

Panel Study of Emerging Transportation Technologies and Trends in California: Phase 2 Data Collection

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A Research Report from the National Center
for Sustainable Transportation

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National Center
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List of Acronyms Used

ACS	American Community Survey
Caltrans	California Department of Transportation
CI	Causal Inference
CMV	Common Method Variance
Gen X	Generation X (Middle-aged adults, 38-58 years old in 2018)
Gen Y	Generation Y or Millennials (Young adults, 21-37 years old in 2018)
Gen Z	Generation Z (Kids, teenagers and young adults, 5-20 years old in 2018)
ICT	Information and Communication Technology
MTC	(San Francisco Bay Area) Metropolitan Planning Organization
NCST	National Center for Sustainable Transportation
NorCal	Northern California
SACOG	Sacramento Area Council of Governments
SANDAG	San Diego Association of Governments
SCAG	Southern California Council of Governments
TRB	Transportation Research Board
UC Davis	University of California, Davis
VMT	Vehicle Miles Traveled

Panel Study of Emerging Transportation Technologies and Trends in California: Phase 2 Data Collection

EXECUTIVE SUMMARY

Individual travel options are quickly shifting due to changes in sociodemographics, individual lifestyles, the increased availability of modern communication devices (smartphones, in particular) and the adoption of emerging transportation technologies and shared-mobility services. These changes are transforming travel-related decision-making in the population at large, and especially among specific groups such as young adults (*e.g.*, “millennials”) and the residents of urban areas.

This panel study improves the understanding of the impacts of emerging technologies and transportation trends through the application of a unique longitudinal approach. We build on the research efforts that led to the collection of the 2015 California Millennials Dataset and complement them with a second wave of data collection carried out during 2018, generating a longitudinal study of emerging transportation trends with a rotating panel structure. The use of longitudinal data allows researchers to better assess the impacts of lifecycle, periods and generational effects on travel-related choices, and analyze components of travel behavior such as the use of shared mobility services among various segments of the population and its impact on vehicle ownership over time. Further, it helps researchers evaluate causal relationships between variables, thus supporting the development of better-informed policies to promote transportation sustainability.

The 2018 data collection for this panel project was completed through a mixed sampling method to maximize the benefits allowed by each recruitment channel while minimizing the sampling biases inherent in the sampling frames. The three methods used were:

- A. A questionnaire was mailed out to a stratified random sample of 30,000 California residents recruited from each county in the state, among whom 1,620 returned the survey via mail and 372 completed the survey online (by the time this report was published);
- B. A sample of 2,000 Californians was recruited using an online opinion panel company to refresh the panel using a quota sampling method based on geographic region, neighborhood type, and selected sociodemographic;
- C. All respondents from the 2015 survey were re-contacted through the same online opinion panel used in that data collection, of which 246 completed the 2018 survey.

The new data collection has provided the researchers with a rich dataset which is in the process of being cleaned and validated. The final sample size is expected to be at least $N=4,000$ after unreliable responses are removed, which is over twice the size of the final 2015 sample of $N=1,975$.

Early analysis of the online component of the 2018 dataset indicates there has been a large increase in the use of ridehailing throughout California from 2015 to 2018. More moderate increases are observed for other forms of shared mobility such as bikesharing and carsharing. Occupancy levels of ridehailing and shared ridehailing trips vary significantly by time of day and day of the week, with higher occupancy observed during weekend nights.

Also, the impacts of ridehailing and shared ridehailing vary by trip purpose, time of the day, length of the trip, and type of service that is used. The preliminary analysis of the 2018 online data shows that ridehailing trips are primarily replacing car or taxi trips while shared ridehailing more often substitute for the use of public transportation. Shorter trips made with these services tend to substitute for trips that would have been otherwise made by walking or bicycling.

Overall, a large majority of respondents in 2018 have heard about automated vehicles (AVs), though many of them are not very familiar with this technology and its applications. Attitudes towards AVs align with expectations, as our preliminary results show that younger respondents appear more willing to be early adopters of the technology while all age groups are reluctant to give up their private vehicles and rely solely on AV based transportation services, *e.g.*, use fleets of AV taxis or shuttles. Most are inclined to maintain their current level of auto ownership. While the perceived safety for occupants and other road users is reported as the primary barrier to the potential adoption of AVs, respondents are unwilling to accept slower travel speeds to increase safety.

During the next stages of this research project, the research team will complete the process of data cleaning and will begin more in-depth data analyses to address many of the research questions listed in the first section of the report, which seek to gain insights into the travel behavior trends of Californians as they relate to the adoption of emerging transportation options and their impacts on other travel choices.

Introduction

The rapid expansion of digital technology, the increased availability of locational data and smartphone apps, and the emergence of technology-enabled transportation and shared-mobility services are transforming transportation demand and supply. These disruptive trends might be confounded with other factors affecting travel patterns, behavioral differences across generations, changes in household compositions and lifestyles, and temporary changes that impact the way individuals interact, work, socialize, and travel. Despite the continued reliance on private cars, at least some segments of the population are apparently becoming more multimodal (Buehler and Hamre 2014) and are more reliant on the use of information and communication technology (ICT) (Circella, Alemi *et al.* 2017). Some of these changes might point towards positive impacts on the transportation sustainability. However, changes brought by new mobility options (e.g., ridehailing) or in the future driverless vehicles might increase the attractiveness of cars and reduce the use of other modes. More research based on the analysis of robust data is required to better understand these trends and support policy making to increase transportation sustainability.

This research will increase the understanding of the impacts of emerging transportation technologies and trends in California through the application of a unique longitudinal approach and the analysis of data collected over three years in the previous phase of the research (Circella, Alemi *et al.* 2016, Circella, Alemi *et al.* 2017, Circella, Alemi *et al.* 2018). The analysis contained in this panel study will address important limitations to the existing research, to date. Research on the changes associated with the adoption of new transportation services and changes in sociodemographics and lifestyles is still in preliminary stages. This is largely due to the lack of longitudinal data or robust analytical approaches to capture the causal relationships among the use of emerging transportation services, vehicle ownership, mode choice, residential location choice and other components of travel behavior. Additional difficulties associated with previous studies include the eventual maturation of emerging transportation services and their evolving impacts over time. Previous research has shown that the adoption of ridehailing might lead to a decline in the use of public transit (Circella, Alemi *et al.* 2017, Clewlow and Mishra 2017, Circella, Alemi *et al.* 2018, Feigon and Murphy 2018). However, the directions of causality behind these trends are still unclear and large heterogeneity exists among users. The deployment of AVs will likely lead to even larger changes in travel demand, including a potential increase in the total vehicle miles traveled (VMT) (Harb, Xiao *et al.* 2018), though these impacts will depend on the policies that are developed to regulate ownership and use (Circella, Ganson *et al.* 2017). These changes sum up to other factors that are already affecting passenger travel in the United States, and that have been attributed a role in explaining the changes in travel demand in recent years (Goodwin 2012, Metz 2012, Metz 2013, Wachs 2013, Sivak 2015, Circella, Tiedeman *et al.* 2016, Alemi, Circella *et al.* 2018). Previous studies were not able to fully investigate such changes only through the analysis of cross-sectional data.

This study capitalizes on the work developed in previous stages of this research project, which allowed us to collect a large longitudinal dataset through two detailed behavioral and attitudinal surveys in 2015 and 2018 with a rotating panel approach (Circella, Alemi *et al.* 2016, Circella, Alemi

et al. 2017, Alemi, Circella et al. 2018, Circella, Alemi et al. 2018, Farzad, Circella et al., *forthcoming*). Throughout this research endeavor, we analyze this dataset and answer a number of research questions related to the impacts of emerging technologies and trends over time, the role of life stages in affecting changes in travel behavior, vehicle ownership and the adoption of technology, the use of various modes of transportation, and users' responsiveness to the introduction of new services (*e.g.*, shared ridehailing services, such as UberPOOL and Lyft Line) and AVs, using longitudinal data. This project informs transportation agencies and the research community on the impacts of emerging technologies and trends on travel demand, helps enhance travel demand forecasting tools, and supports decision-making and investment decisions, to provide transportation services that best fulfill the mobility needs of Californians.

This panel study develops this understanding through a unique longitudinal approach. The study builds on an existing research program funded by the National Center for Sustainable Transportation (NCST) and Caltrans during the past three years, which allowed the collection of the very rich 2015 California Millennials Dataset. As part of the previous Phase I of the research, our team designed a detailed online survey that was administered in 2015 resulting in a sample of 1,975 residents of California, including both millennials (young adults between 18 and 34, in 2015) and members of the preceding Generation X (middle-aged adults, 35 to 50 in 2015), who were recruited through an online opinion panel. The dataset includes many variables of interest and has allowed the development of several analyses of millennials and Gen Xers' attitudinal profiles, travel behavior, vehicle ownership, residential location, and adoption of shared mobility. For additional information on the Phase I of the research, which obtained large visibility in the scientific and planning community due to its ability to shed light into the factors affecting millennials' choices related to residential location, travel behavior and adoption of technology, see Circella, Alemi *et al.* 2016, Circella, Alemi *et al.* 2017, and Circella, Alemi *et al.* 2018.

Now that the study is in the Phase II of the long-term research plan, we have built the longitudinal component of the research through a second wave of data collection that will be integrated with the 2015 California Millennials Dataset. Turning the project into a longitudinal study with a rotating panel structure allows us to harvest the full potential of this research program. In this new round of data collection, we attempted to recall as many of the respondents in the original 2015 sample. However, due to limitations that are discussed later in this report only a fraction was able to participate. In addition, we refreshed the panel with new participants, broadening the research beyond the generational groups of millennials and Gen Xers used in the 2015 study by expanding the data collection to the entire population of adults in California, *e.g.*, including "post-millennials" and the sizable group of baby boomers in the study. We used a combination of sampling strategies, including the use of the online opinion panel and the creation of a paper version of the survey that was mailed to a random sample of respondents in the state, in order to expand the target population of the study, and reach segments, *e.g.*, elderly or people that are not familiar with technology, who would not be well represented in an online survey.

This research provides a unique opportunity to study the impacts of emerging technologies and trends with longitudinal data. It will allow the researchers to disentangle the role of stage in life in



affecting lifestyles and travel decisions, better evaluate the impacts of the lifecycle, periods and generational effects, and investigate the complex relationships behind the formation of travel behavior over time (*e.g.*, modifications in the use of shared mobility and their impacts on vehicle ownership) among the various segments of the population.

Research Questions

Table 1 summarizes a list of potential research questions that will be investigated during the analysis of the data collected in this project. Some of the preliminary analyses presented in this project started to address some of these questions. During the next stages of the research, the researchers will complete inputting the information collected with the paper surveys that were mailed back during the 2018 data collection, will clean the data and augment the dataset with information obtained from other sources (*e.g.*, land use data based on geocoded location of where respondents live) and will develop more in-depth analyses to answer some of these research questions.

Table 1. Potential research questions to be investigated during next stages of the research

Focus of Analysis	Research Questions
Changes in use of shared mobility	<ul style="list-style-type: none"> • How has the adoption of various types of shared mobility services (<i>e.g.</i>, carsharing, bikesharing, ridehailing) changed over the last three years? • How does the adoption of shared mobility vary by geographic region of California, neighborhood type, and segment of the population? • How does the use of services such as ridehailing (<i>e.g.</i>, UberX, Lyft Classic) and shared ridehailing (<i>e.g.</i>, UberPOOL, Lyft Line) change by time of day and trip purpose?
Impacts of shared mobility on other modes	<ul style="list-style-type: none"> • How does ridehailing affect the use of other modes, including public transit, active travel and use of private vehicle, among various groups of users? • To what extent various factors (<i>e.g.</i>, income, student status, presence of children in the household) affect the use of various shared mobility services? • How does the adoption of shared mobility services affect VMT and greenhouse gas emissions? • Does adoption of shared mobility prompt any changes in vehicle ownership?

Focus of Analysis	Research Questions
Use of various travel modes	<ul style="list-style-type: none"> • How does the ownership and use of private vehicles change with stage in life, changes in attitudes and lifestyles and adoption of technology? • How does the use of active modes of travel vary among sociodemographic segments? • Is there a relationship between the adoption of smartphones, the use of social media, and the use of various travel modes (e.g., public transit)? • What users are more willing to modify their vehicle ownership? How does that intention relate to the adoption of other travel modes and lifestyles?
Adoption of e-shopping	<ul style="list-style-type: none"> • How is e-shopping affecting the physical amount of travel for shopping purposes? • What individuals adopt faster delivery-time services (e.g., Amazon Prime)? • How do purchasing behaviors (e.g., “searching in stores and buying online” or “searching online and buying in stores”) vary by groups of users? • How does the return of items purchased online affect goods shipments?
Impacts of stage in life	<ul style="list-style-type: none"> • How do millennials’ travel habit change as they transition into later stages in life, start working, get married, have children and change residential location? • Are post-millennials (Gen Z) different from the millennial generation in terms of travel choices and propensity to use various transportation options? • How does aging affect vehicle ownership and travel behavior? • How does the adoption of travel multimodality vary with stage in life?
Changes in urban form and transportation services	<ul style="list-style-type: none"> • How do changes in residential location and housing market of California regions affect travel behavior of the residents of these areas? • How are changes in transportation options (e.g., shared mobility services, expansion of transit services) affecting travel choices in various regions? • What are the factors that motivate changes in residential location?
Adoption of AVs	<ul style="list-style-type: none"> • How does the willingness to use driverless vehicles vary across the population? • Who are the early adopters, i.e., willing to purchase an AV first? • What ownership (shared vs. personal) and use (shared vs. individual) models for AVs are more popular among various individuals?
Travelers’ response to transportation policies	<ul style="list-style-type: none"> • Would Californians be responsive to policies designed to reduce vehicle ownership by adopting mobility-as-a-service transportation options? • What users might be interested in subscribing for flat-fee programs for ridehailing? • What users are more inclined to share rides with strangers? Under what circumstances would they share?

As previously mentioned, this stage of the research builds on the work developed during previous grants that allowed the development of the Phase 1 of this research. We refer to the set of previous reports from the Phase 1 of the project for additional information regarding the conceptualization of the research, literature review on core research subjects, and detailed analyses from the 2015 data:

- “What Affects Millennials’ Mobility? PART I: Investigating the Environmental Concerns, Lifestyles, Mobility-Related Attitudes and Adoption of Technology of Young Adults in California” (Circella, Alemi *et al.* 2016);
- “What Affects Millennials’ Mobility? PART II: The Impact of Residential Location, Individual Preferences and Lifestyles on Young Adults’ Travel Behavior in California” (Circella, Alemi *et al.* 2017);
- “The Adoption of Shared Mobility in California and Its Relationship with Other Components of Travel Behavior” (Circella, Alemi *et al.* 2018).

Sampling Method Nomenclature

For clarity and consistency, the following nomenclature will be used throughout the report when addressing the different sampling methods used in the study.

