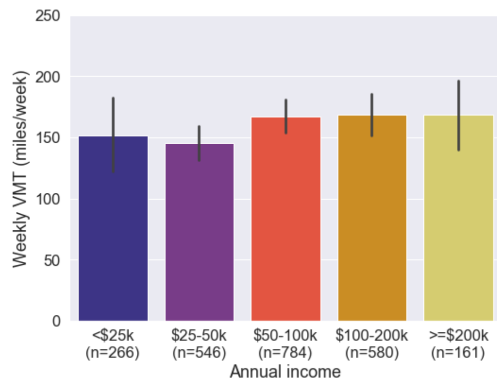


b) Urban classification

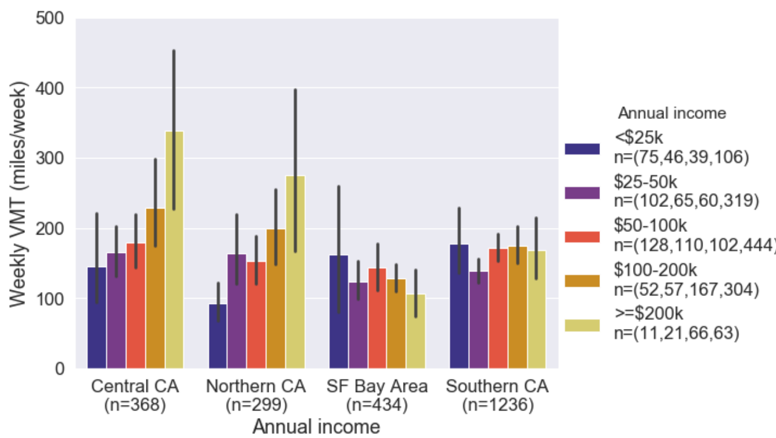
Figure 27. Average Gasoline/Diesel Consumption Rates per Driver by Income and Geography

Note: lines on graphs represent the 95% confidence interval of the estimated means.

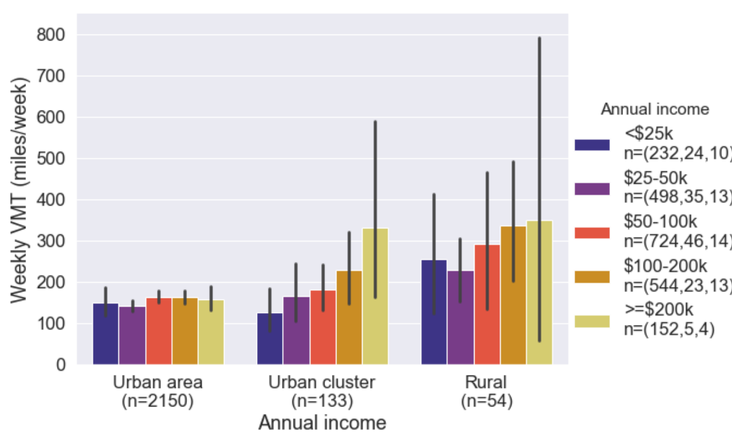
Overall, average weekly VMT does not vary significantly across income groups, with the exception that the $25,000 to $50,000 income group drives significantly fewer miles per driver, on average, compared to the $50,000 to $100,000 and $100,000 to $200,000 income groups. Again, these trends are heavily influenced by the behavior of urban area residents, as reflected by Figure 28c below. While the differences in average weekly VMT across income groups in urban clusters and rural areas are generally not statistically significant due to small sample sizes, we see a slight increasing trend with respect to income in both of these urban classification types. This likely reflects discrepancies in commute distances of urban cluster drivers wherein higher wage earners commute into the urban core and lower wage earners tend to work in more local jobs such as retail, customer service, and education. In Central and Northern CA, where about 15% and 17% of the sample size live in urban clusters (compared to only about 2% of the other two regions), there are significant differences in average weekly VMT across income groups. The highest income group (earning $200,000 or more annually) in these two regions drives significantly more, on average, than the lowest three income groups (earning less than $100,000 annually). In Central CA, the next highest income group also drives significantly more, on average, than the lowest two income groups. In the SF Bay Area, there appears to be a slight decrease in average weekly VMT as income increases, although the differences are not significant. This could explain why the average fuel economy of higher income Bay Area residents is worse relative to other residents of the same region: shorter commute distances may reduce the cost burden of driving.



a) Overall



b) By region



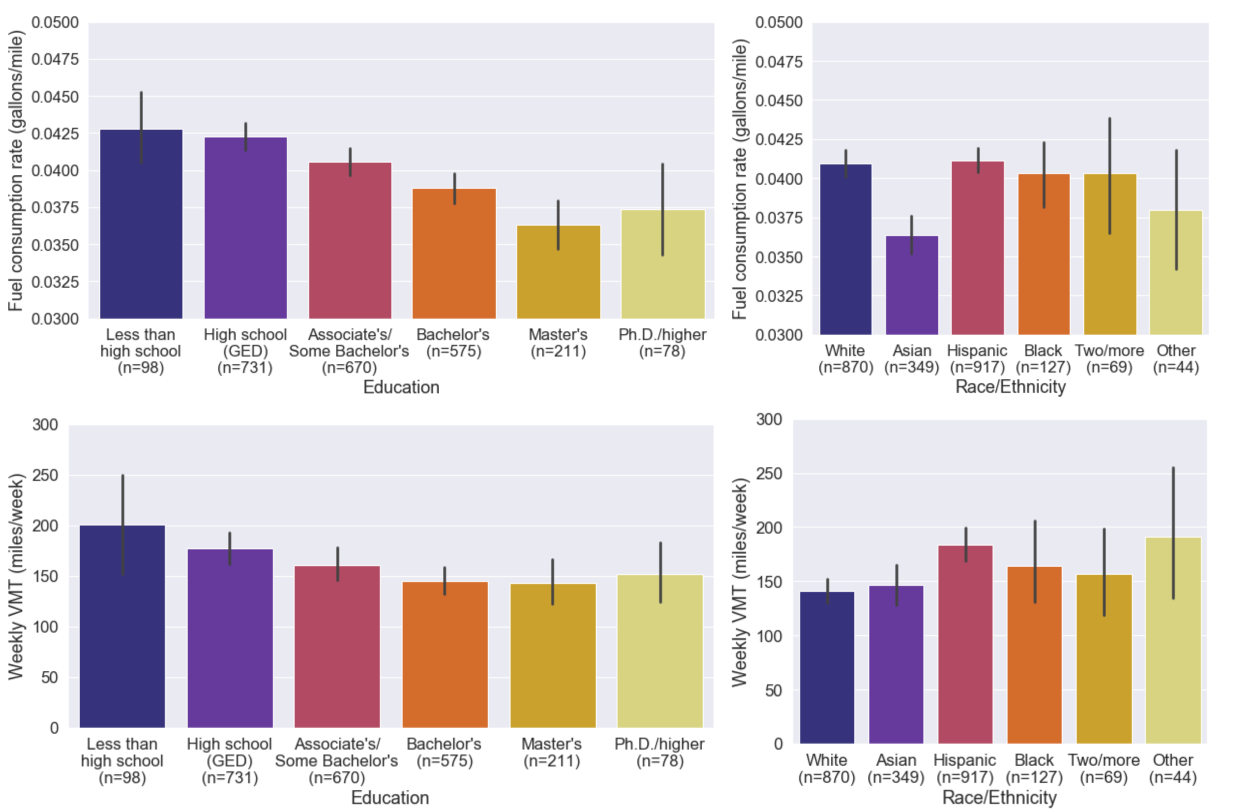
c) By urban classification

Figure 28. Average Weekly VMT per Driver

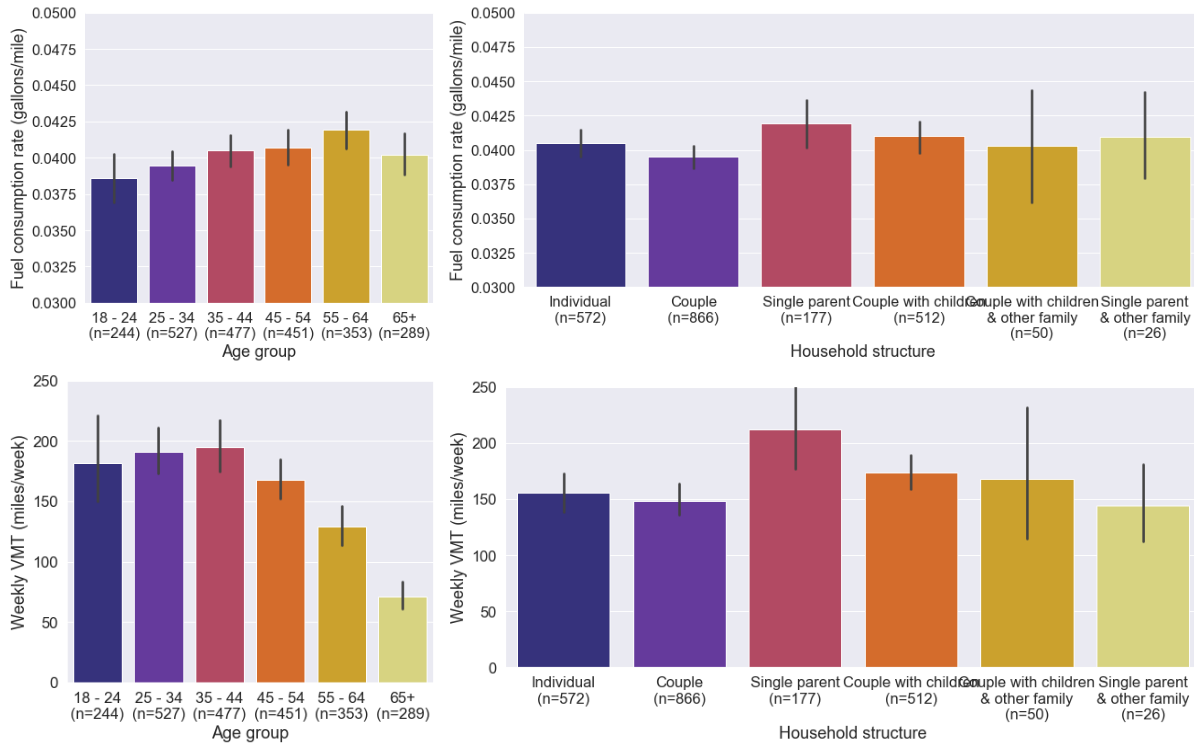
Note: lines on graphs represent the 95% confidence interval of the estimated means.

