Energy Implications of Current Travel and the Adoption of Automated Vehicles

Kelly Fleming[1] and Mark Singer[2]

1 U.S. Department of Energy
2 National Renewable Energy Laboratory

NREL is a national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy
Operated by the Alliance for Sustainable Energy, LLC

This report is available at no cost from the National Renewable Energy Laboratory (NREL) at www.nrel.gov/publications.

Contract No. DE-AC36-08GO28308

Technical Report
NREL/TP-5400-72675
April 2019

Energy Implications of Current Travel and the Adoption of Automated Vehicles

Kelly Fleming[1] and Mark Singer[2]

1 U.S. Department of Energy
2 National Renewable Energy Laboratory

Suggested Citation
Fleming, Kelly and Mark Singer. 2019. *Energy Implications of Current Travel and the Adoption of Automated Vehicles*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-5400-72675. https://www.nrel.gov/docs/fy19osti/72675.pdf.

NREL is a national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy
Operated by the Alliance for Sustainable Energy, LLC

This report is available at no cost from the National Renewable Energy Laboratory (NREL) at www.nrel.gov/publications.

Contract No. DE-AC36-08GO28308

Technical Report
NREL/TP-5400-72675
April 2019

National Renewable Energy Laboratory
15013 Denver West Parkway
Golden, CO 80401
303-275-3000 • www.nrel.gov

NOTICE

This work was authored in part by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Funding provided by the U.S. Department of Energy Office of Energy Efficiency Vehicle Technologies Office. The views expressed herein do not necessarily represent the views of the DOE or the U.S. Government.

This report is available at no cost from the National Renewable Energy Laboratory (NREL) at www.nrel.gov/publications.

U.S. Department of Energy (DOE) reports produced after 1991 and a growing number of pre-1991 documents are available free via www.OSTI.gov.

Cover Photos by Dennis Schroeder: (clockwise, left to right) NREL 51934, NREL 45897, NREL 42160, NREL 45891, NREL 48097, NREL 46526.

NREL prints on paper that contains recycled content.

Acknowledgments

This work has been supported by the U.S. Department of Energy's (DOE's) Vehicle Technologies Office. Additional support came from the National Renewable Energy Laboratory, which is a national laboratory of DOE's Office of Energy Efficiency and Renewable Energy operated by the Alliance for Sustainable Energy, LLC.

The authors would like to specifically thank Rachael Nealer and Jake Ward at DOE's Vehicle Technologies Office, who ensured that the resources necessary for this research would be available.

All judgments in the final analytic methodologies and interpretations are the responsibility of the authors.

List of Acronyms

AV	Automated Vehicle
CAV	Connected and Automated Vehicle
EV	Electric Vehicle
NREL	National Renewable Energy Laboratory
PMT	Person Miles Traveled
TNC	Transportation Network Company
VMT	Vehicle Miles Traveled

Executive Summary

Current travel patterns and energy usage could be dramatically disrupted by new vehicle technologies, specifically in the case of automated vehicle (AV) technology. AV development is rapidly progressing and some experts anticipate it will be widely available to the public within 10 to 30 years (Litman and Litman 2018; Bansal and Kockelman 2017). This transformation in transportation could have a significant impact on the way people travel and potentially on overall energy consumption. Previous studies estimated that the use of AVs could decrease energy consumption by up to 60%, or alternatively increase energy consumption up to 200%, depending on how and where they are used (T.S. Stephens 2016).

AV adoption could have a wide range of potential energy implications, depending on their usage and the efficiency of the AVs. To better understand these implications, a random survey of more than 1,000 adults living in the continental United States was conducted for the National Renewable Energy Laboratory (NREL) using the Opinion Research Corporation (ORC) survey methodology (See A.1). While other survey efforts at the time of the study broadly investigated the barriers to acceptance of AVs, this study uniquely investigated how the technology will affect driving and commuting habits. The results were analyzed to better understand which groups of people will likely adopt AV technology first, how respondents currently travel, and how respondents may change their travel patterns if AVs are widely adopted. It is important to acknowledge that a person's stated preference in an interview about a hypothetical setting often does not match their revealed preference, which is demonstrated in an actual decision-making situation (Keane and Wasi 2013). However, due to the early stage of AV technology, there is limited opportunity to research the revealed preference. Findings from this study are intended to provide an additional resource for model projections used by researchers to understand how transportation innovations may affect travel behaviors in the coming decades.

To further understand current travel habits and where AVs may be used in the future, the study also focused on how different groups of people presently travel based on their residential area and their demographics. Results showed that groups in urban areas who were younger and lower income both tended to drive the fewest daily miles, and people who lived in rural areas and the suburbs tended to drive the most.

Potential energy implications can be extrapolated from demographic and geographic patterns in the survey's responses combined with the perceptions and intended use of AVs. Based on survey results, respondents who were currently most comfortable with AVs tended to be younger people (under 40) who live in urban areas. These people are also the more likely to drive less than 5 miles per day and rent their current home. This could imply that as AVs become available the first areas to see demand for their services and experience their impact could be amongst younger, urban people who rent their home and currently drive little.

Respondents were also asked to estimate how their travel would change if they were comfortable with using AVs. The group of people who wanted to ride in or own an AV were more likely to state their travel would increase than decrease when AV technology becomes available.

The widespread use of AVs has the potential to impact how Americans drive and travel. Survey findings show that vehicle miles traveled (VMT), in addition to energy consumption, will likely

increase if AVs are not more efficient than conventional vehicles today, or if they are not used for ridesharing. These initial insights also signal the need for deeper research in order to better understand how these groups would utilize AVs.

Table of Contents

List of Figures

List of Tables

1 Introduction

Transportation is undergoing a rapid transformation, with electric vehicles (EVs), connected and automated vehicles (CAVs and AVs), ride-hailing, and ride-sharing each with the potential to change the transportation system as we know it. The advancement of automated and electric vehicle technologies may disrupt vehicle ownership and travel patterns, which could result in a dramatic change to transportation energy demand and consumption. Currently, transportation accounts for approximately one third of the United States' energy consumption (Stephens et al. 2016). Understanding the future energy impacts of new technology has proven difficult for many reasons including that many AV technologies are not currently well understood or utilized.

According to a previous review analysis (Stephens et al. 2016), the effect of AVs on the estimated energy consumption could range from -60% to +200%. This wide range of possible use scenarios for AVs reflects that their effect on energy consumption remains largely uncertain. Understanding the way consumers' travel patterns will change if AVs are widely used, as well as gaining insights into what the timeframe of that adoption will be, can help narrow the range of energy consumption change due to AV technology.

Although many public surveys have examined how soon AVs could be adopted and what demographics are more accepting of them, at the time of publication, few published results focused on how people intend to use fully-automated vehicle technology in comparison to conventional vehicles. This information could provide insights into how AVs will change energy consumption in the United States' transportation sector, which could help decision makers and city planners prepare for the future of transportation. More specifically, information learned from this study will help further inform model projections used by researchers to understand what technology and infrastructure are required to support new transportation innovations in the coming decades.

This report presents results from a public survey of stated preferences on AV technology. Using data collected from the general public, the authors gained insights into current travel behavior, those who are likely to adopt AVs first, and how these groups' commuting and driving habits may change. These shifting habits have the potential to affect energy consumption if AV technology is widely adopted in the U.S.

Findings are described as follows:

- Section 2 explains the methods used to obtain data based on responses to surveys
- Section 3 captures the responses to survey questions highlighting current driving behaviors and views of AVs
- Section 4 analyzes responses to survey questions based on demographics and geographical regions, including anticipated changes in behavior when using AVs
- Section 5 extrapolates potential impacts to energy consumption if AVs were widely adopted among different demographic and regional groups, and includes a discussion comparing results of similar studies.

2 Methods

Questions were developed and distributed through the ORC International Survey Methodology. A complete list of survey questions can be found in Appendix A.2. The survey was distributed in February 2017, before some high-profile collisions involving automated vehicles (MacDuffie and Samaras 2018). Any impact the accidents had on the willingness of people to use AV technology was not captured in the results presented in this report.

Data collected answers two priority questions:

1. How likely is a person to adopt AV technology?
2. How will vehicle miles traveled (VMT) and passenger miles traveled (PMT) change if AV technology is adopted?

Each of the answers to these questions can be broken down in terms of demographics and geographic location to identify potential changes to VMT and PMT, and by extension energy consumption. These breakdowns can inform decision makers, researchers, urban planners, and transportation engineers.

The results from this research can be used to inform models used to estimate long-term adoption timeframe for AVs including those used at U.S. Department of Energy (DOE) national laboratories, such as POLARIS (Argonne), BEAM (Lawrence Berkeley), The National Aggregation Framework (Argonne), Systems Dynamics Models (National Renewable Energy Laboratory), and MA3T-MC (Oak Ridge).

To ensure the most informed analysis into how AVs users could change behavior, vehicle use analysis was limited to the 85% of respondents who stated that they had heard of AV technology (see A.2). In doing this, respondents who had never heard of AVs, and presumably did not have a good sense of the way they work, did not skew the results of behavior change based on incorrect notions of what they technology is or is capable of. Specifically, without knowing the purpose of an AV, respondents would not understand how an AV could change their current travel behavior.

It is important to acknowledge that a person's stated preference in an interview about a hypothetical setting often does not match their revealed preference, which is demonstrated in an actual decision-making situation (Keane and Wasi 2013). This difference makes tracking actual consumer actions ultimately more valuable in understanding potential behavior. However, when technologies are not yet available or are new to a marketplace and actual behaviors cannot be tracked at scale, stated preferences provide insights into how consumers may react in new circumstances. In this context, the report provides a supplemental source to validate other data and a new resource when no data are available.

The study conducted by the ORC for the National Renewable Energy Laboratory (NREL) was conducted via telephone with randomly selected telephone numbers. The study in this report used a dual-frame sampling design, in which the sample was drawn from independent landline and cell phone sample frames and is based on responses from individuals across the country who were at least 18 years old. Response samples were weight-adjusted by age, gender, region, race/ethnicity, and education to better ensure that the sample reflects the general U.S. population.

The study relied on ORC's weighting mechanism, which pulls from data reported in the National Health Interview Survey and the U.S. Census Bureau's Current Population Survey. The February 2017 study included 1,011 respondents and had a margin of error of ±3% at the 95% confidence level. Smaller subgroups of the respondents will have larger error margins. Additional study methodology detail is available in A.1.

3 Current Insights: Vehicle Ownership and Travel Patterns

Understanding current travel behavior and the groups of people who are most likely to change their behavior can provide insights into the way connected and automated vehicles will be used as they become more common. For example, Section 3.2 shows that younger people, who will be shown to be more accepting of AVs in Section 4, tend to live in urban areas and may drive shorter daily distances compared to other age groups. Understanding the way they would likely use AVs offers insight into how they might change their annual VMT, and therefore their energy consumption.

The raw survey data delivers glimpses into overall vehicle ownership and driving habits. Figure 1 shows how many vehicles the respondents own. Figure 2 and Figure 3 show the driving habits of the survey respondents, including the respondents' average daily commute and average yearly mileage of vehicles, respectively. In general, most households own one or two vehicles, and travel less than 30 miles per day. Miles traveled per year is more variable, but most respondents reported traveling less than 20,000 miles per year. A significant number of respondents do not own a car and responded that they travel 0 miles daily and yearly.

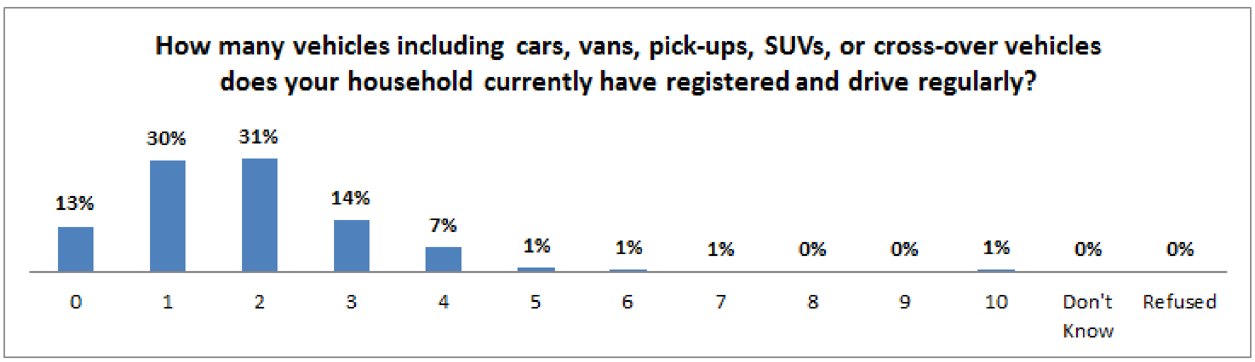

Figure 1. The number of vehicles per household that survey respondents stated they own or lease. This is not intended to include vehicles that are not used frequently, like collectors' vehicles. See question A1 in A.2. Sample size N = 1,011.