Table 2. Sampling method nomenclature

Sample ID	Sampling Method	Details
A	Mail Survey	30,000 paper surveys mailed to a random sample of California residents
A.1	Returned via mail	Respondent opted to complete the provided paper survey and return it via the mail
A.2	Completed via online survey system	Respondent opted to complete the survey via the online survey platform
B	Online Opinion Panel	2,000 respondents collected via an online opinion panel provider
B.1	Longitudinal	1,000 respondents completed the 2018 survey and agreed to participate in future iterations of the study
B.2	Cross-sectional	1,000 respondents completed the 2018 survey
C	Recontact 2015 Respondents	All respondents from the 2015 survey (N=1,975) were re-contacted to solicit participation in the 2018 iteration of the data collection

Literature Review

The following subsections will review the current body of scientific literature related to the topics of properly managing the treatment of time in research design, balancing survey distribution methods to minimize sampling frame biases, recruitment technique to maximize response, and strategies for sampling typically under represented demographic segments. This literature review focuses on the data collection methodology as that is the core content of this report. For a comprehensive literature review of the underlying research topics of mobility of millennials, shared mobility, and new mobility services please see the previous reports from this multi-stage research project (Circella, Alemi et al. 2016, Circella, Alemi *et al.* 2017, and Circella, Alemi *et al.* 2018).

Treatment of Time in Research Design

There are two main approaches for handling the treatment of time when designing a survey-based data collection: longitudinal and cross-sectional. Longitudinal surveys collect data from the same sample over multiple periods of time while a cross-sectional survey collects data from a single point in time (Lynn 2009). Repeated cross-sectional surveys do collect information at different points in time, though using different samples. Each of these approaches has its own strengths and weaknesses and should be used when their characteristics align with the research objectives. The pioneering Puget Sound Transportation Panel Study conducted by Murakami and Watterson (1992) showed the benefits of panel data and being able to determine the travel behavior trends over time.

Longitudinal data can be collected via a variety of methods with the two primary methods for survey-based collections being household panel surveys and panel or cohort surveys (Lynn 2009). These two methodologies have minor differences in their sampling methodologies but perform the same function, which is conducting a multi-topic survey that collects data on “behavioral, attitudinal, and circumstantial data” (Lynn 2009). Due to the wide variety of data typically collected in these types of surveys, Lynn (2009) states that they have the added benefit of being “used by a wide range of users for a broad set of purposes” beyond the original purpose. Lynn (2009) outlines the analysis-based advantages of longitudinal data as being able to determine gross change, unit-level change, allows for aggregation of the data, and clearly established the time-order of events. Rindfleisch *et al.*'s (2008) comprehensive review of longitudinal and cross-sectional methodologies identifies that the two main statistical concerns (validity threats) that dominate the body of knowledge on survey design are the “(1) common method variance (CMV) (*i.e.*, systematic method error due to the use of a single rater or single source) and (2) causal inference (CI) (*i.e.*, the ability to infer causation from observed empirical research)”, which can be mitigated via a longitudinal data collection.

Another beneficial attribute of panel data is that it can be analyzed using methods that are suited for both longitudinal and cross-sectional data set, thus expanding the possible uses for the data (Kalton and Citro 1995). Slicing the data in these different ways can also address issues

in the dataset itself, such as in cases where “observed and unobserved heterogeneity can be separated into their cross-sectional and longitudinal components with relatively small complications” (Lee, Davis *et al.* 2017). As a caveat to this, Kalton and Citro (1995) stated that if “cross-sectional estimates are also of interest, it may be necessary to update the sample at each wave to represent new entrants to the population.”

There are also benefit for the data collection itself. Inherent to the longitudinal approach the data collected provides a rich history of the individuals (Lynn 2009). Lynn (2009) also states that data can be more accurate as the repeated surveying does not rely on long term memories as “recall accuracy tends to be associated with events and circumstances that are rare, salient and recent.” Therefore, if the survey is not collecting data on those types of events and circumstances it can be less accurate.

Longitudinal surveys are not without their drawbacks. Lynn (2009) identifies three major disadvantages as being that (1) if a rare population was not captured in the initial sample it will not be represented for the duration of the study, (2) conditioning of the panel to the survey can cause stagnation in the data, and (3) the persistent issue of the sample attrition will affect the study due to natural drop out, loss of interest, life event changes, or loss of contact method.

Panel conditioning is challenging to mitigate as Chlond, Streit *et al.* (2015) noted during their panel study conducted in German that longitudinal data collection requires continuity in both the design and method of the survey because “any observed changes cannot be distinguished from methodological artifacts and thus cannot be assigned to changing frameworks or changed behavior.” While it is more important to expose the respondents to the potential of conditioning to the questionnaire than exposing them to potential outside factors by significantly altering the questionnaire, this can be minimized by utilizing a rotating panel or refreshing the panel. These sampling methodologies are useful ways to smooth the effects of survey design changes as it is possible to isolate changes from the survey design and actual behavior by comparing the new sample with the longer term participants (Chlond, Streit *et al.* 2015).

Panel data provide extremely rich information, which allow investigating the relationships behind certain human decisions over time and allow disentangling the complex interactions among multiple variables and better identify causal relationships (Kitamura, Aihara *et al.* 1990, Hoogendoorn-Lanser, Schaap *et al.* 2015). However, the availability and use of panel data in transportation planning is not very common, mainly due to the high costs and needed resources for the data collection over longer temporal horizons (Lynn 2009). This long-term commitment to a robust data collection effort is crucial as Ployheart and Vandenberg’s (2010) analysis of longitudinal studies shows that at least three phases of data collection are ideal as they can show if observed changes are real or a measurement error while also revealing if the relationship is linear. They remarked that having only two phases of data collection can be sufficient for analysis but conclusions need to be conservative as it exposes the results to the previously mentioned sources of error (*e.g.*, real vs. measurement error, nonlinear relationships) that are not as prevalent as in

the longitudinal panels with more than three waves of data collection (Ployhart and Vandenberg 2010).

Survey Distribution Methods

Administering surveys for data collection can be completed *in person* by the researchers or through an asynchronous method such as using online survey platforms or sending paper survey via the postal service. The sampling frame for both methods needs to be accounted for as Cole (2005) observed that while web-based sampling has the benefits of a wide reach and low costs it might not be representative of the larger population as not everyone has access to the internet. Additionally, a preference by age group for contact method was observed in Kaplowitz's (2004) study of response rates for mail and web-based surveys with older people preferring mail and younger people responding in higher numbers to online surveys. This finding was supported and expanded to account for demographics traits by Carrozzin-Lyon, McMullin *et al.* (2013) who observed that a "preference for mode of contact appears to strongly align with one's demographic characteristics; rural, older respondents with less formal education opted to complete the mail survey more often, whereas younger, urban respondents with more formal education opted to complete the Web-based version more often."

Loomis and Paterson (2018) conducted a meta-analysis of 11 datasets with varying data collection approaches and observed that a typical mail survey is likely to have a higher response rate compared to a web-based survey, but this was not seen very consistently so no advantage is gained in response rate by favoring either method. The primary concerns for sampling mode selection should consider "survey population, time, resources, data quality, efficiency, and expected response rate (Loomis and Paterson 2018)." The quality of the data acquired via web or mail provided results that are equally reliable (Cole 2005). This was further supported in the meta-analysis conducted by Loomis and Paterson (2018) which observed that "results appear to suggest that in general there are few data differences between the responses to the mail and Internet surveys." Another important factor to account for in selecting a survey distribution method is item non-response, *i.e.*, respondents purposefully skipping a question. Slightly better item non-response rate can be expected via mail surveys compared to online surveys, 2.4 - 19.2% vs 3.3 - 23.2%, respectively (Loomis 2018). However, online survey platforms allow for questions to require a response to proceed in the survey which will drop the non-response rate in the survey to 0% but may increase the incidence rate of incomplete surveys as respondents decide to drop out of the survey before completing it (or they may provide unreliable information to proceed in the survey in presence of questions that are unclear to them, or that they prefer not to answer).

Survey Recruitment for Online and Mail Out/Mail Back Surveys

The next hurdle in successfully administering a survey is the recruitment of the respondents. There are a few tactics that can be applied across web and mail-based sampling methods. To get a respondent to start the survey "one should adopt a researcher higher in power, higher in organizational position or educational achievement, or serving in a national-level educational

institution, as the main contact person. Whenever possible, it is the best to list the formal title and degree of the researcher to validate the authority” (Loomis and Paterson 2018). This tactic adds a level of gravity to the survey and institutional authority to the request to participate in the survey thereby increasing the participation rate. The incident rate of non-deliverable surveys is another issue that arises with both web and mail survey recruitment. While it might seem reasonable to assume the email-based recruitment would be near 100% for delivery given the digital and near instantaneous nature of emails, however Loomis and Paterson (2018) observed that “there was a consistent pattern, with the non-deliverable rate being higher for the Internet mode”.

Incentives are a common method used to entice participants to take a survey. Pan, Woodside *et al.*'s (2018) studied the impact of research identity, organization identity, and incentive on the response rate for online surveys and observed that “a high-power researcher and familiar sponsor generated higher response rates, while a familiar incentive did not.” While this study did not test response for a survey with and without an incentive, it is important to recognize that incentives can still be a factor influencing participation even if it is not as great as the research or organization identity, so it should not be overlooked.

Hoogendoorn-Lanser, Schaap *et al.* (2015) conducted a study on mobility in the Netherlands and observed the following strategies to be effective tools to encourage high response to non-web-based survey: clear communication and instructions, incentives, use of organization logo on materials, free contact methods (800 number and email), and a reminder postcard (Hoogendoorn-Lanser, Schaap *et al.* 2015).

The current body of knowledge regarding this topic indicates that there is no single survey administration tactic that will achieve the desired participation and response rate but rather it requires a varied set of self-reinforcing tactics to get a respondent to tip from inaction to action.

Strategies for Sampling Typically Underrepresented Demographic Segments

Survey-based research is underpinned by the notion that a sample of the population can be used to represent the total population. For this generalizability to be achieved, it is imperative that typically underrepresented demographic segments be included in the sample. Two typical methods used in both longitudinal and cross-sectional surveys to reach rare populations are disproportionate sampling and use of multiple sampling frames (Kalton and Anderson 1986). Longitudinal panels are a useful tool to address this issue as the rare population segments can be aggregated across multiple data collection waves (Binder).

Beyond merely including the rare population in the sample, there can also be additional challenges to get rare population groups to participate in a survey. Pan, Woodside *et al.*'s (2018) study confirmed the results of Chawla and Nataraajan's 1994 study on ethnic bias to researcher's name and suggested using a name that matches the ethnicity of the population

being sampled. The rationale behind this tactic is to build a rapport with the respondent by indicating a commonality and sincerity between the researcher and the potential respondent.

In our modern, diverse society there are subsegments of the population that speak a different language so translating the survey to their preferred language can garner greater participation by allowing them to read the survey in their native language. Translation does open the survey to a new potential source of error by mistranslation, so the translator needs to ensure all three types of meaning/equivalence are achieved, which are *content equivalence*, *semantic equivalence*, and *conceptual equivalence* for valid results to be gained from translated surveys (Tsai, Luck *et al.* 2018). To achieve this Tsai, Luck *et al.* (2018) suggest that at least one of the researchers be fluent in the language being translated to “ensure closest fit” of the three types of meaning/equivalence that are needed for a credible translation.

The review of the literature summarized in this section was used to improve the methods of data collection, increase the response rate, and reduce the sampling issues to the extent possible in this research. Still, the research team recognizes that the sample collected in the study cannot be considered representative of the population of California. Accordingly, generalization of the results from the study to the entire population in the state may prove problematic, in particular when analyzing descriptive statistics from the unweighted sample. In future stages of the research, the research team plans to develop a set of weights to reduce the non-representativeness of the collected sample.

Survey Design

In the following subsection, we will be discussing the process and results of the survey design. As this research effort is a continuation of the 2015 *Panel Study of Emerging Technologies and Transportation Trends*, the survey design utilized the 2015 survey as the foundation, which was revised and updated for the 2018 iteration of the data collection. It was vital for the study's longitudinal dataset to ensure a consistency between the two rounds of data collected, which allows for analysis of trends over time. Therefore, the 2018 survey retains a similar structure and the core content of the 2015 survey but some sections were simplified to reduce the response burden and new questions were included to collect information on new topics deemed important during this stage of the research (e.g., use of shared ridehailing services, and attitudes towards AVs). The research team utilized their access to colleagues at other research institutions, strategic business associates, staff at regional and state agencies, and other partner organizations to provide input on the survey design related to their area of expertise.

Survey Section Overview

The survey collects information on personal attitudes and preferences, adoption of various communication technologies, personal life-styles and work-styles (including telecommuting and mobile work, and adoption of e-shopping), cultural background, residential location and living arrangements, current travel behavior, use of cars vs. non-motorized transportation modes, adoption of alternative-fuel (e.g., electric) vehicles, availability and use of new transportation modes and shared mobility services, aspirations for future travel and purchase of vehicles, and sociodemographic traits. As previously mentioned, we strived to maintain consistency, wherever possible, with the previous survey from 2015 to maintain the longitudinal component of the research while making additions and modifications in the 2018 surveys to address current or future transportation trends that were not well established in 2015. Specific efforts were made to maintain question structure and neutral wording as much as possible to not add sources of bias related to the questions were presented and phrased.

The following sub-sections of the report present the content of each section in the final version of the survey that was used for data collection in the project.

Cover Letter

Two versions of the cover letter were created for the two sampling methods, online and mail. The online versions (Samples B and C) provided a brief introduction the research project, stated their responses would be confidential, and thanked them for participating in the study. This was kept brief to not overburden the respondents with a long page to read.

The mail survey (Sample A) included all the information in the online version while also including additional information as this would be a respondents' primary source of information about the survey. The cover letter provided the instructions on whom should take the survey, *i.e.*, the adult (18+) with closest birthday to the date they received the survey. This additional randomization was

intended to minimize a potential sampling bias of having responses from only the main person in the household that retrieves/opens the mails or the head of the household. The cover letter also provided instruction on how to complete the survey online if that was their preferred method. Providing two options to complete the survey was intended to encourage the highest response rate possible. To further this objective, an incentive was offered of participation in a random drawing for one of many gift cards from a major online shopping retailer. The research team's contact information was provided in the form of an email address and a toll-free 1-800 number to facilitate answering any questions from the respondents.

It is worth noting that on the outside of the survey, there were instructions in English and Spanish to inform the reader that if they wanted to complete the survey in Spanish, a Spanish version of the questionnaire was available via the online survey platform or a Spanish translation of the survey would be provided upon request. While not explicitly stated as an option in the instructions, four requests for the Spanish surveys were received through the toll-free number, which was set up with a virtual switch board to direct calls to an English- or Spanish-speaking member of the research team.