Considering both fuel consumption rates and weekly VMT, we find that there is actually no significant difference in the average quantity of gas or diesel consumed across income groups. However, when comparing income groups within geographic regions, we find that the highest income groups in both Central and Northern CA consume significantly more gas or diesel than all other residents of these regions. This is primarily due to relatively high average weekly VMT by high income urban cluster and rural residents, which make up about 15% and 5%, respectively, of each of these two regions. Moreover, drivers in the lowest income group (earning less than $25,000 annually) consume less gas/diesel on average (about 7.3 and 4.8 gallons per week, respectively) than other drivers in Central and Northern CA. In the San Francisco Bay Area, the lowest income group consumes slightly more gas/diesel on average (about 7.2 gallons per week) compared to other drivers (about 4.8 to 6.8 gallons per week) in the region. Lastly, there is little variation in the average amounts of gas/diesel consumed across income groups in Southern CA, where the lowest income group consumes slightly more than other drivers (about 8.7 gallons per week) and the highest income group consumes slightly less (about 6.9 gallons per week).

Other covariates of the cost burden of fuel taxes and RUC include age, education, race/ethnicity, and household structure. Fuel consumption rates generally increase with age, decrease with education, and are significantly lower among Asian drivers and couples. On the other hand, average weekly VMT also generally decreases with age (as discussed above) and education, and is significantly higher among Hispanic drivers and single parent households. As a result, average weekly gas/diesel consumption decreases with age (significantly so from 45+) and education, is significantly higher for Hispanics and significantly lower for Asians, and significantly higher for single parent households.



a) Education **b) Race/Ethnicity**



c) Age **d) Household structure**

Figure 29. Average Gasoline/Diesel Consumption Rates and Weekly VMT per Driver by Educational Attainment and Race/Ethnicity

Note: lines on graphs represent the 95% confidence interval of the estimated means.

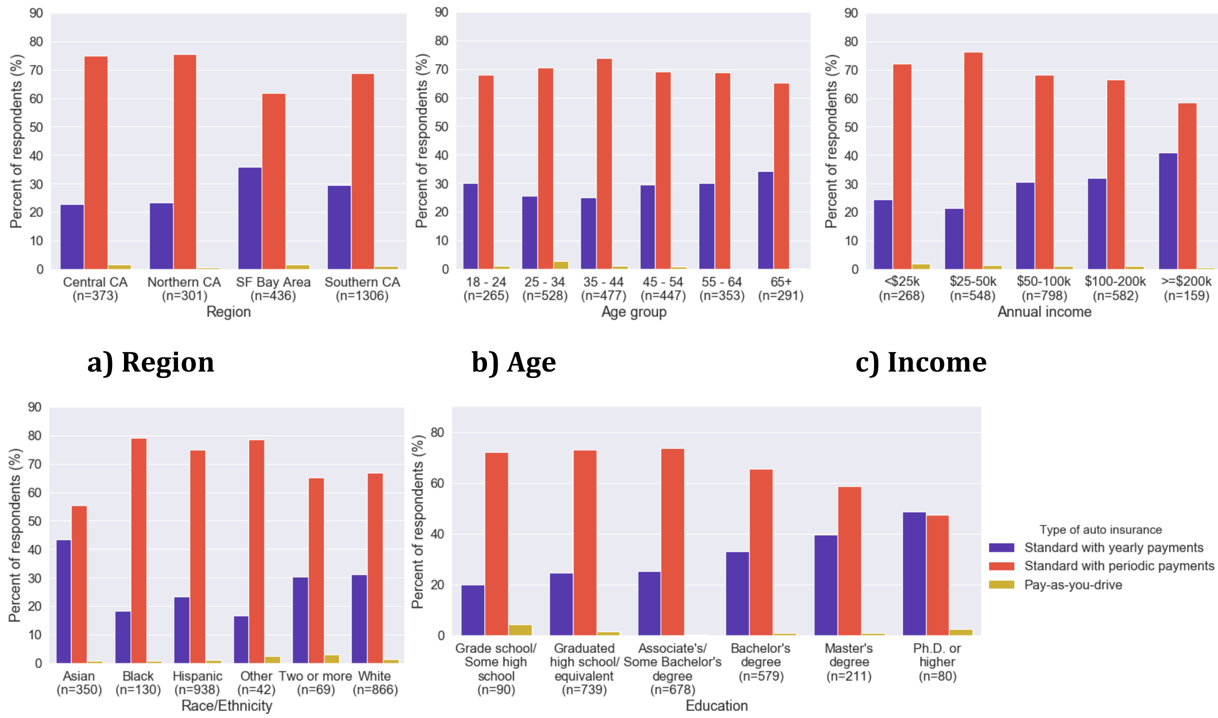
Use of RC-Related Technologies

In this section, the distributions of auto insurance types and financial services are examined to gain an understanding of potential opportunities and challenges to the adoption of an RUC system with various technological characteristics.

Auto Insurance

The survey asked car owners to identify which type of auto insurance they currently use, distinguishing between pay-as-you-drive insurance (e.g., MetroMile, Root, MileAuto) and standard insurance with either yearly or periodic (e.g., monthly) payments. Pay-as-you-drive insurance providers have the potential to play the role of account manager in a RUC system. The technical feasibility of this option was tested in the recent California RUC pilot program. Current adoption of pay-as-you-drive auto insurance may foreshadow early adoption of this option for RUC account management and inform outreach strategies. Moreover, the frequency with which car owners pay for insurance can provide important insight into drivers' sensitivity to the required frequency of payments for RC. While some households/individuals may be able to make annual payments, others may find it difficult to afford such large lump sum payments within the scope of their budget.

About 69% and 29% of Californian car owners use standard auto insurance with periodic and annual payments, respectively, and only about one percent use pay-as-you-drive insurance. The remaining auto owners either don't have insurance, didn't pay for insurance themselves, or noted some other type of insurance. Figure 30 displays the distribution of auto insurance type by various geographic and socio-demographic dimensions. Central California and the San Francisco Bay Area had the highest adoption rates of pay-as-you-drive insurance (about 1.6% in each region) compared to Southern California (1.1%) and Northern California (0.7%). Northern and Central California had the highest rates of periodic payment for standard insurance (about 75% in each region) and the lowest rates of yearly payments (about 23% in each region). The San Francisco Bay Area, which had the highest rate of yearly payments (about 36%), had the lowest rate of periodic payments (about 62%). The rates of each payment type in Southern California were about equal to the statewide averages stated previously.



a) Region **b) Age** **c) Income**

d) Race/Ethnicity **e) Education**

Figure 30. Distribution of Auto Insurance Type by Region, Age Group, Income Group, and Educational Attainment

The use of pay-as-you-drive insurance is highest among 25 to 34 year olds (about 2.8%), the lowest income groups (about 1.9%), and both the lowest and highest educated (about 4.4% and 2.5%, respectively) car owners. In addition, as can be seen in Figure 30 above, preference for yearly payments for standard auto insurance tends to increase with income and education. Conversely, preference for periodic payments decreases significantly with income from about 75% of car owners earning less than $50,000 per year to about 68% of those earning $50,000 to $200,000 per year and about 58% of those earning more than $200,000 per year. Preference for periodic payments also decreases significantly from about 73% of car owners with less than a Bachelor's degree to about 65%, 59%, and 48% of those with a Bachelor's degree, Master's degree, and Ph.D. or higher, respectively. With respect to race/ethnicity, the use of pay-as-you-drive insurance is greatest among car owners of White (about 1.4%), two or more (about 2.9%), or other racial/ethnic groups (about 2.4%). Asian car owners have the highest rate of yearly payments (about 43%), while Black and Hispanic car owners have the lowest (about 19% and 23%, respectively).

Finally, we note that there is no statistically significant difference between the adoption rate of pay-as-you-drive insurance across vehicle types, although it is highest among HEV owners (about 2.5%) and lowest among EV and PHEV owners (0%). In addition, the portions of HEV and PHEV owners that make periodic payments for standard insurance (about 58% and 50%, respectively) are significantly lower than those of gasoline- or diesel-powered vehicle owners (about 70%). These trends likely reflect the socio-demographic distributions across vehicle types, with lower income vehicle owners being more likely to own HEV and ICE vehicles.

Financial Access

Californians' ability to pay for a RUC and reliance on alternative forms of payment was investigated by asking survey respondents to select all forms of payment they use, including cash, checks, credit cards, debit cards, digital wallets (e.g., Apple Pay, PayPal), money orders, and pre-paid/charge cards. The distribution of responses is presented in Figure 31 below, which also includes the portion of respondents that was 'un-banked', meaning they did not select any of the following: checks, credit cards, debit cards, digital wallets.

