EXPLORING THE EFFECTS OF SOCIO-DEMOGRAPHIC AND BUILT ENVIRONMENTAL FACTORS ON THE PUBLIC ADOPTION OF SHARED AND PRIVATE AUTONOMOUS VEHICLES.

A CASE STUDY OF DALLAS-FORT WORTH METROPOLITAN AREA

by

HAMID HAJJAFARI

Presented to the Faculty of the Graduate School of

The University of Texas at Arlington

of the Requirements

DOCTOR OF PHILOSOPHY

in

The University of Texas at Arlington

August 2018

ACKNOWLEDGMENTS

I would like to use this opportunity to acknowledge all the people who have helped me to earn my Ph.D.

First, I would like to express the deepest appreciation to my major advisor, Dr. Shima Hamidi for her continuous help and encouragement during my dissertation procedure.

Dr. Hamidi conveyed an adventure atmosphere in regards to research, which provided me with excitement about this study. She acted as a supportive advisor during all the issues in the last couple of years, which is really appreciated.

Second, I would like to thank my dissertation committee members, Dr. Martinez-Cosio and Dr. Diane Jones Allen, for serving on my committee and for their comments in regards to my dissertation.

Meanwhile, I would like to thank Dr. Thomas Skuzinski and Dr. David Weinreich for their help during the survey design. Their useful feedback strengthened my survey. I also appreciate my colleague, Ahoura Zandiatashbar that always has good advice for my work.

Finally, I appreciate the Office of Graduate Studies at UT Arlington that offered me the Dissertation Research Enhancement Grant. Collecting high-quality data was not possible without this funding.

July 25th, 2018

ABSTRACT

EXPLORING THE EFFECTS OF SOCIO-DEMOGRAPHIC AND BUILT ENVIRONMENTAL FACTORS ON THE PUBLIC ADOPTION OF SHARED AND PRIVATE AUTONOMOUS VEHICLES.

A CASE STUDY OF DALLAS-FORT WORTH METROPOLITAN AREA

Hamid Hajjafari, PhD

The University of Texas at Arlington, 2018

Supervising Professor: Dr. Shima Hamidi

Althogh the self-driving technology promises to solve several urban issues, the deployment of the autonomous vehicles (AV) is an evolutionary process that depends on different factors. One of these factors is the public adoption of AVs that plays a crucial role in the deployment of this technology by controlling the level of market penetration.

By analyzing the cross-national survey studies on AVs acceptance, the author finds that the rate of AVs adoption in America is considerably lower than other developed countries. Although some studies have focused on the AVs adoption in the US and the factors that affect it, there is little evidence regarding the role of built environment on acceptance of driver-less cars. However, previous studies prove the impact of built environmental elements on different travel modes (walking driving and using transit). Therefore, there might be a link between built environment and public adoption of driverless cars as an innovative travel mode. This dissertation addresses this knowledge gap by surveying residents of the Dallas-Fort Worth

(DFW) metropolitan area and measuring built environmental factors around each respondent and analyzing how these factors influence the acceptance rate.

To test the hypothesis of the research, the author designs a survey about the AVs adoption and different sociodemographic, travel preference and travel behavioral factors that influence public adoption in DFW. The author creates a half-mile network buffer around each respondent's location and measures built environmental within each buffer. Then the author statistically analyzes the effects of built environmental and socio-demographic features on people's perception towards shared and private autonomous vehicles.

The findings of the analysis exposed the substantial impact of built environmental factors on the public adoption of shared autonomous vehicles. Living in more accessible neighborhoods increases the likelihood of adopting shared autonomous vehicles and residents of these areas are willing to pay more for this technology. Moreover, neighbourhood accessibility increases the chance of accepting private autonomous vehicle although its effect is not significant.

Besides built environment, other factors that significantly affect SAVs adoption are gender (male), disabilities (that prevent driving), technology-familiarity factor (includes having a post-graduate education, being tech-savvy, experiences of using car-sharing services and driver assistant features), and non-driving travel preference (walking, biking, and using transit). Therefore, male residents, having disabilities, familiar with technology, with non-driving travel preference, and living in accessible neighborhoods, are features of the individuals who are likely to use shared driverless car services.

Moreover, factors that significantly affect public adoption of private autonomous cars are age, gender (male), travel preference, and technology familiarity. Therefore, male residents, young

individuals, people with high technology familiarity, and people who prefer non-driving travel modes are more likely to purchase private autonomous vehicles.

The findings also emphasize the low rate of AVs acceptance in the DFW area that is aligned with the other U.S. cities. Around 47% of respondents show interest to shop for a driver-less car, 35% adopt using a shared autonomous car, and totally 54% accept either private or shared autonomous cars. Moreover, educating survey participants about the technology increases the adoption rate to 63%.

Table of Contents

LIST OF FIGURES

LIST OF TABLES

1 Chapter 1: Introduction

Autonomous vehicles (AV) are one of the most significant contemporary technological leaps in the personal mobility of our era. This technology includes two primary forms of shared autonomous vehicles (SAVs) and private autonomous vehicles (PAVs), and scholars consider them as two independent transportation modes. Predictions indicate that this technology will cause fundamental changes in our cities and might address several current urban transportation issues such as car accidents, lack of parking spaces in downtown areas, traffic congestion, gas emissions, and fuel consumption (Anderson et al., 2014). The influences of this technology will be especially significant in American cities since the transportation systems of these cities are mainly auto-oriented, and this country has the highest number of vehicles in the world (US Bureau of Transportation Statistics, 2009).

Along with the potential advantages of AVs, there will also be new challenges. For example, AVs might bring new costs to update cars and infrastructure; liability; security and privacy concerns (Fagnant & James, 2014). To mitigate against these concerns and fully realize the potential benefits of AVs, a growing body of investigations in various disciplines have been conducting research related to autonomous vehicles. The results of these studies reveal that AVs will be in our cities in the not too distant future. According to the historical deployment rate of prior automatic car technologies (like automatic transmission and hybrid-electric drive) and the public adoption of them, Litman, (2015) predicted that AVs are likely to create about 50% of car sales, 30% of cars, and 40% of all car travel by 2040. Another prediction by Alexander & Gartner, (2014) envisages that AV sales in the U.S. will pass 18 million by 2035, or 75% of all light-duty cars. However, the pace of AVs deployment will significantly depend on several factors, and the public adoption is of these factors. The public is a leading stakeholder, and market penetration of AVs depends heavily on public acceptance of this technology (Bansal & Kockelman, 2017a).

1.1 Problem Statement

Different studies have evaluated public acceptance of autonomous cars in the US, while a few of them have explored socio-demographic factors that influence public acceptance. There is little evidence in the literature regarding the potential influence of the built environment on public adoption of SAVs and PAVs. Additionally, numerous studies have revealed that mobility behavior of residents is affected by built environmental factors (Marlon Gary Boarnet & Crane, 2001; L. Frank, Bradley, Kavage, Chapman, & Lawton, 2007; Giles-Corti et al., 2013; Handy, Cao, & Mokhtarian, 2005). This evidence suggests that there might be a significant relationship between built environmental factors and the rate of adopting SAVs and PAVs as new modes of transportation, although the current literature has yet to explore this issue. This dissertation seeks to address this gap in the literature and assess the hypothesis about the effects of the built environment on public opinion toward autonomous driving technology.

1.2 Research Goals and Objectives

Because public adoption is a crucial determinant in the deployment of any new technology including driver-less technology, this study seeks to evaluate public adoption and finds the factors that influence it and, in particular, measures the effects of built environmental factors on adoption. Accordingly, the main goals of the study are

- Evaluating the public perception about different aspects of AV technology
- Assessing the public preference for private and shared autonomous cars

- Finding the factors that influence public adoption such as socio-demographic, travel preference, travel behavior and built environment
- Quantifying the link between built environment and adoption of SAVs and PAVs
- Gauging the people's opinions regarding the regulatory aspects of autonomous cars
- Exploring the most important benefits and concerns of the AV technology from the users' perspective

1.3 Research Questions

This dissertation seeks to answer the following questions:

- What are the factors that influence people's acceptance of the AV technology?
- What are the main advantages and disadvantages of AV technology for the DFW residents?
- How built environmental and socio-demographic factors affect residents' choice of AVs form (private or shared)?
- What is the DFW residents' willingness to pay (WTP)[1]?
- What are the built environment and socio-demographic factors that affect WTP?

1.4 Research Significance

First, the survey study is designed based on the results of comprehensive reviews of existing surveys about AVs in the U.S. and the results of the real-life implementation of the technology. Consequently, the survey covers a wide range of adoption topics.

---

[1] Willingness-To-Pay (WTP) is the maximum price at or below which a consumer will definitely buy one unit of the product

Second, the Dallas-Fort Worth (DFW) Metroplex is selected as the case study. DFW is a fast-growing metropolitan area that authorities tend to apply innovative transportation approaches to deal with increasing transportation problems in the area. However, there is little evidence of studies that have evaluated the public insight regarding advanced transportation in the area.

Third, this study considers SAVs and PAVs as different transportation means and compares their public adoption rate. The results are also confirm this fact when the SAVs and PAVs have different rates of adoption.

Forth, the study provides different forms of AVs for respondents to select from them based on their needs. The four options that the survey offers include SAVs as a driverless taxi, a driverless taxi with ridesharing, installing a self-driving system on the current car, and purchasing a fully autonomous vehicle.

Fifth, the author spent considerable time researching to ensure the collected data would be a correct representative for the target population. Reviewing previous studies, the author found the socio-demographic elements that have impacts on adoption. These elements had screening criteria for sampling. The study hired a professional survey firm to collect the optimal and accurate data based on the designed sample.

1.4.1 The Importance of Research about Driver-less Technology

Historically, the planning profession had challenges to prepare for innovative transportation technologies. Urban planners mainly focus on the problems of their time, rather than predicting and planning for future concerns and the upcoming technology (Cole, 2001; Couclelis, 2005; Isserman, 1985; Myers & Kitsuse, 2000). The ignorance of the future transportation changes by urban planners has happened several times in history and caused negative outcomes for cities.

For instance, Morris, & Taylor (2009) discuss that, at the beginning of the twentieth century, planners' failure to forecast the influences of private vehicles empowered an engineering-dominated perspective of urban highways that highly concentrated on vehicle throughput.

Another example of this ignorance happened while the highways expanded urban sprawl (Baum-Snow, 2007; Duranton & Turner, 2011). In the same way, misunderstanding regarding aviation technology, the significance of the postal service, and commercial air carriers weakened planners' abilities to affect airport locations, or adjacent land uses (Bednarek, 2001).

Based on this experience, it is possible that urban planners will fail another time to realize the relationship between cities and approaching changes in transportation technology, either by underestimating the impact of driverless vehicles or, conversely, considering them as a solution for all current planning issues. The results of a study by Guerra (2016) confirm that urban planners are not ready for the advent of autonomous vehicles technology. This study reviews current Regional Transportation Plans (RTP) (from 2009 to 2014) of the twenty-five most populated metropolitan areas in the U.S. and concludes that none considers autonomous vehicles, while just one mentiones the new technology. Guerra (2016) concludes that the reason for ignoring AVs in these RTPs is not that the planners are uninformed or cynical regarding AVs, but merely that they are not aware of the vehicles' influences, the short time frame to prepare, and the gap between potential effects and daily investment decisions.

Accordingly, the inadequate preparation of the planning profession for the AV technology may lead to catastrophic outcomes for cities. To avoid this in the future, urban planners need correct predictions and develop a deep understanding of innovative transportation modes. This need shows the importance of research about autonomous vehicles as highly predicted future technology. This study covers a section of the required research about autonomous vehicles.

1.5 Dissertation Outline

The dissertation begins in Chapter 2 where the author explains the different level of car autonomy. Then, the author reviews the literature and explores the promises and perils of the AV technology for cities. Afterward, the author analyzes the topics surrounding public adoption of AVs and discusses the importance of investigating public adoption. I explore the effect of built environment on travel behavior and explain how each built environmental variable affects travel mode choice. Finally, the hypothesis that this research seeks to investigate is presented.

Chapter 3 summarizes previous attempts of investigating AV adoption in the U.S. and internationally. First, previous survey studies about the public perception of AVs in the U.S. are examined and their results and methodologies are compared against one another. Second, an analysis of the real-life implementation of AV technology in Europe is used to illustrate the issues that users faced during implementation. The results of the analysis are used for designing a comprehensive and innovative survey for the study.

In chapter 4, the methodologies applied in this study are explained. The chapter starts with the survey design and then describes the goals of the survey and how the survey is developed. Next, the methods of survey distribution and the potential biases that should be avoided in data distribution are clarified. Conclusively, I discuss how to avoid the potential bias that could be present in the survey design, case study selection, and survey distribution. Then I define the case study area, reasons for selecting this case, the designed sample and the reasons for selecting this type of sampling. After that, I discuss data and variables, different types of data that the study uses, in detail. Moreover, the method for measuring D-Variables is explained. Analytical methods and the reason for choosing and using each method is described.

Chapter 5 discusses the descriptive analysis of the socio-demographic and travel behavior results. Then the study demonstrates the results of the statistical analysis of adoption rate, WTP level and advantages and disadvantages of AVs for respondents. For each of them, the results of the study are compared to the results of previous studies, and the author discusses whether these results were predicted or not. The effect of built environmental factors on adoption is explained for SAVs and PAVs. At the end of this section, the author debates the residents' ideas regarding regulations for AVs.

In chapter 6, the author makes a conclusion based on the results of the study and implicates policies to decision makers. The study indicates how exploring the link between built environment and AVs adoption might contribute in the AVs deployment and what policies are needed for controlling AVs adoption by affecting urban development. Then, the author lists the limitations of the study, identifies the research contributions, and makes recommendations for the future studies.

2 Chapter 2: Literature Review

This chapter reviews the literature about autonomous vehicles. Advantages and disadvantages of the technology are explained and the importsnce of public adoption is decribed.

Then the author explores the effect of built environment on travel behavior and explain how each built environmental variable affects travel mode choice. Finally, I provide the hypotheses of the study.

2.1 Autonomous Driving

There are two primary systems of autonomous vehicles: Autonomous Vehicles (PAVs) and Shared Autonomous Vehicles (SAVs). A PAV is a privately-owned fully autonomous cars that can be shopped with autonomy features or can be the outcome of installing the fully-autonomy system on a human-driven car. The term SAVs refers to a fleet of driverless taxis with on-demand 24/7 services that can be with or without ridesharing. Findings of various investigations indicate that SAVs are a new mode of transportation (Burns, Jordan, & Scarborough, 2013; Chen, Kockelman, & Hanna, 2016). Therefore, in this study, I assess shared autonomous vehicles separately from private autonomous cars.

Moreover, based on the definition of National Highway Traffic Safety Administration Preliminary (NHTSA), there are 5 levels of autonomy as following. (This research focuses on level 4 and level 5 that are full autonomy)

Level 1 (No-Automation): At all times, the driver is in entire and only control of the primary car controls (brake, steering, throttle, and motive power). The driver is also solely in charge of monitoring the roads and for the safe action of all car controls.

Level 2 (Partial Automation) This level includes automation of at least two main control functions planned to work in harmony to relieve the driver of control of those functions.

Level 3 (Conditional Automation) in this level of automation, the driver, can cede full control of all safety-critical functions in specific traffic or environmental circumstances.

Level 4 (High Automation) At Levels 4 and 5, the car can steer, brake, accelerate, monitor the car and road as well as replying to events, deciding when to change lanes, turn, and use signals. At Level 4, the autonomous driving system would inform the driver when circumstances are safe, and only then does the driver switch the car into this mode.

Level 5 (Complete Automation): This level of autonomous driving, needs completely no human attention. The car designers do not consider installing any pedals, brakes, or a steering wheel since the autonomous vehicle system controls all serious responsibilities (National Highway Traffic Safety Administration, 2016).

2.2 The Advent of Autonomous Driving in Cities

The advent of autonomous vehicles in our cities is fast approaching. Some car manufacturers have started selling and marketing high-end cars with options such as automated braking, self-parking, lane-departure warning, and different speed cruise control. There is now a competition to manufacture fully automated vehicles among car manufacturers. For instance, Nissan announced that it is going to mass-market vehicles with automated steering, braking, and acceleration by 2020 (Nissan, 2014). Numerous transit organizations[2] and airports have already operated autonomous trains on fixed guideways for several decades[3] (Furman, 2014). Moreover, the European Union–funded CityMobil2 has tested driverless transit on public streets of seven European cities (CityMobil2, 2015).

Accordingly, the self-driving cars will be on our roads soon. In the short remaining time, we should prepare our cities to adapt to this technology in the way that provides the maximum benefits and causes minimal drawbacks. Although predicting what exactly will happen by the deployment of AVs is unlikely, scholars have been trying to draw an approximate picture of cities with self-driving cars to assess the predicted effects of AVs (Segal & Kockelman, 2016).

Scholars anticipate that the development of AVs and SAVs would influence the land use pattern and transportation system, residents' quality of life, changing what passengers do in cars, costs and time of travel, congestion, and road safety. Conversely, there are many barriers to the deployment of AVs, such as public perception, legal liability issues, and the control and security of the systems (Howard & Dai, 2014).

2.3 Advantages of AV Technology

Based on different research predictions, AVs can fundamentally change transportation systems. They have the potential to prevent deadly car accidents, offer mobility to the elderly, disabled

---

[2] DFW International Airport, Seattle–Tacoma International Airport, Denver International Airport, Las Vegas Monorail, Morgantown Personal Rapid Transit, Hartsfield–Jackson Atlanta International Airport, Washington Dulles International Airport, Detroit Metropolitan Wayne County Airport, Tampa International Airport, San Francisco International Airport, O'Hare International Airport

and disadvantaged residents, reduce the need for parking spaces in downtowns, raise road capacity, decrease fuel consumption, and lower harmful emissions. Research also forecasts that self-driving might reduce a user's transportation expenses and address the last/first mile issues (Levine, Zellner, Shiftan, Alarcon Arquero de, & Diffenderfer, 2013). The verdict of a new study shows that by 2030, fast technological progress and dramatic cost efficiencies in self-driving cars will optimize the energy and economics of oil-powered vehicles; consequently, universal oil demand may drop (Arbib & Seba, 2017). Another predicted consequence of AVs deployment is increased network capacity as a result of decreased traffic congestion, through improving platooning[4] and optimization of current capacity (Fagnant & Kockelman, 2015; Kockelman et al., 2016; Tientrakool, Ho, & Maxemchuk, 2011; Van Arem, Van Driel, & Visser, 2006).

Some studies have predicted the financial benefits of AVs for the US economy. For instance, Fagnant & Kockelman, (2016), used Agent-Based Modeling[5] and estimated over $37.7 billion savings in the U.S. economy caused by the deployment of autonomous vehicles (AVs) from safety, mobility and parking improvements at the 10% market penetration level. However, with 90% market penetration, they predict the savings will be over $447.1 billion, that is four times more than the annual budget of the US Department of Transportation (DOT, 2016). Additionally, autonomous vehicles have the potential to reduce 90% of all crashes that result from driver error and save up to 1,000 lives annually by just a 10% market share (NHTSA, 2008). AVs might also

---

[4] Truck Platooning comprises a number of trucks equipped with state-of-the-art driving support systems – one closely following the other. This forms a platoon with the trucks driven by smart technology, and mutually communicating.

[5] An agent-based model (ABM) is one of a class of computational models for simulating the actions and interactions of autonomous agents (both individual and collective entities such as organizations or groups) with a view to assessing their effects on the system as a whole.

improve personal mobility for a third of the population that does not drive, because of age, disability, poverty, or preference (Guerra, 2015).

Among the predicted benefits of AVs on cities, the possible effects that are emphasized by several investigations are enhancing road safety and addressing the need for parking spaces in downtowns areas. Therefore, I explain these two effects separately in the following sections.

2.3.1 Parking Spaces in Downtowns

AVs could contribute to addressing the lack of parking spaces in two ways. Firstly, Hayes (2011) hypothesized that AVs could economize parking space since they could park inches from each other after they dropped off their passengers and there would be no requirement to open auto doors.

Secondly, in the areas with high parking demand, passengers can get out of their cars and then send the vehicle to park in a distant place with lower parking demand. Zhang, Guhathakurta, Fang, & Zhang, (2015) develop a model to predict the effect of AVs on eliminating parking lots in Central Business Districts (CBDs). The findings of the simulation show that cities may be able to remove over 90% of parking demand for customers who adopt the technology at a low market penetration level of 2%. Meanwhile, the findings indicate that various SAVs operation plans and client's preferences may cause the different spatial distribution of urban parking demand (Zhang et al., 2015).

In another study, Litman (2012) estimated the savings that can be a result of moving parking spaces from CBDs. He measures the total annual parking costs including land, construction, maintenance and operation and indicates that per space annual parking expenses are $3,300 to $5,600 in a CBD while it is $1,400 to $3,700 in other central/urban areas and $680 to $2,400 per space in suburbia. Hence, we can save over $2,000 by transferring a parking space outside of the CBDs, while by moving to suburbia the savings would be $3,000. According to this analysis, each AV will lead to a moved or eliminated parking space that saves $250 in parking costs (Litman, 2016).

In addition to the financial savings, moving parking spaces out of CBDs will significantly free areas in downtown areas that can be used for other land uses. Green spaces, public places, housing, shops, and offices are the purpose land uses to replace parking lots. Meanwhile, it will be an opportunity to manage stormwater, expand street trees, and other sustainable features (Guerra, 2015).

2.3.2 Road Safety

Another highly predicted effect of AVs is decreasing car crashes. AVs can improve traffic safety, with mitigating crash severity and lessening the chance of crashes by providing notices to drivers and controlling the car in dangerous circumstances (Li & Kockelman, 2016). Based on the data from National Highway Traffic Safety Administration (NHTSA), car accidents result in 34,080 fatalities just in 2012 (NHTSA, 2012) where approximately 90% of the crashes were attributed at least in part to driver mistakes (Walker Smith, 2013). The information from the Center for Disease Control (CDC) confirms that car crashes cause 30,000 deaths annually and cost 41 billion dollars for the U.S. economy. Furthermore, more than 2.3 million residents are injured, requiring another 99 billion dollars from the U.S. economy (CDC, 2011). The public health field pays attention to this area as one where public health and urban planning should cooperate to improve the safety of vehicles, motorcycles, pedestrians, and bicycles (American Public Transportation Association, 2010).

Even semi-autonomous cars can considerably improve road safety. An investigation evaluates the advantages and disadvantages of fleet-wide deployment of Blind Spot Monitoring, Lane Departure Warning, and Forward Collision Warning Crash Avoidance Systems within the US light-duty vehicle fleet. The findings indicate that these three technologies could together prevent or decrease the severity for as many as 1.3 million U.S. crashes a year, including 133,000 injury crashes and 10,100 fatal crashes (Harper, Hendrickson, & Samaras, 2016).

A higher level of automation will increase the amount of these savings. A number of investigations have predicted that fully automated driving systems can decrease car accidents by 90% (Anderson et al., 2014; Global Driving Risk Management, 2011). A study by Mearian, (2013) estimated that AVs might prevent 4.2 million car crashes that saves $450 billion and 21,700 lives annually. Estimation of another investigation by Shanker et al. (2013) shows a savings of $488 billion (U.S) from accident avoidance.

Moreover, a study by Li & Kockelman (2016) has anticipated the safety-related profits of autonomous and connected autonomous vehicles such as Forward Collision Warning, Cooperative Adaptive Cruise Control, Do Not Pass Warning, Control Lost Warning, Cooperative Intersection Collision Avoidance Systems and Electronic Stability Control. The results demonstrated that combining eleven Connected Autonomous Vehicles (CAV) technologies, with Cooperative Adaptive Cruise Control, and Cooperative Intersection Collision Avoidance Systems, will cause annual savings of $76 billion for the U.S. together with almost 740,000 functional-life-years saved annually (Li & Kockelman, 2016).