Section A: Your Opinions on Various Topics

This section began with a brief introduction to the topic and a reminder that there is no “right” or “wrong” way to answer the survey if it was their honest opinion. Section A focuses on attitudes and preferences by gauging their agreement with 29 attitudinal statements on a 5-level Likert scale. The core constructs these statements measured were:

- Active Lifestyle/pro-exercise
- Environment
 - Environmental concern
 - Environmental concern and travel behavior
- General Value/Beliefs
 - Trust
 - Variety-seeking
- Role of government on regulating car use
- Perceptions on land-use
- General life satisfaction
- Travel Modes Perceptions
 - Bike
 - Car
 - Transit
- Sensitivity to autonomy in driving
- Materialism – sharing vs. owning
- Technology trends
 - Early adopter
 - Technical savviness

- Time use/multi-tasking
- Perception on commute time

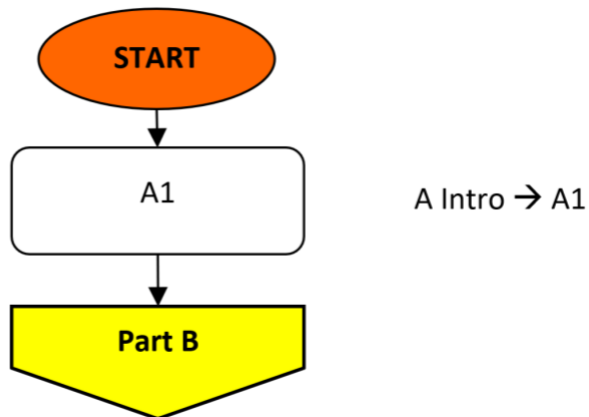


Figure 1. Logic flow and branching for Section A

As this section was structured as one question with 29 statements, it had a high potential for respondents to flatline, *i.e.*, mark all of one response to the whole list. To prevent this and to test for full engagement with the survey, trap questions were included in this section. These questions asked the respondent to enter a specific response and if they failed this task it would indicate that their survey may need to be dropped for quality assurance reasons. In the paper version (Sample A.1) of the survey, one trap question was used while the online versions (Sample A.2, B, C) used two trap questions. An additional trap question was used in the online version as there is a potential for inattentive respondents “flatlining” the section and the prevalence of automated “bots” that attempt to complete surveys distributed through online survey panel vendors. This section consisted of one question so there was no logic/branching in this section (see Figure 1).

Section B: Your Use of Technology

Section B collects information regarding the respondent's familiarity with internet connected devices and services.

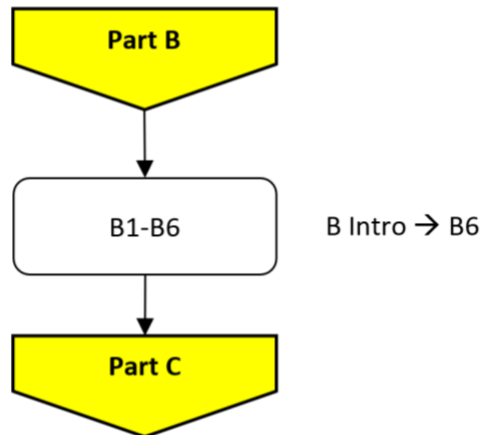


Figure 2. Logic flow and branching for Section B

Questions in the section asked about ownership of devices and the frequency apps/services are used. Online shopping is a prominent activity for people with internet access, which impacts their travel behavior as it correlates to the number of trips made to stores and their use of freight network. The survey collected information on recent purchases, preferred shipping timeframe, and how this has impacted their item search/purchase patterns. This section has no logic/branching through the six questions in the section (see Figure 2).

Section C: Key Aspects of Your Lifestyle

Section C collected information regarding key aspects of their lifestyle such as current housing arrangements, major life events, residential location choice, and car ownership status.

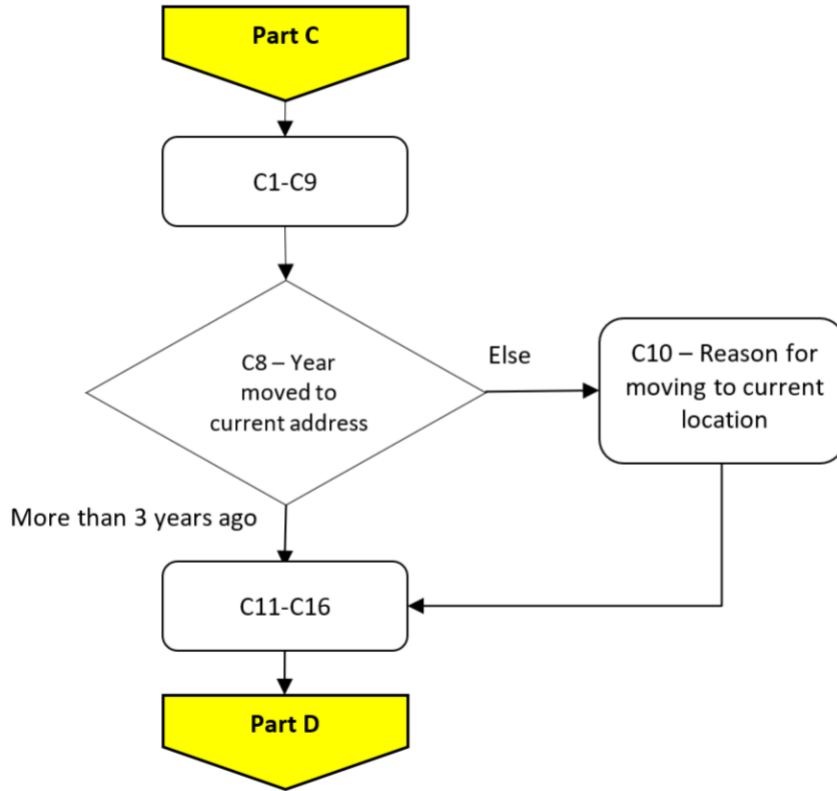


Figure 3. Logic flow and branching for Section C

This section has skip logic following the ninth question (see Figure 3). Using the information provided in the eighth question (the year they moved to their current address), if a respondent had lived there for more than three years they skipped the tenth questions, which asked for the reason they moved to their current location.

Section D: Employment and Work/Study Activities

Section D collected information on employment status, student status, and the corresponding schedule for those activities. After providing their work and student status, skip logic was used in order to not burden respondents with unrelated questions (see Figure 4). If a respondent was not employed or a student, they were instructed to skip to question 6 in Section E. Section E began with questions related to commute travel, so it would not pertain to these respondents. If a respondent was only a student, they skipped question three which asked how many hours they work in a week. Finally, the remaining people that work and either are or are not a student progressed through the section without skipping any questions.

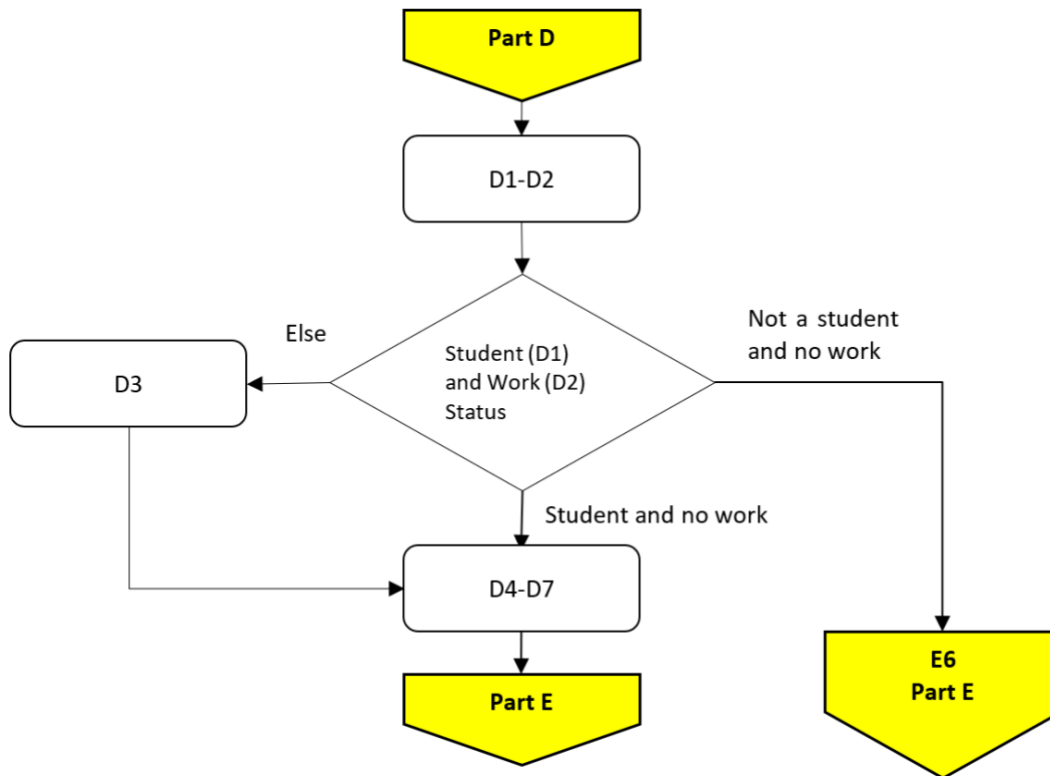


Figure 4. Logic flow and branching for Section D

Section E: Your Current Travel Choices

Section E collected information on current travel behavior. As the beginning of this section, there was a brief introduction which defined terms that were used in the remainder of the survey. This was required since terms such as “trip” and “car” can be interpreted differently and by defining them it would minimize any ambiguities in the terms. The content of this section relates to current commute patterns, most recent leisure/social/shopping trip, average monthly transportation costs, how much they like current modes of travel, and long-distance travel. In addition to the overall travel choices, there were also questions relating to multi-tasking during these trips, presence of any physical or other conditions preventing/limiting travel, and the influence of internet on daily travel. In its totality this section provides a robust understanding of the respondent’s current travel choices.

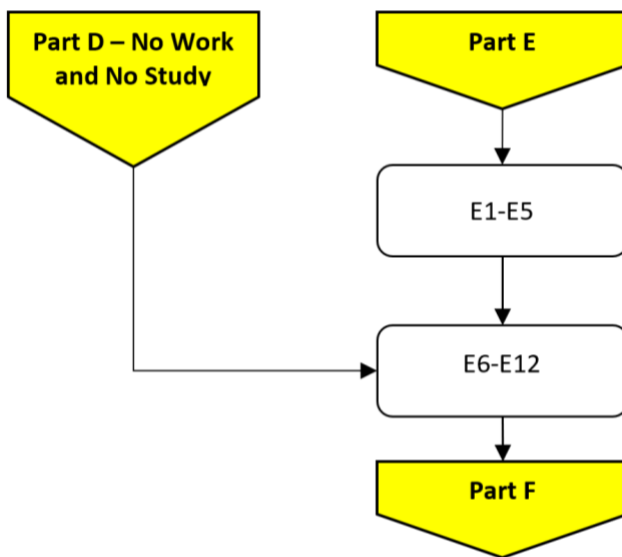


Figure 5. Logic flow and branching for Section E

There is no skip logic/branching starting in the section; but, it does have respondents who neither worked nor student skipping to question 6, which is the first non-work/study related travel question (see Figure 5).

Section F: Emerging Transportation Services

Section F collects information on the emerging app-enabled ridehailing services, *e.g.*, Lyft, Uber, and Via. Questions in this section include frequency of use of the services, a detailed examination of their last ridehailing trip, impact on other modes, and an assessment on current dependency on the services. Following these questions on established services the survey probes the respondents on their willingness to use the emerging shared ridehailing services, *e.g.*, Lyft Line or UberPOOL, and measures their interest in theoretical mobility-as-a-service implementations.

This section expanded compared to the 2015 survey given the rise in popularity of these services and their potential to affect other components of travel behavior, such as travel cost, convenience and security (National Academies of Sciences, Engineering, and Medicine 2016). The 2015 survey already included a sizable section on shared mobility, collecting detailed information on the awareness, adoption and frequency of use of the most common ridehailing services. In the 2018 survey, we also collected information for additional types of shared mobility services that have been introduced during recent years, specifically shared ridehailing services.

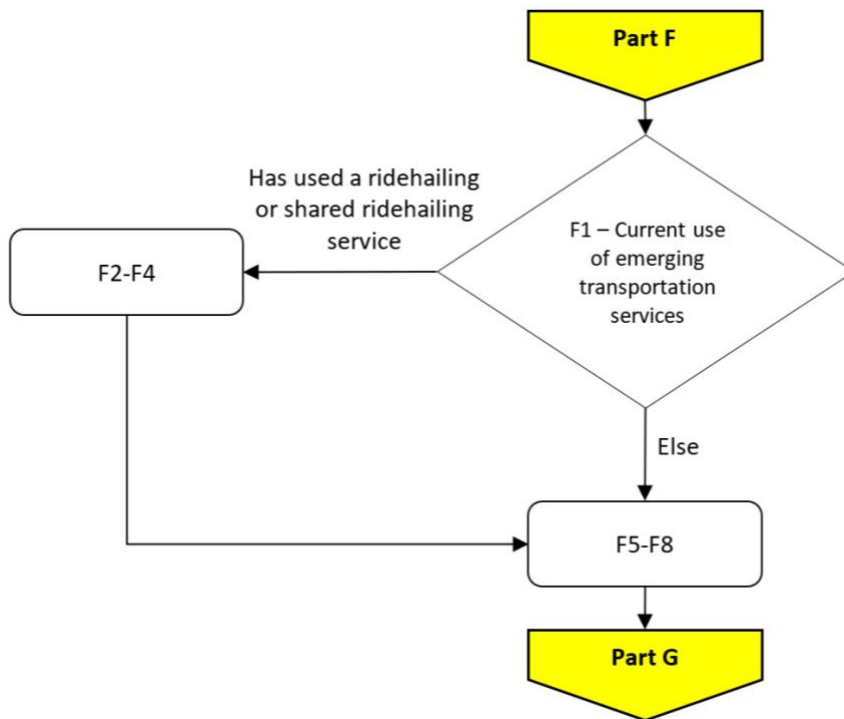


Figure 6. Logic flow and branching for Section F

To measure the likelihood a person would be willing to share a ride via a ridehailing service if a discount was provided a unique question design was used. The second question in the section consists of a table of 13 sub-questions with the last sub-question asking how long they would be

willing to wait for a shared ride over a single occupant ride for a discount over the single occupant cost. To test how price sensitive people would expect to be in this situation, four versions of this question were created with the discounts of 10%, 20%, 30%, and 40%. This was easily implemented in the online versions (Samples A.2, B, C) with one of the four variants being randomly presented to the respondent. The mail version (Sample A.1) of the survey required four versions of the survey to be created and then randomly assigned each address to one of the four versions.

There is one point of logic/branching in this section and is based on the first question which asked about the frequency they have used a list of emerging transportation services. If they have ever used a ridehailing or shared ridehailing service they would proceed to the second question, otherwise they would skip to question five. The paper version had a simplified version of this by instructing the reader to check a box if they have never used a ride hailing service (shared or single) and then skip to question 5. This approach was used as it was a simpler approach than having to review the previous question for a list of specific responses thereby reducing the cognitive burden placed on the respondents.

Section G: Future Mobility

Section G collected information on how new technologies and service may impact their current vehicle ownership and, as an addition to the 2015 survey question, a new block of questions related to AVs was added. These new questions focused on collecting information about a respondent's perceptions and propensity to adopt AVs in scenarios of shared-ownership/shared-use or personal ownership. Prior to the new block of AV related questions which included a brief introduction to the technology, the respondents were asked to provide their current level of awareness of AVs. This was done to measure the respondent's unprimed opinion on the subject. In both the online and paper version, a page break was added after this question so the introduction AVs would not bias the previous question. The introduction to AVs was designed to illustrate the wide range of possibility AV may provide and was presented it in two different ways (pictures and text) to stimulate as much thought and engagement about this new technology.

