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Towards an Understanding of the Travel Behavior Impact of Autonomous Vehicles

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Abstract

This study gathered empirical evidence on adoption patterns of self-driving vehicles, people's likely use of them, and how that might influence amount of travel, mode choice, auto ownership, and other travel behaviour decisions. Because self-driving vehicles are not yet on the market, a car technology acceptance model was applied to understand adoption and use. Researchers implemented a two-stage data collection effort. An online survey was conducted with 556 residents of metropolitan Austin to determine intent to use. Based on results, four "intent to use" categories were determined: (1) extremely unlikely = Rejecters (18%); (2) somewhat unlikely = Conservatives (32%); (3) somewhat likely = Pragmatists (36%); (4) extremely likely = Enthusiasts (14%). Individuals with a higher level of intent to use have any physical conditions that prohibit them from driving; use technology – smartphone, text messaging, Facebook, transportation apps – and are not concerned with data privacy about using online technology; think using self-driving vehicles would be fun, decrease accident risk, and easy to become skilful at using; and believe people whose opinions are valued would like using them. Among those who indicated intent to use, qualitative interviews were conducted to ascertain the impact on their travel behaviour. Most respondents would rather own self-driving vehicles (59%) than just use one (41%), like a Car2Go or Uber taxi. Additionally, respondents reported that using one would have no change on where people would choose to live in Austin (80%), no change to their annual VMT (66%), and no change to the number of vehicles owned (61%).

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Keywords: Automated vehicles, self-driving vehicles, consumer acceptance, travel behavior,

1. Introduction

This study provides a glimpse into the not-so-distant future by asking everyday people how they would respond to the availability of autonomous vehicles. Some elements of the technology are already available in vehicles today.

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Self-parking, adaptive cruise control—which adjusts speed to keep a safe distance from cars ahead—and automated braking are available. In the near future, vehicles might take over driving completely.

Transportation planners, researchers, policy makers have a keen interest in how the market for such vehicles will develop. The big promise is their ability to reduce traffic accidents. The optimistic view is that such vehicles could also create smoother traffic flow and unlock existing capacity on roadways, meaning less-road building. This is because intelligent self-driving vehicles will drive safer and more efficiently than human drivers. If a fleet of self-driving cars could come to people when they needed one, it would mean less personal car ownership and fewer parking lots. The safety and productivity gains would bring significant economic benefits. But the potential societal benefits will not be achieved unless these vehicles are accepted and used by a critical mass of drivers. Consumer demand will determine the pace and scale of market development.

The advent of autonomous vehicles could be truly transformative. But future acceptance and use are highly uncertain. Car ownership could change – either more or fewer vehicles owned. Residential spatial patterns could change—more people living further from downtown or closer to downtown. The amount of car travel (VMT) could increase or decrease, depending on how and when people use self-driving vehicles. Because self-driving vehicles are not yet present in the traffic streams, with the exception of a few test vehicles, it is difficult to reliably predict future consumer demand. Any purported outcomes are just theoretical at this point since the full self-driving technology is not yet available.

1.1 Study Objectives

Self-driving vehicles have the potential to alter travel demand and the transportation system. Because highly automated vehicles are not yet present in the traffic streams, with the exception of few test vehicles, it is difficult to reliably predict future consumer demand. There might be various responses to the introduction of such vehicles into the market, and so basic questions exist.

- How likely are people to use self-driving vehicles?
- What are the factors that influence acceptance and intent to use?
- What is the appeal of self-driving vehicles for people?
- In what ways would people change their current travel behaviour because of access to self-driving vehicles?

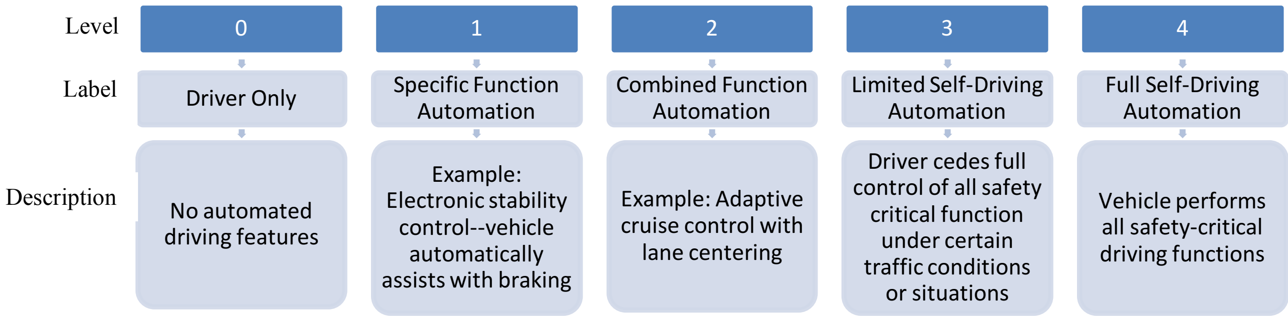
As long as these critical questions go unanswered, public agencies who are owners and operators of the roadway system will be hampered in their ability to prepare for the implications of self-driving vehicles. Thus far, answers to these questions have come largely in the form of speculative future visions with little or no empirical evidence. More recently, research has begun trying to answer these questions by collecting data and developing models.

The objective of this study was to gather empirical evidence on consumer acceptance and adoption, the factors associated with intention to use, and how that might influence mode choice and vehicle ownership decisions. The insights derived from this study will be a first step in understanding how everyday travel could be affected by self-driving vehicles. This information begins to build an evidence base for policy makers and transportation agencies on future mobility requirements and congestion mitigation needs, and therefore, future infrastructure investment.

1.2 Defining Autonomous Vehicles (AVs)

AVs are defined as vehicles where at least some aspects of a safety-critical control function (e.g., steering, throttle, or braking) occur without direct driver input. AVs use sensors, cameras, light detection and ranging (LIDAR), global positioning systems (GPS), and other on-board technology to operate with reduced, limited and/or no human interaction. AVs represent a continuum of advanced driver assistance systems (ADAS) whereby more and more of the driving tasks are transferred from a driver to a vehicle for both convenience and safety. AVs can be passenger, public transport, and freight vehicles. AVs are not necessarily autonomous. Autonomous vehicles are responsible for driving, solely and independently, of other systems. The “Google Car” is a prototype autonomous vehicle.

The National Highway Traffic Safety Administration (NHTSA) has helped to clarify policy and technical discussions around AVs by defining levels of automation (see Figure 1) (NHTSA, 2013). The lowest level is no automation, where the driver is in full control of steering, throttle, and braking. Vehicles with Level 2 automation, such as adaptive cruise control and lane centering, are currently in production and marketplace deployment. At Level 3, the driver is able to temporarily turn attention away from the driving task to engage in other activities but needs to be available to retake control within a few seconds' notice. At Level 4, automated systems replace the driver completely. In this paper, we use the term self-driving vehicles to refer to Level 4 automated systems.



Source: NHTSA, 2013
Figure 1: Levels of Vehicle Automation.

Many feel that the ADAS approach lends itself to evolutionary and iterative progression towards self-driving vehicles. The evolutionary approach is easier for policy making and transportation agencies decision making. Also from a business standpoint, an incremental approach allows automakers to incorporate new features into their vehicles without any disruption to business as usual. It also enables them to offer premium technology and safety-oriented car features that do not depend on breakthroughs in technology, regulation or liability. In this context, Google's entry into the automated vehicle space is disruptive. Google's approach is to focus solely on producing a fully self-driving vehicle, thus allowing it to become a leapfrog competitor to the traditional auto makers with significant implications for state and local policy making. The two approaches are often referred to as bottoms up (i.e., incremental) and top down (i.e., disruptive) (Schwarz et al, 2013). The top down approach is a case where technology is ahead of policy. Vehicles could be put on the roads prior to the necessary regulatory and policy infrastructure—much like Uber taxis have operated in some jurisdictions. Regardless of whether we see bottoms up or top down market entry, consumer demand will determine how the market for these vehicles develops.