2.4 Concerns Around AV Technology

Besides technological barriers, other challenges remain with the deployment of AVs. Expenses hinder large-scale production and mass consumer availability, and complicated problems regarding legal, liability, privacy, licensing security, and insurance regulation (KPMG & CAR, 2012). Additionally, there are challenges concerning implementation and mass-market penetration. The preliminary expenses will possibly not be affordable. Moreover, the testing and licensing standards in America have been established at the state level, instead of developing a national agenda, causing potential inconsistencies from state to state. Liability remains undefined; security concerns lack sufficient privacy standards, and there is a default absence of privacy for the personal trip. Lastly, with the advent of this upcoming technology, several effects, relations with other elements of the transportation system, and implementation details stay indefinite (Fagnant & Kockelman, 2015). Another barrier to the AVs deployment is the need to increase road capacity to accommodate AVs in the network if the policymakers decide to allocate separate lanes to AVs (Childress, Nichols., Charlton., & Stefan, 2015).

Adoption of the driver-less technology by users is a considerable barrier. If users do not show enough trust in this technology, the market penetration may stop regardless of low price and high facility of products.

2.5 Controversial Issues Around AVs

Some outcomes of AVs are controversial and will not be fully understood until AVs are fully deployed, such as their effects on vehicle miles traveled (VMT). On one hand, some modeling studies predict that AV deployment would increase Vehicle Miles Traveled (VMT). Because when an AV arrives at a destination, the passenger may send the car to park in a further place with lower parking price and these empty cars on the roads will surge the VMT (Anderson et al., 2014; Fagnant & Kockelman, 2016). On the other hand, a number of studies state that dynamic, on-demand ridesharing by SAVs systems would compensate for or offset the predicted increased VMT (Fagnant & Kockelman, 2016).

Another controversial issue regarding deployment of AVs is the effects of this technology on public transit usage. On one hand, some scholars believe that the employment of self-driving cars might discourage people from using transit (Litman, 2017). Other scholars disagree, stating that the AVs have the potential to encourage residents to use shared rides, increasing residents' trust in public transit. These scholars give the trend that took place in the San Francisco Bay Area as proof. In 2013, the advent of shared Uber not only did not weaken the transit ridership but it increased the transit ridership as statistics show (Levin & Boyles, 2015).

The effects of AVs on the household financial situation are other aspects of controversy among scholars. On one hand, some researchers discuss that the higher payment for automated features in AVs and potential unemployment of people who are involved in driving industries are the factors that will damage household finance. On the other hand, some scholars discuss the positive influences of AVs on households' finance through decreasing the traffic expenses of the users, parking costs, and fuel costs (Anderson et al., 2014). Furthermore, Fagnant and Kockelman (2013) speculate that AVs will contribute to a better economy for the household by decreasing insurance costs, and travel time. AVs also might decrease medical costs of households by reducing car crashes and improving air quality (Asher, 2014).

2.6 Shared Autonomous Vehicles (SAVs)

Autonomous vehicles have distinctive characteristics that could encourage car-sharing and can address several of the biggest obstacles to car-sharing such as accessibility limitations and reliability. Consequently, SAVs could facilitate ride-sharing opportunities (Kornhauser et al., 2013). SAVs offer new services in transportation systems by providing the convenience of the private cars, and they are more flexible than transit systems (Barth & Shaheen, 2002). By eliminating the fixed rental and returning stations, SAVs provide higher flexibility for passengers compared to the traditional car-sharing program, like Zipcar and Car2go. SAVs also have a privilege to the app based auto-sharing programs such as Lyft and Uber by decreasing the operating expenses and offering higher affordable mobility services for deprived residents. Finally, through connecting various trips and serving them by one SAV, the service plays a potentially important role in traffic reduction (Zhang et al., 2015). Additionally, Kornhauser et al. (2013) analyze the possibility of SAVs system in New Jersey and show that SAVs could encourage ride-sharing travel behavior thoroughly.

Affordable mobility is another potential advantage of SAVs. They may be more economical on a per mile basis than non-autonomous transit, decreasing average trip expenses by removing the labor costs. Burns and colleagues (2013) analyze the Manhattan area and conclude that SAVs might reduce average trip costs from $7.8 to $1 by eliminating human labor costs. A more comprehensive study by Burns et al. (2013) assessed the economic feasibility of a universal autonomous car-sharing system using an agent-based simulation model. The findings indicate that each trip mile ranges from $0.32 to $0.39, based on the fleet size of the SAVs. This trip price is more affordable than having and driving a private vehicle (Burns et al., 2013).

Likewise, SAVs provide services for different groups of deprived residents. The literature emphasizes that SAVs will contribute in elderly travels (Fagnant & Kockelman, 2015) as well as present services for low-income citizens who do not have a private vehicle (Anderson et al., 2014).

Additionally, as the study mentioned before, the effective implementation of SAVs will increase road capacity and decrease VMT. Burghout et al. (2015) presented a framework for the efficient provision of SAVs to commuters, empty-vehicle routing and multi-criteria assessment concerning trip times, passenger waiting time, and fleet size. The findings of this study demonstrate that an SAV-based transportation network needs only 5% of today’s private vehicles and parking spaces. However, the key to the success of this system is that users agree to share their ride, having on average a 13% rise in trip time (30% maximum) and starting opportunity window of 10 minutes. Therefore, SAVs might balance the increased VMT caused by private AVs. Fagnant and Kockelman indicate that AVs system might cause-related costs of about 5% additional unoccupied VMT made throughout the client picking up the process. This negative impact may be improved or even be removed by the rise of ride-sharing behavior (Fagnant & Kockelman, 2014a)

Given the potential advantages of autonomous driving technology, the question is whether the public is ready to adopt this technology. Public adoption of the technology is one of the factors that play a crucial role in the deployment of AVs. Public adoption is essential for the development of any new transportation system technology (Barth & Shaheen, 2002). The next section discusses the public adoption of AV technology in further detail.

2.7 Public Adoption

The public perception is a determinative factor in the deployment of AVs by affecting the tax and insurance regulations, governing policies, and future investment in infrastructure. It also shapes the demand and market for the cars, controls AVs sale, and consequently, the way car manufacturers could market and sell their products (Howard & Dai, 2014). However, user behavior is often difficult to predict and overlooked as a critical component when introducing new transportation systems or technology. Therefore, to analyze the public opinion, we should take a wide variety of factors into account.

Moreover, driverless vehicles will dramatically affect the travel behavior of the residents. A shift to self-driven cars will change what individuals do in their vehicles, traveling cost and time. Therefore, the public should be ready to adopt these changes. However, mobility behaviors are not usually flexible to changes and need strong incentives to accept alteration. Some scholars state that innovation and attraction of the new kinds of mobility usage like SAVs have the potential to attract a considerable amount of users (Roman, 2016). However, this assumption cannot be proven unless with the approval of a broad range of investigations by considering factors that affect public opinion.

A number of studies by different scholars and private firms have assessed public opinion toward AV technology (Bansal, Assistant, & Kockelman, 2016; Haboucha, Ishaq, & Shiftan, 2015; Howard & Dai, 2014; Krueger, Rashidi, & Rose, 2016; Kyriakidis, Happy, & de Winter, 2015; Schoettle & Sivak, 2014, Vujanic & Unkefer, 2011; Cisco Systems, 2013; Ipsos MORI, 2014; Power, 2015, Continental Sommer 2013; KPMG 2013, NerdWallet, and Vallet, 2014). However, little research focused on the characteristics of communities that may adopt AVs more than others while only a few studies have specifically deal with the causes leading to the adoption of AVs. The first one investigated 721 car owners' tendency to shift to AVs on work-related and education-related travels using stated preference data in Israel, the USA, and Canada (Haboucha et al., 2015). The second one examined 347 residents' stated frequencies to use SAVs in Austin under various costs situations and find out the features of potential AVs adopters. It also considers some environmental factors that are limited to population density, distance to downtown, and distance to transit and does not all built environmental factors (Bansal & Kockelman, 2017b).

Therefore, there is no a study to investigate the potential effects of different built environmental factors on the public adoption of AVs. This investigation seeks to address this knowledge gap by testing the impacts of built environmental elements on adoption of PAVs and SAVs.

2.8 Built Environment

Before exploring the effects of the built environment on travel behavior, the author reviews different definitions that scholars present for the notion of the built environment. The US Center for Disease Control and Prevention (CDC) defines the term 'built environment' as "the buildings, roads, utilities, homes, fixtures, parks and all other man-made entities that form the physical characteristics of a community"(CDC, 2007). The built environment comprises not only buildings (residences, schools, workplaces), but the human-made places between structures, such as parks/recreation areas, and the infrastructure that supports human activity including transportation networks, utility networks, flood defenses, and business areas. It also extends overhead in the form of electric transmission lines, underground in the form of waste disposal sites and subway trains, and across the country in the form of highways (Health Canada Division of Childhood and Adolescence, 2002). In addition to buildings and transportation systems, built environment includes the urban form (e.g., the arrangement, function and aesthetic qualities of buildings and streets design) and the different ways in which they interact (James, Troped, & Laden, 2013). Moreover, Glanz & Kegler, (2007) illustrate that, the built environment consists of the neighborhoods, roads, buildings, food sources, and recreational facilities. The places in which we live, work, are educated, eat, and play.

Numerous investigations discover the role of built environmental factors on different aspects of the residents' lives. For instance, built environment influences indoor and outdoor physical environments (e.g., climatic conditions and indoor/outdoor air quality), along with social environments (e.g., civic participation, community capacity, and investment) and consequently public health and quality of life (Health Canada Division of Childhood and Adolescence, 2002). Another well-studied topic around the built environment is the effects of built environment on travel behavior that has been investigated with different studies since the 1990s (as reviewed in Crane 2000; Ewing and Cervero 2001; Handy 1996). Most of these studies use D-variables for measuring built environment since these five factors of the built environment are the ones with the highest impacts on travel behavior.

2.8.1 Built Environment and Travel Behaviour

Different forms of surrounding environments can affect residents' behavior. The first form is the social aspects such as social support, norms, beliefs, and attitudes. The second form is objective (actual) or subjective (perceived) physical including weather or climate, community resources, the information environment and the built environment (Sallis, Owen, & Fisher, 2008).

The environment especially influences behaviors that are formed by environmental limits and provisions, like physical activity (Bandura, 1986; Owen, Humpel, Leslie, Bauman, & Sallis, 2004).

Several behavioral schools of thought consider "environment" as a construct. For instance, social cognitive theory believes that the effective factors on behavior are individual elements integrated with the social and physical environment (Bandura, 1986). A social, ecologic viewpoint recognizes several levels of behavioral factors, including individual, interpersonal, organizational, and community, besides both social and physical environments at different levels (McLeroy, Bibeau, Steckler, & Glanz, 1988). For instance, Glanz & Kegler, (2007) believe that the built environment shape numerous daily decisions of residents. For instances, the urban form of a neighborhood can influence decisions of residents about walking to work or school, often eating at fast-food restaurants, or taking their children to parks (Glanz & Kegler, 2007).

The literature demonstrates the potential causal correlation between certain built environment features and travel behavior, highlighting the natural environmental influences automobile travel patterns (Cervero and Gorham, 1995; Cervero and Kockelman, 1997; Ewing, 1997a; Frank and Pivo, 1995; Handy, 1996; and Kockelman, 1997).

2.8.2 Assessment of the Built Environment

To examine the effects of the built environmental factors on transportation, we need to measure these factors. However, measuring the built environment is complicated due to several dimensions that could be measured, and various aspects of the environment differ in significance by behavior (Glanz, Sallis, Saelens, & Frank, 2007). Studies that measure the built environment are different regarding inconsistent attribute definitions, varying scales of data, and data quality by jurisdictions (Siu et al., 2012). As stated by the literature, there are three main methodologies to operationalizing environmental indicators (Brownson, Hoehner, Day, Forsyth, & Sallis, 2009; Mujahid, Diez Roux, Morenoff, & Raghunathan, 2007).

The first method is related to measuring perceived built environment by residents. It is a method of measuring the built environment by gathering verbal information about residents' insights into their surrounding environment. This method is common in investigations that measure built environment at the individual level usually by surveying people's views of the environment (Badland et al., 2009; Cerin, Leslie, Toit, Owen, & Frank, 2007; Shigematsu et al., 2009).

However, the most unbiased evaluations comprise observation of the physical characteristics of environments although it has some challenges. For instance, besides being valid, these methods must have strong inter-rater reliability. If the hypothesis that environments stimulate behavior within the long term is to be supported, then the methods must possess high test-retest reliability (Glanz & Kegler, 2007).

The second group of studies aggregate neighborhood using secondary data such as Census (Badland et al., 2009; Boarnet, Greenwald, & McMillan, 2008; Boer, Zheng, Overton, Ridgeway, & Cohen, 2007; Cerin et al., 2007; Coogan et al., 2009; Giles-Corti et al., 2013; Lin & Long, 2008; Riva, Gauvin, Apparicio, & Brodeur, 2009). A small number of existing investigations measure the built environment characteristics objectively at high resolution or apply cluster analysis to classify various urban forms (Reid Ewing & Cervero, 2001; Huang, Stinchcomb, Pickle, Dill, & Berrigan, 2009; Lin & Long, 2008; Saelens & Handy, 2008).

Third group of studies quantify built environmental factors within a specific distance of the subjects' residences (Cerin et al., 2007; Duncan, Aldstadt, Whalen, Melly, & Gortmaker, 2011; L. D. Frank et al., 2006; F. Li, Fisher, Brownson, & Bosworth, 2005; McCormack, Giles-Corti,

& Bulsara, 2008; Rodríguez, Evenson, Diez Roux, & Brines, 2009). This method uses geospatial databases and GIS data to improve indicators and is suitable for developing indicators of the built environment that are challenging to measure from specific databases (Mujahid et al., 2007). However, indicators derived from these tools seldom allow for operationalization on a territorial scale.

2.8.3 Effects of D-Variables on Travel Behavior

Cervero & Kockelman, (1997) first defined D-Variables as density, diversity, and design for measuring urban form. Then other studies developed these variables to include destination accessibility and distance to transit (Reid Ewing & Cervero, 2001).

Based on the results of over 200 peer-reviewed studies, the D-variables affect household travel behavior (A the meta-analysis by Ewing & Cervero, 2010; as well as literature reviews by Badoe & Miller, 2000; Cao, Mokhtarian, & Handy, 2009; Cervero, 2003; Crane, 2000; Ewing & Cervero, 2001; Handy, 2005; Heath et al., 2006; McMillan, 2005, 2007; Pont et al., 2009; Saelens, Sallis, & Frank, 2003; Salon et al., 2012; Stead & Marshall, 2001).

Meanwhile several investigations such as Crane (1996), Cervero and Kockelman (1997), Kockelman (1997), Boarnet and Crane (2001), Cervero (2002), Zhang (2004), and Cao et al. (2009b), present economic and behavioral reasons to explain the effects of D-variables on travel choices. Since this investigation seeks to explore the effect of built environmental factors on AVs adoption (as an innovative travel choice), the author selects D-Variables measure. Following is the definition of each D-Variable and how that variable affects travel behavior.

2.8.3.1 2.8.3.1 Density

Density refers to the number of residences, individuals or employment per unit of area (Campoli and MacLean 2002; Kuzmyak and Pratt 2003; TRB 2009). The literature emphasizes that increasing density leads to a decrease in vehicle ownership and driving, and encourages non-driving travel behavior such as walking, biking and using transit.

Several studies show that increasing urban density will improve walkability (Frank and Pivo, 1995; Levinson and Kumar, 1997; Cervero, 1996; Boarnet and Crane, 2001a, 2001b; and Ewing and Cervero, 2001). Density decreases travel distance to destinations and increase the portion of destinations in walking and cycling distances. Therefore, the shorter travel distances increase chances for walking. High density also increases the cost efficiency of developing walkways, trails, and delivery services (Litman & Steele, 2017).

Furthermore, higher population and employment density rise transit ridership. As a result, the cost efficiency of public transportation services increases and causes more frequent and higher quality transit (Litman & Steele, 2017). In the same way, the per capita expenses of developing transit services decrease with higher density. Results of a study by Beaton (2006) reveal that local density influence transit ridership more significantly than household income.

Denser areas usually have higher traffic friction (interactions among road users) which reduces traffic speeds. Meanwhile, higher land costs reduce parking supply and increase parking pricing. Hence, the time and expenses of car trips increase and discourage driving. Manville and Shoup (2005) show the coefficient between residential density and per capita annual VMT is -0.58. In other words, doubling population density leads to a 58% decrease in annual VMT. Another study by Sun, Wilmot & Kasturi (1998) finds that population and job density considerably and negatively affects vehicle ownership and annual VMT.

2.8.3.2 2.8.3.2 Diversity (Land Use Mix)

Land use mix refers to locating different types of land uses (residential, commercial, institutional, recreational, etc.) close together. Land use mix affects travel modes for both commuting and non-commuting trips.

Mixing land uses decreases commute distances, especially if affordable housing is available in job-rich areas, consequently the likelihood of commuting by alternative modes increases (Modarres 1993; Kuzmyak and Pratt 2003). Residents are less likely to commute to work by automobile and more likely to use public transportation if non-residential uses, are close (Cervero, 1996).

Results of an investigation by Boarnet & Crane (2001) illustrate the noticeable association between different commercial focusses and fewer non-work car travels. In mixed-use areas, people can find housing, restaurants, services, schools, cultural facilities, parks, and more in short distances from their residences. Therefore, the need for car ownership decreases and the level of walking activities and transit use increase. Land use mix has an especially important link with the rate of walking trips (Ewing & Cervero, 2001). Research continually emphasizes that areas with high mix land uses, provide safety and convenience for walking, and let inhabitants and employees drive noticeably less. Moreover, land use diversity improves the sense of place in a neighborhood and consequently makes walking more attractive (Freeman, 2001).

Regarding the trip generation level, Sperry, Burris, and Dumbaugh (2012) indicate that mixed-use urban growths increase the total number of trips. However, most generated trips are walking trips; therefore, mixed-use development reduces driving trips. Results of a comprehensive review of research by Spears, Boarnet, and Handy (2014) illustrate that the elasticity of car travel concerning land use mix is -0.02 to -0.11. In other words, if the mix use index increases by 10% results in an average VMT decrease by 0.2% to 01.1%.

2.8.3.3 2.8.3.3 Design (Street Connectivity)

Street networks vary from dense urban grids of highly connected, straight streets to suburban networks of curvilinear streets, cul-de-sacs and sparse intersections. Improved connectivity decrease driving trips by decreasing travel distances between origins and destinations. Connectivity also enhances walking and cycling access especially where routes make shortcuts available. Consequently walking and cycling become more direct than driving.

Results of numerous studies confirm that connected street networks boost walkability and discourage driving (Boarnet and Crane, 2001b; Cervero and Gorham, 1995; Ewing and Cervero, 2001; Handy, 1996; Vojnovic, 2006; Vojnovic et al., 2006). Direct effects of connectivity are the comfort of walking from location to location and the aesthetic links of higher connected networks. Indirect effects of connectivity on walking and transit usage are providing more and shorter routes from each origin to destinations (Berrigan, Pickle, & Dill, 2010). Furthermore, connectivity creates more stops and lower car speed limits that increase the duration of driving trips. Therefore, connectivity results in streets with shorter blocks, and further intersections that together inspire walking.

2.8.3.4 2.8.3.4 *Distance to Transit*

Transit proximity considerably affects travel behavior by decreasing the first/last mile issues. Hess, (2009) indicates that per additional five minutes in perceived walking time to transit leads to a 25% reduction in transit ridership frequency. Another investigation by Durand et al., (2016) indicates that per mile growth in distance from the point of origin to the transit stop decreases the chance of active access by 12%.

Transit proximity causes effects on VMT too. For instance, a report by TransForm, (2014) demonstrates 25-30% VMT reduction among low-income households who reside within half a mile of transit, and 50% less VMT of those residing within a quarter mile of frequent transit service (TransForm, 2014).

After controlling for demographic and geographic factors, findings of a study by Jeihani, et al. (2013) reveal that TOD residents drive almost 20% less compared to other residents. Furthermore, the rates of walking, cycling and transit use are considerably higher for both commute and non-commute trips among these residents.

2.8.3.5 2.8.3.4 *Destination Accessibility*

Accessibility measures the ease of reaching valued destinations. Higher accessibility decreases the average travel distances to destinations. Consequently, the portion of destinations within walking and cycling distances increases.

Cervero & Kockelman, 1997 show that higher density of employment within a short driving commute time can significantly decrease commuting times. Ewing & Cervero, (2011) support this issue by indicating that destination accessibility has a considerable effect on household mode choices of driving, walking and transit usage. For both transit and walking modes, employment densities at destinations are possibly more important than population densities at origins (Ewing & Cervero, 2011). Barnes (2003) indicates that job density influences the commute mode share more than population density. Boarnet & Crane (2000) also illustrate that a higher density of commercial structures leads to a decrease in the non-commuting travel of residents. The threshold for decreasing car commuting meaningfully is when workplace densities arrive in 50-75 employees per gross acre (Frank & Pivo, 1995).

2.8.3.6 2.8.3.5 Demographics

Usually, urban transportation scholars define the associations between built environment and travel patterns such as commuting travel and non-commuting travels by considering socio-economic and demographic features of the target population (Krizek 2003; Manheim, 1979; Martin et al., 1967; Martin and McGuckin, 1998; McNally, 2000). Socio-economic factors play an especially crucial role in defining the variances in individuals' travel decisions and demand (Boarnet and Crane, 2001b; Crane, 1996, 2000; Handy, 1993, 1996; Handy et al., 2005; and Holtzclaw, 1994). Consequently, applying more socio-economic or demographic variables might enhance the statistical models.
The effective socio-demographic variables on travel behavior comprise household size, household income, residential tenure, gender, age, race, and employment.

2.9 Public Adoption and Built Environment

AS the study shows, D-Variables significantly affect different travel modes. Over 200 empirical investigations have focused on the impacts of the built environment on travel behavior. Indeed, this subject is the most studied topic in urban planning since the 1990s, with at least 14 literature reviews (Badoe &Miller, 2000; Cao et al., 2009; Cervero, 2003; Crane, 2000; Ewing & Cervero, 2001; Graham-Rowe et al., 2011; Heath et al., 2006; McMillan, 2005; McMillan, 2007; Pont et al., 2009; Saelens et al., 2003; Salon et al., 2012; Stead & Marshall, 2001) and two meta-analyses (Ewing & Cervero, 2010; Leck, 2006).

The findings of these studies emphasize that individuals residing in traditional districts (characterized by high density, high accessibility, mixed land uses, and rectangular street network) walk more and drive less compared to residents of the suburban area (Cervero & Duncan, 2003; Crane & Crepeau, 1998). Furthermore, over 50 recent empirical investigations have assessed the effects of built environment on travel demand and most of them focused on mode choices, because socio-economic factors influence mode choices too (Reid Ewing & Cervero, 2001).

By reviewing the studies above, the author concludes that building neighborhoods with high density, mixed land uses, connected streets, access to employment and transit proximity in combination, could significantly affect the choice of Americans for traveling. Moreover, private AVs and shared AVs are two innovative transportation modes that based on predictions will be on our cities in the near future. By considering this evidence, the author assumes that D-variables might also affect rider choices whether to use PAVs and SAVs, as new modes of transportation.

2.10 Hypotheses of the Study

Hypotheses 1: The author hypothesizes that a relatively high percentage of the survey recipients in the DFW region would trust PAVs and SAVs with relatively high WTP. The public awareness regarding the increasing growth of population and the need for new modes of transportation in the area has prepared the majority of the public to trust AVs.

- Null-Hypothesis: The DFW residents consider AVs as a non-tested technology that has a long way to go before implementation.

Hypotheses 2: Built environmental factors are expected to influence AV acceptance controlling for socio-demographic variables. The effect of urban form on the different travel mode choices that numerous studies showed has inspired the author to hypothesize the possible consequences of urban form on adopting the new system of transportation including AV technology.