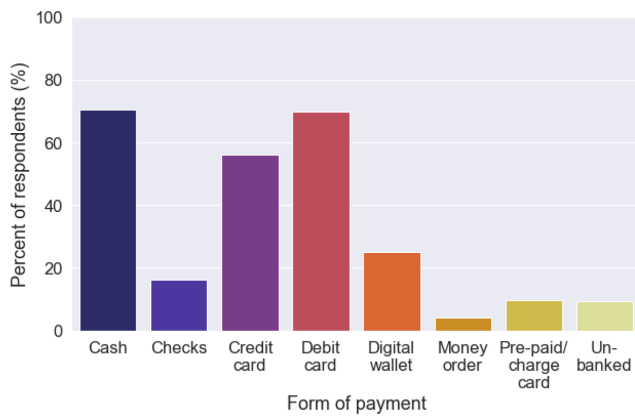


Figure 31. Distribution of Financial Services/Forms of Payment Used

Un-banked individuals made up about 10% of the respondents and were disproportionately young, low-income, low-education, black or Hispanic, and living in rural areas. The portion of un-banked individuals decreased with age, from about 18% and 10% of individuals aged 18 to 24 years and 25 to 34 years, respectively, to about 5% and 3% of individuals aged 55 to 64 years and 65 years or older, respectively. The trend among the youngest age group is influenced in part by the quarter of 18 to 24 years old that are students and not employed, about 22% of which are un-banked. In addition, the portion of un-banked individuals decreases with income and education level from about 21% of respondents earning less than $25,000 annually to about 3% of respondents earning $200,000 or more annually and from about 15% of respondents with no more than grade school/some high school education to about 2% of respondents with a Ph.D. or higher. While the portion of white respondents that is un-banked is slightly lower than average (about 7%), that of black (about 13%) and Hispanic (about 12%) are slightly above average. The portion of un-banked individuals among Asian respondents is the lowest, at about 4%. Finally, the portion of rural residents that is un-banked (about 13%) is slightly greater than that of urban cluster (about 10%) and urban area (about 9%) residents

The adoption rate of digital wallets can also provide insight into the ease with which drivers may be able to adopt app-based forms of RUC account management. About 25% of respondents were using digital wallets at the time of the survey. Adoption of digital wallets generally increases with income and education and decreases with age and urbanization. The adoption rate of digital wallets increases steadily by about 4 to 6% per income group, from about 17% in the lowest income group (earning less than $25,000 annually) to about 36% in the highest income group (earning $200,000 or more). The contrast is even greater across educational attainment, with people with Master's degrees or Ph.D.'s or higher having significantly higher adoption rates of digital wallets (about 31% and 42%, respectively) than less educated individuals (about 27% among Associate's to Bachelor's degree holders and about 21% across less educated individuals). While about 30% of respondents across the 18 to 44 years old age groups use digital wallets, just 27%, 16%, and 8% of 45 to 54 years old, 55 to 64 years old and 65 years or older age groups use digital wallets, respectively. Finally, rural residents have a significantly lower adoption rate of digital wallets (about 16%) compared to urban area residents (about 26%).

Attitudes/Opinions

Respondents were asked to state the degree of agreement or disagreement to four attitudinal questions using a Likert scale with five levels from strongly disagree to strongly agree. The four questions were:

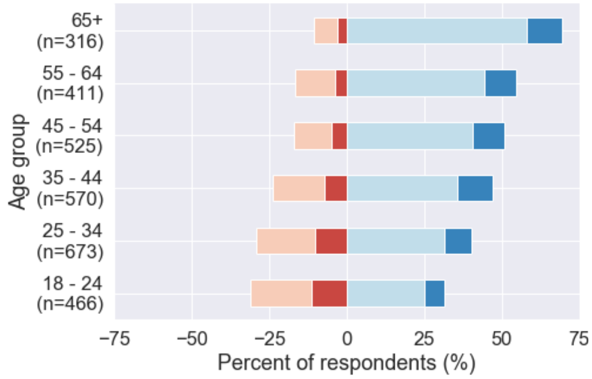
1. I know how public roads and transportation are funded,
2. I think about travel costs when I make daily travel decisions,
3. I am comfortable sharing my location data with private entities (e.g., phone provider, smartphone apps), and
4. I am comfortable sharing my location data with government entities.

Awareness of Transportation Finance

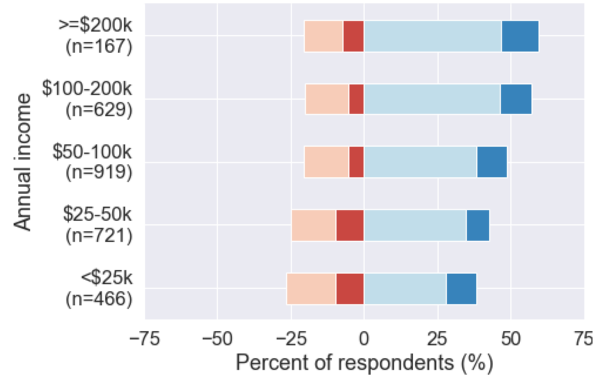
The first of the attitudinal questions reflects the degree to which Californians feel informed about transportation finance. Almost half of respondents say they know how public roads and transportation are funded, with about 38% and 10% saying they agree and strongly agree, respectively, with the statement. On the other hand, about 15% of respondents disagree and about 7% strongly disagree.

While there are few notable differences across regions, rural residents felt significantly less informed about transportation finance compared to urban area and urban cluster residents. Only about 37% of rural residents said they agreed or strongly agreed with the first statement, compared to 54% and 47% of urban cluster and urban area residents, respectively. In addition, only about 15% of urban cluster residents said they disagreed or strongly disagreed that they knew how public roads and transportation are funded - significantly less than other residents.

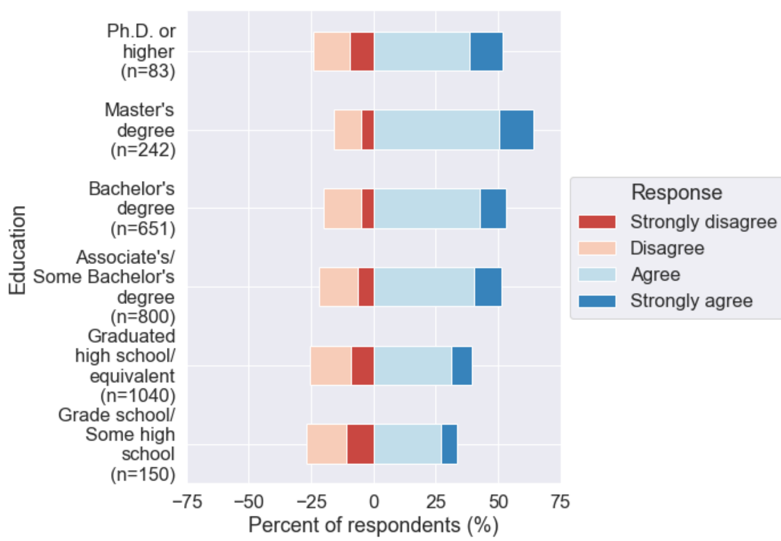
Awareness of transportation funding increased with increasing age, income, and level of educational attainment, as displayed in Figure 32 below. While about 69% of respondents aged 65 years and older agreed or strongly agreed with the statement about transportation finance, only about 31% of 18 to 24 years old respondents did so - the same percentage of 18 to 24 year olds that said they disagreed or strongly disagreed. Similarly, the portion of respondents by age group that agreed or strongly agreed with the first statement increases from about 38% of the lowest income group to about 59% of the highest income group while the portion that disagreed or strongly disagreed decreases from about 26% to 20% from the lowest to the highest income groups. Respondents with Master's degrees felt the most informed about transportation finance, with about 64% agreeing or strongly agreeing with the statement and about 16% disagreeing or strongly disagreeing.



a) Age



b) Income



c) Education

Figure 32. Distributions of Responses to "I know how public roads and transportation are funded." by Age, Income, and Educational Attainment

As displayed in Figure 33 below, white respondents had a significantly higher rate of agreement with the statement about transportation finance awareness compared to all other racial/ethnic groups, with about 46% agreeing, about 12% strongly agreeing, and only about 18% disagreeing or strongly disagreeing. Black and Asian respondents had lower rates of awareness, with about 51% and 44% agreeing or strongly agreeing with the statement, respectively, and about 23% and 22% disagreeing or strongly disagreeing, respectively. Finally, Hispanic respondents had the lowest rate of awareness, with only about 40% agreeing or strongly agreeing and about 26% disagreeing or strongly disagreeing.

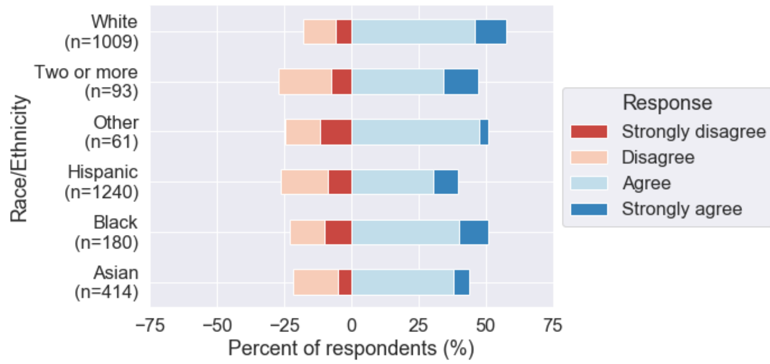
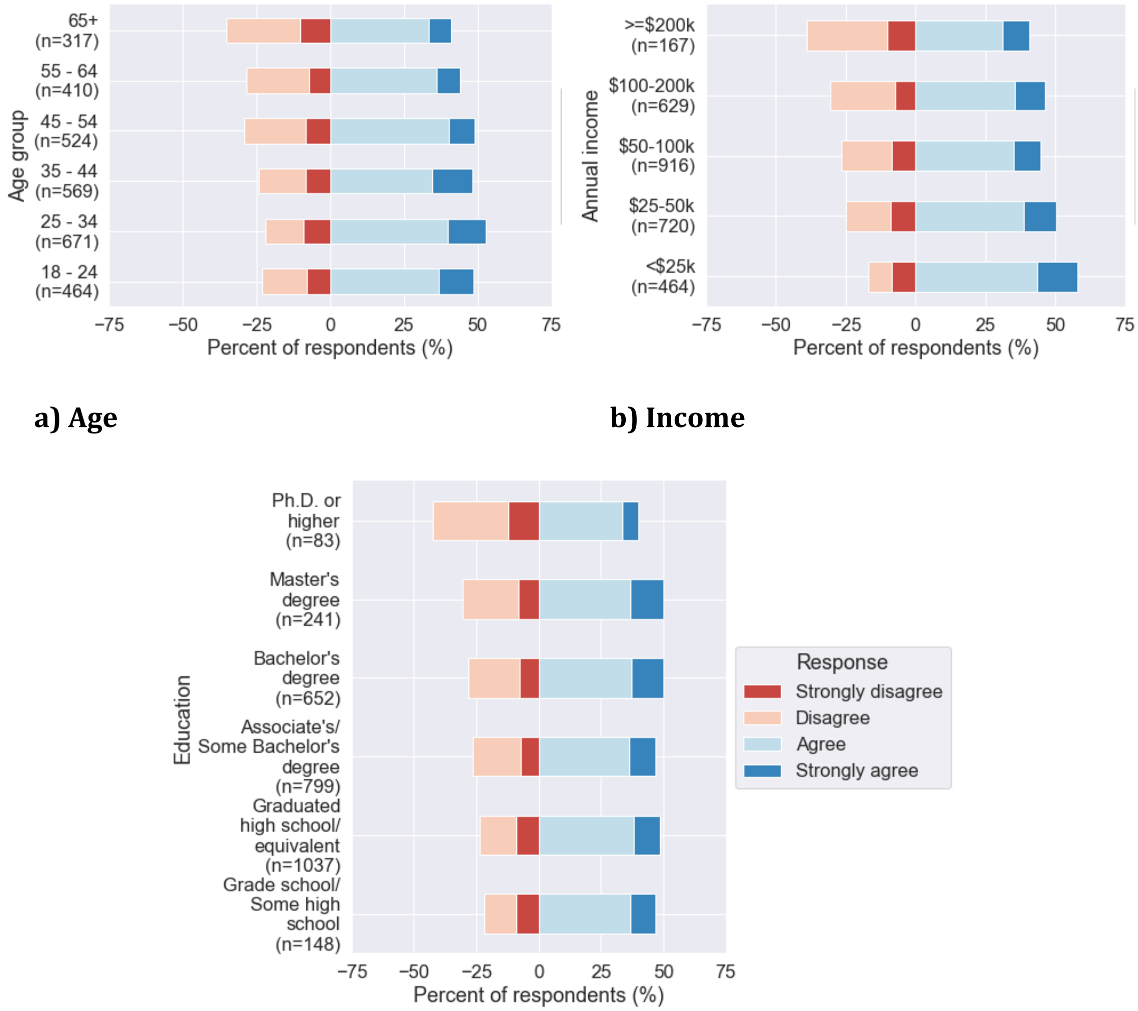