1.3 Vehicle Technology Acceptance and Use

The last decade has witnessed an explosion in the availability of new vehicle technology; a general term referring to the application of mechanical, electronic, information and communication systems and new materials in the driving environment. Some technology is built into the vehicle by manufacturers; some has been added within aftermarket products; some technologies have been brought in the vehicle by drivers (e.g., mobile devices); and some technologies have been applied to roadway infrastructure to inform drivers (e.g., variable message signs) and to support driver safety (e.g., speed cameras). Like the information technology that was introduced into homes and businesses in the 1980s, new vehicle technologies will not benefit users unless they are accepted and used. In the special case of self-driving vehicles, the potential societal benefits (e.g., enhanced safety, reduced congestion, improved air quality) of these vehicles will not be achieved unless they are accepted and used by a critical mass of drivers. Research on this topic can gain much value from the rich history of predecessor research pertaining to acceptance and adoption of information technology.

In the information technology realm, acceptance has been defined as the "demonstrable willingness within a user group to employ information technology for the tasks it is designed to support" (Regan et al, 2014). Frequently used frameworks to define and measure the acceptability of information technology are the Theory of Planned Behavior (Fischbein and Ajzen, 1975) and the Technology Acceptance Model Davis et al, 1989; Turner et al, 2009). Venkatesh et al. (2003) were successful in synthesizing the different underlying concepts in these, and six other, frameworks to form a Unified Theory of Acceptance and Use of Technology (UTAUT). Constructs were combined to form five UTAUT variables: *performance expectancy* – the degree to which an individual believes that using the system would help him/her to attain gains in job performance, *effort expectancy* – the degree of convenience with the use of the system, *social influence* – the importance of other people's beliefs when an individual users the system, *facilitating conditions* – how an individual believes that an organizational and technical infrastructure exists to support use of the system, and *behavioral intention to use* a system. UTAUT was validated in a longitudinal evaluation as determining usage intention and behavior. Osswald et al. (2012) further adapted the UTAUT model to make it applicable to the car context *(7).* Their Car Technology Acceptance Model (CTAM) added the variables, *perceived safety* while driving, *anxiety* in the car context, and *attitudes towards* using the technology, based on automotive research literature. It should be noted that anxiety and attitudes were dropped as non-significant in the UTAUT model.

In the domain of vehicle technology, acceptance has been defined as the "degree to which an individual incorporates the system in his/her driving, or, if the system is not available, intends to use it" *(*Regan et al, 2014*)*. With self-driving vehicles, the intent to use is an importance concept because the technology is not yet on the market. Intent to use is based on level of acceptance. It is not until a product becomes tangible and drivers have an opportunity to experience it "for real" that they can form judgments and provide reliable and valid responses to questions pertaining to *actual* use.

Data on acceptance and use have been traditionally collected via qualitative methods (e.g., focus groups and qualitative interviews) and surveys. Qualitative methods are used for vehicle technologies in the concept stage, whereas surveys have been used when there is a partial or fully functional prototype (Mitsopoulos-Rubens and Regan, 2014). Various researchers have previously conducted surveys on automated driving systems; however, there was a dearth of focus group research available for review.

None of the surveys available for our review, to our knowledge, followed a theoretical or conceptual model of acceptance and use, and all were one-off, customized surveys by academic or industry researchers. The research spans a variety of methodological approaches, data sources, and variables, which resulted in conflicting findings and made it difficult to compare results.

In 2014, Schoettle and Sivak of the University of Michigan Transportation Research Institute (UMTRI) investigated public opinion about autonomous vehicles in the U.S., the U.K., and Australia using SurveyMonkey software *(*Schoettle and Sivak, 2014). SurveyMonkey's Audience tool was used to target and recruit individuals 18 years and older from its respondent databases in the three countries. Researchers used NHTSA's definition of levels of automation in textual form as the basis for the questions asked. Results indicated that most respondents (ranging from 63% to 68%) were interested in having completely self-driving vehicle technology, but, the majority of respondents said they would not be willing to pay extra for this technology. U.S. respondents expressed greater concern than those from the U.K. or Australia regarding data privacy, interacting with non-self-driving vehicles, learning to use the vehicles, vehicle performance in poor weather, and self-driving vehicles not driving as well as humans. Younger respondents, regardless of country, were more interested in having self-driving technology and more likely to expect societal benefits in terms of less traffic congestion, shorter travel times, and lower insurance rates.

Kyriakidis, et. al., of Delft University of Technology, surveyed people in 109 countries in 2014 using a crowdsourced software system, www.crowdflower.com (Kyriakidis et al, 2015). This survey used definitions of manual driving, automated driving, highly automated driving, and fully automated driving developed by the Germany Federal Highway Research Institute (BASt). Respondents indicated that fully automated driving would be easier than manual, whereas partially automated driving was perceived as more difficult. Concerns focused on software hacking and misuse, legal issues, and safety. On average, respondents were willing to pay more for fully automated driving. Willingness to pay was associated with both higher income and vehicle kilometers/miles of travel. Neither age nor gender was a significant factor.

In 2012, researchers from the Center for Transportation Research of the University of Texas at Austin conducted an online survey of 675 respondents in six metropolitan cities of South Korea to investigate consumer preferences and willingness to pay for advanced technology options (Shin et al, 2015). The stated choice approach was applied to understand consumer preferences for alternative fuel choices (e.g., electric hybrid, natural gas, hydrogen) and willingness to pay for smart features (e.g., autonomous driving, connected systems, wireless internet and communication, real-time traveler information). The research found that consumers had the greatest willingness to pay for connectivity and wireless internet and the least for lane keeping.

On the industry side, Continental AG conducted online surveys with car users in four countries (i.e., Germany, China, Japan, and U.S.) in 2013 to examine attitudes towards driving, advance driver assistance systems, and automated driving (Brown et al, 2014)). In all countries, but the U.S., the majority of respondents thought automated driving was a useful advancement (53%, 79%, 61%, 41%, respectively). U.S. respondents were also more likely to say that automated driving scares them. Across the countries, respondents preferred the use of automated driving on long freeway journeys (67%) and in traffic jams (52%) and less on rural roads (36%) and in city traffic (34%). In a segmentation scheme that was developed, U.S. respondents were most likely to be characterized as "wait-and-see" (43%), rather than "skeptics" (37%), or "fans" (20%).

Deloitte Consulting conducted a 2014 Global Automotive Consumer Study in 19 countries (Sommer, 2013). The firm did not release methodological information. In the aggregate, 31% of respondent indicated that they would find full self-driving desirable. Younger persons (i.e., Gen Y) were more favorable about full self-driving (47%). Gen Y consumers ranked vehicles that do not crash and vehicles that use alternative fuels as the technologies from which they expect the greatest benefits.

With a focus on the U.S., researchers at the University of California at Berkeley in 2013 examined public perceptions of self-driving cars (Howard and Dai, 2015). The researchers felt that the main obstacle to collecting valid data was the public's lack of knowledge about self-driving cars, so they targeted science museum visitors in Berkeley, CA. The survey was advertised at the ticket admissions desk and administered in a classroom group setting in the museum. A10-minute informational video was shown to respondents in order to ensure all had similar information. The sample totaled 107 persons of which 41% said that they would retrofit an existing car with self-driving technology and 42% said they would look for self-driving technology in their next vehicle purchase. Income level and the relationship of people to technology were correlated to positive responses regarding adoption of self-driving technology. Respondents' willingness to use self-driving taxis was not high. The most attractive features of self-driving cars were safety, amenities like multitasking, and convenience. Respondents were most concerned with liability, costs, and control.