In compact areas, the rate of residents' adoption of SAVs is expected to be higher than in suburban regions. On the contrary, in suburbia, the adoption of private autonomous vehicles (PAVs) might be higher than central urban districts. The convenience of the AVs and lower fuel consumption could be the reasons for suburban residents to pick PAVs while the inhabitants of the compact areas who use public transportation more often will prefer SAVs as a new type of transit.

- Null-Hypothesis: The adoption of PAVs will be more significant in compact areas, compared to sprawling regions. It is possible that residents of sprawling areas prefer to share their cars with the people who work in the same area and live in the same area to cut their transportation costs. Alternatively, it is possible that residents of compact areas will continue using transit for most of their trips and use PAVs for traveling.

Hypothesis 3: The author assumes that built environmental factors influence residents Willingness-To-Pay (WTP) for AVs. The influence of urban form on households' costs is demonstrated by previous investigations (Hamidi, Ewing, & Renne, 2016). This evidence inspires the author to hypothesize the possible effects of urban form on WTP for the AV technology.

- Null-Hypothesis: The effects of environmental factors are not significant compared to other driving factors. Since the AVs make fundamental changes in the transportation system, the concerns about this technology are not comparable to the other transportation forms. Therefore, residents have similar opinions about this technology regardless of the urban form of the neighborhoods in which they live and their financial situation.

3 Chapter 3: Analysis of Existing Survey Studies about Autonomous Vehicles

This chapter provides a comprehensive and condensed review of previous studies on public adoption of AVs in the U.S. I review and analyze the major behavioral experiment studies that are conducted in the U.S. regarding their methodology, data collection techniques, target population, statistical analysis; and finally the year and place in which they are conducted. Reliable databases such as Google Scholar, Science, ScienceDirect, professional report and academic publications are the sources of selecting these studies. For different queries, I tested the words “autonomous”, “driverless” and “self-driving”, as well as “car”, “vehicle” and “automobile” as synonyms; in combination with the phrases “survey questionnaire”,” public adoption”, “acceptance”, “Willingness-To-Pay”, “travel behavior”, “interview”, “behavioral experiment” and “mode choice”.

I select only studies that have been conducted in the U.S. and have evaluated the Level 4 of autonomy (Full Self-Driving Automation Vehicles), as defined by NHTSA “the vehicle that is designed to perform all safety-critical driving functions and monitor roadway conditions for an entire trip.” Such a design anticipates that the driver will provide destination or navigation input, but is not expected to be available for control at any time during the trip. This includes both occupied and unoccupied vehicles (National Highway Traffic Safety Administration, 2016). Based on the mentioned criteria, 22 research studies were selected.

3.1 Methodological Overview

Table 1 shows a summary of the selected survey studies based on the criteria above. As shown in the table, these studies vary in terms of data collection methods, sample size, the location of the survey distribution, and the time of distribution which consequently resulted in differences in their findings.

All the surveys are conducted since 2013 and used online methods of data collection with one exception. Howard & Dai (2014) applies paper-based data collection, and the researchers asked the respondents to watch a short video regarding AV technology before responding to the questionnaire. This face-to-face interaction provides the opportunity to discuss the issue and explain possible questions that respondents might have. Moreover, residents that are not familiar with technology and do not have access to the online resources are excluded from the online surveys. As the results of a study by Bansal & Kockelman, (2016) demonstrate, the familiarity with technology is an effective factor in AV acceptance. Therefore, the part of society with no access to online sources is excluded from the surveys that damage the reliability of results since these people have a lower chance of acceptance.

The sample sizes differ between 32 to 15,171 respondents, and different target groups are selected such as vehicle owner, transportation experts, students, and faculties. Moreover, Young (2014), conducts interviews with respondents who showed interest in the online questionnaire. Silberg et al. (2013) is the only survey with less than 100 participants and is the only survey that shows the women respondents as less concerned than men which contradicted with the results of the other research studies. Table 6 illustrates a summary of the studies and their results.

Author	**Year**	**City**	**Statistical Analysis**	**Respondents**	**Method**	**Sample size**	**Main Findings**
Bansal & Kockelman,	2017	Texas	Interval regression and ordered probit	General population	Online	1,088	WTP : $7,589, Equipment failure: top concern Experienced drivers: higher WTP Older people: lower acceptance
Bansal& Kockelman,	2016	US	Multinomial logit	General population	Online	2,167	privately held light-duty-car fleet would have 24.8% of level 4 AV penetration by 2045
Bansal, et al.	2016	Austin, TX	Multivariate ordered probit models	General population	Online	347	WTP $7,253 50%: will use AVs after friends do 80%: do not pay more to an SAV service 75%: interested in adding connectivity
Young	2014	US Cities	Descriptive analysis	Vehicle owners	Online, follow up	15,171	Estimate Willingness-To-Pay for autonomous vehicles.
Howard & Dai	2014	Berkeley, CA	Descriptive analysis	General population	Paper-based	107	40% buying or equipping; 45% would not use an AV-Taxi on a monthly basis
Seapine Software	2014	US Cities	Descriptive analysis	General population	Online	2,039	88% of the respondents were concerned about riding in AVs, 79% were worried about equipment failures, concerns: liability (59%), hacking issues (52%)
Silberg et al.	2013	CA, IL, NJ	Descriptive analysis	Vehicle owners	Focus groups (10)	32	Respondents were more interested in adopting autonomous vehicles when they were provided incentives like having designated lanes for AVS
Zmud, et al.	2016	Austin, TX	Descriptive analysis	General population	Online	556	59% prefer PAVs over SAVs; 23% want to reduce vehicle ownership
Casley, et al.	2013	Worcester, MA	Descriptive analysis & Factor analysis	Students and faculty	Online	450	Safety, law, and the cost has a negative impact while productivity, efficiency, and environmental impact has a positive impact on acceptance
Daziano, et al.	2017	US Cities	Conditional, Parametric and semi-parametric	General population	Online	1260	WTP: $4900, range from 0-$10,000 Substantial heterogeneity and demand for AVs is split evenly between high, modest & low
Underwood, et al.	2014	US Cities	Descriptive analysis	Transportation experts	Online	217	The policy community remains largely unaware of AV technology

Vallet	2013	US Cities	Descriptive analysis	Vehicle owners	Online	2,000	90% accept AV with cheaper insurance Trust in AVs will be the main obstacle
Power	2012	US Cities	Descriptive analysis	Vehicle owners	Online	17,400	Males (25%), those between the ages of 18 and 37 (30%), and those living in urban areas (30%) are the most interred to use AVs
Power	2013	US Cities	Descriptive analysis	Vehicle owners	Online	>15,000	Adoption rate rises slightly (21% in 2013 vs. 20% in 2012)
Bonnefon, et al.	2016	US Cities	Descriptive analysis	General population	Online	1,928	Preference for utilitarian AVs and would like others to buy them, but they would prefer to ride in AVs that protect their passengers at all costs.
Schoettle & Sivak,	2014	US, UK, Australia	Descriptive analysis	General population	Online	1,596	The high familiarity of US residents surrounding AVs but lowest trust in this technology compared to the other countries
Schoettle & Sivak,	2015	US	Descriptive analysis	Licensed drivers	Online	505	15.6% accept full autonomy 96% prefer to have a steering wheel plus gas and brake pedals
Schoettle & Sivak,	2016	US	Descriptive analysis	Licensed drivers	Online	618	Concern remains high remarkably
Cisco Systems	2013	US & 9 countries	Descriptive analysis	Vehicle owners	Online	1,514	60% of American trust AVs to ride and 48% of them would let kids ride them
Giffi, et al.	2017	17 Countries including the US	Descriptive analysis	Deloitte consumers	Focus groups, online	22,000	US consumers' interest in advanced vehicle automation has increased since 2014, especially amongst younger generations
Continental	2015	US, China Germany, Japan	Descriptive analysis	Car owners & transportation experts	Focus groups, online	4,100	54% of respondents consider AV technology as a desirable feature
NerdWallet	2015	US	Descriptive analysis	General population	Online	1,000	76% would not let kids ride AVs 50% would not pay extra for AVs (50% men & 43% women) 46% believe AVs are safe

Table 1: Methodologies and Main Findings of Previous Surveys

3.1.1 Acceptance and Concerns around it

Although the rate of awareness among Americans about AVs is higher than other studied countries, the rate of acceptance for U.S. residents is relatively low. For instance, a research study by Schoettle & Sivak, (2015) surveys 505 motorists and shows only15.6% prefers fully-autonomous vehicles while partial-autonomous and non-autonomous are favored respectively by 40.6% and 43.8%. Moreover, the results of an online survey conducted by Valle, (2016) reveals that around 22.4% of the respondents are interested in riding in a fully-automated vehicle, while 24.5% believed that they would never use AVs. Schoettle & Sivak, (2015) show the low rate of trust to AVs when 96.2% of respondents explicate that they prefer to have a steering wheel, in addition to gas and brake pedals (or some other controls) available to control completely self-driving vehicles when desired.

Several studies focused on the reasons for this low rate of AVs acceptance among Americans. For instance, Seapine Software, (2014) surveys 2,039 adults 18 years or older and finds that 88% of them are concerned on riding AVs, 79% are worried about equipment failures, 59% are concerned with liability issues and 52% about hacking issues.

Bonnefon et al., (2016) is the only study that analyzed the reliability concerns of driverless automobiles. The results indicate a meaningfully lower possibility of purchasing these products if the AV programming prioritizes the pedestrians to the car passengers. Additionally, losing the joy of driving a vehicle is another concern. Open Roboethics Initiative, (2014) conducts several online surveys and discloses that about half of the respondents would miss the joy of driving a vehicle and among them; almost 45% would miss having full control over the vehicle.

Although the outcomes of several research studies recognize that trust in AV technology is gradually improving, some other studies show that there is almost no change in this trend. On one hand, an examination by Giffi et al., (2017) indicates that the interest rate in advanced vehicle automation has slightly increased from 36% in 2014 to 39% in 2016 especially among younger generations. Moreover, Bansal & Kockelman, (2017b), predict that the AVs acceptance among U.S. residents would continue to improve. They projected that the privately held light-duty-car fleet would have 24.8% of level 4 AV penetration by 2045 assuming an annual 5% price decrease and continual WTP values (from 2015 forward).

On the other hand, comparing the results of two similar studies by Schoettle and Sivak have conducted three similar surveys in 2014, 2015 and 2016 and demonstrated that the concern about AVs remarkably remains high and almost with no change within these years. For instance, the percentage of very concerned respondents just changed from 35.9 % in 2014 to 35.6 % in 2015.

Additionally, several scholars discussed that informing residents about the advantages of AVs can dramatically influence their viewpoint. Silberg et al., (2013) displayed that respondents were more likely to accept AVs when incentives such as dedicated lanes for AVs is available. Valet, (2014) discusses the substantial impact of the insurance discount in adopting AVs when 90% of respondents show an inclination to purchase a driverless automobile if it comes with a decrease in auto insurance (34% stated “very likely” and 56% likely).

Improving safety is also another incentive for potential AVs users, although a group of respondents considers AVs as a threat to safety. Around 60% of respondents in a survey by Continental, (2015) believe that they would be inclined to utilize AVs in stressful driving situations.

3.1.2 Willingness-To-Pay (WTP)

Different surveys have considered various situations to measure this component, and their results are relatively inconsistent. For instance, the results of a survey by Bansal & Kockelman, (2015) exhibit that WTP to add connectivity and Level 4 automation are $67 and $5,857, respectively. Another study by Bansal et al., (2016) analyze the opinion of 347 respondents from Austin, TX and concludes that the average WTP for adding Level 4 automation to the current vehicles is $7,253 which is considerably higher than WTP for adding Level 3 automation that is $3,300.

Another study by Silberg et al., (2013) surveys three focus groups in America and exposed that the median premium expenses that consumers are ready to spend for automation of a car costs $30,000 is $4,500. Bansal & Kockelman, (2017) notice that around two-thirds of respondents are willing to pay more than $3,000 extra to the price of a conventional vehicle to buy a full automation vehicle.

Moreover, Daziano et al., (2017) survey respondents from different income levels, while the median household income of sample is $50,000. The findings reveal the median WTP of approximately $4,900 for full self-driving. Moreover, this study estimates a considerable heterogeneity in inclinations for self-driving, where a great share of the respondents are prepared to spend over $10,000 for full automation technology while numerous respondents are not ready to pay any amount for this technology.

Contrarily, the results of other investigations demonstrate a considerably low WTP. Case in point, (Danise, 2015) indicated that more than 50% of the US respondents do not intend to pay any extra costs for full automation. Furthermore, Casley et al., (2013) survey 450 university students, and faculties and show most of them think that the automation feature will cost around $5,000 extra the car value, whereas the majority of them are only ready to spend around $1,000 for it. A recent study by Giffi et al., (2017) shows that the WTP for American residents has even decreased by 30% from $1,370 in 2014 to $925 in 2016.

3.1.3 The Issues that Need More Attention

- **Dedicated lanes**: Considering dedicated lanes for AVs is one of the issues that have not been studied extensively. Howard & Dai, (2014) is the only research that paid attention to this issue. Based on the results, 46% of the 107 responses, believe that self-driving cars should operate with conventional traffic while another 38% believe in separate lanes and 11% have no opinion.

- **Built environmental aspects**: The role of built environmental factors on AVs acceptance is relatively understudied. Bansal & Kockelman, (2017) is the only investigation that considers this aspect. The results show that WTP is typically a function of demographics, built environment factors, and thus is expected to change over time. My review suggests that built environmental factors might also affect rider choices whether to use AVs and SAVs, as new modes of transportation.

- **Main concerns**: Although most studies confirm that there is a lack of public trust in the AV technology in the US, there is a substantial difference among studies about the issues caused this mistrust such as willing to pay, major concerns of users and the trend of changes in public trust in AVs. While all the reviewed studies targeted the US cities as their case study, their results do not show a relatively consistent trend in the behavior of U.S. residents with regards to the deployment of this technology.

- **Transit-dependent population**: A group of U.S. citizens that are not studied sufficiently is the residents who do not own a vehicle for a number of reasons. Although the vehicle owners, students, and transportation experts are well-studied focus groups, transit-dependent residents that are the potential users of the shared autonomous vehicles are ignored.

- **Shared autonomous vehicles and autonomous transit**: Scholars have not paid due attention to the shared modes of AVs. Providing the option to select between different types of autonomous vehicles can improve the results of future studies. Reviewing the present surveys in the US, we just found (Zmud et al., 2016) that compared SAVs PAVs.

- **Innovative incentives**: As it is shown in different surveys, providing an incentive for consumers are considerably important to accept new technologies. Therefore, the inclusion of innovative incentives can improve the results of the future investigations.

3.2 The Implications of Real-Life Experiments

Since the AV technology has not been implemented in the U.S. yet, the reviewed survey is designed according to the theoretical modeling of AVs in the future cities. The author believes that reviewing the real-life implementation of the technology is important to find the shortcomings of existing studies. Thus, the author has examined the real-life experiment of AVs implementation in Europe and explains the human behavior in the implementation of AV technology.

CityMobil is a program funded by the European Union to test the possibility of integrating automated vehicles technology in urban spaces (CityMobil Consortium, 2010). The author selects this program to use their experience and draw takeaways for the U.S. In addition to the successful implementation of driverless public transportation, the program surveyed public viewpoints before, during and after implementation and applied the public opinion for the next phases of development. The program aims to adjust roads to make self-driving cars as safe as public transit while providing door-to-door mobility (CityMobil Consortium, 2010). To achieve this goal, cars need not only to be autonomous but should become a part of the Automated Road Transport System (ARTS). The plan had two periods of implementation: CityMobil1 (2006-2011) and CityMobil2 (2014-2016).

CityMobil1 is implemented in four types of ARTS”

- Personal rapid transit (PRT) (implemented in five cities): Autonomous personal transport systems using 4-place cars that drive in dedicated lanes. It serves as taxis transporting passengers without stopping (Alessandrini, Campagna, Site, Filippi, & Persia, 2015).

- Cyber Cars (CC): Autonomous road cars could carry between 4- 20 passengers and serve in a network as a collective taxi. These vehicles carry passengers with various origins and destinations and are implemented in four cities.

- Dual-Mode Vehicles (DMV): Environmentally friendly cars with zero or around zero-emission equipped with a driver assistance system, parking assistance, collision avoidance, and supporting fully- automated driving in certain situations. These cars are implemented in two cities.

- High Tech Busses (HTB): these buses use an infrastructure that either can drive in dedicated lanes or shared lanes with other vehicles. Different levels of automation can be used in these vehicles such as full- driverless and platooning, driver assistance, and guidance.

Based on the evaluating survey of the users, the following results are gained by implementing CityMobil2: This project began in 2014, and within two years, more than 60,000 passengers were carried by autonomous shuttles in 17,9000 trips (CityMobil2, 2016). The ARTS is implemented in different sites and provided services for different kinds of residents to test various issues that might happen about autonomous driving. Table 7 demonstrates the details of the project operations.

City	**Scale**	**Route length**	**No of trips**	**Distance covered (Mile)**	**No of passengers**	**Operation site**
Oristano, Italy	Small	1.3 km	781	1138	2,327	- The first CityMobil2 demonstration. The vehicles operated among pedestrians and cyclists
La Rochelle, France	Large	1.8 km	2100	2342	14,660	-vehicles interacted with cyclists, pedestrians, and cars
Lausanne, Switzerland	Large	1.5 km	4,647	4321	7,000	-The demonstration on a University Campus (EPFL). The implementation of an on-demand mobile application
Vantaa, Finland	Small	1 km	3,962	2456	19,000	-transported visitors from a railway station to an exhibition area
Trikala, Greece	Large	2.3 km	1,490	2219	12,138	-operated on a bus lane along with other road users, including car drivers, cyclists, and pedestrians.
CASA, France	Small	1 km	3,500	2170	4,059	-Provided a mobility solution for workers between the main bus stop and the different workplaces.
San Sebastián, Spain	Small	1,2 km	1,416	1053	900	-in the Scientific and -Interacted with cyclists, pedestrians, and cars. It was connected with the urban public transport center.

Table 2: CityMobil2 Demonstration Sites

The implementation of CityMobil2 faced various barriers in terms of legal, technical and social. These issues can be assessed in the future surveys of users' perception. This way, we can facilitate the implementation of future AVs project. Following are these issues:

- **The speed limit**: the speed limit was a controversial part of the implementation. Legislation of different countries has determined different speed limits for driverless buses. For instance, although the commercial speed in Vantaa, Finland was 40 km/h (28.4 Mil/h); users welcomed it, with a daily demand of 600 trips per day. Nonetheless, the speed limit of the ARTS was a repulsion for the implementation in Lausanne, Switzerland where there is no clear legislation regarding autonomous vehicles in this country. The autonomous buses were only allowed to drive on a university campus with a maximum speed of 20 km/h (12.5 mph). This was a serious concern for users, and even some of them preferred to walk rather than taking the buses (European Commission, 2016).
- **The right of way**: Lausanne, Lausanne was the only site that due to the legislative restrictions, the automated buses drove in dedicated lanes. In the other sites, buses shared streets with other cars, bikes, and people while there was no human backup for the automated buses. They were programmed not to change lanes or make turns while other vehicles could merge into their lanes. The successful implementation of the autonomous shuttle in shared lanes (with no reported accident) significantly increased the public trust in the surveys after implementation.

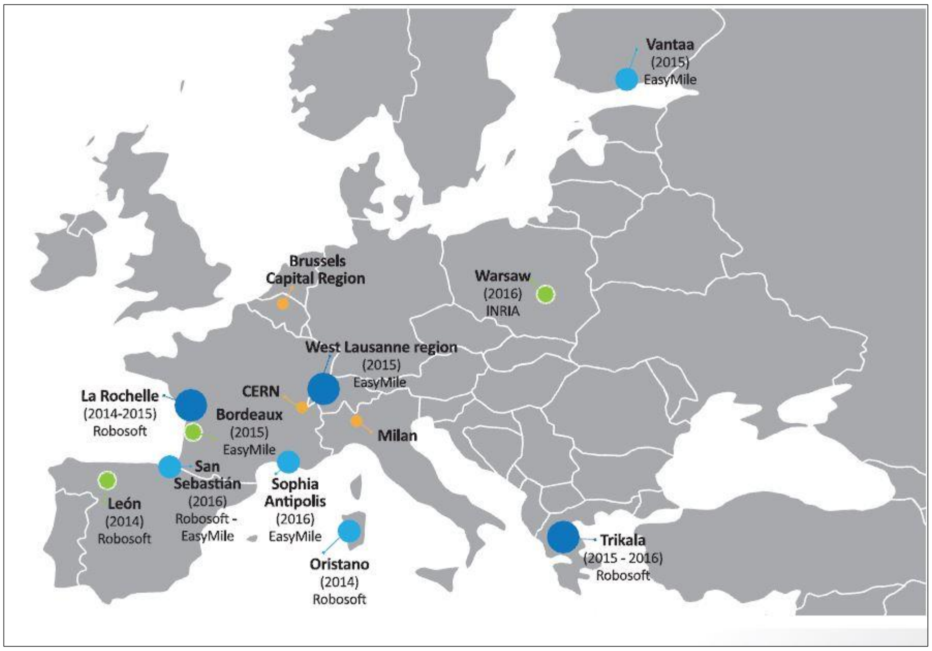


Figure 3-1: Implementation of the CityMobil2
Source: http://www.citymobil2.eu/

3.3 Stated Preference Survey in CityMobil2

In each site, a stated preference survey is distributed to explore the relative preferences of riders to compare conventional road public transport with an Automated Road Transport System (ARTS). Survey distribution is paper-based with face-to-face interviews, in the area adjacent to the proposed route, existing public bus terminal, and the surrounding areas. Passengers waiting for or exiting the automated bus and additional pedestrians were the main targets to interview. According to the study conducted in Vantaa, Finland, initially passengers were not willing to pay more for an automated transport system. However, they changed their opinion after experiencing the successful completion of the project. In other words, the proposed system was not promising enough in the beginning, but the benefits of the system performance eventually attracted users. The best benefit for passengers was more frequent timetables compared to the bus traffic, or even call-based traffic (Karaseitanidis, Lytrivis, Ballis, Amditis, & Raptis, 2013). However, in

Trikala, Greece, the first incentive for users was the innovation of the system (Karaseitanidis et al., 2013).

Meanwhile, the survey conducted in La Rochelle, France during the demonstration, revealed the following results:

- The automated transport system was well known for the residents
- The main reasons for choosing this service are 24h/7d availability, electric motorization and convenient door-to-to mobility to destinations.
- The main concerns were safety, low-speed of shuttles, and difficulty to connecting shuttle to control system
- Generally, the level of satisfaction was considerably high (Nair et al., 2013). Figure 5 shows the acceptance rate of this system in different European cities.