Figure 33. Distributions of Responses to "I know how public roads and transportation are funded." by Race/Ethnicity

Consideration of Travel Costs in Daily Travel Decisions

The second attitudinal question reflects the degree to which respondents think about and potentially incorporate transportation costs into their day-to-day travel decisions. About 48% of respondents agree with this statement (38% agree and 10% strongly agree) while about 26% disagree (15% disagree and 7% strongly disagree). As with the previous statement, there is very little difference in the distributions of responses across regions. Rural residents have a significantly lower rate of agreement compared to urban area and urban cluster residents, with about 21% agreeing and 10% strongly agreeing with the statement. On the other hand, urban cluster residents are the most mindful of transportation costs, with about 44% and 10% agreeing and strongly agreeing with the statement, respectively, and just 15% disagreeing or strongly disagreeing.

The tendency to think about travel costs when making daily travel decisions decreases slightly with age and education, and decreases significantly with income (see Figure 34 below). In particular, respondents 65 years and older and those with the highest level of educational attainment are the least likely to consider travel costs in daily travel decisions, with about 35% and 42% disagreeing or strongly disagreeing with the statement, respectively. In contrast, about 58% of respondents earning less than $25,000 annually agreed or strongly agreed that they think about travel costs when making daily travel decisions, and just 17% disagreed or strongly disagreed.



a) Age **b) Income**

c) Education

Figure 34. Distributions of Responses to "I think about travel costs when I make daily travel decisions." by Age, Income, and Educational Attainment

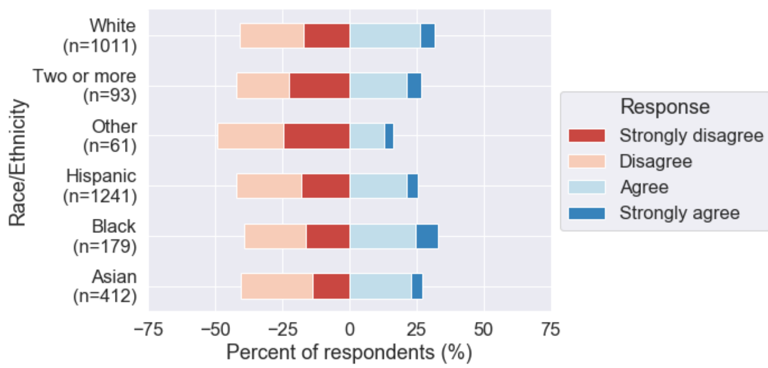
Comfort Sharing Location Data with Private and Government Entities

The last two questions in this section investigate Californian's level of comfort sharing location data with 1) private entities and 2) government entities. As the State considers various account management options for a future RUC system, it is important to understand the potential socio-technical barriers to adoption of GPS-enabled services. While smartphone adoption and internet access is relatively widespread, the acceptance of GPS-enabled services provided by private entities may not necessarily lead to a willingness to participate in a system that enables or is perceived to enable government entities to access personal location data.

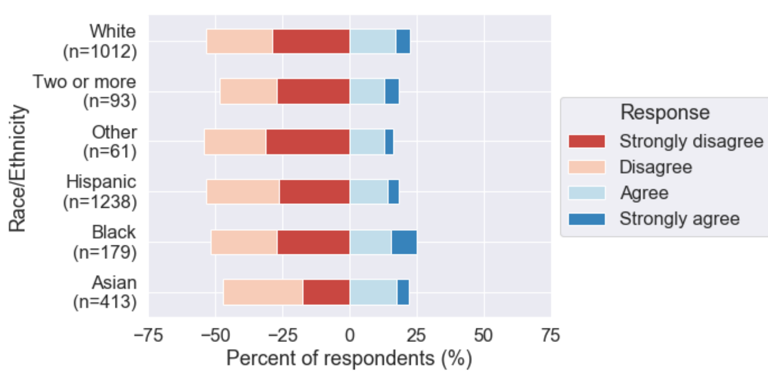
Indeed, about 30% of respondents were less comfortable sharing location data with government entities than with private entities, with about 42% of respondents saying they were uncomfortable sharing location data with private entities and about 52% saying they were uncomfortable sharing location data with government entities. Only about 5% of respondents strongly agreed that they were comfortable sharing location data with either private or government entities while about 23%

said they agreed they were comfortable sharing location data with private entities and about 17% said they were comfortable sharing with government entities. On the other hand, about 25% disagreed with either statement and about 16% and 23% strongly disagreed with being comfortable sharing location data with private and government entities, respectively.

While there are few significant differences in the level of comfort sharing location data across geography, age, and income, there are some notable disparities across racial/ethnic groups (see Figure 35 below). Hispanic respondents were significantly less likely than black and white respondents to agree with either statement, with just 26% agreeing or strongly agreeing with being comfortable sharing location data with private entities and about and about 18% agreeing or strongly agreeing with being comfortable sharing location data with government entities. The distribution of responses was similar across Asians and Hispanics for the statement about private entities but differed with respect to government entities. However, Asians were significantly less likely to differ in the degree of comfort they felt in sharing location data with private versus government entities.



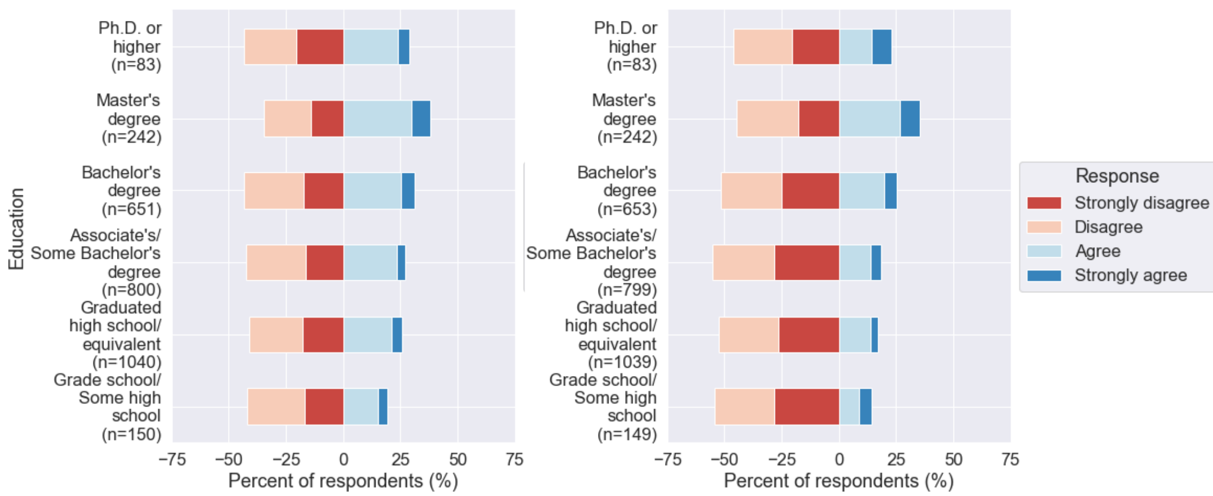
a) Comfort sharing with private entities



b) Comfort sharing with government entities

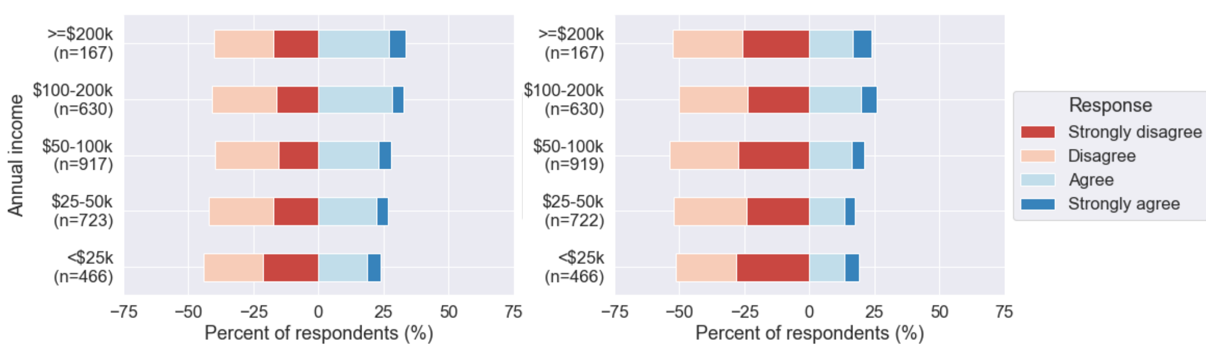
Figure 35. Distributions of Responses to "I am comfortable sharing my location data with private/government entities" by Racial/Ethnic Group