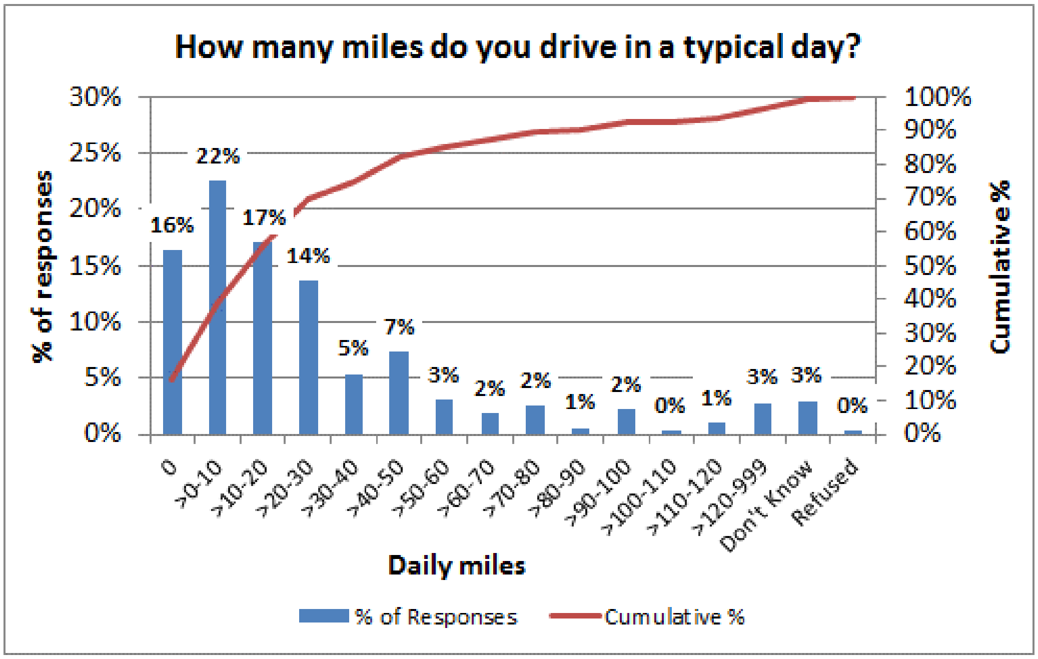

Figure 2. The average daily miles that survey respondents stated to drive. See question A2 in A.2. Sample size N = 1,011.

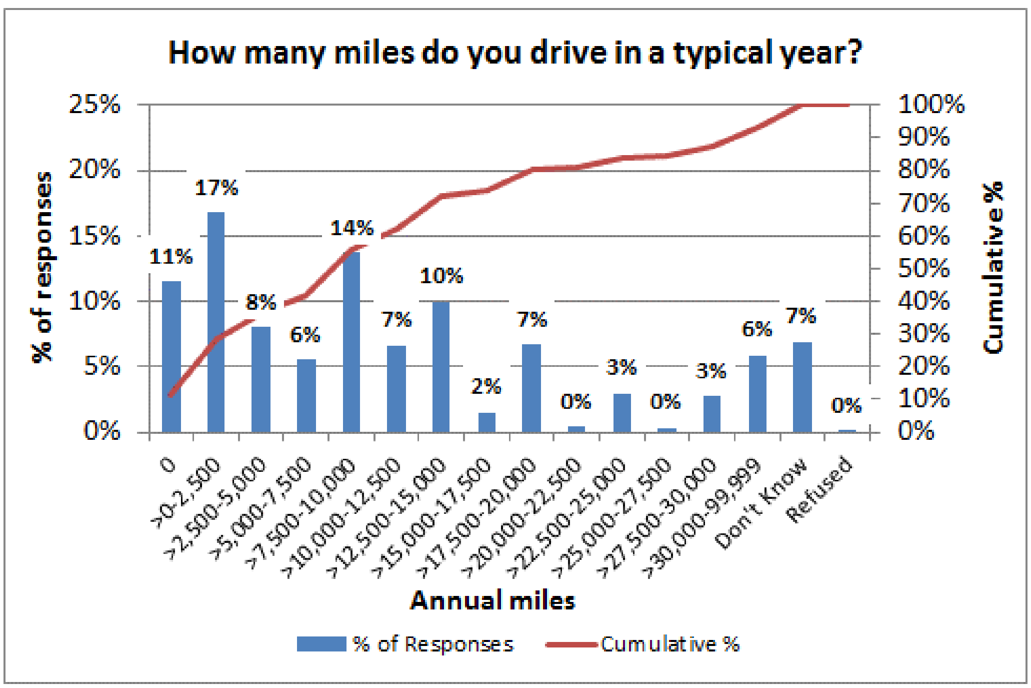

Figure 3. The average miles survey respondents stated to drive per year. See question A3 in A.2. Sample size N = 1,011.

Understanding differences between residential areas can also offer insights into the use of vehicles. Depending on density and proximity to goods and services, driving patterns are dramatically different. People who live in urban areas have more access to alternative modes of transportation, whereas people who live in rural areas tend to rely on personal vehicles to access goods and services that are further away (Pucher and Renne 2005; Schimek n.d.). Figure 4 shows the breakdown of the areas where survey respondents live.

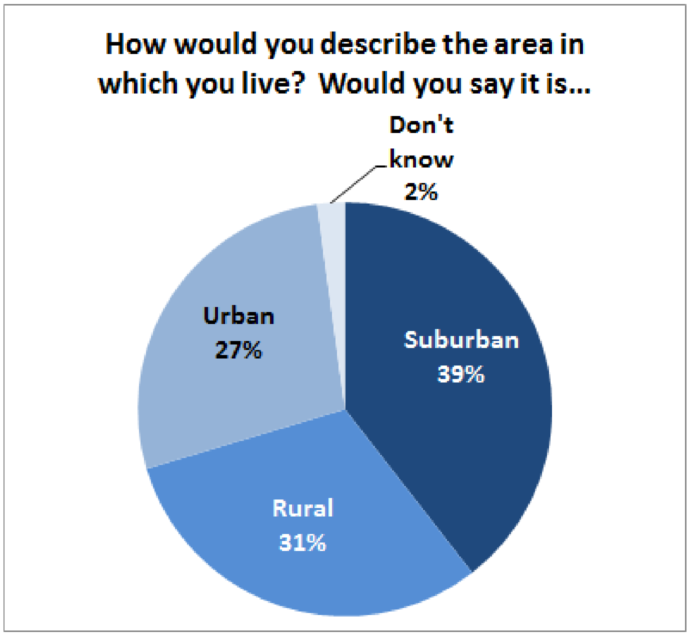

Figure 4. Residence type by area of survey respondents. See question A4 in A.2. Sample size N = 1,011.

In this section, results are broken down further to gain more information about how driving habits vary between different groups of people. Section 4 investigates how likely those groups of people are to be accepting of AV technology.

3.1 Patterns by Residence Area and Type

Understanding a person's driving behavior based on their residential area provides valuable insights into how people might use an AV. Vehicle usage significantly varies depending on the type of area a person lives. For example, people who live in urban areas are much more likely to have shorter commutes, more access to goods and services within a short distance, and many options for alternative modes of transportation (Pucher and Renne 2005; Arcury et al. 2005), whereas someone living in a rural area needs access to a personal vehicle to access basic needs like jobs, healthcare, education, and groceries. To better understand current driving behavior, types of residences were divided into urban, suburban, and rural categories. An individual respondent's area type was self-identified, although census region information was gathered.

Survey results showed that urban residents currently drive much less than both suburban and rural residents. Figure 5 illustrates the responses to the question: "*How many miles do you drive in a typical day?*" broken down into the three residential categories. The results show that 38% of urban residents drive 5 miles or less per day compared to 24% of suburban and 20% of rural residents. In contrast, 7% of urban, 15% of suburban, and 22% of rural residents drive more than 50 miles per day. The same method was used to analyze how annual VMT can change based on residential area type. Results are shown in Figure 6. Similarly, a large percentage (41%) of people who live in urban areas drive less than 2,000 miles per year, especially compared to people in rural (24%) and suburban (25%) areas.

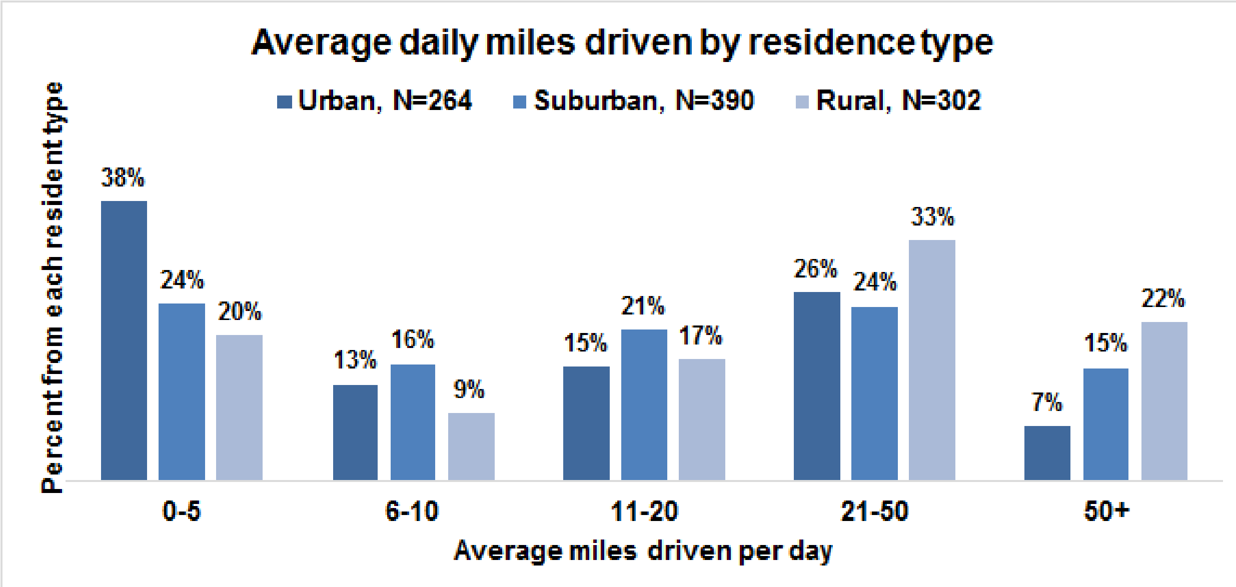

Figure 5. Current daily miles driven by urban, suburban, and rural residence type. For example, 38% of urban residents report traveling less than 5 miles per day. Sample excludes respondents that did not provide a daily mileage.

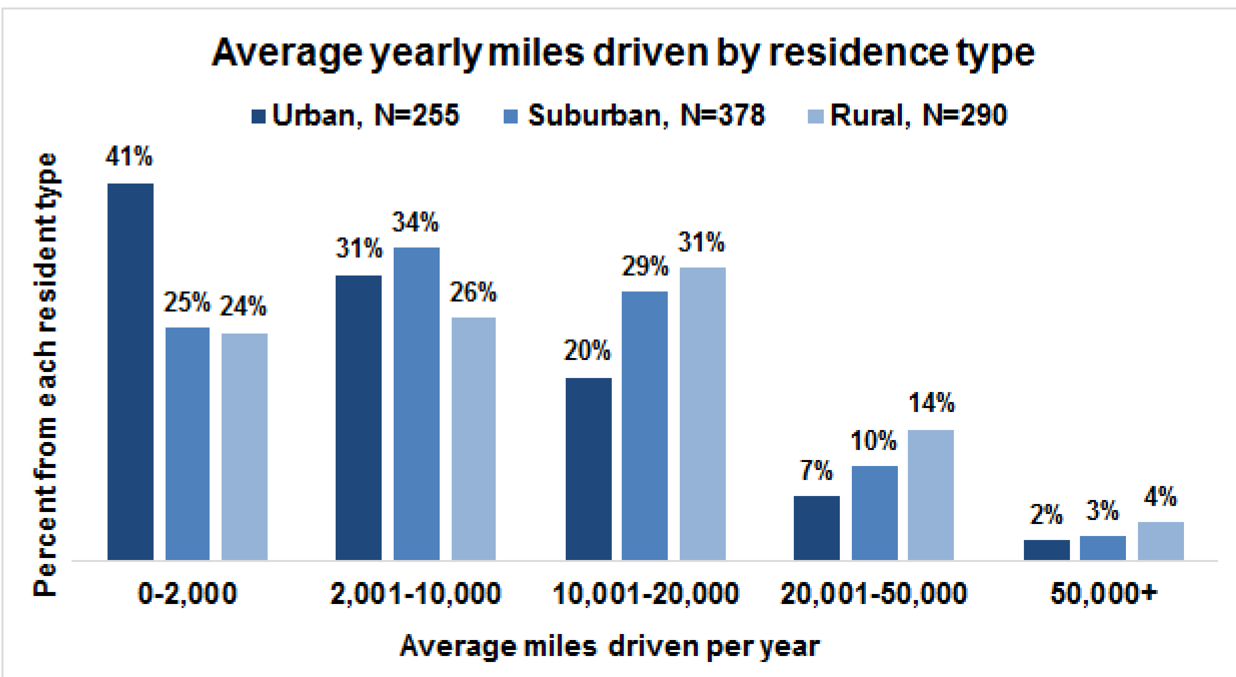

Figure 6. Current yearly miles driven by urban, suburban, and rural residence type. For example, 41% of urban residents report traveling less than 2,000 miles per year. Sample excludes respondents that did not provide a yearly mileage.