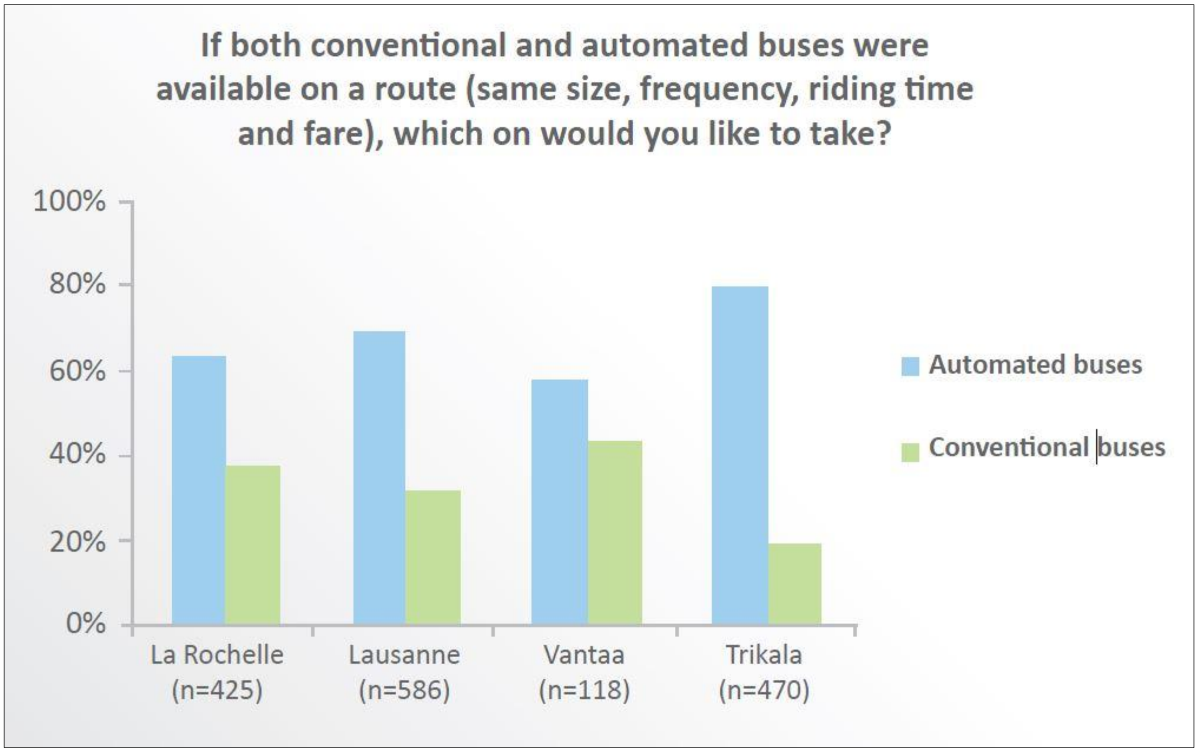


Figure 3-2: Results of a Survey after Implementation of Automated Buses
Source: http://www.citymobil2.eu/

3.4 Public Perception after Implementation

- The users prefer the Dual-Mode Vehicles (DMV) to other forms
- Survey respondents indicate further interest in paying for the innovative services presented by the ARTS and willing to substitute the private vehicle with this innovative technology.
- Users consider the PRT as the most convenient form of ARTS regarding emission reduction and performance.
- In the city center of small/medium cities, users show relatively higher acceptance of dual-mode cars and PRT (CityMobil Consortium, 2006).

3.5 Lesson Learned from the CityMobil Project

- **Showcasing**: The considerable difference in the public acceptance before and after the implementation confirms that even short time showcasing of the technology result in a noticeable impact on public opinion. Accordingly, there is a need to assess public opinion in the U.S. after the showcasing of the technology. This will present a more realistic picture of the public perception about automated vehicles.
- **Environmental benefits**: The environmental benefits of AVs are frequently ignored subjects in the U.S. surveys. As it is shown in the CityMobil1 project, environmental topics could be one of the main incentives for users to select AVs.
- **Legal issues**: Another takeaway from the CityMobile project is that legal issues such as speed limit and right of way could affect the acceptance of the AVs. Analyzing the public perception about these issues would help the policymakers to implicate legislations that facilitate deployment of autonomous cars.
- **Comparing different types of AVs**: In CityMobility1, three types of shared and private autonomous vehicles are tested and then the user's perception are evaluated for each of them. The results of the survey were the base for the selection of the autonomous buses to implement in CityMobil2. Considering different types of AVs in a survey will give the respondents the opportunity to choose the one that is well matched with their needs. For instance, low-income residents might tend to take advantage of the relatively affordable SAVs instead of paying higher costs for buying a PAV.
- **Overlooked issues:** As it is shown in the case study of La Rochelle, the main incentive for using shared autonomous vehicle is factors such as availability, electric motorization, and door-to-door mobility. These factors are not well-studied in the U.S. surveys.

3.6 Concluding Remarks

Although autonomous driving is the topic of a significant number of investigations, users' perception toward this technology is not broadly explored. Since AVs technology is not implemented on a large scale in the U.S., the actual public perception is not comprehensively studied. Therefore, the author analyzes the results of the real-life implementation of the AVs in Europe and compares them with existing surveys in the U.S. to explore the areas that have not studied well.

The results of this analysis confirm that although different aspects of the acceptance are considered and analyzed in previous studies, topics such as the effects of built environmental, legislative, autonomous transit are not widely studied in the U.S.

In terms of methodology, comparison of different types of autonomous vehicles is the method that scholars in the U.S. have not taken into closer consideration. To the best of my knowledge, Zmud et al., (2016) is the only study that compared shared autonomous vehicles SAVs with privately-owned autonomous vehicles (PAVs).

4 Chapter 4: Methodology

In this chapter, I explain the methodologies that I apply in this study. The chapter starts with the steps taken for designing the survey, collecting data, processing and analyzing data. First, I describe the stages of my work in the research design. Then I define the case study, the sample that I design and the reasons for selecting this sample. After that, I discuss data and variables, analytical methods and measuring built environment.

4.1 Research Design

After creating research questions and highlighting the importance and relevance of the study confirmed by supporting literature, the author seeks for the methods to respond the questions. Analyzing different methodologies, the author determines the most effective way to collect high-quality data and accordingly, defines six main phases as the following.

In the first phase: To create a comprehensive and innovative survey, the study analyzes the existing survey studies concerning the AVs acceptance in the United States. The results are compared and contrasted, methodologies, strengths, and weaknesses, to elicit takeaways for designing the ideal study survey. Additionally, the author closely examines the results of the real-life implementation of autonomous driving in Europe.

In the second phase: According to the results of the first phase, questions and the author decides criteria upon for the research survey.

In the third phase: A sample for data collection is designed considering the demographic factors that affect AVs adoption. Based on the success of the sample, the data regarding public perception towards AVs is collected.

In the fourth phase: Using the Geographic Information System (GIS), the author geocodes the location of the respondents and then make buffers around each location. Henceforth, measuring urban form factors surrounding its perimeter. Using online resources, secondary data is collected to measure built environmental factors such as density, mixed-use, and street connectivity.

In the fifth phase: Several statistical models are then created to measure the effects of built environmental factors (independent variables) on the rate of adopting AV technology (dependent variables).

In the sixth phase: The results are analyzed using different statistical methods, directly followed by a discussion of the results thus deriving policy implications and making a conclusion.

4.2 Survey Design

A well-executed survey is a systematic and precise method of gathering data that have become widely used as a research tool in academia. Moreover, in professional disciplines, a survey has gained considerable credibility as a research technique in recent years (Thayer-Hart & Jennifer Dykema, Kelly Elver, Nora Cate Schaeffer, 2010). The ultimate goal and major advantage of sample survey research is the ability to suggest generalizable findings for an entire population by drawing inferences based on data derived from a small sample portion of that population. To accurately derive generalizations, the researcher must apply a scientific and orderly system of data collection. The main advantages of employing survey for data collection in this study are explained as following":

1. Surveys can elicit information from large samples of the population, and they are well suited to collect sociodemographic data that represent the composition of the population (McIntyre, 1999).

2. Surveys are comprehensive in the type and amount of variables that can be investigated, do not need a high budget to be implemented and are relatively easier to generalize (Bell, 1996).

3. Surveys can gain information regarding the attitudes that are otherwise complicated to measure by other observational methods (McIntyre, 1999).

4. Surveys offer estimations for the true population, not exact measurements (Salent & Dillman, 1996).

Due to these advantages, the author chooses to implement a survey to analyze public perceptions towards the AV technology in the DFW Metroplex The process of conducting a survey includes five distinct steps:

1. Plan Survey Process
2. Developing Questions
3. Test & Train
4. Collect Data

4.2.1 Survey Goals

- Collecting data about the perceptions of DFW residents towards the following issue:
- The main advantages and disadvantages of AV technology for the residents
- The DFW residents' Willingness-To-Pay (WTP)
- The preferred types of AVs for the residents (private or shared)
- The socio-demographic information of the respondents

4.2.2 Developing Survey Questions

A surveyor can improve the likelihood of accurate responses by using sentences that are simple and understandable for everyone with any level of education (needs reference). Meanwhile, the survey is organized in a way that makes minimal confusion for the respondents by applying the following points:

- Applying words with a single definition or meaning
- Searching for word familiarity ratings
- Utilizing simple words with clear meanings
- Making simple and to the point sentences. A well-written question has the same meaning to whole respondents.
- Avoiding Double-barrel questions and asking only one question at a time
- Starting with broad, general questions and progress to specific and harder ones (J. L. Brown, 2017).
- Avoiding negatives and double negatives
- Controlling the number of ranking options
- Covering all options without overlapping in a multiple choice question
- Considering “Does Not Apply” or “Don’t Know.” options for questions that don’t apply
- Avoiding biased question
- Avoiding yes/no questions cautiously

4.2.3 Controlling For the Potential Biases

The order of question can affect respondents' choice. The most significant points that the author considered for designing an unbiased survey are:

Order Effects: The location of a question can have a significant effect on the outcome through the particular choice of words used in the question. When deciding the order of questions in the survey, the author considers how questions early in a survey might affect unintended effects on how attendees respond to subsequent questions. Earlier questions especially the ones that are directly preceding other questions might influence the context of the following questions. This influence is called "order effects" (U.S. Survey Research, 2014). To address this bias, the author asks about AV adoption before asking about the pros and cons to make sure that survey information does not influence the respondent's idea.

Contrast Impact: some studies recommend to ask more specific questions before more general questions (e.g., a question regarding happiness with marriage questions regarding general happiness) can lead to a contrasting impact. To avoid this bias, the author has randomized the order of the questions for each section of the survey. The random ordering avoids any priming, providing every question an equal opportunity of being first to read. (FluidSurveys Team, 2015). Salant and Dillman (1994) stated that response options should be limited to less than five choices and a series of questions should be used to address relatively more complex and abstract issues.

4.2.4 Survey Structure

The survey starts with a brief introduction surrounding the AV technology to make the respondent is familiar with the subject. Then in different sections, respondents answer the questions regarding various aspects of AVs and SAVs. Meanwhile, the author used the Qualtrics survey development tool[6], for easy survey creation and strong analysis of data. After the final approval of the survey by the members of the dissertation committee, the author submit an exempt-level IRB protocol in the Profiles IRB (Institutional Review Board) Submission system for approval [7].

The main sections of the questionnaire are as follows:

- **Section A**: Asks participants about their demographic features such as age, gender, education level, income, ethnicity, household characteristics, and house address.
- **Section B**: Asks participants about their travel behavior like transportation modes that they use, average traveled miles, their familiarity with technology and relationship to cars
- **Section C:** The survey asks respondents about their perception of autonomous vehicles and their intention to buy or use different AVs. Meanwhile, the Willingness-To-Pay for each mode are the other questions in this chapter.
- **Section D:** Questions in this section are surrounding the legal aspects of autonomous driving. Meanwhile, the effects of the driverless technology on another mode of transportation such as walking and transit are the other topics in this section.
- **Section E:** Different predicted advantages and disadvantages of driverless cars are explained in this section and ask respondents to rate these features.

---

[6] Qualtrics software enables users to do many kinds of online data collection and analysis including market research, customer satisfaction and loyalty, product and concept testing, employee evaluations and website feedback.

[7] Institutional review board (IRB), is a type of committee that applies research ethics by reviewing the methods proposed for research to ensure that they are ethical. All Human Subjects Research conducted by students, faculty, or staff of American University must receive approval from the American University IRB

- **Section D**: Again asks participants about perception toward AVs to analyze whether familiarity with advantages and disadvantages affected their idea. The perception of respondnets regarding other innovative transportation modes such as flying taxis, The Hyperloop and Bullet Train are asked in the section

In this research, based on the type and goals of the survey, the author has selected the following mode:

- Survey population: 300
- Contacting methods: Data collection based on the designed sample
- Survey techniques: Online Survey

4.3 Case Study Selection

The Dallas-Fort Worth (DFW) metropolitan area is selected as the case study for this investigation due to various reasons that are explained in this section.

The DFW metropolitan area includes eleven counties that are Collin County, Dallas County, Denton County, Ellis County, Hood County, Johnson County, Kaufman County, Parker County, Rockwall County, Tarrant County, and Wise County (figure 1). The Metroplex is the fourth largest metropolitan area in the nation by 7,246,350 residents (Census, 2016). The population density is 766 people per square mile. In total, 2,445,239 households live in the Metroplex with Median household income of $59,530 and the per capita income for the MSA is $21,839 (US Census, 2010). Moreover, the region is racially diverse with a total minority population of approximately 50.63%.

The population growth has been fast. It is the second most significant gains of any metro areas in the country by adding 145,000 residents per year (USC, 2016). Although the population of the area was around three million in 1980; it reached 6,371,773 in 2010 based on the United States Census (figure 2). However, the North Central Texas Council of Governments (NCTCOG) has predicted that the population of this area will pass 10 million by 2040 (NCTCOG, 2015), if it continues to grow at the present rate.

The significant population growth in the area will raise the traffic congestion (NCTCOG, 2011). New policies, construction, and modes of transportation are needed to control the increasing congestion (Figure 2). Lu & Tang, (2004) analyzed the DFW area to explore the relationship between the complexities of road systems with the growth of human settlements. The results emphasized that the development of the area will lead to a more complex road network to meet its transportation demand (Lu & Tang, 2004). AV technology could be a part of this elaborated road network that will contribute to addressing future transportation demands. However, research studies are needed for implementation of this mode of transportation in the area.

The DFW metro area offers a diverse variety of urban forms ranging from compact places, such as Downtown Dallas and Downtown Fort Worth, at one end of the urban form continuum to suburban and sprawl areas at the other. The Metroplex area consists of eleven counties that are substantially diverse in terms of population density, urban design, land use diversity, demographics and public transportation systems (Figure 4). Comparison of data gained from each of these counties will provide a broad perspective regarding the factors that influence public adoption. Therefore, the findings of the research in the DFW region can be generalized to other American cities.

The DFW area is a hub for innovative transportation modes, and the authorities welcome technology. Dallas Mayor Michael Rawlings stated that "Every part of this marketplace, we see tremendous growth. So it’s going to need innovative transportation answers.” Dallas has to be “multi-modal,” with many ways to get around. He touts the construction of a high-speed rail link to Houston, for instance. “Anytime there’s innovation in the marketplace; I don’t think anybody truly knows the results of these things or the costs,” he says. “We’ve got to be multimodal there’s no question in this city.”(Captain, 2017). The Hyperloop project is another upcoming innovative transpiration modes that are under consideration to connect the DFW area to Houston and Austin metropolitan areas (Goodman, 2017). Moreover, the DFW area is selected as one of the two Uber sites chosen to test in the world (besides Dubai) to demonstrate flying vehicles by 2020, with full-scale operations (Financial Times, 2017). All of the above, AV technology might be a supplement to the other innovative transportation modes currently under consideration or construction in the region.

Besides the High-Speed Rail and Hyperloop projects, there are other planned transportation projects such as the Dallas-Fort Worth Core Express Project, Lone Star Regional Rail Project, and the Texas-Oklahoma Passenger Rail Study. Implementation of these projects will provide an innovative opportunity for the DFW area to be connected to the metropolitan areas of Houston (which has the largest gains of any metro areas in the nation by adding about 159,000 residents annually), Austin and Oklahoma City in less than a half an hour trip will increase the number of trips to this area. Consequently, in addition to the growing population, the number of passengers traveling to the area will surge.

Furthermore, as a result of the relatively low density of the population in most parts of the region, fixed route public transportation such as a bus or light rail may not be functional and cost-efficient. Moreover, in some conservative parts of the region, residents might not be welcoming to the traditional modes of public transit such as fixed route buses. For instance, Arlington is the largest American city without transit system. However, the authorities of Arlington hope that the attractions of shared autonomous vehicles will change public opinions about shared riding.

Finally, since the author lives in the DFW area, he has access to a wide variety of data resources, and can easily conduct interviews over an extended period, in a diverse set of geographies within the region.

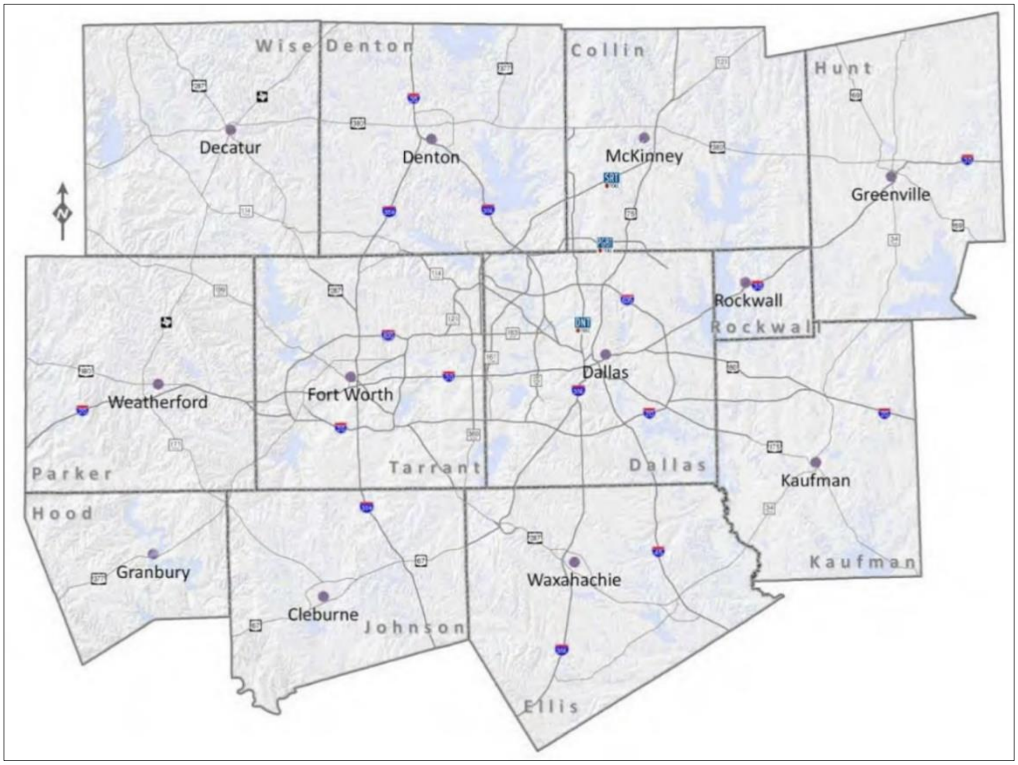


Figure 4-2: Counties of the DFW area

Source: http://dfwpts.com/test/site_flash/images/counties_d_lg.jpg

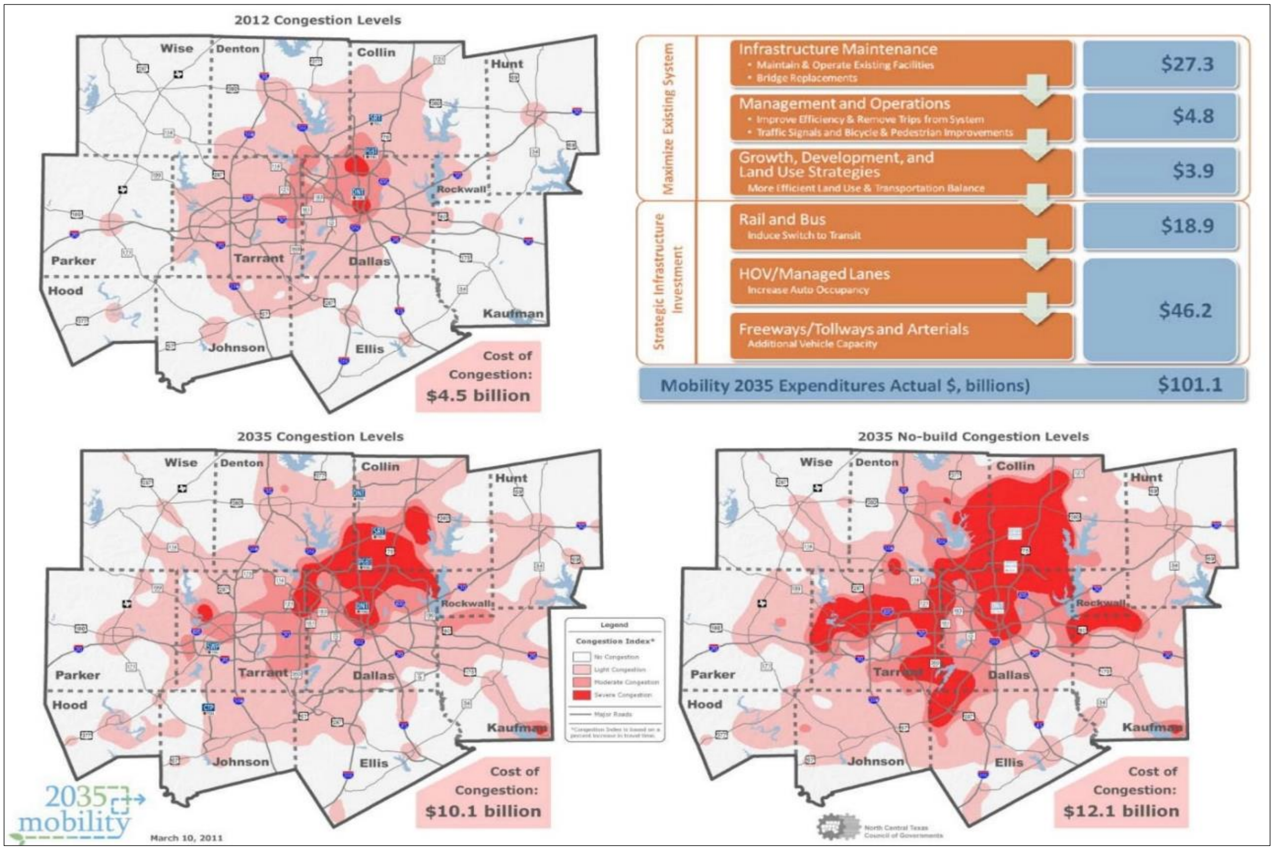


Figure 4-2: Congestion Costs in the DFW Metroplex with and without New Developments
Source: Mobility 2035 for North Central Texas. North Central Texas Council of Governments (NCTCOG), 2015

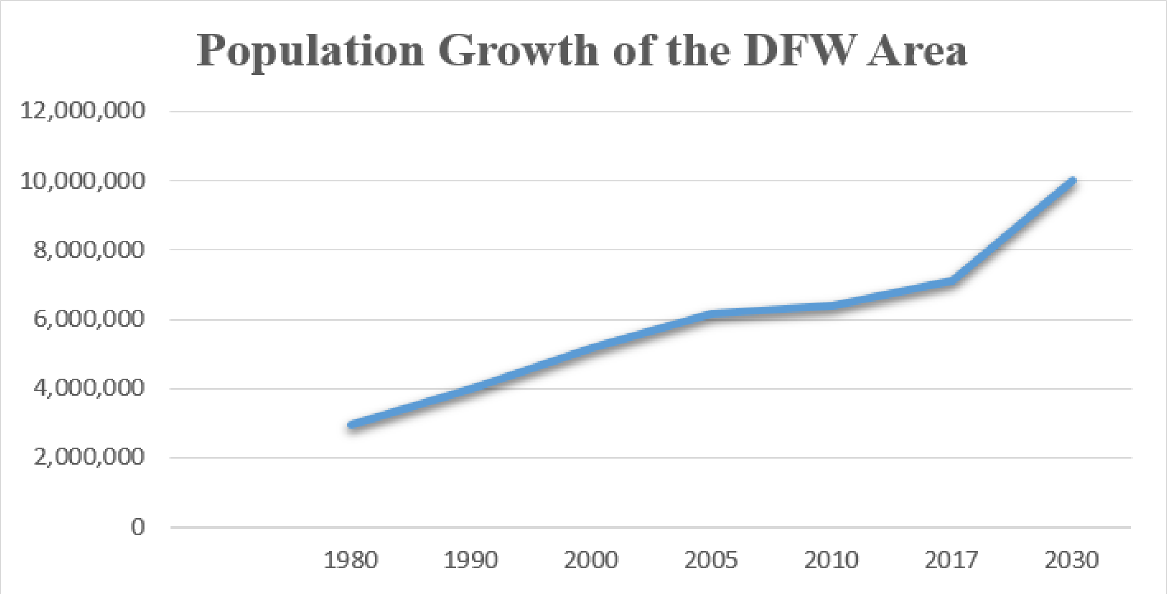


Figure 4-1: The Current and Predicted Trend of Population Growth in DFW Area
Source: United States Census, 2016

4.4 Survey Distribution & Data Collection

In order to understand the perception of the DFW residents, the study needs to create a sample of residents by recruiting participants for the survey. Sampling aims to improve the representativeness of the sample. The author accesses different types of sampling and selects the one that is appropriate for this study. Additionally, the author defines the criteria for sampling that are explained in this section.