In a 2014 survey, the market research firm, J.D. Power found that nearly one-fourth (24%) of vehicle owners in the U.S. were interested in paying to have autonomous driving mode ($3000) in their next vehicle. This was up from 21% in 2013 and 20% in 2012 (J.D. Power, 2015). The J.D. Power survey is an annual cross-sectional survey of vehicle owners and assesses interest and purchase intent for 61 emerging automotive technologies both before and after the market price is known. The technologies that garnered the most consumer interest were wireless connectivity systems, which create a communication link between electronic devices and the vehicle, and a device/application link, which allows viewing and controlling electronic devices and apps though factory-installed equipment (83% and 78%, respectively).

While the aforementioned surveys examined acceptance and use, none looked at the question of potential impact on travel demand. There were several studies that applied modeling techniques to existing datasets to examine such questions. These studies concluded that vehicle ownership would decrease, VMT would increase, and transit mode share would decrease. While such studies provide direction in terms of potential impacts, they are limited in deepening our understanding of the determinants of acceptability, adoption, and use of self-driving vehicles.

Schoettle and Sivak from UMTRI analyzed 2009 National Household Travel Survey (NHTS) data files to examine the impact of self-driving vehicles on household vehicle demand and use (Schoettle and Sivak, 2015). They investigated the potential for reduced vehicle ownership within households due to new opportunities for sharing of completely self-driving vehicles that would employ a "return-to-home" mode. They found that 84% of households had no trips that overlapped or conflicted and thus, would permit sharing of self-driving vehicles within the household. They concluded that such sharing would result in a 43% reduction in the average number of vehicles per household (from the current 2.1 vehicles per household to 1.2 vehicles per household).

Harper et al. estimated the impact of a fully automated vehicle environment on total VMT due to increased mobility from non-drivers, elderly, and people with travel-restrictive medical conditions (Harper et al, 2015). Using 2009 NHTS data, they first computed and analyzed average annual VMT for drivers, non-drivers, the elderly, and those with and without travel-restrictive medical conditions. Then, they computed three demand wedges. In demand wedge one, the assumption was made that non-drivers would travel as much as drivers within each age group and gender. If this were to occur, total annual VMT would increase by 148 billion miles (a 6% increase in total VMT). In demand wedge two, they assumed that the driving elderly without medical conditions would travel as much as the general population within each gender. The total increase in VMT was about 55 billion miles. Demand wedge three followed the assumption that drivers with medical conditions would travel as much as drivers without them within each age group and gender, resulting in an increase of 57 billion miles more annually. If all three demand wedges were combined and took place simultaneously, the VMT would increase by about 12%. The paper notes that the effect of vehicle automation on the travel characteristics of the elderly and those with a travel-restrictive medical condition will depend on the cost of AV technology and their willingness to adopt.

To help decision-makers understand the impact of AV technology on regional plans, Childress et al. used the Seattle region's activity-based model to test a range of travel behavior impacts (Childress et al, 2015). Four scenarios were considered: (1) AVs use existing facilities more efficiently and capacity increases by 30%; (2) Important trips are in AVs, capacity increases and value of time decreases by 65% for high value of time household trips; (3) All cars are self-driving and none are shared, capacity increases, value of time decreases, and parking costs decrease by 50%; (4) All autos are automated, all costs of auto use are passed onto the user, and per-mile auto costs increase to $1.65. Under these scenarios, VMT increases by 4% in Scenario 1, increases by 5% in scenario 2, increases by 20% in scenario 3, and reduces by 35% in scenario 4. There is little difference in mode shares from the base year except for scenario 4, in which the single occupancy vehicles (SOV) share reduces from 44% to 29%, transit increases from 3% to 6%, and walk increases from 9% to 13%.

Levin and Boyles developed a model to analyze the impact of AV availability on AM peak transit demand (Levin and Boyles, 2015). The model simulates the effect of vehicles that drop off passengers at their destination and return to pick up passengers at the end of the day – enabling an assessment of the cost impacts of avoiding parking fees, but incurring additional costs from travel time, monetary fees, and fuel. An accompanying assumption was that AV use increases road capacity and reduced travel times. A multi-class four-step planning model was tested on the Austin downtown network including its bus routes. Results indicated that parking cost was a main incentive for transit and that avoidance of parking costs through AV round-trips resulted in both an increase in AV round-trips relative to one-way and park trips and a decrease in transit use. Increases in travel times were offset by the road capacity increases of AV use.

Fagnant et al. examined the potential impact of a shared autonomous (or fully automated) vehicle fleet (SAV), combining features of short-term on-demand rentals with self-driving capabilities, on trip making in Austin (Fagnant et al, 2015). Simulating a sample of trip from the region's planning model to generate demand, they found that each SAV was able to replace around nine conventional vehicles within the downtown area while still maintaining a reasonable level of service. Additionally, approximately 8% more VMT could be generated due to SAVs operating in an empty mode to the next traveler or relocating itself to a more favorable location to find potential passengers.

2. Methodology

Relying on the conceptual foundation provided by CTAM and learning from the strengths and limitations of preceding research, we designed a two-part study to investigate the potential uptake of self-driving and how this might impact travel behaviour. We applied CTAM to predict intention to use and then, among those intending to use, we explored what might be the impact on their travel behaviour (see Figure 2: Conceptual Framework). In applying the CTAM, we added three variables, desire for control, technology use, and technology acceptance. We also did not use the CTAM variable, facilitating conditions, because of the high level of uncertainty regarding facilitating infrastructure for such vehicles. Given the fact that self-driving vehicles are a new technology with which respondents would have no actual experience, we used both quantitative and qualitative methods. In the first part, data were collected via an online survey, and in the second part, data were collected in qualitative, face-to-face interviews. The research protocol was approved by the Institutional Review Board (IRB) of Texas A&M University.

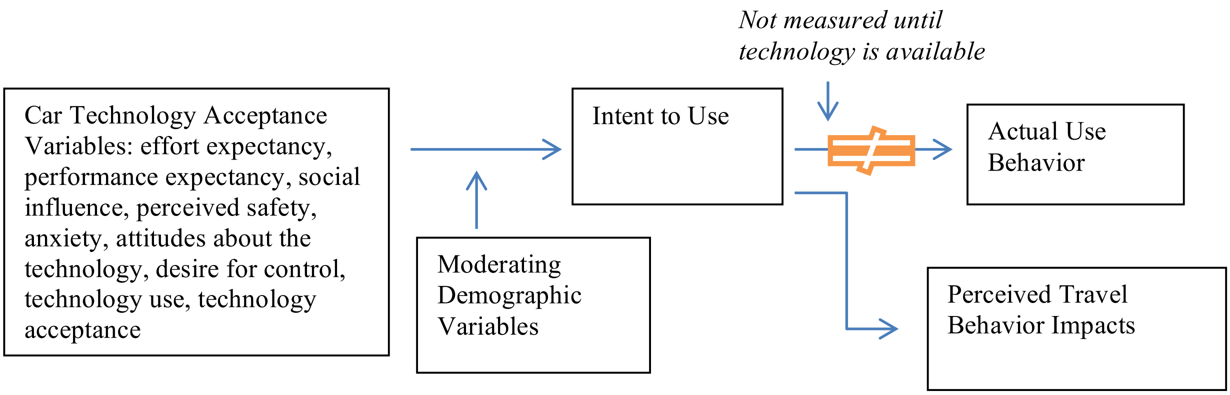


Figure 2: Conceptual Model for Research Framework

2.1 Online Survey

For the online survey, we contracted with ResearchNow, an online sample provider, to target and recruit potential respondents in metropolitan Austin, Texas, that were distributed among four age categories: less than 30, 30-45, 46-65, and 66 and older. In total, 556 persons completed the online survey, which took an average of 12 minutes to complete. A 35-question survey was created and placed on the ResearchNow platform. Questions included:

- Intent to use self-driving vehicles
- Demographic items (gender, age, travel-restrictive medical conditions, income, education, household size, presence of children, zip code)
- CTAM variables (performance expectance, effort expectancy, social influence, perceived safety, anxiety about self-driving vehicles, attitudes towards self-driving vehicles, perceived safety)
- Personality scales (desire for control, technology acceptance, technology use)
- Travel behaviour variables (vehicle own/lease, automated features on vehicle, employment and student status, commute mode, driver's license, use of new transportation services, VMT in 2014)
- Other potential influencing factors (privacy concerns, adoption curve).