Variation of current vehicle ownership by residential area type were also analyzed. Survey results showed that urban residents own fewer vehicles. Figure 7 shows that 21% of urban residents do not currently own a car, compared to 7% and 11% of suburban and rural residents, respectively, and 12% of the total respondents. Further, suburban and rural residents are more likely to own multiple vehicles per household than urban residents. Less than half (44%) of urban residents own more than one vehicle, compared to 61% and 63% of suburban and urban residents, respectively.

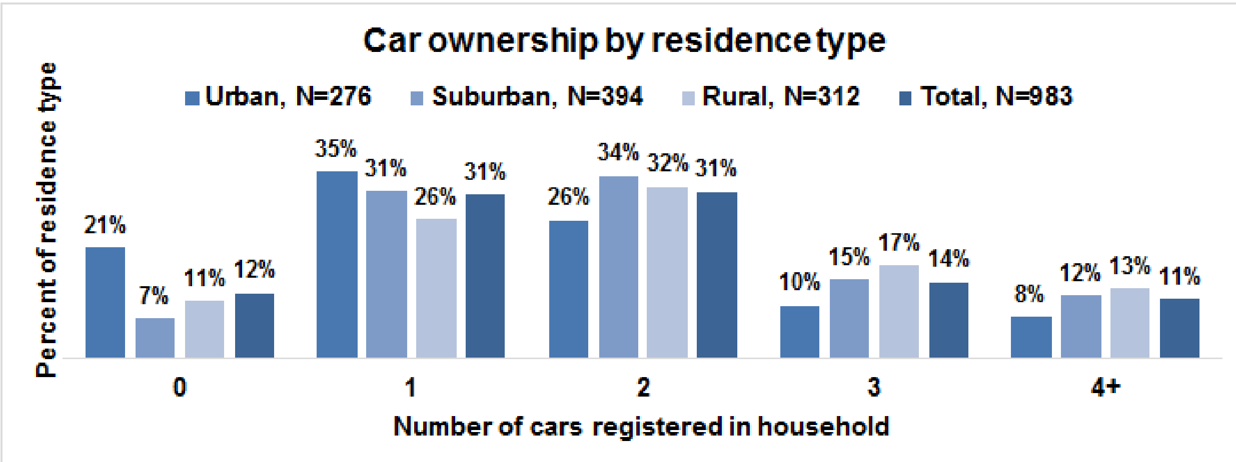

Figure 7. Number of vehicles per household by residential area type. Sample excludes respondents that did not provide their car ownership.

3.2 Patterns by Age Group

Age has shown to be a predictor of behavior in the adoption of new technology (Shaheen et al. 2017). However, understanding the relationship between age and other travel behavior indicators will give us more insight into how travel will evolve as the population ages. The type of residential area in which a person lives can have a significant influence on driving and commuting habits. People who live in urban areas are more likely to walk, bike, or use public transit than people who live in suburban and rural areas. Figure 8 shows that respondents under the age of 35 are more likely to live in urban areas than those between 45 to 75 years old. Whether the urban population remains young, or people move to the suburbs as they age is out of the scope of this study, though other reviews on this topic have been covered extensively (Kolko 2015).

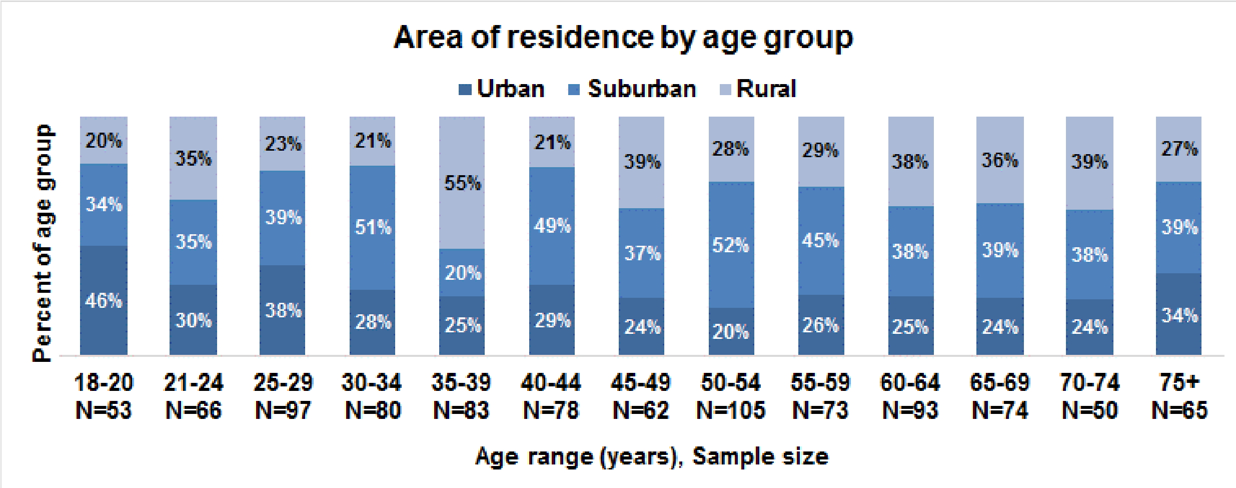

Figure 8. Area of residence versus age range of respondent. Sample excludes respondents that did not provide their age or did not provide an urban, suburban, rural designation.

Current driving habits can also be broken down by age group to analyze how they might change as people get older. As shown in Figure 9, a large fraction of people under the age of 20 and over the age of 70 presently drive less than 5 miles per day.

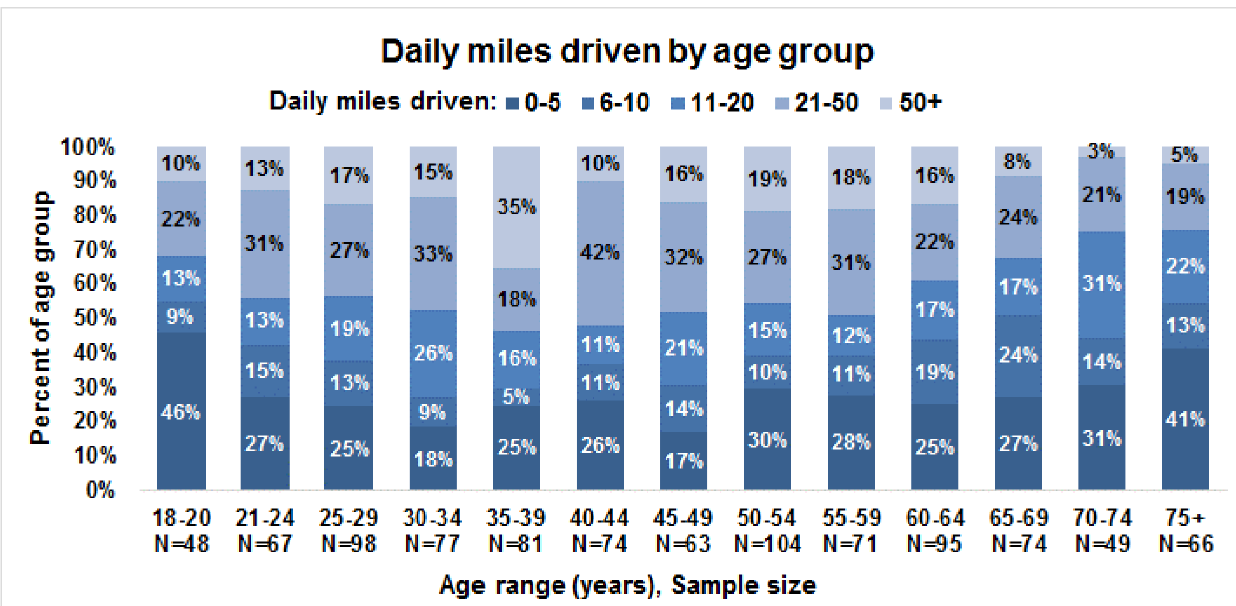

Figure 9. Average daily miles driven by age group. Sample excludes respondents that did not provide their age or a daily mileage.

3.3 Patterns by Income

Income levels are correlated with travel behavior, residential location, and purchasing and technology barriers (Shaheen et al. 2017). Understanding where people live based on their income could help predict where automated vehicles would be deployed first, based on current travel patterns and technology adoption rates. Figure 10 shows residential area types broken down by income ranges. The figure shows that people with incomes below $75,000 per year are spread out among urban, rural, and suburban areas. However, people with incomes above $75,000 per year tend to live in suburban areas at much higher rates than people with lower incomes.

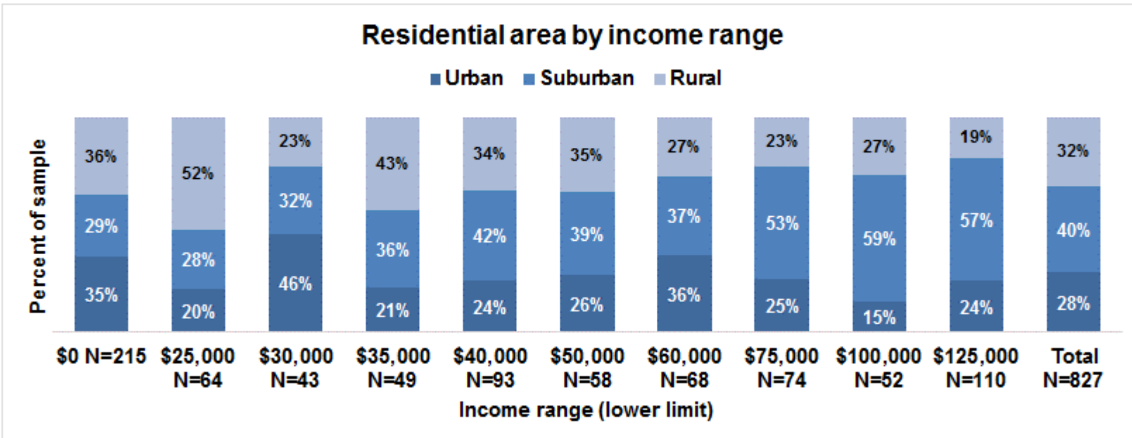

Figure 10. Residential area type broken down by income range. Income displayed is the lower limit (for example, the first set is a range from $0–$24,999). Sample excludes respondents that did not provide their income or did not provide an urban, suburban, rural designation.

Figure 11 shows the average daily miles driven broken down by income range. Households with income less than $35,000 tend to drive fewer miles per day than other income levels, and people with incomes over $75,000 tend to drive over 20 miles per day more than other income groups. This is consistent with the observation that people with high incomes live in suburban areas, where they are more likely to commute by vehicle than other modes like public transportation. Conversely, low income populations tend to have less access to vehicles and travel more via alternative modes of transportation (Center for Neighborhood Technology 2018).

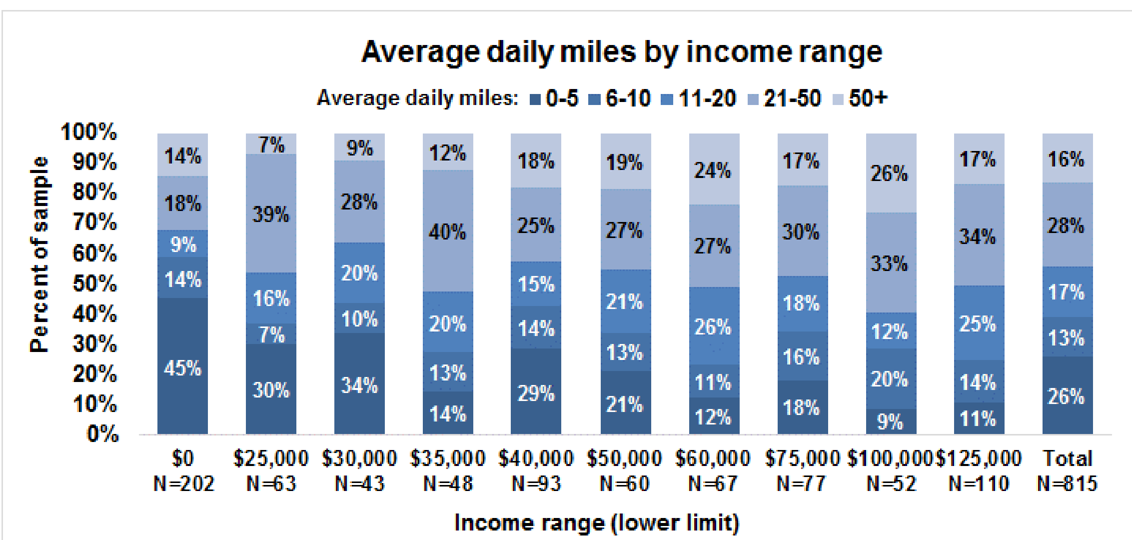

Figure 11. Average daily miles driven broken down by income level. Income displayed is the lower limit (for example, the first set is a range from $0–$24,999). Sample excludes respondents that did not provide their income or a daily mileage.

This pattern can further be observed by assessing the average vehicle registration by income level, which is shown in Figure 12. Twice as many people making less than $25,000 do not own a vehicle (27%) as the total rate (12%). Households with incomes over $60,000 tend to own two or more vehicles at percentages higher than lower income households. Of households with incomes over $100,000 nearly half own three or more vehicles.