4.4.1 Sampling Types

There are two primary sampling methods: probability-based samples and non-probability-based samples. In the probability-based samples, the surveyor has access to a list of contact information of the members in the target population (i.e., a “sampling frame”) and utilizes some form of random selection to create a sample. Surveyors use computers as the mechanism for generating random numbers as the basis for random selection (Yeager et al., 2011).

However, the challenge posed by the lack of a sampling frame sometimes lead researchers to conduct nonprobability (Villalon & Leclair, 2004). Nonprobability sampling does not include random selection, and survey participants can choose not to participate in the survey (‘opt out’). Therefore, samples are selected based on the subjective judgments of the researcher, instead of random selection.

In both types of survey, there is the possibility of bias, and there is often no way to assess the potential magnitude of the bias since there is no information on those who choose not to participate. However, as much as the collected demographic data of the sample is closer to the demographics of the area, the accuracy of the survey is higher.

In this study, the author uses non-probability samples due to the access limitation of contact data for all DFW residents, as well as the limitations of time and budget for the study.

4.4.2 Sampling of the Study

Previous studies show that key socio-demographic characteristics that significantly influence AVs acceptance are demographic characteristics such as gender, age,disabilities, and education, as well as other factors such as travel patterns, and familiarity with technology (Bansal, Assistant, & Kockelman, 2016; Haboucha, Ishaq, & Shiftan, 2015; Howard & Dai, 2014; Krueger, Rashidi, & Rose, 2016; Kyriakidis, Happy, & de Winter, 2015; Schoettle & Sivak, 2014).

The target sample of the study is 300 respondents that are directly proportionate to age, gender, disabilities, and location, to the population of the area based on the 2016 American Community Survey. The study includes four factors of age, gender, disabilities (that prevent driving) and geographic location as criteria to select respondents. The number of respondents for each factor is a ratio of the percentage of that variable to total the number of respondents. For instance, the percentage of the population who are male is 49.24% of the total population. By dividing this number to 100 and multiplying by 300 (total number of respondents), I computed the number of male respondents.

$49.24/100 = X/300$, $X=148$ or $49.37/100*300 = 148$

Table 3 and Table 4 respectively show the demographic characteristics and the location of the population in the area and the expected number of respondents for each group.

However, the calculation for the age variable is different since the survey does not include the population under 18 years old (27.2 %). Therefore, the ratio is calculated by dividing the total number of respondents to the percentage of 18 plus population (300/72.8=4.12). For instance, the category of 18-24 years old is 9.4% of the total population. Hence, the expected population in this age category is approximately 38 respondents (9.4*4.12= 38.7). Table 3 illustrated the percentages of age categories in the study area and the expected number of respondents for each category.

	Features	Percentage of population	Number of Respondents
Age	Under 18	27.2%	-
	18-24	9.4%	39
	25-34	14.8%	61
	35-44	14.7%	60
	45-54	14%	58
	55-64	10.3%	42
	65<	9.6%	40
Gender	Female	50.76%	153
	Male	49.24%	147
Disabilities	No disabilities	90%	270
	With a disability	10%	30

Table 3: The Demographic Criteria for Designing the Sample

4.4.3 Location of Respondents

In order to cover respondents from all 12 counties in DFW, the author collectes the population data of each county from the USC, (2016) and calculates the ratio of the county population to total population. Based on this ratio the expected number of respondents in each county is calculated. For instance, Denton County has 10.6% of the total population (754,650 residents) therefore 10.6% of the total respondents are from this county (32 respondents). Since the study measures the impacts of urban form, the rural areas are excluded and all respondents selected from the urbanized portion of the DFW metro area. The seven selected counties include more than 95% of the population of the Metroplex.

	County	Population	Percentage	Respondents
1	Dallas	2,618,148	38.10%	115
2	Tarrant	2,054,475	29.90%	90
3	Collin	969,603	14.11%	42
4	Denton	836,210	12.17%	36
5	Ellis	173,620	2.53%	8
6	Rockwall	96,788	1.41%	4
7	Kaufman	122,883	1.79%	5
	Total	6,871,727	100%	300

Table 4: Distribution of population in the Area and Expected Respondents
Source: USC, Population Estimates, July 1, 2017

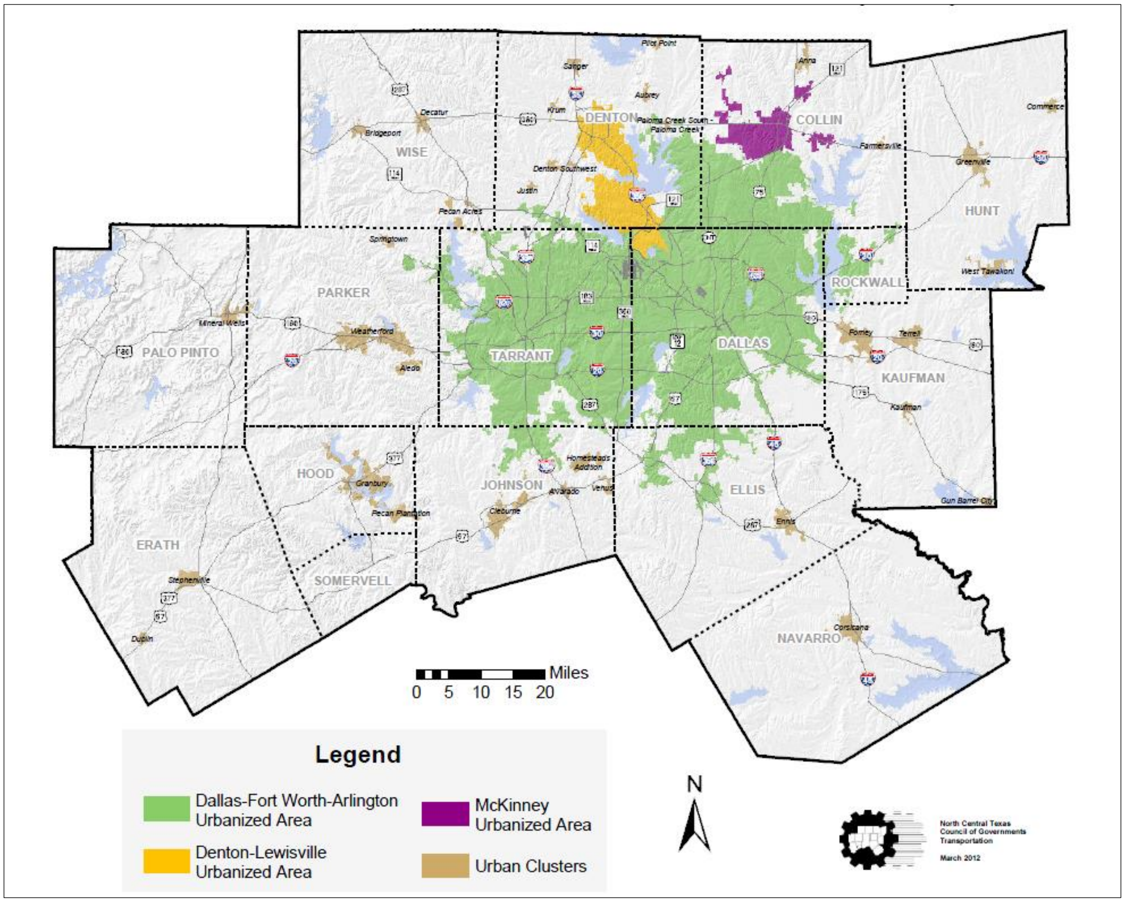


Figure 4-3: Urbanized areas of Metroplex
Source: https://www.nctcog.org/

4.4.4 Pretest and Train

After finalizing the survey design by advisory committee members and obtaining the IRB approval, I proceed with the pre-testing data collection. Qualtrics draw a small sample of 30 respondents (10% of the sample) similar to those used in the main study to attain the information required and test the validity and accuracy of the survey.

Pre-testing is essential to make sure that the survey has considered the following points:

- Questions and choices are clear and detailed
- The survey is inclusive and unbiased

- Information is possible to attain
- The terminology is used properly

Generally, the quality of the survey is evaluated throughout this pretest. The author uses this sample network as the test bed for whole measures to be unified and advanced for the comprehensive network. After analyzing the results of pretest and making sure, I make the survey question are unbiased and clear to understand, I start the main process of survey distribution.

4.4.5 Survey Distribution

The author uses Qualtrics Panel as a professional survey software to conduct the survey. Qualtrics has developed a series of proprietary computer software programs that facilitate and automate the process of conducting surveys, polls, intercepts, and reports. Qualtrics Panel provides contacts for targeted groups including specific parameters that have been identified for the study. This software also can include but is not limited to specific age ranges, genders, ethnicities, behaviors, and more.

The number of respondents for each category is given to the Qualtrics Panel Management, and the data was collected accordingly. Qualtrics Panel Management facilitates recruiting, engaging, and rewarding the in-house panel of survey respondents and provides a project manager who improves checking each response. Additionally, the author can build rich, in-depth profiles for each panel member, providing more targeted and personalized research, every time he uses his panel.

Qualtrics sent the survey out through its panel partner to the targeted respondents, inviting respondents to complete the online survey in return for an incentive/ cash honorarium.

Qualtrics reviews quotes and screeners, add redirects and approve the survey before launching to the targeted respondents. This can include evaluating additional skip logic or display logic.

As it is discussed in the sampling section, the author has designed a 300-respondents sample that reflects geographical location, age, and gender and race of the target population. Qualtrics is able to collect data based on the criteria of the sampling. For instance, 106 respondents are from Dallas County, or 30 respondents are disabled (According to the ratio of disabled population to the target population). Moreover, the Incident Rate of data collection is 80%. It means Qualtrics is supposed to collect 375 responses to make sure at least 300 responses are qualified for the research. The author has two weeks due time to check all responses and clean data, and if any of the responses have any issue such as duplicate records and straight-lining, the author can ask Qualtrics to replace that survey with a new one.

4.4.6 Data Cleaning

After collecting the data, the author cleaned data to make sure all the respondents answer the questions, and there is no mistake in the responses. The author removes incomplete respondents and askes Qualtrics to replace them with new respondents. To evaluate and clean the data, the author applied a number of priorities and post hoc techniques as follows:

1- Checking the duration to response: Based on the experience that respondents who complete the survey too quickly (less than 30%-50% of the median time),are likely not reading or answering the questions appropriately. In this study, the author identifies and removed responses with under 5 minutes duration time.

2- Spell checking: The author checks the spelling of the answers to the questions regarding the county of residence and the closest intersection (open-ended responses).

3- Duplicate rows: the author identifies duplicate and removed. Duplicate records are assumed to be indicated by two surveys with the same information and response in separate submissions

4- Christmas-tree: This pattern happens when a respondent selects the choices in a diagonal pattern without reading the questions carefully.

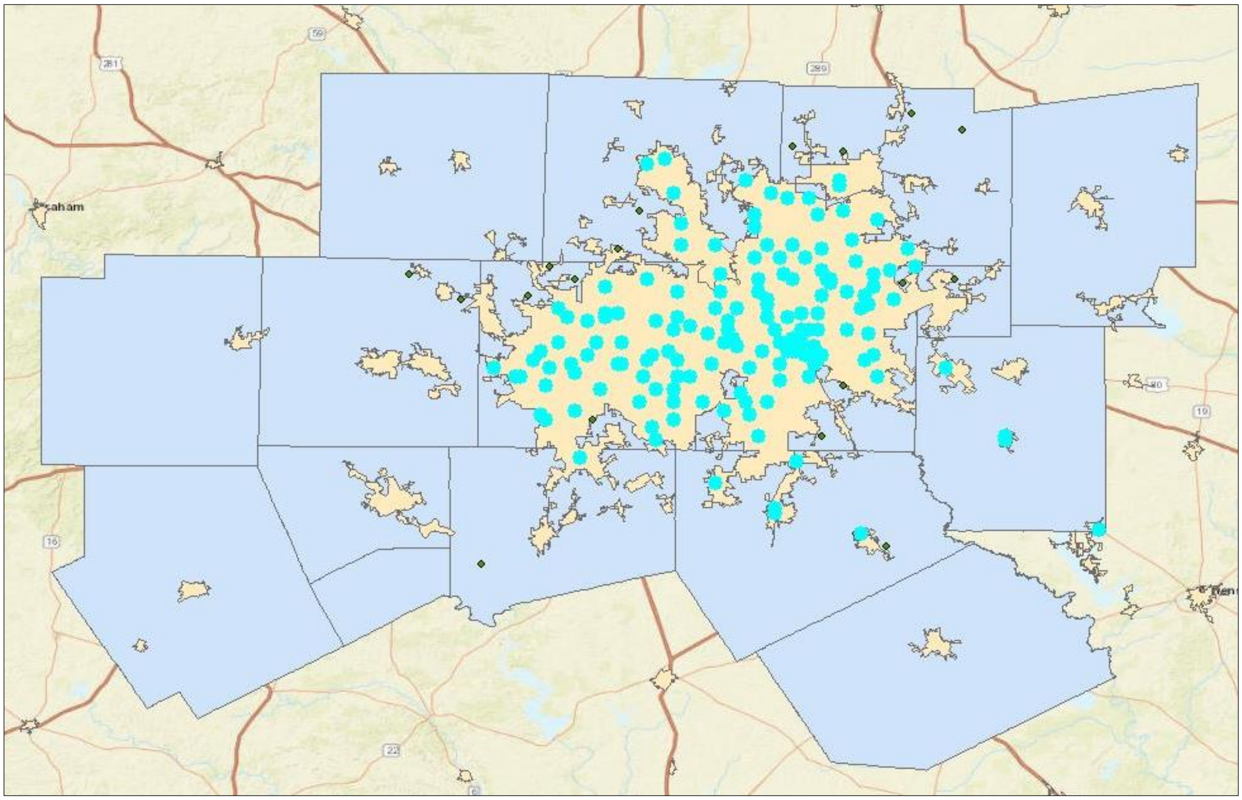


Figure 4-4: Geocoding the Locations of the Respondents

5- Trap questions: trap questions are included in the surveys to identify respondents who are not reading the questions before selecting their response, or who are using automated response methods.

   For instance, a question asks about the number of householders following with the question about the number of licensed members in the household. The respondents who pick higher numbers for the licensed drivers in the household than the number of household members are removed from the sample

6- Checking address: after geocoding the addresses, the respondents who are out of DFW metropolitan area removed. Meanwhile, the respondents who are out of the urbanized areas of the DFW metropolitan area are identified and removed.

4.4.7 Technical Consideration in Survey Distribution

To assure the quality data collection is high, the author checks the most important social issues that affect collecting the high-quality data discussed by Lofland & Lofland (1995):

4.4.7.1 Ascriptive Categories

A considerable number of studies on fieldwork have attention and sensitivity, documented the many contexts and situations in which ascriptive categories (particularly gender) can create barricades to the achievement of rich data (see, for example, Darn 1986; El-Or 1992; Martio 1978, 1980; Reinharz 1992, Chapters 2 and 3; Warren 1988; Wasserfa1l1993; R. Wax 1979). Ascriptive identity categories are realities- albeit socially built ones-and, as a result, requires to be considered in preparing a study. However, they should not be over-highlighted.

However, Lofland & Lofland, (1995) discussed that even if a researcher is not "identical" to investigated people, it does not mean a study of this nature is impossible or even that it will be problematic. In this study, the author is an international student collecting data on US residents. However, the author lives in the area for five years and has a relatively good knowledge of the area. He also consults with local people and by reviewing the studies about the area, increases his familiarity with the region.

4.4.7.2 Large Setting

Fieldwork studies are traditionally and usually, conducted by the "solo operator" (Manniog, 1977). However, the extent and difficulty of some research settings or subjects may create challenging between the single fieldworker and the data the researcher is responsible. In these situations, the researcher should take the possibility of a team examination into account. On the other hand, excessively large teams usually produce big problems, particularly if many of their members are "hired hands" (Florez and Kelling 1984; Roth 1966; Staggenborg 1988).

In teams with two or three members, even when the members have the same position and obligation, troubles of communication and coordination can arise (Shaffir, Marshall, and Haas 1980). However, two or more people working together in coordination have positively developed various field investigations (Becker, Geer, and Hughes 1968; Becker, Geer, Hughes, and Strauss 1961; Glaser and Strauss 1968, 1965; Snow and Anderson 1993; Snow, Robinson, and McCall 1991). In this research, the case study is a populated and widespread area, and it makes it difficult for the author to travel to the whole area. To address this limitation, the Qualtrics Panel is hired to collect data.

4.4.7.3 Ethical Considerations

Salant and Dillman (1994) pointed out the significance of maintaining the confidentiality of individual responses and presenting survey findings just at the aggregate level. All the collected data are used just for the research and are not shared with any organization or person. The author uses UTA Box[8] to save data and makes sure that no one can get access and use the data.

4.4.7.4 Controlling for limited-English proficiency

Nonresponse level is generally higher among ethnic groups than among the native population (Feskens, Hox, Lensvelt-Mulders, & Schmeets, 2007). High nonresponse rate can have severe outcomes for investigators since it may lead to biased survey estimates. Meanwhile, higher ethnic minority response rates can present a reasonable estimate of subpopulations.

The low rate of responses among minorities is mainly due to unfamiliarity with the English language. In order to address this, the author designs the survey in the two most common languages in the area that are English, Spanish. At the beginning of the survey, there is an option for respondents to pick the language that they that they like to respond question with. Based on the United States Census, (2016), 86.7% of residents in the case study area are not Limited English Proficiency (LEP), and 10.6% are Spanish LEP. Accordingly, the survey covers more than 97% of residents in terms of language barriers.

---

[8] Box online storage is like a hard drive in the cloud. Store documents and files in Box and then access them anywhere, anytime, from any device. Box also can synchronize files from your local hard disk automatically providing a backup that will always be available from other computers and devices.

Another factor that plays an important role in the low rate of responses among minorities is unfamiliarity of an ethnic minority with the survey or survey organization. The author addressed this issue by announcing the survey in a more custom-made mode.

Moreover, the incentive that is considered for participating in this survey can increase the chance of response by minorities.

4.4.7.4 4.4.7.5 Biases in Data Collection

The following are a number of biases that may affect the validity of the data collected by the survey.

Under-coverage: It occurs when some members of the population are inadequately represented in the sample. To avoid this bias, the author designs the sampling in a way that includes a diverse range of the population of the area in terms of age, gender, race, and location.

Nonresponse error: Nonresponse is the failure to collect information from sampled respondents. There are two types of nonresponse: unit nonresponse and item nonresponse. Unit nonresponse occurs when the survey fails to obtain any data from a unit in the selected sample. Item nonresponse (incomplete data) occurs when the unit participates, but data on particular items are missing. Qualtrics controls this bias through finding respondent that accept to answer the entire survey.

Other sources of error include the intentional misreporting of behaviors by respondents to confound the survey results or to hide inappropriate behavior. Finally, respondents may have difficulty assessing their behavior or have poor recall of the circumstances surrounding their behavior. To avoid these biases, the survey is designed in a way that asks no confidential or sensitive question.

4.5 Data and Variables

In this study, the author uses both primary and secondary data sources. The primary data is gained from the survey, and the secondary data from different online sources.

The dependent variables of the study are the adoption of driverless cars (private/shared) and Willingness-To-Pay for autonomous vehicles (private/shared). The independent variables of the study are in three categories: socio-demographic variables, travel behavior/preference variables and built environmental variables (D-Variables). Table 5 demonstrates the dependent and independent variables of the study, a definition for each variable, and the source of the data.

4.5.1 Public Adoption Variables

After a review of existing research reveals in chapter 2, scholars consider SAVs as a separate mode of transportation from PAVs because of its unique characteristics (Burns, Jordan, & Scarborough, 2013; Chen, Kockelman, & Hanna, 2016). In view of that, the research assesses public adoption for both SAVs and PAVs in two options for each, so in total four AVs adoption options are presented to the participants as Table 13 illustrates.

The reason for this kind of assessment is that each option has its own features that might be attractive for some groups of the population. For instance, low-income users might not be able to afford to buy a PAV so that SAVs services could be a more suitable option for them. Similarly, some residents might not like the idea of car-sharing, but a private AV can be an appealing choice for them. In the end, the author created an index called acceptance to examine the overall

AVs acceptance by determining the percentage of the respondents who picked at least one form of AVs adoption.

4.5.2 Socio-Demographic Variables

Gender, age, and disabilities are the variables that the author uses to design sampling. Besides these variables, other socio-demographic variables of residents that the survey collects are: ethnicity, level of education, annual household income, type of residence, household size, number of licensed drivers in the household, employment, level of familiarity with technology.

4.5.3 Travel Behavior/Preference Variables

Besides socio-demographic variables, the survey gathers information regarding the travel behavior of residents such as car ownership, type of car insurance, the average annual VMT for commuting and non-commuting purposes, number of owned cars in the last ten years, number of experienced car-assistant features, and experience of car-sharing services.

4.5.4 Built Environmental Variables

In order to measure D-Variables, the study needs the location of respondents. Thefore the survey askes respondents' location and the author geocode the collected data. Geocoding help the author to identify the locations out of urbanized areas[9] and remove them. Figure 6 illustrates the locations of the respondents that are used in the analysis. GIS Analysis (Geocoding)

---

[9] The term "urbanized area "as defined by the U.S. Census Bureau denotes an urban area of 50,000 or more people. Urban areas are defined by core census block groups or blocks with population densities of at least 1,000 people per square mile and surrounding census blocks with densities of at least 500 people per square mile.