Finally, the level of comfort sharing location data with either government or private entities generally increases with increasing education and income level. The portion of respondents that feels comfortable (either agree or strongly agree) sharing location data with private entities increases from about 19% of respondents with less than a GRE to about 38% of those with a Master's degree (see Figure 36 a) below). Similarly, the portion of respondents that feels comfortable sharing location data with government entities increases from 14% of the lowest education group, to about 36% of those with a Master's degree (see Figure 36 b) below).. Interestingly, the most educated group (having a Ph.D. or higher) is less comfortable sharing location data than the second-highest group, with just 29% and 23% feeling comfortable sharing with private and government entities, respectively. The increase in comfort sharing location data is less dramatic across income groups, rising from 24% of the lowest income group agreeing or strongly agreeing with the statement about private entities to about 34% of the highest income group and from about 19% agreeing or strongly agreeing to the statement about government entities to about 24%.



a) Comfort sharing with private entities **b) Comfort sharing with government entities**

Figure 36. Distributions of Responses to "I am comfortable sharing my location data with private/government entities" by Education Attainment



a) Comfort sharing with private entities **b) Comfort sharing with government entities**

Figure 37. Distributions of Responses to "I am comfortable sharing my location data with private/government entities" by Income Group

Discrete Choice Analysis Results

A total of N = 8,049 observations 2,683 individual respondents were used to estimate the model presented in Table 11 below. The estimated model had a null log-likelihood of -13,851.38 and a fitted log-likelihood of -6,321.84 with a pseudo r-squared value of 0.55 and a pseudo r-bar-squared value of 0.54.

Table 11. Discrete Choice Model Results

		Drive alone	**Drive a carpool**	**Ride in a carpool**	**Ride alone in a TNC**	**Pool in a TNC**	**Public transit**
Intercept	**Mean ASC (standard deviation)**	0 (2.45***)	0.43 (2.14***)	0.56 (1.74***)	-1.61 (1.67***)	-1.88 (0)	-2.63* (2.22***)
Travel time (min)	**Wait time**	-		-0.030*			
	In-vehicle time	-0.036***	-0.018*	-0.051***	-0.044***	-0.028*	-0.032***
Non-driving costs	**Under $50,000**	-0.024*					
	$50,000 to $100,000	-0.044					
	$100,000 and above	-0.061*					
Gas cost (estimated $) - scenario 1	**Under $50,000**	0.034					
	$50,000 to $100,000	-0.24					
	$100,000 and above	-0.36*					
Gas cost (estimated $) - scenario 2	**Under $50,000**	-0.24*					
	$50,000 to $100,000	-0.56*					
	$100,000 and above	-0.51					
Gas cost (estimated $) - scenario 3	**Under $50,000**	-0.35*					
	$50,000 to $100,000	-0.87*					
	$100,000 and above	-0.86*					
Gas cost (stated $) - scenario 1	**Under $50,000**	0.026					
	$50,000 to $100,000	-0.54*					
	$100,000 and above	-0.22					
Gas cost (stated $) - scenario 2	**Under $50,000**	-0.15					
	$50,000 to $100,000	-0.67*					
	$100,000 and above	-0.60*					
Gas cost (stated $) - scenario 3	**Under $50,000**	-0.41*					
	$50,000 to $100,000	-1.04**					
	$100,000 and above	-0.80					
RC ($) - scenario 3	**Under $50,000**	-0.39					
	$50,000 to $100,000	0.22					

	$100,000 and above	-0.062					
Trip purpose	**medical/dental appointment**	0					
	restaurant/bar	0	1.61***	1.66***	1.48***	1.99***	1.17***
	grocery shopping	0	0.30	0.26	-0.11	-0.31	0.017
	work/school	0	0.75**	0.74*	-0.11	-0.10	0.85**
Region	**Central CA**	0					
	Northern CA	0	-0.074	0.14	0.00	-0.72	0.065
	San Francisco Bay Area	0	0.16	0.53	0.98*	0.39	0.81*
	Southern CA	0	-0.012	0.14	0.38	-0.11	-0.39
Urban classification	**Rural**	0					
	Suburban	0	0.52	0.17	0.28	-0.26	-0.49
	Urban	0	0.00	-0.43	0.52	-0.61	0.91
Age	**Years old**	0	-0.043***	-0.038***	-0.038***	-0.045***	-0.036***
Income	**Under $50,000**	0					
	$50,000 to $100,000	0	-0.16	-0.30	-0.75	-0.87*	-0.68
	$100,000 and above	0	-0.84*	-0.16	0.11	-0.57	-1.20**
Race/Ethnicity	**Other**	0					
	White	0	-0.08	0.094	-0.57	0.54	-0.19
	Hispanic	0	-0.10	0.41	-0.54	1.00	0.49
	Asian	0	0.19	0.47	-0.82	0.081	0.47
	Black	0	-0.87	-0.44	-0.41	0.44	-0.38
Mode share	**Drive**	0	-5.59***	-6.26***	-3.65***	-4.94***	-4.22***
	Public transit	0	-1.55	2.32**	5.63***	4.53***	8.95***
Vehicle ownership	**Number of vehicles**	0	0.20	-0.09	-0.18	0.17	-0.41*
Vehicle Type	**Gasoline ICE**	0	0.45	0.17	-0.50	-0.21	-0.17

* : p-value < 0.1; ** : p-value < 0.01; *** : p-value < 0.001

The ASCs can be interpreted as the relative baseline systematic preferences for each of the alternatives. The estimated coefficients of the ASCs suggest that, all else equal (i.e., if all travel modes had the same wait time, in-vehicle travel time, and costs), the average individual in the sample prefers car-based modes over either TNC option or public transit. Even with the parameters controlled for in the model, there are large variances in these baseline preferences, as demonstrated by the estimated standard deviations (in parentheses) of the ASCs. Of all the modes, only the mean public transit ASC is significant, suggesting that the average person is significantly less likely to prefer public transit over other modes, all else equal. TNCs are also generally less preferred than carpooling and driving alone, though there is a large variance in the preference for riding alone in a TNC, suggesting that most people range from preferring driving alone to riding alone in a TNC to being indifferent between the two options.

Next, we examine the travel time parameters: wait time and in-vehicle travel time. Only riding in a carpool, TNC, or public transit included wait times. In comparison to the estimated coefficients for in-vehicle time for each of these modes, the sensitivity to wait time (significant at the 90% confidence level) was about the same as the sensitivity to in-vehicle time of pooling in a TNC or public transit. The sensitivity to in-vehicle time of driving alone was significantly greater than that of driving a carpool. This result is unexpected and may reflect some degree of sensitivity to the incentive of being paid to drive a carpool, for which further investigation and model refinement is needed to make a conclusion. While there is some variation in the estimated coefficients of in-vehicle time of the passenger modes (riding in a carpool, riding alone in a TNC, pooling in a TNC and public transit) suggesting that people are most sensitive to in-vehicle time for riding in a carpool, the differences are generally not significant at the 95% confidence interval.

All of the cost coefficients are interacted with annual income, enabling an investigation of the heterogeneity in the sensitivity to travel costs of different types across income groups. Sensitivity to non-driving costs, including the amount paid or received for riding or driving in a carpool, TNC fares, and public transit fares, is significant at the 95% confidence level. There is a slight increase in the sensitivity to non-driving costs with increasing annual income, although the differences between income groups are not significant. The sensitivity to unstated driving costs increases significantly from scenario 1 to 2, across all income groups, confirming the hypothesis that the salience of driving costs increases when attention is drawn to gas prices. However, the model does not suggest significant differences in the sensitivity to driving costs between respondents that were or were not presented with estimated gas costs during the choice experiments. Across both experiment types, sensitivity to estimated driving costs was significantly lower among respondents earning less than $50,000 per year compared to the other two income groups. While this may seem counter-intuitive, it likely reflects a stronger dependency on personal vehicles among the lowest income group that may even increase with respect to one's driving costs. This preliminary hypothesis suggests that low income individuals with poor fuel economy vehicles may be among the most car dependent and thus least sensitive to changes in driving costs. Sensitivity to driving costs is highest in the third scenario, in which a mileage-based RUC was also included. While the higher two income groups were insensitive to the mileage-based RC, the lowest income group was about equally sensitive to the mileage-based RUC as they were to driving costs in the third scenario.

Next, we examine the effects of the trip purpose and various individual-specific characteristics on the baseline modal preferences, with a particular focus on results related to a preference for driving. While there is no significant difference in modal preferences for either medical/dental appointments or grocery shopping trips, the model suggests that people are significantly more likely to consider non-driving modes for trips to a restaurant/bar than any of the other trip purposes included in the experiments. Furthermore, people are significantly more likely to carpool or use public transit for commuting to work/school than for traveling to medical/dental care or grocery shopping, though less so than when going to a restaurant/bar.

There were few significant differences in modal preferences across regions or urban classifications. Namely, San Francisco Bay Area residents are significantly more likely to choose riding alone in TNCs or public transit and slightly more likely to choose to pool in carpool or TNC than residents of any other region. Residents of Southern California were slightly more likely to choose to ride alone in a TNC and slightly less likely to choose to use public transit compared to residents of Central and Northern California. Furthermore, suburban residents were the most likely to choose to drive a carpool than urban or rural residents and slightly less likely to choose to pool in a TNC or public transit. Urban residents were the least likely to choose to ride in a carpool or pooled TNC and most likely to choose to ride alone in a TNC or ride in public transit.

The model suggests that the likelihood to choose any mode other than driving alone decreases significantly with age. Furthermore, the likelihood to choose to drive a carpool or use public transit is significantly from the lowest two income groups to the highest group, and the likelihood to choose a pooled TNC is significantly lower in the middle income group than in the lowest or highest groups. The current model specification does not reveal significant differences in modal preferences across racial/ethnic groups, though an examination of the corresponding coefficients suggests that:

- Black drivers are the least likely to choose to drive a carpool,
- Hispanic and Asian respondents are the most likely to choose to ride in a carpool while black respondents are the least likely,
- Asian respondents are the least likely to choose to ride alone or pool in a TNC,
- Hispanic respondents are the most likely to choose to pool in a TNC, and
- Hispanic and Asian respondents are the most likely to choose to use public transit while back respondents are the least likely to choose to do so.