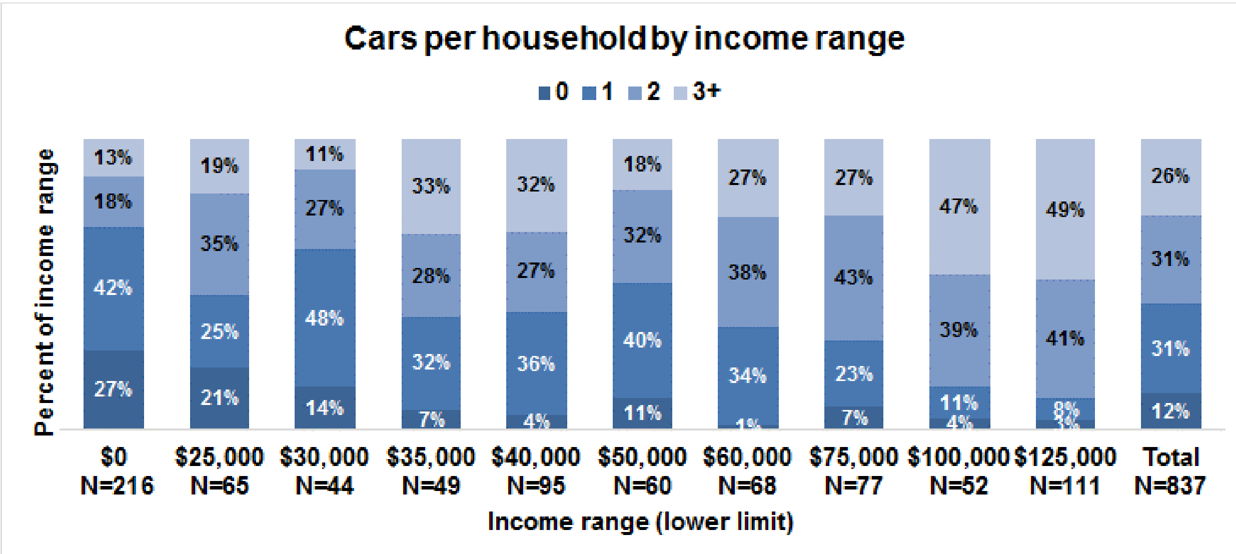

Figure 12. Vehicles registered per household broken down by income range. Income displayed is the lower limit (for example, the first set is a range from $0–$24,999). Sample excludes respondents that did not provide their income or car ownership.

4 Awareness of AVs and Likelihood of Adoption

Overall, survey respondents had a high awareness of AV technology. A large majority (85%) of respondents stated they had heard of the technology. Figure 13 shows the survey respondents' awareness and comfort level with AV technology. While most people said they believe the technology will become common, less than half of respondents stated they would be comfortable riding in an AV, and one third of respondents stated they would be interested in owning an AV. Note this survey was given before several high-profile AV fatal accidents, and other surveys have shown a decline in trust as a result (AAA 2018b). Interestingly, 8% more people stated they would want to ride in an AV than stated they wanted to own one, which provides some insight into how people envision using them. This could mean that people view AVs as more of an option for commercial use, such as ride hailing, than for personal ownership. The following sections analyze in more detail who responded more willingly and perhaps why they did so.

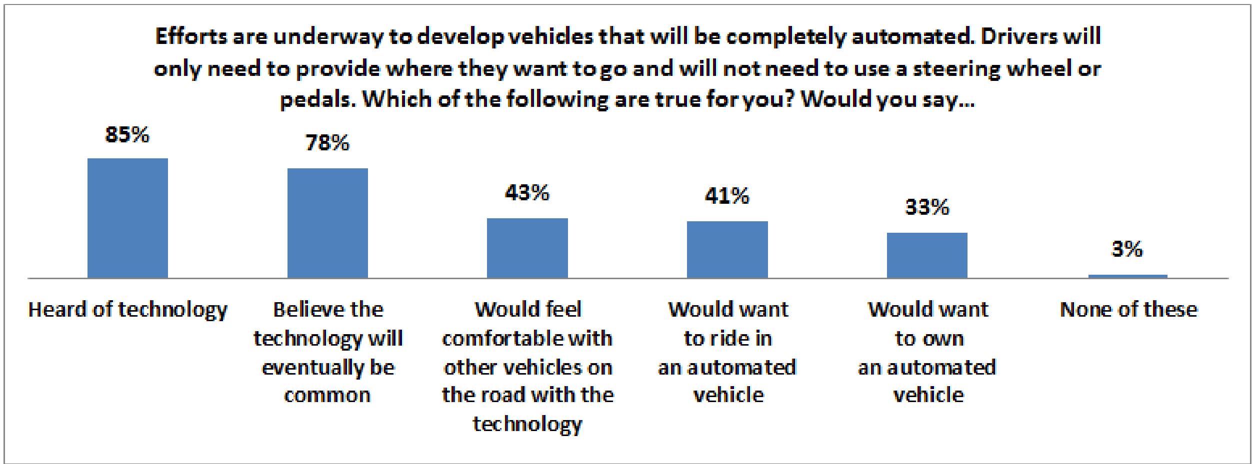

Figure 13. Answers to survey question addressing awareness of and likeliness to use AV technology. See question A5 in A.2. Sample size N = 1,011.

People who stated they are interested in using an AV listed "convenience" and "safety" as the main reasons for their decision, shown in Figure 14. More than half of people also listed the "ability to multi-task" as a reason to use AV technology.

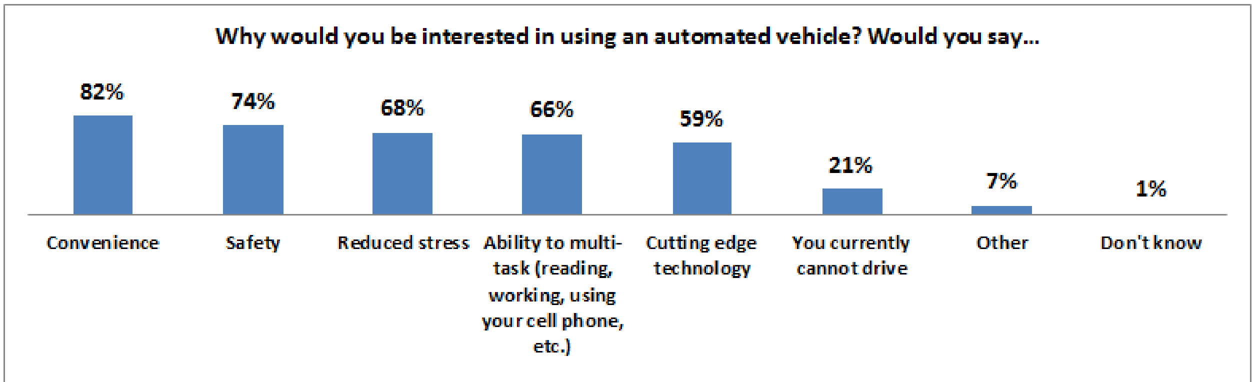

Figure 14. Reasons people listed for being interested in an AV. See question A6 in A.2. Sample size N = 445.

Similarly, people overwhelmingly listed "vehicle control" and "safety" as the main reasons for not being interested in an AV. Figure 15 shows the breakdown of why people answered that they would not be interested in using an AV.

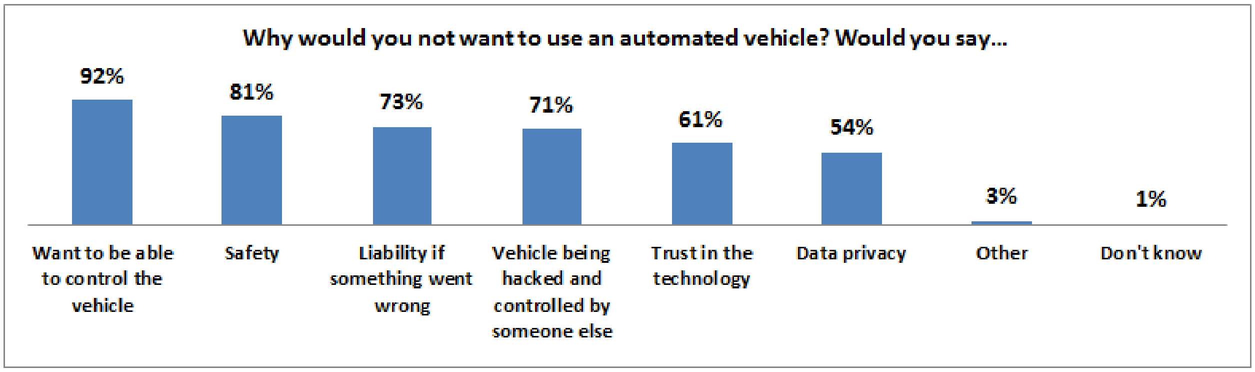

Figure 15. Reasons people listed for being hesitant to use an AV. See question A7 in A.2. Sample size N = 565.

Even if the concerns shown in Figure 15 were addressed, most people expressed that they would not want to be early users of AV technology. Figure 16 shows that only 10% of all survey respondents expressed willingness to be among the first users of AV technology, even when their concerns were sufficiently addressed, and over half of respondents stated they would be among the last people to use the technology.

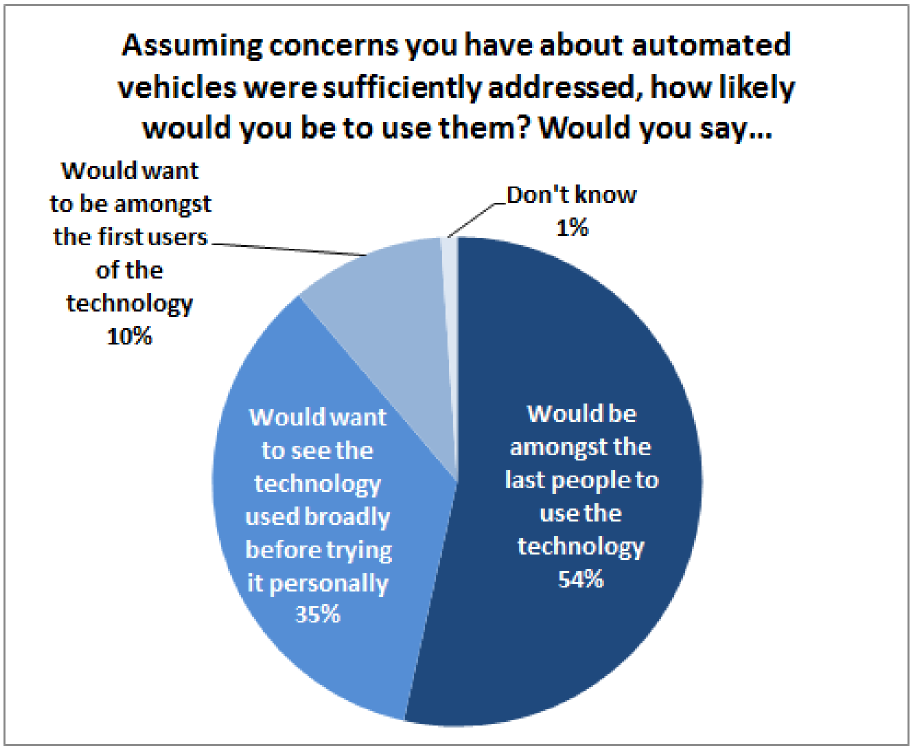

Figure 16. How soon people think they would adopt AV technology once their concerns were addressed. See question A8 in A.2. Sample size N = 1,011.

Despite the hesitation many respondents showed for accepting and using AV technology, the likelihood that the technology will eventually become commonplace is high (Becker and Axhausen 2017).

4.1 Patterns by Residence Area and Type

Figure 17 shows that urban residents are the most likely to be willing to ride in (53%) and own (44%) an AV, whereas rural residents are the least likely (32% and 28%, respectively). The acceptance of the technology among urban residents could mean that AV use as a whole, in addition to the infrastructure developed to support them, will be determined first by urban residents.