After the first ten questions, a six-sentence paragraph described self-driving vehicles and prompted respondents to view a two-minute video on self-driving vehicles before continuing with the next questions. After the last question, respondents were asked if they would be willing to participate in a 30-minute qualitative interview on the topic of future travel behaviours, with a $50 incentive.

2.2 Face-to-Face Interviews

The face-to-face interviews were conducted only with persons who indicated an intention to use. In total, 205 persons met this criterion. Respondents who also were willing to participate in the follow-up interview were contacted by ResearchNow and asked to provide contact information to schedule that interview. Of these persons, we were able to identify, contact, schedule, and interview 44 persons at the offices of the Texas A&M Transportation Institute in Austin, Texas. Questions included:

- Preference for being driver or passenger on short-distance, long-distance trips
- Feeling of safety when driving and feel safer or less safe in self-driving vehicle
- Concern for data privacy in self-driving cars
- Prefer to own self-driving car as personal vehicle or use as shared vehicle
- If own: willingness to pay, preference for vehicle size
- If shared: willingness to pay for access to self-driving car-share vehicle
- If self-driving vehicles available today: changes in household vehicles, VMT, residential location, commute mode, mode or frequency of inter-city trips within Texas and outside of Texas.

3. Intent to Use Self-Driving Vehicles

The data on intent to use self-driving vehicles and the factors that are associated with it are from an online survey of 556 Austin residents.

3.1 Intent to Use Segmentation

Austin residents were asked about their intent to use self-driving vehicles, "*imagine that self-driving vehicles were on the market now either for purchase or rental. What is the likelihood that you would ride in a self-driving vehicle for everyday use?"* In responding, the sample was evenly split – with 50% indicating an intent to use and 50% not.

Responses to the question were used to segment respondents into four "intent to use" categories (see Figure 3): Rejecters (extremely unlikely), Conservatives (somewhat unlikely), Pragmatists (somewhat likely), and Enthusiasts (extremely likely). The smallest segments were those at the intense ends of the spectrum: Enthusiasts (14%) and Rejecters (18%). The rest of the people surveyed are in a wait and see mode; with most, thinking that they would be somewhat likely to use, Pragmatists (36%). Fewer thought they would be somewhat unlikely to use, Conservatives (32%).

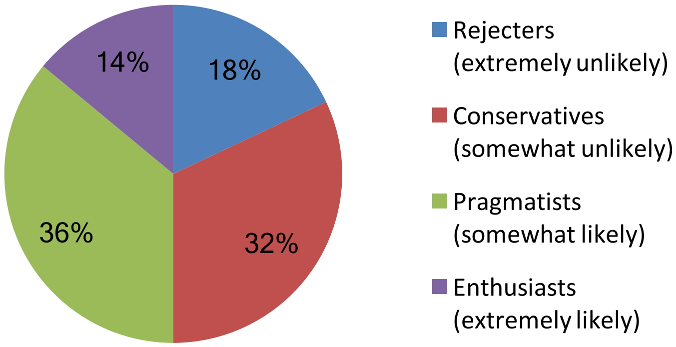


Figure 3: Intent to Use Self-Driving Vehicles. (N=556)

Rationales for intent to use were probed in the follow-up face-to-face interviews. These are discussed in detail in the chapter on Impact on Travel Behaviour. Six main categories of reasons surfaced in the interviews: Safer than human drivers, Relieve stress of driving, Mobility enabler for aging seniors, Ability to be productive while traveling in a car, Trust that technology will be adequately tested, Comparability to public transit experience, and Attraction of "new" technology.

Austin is a technology hub and the intent to use self-driving vehicles might be influenced by its technology focus. This is not necessarily the case. A majority of the sample (66%) considered themselves, late adopters on the technology adoption curve. They wait awhile before adopting new technology, and so are not necessarily eager to jump on the self-driving car bandwagon. Early adopters (e.g., among the first to adopt new technology) comprised 21% of the sample, and Laggards (e.g., among the very last) were 13% of the sample. Still technology use among the survey sample was quite strong, which is reflective of Austin's character (Table 1).

Table 1: Frequency of Technology Use (N=556)

Frequency	Smartphone	Facebook	Internet Shopping	Emailing	Text Messaging	Transportation Apps
Never	10%	23%	5%	0.7%	7%	31%
Several times/month	3%	10%	58%	5%	7%	32%
Several times/week	5%	20%	28%	15%	20%	26%
Several times/day	41%	38%	7%	54%	45%	6%
Several times/hour	41%	9%	2%	25%	21%	5%
Total	100%	100%	100%	100%	100%	100%

3.2 Factors Associated with Intent to Use

Demographic variables were not strongly related to intent to use. For example, age of the respondent was not as predictive of their intent to use as one might expect. Table 2 provides the distribution of intent to use self-driving vehicles by age. Younger persons (less than 30 years) were split 50-50 on intention to use as were persons 65+. A slight majority of persons 30-45 years (53%) and 45-65 years (55%) were likely to use.

Table 2: Intent to Use Self-Driving Vehicles by Age.

Segment	Less than 30 Years (n=132)	30-45 Years (n=155)	46-65 Years (n=167)	65+ Years (n=102)
Rejecters Extremely unlikely	24%	14%	22%	15%
Conservatives Somewhat unlikely	26%	33%	33%	35%
Pragmatists Somewhat likely	39%	36%	32%	36%
Enthusiasts Extremely likely	11%	17%	13%	14%
Total	100%	100%	100%	100%

On the other hand, having a physical condition that prevented driving was predictive. All of the small number of persons (n=11) with a travel-restrictive disability were likely to use.

Gender differences were observed. Males, more than females, are likely to use, and 18% of males were Enthusiasts, compared to 11% of females. In terms of household income, most of those with a household income less than $25k were unlikely to use (56%), while those earning $25k - $50k were more likely to use (54%). In other income categories, people were equally unlikely and likely to use. Educational attainment was not associated with intent to use. But the presence of children in the household was associated. Households with children were less likely to indicate intent to use than households without children (51% and 45%, respectively). However, over one-third of the 20 households in the sample with three or more children were "Enthusiasts."

Half of respondents were unlikely to use. The most frequent reasons cited for being unlikely to ride in self-driving vehicles for everyday use were: lack of trust in the technology (41%), safety (24%), and cost (22%). These big picture reasons overshadowed other, more individualistic personality traits such as liking to drive or desire for vehicle control. See Table 3.

Table 3: Reasons for Not Intending to Use Self-Driving Vehicles.

Reason	Frequency	Percent	Cumulative Percent
Lack of trust in this technology	117	41%	41%
Safety concerns	69	24%	65%
Cost concerns	61	22%	87%
Like to drive	20	7%	94%
Desire for control of vehicle	6	2%	96%
Insurance/liability uncertainties	2	1%	97%
Anti-technology in general	2	1%	98%
Lack of information about it	2	1%	99%
No need for it	2	1%	100%
	282	100%	

Data privacy was mentioned by only one individual as a reason for being unlikely to ride in a self-driving vehicle, but based on other questions, data privacy was found to be associated with intent to use self-driving vehicles (Table 4). The higher the level of data privacy concerns, the less likely a person was to use self-driving vehicles. Among total respondents, opinions on data privacy were split: 51% had concerns about using internet or internet-enabled technologies in *most* or *all* situations, and 49% had concerns in *some* situations or *not at all*.

- 71% of people with no data privacy concerns were likely to use self-driving vehicles, as were 57% of those who only had concerns in some situations. Only 5% of the total sample indicated that they had no concerns at all.

- 60% of people who expressed data privacy concerns about using online technology in all situations were unlikely to use self-driving vehicles, and 57% of people concerned in most situations also were unlikely to use.

Table 4: Intent to Use Self-Driving Vehicles by Level of Data Privacy Concern.