Respondents' travel profiles are a significant predictor in their modal preferences. The likelihood of choosing a mode other than driving alone decreases significantly with drive alone mode share, while that of choosing a driving mode decreases significantly with public transit mode share. In addition to the likelihood of choosing public transit, the likelihood of choosing to ride in a carpool or use a TNC also increases significantly with public transit mode share, likely reflecting the modal preferences of individuals with a car-free or car-light travel profile.

Lastly, the number of vehicles owned/leased by an individual as well the fuel type(s) of their vehicles has a slight effect on their modal preferences, as reflected by the model results. The likelihood to choose public transit decreases significantly with the number of cars owned/leased by an individual. Moreover, owners of gas-powered vehicles are slightly more likely to prefer driving alone or in a carpool and slightly less likely to choose TNCs or public transit.

Conclusions and Recommendations

This study investigates the potential social equity and travel behavior implications of a mileage-based RUC in California. Best practices, lessons learned, and diverse stakeholder perspectives were gleaned from literature review and expert interviews with both topical and community-based experts. In addition, a general population stated preference survey across the State of California produced rich disaggregate analysis of the relative burden of gas taxes and mileage-based RUC across various socio-demographic and geographic dimensions.

Expert interviews revealed potential opportunities and challenges of a RUC system, particularly regarding social equity. The key takeaways from the literature review and expert interviews are summarized as follows:

- **Gender and Household:** Studies have revealed that people of different genders and household sizes have varying travel behaviors and incomes that may result in a disproportionately high cost burden from transportation, regardless of the form of road user fee: fuel tax or RUC.
- **Rural Residents:** Residents in rural areas may be concerned that their need to drive longer distances to reach goods and services may result in disproportionate impacts from a RUC system. Although research has found that rural residents are likely to have the greatest cost savings, on average, as a result of a shift to RUC from fuel taxes, prevailing disparities in the distribution of land use and affordable housing seem to weigh more heavily in the public perception of RUC. While there has historically been low participation from rural residents in prior RUC studies, the upcoming private/public roads project being launched by Caltrans in 2023 aims to increase understanding of the unique needs of rural and tribal residents for a successful transition to RUC. The study also aims to pilot technology capable of distinguishing VMT on private versus public roads to increase the fairness of RUC payments.
- **Un- and Under-Banked Households:** Access to financial institutions for services, such as debit and credit cards, may be critical components for RUC system participation. Ensuring that all households, including those who do not have access to banking services, are included is an important consideration in the development of an equitable RUC system.
- **Low-Income Households:** Similar to un- and under-banked households, ensuring that low-income households have access to financial resources and services is an important element in a RUC system. During the California RUC pilot, only a few participants were from low-income households, limiting the understanding of their perceptions and the potential impacts of RUC. Experts also noted a lack of affordable housing and disparities in the level of service of driving alternatives in lower income communities having an impact on road use and disparities in VMT across income groups. Moreover, since more fuel efficient vehicles have historically been financially out of reach for many low-income households, these drivers have not only been driving farther distances, but they are paying more per mile driven compared to other households. Although drivers of less fuel efficient vehicles are likely to pay less under a RUC than fuel tax system, heightened awareness of travel costs and car dependency likely contribute to negative perceptions of the shift to a RUC.
- **Equity Strategies:** Strategies to improve the overall equity of transportation may be able to address potential challenges for a variety of groups. Even though the impacts of a shift to a

RUC are expected to be progressive, addressing public perception challenges (e.g., that a RUC is an additional tax and people who drive more will pay more) is key for encouraging participation and adoption. Education and outreach is vital to ensure that underserved population groups understand the potential benefits of a shift to a RUC and have the opportunity to express the potential burdens that an RUC system may produce so that mitigation strategies can be considered.

- **Program Design:** In addition to outreach, program design is critical for providing a diversity of options to mitigate barriers to adoption of a RUC system; ensuring that RUC programs (e.g., payment options) are easy to use and privacy is protected can help encourage long-term RUC viability.

The intensity and composition of road use by Californians varies significantly across geographies and socio-demographic profiles. The following bullets outline key takeaways from the analysis of baseline travel behavior:

- **There are regional differences in average total miles traveled per person in the state of California:** On average, Central and Southern Californians travel most often in a typical week while Central Californians travel the farthest total distance, followed by Northern and Southern Californians; Central and Northern Californians have the greatest average commute PMT; Central Californians have the greatest average PMT for essential trip purposes; SF Bay Area residents have the least PMT for essential and social trip purposes and least overall PMT.
- **Total average VMT (by driving alone or carpooling) per person decreases with population density from rural to urban areas**, reflecting longer travel distances and greater car reliance in less densely populated areas of California.
- **The San Francisco Bay Area has the lowest rate of VMT as a portion of PMT, resulting from:** significantly less average VMT per person for essential and social trip purposes and slightly less average VMT per person for commuting, slightly greater rates of active transportation for essential and social trip purposes, and significantly greater rates of public transit usage compared to the other three study regions.
- **There are greater disparities in road usage for essential trip purposes than for commuting:** on average, rural residents travel about twice as far for essential trip purposes than do urban area residents and about a third farther than urban cluster residents.
- **Age and household structure play an important role in determining the intensity of road use across Californians**: across all trip purpose, the average VMT per person increases with age from ages 18 to 44 then declines with age, primarily due to trends in average VMT per person for commute and essential trip purposes; persons living in households with children have the highest VMT, on average, with single parent households driving/carpooling the greatest total distance followed by couples living with children and/or family.
- **VMT increases with income level regardless of urban classification**, primarily due to higher employment rates among higher income groups that leads to significantly greater average weekly commute VMT per person.
- **Californian's drive/carpool VMT varies notably across employment sectors:** Commuters employed in the manufacturing/logistics/transportation, law enforcement, and government/public administration sectors have significantly greater average weekly

drive/carpool VMT than those employed in arts/entertainment/hospitality/food services, professional/business services/IT/sciences, education/childcare, healthcare/social services, retail/customer services due to both long commute distances and high frequency of commuting; essential workers have higher than average commute frequencies but shorter than average commute distances.

- **There are few significant differences in average VMT per person across race/ethnicity:** Hispanic residents tend to have greater VMT per person; black residents have greater average VMT per person for commuting, although the differences are not significant.
- **TNC use makes up about 2.8% of total weekly PMT, on average, and about 3.7% of PMT for social trips, with some regional variation:** the San Francisco Bay Area and Southern CA have highest overall rates of TNC use; the total average weekly VMT by TNCs increases significantly from about one mile per week per person in urban clusters and rural areas to about five miles per week per person in urban areas.
- **TNC VMT does not vary significantly across income groups, although the results generally support prior research:** the $25,000 to 50,000 income group has the greatest average TNC VMT per person while the highest income group has the lowest; lower income groups have greater average TNC VMT per person for essential trip purposes.
- **Black and Hispanic residents travel significantly greater distances by TNCs, on average, across all trip purposes.**

The rates of remote work and the use of grocery, restaurant, and package delivery services represent potentially significant shifts in not only the quantity of VMT by personal vehicles but also the distribution of VMT across the population. The ability to work from home - an option extended to many for the first time out of necessity at the onset of the COVID-19 pandemic - is predicated on industry type and job function, enabling mostly higher income office-based workers to reduce or even eliminate commuting. Although remote work policies are largely still under development, many large employers have committed to partially or fully remote work policies for the long-term which may also cause a redistribution of certain population groups throughout the state. The adoption of delivery services has also grown significantly as a result of the COVID-19 pandemic, with research suggesting that the transformation in consumer and travel behavior is likely to persist into the post-COVID era. Similar to work from home rates, the use of delivery services varies with need, ability (in this case mostly financial) and preferences across the population, all of which results in a shifting of VMT from personal vehicles to those of delivery drivers. Whether the costs of that road usage are borne by the service provider, contracted delivery driver, or the consumer may vary across services and providers and is ultimately an important consideration for the development of sustainable and equitable RUCs.

Key takeaways from the analysis of emerging trends in travel behavior relevant to RUCs are as follows:

- **The portion of Californians working from home increased from about 29% prior to the COVID-19 pandemic to about 51% at the time of the survey:** the portion working from home one to four days per week increased from about 16% to about 23%; the portion working from home five or more days per week increased from about 14% to about 28%; the overall average work from home rate across employed residents of the state doubled from about 1.1 to about 2.2 days per week.

- **The impact of the COVID-19 pandemic on work from home rates varies significantly by geography**: on average, work from home rates changed the least in Central CA and in urban clusters; San Francisco Bay Area workers were most likely to have a fully remote work schedule (5+ days per week); Southern Californians had the highest rate of partial work from home schedules (1-4 days per week).
- **Work from home rates following the COVID-19 pandemic increase with age**, reflecting the elevated risk factors in exposure to COVID among older workers
- **Work from home rates increased significantly with income and were highest among professional/business services/it/science and government/public administration sectors**.
- **Work from home rates have a significant impact on total drive/carpool VMT, primarily due to the decrease in commute VMT:** people working from home three or more days per week drive/carpool about 86 miles per week less, on average, compared to those working from home two or fewer days per week.
- **Delivery services are becoming a regular part of Californians' lives:** at the time of the survey, about 38%, 54%, and 88% of Californians were ordering grocery, restaurant, and package deliveries, respectively, at least once a month; about 47% of Californians were ordering package deliveries one or more times per week.
- **Geographic differences in the use of delivery services are more notable across urban classification:** on average, urban clusters have significantly lower frequencies of deliveries across all three service types; rural areas have the greatest portion of weekly package deliveries.
- **The frequency of use of delivery services is strongly related to income and age:** the portion of people receiving one or more packages per week increases significantly with increasing income levels; the average frequency of restaurant deliveries among the highest income group is significantly higher than that of lower income groups; across all delivery types, the eldest two age groups (55 and older) have the lowest delivery frequencies while the middle age groups (from 25 to 54 years old) tend to have the highest.
- **Delivery services may aid in overcoming barriers to accessing essential and social services, particularly for zero-vehicle households and individuals with a medical condition that restricts mobility:** the use of restaurant and grocery delivery services is higher among zero-vehicle households; people with a medical condition/handicap have significantly greater average grocery delivery frequencies.