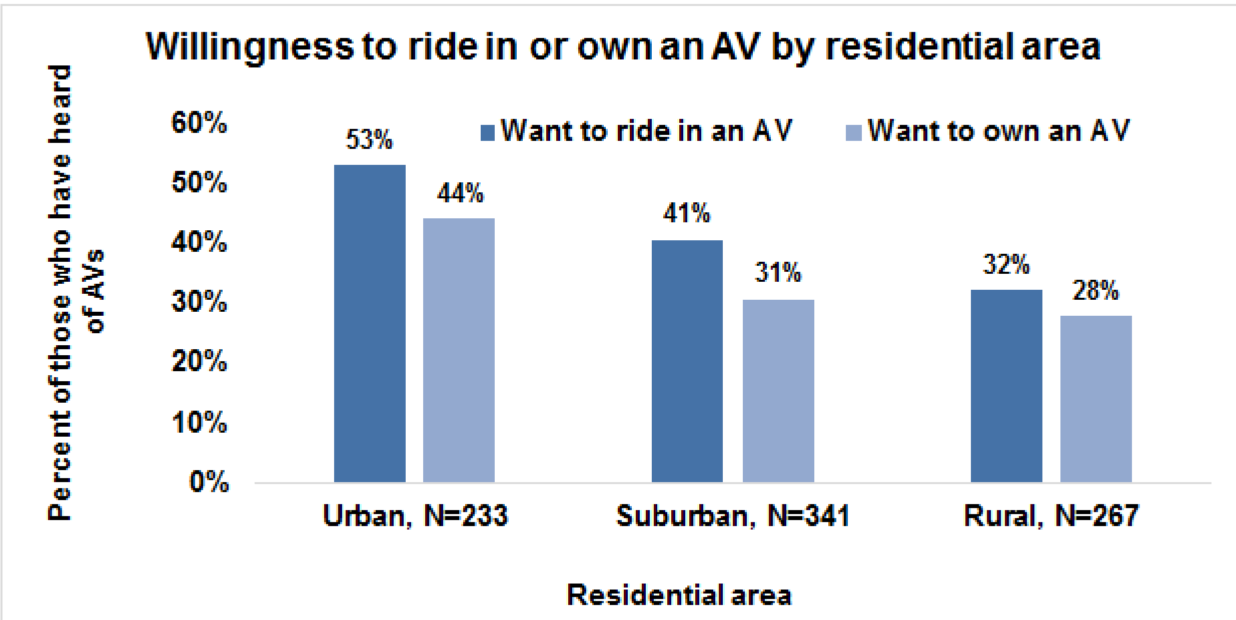

Figure 17. Willingness to ride in or own fully autonomous vehicles by residential area. Sample includes only those respondents that have heard of the technology (see question A5 in A.2).

Figure 18 shows the breakdown of people who want to ride in or own an AV, categorized by whether they rent or own their home. The data shows that people who rent are much more likely to want to ride in (50%) or own (46%) an AV than people who own their homes (36% and 25%, respectively).

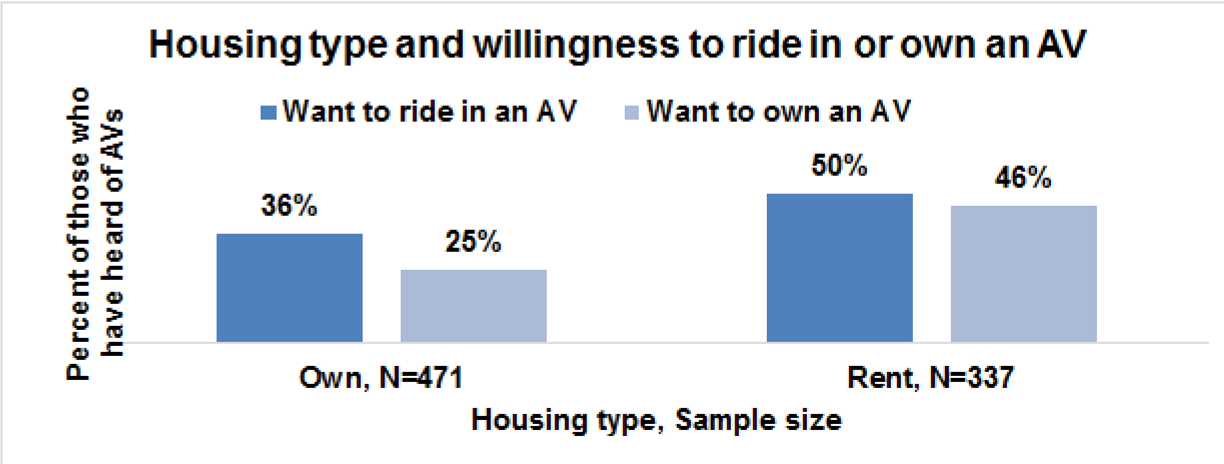

Figure 18. Wish to ride in or own an AV, broken down by people who rent versus own their homes. Sample excludes respondents that did not provide a housing type or had not heard of the technology (see question A5 in A.2).

Figure 19 shows the expected changes in commute based on AV technology availability, separated by respondents who rent and those who own their homes. The data shows that people who own their house expect their commute to remain unchanged (61%) much more than people who rent (40%). A larger percentage (30%) of those who rent their home compared to 17% of home owners expect their commute distance to increase. Similarly, renters are more likely (30%) to expect their commute to decrease than home owners (23%). Overall, respondents who rent are more likely to believe AVs have the potential to change their commute than people who own their homes, signaling they might be more likely to consider a commute change.

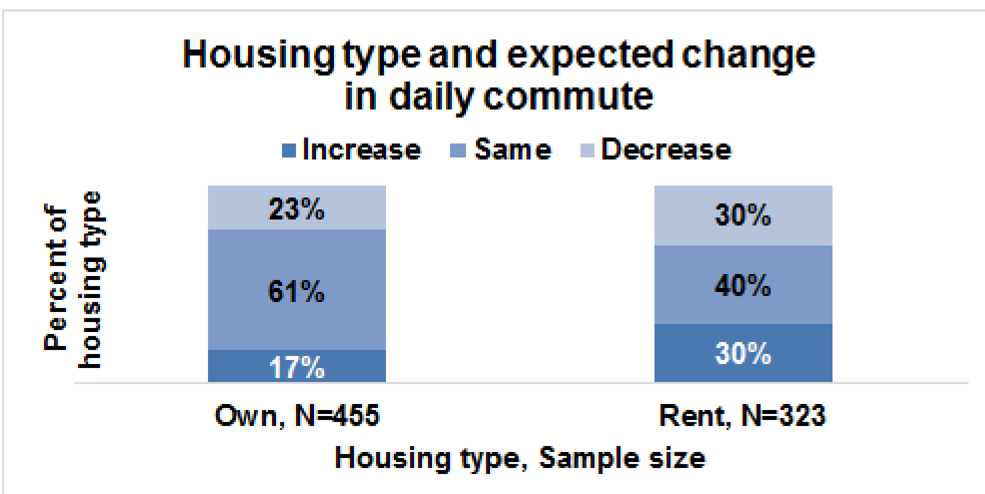

Figure 19. Expected change to daily commute with full access to an AV, broken down by housing type. Sample excludes respondents that did not provide a housing type, an expected commute change, or had not heard of the technology (see question A9 in A.2).

4.2 Patterns by Age Group

Figure 20 shows that respondents under the age of 35 are much more likely to be willing to ride in or own an AV (Question A5 in A.2). Combining the findings of Figure 20 with Figure 17, it can be noted that both younger and urban respondents are more likely to be interested AVs. These combined findings relate to the finding in Figure 8 that younger respondents are more likely to live in urban settings. Also, notably, respondents between ages 25 and 35 show a large discrepancy between their willingness to ride in and or own an AV. As younger people are presently more likely than other groups to use ride-hailing platforms, these results could infer that first adopters of AV technology would be more likely to use AVs for ride-hailing and ride sharing applications rather than private usage (Shaheen and Sperling 2018).

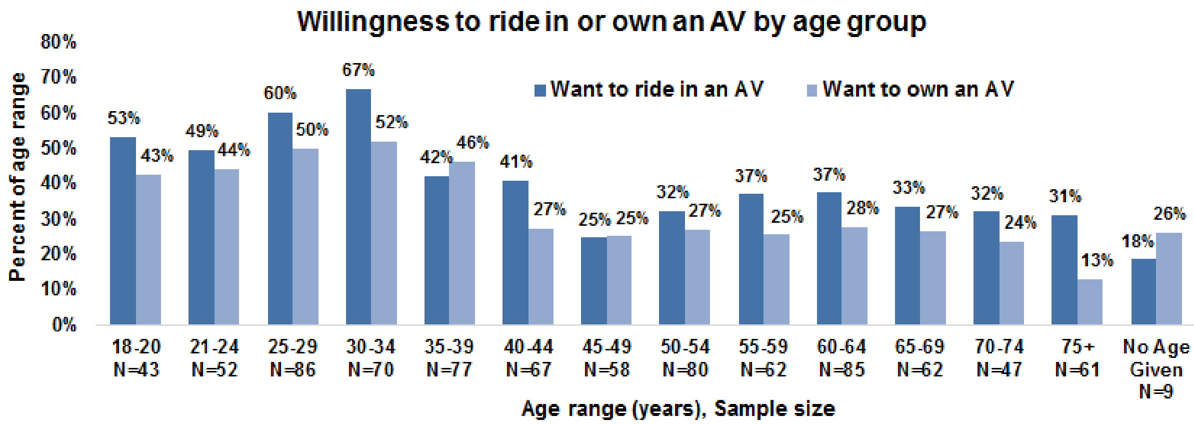

Figure 20. Desire to ride in or own a connected and automated vehicle according to age. See question A5 in A.2. Sample excludes respondents that had not heard of the technology.

4.3 Patterns by Income

For AV technology to be widely adopted, its existence and application would need to be commonly understood by the public. Low income areas are often the last adopters of technology, sometimes because they are the last to become aware of its existence (Anderson 2017). AVs have the potential to provide increased mobility to low-income communities that do not currently have access to a personal vehicle and who do not live near public transportation. Ride hailing services have been shown to provide increased access to mobility in low income areas (Brown 2018). If AV technologies were to be applied in ride hailing applications, utilization of the technology in currently under-served communities would likely increase energy consumption (Stephens et al. 2016). However, Figure 21 shows that low-income people are less aware (78% in households making under $25,000) of AV technology than overall (85%), so are also less likely to be among early adopters.

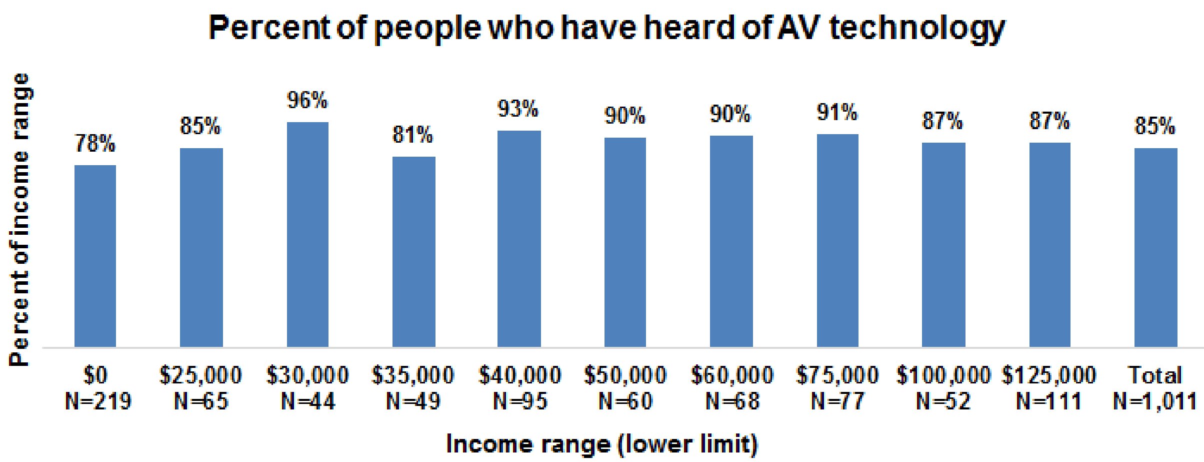

Figure 21. Awareness of AV technology broken down by income range. Income displayed is the lower limit, with the first set ranging from $0-24,999. Sample excludes respondents who did not provide their income and those that had not heard of the technology. See question A5 in A.2.

4.4 Patterns by Adoption Timeframe

In general, respondents' willingness to own or ride in AVs was not a strong predictor of whether they expected their commute to change. However, this willingness does provide insights into their level of acceptance around sharing or privately owning an AV. If AVs are privately owned, overall VMT and energy would be impacted differently than if passengers used AVs through a service, either for individual ride-hailing or ride sharing.

Figure 22 shows survey responses indicating the timeframe in which people see themselves adopting AV technology—broken out by current commute times—once their concerns surrounding the technology are met. A large percentage (43%) of early adopters are people who currently drive less than five miles per day. This may indicate that a large portion of people who will initially use AVs are those who currently drive little. There was little difference in the average daily miles driven of those who want to see the technology first and those who expect to be among the last to use the technology.

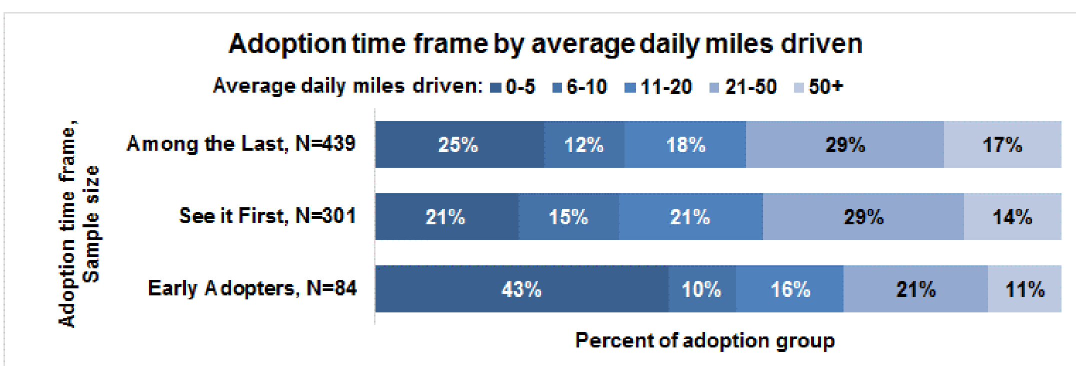

Figure 22. Assuming concerns are addressed, the chart above illustrates the timeframe people see themselves adopting AV technology, segmented by current driving distance. Sample excludes respondents that had not heard of the technology, did not provide a daily mileage, or did not provide an adoption timeframe (see question A8 in A.2).