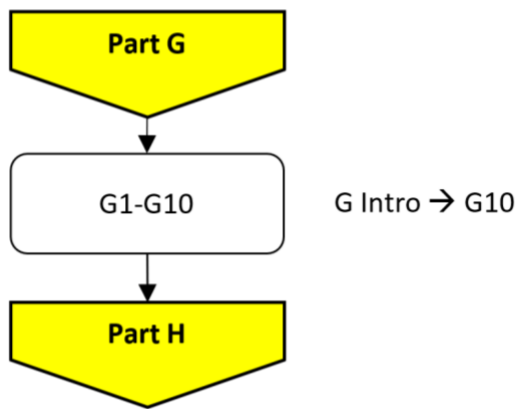


Figure 7. Logic flow and branching for Section G

There is no logic/branching in the section (see Figure 7). As this is the penultimate section in the survey and there is potential for fatigue from the respondents, a third trap question was included in question five. The results of this trap question will be considered in conjunction with the prior trap questions and other data validation tests to determine if a respondent should be dropped from the dataset.

Section H: Some Background about Yourself

Section H collects basic sociodemographic questions from the respondents. Collecting data on their age, ethnicity, gender, education, and income will allow the researchers to generalize the findings from the sample to the population of California.

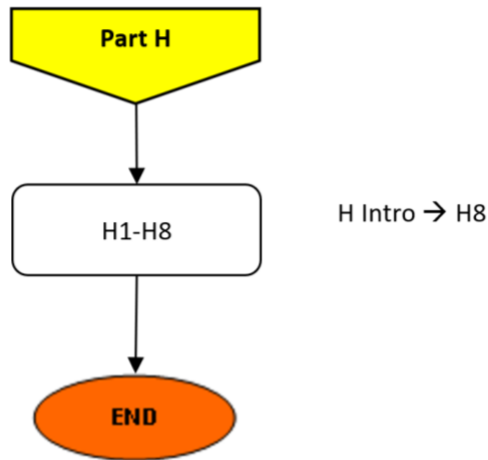


Figure 8. Logic flow and branching for Section H

There is no logic/branching in this section (see Figure 8). Following the end of the survey, there is a heartfelt thank you to the respondents for their time and effort and up to two additional questions, depending on the distribution method. The mail survey (Sample A.1) and its corresponding online survey (Sample A.2) ends first with a question asking if the researcher team can contact them for one of the following reasons: 1) to be entered in the drawing for the incentive, 2) to be available for any follow-up questions based on their responses to the survey, and 3) willing to participate in future iterations of the survey, *i.e.*, the longitudinal component of this ongoing research effort. As part of that question, the respondents are asked to provide their preferred contact information. This is followed by an open response question for any additional comments about the survey itself or topics raised in the survey. The online only versions (Sample B, C) of the survey only have the second of those two questions as the panel vendors directly handle the distribution of the incentives for their respondents and also do not allow for personally identifiable information, such as the contact information, to be provided unless in special cases like in our efforts to build on our longitudinal panel (Sample B.1), which will be discussed in detail in the Data Collection Methodology section.

Survey Length

After completing the 2015 survey many respondents noted that the survey length was too long. Reducing the time needed for completion was an important issue that needed to be addressed because as the length of the survey increases the potential for fatigue increases thus calling into question the validity of responses from later parts of the survey. This was addressed by consolidating the number of sections in the survey from eleven in 2015 to eight in 2018. While the number of sections is cosmetic in nature, the reshaping of the survey flow did focus the content to be reduced to stay within the topics of each section. This led to a reduction of 31% in number of questions from the 2015 survey, which consisted of 159 questions, and the 2018 survey which consisted of 109 questions. This resulted in a survey that was designed to be completed in 30 minutes.

Distribution Method Considerations

Given the unique natures of the two distribution methods, through an online opinion panel and by mail, we made a concerted effort to design the survey in a manner so there was consistency between them, thereby not introducing an unintended source of error or bias in the data collection. The paper survey drove the design as it would be the most limiting of the versions due to the inability to force responses, no response validation on open ended questions, and the additional effort required by respondents to correctly follow skip logic/branching. Efforts were primarily directed at reducing and simplifying the skip logic/branching. It was used three times and spread out across three sections to not over-burden the survey respondents. Also, the criteria to skip certain questions were presented as simply as possible with the key criteria being in bold typeface to have it stand out on the page in the paper version of the survey.

Testing and Survey Design Quality Assurance

Once the content and formatting of the survey was near finalized, we tested the survey by conducting a multistage pretest. In the first round of pretesting team members took the survey to conduct a final pass on copyediting the document as well as to experience taking the survey in the same manner as a respondent might. This provided feedback that was useful in identifying small items that needed correction. In the next stage of the pretest, we utilized a convenience sample of colleagues and other peers to run a pretest of people that had not seen the survey before. They were able to complete the survey either via the online platform or by printing a copy of the mail survey. A total of 18 pretest surveys were completed and based on their feedback, we were able to modify questions for clarity, correct small typos, and confirm the estimated time to complete the survey at 30 minutes.

Data Collection Methodology

This study provides a unique opportunity to improve the understanding of the impacts of emerging technologies and transportation trends by creating a longitudinal dataset with a rotating panel structure. In the study, we build on the existing research program that has been carried out by the research team over the past few years and that led to the 2015 data collection in this research.

Figure 9 summarizes the sampling strategy for the second wave of data collection in this panel study. The expected sample size at the end of this phase of the data collection is 4,300.

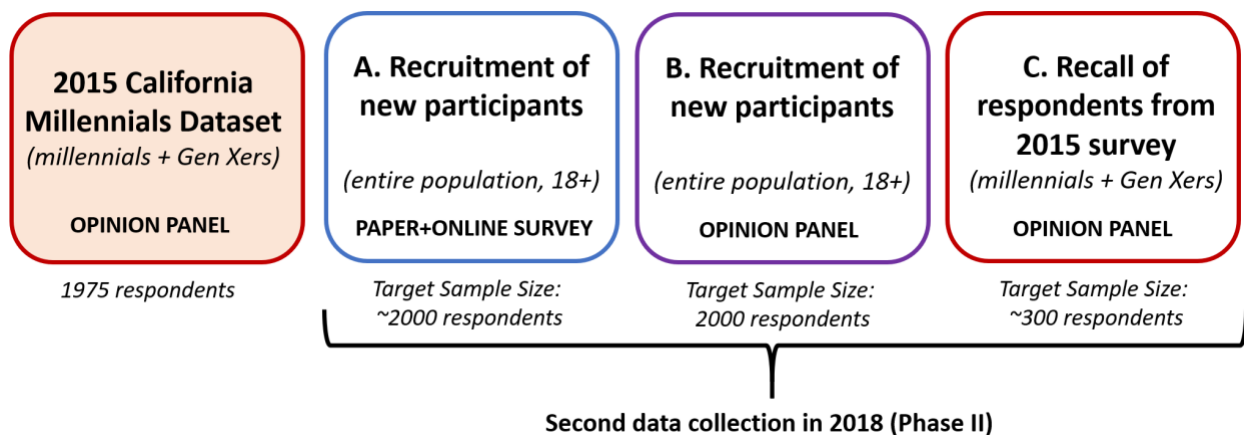


Figure 9. Sampling strategy for second round of data collection in Phase II of the research

2015 California Millennials Dataset

The California Millennials Dataset was collected in fall 2015 during the Phase I of the research. We designed and administered an online survey to a sample of more than 2400 residents of California recruited through an online opinion panel. The sample included 1400 millennials, *i.e.*, young adults 18 to 34 years old in 2015, and 1000 members of the preceding Generation X (Gen X), *i.e.*, adults between 35 and 50 years old. We employed a quota sampling approach to ensure that enough respondents were included from each of six main geographic regions of California and from three neighborhood types (urban, suburban, and rural). After data cleaning, the final dataset included 1975 valid cases after a comprehensive review process, which looked for consistency and reliability in the responses.



Figure 10. Regions of California included in this study

For the purposes of these studies, we divide California in six major regions, respectively:

- San Francisco Bay Area, identified by the boundaries of the Metropolitan Transportation Commission (MTC);
- Los Angeles/Southern California, identified by the boundaries of the Southern California Council of Governments (SCAG);
- Sacramento region, identified by the boundaries of the Sacramento Area Council of Governments (SACOG);
- San Diego, identified by the boundaries of the San Diego Association of Governments (SANDAG);
- Central Valley, corresponding to the eight counties in the central San Joaquin Valley
- Northern California and Others, which includes the rest of State not included in previous regions.

The California Millennials Dataset contains information on the respondents' personal attitudes and preferences, lifestyles, adoption of online social media and ICT, residential location, living arrangements, commuting and other travel-related patterns, auto ownership, awareness, adoption and frequency of use of shared mobility services (car-sharing, bike-sharing, dynamic ridesharing and ridehailing services such as Uber or Lyft), propensity to purchase and use a private vehicles vs. use of other means of travel, major life events that have happened in the past three

years that might have influenced the current lifestyles, residential location and travel behavior, environmental concerns, political ideas and sociodemographic traits (for detailed information on the survey content, data collection effort and sampling strategy, see (Circella, Alemi et al. 2016). We augmented the 2015 dataset with additional variables measuring land use and built environment characteristics of each respondent's address using external sources including the U.S. Environmental Protection Agency's Smart Location Dataset and the *walkscore*, *bikescore* and *transitscore* from the commercial website walkscore.com. Phase I included analyses of residential location and adoption of multimodal travel, VMT and other components of travel behavior and vehicle ownership of millennials and Gen Xers (Circella, Alemi et al. 2016).

2018 California Dataset

We used a combination of sampling strategies for this second wave of data collection, to create a sample that would minimize the sampling issues associated with each recruiting and sampling channel.

Sample A – Mail Survey

A paper version of the survey was mailed to a random sample of 30,000 addresses in the state. This approach allowed us to reach most major segments of the population, including the elderly or people not familiar with technology, who are less likely to be part of online opinion panels.

The mailing addresses were provided by a vendor that maintain comprehensive lists of postal addresses in California. They created the mailing list based on the sampling rates presented in Table 3. Given the population disparities between the different regions, the researchers adjusted the sampling rates to obtain sizable numbers of respondents in all six regions. Using this stratified random sampling approach helped reduce the very large number of respondents from the Los Angeles region that would be recruited if true random sampling was used. Prior to mailing the surveys, all addresses were validated with the United States Post Office to make sure they were bonafide addresses and that the person was still a resident at that address.

Table 3. Sample rate for each region for mail out/mail back survey

	Population	% of California Population	# Invitations with Constant Sampling Rate	Final Sampling Rate	Final # Invitations	% Over/Under Sampling
Central Valley	4219,854	10.67%	3,202	0.091%	3,820	119.27%
MTC	7756,158	19.62%	5,885	0.090%	6,982	118.61%
NorCal and Others	2752,763	6.96%	2,089	0.140%	3,854	184.50%
SACOG	2498,563	6.32%	1,896	0.150%	3,749	197.68%
SANDAG	3337,685	8.44%	2,533	0.120%	4,006	158.15%
SCAG	18,971,630	47.98%	14,395	0.040%	7,589	52.72%
Total	39,536,653	100.00%	30,000	0.076%	30,000	100.00%

Sample B – Online Opinion Panel

We also refreshed the panel by adding a group of new participants in this wave of data collection that were collected via an online opinion panel. Similarly, for future waves of data collection in this panel study we will continue to refresh the panel at each round of data collection with a similar approach to make up for the naturally-accruing dropping out of respondents from the panel. Sample B collected 2,000 participants and utilized a similar methodology to what was used for the 2015 California Millennial Dataset data collection. This method also facilitated expanding the age cohorts in the study with younger respondents between 18 and 21, *i.e.*, members of Gen Z, and baby boomers who were not included in the data collection in 2015.

The sampling conducted for this sub-sample utilized a quota methodology. This was used as online panels tend to be a skewed sampling frame (towards younger, more often female, unemployed respondents), so the quota system would allow for this issue to be corrected. The quotas were established by using the most current 5-year estimates from the American Community Survey (ACS) (see Tables 4-6). This also allowed us to control for varying travel behavior associated with land use/neighborhood type in the study, *i.e.*, quotas were established for each pairing of region and neighborhood type for each key age group.

Table 4. Sampling quotas by region

Region	Percent of Sample	Target Sample Size
Central Valley	12%	120
MTC	27%	270
SACOG	10%	100
SANDAG	12%	120
SCAG	29%	290
NorCal & others	10%	100
Total		1,000

Table 5. Sampling quotas by neighborhood type (nested within region)

Neighborhood type	Percent of Sample	Target Sample Size
Rural	17%	170
Suburban	44%	440
Urban	39%	390
Total		1,000

Table 6. Sampling quotas by age (nested within neighborhood type)

Age	Percent of Sample	Target Sample Size
18-38	46%	460
39-53	35%	350
54+	19%	190
Total		1,000

We also controlled for other sociodemographic factors beyond region and neighborhood type to minimize the non-representativeness of the sample and mimic the characteristics of the population of California. The quotas presented in Table 7 were *soft* quota targets which allowed for +/- 5% deviations on the targets and, if the quota proved to be hard to attain after a diligent effort, they could be relaxed to +/- 10% of the target.

Table 7. Targets by age group for eight key sociodemographic factors

		Ages 18-37		Ages 38-53		Ages 54+	
		% of Sample	Sample Size	% of Sample	Sample Size	% of Sample	Sample Size
Sample Size/Age Group			460		350		190
Gender							
	Male	50.00%	230	50.00%	175	50.00%	95
	Female	50.00%	230	50.00%	175	50.00%	95
Children in Household							
	Yes	35.00%	161	35.00%	123	35.00%	67
	No	65.00%	299	65.00%	228	65.00%	124
Household Income							
	Less than \$24,999	18.40%	85	18.40%	64	18.40%	35
	\$25,000 to \$49,999	19.40%	89	19.40%	68	19.40%	37
	\$50,000 to \$74,999	16.30%	75	16.30%	57	16.30%	31
	\$75,000 to \$99,999	12.20%	56	12.20%	43	12.20%	23
	\$100,000 to \$149,999	15.70%	72	15.70%	55	15.70%	30
	\$150,000 or more	18.00%	83	18.00%	63	18.00%	34
Age							
	18-27	50.20%	231				
	28-37	49.80%	229				
	38-46			55.90%	196		
	47-53			44.10%	154		
	54+					100.00%	190
Race							
	White	53.40%	246	62.70%	219	68.30%	130
	African American	5.80%	27	6.20%	22	5.70%	11
	Asian	13.80%	63	17.00%	60	15.30%	29
	Other	27.10%	125	14.10%	49	10.80%	21
Hispanic							
	Yes	41.60%	191	40.70%	142	23.50%	45
	No	58.40%	269	59.30%	208	76.50%	145
Work Status							
	Employed	68.00%	313	76.20%	267	39.70%	75
	Not Employed	32.00%	147	23.80%	83	60.30%	115
School Status							
	Enrolled	30.30%	139	2.00%	7	1.00%	2
	Not Enrolled	69.70%	321	98.00%	343	99.00%	188

Sample C – Recontact 2015 Respondents

Finally, we recalled the respondents that completed the 2015 survey using the same online opinion panel vendor. We initially expected to be able to retain close to 50% of the respondents from the 2015 data collection (e.g., approx. 1,000 respondents). However, during the data collection process it became clear that this goal would not be achieved for three key reasons. First, when the respondents took the first survey in 2015 there was no mention of future surveys so there was no expectation to be contacted again. Second, there was no contact in the intervening 3 years to keep them engaged and invested with the success of the project which is needed to garner high levels of participation in longitudinal surveys. Third, there was no guarantee the full panel would remain active within the panel vendor’s research efforts over the 3-year period – endangering the only means to contact these respondents available to the researchers. These factors led to a low number of responses with 246 completed surveys among the 1975 respondents from the 2015 survey.