Segment	Not at all Concerned (n=28)	Concerned in Some Situations (n=245)	Concerned in Most Situations (n=208)	Concerned in All Situations (n=75)
Rejecters Extremely unlikely	11%	14%	23%	24%
Conservatives Somewhat unlikely	18%	30%	34%	36%
Pragmatists Somewhat likely	43%	40%	33%	29%
Enthusiasts Extremely likely	28%	16%	10%	11%
Total	100%	100%	100%	100%

Early Adopters of technology (in general) embraced using self-driving vehicles (Table 5). Early Adopters were defined as being among the first to adopt new technology, while Late Adopters are people who wait awhile. Laggards are among the last to adopt new technology if at all. Age was related to the adoption curve, with the largest proportion of Early Adopters in the less than 30 age group and the largest proportion of Laggards in the over 65 age group. Early adopters skewed heavily towards intent to use (65%), whereas Laggards skewed in the other direction - toward not using (62%). The few Early Adopters who were rejecters mainly cited concerns about cost as their main reason for not using. The small number of Laggards who were enthusiasts tended to be either younger than 30 or older than 65 years.

Table 5: Intent to Use Self-Driving Vehicles by Adoption Curve

Segment	Early (n=118)	Late (n=365)	Laggard (n=73)
Rejecters Extremely unlikely	9%	19%	30%
Conservatives Somewhat unlikely	26%	34%	32%
Pragmatists Somewhat likely	43%	37%	19%
Enthusiasts Extremely likely	22%	10%	19%
Total	100%	100%	100%

Currently owning or leasing a vehicle had no effect on people's intent to use. However, currently owning a vehicle with highly automated features did have an effect, and these individuals were more likely to be Enthusiasts (20%) than those without (12%).

Among those currently employed, their commute mode was related to intent to use (Table 6). Commute mode was defined as how people usually got to work last week (i.e., the single mode used for the longest time), and 85% of full- or part-time workers indicated they were vehicle drivers. By a slight majority (52%), vehicle drivers were unlikely to use self-driving vehicles, whereas the majority of users of all other modes (i.e., vehicle passengers, walkers, or telecommuters) were likely to use self-driving vehicles (57%). This was particularly true of vehicle passengers though they were a very small sample (n=17). The utility of self-driving cars for users of other modes, relative to drivers, might be perceived greater convenience of access and egress or enhanced mobility for those who do not own a car or cannot drive.

Table 6: Intent to Use Self-Driving Vehicles by Commute Mode

Segment	Vehicle Driver (n=304)	All Other Modes (n=53)
Rejecters Extremely unlikely	20%	15%
Conservatives Somewhat unlikely	32%	28%
Pragmatists Somewhat likely	36%	42%
Enthusiasts Extremely likely	12%	15%
Total	100%	100%

Self-reported vehicle miles travelled in 2014 (VMT) had no effect on intent to use. But frequency of driving did make a difference. People who drove quite infrequently or almost never expressed a strong intention to use self-driving vehicles (Table 7). These people tended to have a travel-restrictive disability or to be low-income (i.e., earning less than $24,999 in 2014) highlighting the accessibility benefits that have been tied to self-driving vehicles.

Table 7: Intent to Use Self-Driving Vehicles by Frequency of Driving a Motor Vehicle

Segment	Every Day (n=409)	A Few Days per Week (n=112)	A Few Days per Month or Almost Never (n=35)
Rejecters Extremely unlikely	19%	20%	8%
Conservatives Somewhat unlikely	32%	37%	20%
Pragmatists Somewhat likely	36%	31%	49%
Enthusiasts Extremely likely	13%	13%	23%
Total	100%	100%	100%

3.3 Predictors of Intent to Use

Transportation decision makers, policy makers, even researchers, have their preconceptions about the types of consumers who will adopt and use self-driving vehicles. Many feel that it will be Millennials because of their reliance on technology. Others think it will be seniors because the technology will enable mobility well into old age. As our survey results indicate, demographic variables such as age might not be the best predictors of intent to use.

The prior studies discussion in Appendix B presents the Car Technology Acceptance Model (CTAM) that was used to identify variables that explain new technology adoption and use. These variables are psychological and personality variables that have been shown to distinguish users who accept or reject technologies. They include such items as attitudes towards using technology, perceived safety while driving, anxiety in the car context, and social influence. In previous technology studies, these psychological or personality variables were more predictive than demographic ones. The research team conducted some higher level analyses to examine the significance of the different types of variables (e.g., demographic, personality, behavioural) in the survey. After isolating the significant variables, a regression model was developed to examine determinants of intent to use. The results indicated that individuals who have a higher level of intent to use self-driving vehicles are the ones who:

- have any physical conditions that prohibit them from driving
- think self-driving vehicle would decrease accident risk
- use Smartphones, text messaging, Facebook, transportation apps
- are not concerned with data privacy about using online technology
- think using a self-driving vehicle would be fun
- think it would be easy to become skilful at using self-driving vehicles, and
- believe people whose opinions they value would like using self-driving vehicles.

At this early stage in market development for self-driving vehicles, the personality and psychology of the consumer is much more important than his or her demographic profile.

4. Impact on Travel Behaviour

The data on impacts on travel behaviour are from qualitative, face-to-face interviews with 44 persons who indicated that they would likely use self-driving vehicles in the online survey and also agreed to participate in a follow-up interview. The use of qualitative interviews, rather than a survey, enabled the ability to clarify questions and responses to ensure accurate information was collected. This method also facilitated the capture of opinions, perceptions, and behaviours in peoples' own words. Characteristics of these 44 persons include:

- 9% were less than 30, 50% were between 30 and 45 years, 23% were between 46 and 64 years, and 18% were older than 65 years.
- Most (75%) prefer to be the driver, rather than passenger, when traveling in a conventional car in an urban area, but by a slight margin (55%) prefer to the passenger for long-distance trips.
- The majority (71%) are not at all or only somewhat concerned that their data is not kept private when using internet-enabled technologies. More (82%) are not at all or only somewhat concerned that their data would not be kept private when using self-driving cars.
- Most (69%) feel moderately or extremely safe in vehicles today when driving.
- Virtually all would feel safer (46%) or about the same as now (48%) in a self-driving vehicle.

4.1 Rationale for Intent to Use

It is important to find out why individuals decide to use self-driving vehicles as the intention to use could provide insights into the potential impacts on travel behaviour. The first question these individuals were asked was: *You indicated in prior online survey that you would likely ride in a self-driving vehicle for everyday use. Can you tell me your reasons for that answer?* Six main categories of reasons surfaced in the interviews:

- Safer than human drivers
- Relieve stress of driving
- Comparability to public transit experience
- Trust that technology will be adequately tested
- Attraction of "new" technology
- Mobility enabler for aging seniors
- Ability to be productive while traveling in a car.

The first two reasons, safety and relief from stress, spanned different age groups. Respondents regardless of age truly felt vehicles would be better "drivers" than humans. "If everybody is in an automated car, it would be safer" (less than 30). "I feel as more and more people obtain such vehicles, it will increase safety and decrease human errors" (30-45 years). "I get nervous driving; other drivers tend to drive careless. [I] would like this idea" (46-65 years). "[I like] ability to avoid other cars and traffic" (65+ years).

Also regardless of age, respondents thought traveling would be less stressful in self-driving vehicles, especially in Austin traffic, which they pointed out as being particularly bad. "With Austin traffic, it would be convenient not to have to worry about the drive to work" (45-65 years). "Mostly for lack of stress caused when driving to and from work; traffic related [concerns] and having to pay attention" (30-45 years). In addition, driving to several of the respondents "felt like a chore." "[Driving] is something you have to do to get from point A to point B…if there was technology to do it I would definitely be willing not to have to drive" (less than 30). "I do not like to drive, especially in Austin" (45-65).