5 Insights and Potential Changes to Driving Patterns

This survey asked respondents if they would expect to change their current driving behavior if they used an AV; the results give us insights into future implications for energy and emissions. Understanding the change in driving patterns resulting from the implementation of AVs will deliver the most insight into how driving and energy consumption will change if the technology is widely used. Based on survey answers, we can learn more about how people think they will change their driving habits, including how many miles they drive.

5.1 Potential Change to Commute and Miles Driven

People who are the first adopters of a technology help set the standard for their use, especially for a technology like an AV, where infrastructure planning and policy will likely be implemented simultaneously to support its use. As described in Section 3, people who live in suburban and rural areas tend to drive more than people who live in urban areas. If people rely on AVs to commute and have more geographical freedom to live and work in different places, they may change their VMT, PMT, and energy consumption.

After removing survey respondents who had not heard of AV technology (see question A5 in A.2), the expected change to driving distance can be broken down by region and trip purpose. Figure 23 shows the expected change in driving distance segmented by trip purpose (e.g., commuting, errands and recreation, or long distance trips) for respondents who answered that they want to ride in an AV. Figure 24 shows the same for respondents who answered that they want to own an AV. Large percentages (51%) of those that want to ride in an AV and (47%) that want to own an AV expect their commute to not change. However larger percentages of each expect commutes to increase rather than decrease. A similar pattern can be observed for driving for errands and recreation. Both groups of respondents expected to increase their long-distance travel. This could have implications for air and rail travel, as it could change whether people choose to take a long-distance road trip instead of a flight if they were not required to drive their cars (Kockleman 2018).

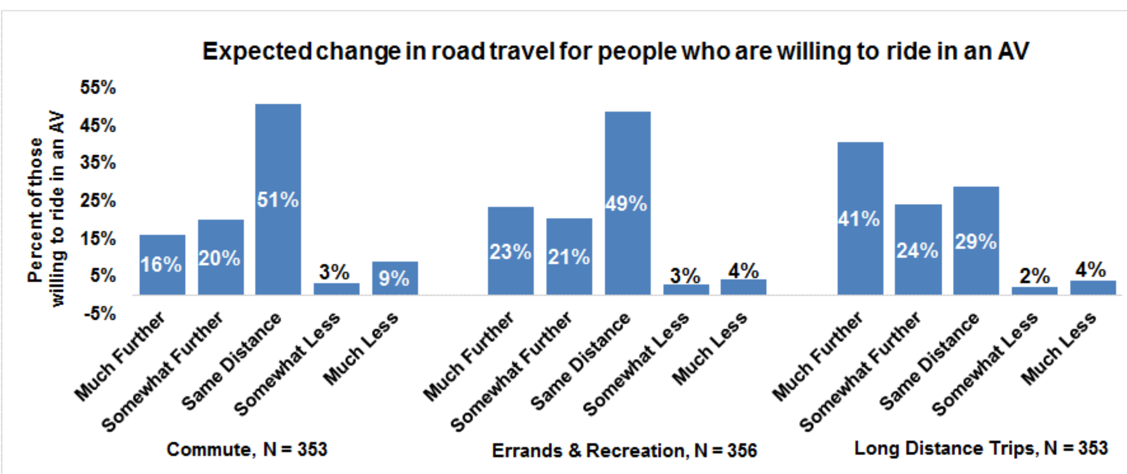

Figure 23. Expected changes to driving behavior for commuting, errands, and long-distance trips are shown above for survey respondents who answered that they want to ride in an AV. Sample excludes respondents that had not heard of the technology or did not provide expected changes in behavior (see questions A9, A10, and A11 in A.2).

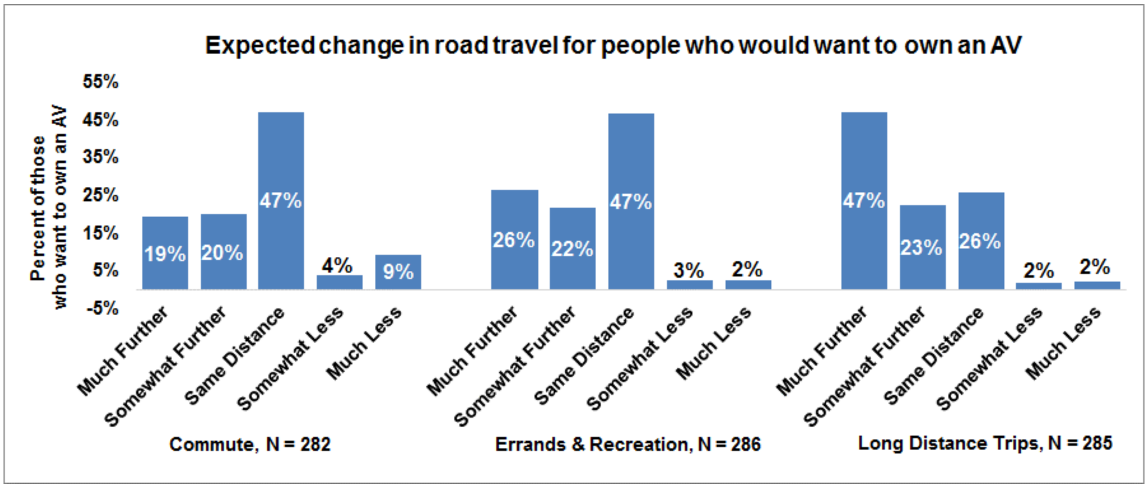

Figure 24. Expected changes to driving behavior for commuting, errands, and long-distance trips are shown for survey respondents who answered that they want to own an AV. Sample excludes respondents that had not heard of the technology or did not provide expected changes in behavior (see questions A9, A10, and A11 in A.2).

Analyzing survey data to assess respondents' current driving habits and to investigate how respondents expect their commutes to change with AV usage, can provide a better understanding of how overall driving may change. Figure 25 and Figure 26 show the expected change to commute, segmented by the current commute patterns for respondents who answered that they were willing to ride in or own an AV. The resulting patterns for respondents who want to ride in an AV and respondents who want to own an AV are similar. The largest portion of each overall group expected their commute to remain the same, while more respondents expected their commute to increase than to decrease.

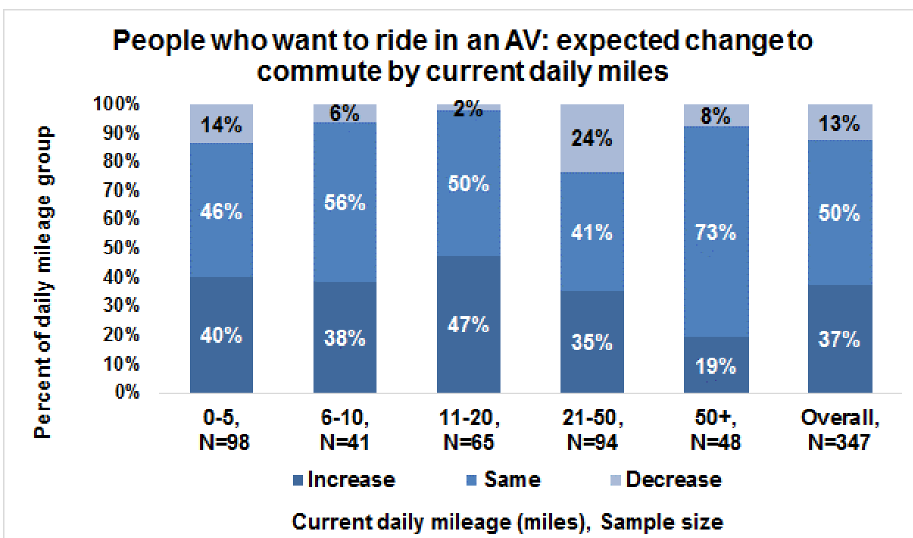

Figure 25. Predicted changes to commute, broken down by current commute distance of respondents who answered they want to ride in an AV. Sample excludes respondents that had not heard of the technology, did not provide a daily mileage, or did not provide an expected change in commute (see question A9 in A.2).

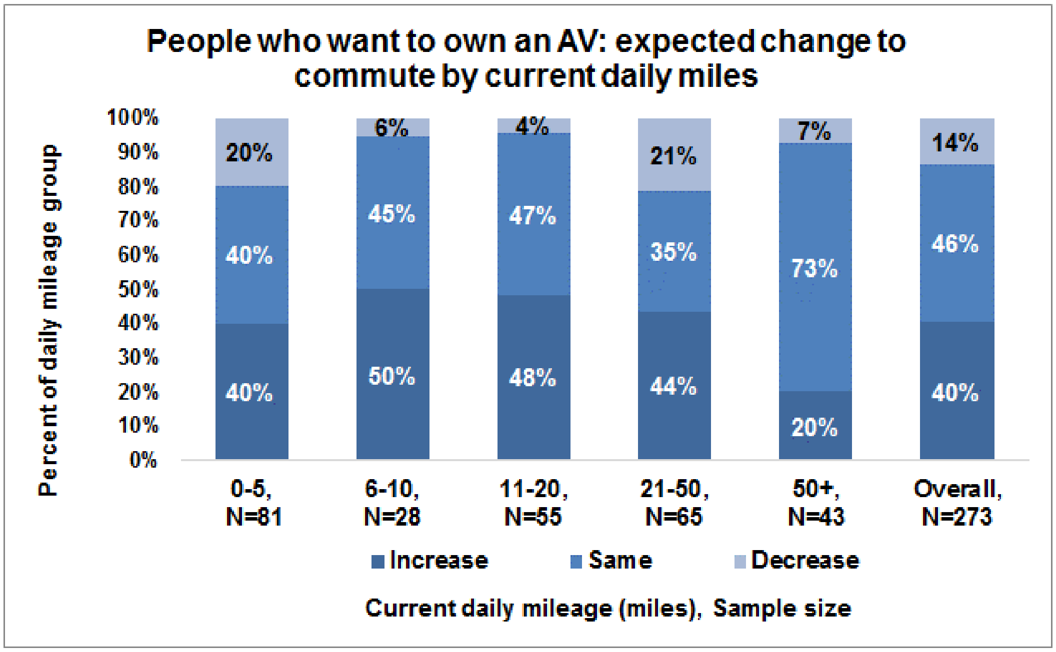

Figure 26. Predicted changes to commute, broken down by current commute distance of respondents who answered they want to own an AV. Sample excludes respondents that had not heard of the technology, did not provide a daily mileage, or did not provide an expected change in commute (see question A9 in A.2).

Overall, more people said they were willing to ride in an AV than those willing to own one. There are several possible reasons for this, including that people expect AVs to be expensive, and therefore they would be unlikely to own one. Another possible reason is that people expect to ride in AVs provided by ride hailing, ridesharing, and carsharing platforms. These scenarios would have a much different impact on energy use than if people owned AVs (Stephens et al. 2016). More research is needed to fully understand whether people would be more likely to own or share AVs, and how that could affect overall energy consumption.

Figure 27 further explores expected changes in commuting distance, where respondents' technology adoption timeframe is shown according to expected change in commute. A large percentage (39%) of early adopters and 36% of those that want to see the technology first would expect their commute mileage to increase, but only 9% of those respondents that thought they would be among the last to adopt the technology thought they would increase their commute. Conversely, 39% of respondents who thought they would be among the last to adopt the technology thought their commute would decrease, but 17% of early adopters and 10% of those that want to see the technology first thought their commute would decrease. Early adopters reported the lowest percentage (44%) that believe their commute would stay the same. This could signal that people who want to use the new technology would like alternatives to their current mode of transportation to work and may be willing to change the distance they travel each day to accommodate that.

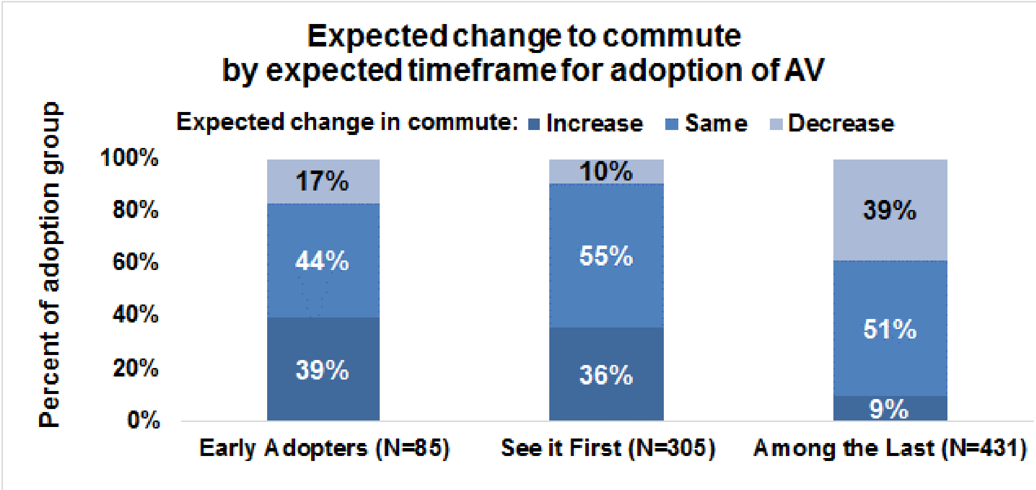

Figure 27. Expected change to commute by the timeframe of AV technology adoption. Sample excludes respondents that had not heard of the technology, did not provide an adoption timeframe, or did not provide an expected change in commute.