Survey Administration

The 30,000 paper surveys were printed by the UC Davis in-house printing services, while the envelope stuffing and mailing was executed by UC Davis mailing office. To encourage a higher response rate a postcard was sent out to all the address that had not already returned a survey. The creation and processing of the postcards were handled by the same vendors. The online surveys were created on the Qualtrics online survey platform. Distribution of the online survey was conducted by two different online panel vendors for Sample B and Sample C.

Table 8 presents the response rates that were achieved by the time of writing of this report. For Sample A, we anticipated a response rate of 6-8% given the length and content of the survey and considering the continual general decline of response rates expected for unsolicited survey requests. The results for recruitment for this method were near the lower bounds of our expectations. At the time of writing of this report, information on the number of invites sent out by the opinion panel vendor for Sample B was not available. Therefore, the response rate for the online panel could not be calculated. As is typical with panel vendors, the 2015 California Millennial Dataset was created from a combination of an internal list of respondents as well as external lists from other sources. So, for Sample C it is worth noting that of the full 1975 respondents in the 2015 dataset only 315 were still active with the vendor in 2018. This means that the response rate for this sample could be as high as 77% based on respondents that were certainly still active within the panel (N=315). However, a more accurate estimate of the response rate for this sample is approximately 12%, if we consider that the opinion panel vendor was able to reach the remaining respondents from the 2015 survey through partner online panels.

It is worth noting that the research team is using this experience to shape plans for building the panel for future iterations of this study. We are directly collecting contact information for the majority of respondents in the 2018 sample, so we will be able to recontact respondents to provide updates on the research, and have already primed them with the idea of being re-contacted later for future phases of the data collection. This will have the benefit of reducing future costs of the data collection, reduce attrition, and help stimulate a higher response rate in future data collection efforts.

Table 8. Response rate by sub-sample (raw data without any filtering)

Type	Number of Invitations	Number received	Response Rate
A. Mail Survey	30,000	1,992	6.64%
A.1 Returned via mail		1,620	5.40%
A.2 Completed via online survey system		372	1.24%
B.1 Online Opinion Panel - Longitudinal	N/A**	830	-
B.2 Online Opinion Panel - Cross-Sectional	N/A**	1,003	-
C.2015 Panel Recontact	1939*	246	12.69%
Total		4,071	

* Maximum number of invitation possible

** Number of invitations sent has not yet been provided by panel vendor

Table 9. Data composition (raw data without any filtering)

	Online	Paper	Total
A. Mail Survey			
Count	372	1,620	1,992
Percent by row	18.67%	81.33%	100.00%
Percent by total	9.14%	39.79%	48.93%
B.1 Online Opinion Panel - Longitudinal			
Count	830	N/A	830
Percent by row	100.00%	N/A	100.00%
Percent by total	20.39%	N/A	20.39%
B.2 Online Opinion Panel - Cross-Sectional			
Count	1,003	N/A	1,003
Percent by row	100.00%	N/A	100.00%
Percent by total	24.64%	N/A	24.64%
C. 2015 Panel Recontact			
Count	246	N/A	246
Percent by row	100.00%	N/A	100.00%
Percent by total	6.04%	N/A	6.04%
Total	2,451	1,620	4,071
Percent	60.21%	39.79%	100.00%

Time to Complete the Survey

As previously discussed, the survey was designed to be completed in 30 minutes to reduce response fatigue, encourage higher survey engagement and response rates thus providing higher quality data. This was proven to be an accurate estimated time to complete the survey as seen with the results from the online surveys (see Table 10). It is worth noting that Sample A.2 did exceed the desired time to complete with a median time of 37.8 minutes. It is likely that



the time difference can be attributed to different levels of experience with online surveys across samples, but this will warrant further examination during the analysis stage of the research to see if this hypothesis holds true.

Table 10. Completion times for online versions of survey

Online Survey Version	Median Completion Time (Minutes)
A.2 Mail Survey completed via online survey systems (N=372)	37.8
B.1 Online Opinion Panel - Longitudinal (N=830)	29.9
B.2 Online Opinion Panel – Cross-sectional (N=1,003)	31.4
C. Recontact 2015 Respondents (N=246)	27.8

Response over Time by Distribution Method

Figure 11 depicts the responses across all sampling methods by the time they were received, and the total responses received during the data collection period. There are two unique characteristics for Sample B that are clearly displayed in the figure: the delayed start for both sub-samples in this group and the early plateaus in the responses received. The late start was the result of personnel changes within the panel vendor and was resolved as quickly as possible to reduce any impact the delay might have on the data collection. The other interesting feature for Sample B.1 and B.2 is the early plateaus that occurred in the data collection. This was the result of the vendor conducting a “soft launch” of the survey, which was a process of collecting 10% of the final sample size to ensure the quota system was functioning correctly, the survey was recording data correctly, and that the responses were of high quality. After the review process was completed and any anomalies were addressed, the sampling resumed. No major issues were uncovered during this process, but it did vet our trap question system by terminating multiple cases, which were suspected automated response, as well as to establish the minimum acceptable time to complete the survey (14 minutes, half of the median time).

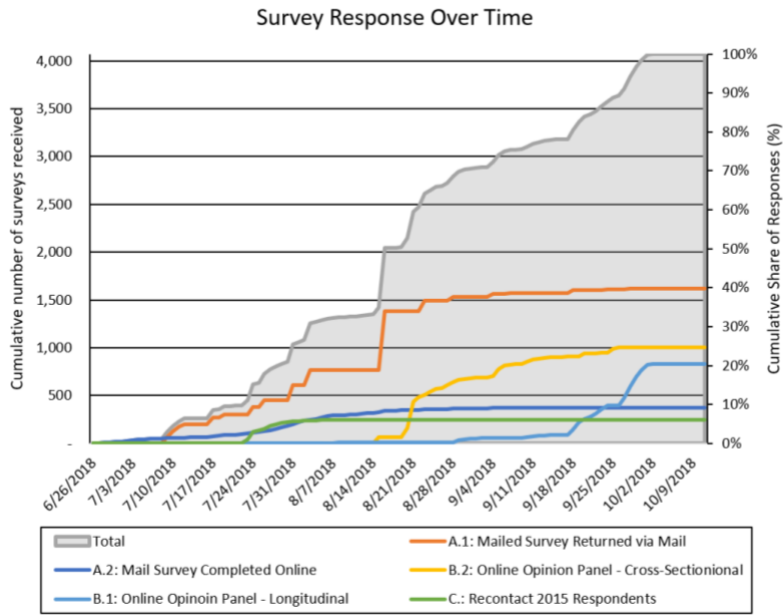


Figure 11. Survey response of time for all survey methods

Preliminary Findings from the Analysis of the Online Component of the 2018 Dataset

This section presents some preliminary analyses that were carried out using the online portion of the sample that was already available for analysis at the time this report was written. We need to underscore that these preliminary findings are based on the analysis of unweighted data, the consistency/reliability of individual responses have not yet thoroughly examined, and that the dataset only includes data collected via online methods (Samples A.2, B, C).

During the next stages of the research project, the research team will complete inputting the data collected with the mail (paper) surveys, as well as will perform a number of activities to ensure the quality of the data, and will remove incomplete or otherwise unreliable responses. We also plan to develop a set of weights to reduce any non-representativeness of the sample and deviations from the population of California in key sociodemographic traits, and we plan to augment the data by matching information available from other sources (*e.g.*, land use data based on the place of residence) before carrying out more in-depth analyses to answer the research questions described in the early sections of this report.

Still, the early findings presented in the remainder of this section helps illustrate some of the patterns observed in key variables in the dataset, with particular respect to the adoption of shared mobility services, their impacts on the use of other modes, and Californians' perspective towards the use of AVs. Early results from the online component of the dataset were presented at the 3 Revolutions Future Mobility Research Workshop at UC Davis on October 23-24, 2018.

Adoption of Shared Mobility Service and Impact on Travel Behavior

With respect to the adoption and frequency of use of carsharing and bikesharing services, the preliminary analysis of the data obtained from the online dataset shows that compared to 2015 more people used carsharing and bikesharing services in 2018. However, the adoption and frequency of use of these services did not increase as quickly as the fastest growing type of shared mobility: ridehailing services. As shown in Figure 12, on average, the adoption and frequency of use of carsharing and bikesharing have increased from 2015 to 2018. In contrast, we observed more dramatic changes in both the adoption and frequency of use of ridehailing services (as shown in Figures 13 and 14). In 2018, a substantial number of users (especially in larger cities of California) also reports having used *shared* ridehailing services, which were only available in very few selected markets in 2015. We stress that particular care should be used in interpreting these results, in particular considering that the data from 2018 are unweighted (sample weights will be developed during the next stage of the research) and refer to the online-only portion of the sample. Further, the data collection in 2018 included respondents from all age groups, including older adults, while the 2015 dataset only included individuals between 18 and 50 y.o. by the time of the survey. The latter might explain some patterns in the data, *e.g.*, the higher proportion of respondents that are unfamiliar with carsharing in 2018.

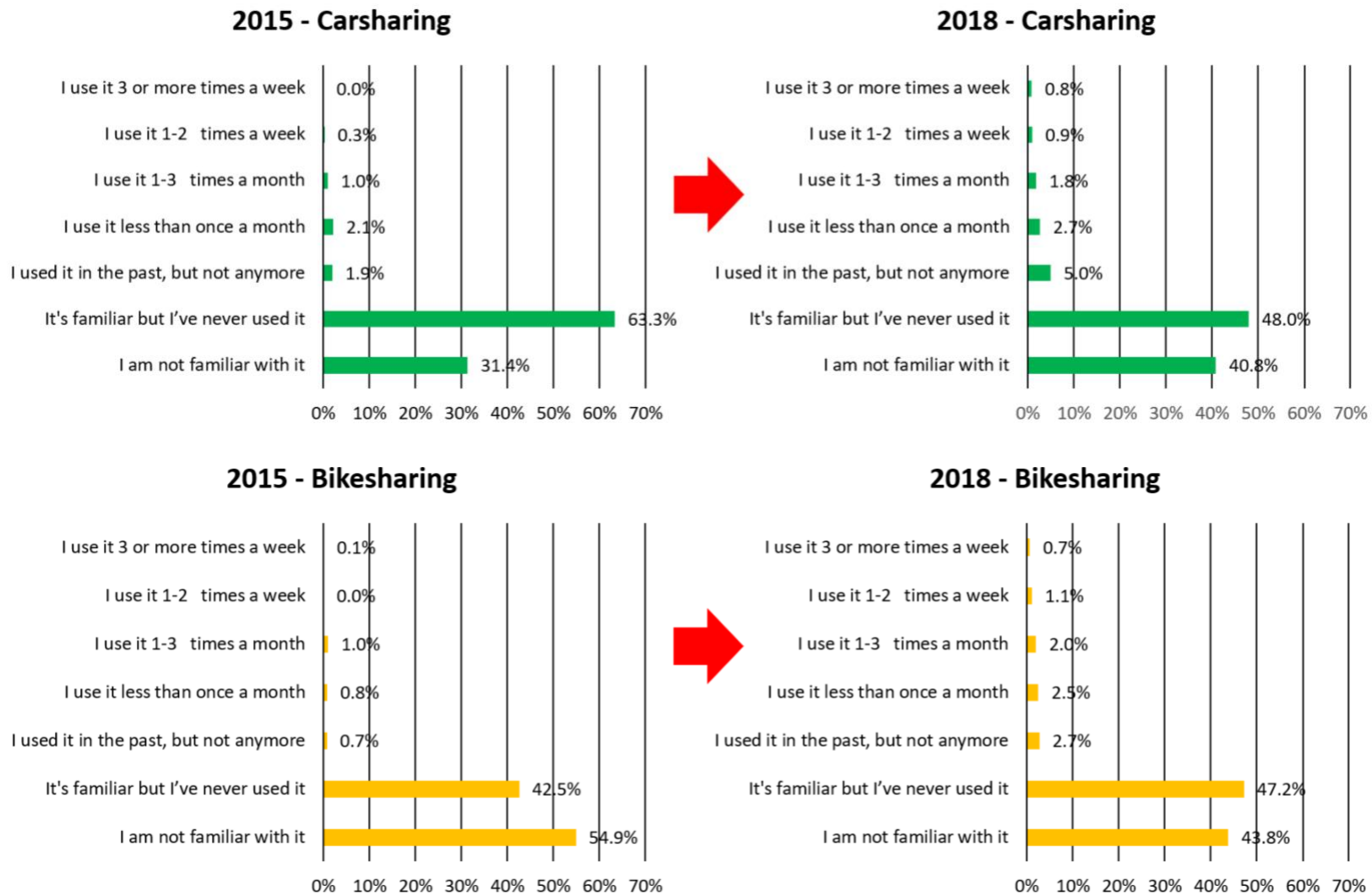
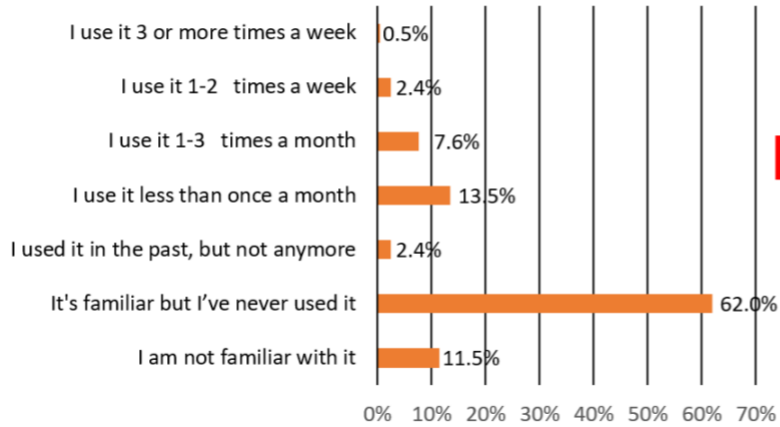


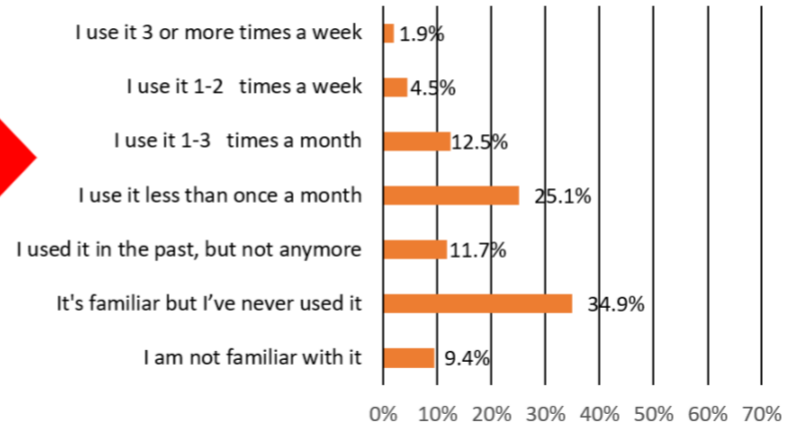
Figure 12. Changes in the adoption of bikesharing and carsharing between 2015 and 2018 (2018: Unweighted data, N=2,260; 2015: Weighted data, N=1,961)