Some people equated the experience of using a self-driving vehicle to using public transit. The implication was that a self-driving vehicle would be more convenient than traditional public transit, and therefore, desirable. "I used public transit often when I lived overseas and I enjoyed the ride with no responsibilities" (less than 30). "I look at it like when I could take mass transit, I did not have to focus on driving" (30-45). "I would be interested in using it somewhat the way you would use public transportation…read something" (46-65).

One thing that might have made these respondents more comfortable about using self-driving technology was their trust that the vehicles would not be allowed on the roads until proven safe. "By the time they allow it on the road, it will be safer than my driving" (65+). "Before something like this comes to market, it would be tested a lot"

(30-45). “By the time it gets to market, it will be so mistake-proof, it would be safer without human errors” (46-65).

One major rationale category had to do with the attraction of new technology. Several respondents said they would likely ride in a self-driving vehicle simply because it was “new”. “First reason at this point it is something very new and different. I like technology” (46-65). “I already have a car that has steering assist. It reads the stop signs and signals” (65+). “New technology, and I want to be a part of it” (45-65). “It is the wave of the future” (30-45).

There were also age-specific rationales, such as facilitating mobility as one grows older. Those individuals older than 65 years recognized that as they were aging such vehicles would be useful. “By the time they allow it on the road, it will be safer than my driving.” “As I get older I would find this technology more and more appealing”. “Easier as I get older. I get distracted and my reflexes are not as good as they used to be.” Even a couple of the persons ages 46-65 pointed out the benefits as they age. “Becoming disabled soon, I will not be able to drive myself.” “Also entering my older years, it will benefit me.”

The ability to be more productive while traveling in a car was also a frequently cited rationale, especially among persons between the ages of 30 and 45 years. “I could do something productive on my trip.” “We waste a lot of time behind the wheel. To be able to be productive like on a plane or rail.” “It would let me do other tasks, such as eating, watch a movie, be on cell phone while you are on your trip.” “It would be easier to conduct business or for personal time.” “I spend a lot of time driving, it would nice to be able to do other things.” “My commute is short but it would allow me to do other things.” “Reduce stress of living in big city. Get in vehicle and work on other things. Make it a more productive trip.”

4.2 Perceptions of the Self-Driving Experience and Potential Concerns

Respondents were asked: Imagine that you were riding by yourself in a self-driving vehicle on a trip to the grocery store. Describe what you think the experience would be like. Words the respondents used to describe the self-driving experience included: nervous, carefree, convenient, relaxing, and independent.

Several respondents said that they would be nervous at first because it is something new. They described themselves as being hyper aware of how the car is reacting and trying to figure out how it knew to do certain things. “What is the car going to do in x situation?” Others mentioned that they might not be able to relax at first. They would feel a need to “over-correct or over-ride the system.” “I would probably have my hands on the steering wheel (if there was one).” “Once I knew [the car was able to handle all situations] I would probably do other things.”

Respondents that were apprehensive were a minority. The majority of respondents ticked off the things that they would be doing on the trip, such as reviewing grocery list, using cell phone, flipping through radio stations, taking care of personal matters, talking to children in car, doing work or homework. Others talked about doing nothing, “get in the car and tell it where to go. It takes me there.” “I could relax my mind would be free.”

When asked: Where would you sit, most people answered driver’s seat – at least at first. “Driver’s seat, habits die hard.” “Driver’s seat in case I would have to switch it to manual.” “Driver’s seat. I would want to still see the controls.” “Still sit in driver’s seat at least at first. Just because I am used to sitting in the driver’s seat.” After getting comfortable with the self-driving vehicle, they would then sit in the passenger seat or the back seat, whichever would be more comfortable. A few said that they would sit on the passenger side right off the bat. “Passenger side and probably focus on my computer surfing the web.” “Passenger side because there is more room and focus on whatever task I had at hand and wanted to get done.”

Respondents were asked: *Can you think of any potential problems or concerns you might have in using a self-driving vehicle?* The most frequently cited concerns related to system failure or malfunctions in the technology. “Failure of the car…is there sufficient redundancy?” “If you’re in a car that is connected, what happens when you lose connection?” “What if you get struck by lightning?” “You’d want to know that the car wouldn’t glitch out - leave you stranded.” “What if it malfunctions and causes an accident.” “With new technology, when it first comes out, generally there are bugs.”

Other items mentioned by a few people included “someone hacking in,” “an environment where not everyone is driving a self-driving vehicle”, and the “vehicle’s handling of unforeseen events.” The concerns about hacking were not just about hacking when the vehicle was operating but identity theft. “How does the vehicle know it is me getting into the car and not someone trying to steal my vehicle?” Cost was only mentioned by two persons. Two people also mentioned losing the capability or the fun of driving.

But even though nearly 8 out of 10 survey respondents had heard of self-driving vehicles before participating in this study, most of the issues raised were actually questions about technology.

- How fast can it stop if a kid steps in front. Is the reaction time faster than a human?
- How to program it? Do I have to use MapQuest or whatever?
- Does it see potholes and speed bumps?
- Does it only go the exact speed limit?
- Does it know what to do at a flooding location? Does it even know that an area has the potential for flooding?
- Do I need to give it specific commands?
- Would they be rentals?
- Is it voice activated?

4.3 Interest in Owning Self-Driving Vehicles

There is much uncertainty surrounding the question of whether the self-driving vehicle market will develop as a privately owned vehicle market or a shared vehicle market. Respondents were asked to assume that self-driving vehicles were available for use today, and asked: *Would you be more interested in owning one or just using one, like a Car2go or Uber taxi?*

Most (59%) indicated that they would be more interested in owning a self-driving vehicle than in using one, like a Car2Go or Uber taxi.

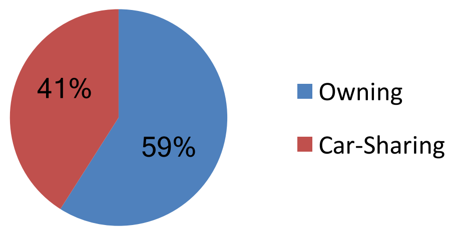


Figure 3: Intent to Use Self-Driving Vehicles. (N=44)

There has been much speculation that with self-driving vehicles, there would be a lot of occupant-free cars on the road because usage would be as shared vehicles – in fleets or within households. But at this early stage in market development, such concepts are not top of mind for people. The majority of respondents who were interested in owning a self-driving vehicle indicated that they would use their self-vehicle just the same as a conventional vehicle—to and from work, errands, shopping, and visiting family and friends. Only few persons mentioned anything out of the norm. It was as though they did not fully grasp the new opportunities that might unfold with ownership of a self-driving vehicle. One individual assumed that an insurance discount would be given because of its enhanced safety functionality, and so he would have his teenage son drive the self-driving vehicle. Another said, "I'm the less confident driver so I would use it." A couple mentioned that their young children could use it to go to school.

There has also been speculation that people might be interested in purchasing large, multi-purpose vehicles with amenities for work and play. But most respondents did not envision changing vehicle size if they were to purchase a self-driving vehicle. Regardless of the size of the personal vehicle that they drive most now (e.g., compact, mid-size, full-size, mini-van or large SUV), they would consider the same size in purchasing a self-driving vehicle. Five people recognized the social opportunities inherent in self-driving vehicles and so indicated that they would be purchase larger vehicles (from compact or mid-size). Three persons said they would go smaller (from a mid-size or full-size).

4.4 Factors Influencing Intention to Own

An important factor in people's intention to own a self-driving vehicle was convenience. "Convenient to have it when I needed one." "For having it there when I needed it and not having to call someone." "[There are the] same negatives associated with shared vehicles as with public transit like convenience of access and egress." "More freedom to do other things while on my trips." "Would not be interested in using it just here and there. Would want it as my vehicle to use whenever I need it." "If it got to the point where the great majority of the cars on the road were self-driving cars (like Ubers or car shares) then maybe car share but for now it seems inconvenient." Also mentioned as a factor in whether people would own or car share was price. While most people thought car-sharing would be less expensive (see section on Interest in Shared Self-Driving Vehicles), a few thought it would less expensive to own. "The cost – would like a discount for new users." "If there were a sharing option, I think it would be more expensive. They take their cost plus a profit." Only one or two people mentioned liability, legislation, vehicle size, brand, or rules of the road. On the latter, law enforcement rules were mentioned. "Can I drink and have the vehicle drive me home?"