Vehicle ownership rates and the distribution of vehicle fuel type, fuel efficiency, and ultimately, VMT and taxable fuel consumed varies significantly across geographic and socio-demographic dimensions:

- **About 86% of respondents reported owning or leasing one or more vehicles, with some variation in vehicle ownership rates across geographies:** the San Francisco Bay Area and Northern California had slightly lower vehicle ownership rates compared to Southern and Central California; urban cluster residents have the highest vehicle ownership rates and rural residents have the lowest vehicle ownership rates; urban area residents have the lowest rate of owning more than one vehicle per household.
- **Vehicle ownership rates increase with income and age and are significantly higher among households with children than in those without.**

- **Vehicle ownership is highest among white and Asian residents**; black and Hispanic residents are significantly less likely than white and Asian residents to own two or more vehicles.
- **Geographic differences in fuel economy suggest disparities in the cost burden of fuel excise taxes and the potential impact of a shift to RUCs:** drivers in the San Francisco Bay Area and urban areas have lower fuel consumption rates, on average, compared to other drivers in the state; across regions, urban cluster residents have significantly higher fuel consumption rates than either rural or urban area residents, reflecting the relatively high ownership rates of ICE vehicles in urban clusters; across all regions except for Southern California, urban area residents have the lowest fuel consumption rates. While drivers with lower than average fuel consumption rates are currently paying the least amount of fuel taxes per mile driven, they are likely to experience the greatest increase in taxes paid as a result of a shift to RUCs. Similarly, drivers with higher that average fuel consumption rates are likely to experience a decrease in taxes paid, although those who are unable to upgrade to a more fuel efficient vehicle due to the various barriers to acquiring and operating HEVs, PHEVs, and BEVs, are likely to continue to have a higher than average cost burden of driving. Whether or not it is appropriate to address these issues with the design of an RUC system is a matter of public policy, and it is worth noting that there are various state-led efforts to address the inequities in access to electric vehicles to support California's aggressive electrification targets.
- **While rural road users pay less per mile driven than other Californians, they pay significantly greater sums of fuel taxes due to significantly greater average VMT per driver:** rural drivers consume about 14.5 gallons per week, on average, compared to about 9.9 and 7.5 gallons per week consumed by the average urban cluster and urban area driver, respectively. The high cost burden of travel for rural residents reflects greater travel distances and car dependency – factors that are independent of vehicle type and fuel tax or RUC system. RUC-related strategies to address these inequities include ensuring that the mileage accounting systems are capable of distinguishing miles driven on private versus public roads and targeted reinvestment of revenues in rural communities. Caltrans is launching a project to further investigate the former strategy; the latter strategy presents an important opportunity for future research.
- **Vehicle fuel economy generally increases with income, although this trend is primary driven by urban area residents:** the highest two income groups (earning $100,000 to $200,000 and $200,000 or more annually) have significantly higher rates of BEV, PHEV, and HEV ownership; the second-lowest income group has the worst average fuel economy and the highest fleet share of ICE vehicles; in urban clusters, the average fuel consumption rate of the highest income group is similar to that of the lowest income groups. While the overall trend in fuel economy with respect to income suggests that hybrid and electric vehicle ownership correlates with the ability to pay for such vehicles, the non-linearity in this trend among urban cluster residents reflects the significance of personal preferences and perhaps even cultural influences in vehicle purchasing decisions.
- **The relationship between average VMT per driver and income varies across geographies:** average VMT per driver increases with increasing income in urban clusters and rural areas as well as in Central and Northern CA; average VMT per driver is only slightly higher among those earning $50,000 or more annually in urban areas compared to

those earning less; average VMT per driver decreases slightly with income in the San Francisco Bay Area.

- **Across all regions of the state, there is no significant difference in the overall average quantity of gas or diesel consumed across income groups.**
- **There are significant differences in the overall average quantity of gas or diesel consumed across income groups within less densely populated regions of the state:** the highest income groups in both Central and Northern CA consume significantly more gas or diesel than all other residents of these regions, primarily due to relatively high average weekly VMT by high income urban cluster and rural residents; drivers in the lowest income group (earning less than $25,000 annually) in Central and Northern CA consume less gas/diesel on average than other drivers.

Awareness of current road transportation finance mechanisms, consideration of travel costs, and comfort sharing location data are all potential challenges for public acceptance and the perception of an RUC system. The key findings with regards to these aspects are summarized as follows:

- **Just under half of respondents say they know how public roads and transportation are funded;** awareness of transportation funding increased with increasing age, income, level of educational attainment, and population density; white respondents felt informed about transportation funding at a significantly higher rate compared to all other racial/ethnic groups; Hispanic respondents had the lowest rate of awareness.
- **About half of respondents say they think about travel costs when making daily travel decisions; t**he tendency to think about travel costs when making daily travel decisions decreases slightly with age and education, and decreases significantly with income.
- **About 30% of respondents were less comfortable sharing location data with government entities than with private entities;** Hispanic respondents were significantly less likely than black and white respondents to feel comfortable sharing location data with government entities.

Finally, a discrete choice model was estimated to investigate heterogeneity in the sensitivity of demand for driving to travel costs, with the following key findings:

- **There is a strong baseline preference for personal auto use among Californians**; the average Californian prefers not to use public transit.
- **The modal choices of drivers are generally insensitive to driving costs;** the sensitivity to driving costs increases when attention is drawn to gas prices.
- **Low-income drivers are generally less sensitive to driving costs when choosing travel modes compared to higher income drivers;** the likelihood to choose to drive may actually increase with worsening fuel economy, reflecting socio-economic disparities in the affordability of fuel efficient vehicles and car dependency.
- **The mode choices of the highest two income groups were insensitive to the mileage-based RUC**; the lowest income group was equally sensitive to gas prices and the RUC.
- **Californians are significantly more likely to consider non-driving modes for trips to a restaurant/bar;** they are significantly more likely to carpool or use public transit for commuting to work/school than for traveling to medical/dental care or grocery shopping, though less so than when going to a restaurant/bar.

- **Respondents' travel profiles are a significant predictor of their modal preferences:** drive alone and public transit modal shares are significantly related to lower and higher likelihood of choosing a non-driving mode, respectively.

Further refinement of the model is necessary to reach conclusive results regarding the relative sensitivity to driving costs and the potential equity implications with respect to the adoption of a RUC system. Calibration of the model with respect to revealed travel behavior is recommended, as was originally intended in the design of this study. Plans to compare the model results with data from the RUC pilot program were not realized due to a small and under-representative sample of pilot participants.

This study highlights the need for detailed disaggregate analysis of travel behavior and demand sensitivity in the assessment of equity implications of changes in transportation policies such as the potential shift to RUCs. We observed significant disparities in the intensity of road use and the relative cost burden of travel across population groups in the State of California, particularly across geographies, population density, and income groups. The analysis of baseline travel behavior demonstrates that existing disparities in land use, car dependency, and purchasing power across Californians are reflected in the distribution of the cost burden of travel in the state. While the distribution of fuel consumption rates across Californians generally suggests that the change in payments due to a shift to RUCs from fuel taxes will be progressive, the scale of these payments in comparison to total transportation costs is not likely to have a noticeable impact on drivers' budgets nor on the prevailing inequities in the distribution of the travel costs in California.

Although RUCs equalize the amount of taxes paid per mile driven across all drivers while providing a more stable transportation funding mechanism than fuel taxes amid an accelerating shift to electric vehicles, the public perception of the fairness of RUCs is likely to be tainted by various factors that are independent of the policy's goals and outcomes. The analysis of respondents' attitudes/opinions as well as the preliminary DCA results reflect a general lack of awareness and sensitivity to existing fuel taxes. Yet, when attention was drawn to gas prices, the sensitivity of demand to driving costs increased. Thus, resistance to the adoption of RUCs on the basis of equity concerns is likely to be driven by dissatisfaction with the inequities of the status quo, which are highly correlated with VMT – precisely the unit of charge proposed by RUCs.

The literature review and expert interviews highlighted a number of proactive design and implementation strategies for RUCs that can address inequities in the barriers to adoption and compliance. In addition to comprehensive education and outreach efforts, the strategies discussed in this report can alleviate many of the logistical and perception-related challenges for public acceptance of and participation in a RUC system without expanding the scope of the policy's main objectives. Strategies involving differential RUC rate structures and/or prioritization of revenue reinvestment can increase the progressivity of RUCs, which have a meaningful impact on equity in the California transportation system. The task of weighing those potential benefits against political feasibility is ultimately in the hands of the public and policymakers shaping the future of RUCs.

Recommended next steps for this research include the continued investigation of refined model specification and calibration and/or validation with respect to revealed preference data which may be available over the course of drastic changes in fuel prices that have occurred since the completion of the survey. In addition, further investigation into the potential opportunities and challenges for various rate setting and revenue reinvestment schemes aimed at reducing the existing disparities in travel distances per capita and car dependency among underserved populations in the state is recommended.

Appendix A. Topical Expert Interview Protocol

We are working with the University of California, Berkeley's Transportation Sustainability Research Center (TSRC) and the California Department of Transportation (Caltrans) on research to better understand the potential opportunities and challenges for implementing mileage-based road user charges (RCs) in California. We want to gain your insight on different areas of RCs, such as barriers to adoption and behavioral impacts, particularly with respect to underservedpopulations.

With your consent, we would like to record the audio of this interview.

1. Do you have any questions before we get started?
2. Can you describe your role in your organization and how it relates to road use charges?

Program Participation

1. What do you think are some barriers to adoption of or participation in a RUC program? For example, a lack of awareness of gas taxes?
   - Are there any barriers that are specific to California or some parts of California?
2. What kind of outreach, program elements, or technological solutions can help to engage and support participants with adoption of a road user charge?, such as older adults or individuals without smartphones?
3. How can un- and under-banked households be better included in RUC programs that are app-based?
4. What do you think is the most efficient and effective way to include shared vehicles, such as vehicles from a carsharing fleet or shared automated vehicles, into a RUC system?