5.2 Comparison to Other Surveys

Many research surveys have been conducted to understand potential use and barriers to acceptance for connected and automated vehicles. Table 1 lists other surveys on this topic and a link to their results.

Much of the existing research at the time of this study into public views of connected and automated vehicles focused on the barriers to broad public acceptance. A primary barrier to acceptance has been found to be concern about the safety of the technology (IEEE 2015). However, the portion of the public concerned about the safety of AVs has been found to vary widely by different survey efforts. For example, Volvo reported 68% of the public believes AVs could reduce accidents (Volvo Car USA 2016), but AAA has reported a large majority (75%) would be afraid to ride in an AV (AAA 2016). Some evidence showed the public was becoming more comfortable with the technology in early 2018 (AAA 2018a); a series of high profile AV accidents that followed could be an underlying reason that concern began to rise again (AAA 2018b).

This study is unique because of its focus on the potential impacts of AVs on driving habits and commute distance. However, other survey research has investigated this question as well. A 2016 study of Austin area residents by Texas A&M University (Transportation Policy Research Center n.d.) found 25% would expect to increase their VMT. In the same study, respondents expected to increase VMT for long-distance travel, and a large majority (80%) did not expect to change their commute distance.

Kockelman has investigated the public's willingness to pay (WTP) for AV technologies in a series of research that includes potential VMT effects (Bansal and Kockelman 2017). Kockelman's group also found that a large majority of respondents (74% and 81.5% respectively) would not expect to shift their residence closer or further from city centers (Bansal et al. 2018, 2017). Kockelman (Kockelman et al. 2016; Gurumurthy and Kockelman 2018) also reported interest in increasing VMT due to long distance travel. A component of this increase is expected to be due to mode shifting, as travelers decide to use AVs instead of flying.

These related studies have reported an interest in increased VMT from long distance travel. This is consistent with the finding from this study, that respondents report a higher likelihood of increasing VMT due to long distance travel than increased travel for commuting or recreation and errands.

Table 1. Surveys Related to Acceptance of AVs

Source	Date	Respondent group	Link
IEEE	Oct-15	IEEE experts and social media	https://www.ieee.org/about/news/2015/15october_2015.html
Volvo	Jun-16	50,000 worldwide	https://www.media.volvocars.com/us/en-us/media/pressreleases/193745/survey-new-yorkers-and-californians-ready-for-autonomous-cars-texas-and-pennsylvania-residents-skept
AAA	Jan-16	1,832 adults	https://newsroom.aaa.com/2016/03/three-quarters-of-americans-afraid-to-ride-in-a-self-driving-vehicle/
	Jan-17	1,012 adults	http://newsroom.aaa.com/2017/03/americans-feel-unsafe-sharing-road-fully-self-driving-cars/
	Jan-18	1,004 adults	https://newsroom.aaa.com/2018/01/americans-willing-ride-fully-self-driving-cars/
	May-18	1,014 adults	https://newsroom.aaa.com/2018/05/aaa-american-trust-autonomous-vehicles-slips/
University of Michigan Transportation Research Institute	Apr-14	1,596 adults US, UK, Australia	https://deepblue.lib.umich.edu/bitstream/handle/2027.42/106590/102996.pdf?sequence=1&isAllowed=y
	Jul-14	1,533 adults US, UK, Australia	https://deepblue.lib.umich.edu/bitstream/handle/2027.42/108384/103024.pdf?sequence=1&isAllowed=y
	Oct-14	1,722 adults in China, India, Japan, US, UK, Australia	https://deepblue.lib.umich.edu/bitstream/handle/2027.42/109433/103139.pdf?sequence=1&isAllowed=y
	Jul-15	505 adult drivers in US	https://deepblue.lib.umich.edu/bitstream/handle/2027.42/114386/103217.pdf?sequence=1&isAllowed=y
Texas A&M Transportation Institute	Jan-14	OEMs and Public officials	http://static.tti.tamu.edu/swutc.tamu.edu/publications/technicalreports/600451-00029-1.pdf
	Apr-16	556 Austin residents	http://d2dtl5nnlpfr0r.cloudfront.net/tti.tamu.edu/documents/TTI-2016-8.pdf
VOX	Aug-16	2,102 registered voters	http://www.vox.com/2016/8/29/12647854/uber-self-driving-poll

Source	Date	Respondent group	Link
University of Texas at Austin	2016a	347 Austin residents	http://www.caee.utexas.edu/prof/kockelman/public_html/TRB16NewTechsAustin.pdf
	2016b	2,167 US Residents	http://www.caee.utexas.edu/prof/kockelman/public_html/TRB16CAVTechAdoption.pdf
	2017	1,088 Texas residents	http://www.caee.utexas.edu/prof/kockelman/public_html/TRB17TxOpinionsCAVs.pdf
	2018	2,588 US Residents	http://www.caee.utexas.edu/prof/kockelman/public_html/TRB19SurveyDRS.pdf
Klashwerks	Feb-17	3,116 car drivers	https://medium.com/ravencompanion/2017-state-of-driving-survey-61867972262f#.yqwnasgfp
Bloomberg Government State Farm	Sep-16	1,005 Americans	http://www.transpogroup.com/assets/bloomberg-survey---public-perceptions-of-driverless-cars-report.pdf
Delft University of Technology	Oct-14	5,000 in 109 countries	https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2506579

6 Conclusion

Automated vehicles have the potential to impact the way society functions by offering increased mobility options. This will likely have an effect on energy usage in the United States. The survey results described in this paper offer a deeper dive into understanding how people expect to use AVs.

Survey data investigated current travel behavior related to residential area and type as well as demographics. Results showed that people who live in urban areas tend to be younger, own fewer vehicles, and drive less than people who live in suburban and rural areas. Further, results showed that people who live in suburban and rural areas tend to use more vehicles and drive more.

Survey respondents were also asked about their knowledge and perception of AVs. Awareness of AV technology was 85% total, and nearly 90% across all income groups except people who make less than $25,000 per year. People who were willing to ride in, or wanted to own, an AV tended to be younger, live in urban areas, and drive fewer daily miles. People who rented their homes were more likely to want to ride in, or own, an AV compared with people who own their homes.

Finally, survey respondents evaluated their expected travel behavior changes as a result of AVs being readily available. People who wanted to become the first to adopt the technology were more likely to expect their commute distance to change. Of respondents who were familiar with AV technology and wanted to ride in or own an AV, more of them expected their commute, recreation and errands driving, and particularly long-distance driving to increase rather than decrease with the availability of AV technology.

Overall, results indicate that respondents that are younger, live in urban areas, rent their home, and drive little, are more likely to be willing to use AV technology. Those that have heard of AV technology and currently want to ride in or own an AV stated they are more likely to increase than decrease driving with the technology available. If this shift in behavior occurred across the public more broadly as the technology becomes prevalent, it would likely result in increased energy consumption, if AVs were powered by fossil fuels and not utilized as a ride sharing service (Chase, Maples, and Schipper 2018). However, data are preliminary, and more studies should be done to further investigate the potential behavioral impacts widespread adoption of automated vehicle technology may have.

References

AAA. 2016. “AAA Fact Sheet, Vehicle Technology Survey.” AAA. 2016. http://publicaffairsresources.aaa.biz/wp-content/uploads/2016/02/Automotive-Engineering-ADAS-Survey-Fact-Sheet-FINAL-3.pdf.

AAA. 2018a. “More Americans Willing to Ride in Fully Self-Driving Cars | AAA NewsRoom.” https://newsroom.aaa.com/2018/01/americans-willing-ride-fully-self-driving-cars/.

AAA. 2018b. “American Trust in Autonomous Vehicles Slips | AAA NewsRoom.” AAA. Accessed August 14, 2018. https://newsroom.aaa.com/2018/05/aaa-american-trust-autonomous-vehicles-slips/.

Anderson, Monica. 2017. “Digital Divide Persists Even as Lower-Income Americans Make Gains in Tech Adoption.” Pew Research. 2017. http://www.pewresearch.org/fact-tank/2017/03/22/digital-divide-persists-even-as-lower-income-americans-make-gains-in-tech-adoption/.

Arcury, Thomas A., John S. Preisser, Wilbert M. Gesler, and James M. Powers. 2005. “Access to Transportation and Health Care Utilization in a Rural Region.” *The Journal of Rural Health* 21 (1): 31–38. https://doi.org/10.1111/j.1748-0361.2005.tb00059.x.

Bansal, Prateek, Graduate Research Assistant, Kara M Kockelman, and E P Schoch. 2017. “ARE WE READY TO EMBRACE CONNECTED AND SELF-DRIVING VEHICLES? A CASE STUDY OF TEXANS.” *Transportation*. Vol. 44. http://www.caee.utexas.edu/prof/kockelman/public_html/TRB17TxOpinionsCAVs.pdf.

Bansal, Prateek, Graduate Research Assistant, Kara M Kockelman, and Amit Singh. 2018. “ASSESSING PUBLIC OPINIONS OF AND INTEREST IN NEW VEHICLE TECHNOLOGIES: AN AUSTIN PERSPECTIVE 2 3.” http://www.caee.utexas.edu/prof/kockelman/public_html/TRB16NewTechsAustin.pdf.

Bansal, Prateek, and Kara M. Kockelman. 2017. “Forecasting Americans’ Long-Term Adoption of Connected and Autonomous Vehicle Technologies.” *Transportation Research Part A: Policy and Practice* 95 (January): 49–63. https://doi.org/10.1016/J.TRA.2016.10.013.

Becker, Felix, and Kay W. Axhausen. 2017. “Literature Review on Surveys Investigating the Acceptance of Automated Vehicles.” *Transportation* 44 (6): 1293–1306. https://doi.org/10.1007/s11116-017-9808-9.

Brown, Anne. 2018. " Ridehail Revolution: Ridehail Travel and Equity in Los Angeles." http://www.its.ucla.edu/2018/06/27/ridehail-revolution-groundbreaking-its-dissertation-examines-discrimination-and-travel-patterns-for-lyft-uber-and-taxis/.

Center for Neighborhood Technology. 2018. “AllTransit.” 2018. https://alltransit.cnt.org/.

Chase, Nicholas, John Maples, and Mark Schipper. 2018. “U.S. Energy Information Administration - EIA - Independent Statistics and Analysis.” EIA Annual Energy Outlook 2018. 2018. https://www.eia.gov/outlooks/aeo/av.php.

Gurumurthy, Krishna Murthy, and Kara M Kockelman. 2018. “MODELING AMERICANS’ AUTONOMOUS VEHICLE PREFERENCES: A FOCUS 1 ON DYNAMIC RIDE-SHARING, PRIVACY & LONG-DISTANCE MODE CHOICES 2.” http://www.caee.utexas.edu/prof/kockelman/public_html/TRB19SurveyDRS.pdf.

IEEE. 2015. "IEEE Survey Indicates When it Comes to Driverless Cars - You Can Take Me, but not My Kids". IEEE. 2015. https://www.ieee.org/about/news/2015/ieee-survey-indicates-when-it-comes-to-driverless-cars-you-can-take-me-but-not-my-kids.html.

Keane, Michael, and Nada Wasi. 2013. "The Structure of Consumer Taste Heterogeneity in Revealed vs. Stated Preference Data." Oxford, U.K.: University of Oxford. Accessed August 2015, www.nuffield.ox.ac.uk/economics/papers/2013/SP_RP_data%20-%20Final.pdf.

Kockelman, Kara, Paul Avery, Prateek Bansal, Stephen D Boyles, Pavle Bujanovic, Tejas Choudhary, Lewis Clements, et al. 2016. “Implications of Connected and Automated Vehicles on the Safety and Operations of Roadway Networks: A Final Report (FHWA 0-6849-1).” https://library.ctr.utexas.edu/ctr-publications/0-6849-1.pdf.

Kockleman, Kara. 2018. “Energy and Emissions Implications of Self-Driving Vehicles.” In *Automated Vehicles Symposium*. San Francisco, CA.

Kolko, Jed. 2015. “Why Millennials Are Less Urban Than You Think | FiveThirtyEight.” FiveThirtyEight. 2015. https://fivethirtyeight.com/features/why-millennials-are-less-urban-than-you-think/.

Litman, Todd Alexander, and Todd Litman. 2018. “Autonomous Vehicle Implementation Predictions Implications for Transport Planning.” www.vtpi.orgInfo@vtpi.org.

MacDuffie, John Paul, and Constantine Samaras. 2018. “Autonomous Car Crashes: Who - or What - Is to Blame? - Knowledge@Wharton.” University of Pennsylvania, Wharton. http://knowledge.wharton.upenn.edu/article/automated-car-accidents/.