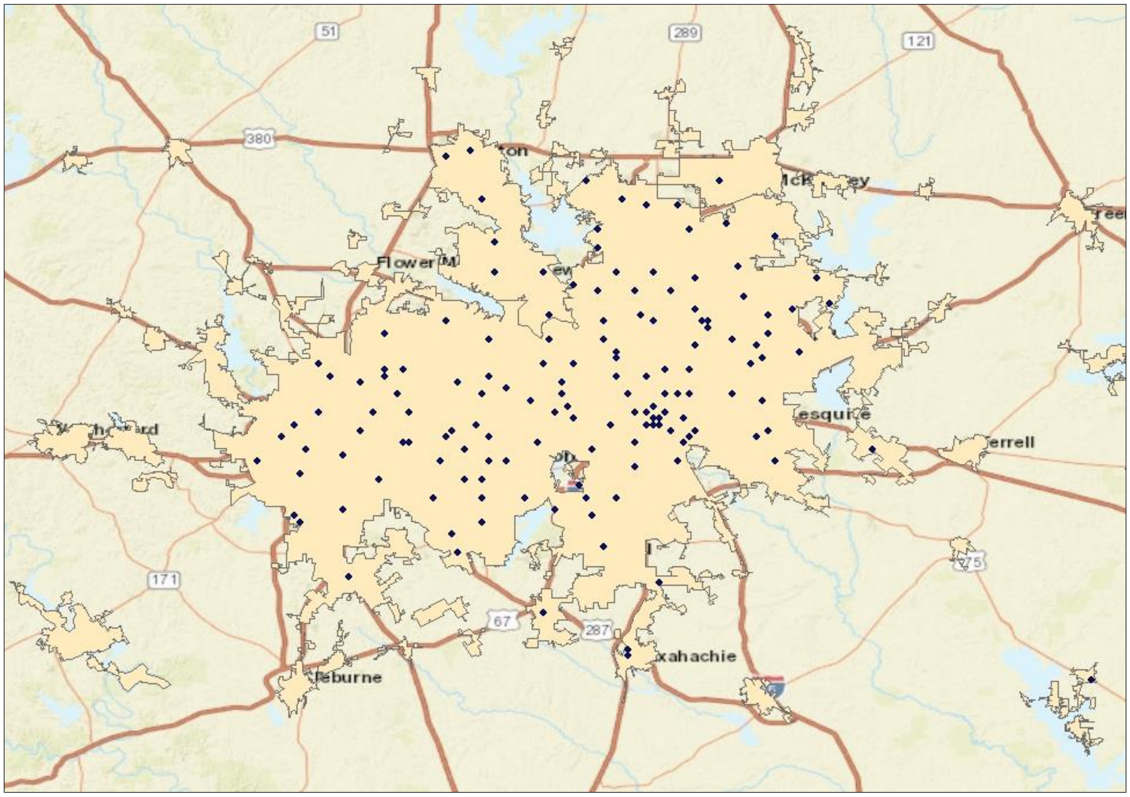


Figure 4-5: Geocoded Locations of the Respondents

4.5.4.2. Impact Areas (Network Buffers)

In order to accurately measure the built environment around each respondent's place of residence, the author creates network buffers. Euclidean buffer identifies a straight-line distance, and creates a circle to show the area that is within that distance. However, making a network buffer around a point not only indicates a distance but also signifies the maximum distance that can be traveled along a network, such as a road network. The outcome is a service area covering the roads that can be reached within the specified distance (0.5 miles in this case).

The author make a half-mile network buffer around the address of each respondent in order to estimate values of D-Variables in the buffer area and model the precisely built environment in which each respondent lives.

Several studies recommend the half-mile distance for measuring built environment (Ewing, 1998; O'Sullivan & Morrall, 1996; Sallis, Frank, Saelens, & Kraft, 2004; Khan, Kockelman, & Xiong, 2014). For instance, Brownson et al., (year) define a neighborhood as a half-mile radius or a 10 min walk from the residents' house. In this distance, they measured the physical and social environments, including perceptions of the community environment (e.g., whether the neighborhood is pleasant), safety, access to recreation and shopping destinations, and conditions of the neighborhood and facilities (Brownson et al., 2004).

Ewing, (1998) discuss that most residents do not walk more than a half mile. Therefore transit station may not be farther than a half mile away to cover a service area. This method causes the call in numerous transit-oriented growth manuals for transit routes every half mile, and for collectors or arterials to set apart consequently (Denver Regional Council of Governments, 1993; U.S. Department of Transportation, 1998; W. Bowes & Noxon, 1991). Collectors and arterials are preferred for transit use over local roads due to their broader lanes, and longer distances end to end. The half-mile spacing of higher-order streets and transit routes is a reasonable target for network density, as stated in the book *Best Development Practices* (Ewing, 1996).

After buffering, the study calculates the Federal Information Processing Standard Publication (FIPS) codes for each location and performed the spatial join to calculate the D-Variables for each buffer area.

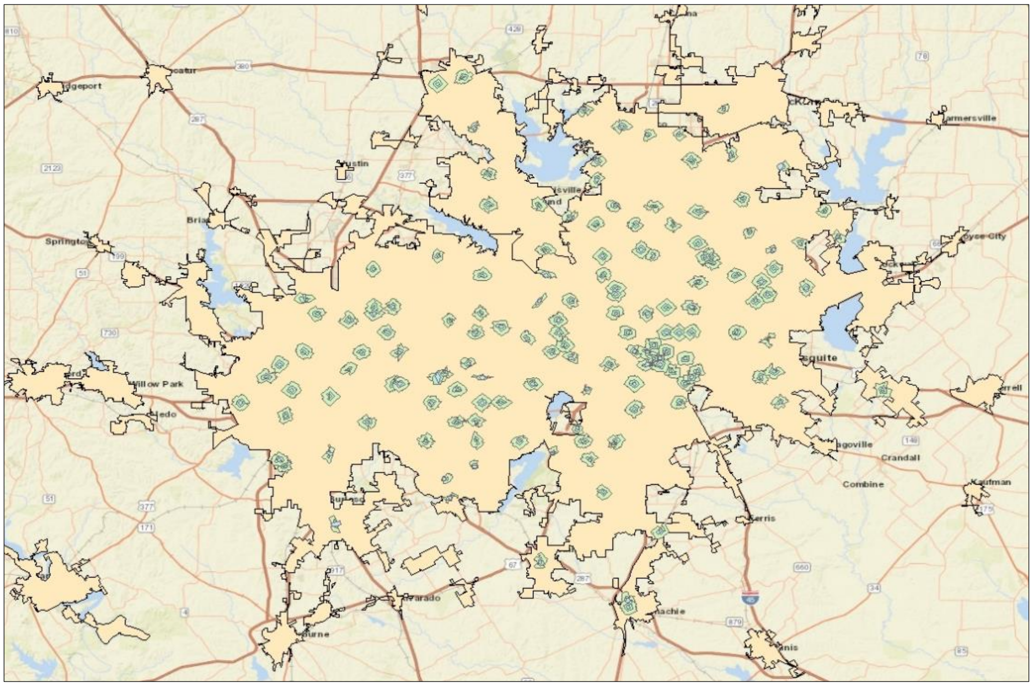


Figure 4-7: Hal-a-Mile Network Buffers Around the Location of each Respondent

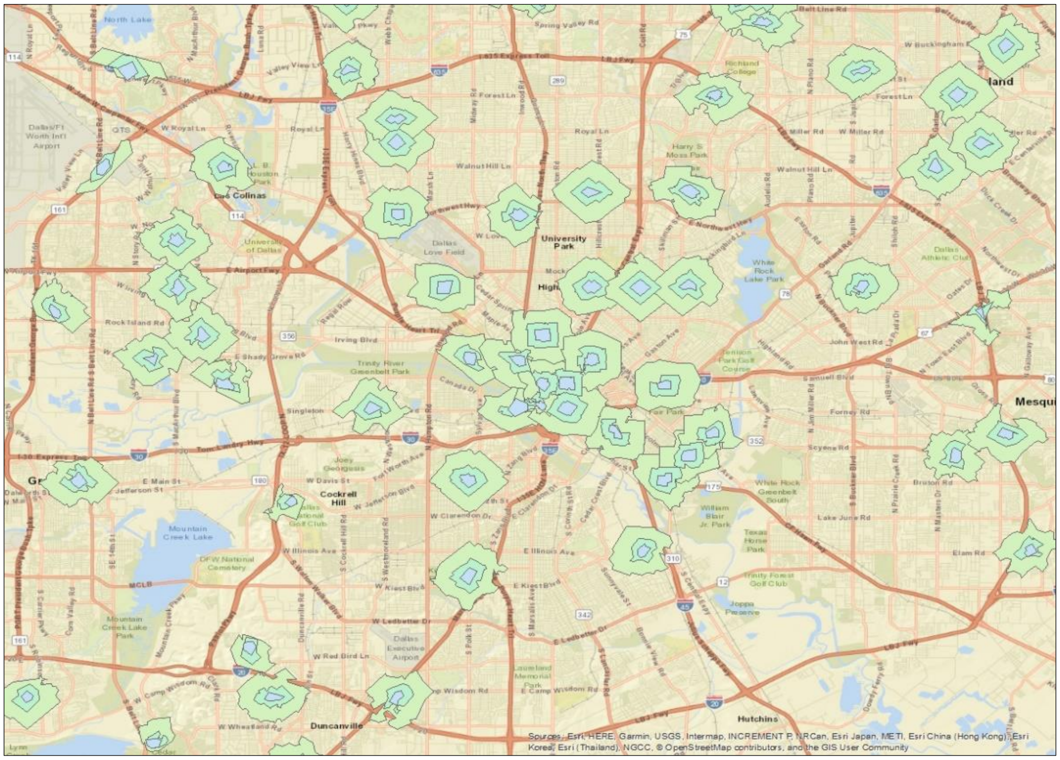

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, © OpenStreetMap contributors, and the GIS User Community

Figure 4-7: A Zoomed-in View of Network Buffers

4.5.4.1 4.5.4.3 Measuring D-Variables

After creating half-mile network buffers around each location, the author measures the D-Variables within each buffer as follows. Table 5 indicates a summary of all variables and how the study measures D-Variables.

Density index reveals how intensively land is utilized for population, housing, employment, building floor area, and other constructions.

Research usually measures density as the sum of residents, employees or residential units per unit of area (acre, hectare, a square kilometer or square mile) that comprises considerable undeveloped regions. For many applications, it is better to use weighted density, which weights these densities by each tract's share of that factor for the metropolitan region. This reflects the weighted average densities in the areas where people live or work. A substitute method is net density that does not include undeveloped areas, but it needs comprehensive land use data. However, weighted density requires just a census tract population /employment data and land area (Kolko, 2011).

The study area might be gross or net, and the factor of interest might be population, dwelling units, employment, or building floor area. Most studies sum population and employment to measure activity density per areal unit (Chatman, 2005). This study uses the ''total activity density'', which is the activity density within a half-mile of a location (sum of population and employment divided by gross land area in square miles in 1000s).

Diversity indicates the degree that is a mixture of land-uses existing in a given area and the level to which these land uses are balanced in the area, floor area, or employment. Scholars compute land use diversity with different methods. The entropy index measures the land use mix between five different land uses (retail, entertainment, health, education, and personal services) and the higher value of index means more mixed land uses.

The job–population balance is a variable to measure land use diversity based on the balance between employment and population of residents within a given area (Cervero 2002). The range of this index is between 0 to 1 where 0 means only employment or residential uses exist within a half mile, and 1 indicates the ratio of jobs to residents that is optimal from the standpoint of trip generation (Weitz 2003; Kuzmyak & Pratt 2003).

Entropy index is the most common method that indicates the diversity of land uses in a region. The entropy index ranges from 0 to 1, where 0 means all land areas belong to a single use, and 1 shows that land areas are equally divided among the five uses.

The equation for entropy measure is:

$$\sum_{i=1}^{n} \sum\nolimits_{j} ((P_j * LN(P_j)) / LN(j)) * ((BJ_i + BP_i) / (TJ + TP))$$

where:
i = census tract number (excluding those with fewer than 100 persons per square mile)
n = number of census tracts in the county
j = number of sectors
Pj = proportion of jobs in sector j
JP = jobs per person in the metropolitan area
TJ = total jobs in the county
TP = total residents in the county

The study selects entropy because of its simplicity and their ability to manage several groups or classifications. Entropy is broadly used in travel investigations.

Design (Street Connectivity) is the level in which streets are connected and allow direct travel between destinations. Connectivity measures include average block size, proportions of four-way intersections, and densities of intersections per areal unit.

There is a link between street connectivity and block size. Smaller block sizes lead to more direct and shorter paths while large blocks create lower street connectivity. To measure connectivity, Ewing et al., (2010) define three variables of the average block length, average block size, and the percentage of blocks that are less than 1/100 square mile, which is the typical size of an urban block.

Intersection density is another method of measuring connectivity that leads to more significant results compared to measuring block size. It can be because walkability may be limited even if connectivity is excellent when blocks are long. Intersection density is calculated by dividing the total number of intersections in the area by the land area to obtain intersection density.

Percentage of four-or-more-way intersections is the purest metric of measuring connectivity. Four-way intersections make more routing choices available compared to three-way intersections (Ewing & Cervero, 2010). The method is the highest used method in investigations of built environmental effects on individual travel behavior. Accordingly, the author applies this method to measure street connectivity

To calculate this index, the author divides the number of four-or-more-way intersections (with a half-mile radius) by the total number of intersections and multiplies by 100.

Distance to transit

This index represents the level to which destinations are accessible by public transportation. Some studies define it as the average of the shortest street ways between the dwellings or places of work to the nearest rail station or bus stop.

Another method to measure transit proximity is transit route density that calculates the number of stations in the half-mile buffers. This study uses this method since it considers all transit stations in a half-a-mile buffer from a resident’s location (half-a-mile is the standard walking distance to transit.)

Destination Accessibility

This index refers to the degree that a location can be accessible and can be regional or local. Some scholars define regional accessibility as simply distance to the central business district. However, the majority of studies define it as the number of employment opportunities or other attractions accessible within an assumed travel time, which is likely to be highest at central locations and lowest in fringe areas. This study measures the destination accessibility with a variable that measures the proportion of regional employment accessible within a 45-min driving rip time.

Type	**Symbol**	**Definition**	**Source**
Dependent Variables			
Adoption	adtpav	Adoption rate of PAVs	Survey datasets
	adtsav	The adoption rate of SAVs	Survey datasets
Willingness-To-Pay	wtppav	Willingness-To-Pay for PAVs (the cost that the respondent is willing to pay beyond the original price for having the autonomous technology)	Survey datasets
	Wtpsav	Willingness-To-Pay for SAVs (A comparison with the price of human-driven car-sharing services)	Survey datasets
Independent Variables			
Density	actdenhmi	Activity density within a half mile (sum of population and employment divided by gross land area in square miles in 1000s)	Census, 2010 LEHD (Longitudinal Employer–household Dynamics)
Design	int4wayhmi	The proportion of 4-way intersections within a half mile (4 or more way intersections divided by total intersections)	ESRI(TomTom)
Diversity	entropyhmi	Land use mix within a half mile of a household (entropy index based on net acreage in different land use categories that ranges from 0, where all developed land is in one use, to 1, where developed land is evenly divided among uses)	Computed in the study using 2010 LEHD data
Distance to Transit	Dentransit	Bus stop density within half miles (the number of bus stops divided by land area in square miles)	GTFS (General Transit Feed Specification)
Destination Accessibility	job45minD	The proportion of regional employment accessible within a 45-min driving travel time via	LEHD and business analyst
Socio-Demographic Variables			
Age	age	Age (year)	Survey datasets
Gender	male	Gender	Survey datasets
Income	hhinc	Household Annual Income	Survey datasets
Race	race	Race (Being white)	Survey datasets
Employment	empl	Employment	Survey datasets
Education	Edgrad	Having post-graduate education (Master/ Ph.D.)	Survey datasets

VMT	vmt	Annual VMT for commuting and non-commuting goals	Survey datasets
Disabilities	disa	Having disabilities that prevent driving (dummy variable; yes=1, no=0)	Survey datasets
Travel Behavior and Travel Perception Variables			
	vmt	Annual VMT	Survey datasets
	disa	Disability (dummy variable; yes=1, no=0)	Survey datasets
	Techsav	Technology familiarity with the level of tech Savvy	Survey datasets
	Carshar	Never used services such as Uber/Lyft	Survey datasets
	DVexp	Number of Driver Assistant Features that have experienced	Survey datasets
	Walkpre	Preference of walking rather than driving a car	Survey datasets
	Trans2car	Preference for using transit rather than driving a car	Survey datasets
	Bik2car	Preference for biking instead of driving a car	Survey datasets

Table 5: Type, Definition, Scale and the Source of Variables of the Study

4.6 Analytical Methods

The primary analytical methods of the research are statistical analysis methods such as Descriptive Statistics, Multiple Linear Regression, and Principal Component Analysis.

4.6.1 Descriptive Analysis

The study uses descriptive statistics to summarize the survey responses to various dimensions of AV adoption. The author utilizes both measures of descriptive statistics namely central tendency and measures of variability or spread. Measures of central tendency contain the mean, median and mode. Measures of variability contain the standard deviation or variance, the minimum and maximum variables, and the kurtosis and skewness.

4.6.2 Multiple Linear Regression

The author applies four linear regressions models in order to test whether changes in SAVs adoption and PAVs adoption can be attributed to changes in neighborhood accessibility, controlling for changes in socio-demographic characteristics, travel behavior, and travel perception.

Dependent variables of these models are the adoption of private AVs, adoption of shared AVs, Willingness-To-Pay for private AVs, and Willingness-To-Pay for shared AVs. These models explain the direction and significance of each independent variable’s impact on dependent variables. This study controls for multicollinearity and identifies the variables that that measure the same or similar things. Then, the author combines these variables through factor analysis Principle Component Analysis and creates three variables that the next section explains the process in details.

The author tests the assumptions of linear regression that are linearity of residuals, independence of residuals, normal distribution of residuals, and equal variance of residuals.

As Figure 4-3 illustrates, none of the four dependent variables suffers from nonlinearity, outlying values, and heteroscedasticity when plotted against the linear version of the built environmental index.

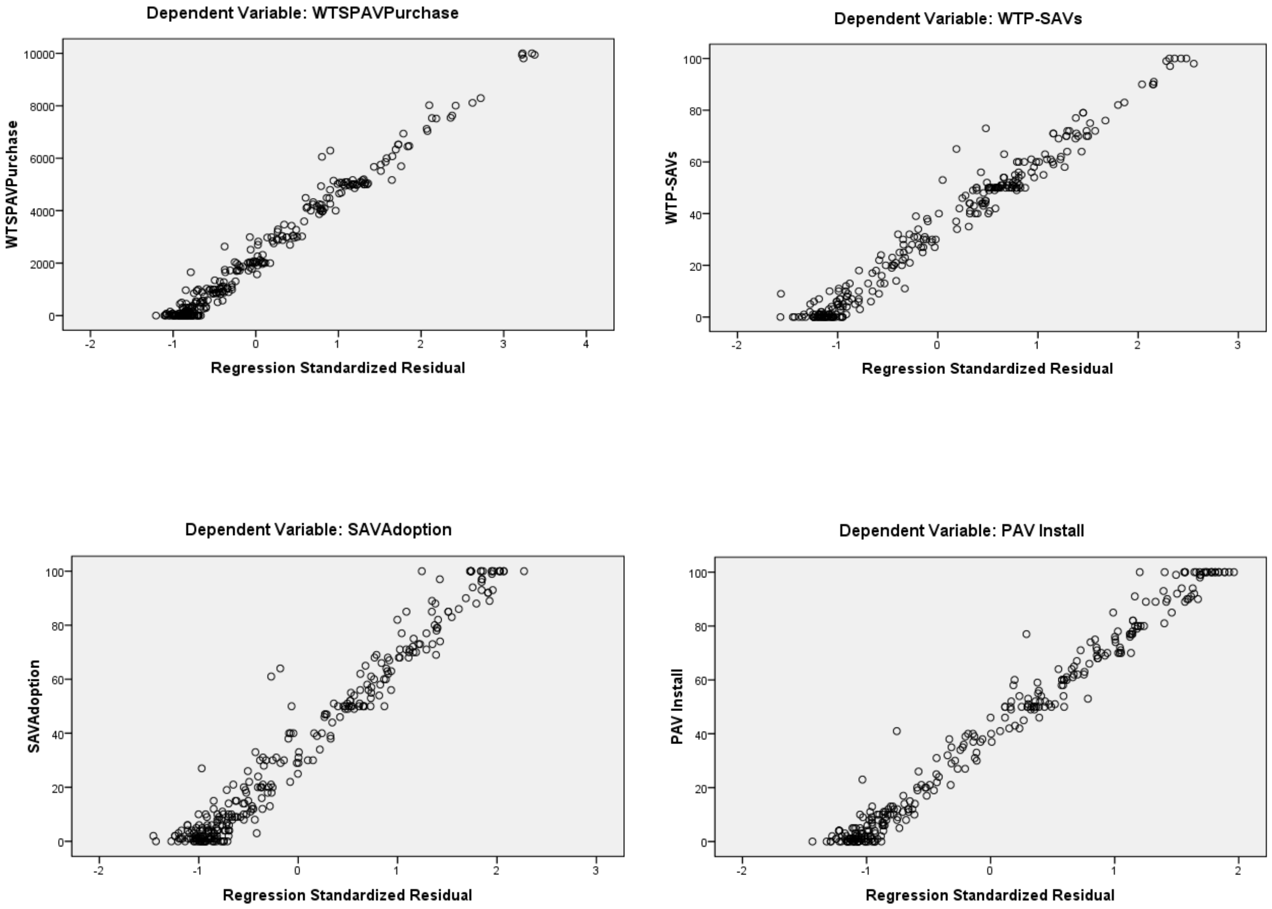


Figure 4-8: Scatterplots of the Dependent Variables vs. Built Environmental Factor

4.6.3 Principle Component Analysis (PCA)

PCA is an analytical method that takes numerous correlated variables and extracts few factors that represent the common variance in the original dataset to avoid multicollinearity in the model. Multicollinearity happens when there are high inter-correlations or inter-associations among the independent variables.

The extracted elements, or principal components, are weighted combinations of the original variables. The purpose of PCA is to control a handful of linear combinations of the original variables that can be utilized to summarize the data set without losing considerable information (Ewing, Hamidi, & Grace, 2016). Due to the simplicity of PCA, the author selected and applied it to remove multiple, correlated variables from models. Accordingly, I created three Principle Components that are: built environment factor, travel preference factor and technology-familiarly factor.

Principle Components are linear combinations of observed variables, catching the variance common to these variables. The strong correlation between an original variable and a principal component causes high loading and weight for the original variable in the overall principal component score.

The study rotates factors since the study only using a single element to signify each of the constructs (built environment, technology familiarity, and travel preferences), and the first principal component extracted embodies more of the common variance than any other factor can.

B-Factor: As the study discusses in the literature review, increasing variables of density, diversity, design, distance to transit (inversely) and destination accessibility increases non-driving travel behavior of residents. It means they all measure the same notion but some of them overlap (e.g., diversity and destination accessibility) and might cause multicollinearity in the models. To avoid multicollinearity, the author combines these variables using principal component analysis and creates a new variable of B-Factor. This index indicates the degree that a neighborhood is accessible and suitable for non-driving travel modes.

The principal component selected to represent the built environment was the first onethe extracted, the one capturing the largest share of common variance among the component variables, and the one upon which the component variables loaded most heavily (Table 6).

As the study discusses in Chapter 2, the variables of density, diversity, design, and destination

The principal component selected to represent the built environment was the first one extracted, the one capturing the largest share of common variance among the component variables, and the one upon which the component variables loaded most heavily (Table 7). It is the only principal component with an eigenvalue[10] greater than 1 (It is 1.83), a common cutoff point above which principal components are retained. This one principal component accounts for almost 45% of the variance in the dataset.

Component matrix		
Variables	**Definition**	**Loading**
actdenH	Activity density within a half mile (sum of population and employment divided by gross land area in square miles in 1000s)	.267
entropy	Land use mix within a half mile of a household (entropy index based on net acreage in different land use categories that ranges from 0, where all developed land is in one use, to 1, where developed land is evenly divided among uses)	.160
pct4way	The proportion of 4-way intersections within a half mile (4 or more way intersections divided by total intersections)	.559
Dentransit	Bus stop density within half miles (the number of bus stops divided by land area in square miles)	.517
job45minD	The proportion of regional employment accessible within a 45-min travel time via transit	.714
Extraction Method: Principal Component Analysis		

Table 6: Variables Loading on the Built Environment Factor

---

[10] Eigenvalues measure the amount of the variation explained by each principal component and will be largest for the first principal component and smaller for subsequent principal components. An eigenvalue greater than 1 indicates that a principal component accounts for more variance than one of the original variables.

All component variables load on this principal component with expected signs. As Table 6 demonstrates, The proportion of 4-way intersections, land use mix, activity density, bus stop density, and the proportion of regional employment are all variables with the positive loading on B-factor. These are the variables increase the accessibility of an area.

T-Factor: The travel-preference factor is an index that represents a preference for non-driving transportation modes (walking, transit, and biking). Responses to travel-preference questions allowed us to place respondents on a scale from most inclined toward driving to least inclined toward driving.