2015 - Ridehailing



2018 - Ridehailing



2018 - Shared Ridehailing

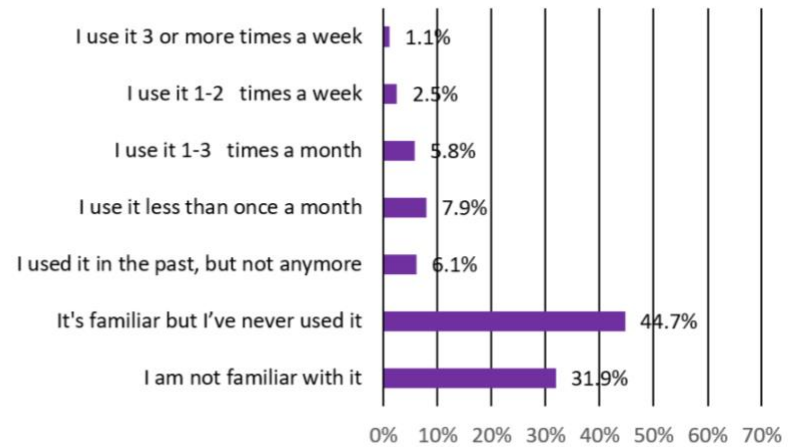


Figure 13. Changes in the adoption of ridehailing (and the appearance of shared ridehailing) between 2015 and 2018 (2018: Unweighted data, N=2,263; 2015: Weighted data, N=1,961)

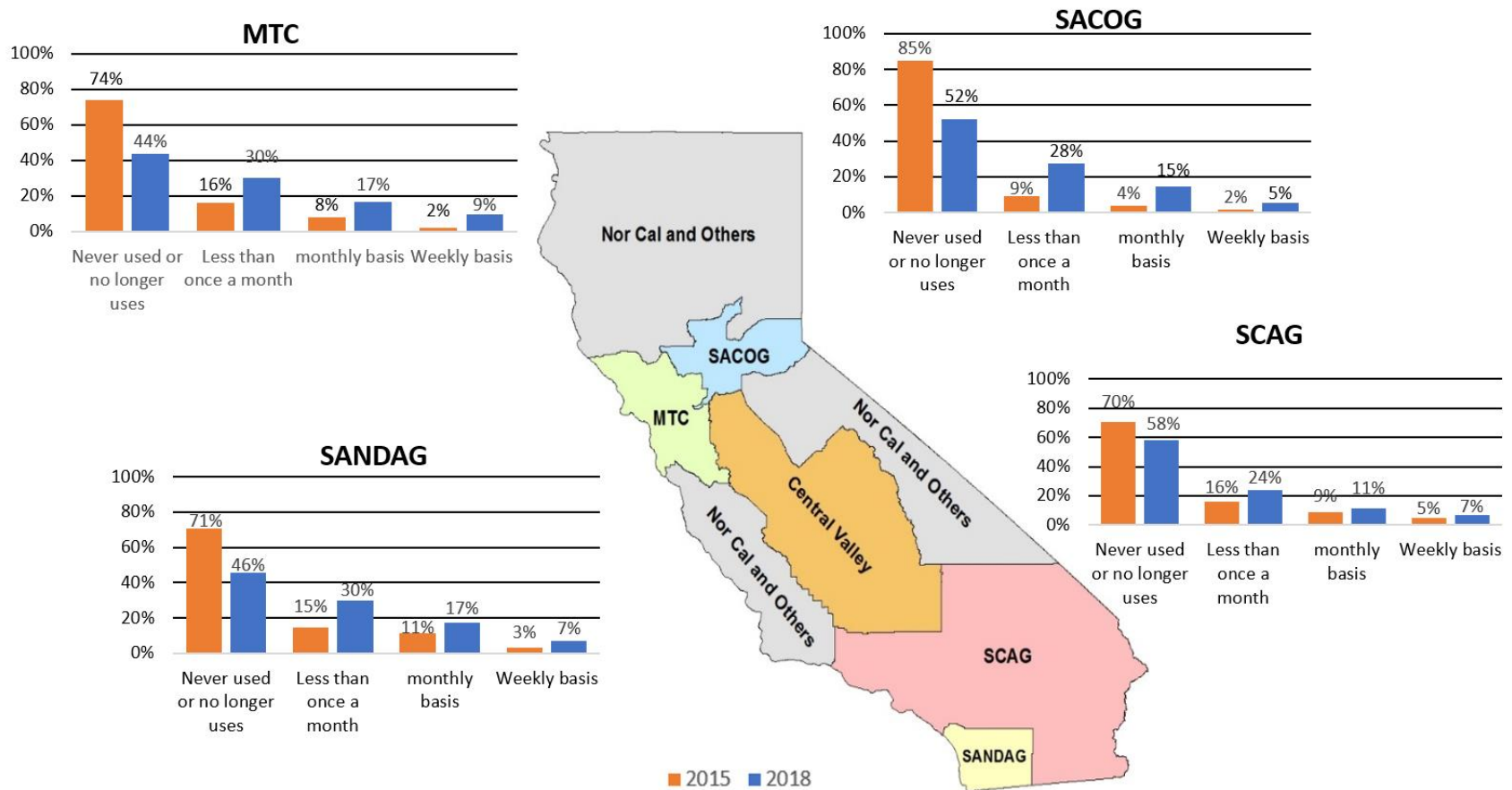


Figure 14. Changes in the adoption of ridehailing by region of California between 2015 and 2018 (2018: Unweighted data, N=3,578; 2015: Weighted data, N=1,620)

Early analysis of the online component of the 2018 dataset indicates that the adoption and frequency of use of ridehailing services have approximately doubled from 2015 to 2018. As shown in Figure 14, this growth seems to be consistent throughout the four major region of California, including the San Francisco Bay Area (MTC), Sacramento (SACOG), Greater Los Angeles (SCAG) and San Diego (SANDAG).

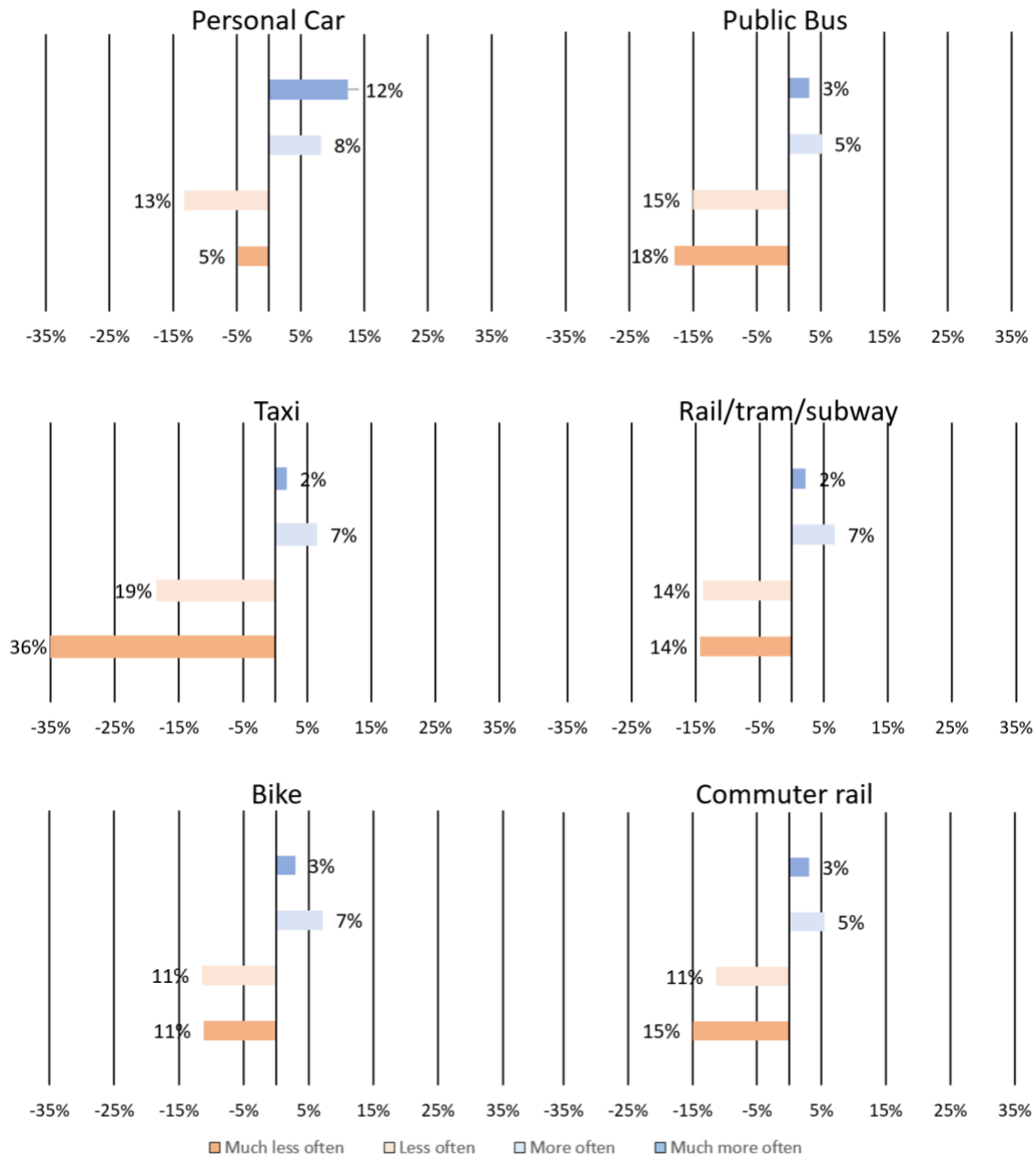


Figure 15. Distribution of the effects of the use of ridehailing on the use of other transportation modes (Unweighted data, N=1088, Multiple answers were allowed)

Similar to 2015, we asked several questions about the general impacts that ridehailing had on the use of other means of transportation. Figure 15 summarizes these general impacts on the use of private vehicles, taxis, bikes, and different modes of public transportation. As shown in this Figure 15, in general the use of Uber/Lyft led to decrease in the use of other means of transportation, in particular, the use of taxi services. In future stage of this research, we plan to investigate these variables while controlling for the frequency of use of ridehailing and other sociodemographic characteristics of respondents.

We further looked at the frequency of use of ridehailing by vehicle ownership status at the household level. As shown in Figure 16, we found that frequent ridehailing users tend to live more in households with lower car availability. However, the direction of this relationship is not clear yet, so we plan to better address the question about the impact of ridehailing on vehicle ownership through an in-depth analysis of both 2015 and 2018 datasets.

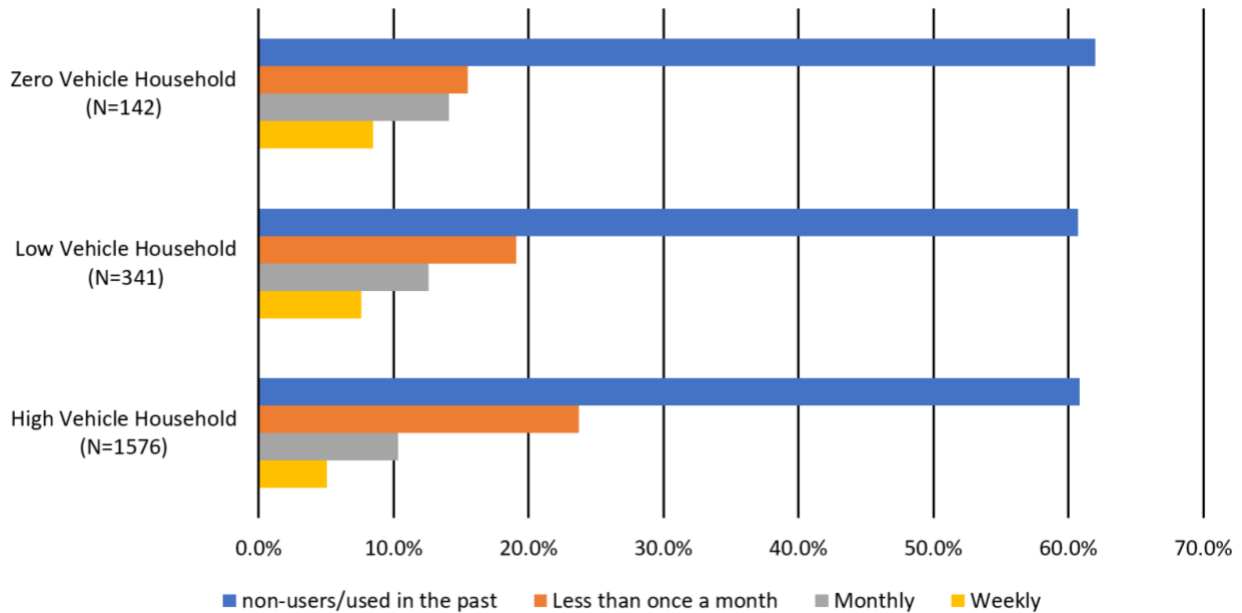


Figure 16. Frequency of use of ridehailing by household vehicle ownership status (Unweighted data, N=2,261)

We further looked at the distribution of the use of ridehailing services and individual’s response to the question about the changes in their vehicle ownership *in response* to their use of such services (Figure 17). Interestingly, we found that frequent ridehailing users are less likely to decrease the number of cars in their household, possibly as many of them lived in the household with lower vehicle ownership in the first place, or because this simple measure might hide some effects due to a change of household income or stage in life. In future stages of the research, we plan to investigate the impact of the adoption of ridehailing on changes in vehicle ownership through the estimation of relational models that can account for the impacts of several groups of explanatory variables.