Pucher, John, and John L. Renne. 2005. “Rural Mobility and Mode Choice: Evidence from the 2001 National Household Travel Survey.” *Transportation* 32 (2): 165–86. https://doi.org/10.1007/s11116-004-5508-3.

Schimek, Paul. n.d. “Household Motor Vehicle Ownership and Use: How Much Does Residential Density Matter?” Accessed August 14, 2018. https://journals.sagepub.com/doi/pdf/10.1177/0361198196155200117.

Securing America’s Future Energy. 2018. “Transportation Network Companies: Broadening Access and Improving the Efficiency of Travel.” http://www.schallerconsult.com/rideservices/automobility.pdf.Accessed.

Shaheen, Susan, Corwin Bell, Adam Cohen, and Balaji Yelchuru. 2017. "Travel Behaviour. Shared Mobility and Transportation Equity," 66.

Shaheen, Susan, and Daniel Sperling. 2018. "Shared Mobility: The Potential of Ridehailing and Pooling." In *Three Revolutions: Steering Automated, Shared, and Electric Vehicles to a Better Future*, 55–76.

Stephens, T S, J Gonder, Y Chen, Z Lin, C Liu, and D Gohlke. 2016. "Estimated Bounds and Important Factors for Fuel Use and Consumer Costs of Connected and Automated Vehicles." https://www.nrel.gov/docs/fy17osti/67216.pdf.

Transportation Policy Research Center. n.d. "Revolutionizing Our Roadways: Consumer Acceptance and Travel Behavior Impacts of Automated Vehicles." Accessed August 20, 2018. https://d2dtl5nnlpfr0r.cloudfront.net/tti.tamu.edu/documents/TTI-2016-8.pdf.

Volvo Car USA. 2016. "Survey: New Yorkers and Californians Ready for Autonomous Cars; Texas and Pennsylvania Residents Skeptical - Volvo Car USA Newsroom." Volvo Newsroom. 2016. https://www.media.volvocars.com/us/en-us/media/pressreleases/193745/survey-new-yorkers-and-californians-ready-for-autonomous-cars-texas-and-pennsylvania-residents-skept.

Appendix

A.1 ORC International Survey Methodology

The following pages describe the methodology used for the ORC International Telephone CARAVAN® survey conducted February 23-26, 2017.

The study was conducted using two probability samples: randomly selected landline telephone numbers and randomly selected mobile (cell) telephone numbers. The combined sample consists of 1,011 adults (18 years old and older) living in the continental United States. Of the 1,011 interviews, 510 were from the landline sample and 501 from the cell phone sample. The margin of error for the sample of 1,011 is +/- 3.08% at the 95% confidence level. Smaller subgroups will have larger error margins.

Surveys are collected by trained and supervised U.S.-based interviewers using ORC International's computer assisted telephone interviewing (CATI) system. Final data is adjusted to consider the two sample frames and then weighted by age, gender, region, race/ethnicity and education to be proportionally representative of the U.S. adult population.

As a founding member of the Code of Standards of the Council of American Survey Research Organizations (CASRO) and a member of the European Society for Opinion and Marketing Research (ESOMAR), ORC International adheres to a rigorous Code of Standards and Ethics for Survey Research. As required by CASRO, ORC International maintains the anonymity of respondents. No information will be released that in any way will reveal the identity of a respondent. ORC International's authorization is required for any publication of the research findings or their implications.

Sampling

Telephone CARAVAN® uses a dual frame sampling design. This means that the sample is drawn from two independent sample frames—one for landlines and one for cell phones.

Landline Sample

ORC International's Random Digit Dial (RDD) telephone sample is generated using a list-assisted methodology. That is, the updated white page listings that are used to identify telephone number banks (the first 8 digits of the phone number) with a listed phone number in them. The standard that we use is 2+, meaning that a bank needs to have two or more listed households to be considered working. The Genesys Sampling in-house system is used to generate list-assisted Random Digit Dialing sample.

The standard GENESYS RDD methodology produces a strict single stage, EPSEM (Equal Opportunity of Selection Method) sample of residential telephone numbers. In other words, a GENESYS RDD sample ensures an equal and known probability of selection for every residential telephone number in the sample frame.

Cell Phone Sample

The cell phone sample, also RDD, has been supplied by SSI, Inc. using their proprietary Cell/WINS technology. The cell phone sample is generated from cell phone 1,000 series blocks with all the 100 series banks within each block turned on. The sampling interval is then calculated by dividing the universe of all possible numbers by the number of records desired, thus specifying the size of the frame subdivisions. Within each of the subsets one number is selected at random giving all numbers an equal probability of selection.

Weighting

In probability-based samples such as CARAVAN®, the basis of the weighting is the inverse of the selection probability. Then, weighting adjustments are frequently used to reduce the potential for biases that may be present due to incomplete frame coverage and survey nonresponse—both inherent in all telephone surveys. These adjustments may take advantage of geographic, demographic, and socioeconomic information that are known for the population and measured in the sample surveys. The adjustments reduce potential bias to the extent that the survey respondents and nonrespondents (noncontacts, refusals, etc.) with similar geographic, demographic, and socioeconomic characteristics are also similar with respect to the survey statistics of interest. In other words, post-survey weighting adjustments reduce bias if the weighting variables are related to (correlated with) the survey measures and the likelihood of survey participation.

The CARAVAN® *landline-cell* combined sample is a dual frame sampling design. This means that the sample is drawn from two independent sampling frames—one for landlines and one for cell phones. Adults with a landline but no cell phone (A) must be reached through a landline telephone sample. Adults with a cell phone and no landline (C) must be reached through the cell phone sample. Adults with both a landline and a cell phone (B) can be reached through either of the frames. Sampling from the two frames results in these four groups:

a_1: Landline respondents without a cell phone (landline only)

b_1: Landline respondents with a cell phone (dual user)

b_2: Cell phone respondents with a landline (dual user)

c_2: Cell phone respondents without a landline (cell only)

The dual user groups (b_1, b_2) are further classified into two subgroups:

Cell mostly: those who receive most calls on a cell phone

Landline mostly/Mixed use: those who receive most calls on a landline or who receive calls on both regularly

The National Health Interview Survey (NHIS) provides estimates of these user group populations. The landline sample and the cell sample are weight-adjusted to their respective population proportions as reported from the NHIS. Once this design weight is calculated, the combined sample is weighted to represent the U.S. population using data from the U.S. Census Bureau's American Community Survey (CPS). This form of weighting is referred to as *calibration weighting*[1] in that survey respondents are assigned weights that are calibrated to reflect the population. The calibration weighting for CARAVAN® is based on a series of ratio

[1] For a summary of calibration weighting, refer to Kalton, G. and I. Flores-Cervantes (2003) "Weighting Methods", Journal of Official Statistics.

adjustments called iterative proportional fitting, or "*raking*"[2] which was first introduced by Deming and Stephan for use in the 1940 U.S. census.

Definition of Classification Terms

The following definitions are provided for some of the standard demographics by which the results are tabulated. Other demographics are self-explanatory.

Income

The income groupings refer to the total household income for 2016 before taxes.

Geographic Region

The states are contained in four geographic regions as follows:

North East

- New England: Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut
  Middle Atlantic: New York, New Jersey, Pennsylvania

Midwest

- East North Central: Ohio, Indiana, Illinois, Michigan, Wisconsin
  West North Central: Minnesota, Iowa, Missouri, North Dakota, South Dakota, Nebraska, Kansas

South

- South Atlantic: Delaware, Maryland, District of Columbia, Virginia, West Virginia, North Carolina, South Carolina, Georgia, Florida
- East South Central: Kentucky, Tennessee, Alabama, Mississippi
  West South Central: Arkansas, Louisiana, Oklahoma, Texas

West

- Mountain: Montana, Idaho, Wyoming, Colorado, New Mexico, Arizona, Utah, Nevada
  Pacific: Washington, Oregon, California, Hawaii, Alaska

About ORC International

ORC International is a collaborative and consultative research partner to hundreds of organizations around the globe. The organization possess a wide variety of resources, tools, and technologies to collect and analyze information for clients.

ORC International is ISO 20252 certified. To achieve certification, ORC International passed a comprehensive, on-site audit. The certification establishes globally recognized terms, definitions, and service requirements for project management in research organizations. Processes outlined in ISO 20252 are designed to produce transparent, consistent, well documented and error-free methods of conducting and managing research projects. Adherence and certification to such

[2] Deming, W. E. and F. F. Stephan (1940) "On a Least Squares Adjustment of a Sampled Frequency Table When the Expected Marginal Totals are Known," Annals of Mathematical Statistics.

standards provides a basis of confidence for clients and other constituencies that the work produced is being executed with quality processes and controls in place. The internationally recognized standard also provides a basis for subcontractor evaluation.

A.2 Survey Questions and Answer Choices

A1 How many vehicles including cars, vans, pick-ups, SUVs, or cross-over vehicles does your household currently have registered and drive regularly?
(RECORD A NUMBER. RANGE IS 0–10, DON'T KNOW, REFUSED)

A2 How many miles do you drive in a typical day?
(RECORD A NUMBER. RANGE IS 0–999, DON'T KNOW, REFUSED)

A3 How many miles do you drive in a typical year?
(RECORD A NUMBER. RANGE IS 0–99,999, DON'T KNOW, REFUSED)

A4 How would you describe the area in which you live? Would you say it is…
(READ ENTIRE LIST BEFORE RECORDING ONE ANSWER)
- 01 Urban
- 02 Suburban
- 03 Or, rural
- 99 DON'T KNOW/REFUSED

A5 Efforts are underway to develop vehicles that will be completely automated. Drivers will only need to provide where they want to go and will not need to use a steering wheel or pedals. Which of the following are true for you? Would you say…
(READ LIST. RECORD AS MANY AS APPLY. WAIT FOR YES OR NO FOR EACH)
[RANDOMIZE]
- 01 You have heard of the technology
- 02 You would feel comfortable with other vehicles on the road with the technology
- 03 You would want to ride in an automated vehicle
- 04 You would want to own an automated vehicle
- 05 You believe the technology will eventually be common
- 98 NONE OF THESE
- 99 DON'T KNOW/REFUSED

[ASK IF A5 (03–04)]
A6 Why would you be interested in using an automated vehicle? Would you say…
(READ LIST. RECORD AS MANY AS APPLY. WAIT FOR YES OR NO FOR EACH)
[RANDOMIZE]
- 01 Safety
- 02 Convenience
- 03 Reduced stress
- 04 You currently cannot drive
- 05 Cutting edge technology
- 06 Ability to multi-task during travel, for example, reading, working, using your cell phone, etc.

95 OTHER (SPECIFY)
99 DON'T KNOW/REFUSED

[ASK IF A5 NOT (03–04)]
A7 Why would you not want to use an automated vehicle? Would you say…
(READ LIST. RECORD AS MANY AS APPLY. WAIT FOR YES OR NO FOR EACH)
[RANDOMIZE]
01 Safety
02 Trust in the technology
03 Data privacy
04 You want to be able to control the vehicle
05 The liability if something went wrong
06 The vehicle being hacked and controlled by someone else
95 OTHER (SPECIFY)
99 DON'T KNOW/REFUSED

A8 Assuming concerns you have about automated vehicles were sufficiently addressed, how likely would you be to use them? Would you say…
(READ ENTIRE LIST BEFORE RECORDING ONE ANSWER)
01 You would want to be amongst the first users of the technology
02 You would want to see the technology used broadly before trying it personally
03 Or, you would be amongst the last people to use the technology
99 DON'T KNOW/REFUSED

A9 If you were comfortable with automated vehicles and used one instead of a traditional vehicle, would the distance you would be willing to commute change? Would you say…
(READ ENTIRE LIST BEFORE RECORDING ONE ANSWER)
01 You would be open to a much farther commute
02 You would be open to a somewhat farther commute
03 You would not expect to change commute distance
04 You would consider a somewhat shorter commute
05 Or, you would consider a much shorter commute
99 DON'T KNOW/REFUSED

A10 If you were comfortable with automated vehicles and used one instead of a traditional vehicle, how would your driving habits change for ERRANDS AND RECREATION DESTINATIONS? Would you be likely to drive…
(READ ENTIRE LIST BEFORE RECORDING ONE ANSWER)
01 Much further
02 Somewhat further
03 The same distance
04 Somewhat less
05 Or, much less
99 DON'T KNOW/REFUSED

A11 If you were comfortable with automated vehicles and used one instead of a traditional vehicle, how would your driving habits change for LONGER DISTANCE ROAD TRIPS? Would you be likely to drive…
(READ ENTIRE LIST BEFORE RECORDING ONE ANSWER)

01 Much further
02 Somewhat further
03 The same distance
04 Somewhat less
05 Or, much less
99 DON'T KNOW/REFUSED

A12 If you used an automated vehicle, how would you want the vehicle to choose your route? Please select the top three factors from the list I am about to read. Would you say…
(READ ENTIRE LIST BEFORE RECORDING UP TO THREE)
[RANDOMIZE]

01 Lowest cost
02 Least traffic congestion
03 Most energy efficient
04 Shortest distance
05 Shortest travel time
06 Most use of highways
07 Most use of local roads
08 A personally appealing route, for example, with nice scenery or landmarks
98 NONE OF THESE
99 DON'T KNOW/REFUSED