The principal component selected to represent travel preferences is the first one extracted, the one capturing the largest share of common variance among the component variables, and the one upon which the component variables loaded most heavily (Table 7). With eigenvalues of 2.217, it is the only principal component with an eigenvalue greater than 1, a common cutoff point above which principal components are retained. This one principal component accounts for almost 61% of the variance in the dataset. All component variables load with expected signs. Preference to walk, preference to use transit and preference to the bike are three variables with positive loading that all indicate non-driving choices.

Component matrix		
Variable	**Definition**	**Loading**
Walkpre	Preference of walking rather than driving	.747
Trans2car	Preference for using transit rather than driving a car	.750
Bik2car	Preference for biking instead of driving a car	.842

Table 7: Variable loadings on non-driving preference factor

Tech-Factor: The technology familiarity factor is an index that symbolizes the level of familiarity with the technology of respondents. Responses to Tech-Factor questions let us rank respondents on a range from the most familiar to the least familiar to technology. Components of this index include the general knowledge of respondents (post-graduate education and tech Savvy variables) as well as the familiarity with transportation innovations (experience of car-sharing services and experience of Driver Assistant Features variables).

The principal component selected to represent technology familiarity preferences is the first one extracted, the one capturing the largest share of common variance among the component variables, and the one upon which the component variables loaded most heavily (Table 8). It is the only principal component with an eigenvalue greater than 1(1.53), a common cutoff point above which principal components are retained. This one principal component accounts for almost 40% of the variance in the dataset. All component variables load with expected signs. Having higher education, being tech-savvy, and the number of experienced driver assistant features are the variables with positive loading. Oppositely, never experienced car-sharing services, is the only variable with negative loading.

Component Matrix		
Variable	**Definition**	**Loading**
Edgrad	Having post-graduate education (Master/PhD)	0.514
Techsav	Technology familiarity with the level of tech Savvy	0.671
Carshar	Never Used services such as Uber/Lyft	-0.649
DVexp	Number of Driver Assistant Features that have experienced	0.636

Table 8: Variable loadings on technology familiarity factor

5 Chapter 5: Results and Discussion

In this chapter, the author presents the major results of socio-demographics, travel behavior, and the adoption rate of the respondents. Next, the chapter discusses the results of the statistical models of adoption rate, WTP level, and explains the effective factors on adoption. Then, the author explains the results of other issues surrounding AVs such as adoption of other innovative transportation modes, and public perceptions regarding the regulatory aspects of AVs.

5.1 Socio-Demographic Characteristics

Based on examining previous survey studies, the author determines four main demographic variables affecting AVs adoption that are age, gender, disabilities and place of residence. The sampling is designed according to these variables and data is collected (Table 8).

	Features	**Frequency**	**Percent**
Gender	Female	156	50.2%
	Male	152	48.9%
	Other	3	1.0%
Age	18-24	43	13.8%
	25-34	79	25.4%
	35-44	58	18.6%
	45-54	53	17.0%
	55-64	38	12.2%
	65<	40	12.9%
County	Collin	38	6.3%
	Dallas	128	21.3%
	Denton	30	5%
	Ellis	7	1.1%
	Kaufman	3	0.5%
	Tarrant	105	17.5%
Disabilities	Non-disabled	279	89.7%
	Disabled	32	10.3%
Total		311	100.0%

Table 7: Collected Data Based on the Sample

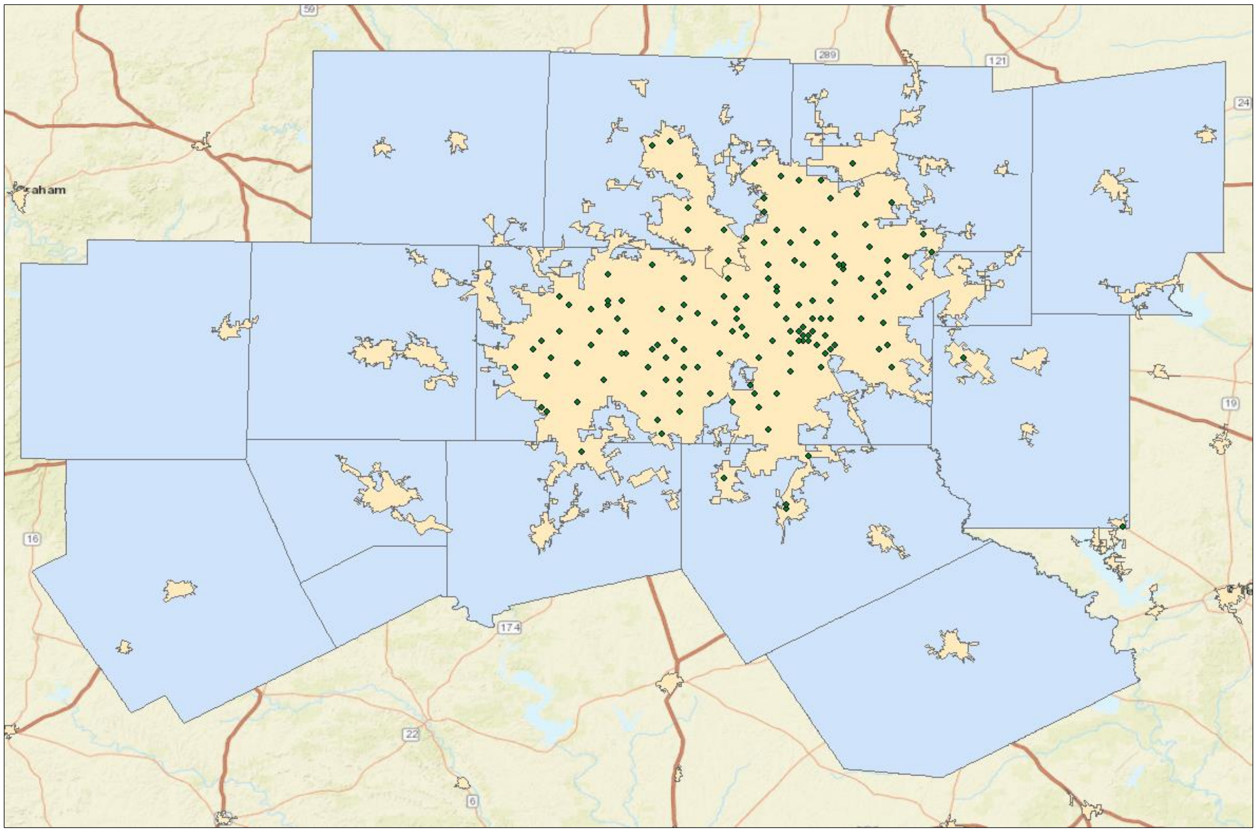


Figure 5-1: Distribution of Respondents in the Urbanized Areas

The survey also collects other socio-demographic data such as ethnicity, education, household size, housing type, employment, and income. The results are used as control variables in the statistical models. Examination of the results indicates that sampling is a decent representative of the target population and collected data is reliable. For instance, around 66% of the survey respondents are white (Caucasian), and 14% are African Americans, which is similar to the ratio of these ethnic groups in the study area.

Furthermore, the average income of the respondents is $88,067, and the respondents are distributed in different income categories as it is shown in Table 9.

Socio-demographics	**Attributes Level**	**Frequency**	**Percent**
Ethnic Groups	African American	43	13.8%
	American Indian or Alaska Native	6	1.9%
	Asian	23	7.4%
	Hispanic	25	8.0%
	Other	8	2.6%
	White (Non-Hispanic)	206	66.2%
Education	Associates degree	36	11.6%
	Bachelor’s degree	119	38.3%
	Master/ Ph.D.	75	24.1%
	High school diploma	76	24.4%
	Less than High school	5	1.6%
Household size	1 Member	50	16.1
	2 Members	114	36.7%
	3 Members	49	15.8%
	4 Members	51	16.4%
	More than 4 Members	47	15%
Housing Type	Apartment	74	23.8%
	Dormitory or other institutional housing	2	0.6%
	Multi-family house	8	2.6%
	Single family house	205	65.9%
	Townhouse	22	7.1%
Employment	Employed full-time	169	54.3%
	Employed part-time	37	11.9%
	Full-time student and not employed	15	4.8%
	Not currently employed	38	12.2%
	Retired	52	16.7%
Income	Under $30,000	49	16%
	$30,000-$60,000	61	20%
	$60,000-$90,000	71	23%
	$90,000-$120,000	48	15%
	$120,000-$150,000	30	10%
	$150,000-$200,000	52	17%

Table 8: Socio-Demographic Information of Respondents

In terms of household size, 36.7% of respondents live in a household with 2 members. 54.3% of respondents are employed full-time while 11.9% are employed part-time, and 12.2% are retired. Moreover, 65.9% of respondents live in single-family residences, and 23.8% live in apartments. Regarding residential types, around 65% of the respondents live in the single-family detached houses, 24% live in the apartments and around 8% live in detached houses (townhouses).

5.2 Travel Behavior and Travel Preferences

In the survey, the author designed questions to evaluate the travel behavior and travel preferences of respondents. Since this study measures future travel behavior and preference of the residents towards AVs, the current travel behavior and perception might be an effective element in shaping future ones. However, travel behaviors do not always reflect people’s travel preferences. For instance, some people might prefer to walk or use transit, but there are not appropriate sidewalks and frequent transit service in their neighborhoods. To tackle this issue, the questions were designed to assess both travel preference and travel behavior.

5.2.1 Travel Preference

To analyze the travel preference of the respondents, the survey asks respondents to designate their agreement with six statements. The highest rate of agreement is with the statement that “Traveling by car is safer overall than walking or riding a bike” by 55.55% of scores. Afterward “Travel time is generally wasted time” has the second highest score by 46.89%. On the other hand, statements of “Public transit can sometimes be easier for me than driving” and “I prefer to bike rather than drive whenever possible” has the lowest average score with just 24.85%.

Question	Mean Score	Frequency	Percentage
I prefer to walk rather than drive whenever possible	40.45	119	38.26%
Traveling by car is safer overall than walking or riding a bike	55.55	168	54.02%
Public transit can sometimes be easier for me than driving	34.42	104	33.44%
I prefer to bike rather than driving whenever possible	24.85	62	19.94%
I am willing to pay a toll or a tax to pay for new highways	38.77	116	37.30%
Travel time is generally wasted time	46.89	140	45.02%

Table 9: Travel Preference of the Respondents

The results show that there is a considerable variation in respondents' preference regarding their travel mode choice. Accordingly, while there is no consensus on any of the modes, driving is more popular than transit, walking, and biking. These results were predictable since the study area is a relatively auto-oriented region (Hamidi et al., 2015) and the mutual effects of travel behavior and travel preferences can rationalize these results.

Although most attendees prefer driving compared to other modes, the relatively low rate of responses to the statement "I am willing to pay a toll or a tax to pay for new highways" confirms that residents would not like to pay for new construction although they prefer automobiles.

Furthermore, as it is mentioned in the methodology chapter, the author combines three factors of transportation preference and defines an index that represents the non-driving preference of respondents. The non-driving index places participants on a scale from most willing towards driving to the least willing towards driving (Willingness to use other transportation modes such as walking, biking and transit usage).

5.2.2 Travel Behavior

As the following Table 13 indicates, the most common transportation modes are respectively personal cars, car-sharing, transit and walking/biking. Meanwhile, personal automobile, car-sharing, walking/biking, and transit are the most common transportation modes for non-commuting purposes.

The high percentage of using personal-automobiles was expected, however, the relatively high rate of walking/biking usage was unexpected.

Moreover, the average miles driven for commuting is 203 miles per week, and the average driving miles for non-commuting prepossess is 198 miles a week. This means respondents drive around 40 miles in a day. It is close to the average commute time of the study area, which is 26 minutes to work (IndexMundi, 2013).

	Commute to work		**Daily life**	
	Frequency	Percentage	Frequency	Percentage
Personal automobile	158	50.8%	227	73%
Transit	30	9.6%	72	32.2%
Car-Sharing	53	17%	147	47.3%
Walking/Biking	37	11.93%	134	43.22%

Table 10: Transportation Modes

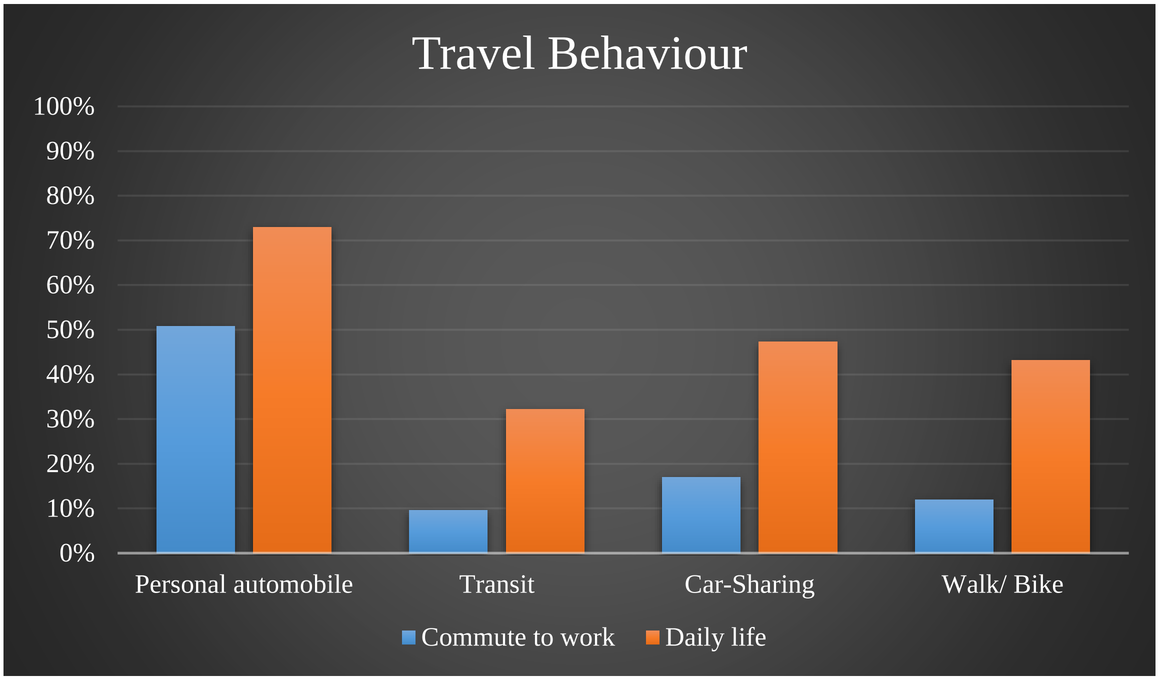


Figure 5-1: Travel Behavior for Commuting and Non-Commuting Purposes

5.2.2.1 Automobile-Ownership/Usage

As the results show, personal cars are the most common mode of transportation for the residents in the study area, as expected.

Given the outcome, over 90% of respondents own or lease a car (81.3% own and 10.0% lease), and only 8% do not own a car. Additionally, 73.3% of car-owner respondents have full-coverage insurance for their vehicles. Two or more householders have a drivers license in 75% of respondents' families. 94% of respondents have bought at least one car during the last ten years and the average number of cars purchased in the last ten years is 3.1022.

	Features	Frequency	Percentage
Car Ownership	Own	252	82%
	Lease	31	10.0%
	None	27	8%
Insurance Coverage	Comprehensive	20	6.4%
	Full-coverage	228	73.3%
	Liability	33	10.6%
	None	30	9.4%
Licensed Householders	1 Householder	74	23.9%
	2 Householders	169	54.5%
	3 Householders and more	67	21.5%
Car-Shopped in the past ten years	No car	14	5.98%
	1 Car	63	26.92%
	2 Cars	90	38.46%
	3 Cars or more	67	13.25%
Driver-Assistant Features	Experienced 0	35	12%
	Experienced 1-2	148	48%
	Experienced more than 3 or more	127	40 %
Uber/Lyft experience	Every day	15	4.8%
	At least once a week	21	6.8%
	Between 1-3 times a month	36	11.6%
	Less than once a month	121	38.9%
	Never used them	118	37.9%

Table 11: Different Aspects of Automobile Usage

In terms of experiencing driver-assistant features, 87% have experienced these facilities, and only 12% of the survey participants have not experienced any driver-assistant features. 47% have experienced 1 or 2, and 40% have experienced more than 2 driver-assistant features. It manifests that a large percentage of respondents have experienced some autonomous features.

Although the statistics regarding the popularity of driving is noticeable, the popularity of car-sharing is relatively low. Only 23% have used car-sharing services at least once a month. While 38.9% have experienced it atleast once but do not use them regularly. Another 37.9% have never experienced these services, either for commuting or other non-work related purposes. The findings are aligned with the results of the earlier questions and emphasize a low rate of using ride-sharing modes.

5.3 Advantages and Disadvantages of AVs for

In order to explore the significant components that shape public adoption, the survey includes 13 questions on advantages and 11 questions on disadvantages of AV technology. Questions include AVs effects on both their personal lives and social aspects.

5.3.1 Advantages

Improving travel safety is ranked as the most important benefit of AVs as mentioned by the 81% of participants. Road safety is the most predicted effect of AVs that scholars repeatedly emphasize AVs ability to save residents' health and wealth by lessening car crashes. Road safety is a most important aspect of AVs for respondents in other studies too. A survey by Continental, (2015) shows that the most important aspects of AVs for respondents is road safety. Around 60% of respondents believe that they would be inclined to utilize AVs in stressful driving situations. Another study by Casley et al., (2013) obtains 467 responses about the effective features to determine the attraction of driver-less cars. The findings expose that safety affect people's choice by 82%.

Afterward, safety, improving mobility for residents who cannot drive, reduction in car insurance, and traffic impacts are respectively the most important benefits of AVs from the respondents' point of view.

Decreasing insurance price is the third most important incentive for customers by 77% of participants that is supported by previous studies. For instance, Vallet, (2013) discusses the substantial impact of the insurance discounts in adopting AVs when 90% of respondents show an inclination to purchase a driverless automobile if it comes with a decrease in auto insurance (34% stated “very likely” and 56% likely).

Conversely, the least important perceived benefit of AVs is facilitating electric cars, on-demand door-to-door services, and activities while riding AVs. By dividing the benefits of AVs into 3 categories, I find that the most important category for users is safety, efficiency and convenience.

	Advantages	**Mean Score**	**Percentage Agreed**
1	Increasing safety	79.69	81%
2	Mobility improvement for ones who cannot drive	74.49	80%
3	Decreasing car insurance costs	70.37	77%
4	Traffic impacts	69.51	74%
5	Fuel economy	65.60	73%
6	Environmental benefits (air quality)	65.42	68%
7	Decreasing parking needs	65.30	73%
8	Decreasing the stress of driving	64.56	69%
9	Reduced driving time	64.03	70%
10	Serving in disasters	63.85	72%
11	Activities while riding in AVs	61.34	65%
12	On-demand door-to-door services	57.37	62%
13	Facilitating electric cars	57.21	60%

Table 12: Pros and Cons of AVs for Respondents

5.3.2 Disadvantages

Among the perceived drawbacks of AVs, equipment failure and hacking vulnerability are the highest concerns for respondents with 81% and 78% rate respectively. Other top concerns such as legal liability and privacy gap are asked in detail in separate questions, and the high costs of driverless system installation is a concern that should be considered by automakers.

These outcomes are similar to what literature shows. Bansal & Kockelman, (2017b) finds equipment failure as the most important concern for American residents. Seapine Software, (2014) surveyed 2,039 residents all over the U.S. Results point out that highest concerns for participants are equipment failures (79%), liability (59%), and hacking issues (52%).

On the bottom of the concerns list factors such as learning technology, losing the joy of driving and potential unemployment of people in driving industry received on average scores of less than 50 percent, which puts them in the category of “Not Concerned” for participants.

These results are in line with results of Open Roboethics initiative, (2014) that discloses about half of the respondents would miss the joy of driving a vehicle and among them; almost 45% would miss having full control over the vehicle.

The results of the advantages/disadvantages questions indicate the importance of safety issues for residents. Therefore, there is a necessity of offering and commercializing AVs when they are in perfect condition for performance. Some experts discussed that an imperfect machine is performing better than humans (Shapiro, 2016). However, the public is more sensitive to the mistake of a machine compared to human errors, and possible failure of the technology might dramatically damage the public’s trust.

	Disadvantages	**Mean Score**	**Percentage Concerned**
1	Hacking vulnerability	74.16	81%
2	Legal liability	72.04	78%
3	Equipment failure	74.47	77%
4	Privacy gap	67.14	74%
5	Lack of full control	66.91	74%
6	Price of driver-less system installation	67.6	73%
7	Interacting with pedestrians and bicyclists	65.86	72%
8	Interacting with human driven cars	66.5	70%
9	Learning technology	49.76	50%
10	Losing the joy of driving	45.87	43%
11	Unemployment of drivers	42.61	41%

Table 13: Most Critical Concerns Surrounding AVs

5.4 Public Adoption of Driver-less Technology

As Table 13 shows 47% of participants either tend to install an autonomous driving system on the car or incline to purchase a fully-autonomous automobile. The result of PAVs adoption is approximately aligned with previous studies. Howard & Dai (2014) states that only 40% are interested in shopping PAVs or installing the autonomy system.

In totality, around 35% of respondents adopt either SAVs as a taxi or SAVs with carpooling. A research study in Austin by Kockelman and Singh (2016) indicate similar results that 41% of participants adopt an SAV weekly at a competitive charge of $1 per mile. The slightly higher rate of SAVs adoption in Austin can be due to the fact that Austin has a higher adoption rate compared to the average of American cities. For instance, in 2016, Bansal and Kockelman sample finds 40% adoption in the U.S. cities, while this figure is around 50% in the Austin sample of Zmud, etc., (2016).

Variable	Definition	Mean Score	Adopters (%)	PAVs/ SAVs	Adopters (%)
PAVs Buy	Purchasing a car that can fully drive by itself without your involvement	40.05	38.91%	Either form of PAVs	46.95%
PAVs Install	Installing a driverless driving system on the car (The driver (can switch the system on/off)	39.82	38.26%		
SAVs Taxi	Using a driver-less car-sharing service	34.74	32.80%	Either form of SAVs	34.73%
SAVs Carpool	Using driver-less car-sharing service with carpooling	29.17	24.76%		

Table 14: Public Adoption of Different Forms of AVs

5.4.1 PAVs Adoption and Causes

In order to explore factors that influence PAVs adoption, the author estimates a linear regression model with SPSS 23 software. The dependent variable of the model is PAVs adoption while independent variables are Age (18-24), Age (55-64), Race (white), T-Preference, B-Factor Tech-Factor, Income, Disabilities, and Gender (male).

Along with the results of the model, the Tech-familiarity variable is the most significant factor. It includes higher education, higher technology familiarity, the higher experience of using Driver-Assistant facilities and experience of using car-sharing services. These results are expected by the author and they confirm the results of previous studies that higher technology familiarity leads to better AVs adoption (Bansal & Kockelman, 2017a; Bansal et al., 2016).

Variables	**coeff**	**Std. Error**	**t-ratio**	**Sig.**
Age18-24	15.838	6.029	2.627	0.009
Age55-64	-12.798	6.125	-2.089	0.038
Race	-.210	4.401	-0.048	0.962
T-preference	0.261	0.080	3.282	0.001
B-factor	0.060	0.078	0.772	0.440
Tech-factor	0.345	0.086	4.034	0.000
Income	-5.059E-006	0.000	-0.131	0.896
Disabilities	2.185	6.465	0.338	0.736
Gender	3.648	3.870	0.943	0.347

Table 15: Effective Variables on PAVs Adoption

Travel Preference factors are also significantly correlated with adoption. Residents who prefer transit, walking, and biking to an automobile are significantly more likely to adopt. This can be due to the mentality of the people who do not like driving and are looking for new modes of technology to replace driving.

The demographic aspects that are significantly associated with PAVs adoption: age. The age group of 18-24 is 15 percent more likely to adopt PAVs while respondents in the age group of 55-64 are 12 percent less likely to adopt. These results were predictable and are aligned with the findings of previous studies that young people are more inclined to adopt (Power, 2012; Bansal, Kockelman, & Singh, 2016; Schoettle & Sivak, 2015, Schoettle & Sivak, 2015).