4.5 Interest in Shared Self-Driving Vehicles

Many persons have speculated that car-sharing will be the primary business model for self-driving vehicles. But among the Austin respondents, fewer were interested in using a shared self-driving vehicle, like Zipcar, Car2go, or Uber taxi, than in owning one (41% and 59%, respectively). There were no age or income effects that were associated with interest in car-sharing. Two categories of reasons underpinned this choice: (1) gaining experience and (2) cost. By far, most people said that they would want to "try it out to see if I like it." They would not want to invest in one before experiencing it. "To start with I would do the share car just so I could get experience and gain trust in the vehicle". "Would first want to see how they work and if I liked them." "I already have a vehicle, but it would be nice to have the option of not having to drive myself on long trips." Others were budget conscious. "The trade-off of sharing compared to owning car would be cheaper." "Would rather pay for a vehicle when I need it then have to worry about all the upkeep." "It would be costly to own one and it would take years to get an older model." "More practical method. If you are not going to control the vehicle why not use as a mass usage."

In answer to the question, *how much extra would you be willing to pay to access a self-driving car-share vehicle above the average rate of $10 per hour*, by far the most frequent response was "a slight amount" as compared to "zero" or a "great amount." Main rationale was that they understood that as a new technology the cost would go up but they thought not too much because of the economies of scale that come with car-sharing and being driver-less. "You are replacing human labour with computer so it should not go up too much. When things first come out they are usually more." Three people said they would pay a great amount more. "I would pay double, I would not use it all day since it is by the hour. Would make it worth it." Two persons said they would pay zero, basically because "I am cheap." Regardless of their willingness to pay, many people assumed that with time "the price would go down."

4.6 Impact on Number of Vehicles Owned

A vision that has been promulgated concerning self-driving vehicles is that households will reduce the number of vehicles owned because of the capability to share cars within the household. A self-driving vehicle can take one worker in the household to work and then return to take the second worker or to ferry children to school, or both. The auto would not be sitting idle during the day in a workplace garage. Interview respondents were asked, *you currently own "x" number of cars, how would that change if self-driving vehicles were available today?*

In terms of vehicle ownership, three of five respondents (61%) indicated that being able to own or access a self-driving vehicle would have no change on their current vehicle ownership, whereas 23% indicated they would reduce the number of vehicles owned. A smaller percentage (16%) said they would increase the number of household vehicles.

Table 8: Change in Number of Vehicles Owned. (N=44)

	Current Number of Vehicle Owned				
	Zero Vehicles	One Vehicle	Two Vehicles	Three or More Vehicles	Total
No change	1	9	14	3	27 (61%)
Reduce	0	2	5	3	10 (23%)
Increase	1	4	0	2	7 (15%)
Total	2	15	19	8	44 (100%)

Respondents who answered "no change" tended to report that they would switch out a conventional vehicle for a self-driving vehicle. Most did not conceive of being able to share the same self-driving vehicle within household members. “We each need the ability of having our own car because our schedules are different.” “Need both cars, I work and my wife takes kids around.” “She needs a car and I need a car.” “Would get rid of our oldest vehicle and have the self-driving for a back-up if we needed to do two different things at same time.”

People who responded “reduce” did consider the special aspects of self-driving cars. “If it had the ability to take me to work and go home for her to use for the day and come back to get me at the end of the day. Would reduce to one vehicle.” Others suggested that they would reduce a vehicle and use the “car sharing program.”

The few who said they would increase would add a self-driving vehicle to their existing stock. In their minds, it would be like adding a special utility vehicle. “I might increase to add the self-driving vehicle that could take my son around and still have vehicle to run errands.” “I would keep my truck for pulling my boat.” “Would keep my car now and get the self-driving vehicle. It would be less wear on the vehicle and use the older one when I have time.”

4.7Impact on VMT

There is much uncertainty as to whether self-driving vehicles would increase VMT or reduce it. Some speculate that people would live further away from work or school because they could do other activities on their commutes which would increase VMT per capita. Others believe that self-driving vehicles will be making lots of zero-occupant trips because owners would not want the vehicles to sit idle, which would add to overall VMT. There is also the vision that the mobility challenged (e.g., elderly or impaired) would travel more often and that this too would increase VMT. On the opposite end of the spectrum, some believe that self-driving car-sharing programs will bring a decrease in VMT per capita, as has been found with conventional car-sharing programs.

In the online survey, 16% of respondents indicated that they drove less than 5,000 miles in 2014; 35% reported driving 5,000 to 10,000 miles, 35% reported driving 10,000 to 15,000 miles, and 15% reported driving more than 15,000 miles in 2014. In the follow-up, interview respondents were asked, *you now “x” miles in an average week, how would that change if self-driving vehicles were available today?*

In the follow-up, most (66%) said their annual VMT would stay the same; 25% indicated it would increase. Respondents were mostly vehicle drivers. There was only 1 person who took public transit. None of these individuals had any disability preventing them from driving or were currently non-drivers. We did not find an age effect in terms of a reported increase in VMT. Those persons age 66 and older were no more likely to increase their VMT than other age groups.

Table 9: Change in VMT. (N=44)

	Current VMT				
	Less than 5,000	5,000 to 10,000	10,000 to 15,000	More than 15,000	Total
Stay the same	3	4	10	12	29 (66%)
Increase	1	6	3	1	11 (25%)
Decrease	0	2	1	1	4 (9%)
Total	4	12	14	14	44 (100%)

People who believe their VMT would “stay the same” as now do not believe that self-driving vehicles will change their routines, their routes, or their activities. “Daily routine would not change.” “I do not see doing anything different than I normally do.” “[I] will not change my habits just because I have a car that takes me places.”

On the other hand, the persons who answered “increase” did think that having a self-driving vehicle would induce travel. Some of this travel would be long-distance or leisure travel. But local travel might increase as well. “I would go on more trips since I would not have to drive.” “We might take longer day trips. The car could take us there and back.” “Give us flexibility to visit friends and family out of town. [We] could go downtown more.” “Turn down a lot of things because I do not want to drive.” “Might go out more, could nap on the way there.”

The primary reasons that a few people said they would drive less are (1) they would use car-sharing or (2) their travel would probably go from A to B more efficiently.

Much speculation surrounds whether people with access to self-driving vehicles would relocate to residences farther from where they work. Most of our sample (80%) said they would not change where in the Austin region they live today. People choose where they live for a variety of factors: price, schools, neighbourhood amenities, public services, etc. Access to a self-driving vehicle, at least under their current knowledge of the travel opportunities such a vehicle would bring, would not change their location choice. “I would not move for a car.”

Nine people said they would change where they live. Of these, most would move farther out. “Might move farther out to get more house for the money and be productive and less stressed on the way to work.” “Be able to live further out but with convenience of a self-driving car.” Two persons indicated that they would move closer to downtown Austin. “I would want to live in the city closer to public services as I get older. I do not like driving the city now.” “Car share services would more likely be in Austin so I would need to be closer.”

4.8 Impact on Long Distance Travel

Of 44 respondents, 57% said they occasionally make inter-city trips in Texas and 43% said they frequently make them. When asked *if the mode of travel for inter-city trips would change if self-driving vehicle were available today*, 45% of them said they would change. But the mode would not change, the frequency would. “I might travel more frequently and to different destinations.” “I would be willing to make more trips.” “I would probably be going on more trips since I wouldn’t have to be the driver.” Most of this travel is done in vehicles as a driver or passenger. Only 3 persons said they mostly use air, and of these, two would not change their behaviour if self-driving vehicles were available.