Program Impacts

1. What challenges do you think exist for rural residents participating in a RUC system?
2. What challenges do you think exist for low-income households participating in a RUC system?
3. What challenges do you think exist for racial minorities in participating in a RUC system?
4. What strategies can be employed to mitigate the potential negative impacts on participants? (such as female drivers paying a higher percentage of their incomes for higher RCs)

California is piloting several RUC payment mechanisms, including: user-based insurance, pay-at-the-pump or charge point, and payment via transportation network companies (e.g., Lyft, Uber) as a line item in charges per ride.

5. What challenges do you think exist for disadvantaged communities participating in a RUC system using each of these mechanisms?

- Do you think there is a difference in the access to information or in the value of information provided by any of these mechanisms that may disproportionately advantage or disadvantage certain groups?

6. How do you think RCs will impact mode choice and trip routing decisions?
    - What strategies do you think are effective for monitoring or better understanding changes to trip routing?
7. Can you provide insight on how to alter a RUC system to better accommodate low-income households who may not have as much flexibility with mode or route choice?

Program Sustainability

1. What do you think are some of the biggest challenges in sustaining a RUC program in the long-term?
2. What are some internal or organizational changes that can be made to make a RUC system more efficient and/or sustainable?
3. Can you provide insight on effective measures to ensure compliance and enforcement of RUC payments?

Final Questions

1. Is there anything else you would like to share that we haven't discussed?
2. Do you have anyone else you recommend we talk to for this study?
3. Can we contact you again if we have any follow-up questions?

Appendix B. Community Organization Expert Interview Protocol

We are working with the University of California, Berkeley's Transportation Sustainability Research Center (TSRC) and the California Department of Transportation (Caltrans) to better understand the use of road use charges (RCs) in California. We want to gain your insight on the needs and barriers of disadvantaged communities in California with respect to RCs, such as the financial burdens of transportation, access to technology and information in an RUC system.

1. Do you have any questions before we get started?

2. Can you describe your role in your organization, the community you work closest with, and how your role relates to mobility?

Mobility Barriers

1. What do you think are some of the barriers of community members in accessing transportation?
    a. What technological barriers affect mobility for the community members you work with?
    b. What cultural barriers affect mobility for the community members you work with?
    c. How are community members financially burdened by the cost of transportation?

2. Are there ways in which technology has facilitated better mobility for community members?

3. How do you think changes in the costs of driving would affect mobility for community members?
    a. E.g., Would a decrease or increase in costs cause them to change their usual travel patterns? To gain or lose access to certain activities or destinations?

Program Participation

1. What do you think are some barriers to adoption of or participation in a RUC program? For example, a lack of awareness or difficulty accessing technology or information?
    - Are there any barriers that are specific to the community you serve?
2. What kind of outreach or program elements can help to engage and support community members in participating in an RUC program?
3. How can un- and under-banked households be better included in RUC programs that are app-based?

Program Impacts

1. What challenges do you think exist for racial minorities in participating in a RUC system?
2. What challenges do you think exist for rural residents participating in a RUC system?
3. What challenges do you think exist for low-income households participating in a RUC system?
4. What strategies can be employed to mitigate potential negative impacts on participants? (such as female drivers paying a higher percentage of their incomes for higher RCs)

The state is piloting several RUC payment mechanisms, including: user-based insurance, pay-at-the-pump or charge point, and payment via transportation network companies (e.g., Lyft, uber) as a line item in charges per ride.

5. What challenges do you think exist for community members participating in a RUC system using each of these mechanisms?
    - Do you think there is a difference in the access to or value of information provided by any of these mechanisms that may disproportionately affect certain groups?

Final Questions

1. Is there anything else you would like to share that we haven't discussed?
2. Do you have anyone else you recommend we talk to for this study?
3. Can we contact you again if we have any follow-up questions?

Appendix C. Demographic Distributions of Survey Responses by Distribution Method

Table 12. Distribution of Gender in the Survey Sample by Distribution Method

	Central California		Northern California		San Francisco Bay Area		Southern California	
	DMV n=80	Qualtrics n=401	DMV n=11	Qualtrics n=370	DMV n=14	Qualtrics n=552	DMV n=44	Qualtrics n=1,579
Gender								
Female	55%	59%	82%	53%	57%	52%	45%	56%
Male	45%	40%	18%	46%	43%	46%	55%	43%
Other	0%	1%	0%	0%	0%	1%	0%	0%
I prefer not to answer	0%	0%	0%	0%	0%	1%	0%	0%
Age (years)								
18 to 24	28%	18%	0%	12%	7%	12%	32%	16%
25 to 34	33%	25%	18%	20%	21%	20%	27%	22%
35 to 44	19%	18%	18%	17%	36%	18%	20%	20%
45 to 54	8%	16%	9%	18%	7%	18%	11%	18%
55 to 64	11%	14%	27%	16%	7%	17%	7%	12%
65 and over	3%	7%	27%	16%	14%	14%	2%	9%
I prefer not to answer	0%	1%	0%	2%	7%	1%	0%	3%
Annual income								
Under $25,000	35%	24%	36%	20%	29%	13%	32%	12%
$25,000 to $50,000	23%	26%	36%	21%	36%	15%	25%	27%
$50,000 to $100,000	20%	33%	18%	33%	21%	23%	23%	32%
$100,000 to $200,000	4%	13%	0%	16%	0%	33%	5%	21%
$200,000 or above	1%	3%	0%	6%	7%	12%	5%	4%
I prefer not to answer	18%	2%	9%	4%	7%	3%	11%	3%
Education								
Less than high school	14%	5%	0%	5%	7%	4%	10%	5%
High school graduate	51%	41%	9%	33%	50%	26%	43%	35%
Some college or associate's degree	19%	28%	27%	35%	14%	22%	14%	26%
Bachelor's degree	9%	16%	36%	18%	14%	27%	23%	22%
Graduate/professional degree	0%	8%	27%	8%	7%	20%	7%	9%
I prefer not to answer	9%	2%	0%	2%	7%	1%	2%	2%
Race/Ethnicity								
Hispanic	66%	45%	0%	25%	43%	25%	68%	48%
White/Caucasian	16%	37%	55%	52%	0%	36%	20%	28%
Black/African American	3%	6%	0%	5%	43%	7%	7%	6%
Asian	6%	7%	0%	10%	14%	27%	5%	12%
Other	3%	2%	0%	2%	0%	1%	0%	2%

Two or more races	1%	2%	27%	4%	0%	3%	0%	3%
I prefer not to answer	5%	0%	18%	2%	0%	1%	0%	1%

References

Atkinson, R. (2019). *A Policymaker's Guide to Road User Charges.* Information Technology & Innovation Foundation.

Ben-Akiva, M. E. and S.R. Lerman (1985). Discrete Choice Analysis: Theory and Application to Travel Demand, MIT Press, Cambridge, Ma.

Bonsall, P., and C. Kelly (2005). Road user charging and social exclusion: The impact of congestion charges on at-risk groups. *Transport Policy*, 12 (5), pp 406-418.

Bureau of Labor Statistics. (2018). 'Women had higher median earnings than men in relatively few occupations in 2018,' *The Economics Daily.* U.S. Bureau of Labor Statistics.

Cain, A., and P. Jones (2008). Does Urban Road Pricing Cause Hardship to Low-Income Car Drivers?: An Affordability-Based Approach. *Transportation Research Record,* 2067(1), pp 47–55. https://doi.org/10.3141/2067-06

California Department of Transportation (Caltrans). (2022). *Public/Private Roads Project*. From California Road Charge: https://caroadcharge.com/projects/public-private-roads-project/

Federal Deposit Insurance Corporation. (2017). *FDIC National Survey of Unbanked and Underbanked Households.* Washington: Federal Deposit Insurance Corporation.

Jenn, A. (2019). *Lessons Learned for Designing Programs to Charge for Road Use, Congestion, and Emissions.* UC Davis: National Center for Sustainable Transportation. http://dx.doi.org/10.7922/G2VD6WP6

Jenn, A., and K. Fleming (2020). *Federal Road Charge Tax Administration Process.* UC Davis: National Center for Sustainable Transportation. https://ncst.ucdavis.edu/research-product/federal-road-charge-tax-administration-process

Kirk, R., and M. Levinson (2016). Mileage-Based Road User Charges. Congressional Research Service. https://sgp.fas.org/crs/misc/R44540.pdf

Lazarus, J. R., Caicedo, J. D., Bayen, A. M., and S. A. Shaheen (2021). To Pool or Not to Pool? Understanding opportunities, challenges, and equity considerations to expanding the market for pooling, *Transportation Research Part A: Policy and Practice*, 148, 2021, 199-222, https://doi.org/10.1016/j.tra.2020.10.007.

McGuckin, N., and S. Liss (2005). Aging Cars, Aging Drivers: Important Findings from the National Household Travel Survey. *Institute of Transportation Engineers*.

McMullen, S., Wang, H., Ke, Y., Vogt, R., and S. Dong (2016). *Road Usage Charge Economic Analysis.* Oregon Department of Transportation. https://www.oregon.gov/ODOT/Programs/ResearchDocuments/SPR774_RoadUsageCharge_Final.pdf

National Academies of Sciences, Engineering, and Medicine. (2006). Research on Women's Issues in Transportation, Volume 1: Conference Overview and Plenary Papers. *The National Academies Press*.

Train, K., 2009. Discrete Choice Methods with Simulation, 2nd ed. Cambridge University Press, Cambridge.

Weatherford, B. A. (2011). Distributional Implications of Replacing the Federal Fuel Tax with per Mile User Charges. *Transportation Research Record*, 2221(1), 19-26.

Weatherford, B. A. (2012), Mileage-Based User Fee Winners and Losers: An Analysis of the Distributional Implications of Taxing Vehicle Miles Traveled, with Projections, 2010-2030. Santa Monica, CA: RAND Corporation. https://www.rand.org/pubs/rgs_dissertations/RGSD295.html.