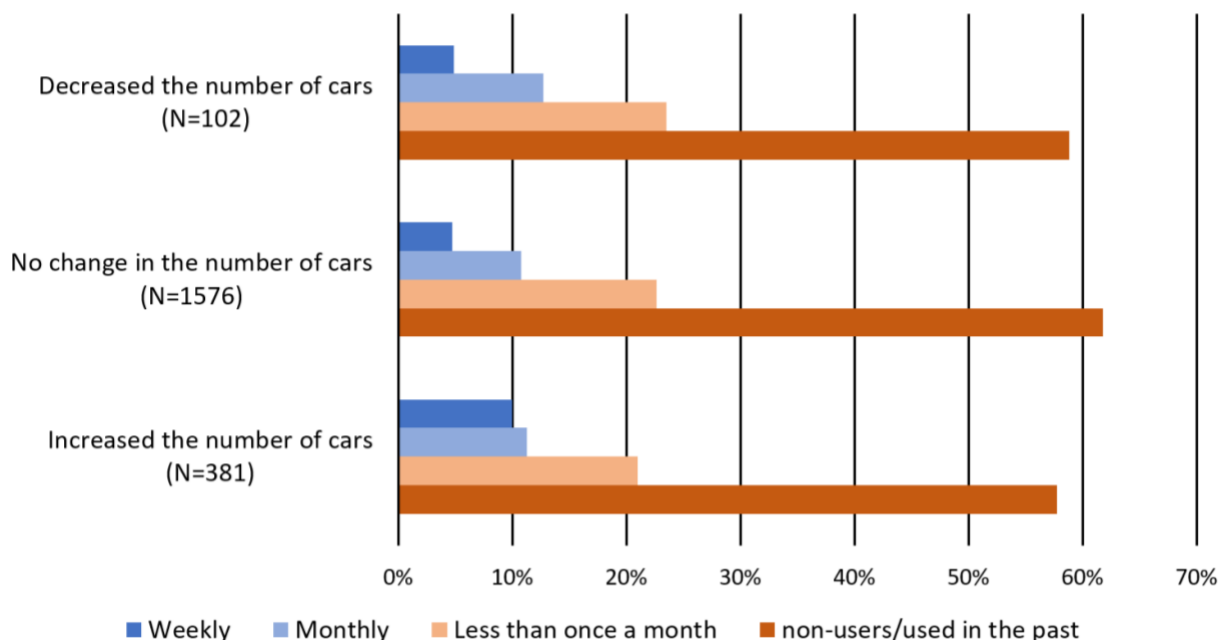


Figure 17. Frequency of use of ridehailing by type of change in vehicle ownership during the previous three years (Unweighted data, N=2,059)

We also collected a large amount of information on the last trip that was made by each individual using either ridehailing or shared ridehailing services. The information collected includes:

- Type of service that was used (*ridehailing vs. shared ridehailing*)
- Origin and destination
- Day of the week and time of the day
- Travel time
- Waiting time
- Travel cost
- Trip purpose
- Occupancy
- Reason(s) for use of ridehailing
- Impacts on use of other travel means
- Trade-off between waiting time and sharing with others

Following we present the distribution of some of these variables obtained from the online dataset. Out of 1,286 reported last Uber/Lyft trips, 14.5% of them were made by shared ridehailing services such as UberPOOL and Lyft Line (Figure 18). We found that the majority of both regular ridehailing and shared ridehailing trips were made on weekdays. It is also

noteworthy that the popularity of shared ridehailing services slightly improved for trips made during weekend nights (including Friday night), as shown in Figure 19.

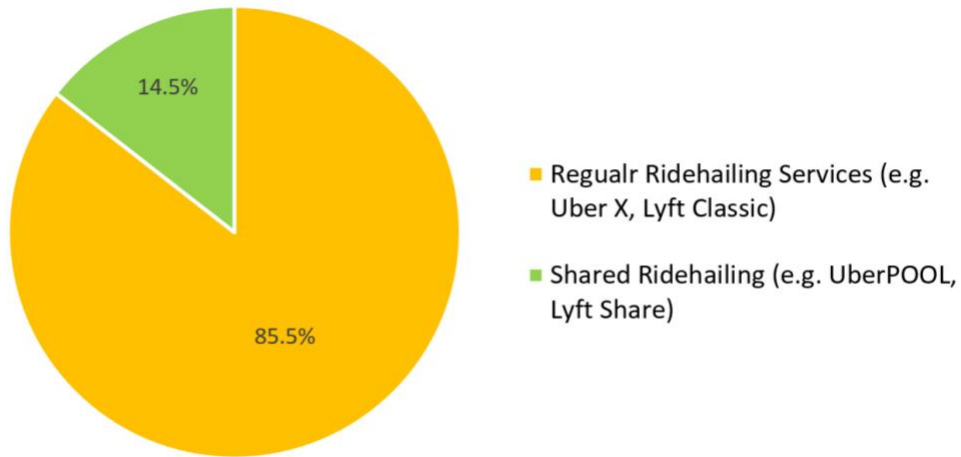


Figure 18. Type of service that was used for the last ridehailing trip (Unweighted data, N=1,286)

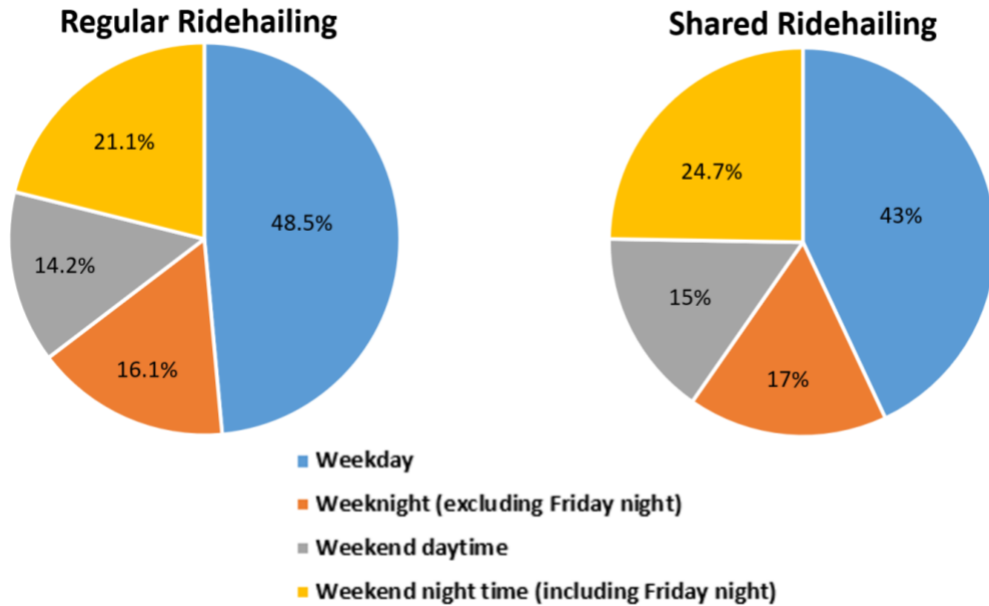


Figure 19. Type of service by time of day and day of the week in which the last ridehailing trip was made (Unweighted data; N ridehailing users=1,098, N shared ridehailing users=186)

Figure 20 shows the occupancy levels of ridehailing and shared ridehailing trips across different day of the week and time of day. As shown in this figure, the occupancy level increases from *weekday* to *weekend* and from *day time* to *night time*.

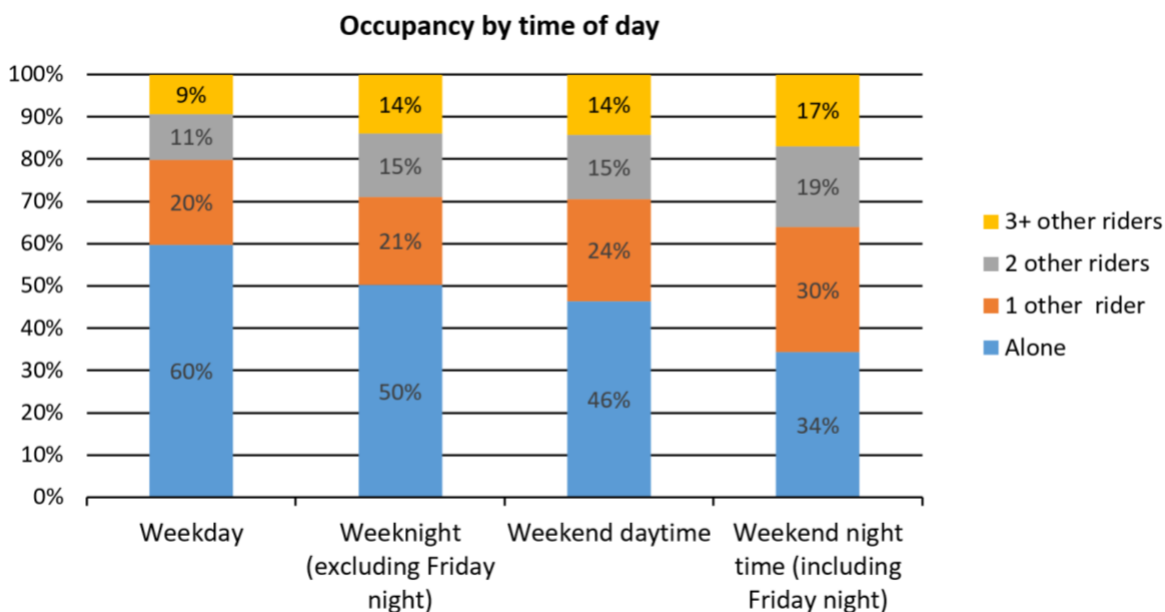


Figure 20. Vehicle occupancy for the last ridehailing trip by time of the day and day of the week (Unweighted data, N=1,278)

In the 2018 survey, we also asked respondents to report how they would have traveled if Uber/Lyft had not been available for the last trip they made using these services. The preliminary analysis of the online data (Figure 21) shows that both regular and shared ridehailing services primarily replaces trips that would have been otherwise made by car. Not surprisingly, we found that regular ridehailing services are more likely to substitute for taxi trips compared to shared ridehailing services, as the former share more commonalities (*e.g.*, cost structure) with taxis services. More interestingly, we found that shared ridehailing services can be a stronger competitor in substituting trips that would have been otherwise made by public transportation and/or active modes, whose users may be more cost-sensitive. In a non-trivial number of cases (7.5% of trips using ridehailing and 6.5% of trips using shared ridehailing), the respondents reported that they would have not made the trips at all if these services had not been available, confirming results from previous related studies that have shown the role of these services in expanding mobility options and also inducing additional trips among some users.

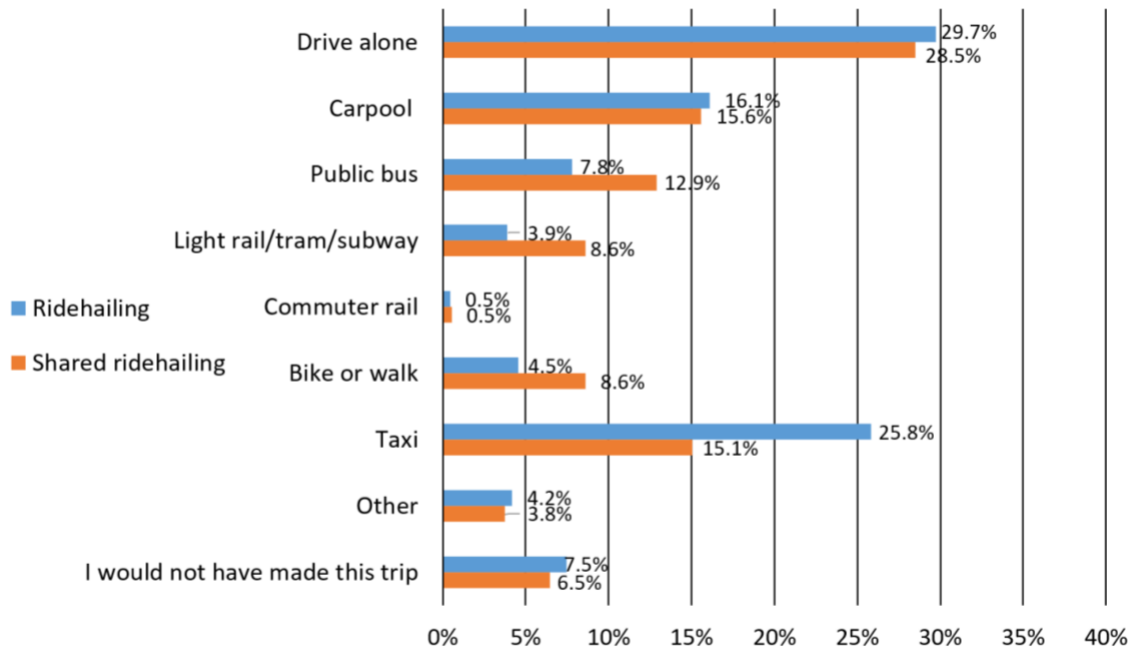


Figure 21. Distribution of the effects of the last trip made with ridehailing (blue) and shared ridehailing (orange) on the use of other transportation modes (Unweighted data, N ridehailing= 1,100; N shared ridehailing=186)

We further looked at the impacts by trip distance and found that shorter ridehailing trips tend to substitute for trips that would have been otherwise made by walking or bicycling (Figure 21).

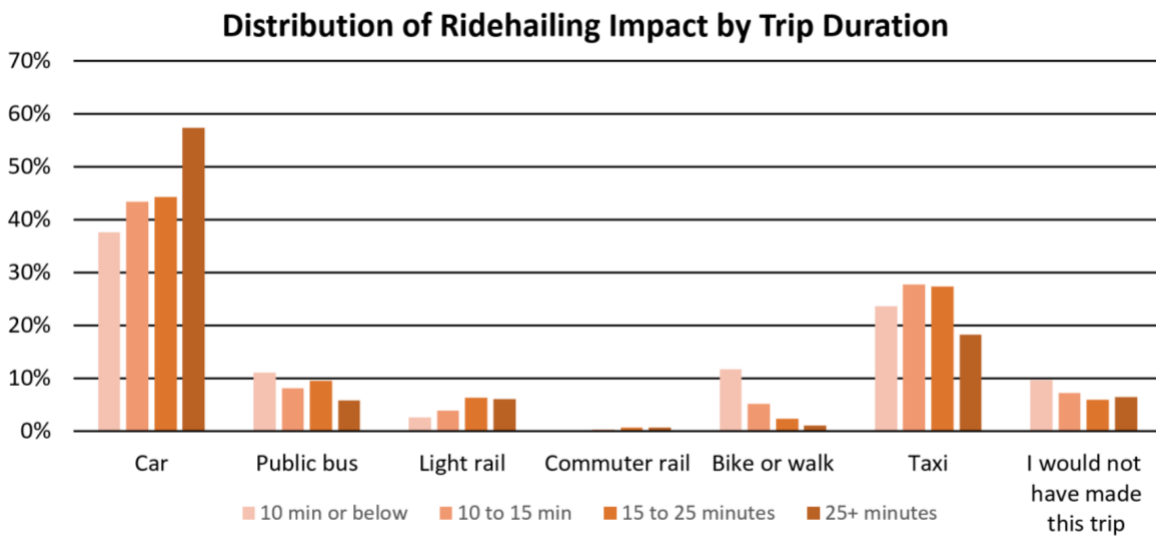


Figure 22. Travel modes replaced by the last ridehailing trip by its duration (Unweighted data, N=1,198)