These persons were also asked *if their mode of travel would change for trips outside of Texa*s. Most people (76%) currently use air to travel outside of Texas. Forty-two percent said they would change their mode of travel. Most persons said, they would probably take the self-driving vehicle more for these trips (rather than air) if the car was fuel efficient and they had the time for the drive. “I would probably travel in self-driving vehicles, I could see more and it may be cheaper than flying.” “If it were close enough where the fuel expense was less than plan, I would take the vehicle.” Of the people who would not change from air to the self-driving vehicle, the main reasons were time and distance. “I don’t have the team to drive – full day to drive somewhere and to drive back.” “Because of the distances involved.” “Time factor; time issues.”

5. Conclusions

5.1 How Likely Are People to Use Automated Vehicles?

The sample was evenly split on intent to use self-driving vehicles, with half likely and half unlikely to use. This is indicative of the early stages of research into the topic and the fact the public is aware of but not very knowledgeable about self-driving vehicles. As knowledge increases, we would expect the results to tilt in one direction versus the other. Many transportation experts expect that the public will tilt towards acceptance and use of self-driving vehicles.

In our sample, nearly 7 of 10 persons were in a wait and see position, with 36% “somewhat” likely to use and 32% “somewhat” unlikely to use. Narrow slices of the sample had definite views, with 18% being “extremely” unlikely to use and 14% being “extremely” likely to use. A segmentation scheme was developed to portray the differences in acceptance and intent to use: Rejecters (extremely unlikely), Conservatives (somewhat unlikely), Pragmatists (somewhat likely), and Enthusiasts (extremely likely).

The top reason someone was unlikely to use was lack of trust in the technology, and this factor has also been observed in previous research although stated in other ways.

5.2 What Are the Factors that Influence Acceptance and Intent to Use?

Further analysis showed that intent to use was higher from some population segments. Interestingly, age was not a significant factor in intent to use nor was household income as many have suggested. While vehicle ownership per se was not a significant factor, currently owning a vehicle with highly automated features was significant. Trust in the vehicle performing appropriately may be the reason.

Psycho-social variables were important to acceptance and intent to use. Where people fell on the adoption curve was highly associated, with Early Adopters likely to be Enthusiasts or Pragmatists, and Laggards likely to be Rejecters or Conservatives. Previous research had found that variables such as perceived safety benefits and data privacy were significant in adoption, and our research supported these findings. The more concerned a person was about data privacy issues, the less likely their intent to use self-driving vehicles. However, desire for control was not found to be associated with intent to use as many people have hypothesized.

We developed a regression model to identify the significant predictors of intent to use from among the various demographic, behavioural, and psycho-social variables in our study. Model results indicated that that the only demographic variable associated with intent to use was having physical conditions that prohibit driving. Other variables were psycho-social, such as thinking that using self-driving vehicles would be fun, that there would be a decreased accident risk, and that it would be easy to become skilful at using self-driving vehicles. Not surprisingly, such findings suggest that likely users are focused on personal benefits rather than societal benefits. Also there is an underlying social aspect to likelihood of use. Use of social media technology (i.e., text messaging, Facebook) was found to be predictor rather than more than use of conventional technology, such as emailing and online searching. Social influence was also a strong determinant. This may stem from the car often being regarded as a status symbol which highlights the connection between intent to use and the social environment.

5.3 What Is the Appeal of Self-Driving Vehicles for Consumers?

Those who were likely to use self-driving vehicles were asked “why”. While the reasons varied from person to person, the top aspects were that the vehicles would: be safer than human drivers, relieve stress of driving, allow people to be productive while traveling in a car, be like using public transit but better, be the wave of the future, be a mobility enabler for aging seniors, and be adequately tested before being placed on the market. In the same vein, words likely users used to describe the experience were: carefree, relaxing, and convenient; only a few said they would be “nervous.” So generally, people who currently think they would be likely to use these vehicles view the experience as a positive change. Their biggest worries are related to self-driving system malfunctions or glitches. The questions they had about the technology emphasized the situation that people may be aware of the technology but not very knowledgeable about it.

5.4 In What Ways Would People Change their Current Travel Behaviour?

People can access self-driving vehicles in two ways: personal vehicle ownership or use as a shared vehicle, like Uber taxi or Zipcar. Private ownership was preferred over car-sharing by a 3 to 1 margin. At least for this sample at this time in Austin, the shared mobility market was not the desired choice even though it may be how some self-driving vehicle providers see the market developing.

We did not find the dramatic impacts on travel behaviour in this research about which people have speculated, at least not at this point in time when knowledge and experience with the technology is so low. Most respondents said they would not change their vehicle ownership, VMT, or residence location. Because we thought that people would have a difficult time conceiving of possible changes for a technology they have not experienced, we conducted the qualitative interviews. This method enabled interviewers to clarify and probe respondents’ answers.

In terms of vehicle ownership, in 2012, there were two vehicles per household (median) in Austin. There would be almost no change in the number of vehicles owned due to self-driving vehicles because at this point in time most people said that they would switch out one of the conventional vehicles that they own for a self-driving one. These people did not conceive of the self-driving vehicle as being able to do double-duty within a household, that is serving the mobility needs of multiple persons in the household because the vehicle could drive itself to and from pick-ups and drop-offs. Currently only about 5% of households in Austin have zero vehicles. These survey data do not indicate that this number will grow.

Average annual VMT would stay about the same as well, which was about 25 miles per day per capita. People did not think their routines, their routes, or their activities would change because of the availability of self-driving vehicles. About one in four person thought their VMT would increase due to induced travel; much of it long-distance or leisure travel. Few if any could conceive of reducing their VMT; those who did cited car-sharing as the reason. Few people would change their residential location due to access to a self-driving vehicle. Not all would move further out to get more house for the money. Some would move closer to downtown to be able to access self-driving car-sharing services which they believe will be more prevalent in the central city.

It was in long-distance travel that for the moment people could envision the biggest changes in their current behaviours. Many would increase the frequency of their long-distance (inter-city) trips. In a future world of self-driving vehicles, one could conceive of more long-distance travel by vehicle beginning and ending in Austin – both of which would impact current conditions.

5.5 Summary and Future Research Opportunities

These results provide some of the first data on what types of people are likely to use self-driving vehicles and why. Since AVs are not currently available, it is not possible to verify that intention to use will correlate with actual usage. The correlation across a variety of studies in different fields indicates that the CTAM model (which we used) is capable of predicting actual use and lends credibility to our research approach and findings.

This study began by laying out basic questions as to future consumer demand for self-driving vehicles and its impact on travel behaviour. These vehicles are not yet on roadways, and so it was challenging to capture reliable and accurate information about people's intent to use and their behavioural responses to its use. But the collection of such information has to start now in order to grow an evidence base on likely impacts. That said, while respondents were aware of the concept of self-driving vehicles, they were not very knowledgeable of them. Researchers and policymakers are looking for specific impacts on travel behaviour, but it is difficult for early research to surface them because the general public is not yet familiar with the new opportunities (or challenges) self-driving vehicles may bring, such as within household car-sharing, new types of car-sharing fleets, or the challenges of mixed fleets on the road.

Our methodology was designed to account for the fact that large portions of the general public are uninformed about self-driving vehicles and this research surfaces the need for public education and outreach on the topic. Realizing that "public opinion polls are not substitutes for thought," this study used a two-phased approach of online survey and face-to-face interviews. And it was effective. By having people answering questions in a qualitative manner, we were able to learn about their misconceptions or uncertainties with the technology. This information will be useful for future studies.

There are many opportunities for further research. We would like to replicate our survey within a larger population, e.g., the state of Texas or the nation, to determine whether the findings will remain consistent with a diverse population. We acknowledge that the Austin MSA may not be representative of all potential users of self-driving vehicles. Do age or income matter? It would also be informative to be able to conduct more of the face-to-face interviews. Budget precluded the research team from being able to implement many potentially fruitful respondent re-contact strategies. Also future research needs to assess how the determinants perform over time. Acceptance and adoption may be conceived as an experience factor and as the vehicles become available, the determinants may change.

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