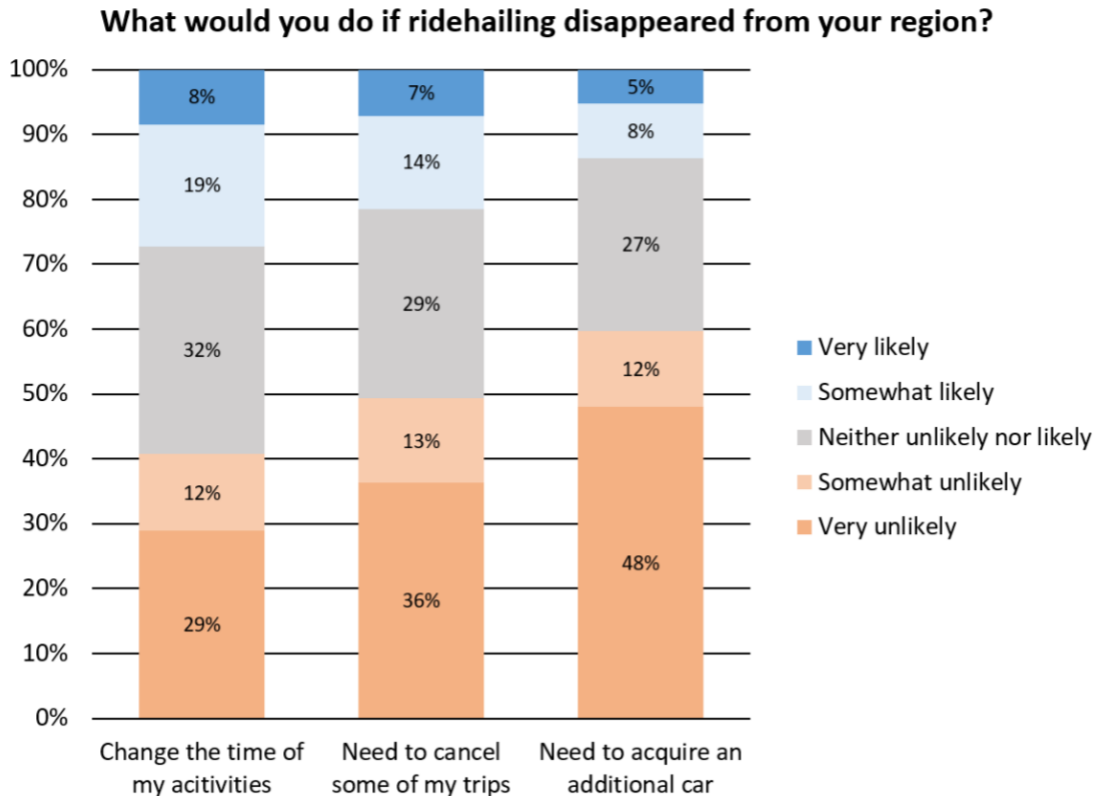


Figure 23. Expected impacts on activities and vehicle ownership if ridehailing suddenly disappeared from the respondents’ home region (Unweighted data, N=1,282)

We further expanded our analysis to understand the impacts on other components of travel behavior, including changes in the activity pattern and vehicle ownership. As indicated in Figure 23, about 27% (responses for “Very likely” and “Somewhat likely” combined in the first bar) and 21% (the same in the second bar) of ridehailing users, respectively, reported that they would need to change the time of their activities or completely cancel some of their trips if ridehailing suddenly disappeared from their region. The share of this changes shrank to only 13% (in the third bar) when it comes to the need to acquire an additional vehicle, showing that a majority of respondents have a satisfactory level of access to vehicles to fulfill their mobility needs, either whether they already own a vehicle or not. Only a minority of ridehailing users feel they would need to purchase another vehicle if ridehailing services suddenly disappeared from their region.

Attitudes and Perceptions towards Automated Vehicles

With respect to familiarity with and propensity to use AVs, we found that a large majority of respondents in 2018 have heard about AVs, though many of them are not very familiar with this technology and its applications (Figure 24). Attitudes towards AVs align with expectations, as our preliminary results show that younger respondents appear more willing to be early adopters of the technology while all age groups including the younger respondents are reluctant to give up their private vehicles and rely solely on AV based transportation services,

e.g., use fleets of AV taxis or shuttles. Most are inclined to maintain their current level of auto ownership. While the perceived safety for occupants and other road users is reported as the primary barrier to the potential adoption of AVs, respondents are unwilling to accept slower travel speeds to increase safety (not included in the report for brevity).

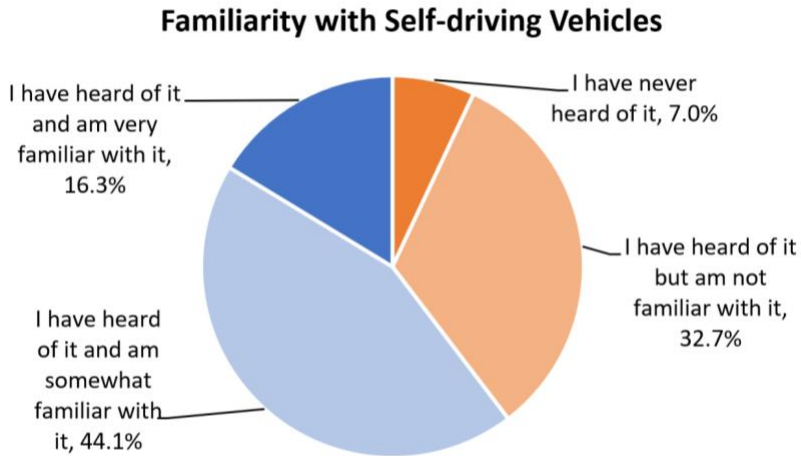


Figure 24. Self-reported level of knowledge and familiarity with self-driving vehicles (Unweighted data, N=2,263)

How many years do you think it will take for cars to be fully self-driving?

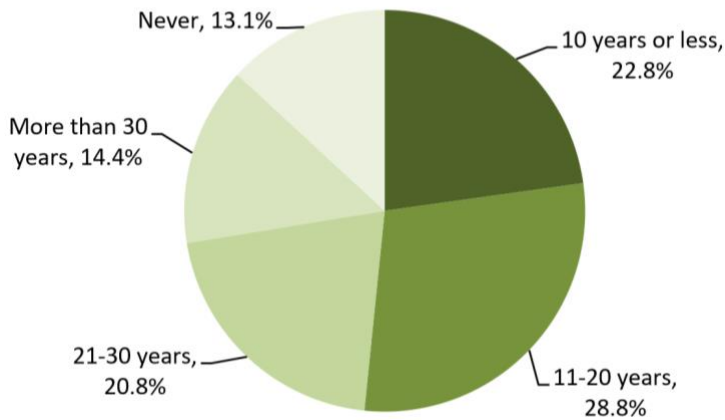


Figure 25. Expectations about availability of fully self-driving vehicles on the market (Unweighted data, N=2,259)

“Be one of the first people to buy a self-driving vehicle...”

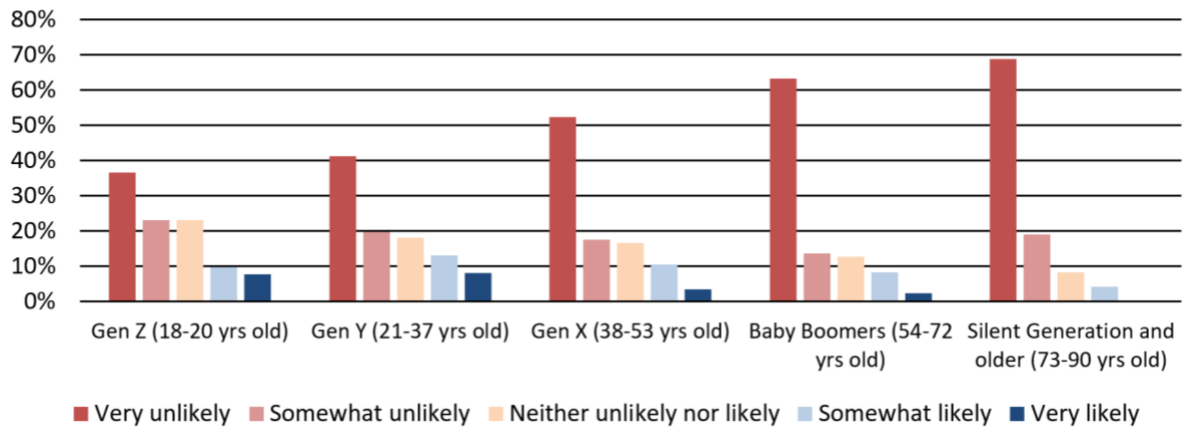


Figure 26. Interest in being an early adopter of AVs by age group (Unweighted data, N=2,260)

In this section we asked about the likelihood of changing vehicle ownership in a future with widespread access to self-driving vehicles, and found that there is still significant inertia resisting the change in terms of changes in vehicle ownership and use models. More than half of the respondents reported that they anticipate not changing the number of vehicles in the household in place of using driverless taxis or shuttles. However, it is too early to make any inferences about this topic, as the cost of use of driverless taxi or shuttle is expected to decrease significantly compared to the use of personal vehicle, as well as individual perceptions and preferences in this area might change in the future as an effect of changing habits (*e.g.*, use of ridehailing), exposure (awareness and direct experience of automation technology) and peer’s influence (*e.g.*, recommendations from friends and family, or simple emulation of others’ behaviors). Certainly, the expectations and propensity towards the adoption of shared vs. private models of vehicle ownership (and use) is an important topic that will plan to study in future stages of the research.

Expectations about the Adoption of AVs and Changes in Vehicle Ownership

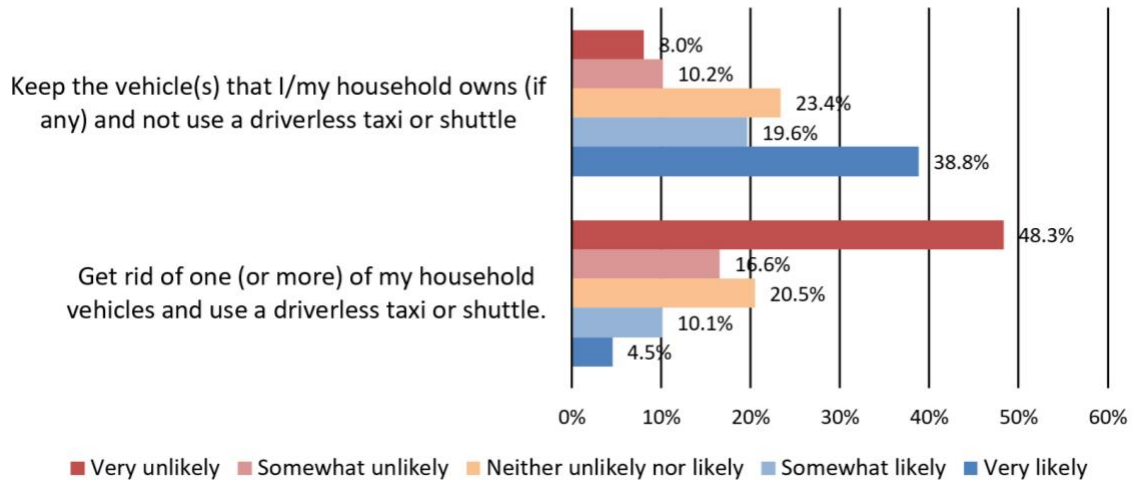


Figure 27. Expectations about future adoption of AVs and related changes in household vehicle ownership (Unweighted data, N=2,252)

Conclusions and Next Steps of the Research

This report summarizes the efforts carried out during 2018 with the second round of data collection in the California Panel Study of Emerging Transportation Trend. This research helps to increase the understanding of the impacts of emerging transportation technologies and trends in California through the application of a unique longitudinal approach. The significance of the research is particularly relevant at a time in which the rapid expansion of digital technology, the increased availability of locational data and smartphone apps, and the emergence of technology-enabled transportation and shared-mobility services are quickly transforming transportation, while traditional data collection efforts (*e.g.*, National Household Travel Survey data) have limitations in investigating these topics.

This report includes some preliminary findings from early analyses of the data collected in 2018. We remind the readers that the presented findings are preliminary and the following caveats should be noted: (1) The dataset only includes data from surveys that were completed online, *i.e.*, Samples A.2, B and C (following the definitions presented in the *Sampling Method Nomenclature* section of this report); (2) The data have not been yet weighted to correct for non-representativeness of the sample and deviations from the characteristics of the population of California; and (3) a full process of cleaning and quality check of the data has not been completed.

Among the preliminary findings from this project, the analysis of the online component of the dataset shows a sharp increase in the use of ridehailing in California between 2015 and 2018, with the appearance of the use of shared ridehailing in many urban areas of the state (this option was only available in beta testing in selected markets, *e.g.*, San Francisco, in 2015), while the changes in the use of other forms of shared mobility, *e.g.*, bikesharing and carsharing, are more moderate. Further, the results show that occupancy levels of ridehailing and shared ridehailing trips vary significantly by time of day and day of the week, with higher occupancy observed during weekend nights. Also, the impacts of ridehailing and shared ridehailing vary by trip purpose, time of the day, duration of the trip, and type of service that is used.

Ridehailing trips are found to more often replace trips that would have been otherwise made by car or taxi. Shared ridehailing trips are more often substituting for the use of public transit. Shorter trips made with these services tend to substitute for trips that would have been otherwise made by walking or bicycling.

Attitudes towards the adoption of AVs vary significantly by groups of individuals. While vast majority of respondents in 2018 have heard about AVs, many of them are not very familiar with the practical applications for the technology. The initial results indicate that younger respondents tend to more often report an interest to be early adopters of the technology. However, most respondents are skeptical of the idea of replacing their private vehicle with access to services, for which users are given access to the fleets of AV taxis and shuttles owned, maintained, and operated by service providers. This is supported as most of the respondents expect the same level of car ownership in an AV future. Respondents indicated that safety

concerns would be important for adoption of AVs. However, they would not be willing to have longer travel times, *i.e.*, travel at a lower speed, to increase the safety of pedestrians and other road users.

Next Research Steps

During the next stages of the research project, the research team will finish inputting the data collected from Sample A.1, as well as perform a number of activities to ensure the quality of the data and remove incomplete or otherwise unreliable responses. We also plan to develop a set of weights to reduce any non-representativeness of the sample and deviations from the population of California in key sociodemographic traits. We will also augment the data by matching information available from other sources (*e.g.*, land use data based on the place of residence) before carrying out more in-depth analyses on the variables of interest and answer the research questions described in this report.

We will carry out detailed descriptive statistics for all main variables of interest on both the (a) new dataset collected in 2018 and (b) the combined longitudinal/repeat cross-sectional dataset obtained through the combination of the two datasets collected in 2015 and 2018 in the panel study. Further, we will estimate multivariate models to explore the relationships among variables, and investigate the factors underlying the adoption of certain emerging trends in transportation, as well as differences across groups of individuals, in terms of personal attitudes and preferences, residential location, sociodemographics, among other variables.

This is the fourth year of this panel study, and by building the longitudinal component of this dataset it will allow us to explore a number of research questions through many analyses which will span over the following years. Further, extensions of the project to other states and countries were already executed or being planned. A related data collection was conducted in Georgia in 2017-2018, and another related data collection will be carried out in early 2019 in four major metropolitan areas in US (Arizona, Texas, Georgia, and Florida), allowing future comparisons of results and more generalizable findings beyond the borders of California. As an extension to the triennial data collection of this longitudinal study, annual updates of the data collection will be conducted. These annual data collections will be smaller in scope but will allow the research team to account for rapid changes in the adoption of emerging transportation solutions in the in-between years as well as to be able to more quickly react to changes in the transportation landscape and the introduction of new disruptive services. It will allow us to continue to study how the expectations and propensity towards the adoption of shared vs. private models of vehicle ownership (and use) change over time, and relate the observed changes in travel choices to other key changes in lifestyles, the economy and society.

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