It can be due to the fact that the younger generations are more familiar with technology and trust it more. Technology is inherent in their daily lives and interwoven into every facet of their existence. Concurrently, older people are usually more conservative and inflexible to change. Although variables such as built environmental factors, driving disabilities, and gender (male) positively stimulate adoption, their weight is not significant. Race (white), and income have negative and insignificant effects on adoption.

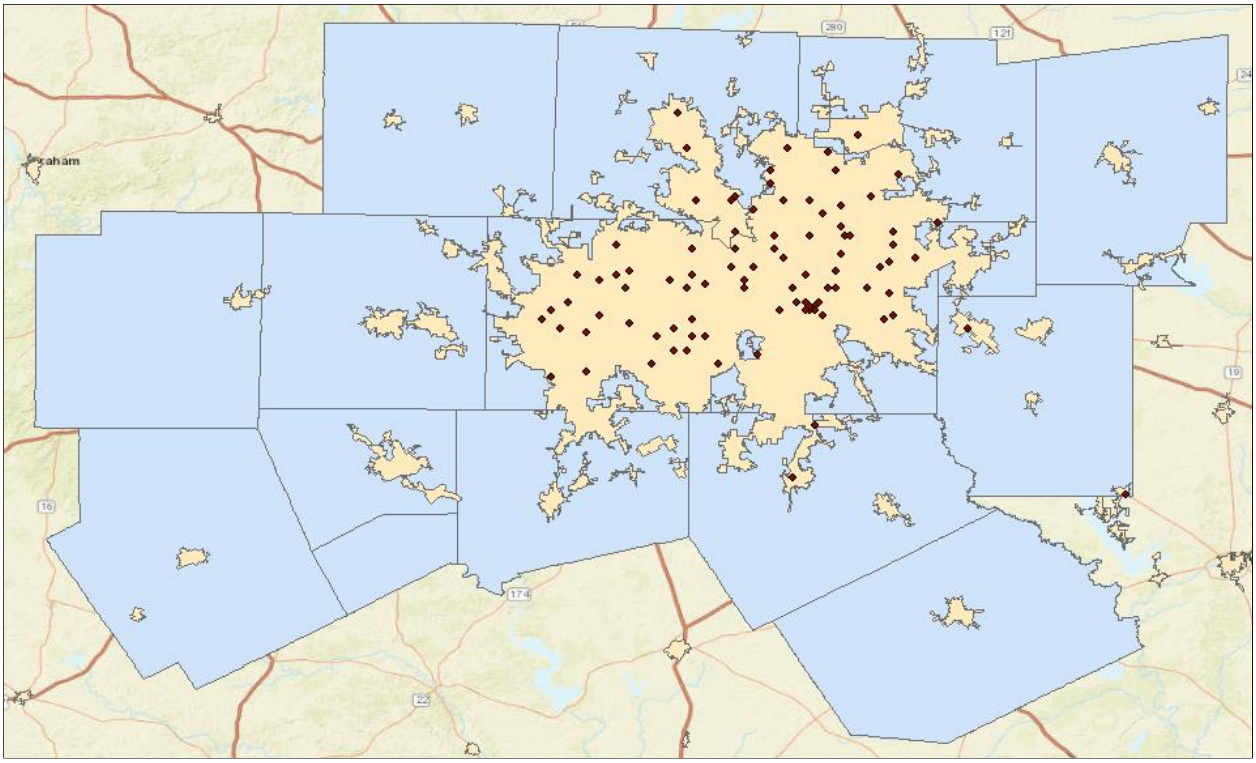


Figure 5-1: Location of PAVs Adopters

5.4.2 SAVs Adoption

The results of the linear regression of the SAVs adoption uncover that the influential variables on SAVs adoption are not the same as the effective variables on PAVs adoption. This highlights the fact that SAVs are an independent transportation mode.

Transportation preference is the most significant variable affecting SAVs adoption. Residents, who prefer non-driving transportation modes, are significantly more likely to use SAVs. This critical element influences both PAVs and SAVs adoption with a highly significant effect. Surprisingly, travel behavior variables do not have a substantial impact on adoption. It shows that travel preference has an even more significant impact in choosing travel mode than travel behavior.

Technology familiarity is the second most significant variable. This important factor affects both SAVs and PAVs adoption. This effect is also strongly supported by literature.

It means, people with the significantly higher likelihood of adopting SAVs are ones with a high education level, more familiar with the technology, have used more driver-assistant features, and have experienced Uber/Lyft. It emphasizes the role of awareness and experience. From this, the author concludes the AVs developers should prepare more opportunities for people to know and experience autonomy before presenting the products to the market.

Gender is the third most significant cause of adoption. Male respondents are 6% more likely to adopt. This statistic is already proven by many AVs adoption studies. We can attribute it to the higher interest in automobiles for men in general.

The impact of the built environment factor is also significant and positive, which is the answer to the central question of this study. Consequently, there is more possibility of SAVs adoption for the residents of accessible areas with features such as mixed- land use, a higher number of 4-way roads (higher street connectivity), higher population and employment density, and more top accessible jobs. Every unit rise in accessibility, leads to a 0.15 unit increase in SAVs adoption, holding all other variables constant.

Having disabilities that prevent driving is the third variable that positively and significantly influences adoption. For citizens who cannot drive due to physical/mental disabilities, the predicted SAVs adoption would be 13 points higher than for able-bodied people. As the study shows, providing mobility for people who can’t drive is an essential aspect of AVs for residents.

However, the adoption level of the elderly is low, so SAVs developers can pay their attention to the disabled who significantly adopt the technology in shared mode.

Finally, variables such as Age (18-24) and Race (White) have positive effects on adoption, but their effects are not significant. On the other hand, variables such as income and age (55-64) have negative and insignificant influence.

Variables	**coeff**	**Std. Error**	**t-ratio**	**Sig.**
Age 18-24	6.686	5.030	1.329	0.185
Age 55-64	-6.968	5.110	-1.364	.174
Race	0.665	3.672	0.181	0.856
T-Preference	0.353	0.066	5.321	0.000
B-factor	0.150	0.065	2.291	0.023
Tech-factor	0.242	0.071	3.391	0.001
Income	-4.312E-005	0.000	-1.336	0.183
Disabilities	13.466	5.393	2.497	0.013
Gender	6.101	3.229	1.890	0.060

Table 16: Effective Variables on SAVs Adoption

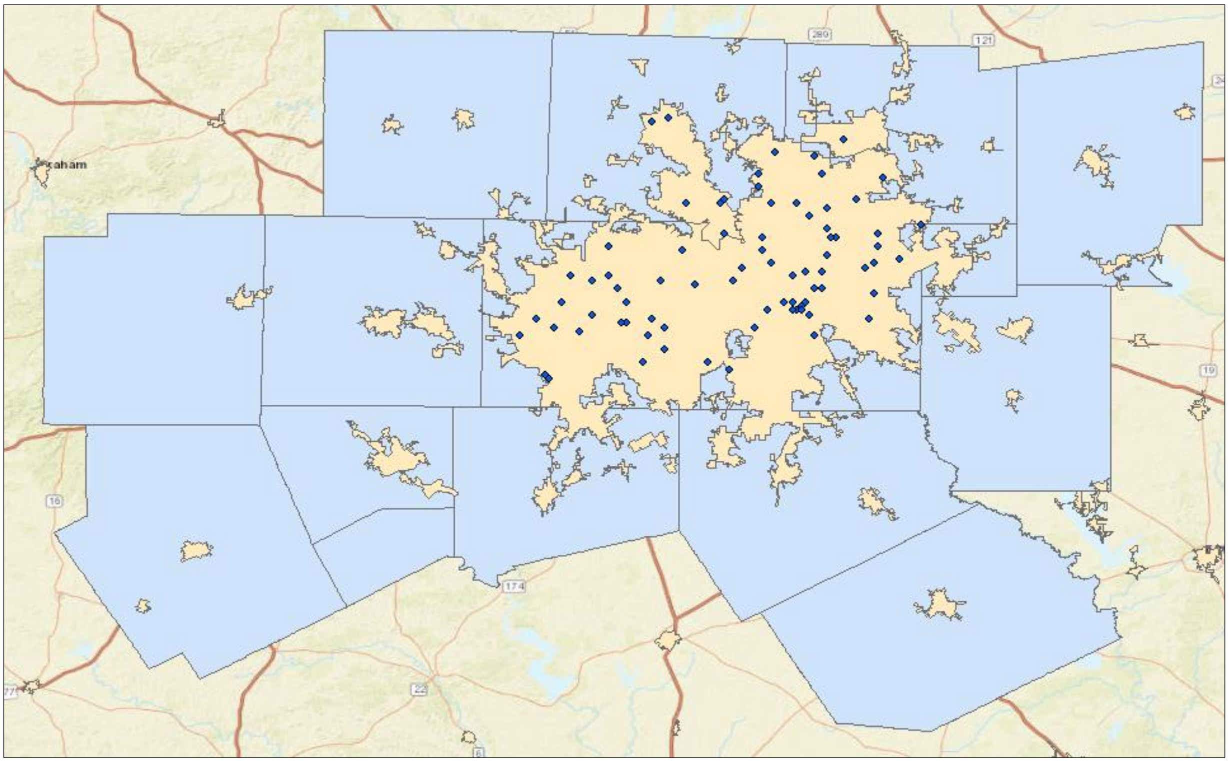


Figure 5-2: Locations of SAVs Adopters

5.4.3 Overall Acceptance

The results of the survey indicate that 54% of the respondents adopt at least one form of AVs. After the respondents became relatively more familiar with the technology, the survey asked again about the adoption of different types of AVs at the end of the survey questionnaire. The purpose of this replication is to analyze if the level of familiarity would make any changes on the respondents' perception of AVs adoption. The results show that familiarity with the technology increased the adoption rate of this technology from 54% to 63.98%. Increasing adoption rate is more considerable on SAVs than PAVs.

However, the author uses the initial adoption rate since this sample is representative of the whole study area, and obviously, people that are not involved in the survey do not have the opportunity to learn more about AVs.

As the study emphasized, SAVs and PAVs are considered two independent modes of transportation (Burns, Jordan, & Scarborough, 2013; Chen, Kockelman, & Hanna, 2016). Therefore the rate of adoption for each one is different as Table 16 demonstrates. Moreover, people with different priorities might utilize different types of PAVs (Install/Purchase) or SAVs (Carpooling/ Taxi).

In order to evaluate the adoption of self-driving technology, regardless of the self-driving option, the author created an index called Overall Acceptance. It measures the number of respondents that adopt at least one form of autonomous vehicles. Subsequently, 13% picked just one form, 14% two forms, 10% three forms, and 15% for all four forms. Overall, 54% of respondents adopt at least one form, and 46.3% are not inclined to any forms of AVs.

Moreover, the survey asked respondents two times about their AV adoption. Once before questions of AVs benefits and drawbacks, and once after that. As Diagram 1 shows, the general acceptance rate increases by 9% from 53% to 63%. Although the PAVs adoption decreases slightly, SAVs adoption significantly increased. Particularly, for SAVs-Carpool, those increase and go from 24.76% to 36.66%.

Acceptance Modes		
Number of AV modes	Frequency	Percent
No Mode	144	46.3%
1 Mode	43	13.8%
2 Modes	45	14.5%
3 Modes	31	10.0%
4 Modes	48	15.4%
At least 1 mode	168	54%

Table 17: Acceptance of Different Forms of AVs

This shows the importance of public awareness about AVs technology before presenting it on a large scale. The AV technology benefits such as road safety improvements, the low costs of SAVs compared to human-driven taxis, or the mobility improvement for persons who cannot drive, could be factors that were not considered by the respondents at the first round of adoption questions.

Several investigations confirm this fact that informing residents about the advantages of AVs can dramatically influence their viewpoint. Silberg et al., (2013) displayed that respondents are more likely to accept AVs when incentives such as dedicated lanes for AVs is available. Valet, (2014) discussed the substantial impact of the insurance discount in adopting AVs when 90% of respondents showed an inclination to purchase a driverless automobile if it comes with a decrease in auto insurance (34% stated “very likely” and 56% likely).

According to Table 17, the adoption rate for all AV modes is less than 50%. It is in harmony with other studies that emphasize the low rate of adoption in the U.S. compared to other countries. For example, the result of a surveying 1500 individuals from the U.K., U.S. and Australia, reveal that Americans have the lowest adoption level (Schoettle & Sivak, 2014). Repetition of this survey in 2016 yielded similar results.

Conversely, surveying 22,000 persons from 17 countries including America, displays an increase of consumers’ interest in advanced vehicle automation since 2014, especially among younger generations (Giffi, et al., 2017).

Valet, (2014) discussed the substantial impacts of insurance discounts in adopting AVs when 90% of respondents indicated a preference to purchase a driverless automobile if it comes with a reduction in auto insurance rates (34% stated "very likely" and 56% likely). Improving safety is also another incentive for potential AVs users. Although, a group of respondents considered AVs as a threat to safety. Around 60% of respondents in a survey by Continental, (2015) believed that they would be inclined to utilize AVs in stressful driving situations.

Generally speaking, the results of the analysis confirm the findings of previous studies about the low rate of adoption in the U.S. (Schoettle & Sivak, 2015; (Valle, 2016)). However, by defining the Overall Acceptance index, the study shows that the public accepts the technology by more than 50% if different modes of AVs are available. Moreover, increasing public awareness about the benefits of the technology will increase this rate to more than 60%.

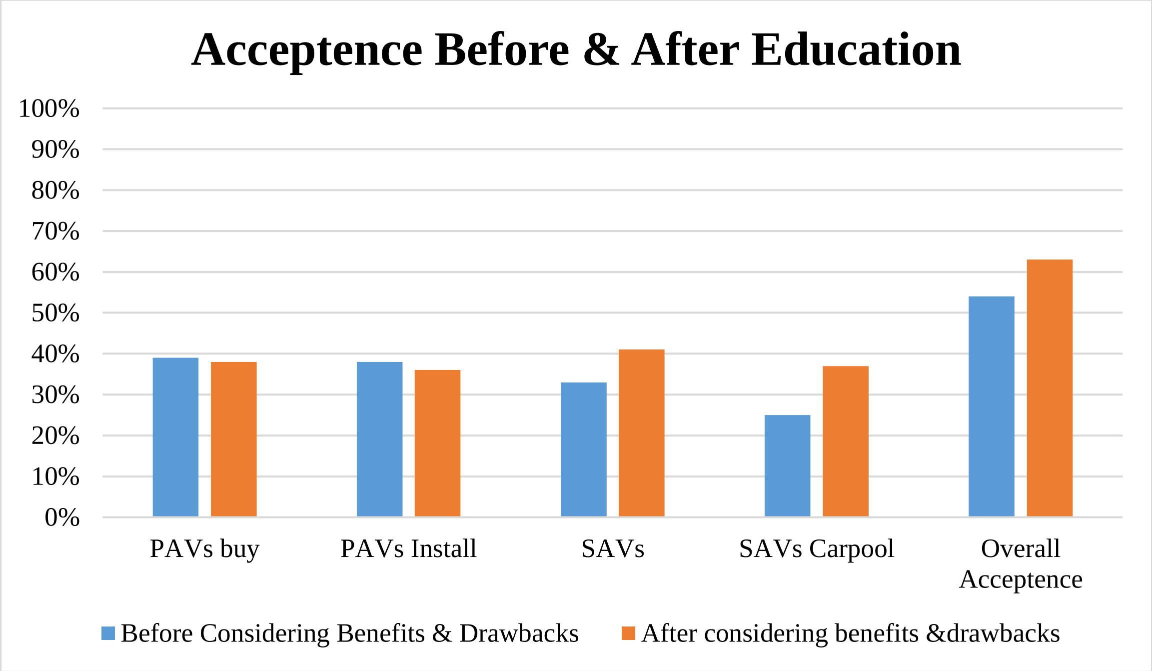


Figure 5-3: Adoption Rate Before and After Considering Benefits and Drawbacks

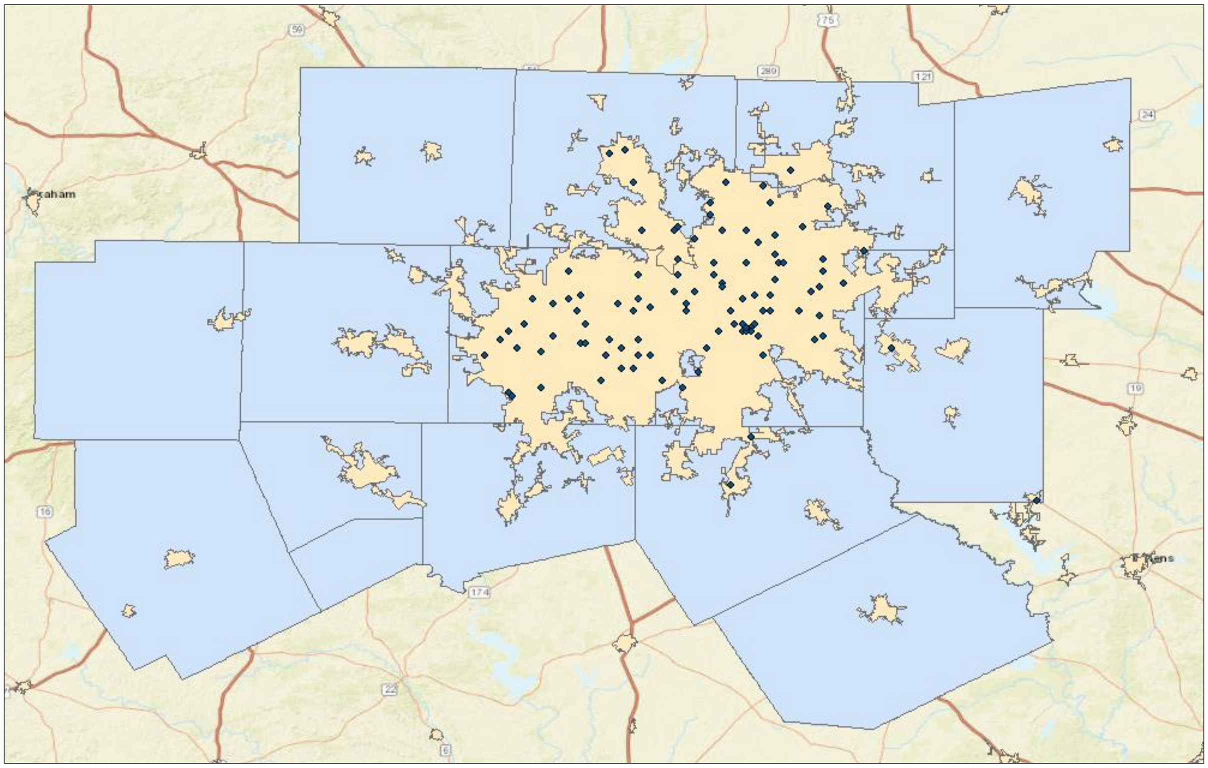


Figure 5-4: Locations of AV Technology Adopters

The results of this survey are in agreement with literature that shows a trend of improving AVs acceptance in the U.S. The results of recent studies indicate a higher adoption rate compared to the earlier ones. For instance, a study by Power (2012), expresses 36% public adoption in the US.

In 2014, this figure increased to 37% and then to 39% in 2016 (Giffi et al., 2017).

Moreover, Bansal & Kockelman, (2017b), predicts that the AVs acceptance among U.S. residents would continue to improve. They projected that the privately held light-duty-car fleet would have 24.8% of level 4 AV penetration by 2045, assuming an annual 5% price decrease and continual WTP values (from 2015 forward).

Adoption rate								
Education	Adoption rate before considering benefits & Drawbacks of AVs				Adoption rate after considering benefits & Drawbacks of AVs			
SAVs/PAVs	PAVs		SAVs		PAVs2		SAVs2	
AVs Mode	PAVs Buy	PAVs Install	SAVs Taxi	SAVs Carpool	PAV Buy2	PAV Install 2	SAVs Taxi2	SAVs Carpool 2
Mean Adoption Score	40.05	39.82	34.74	29.17	40.40	37.38	42.54	39.14
Median Adoption score	31.00	38.00	21.00	15.00	43.00	34.00	46.00	40.00
Number of Adopters	121	119	102	77	119	113	129	114
Percentage of Adopters	38.91%	38.26%	32.80%	24.76%	38.26%	36.33%	41.48%	36.66%
SAVs/PAVs Adoption	46.95%		34.73%		45.34%		56.59%	
Overall Acceptance	54%				63%			

Table 18: Adoption of each Mode of AVs and General Acceptance

5.5 Built Environment and Effects on Adoption

As chapter five shows, the study measures five main built environmental features around a half mile network buffer of each respondent's location. Results show that on average, the score of mixed-use entropy in half-mile network buffers of respondents' locations is 0.41. The entropy ranges from 0, where all developed land is in one use, to 1, where developed land is evenly divided among land uses. Therefore, the entropy score below 0.5 shows that the majority of the respondents live in the areas with low land-use mix.

The average activity density is 8.1 within buffers. It points out that the mean sum of the population and employment divided by gross land area in one square mile is around eight, which is a relatively low activity density.

The mean of the distance to transit is around 2 miles. However, the favorable distance to transit is less than a half-mile. Schlossberg, et al., (2007) explore that 75 % of transit users walk less than one mile (12 minutes) to reach a rail station. Hence, the majority of residents have low accessibility to the transit stations. It can be the reason for the low adoption rate of shared AVs. The residents with lower opportunities for using transit might have a lower chance of accepting car-sharing because they are not familiar with the idea.

The average proportion of 4-way intersections within a half-mile (4 or more way intersections divided by whole intersections) is 35. It means 35% of intersections are 4-ways intersections that create more connectivity. This is a sign that the street connectivity of the area is relatively low.

The mean proportion of regional employment accessible within a 45-minutes drive is 2.5 jobs. It indicates the low population accessibility in the majority of the locations. These results justify the average commuting time in the DFW area, which is 26 minutes each way (IndexMundi, 2013).

The overall outcomes emphasize low density, low mixed-use diversity, low street connectivity, low destination accessibility, and long distances to transit for the majority of the residents. Therefore, the neighborhood accessibility is low in the study area and built environmental features of the areas are sprawl. These findings support the literature that Dallas-Fort Worth area is among the highest sprawled metropolitan areas in the nation (Ewing & Hamidi, 2014; Burchell, 2015).

5.5.1 Built Environment and Public Adoption

As the study discusses in the literature review, numerous investigations prove the impact of the built environment on residents' behavior and especially their travel behavior. Scholars broadly define this effect by measuring D-Variables. However, there is a question on whether D-Variables affect residents' choice of SAVs and PAVs as innovative transportation modes.

This dissertation provides a comprehensive analysis of how the characteristics of neighborhoods influence adoption rate. The author measures five D-Variables within a half mile network buffer from each respondent's house and explores their correlation with both PAVs adoption and SAVs adoption.

Results of this analysis reveal the positive and significant effect of D-Variables on SAVs adoption. Accordingly, there is a high likelihood of using SAVs among the inhabitants of accessible neighborhoods that are characterized by high density, mixed-use, high street connectivity, high employment accessibility, and low distance to transit. Accordingly, for each unit of increase in built environmental factors, the likelihood of SAVs adoption rises by 0.15 unit and Willingness-To-Pay for using shared autonomous services increases by 0.10 unit. For instance, if the authorities can double the density, mixed use, street connectivity, job accessibility, and half the average distance to transit, the rate of SAVs adoption will increase by 15% and Willingness-To-Pay for SAVs services increase by 10% (reaches to 42% of current car-sharing services).

Moreover, the impact of built environmental factors on PAVs adoption is positive, but this impact is not significant. The reason might be that shopping private AVs is a kind of personal decision, and the personal preference of people is a more important factor than built environment.

As the study discusses in chapter 1, literature provides little evidence about the correlation between the built environment and AVs adoption. To the best knowledge of the author, Bansal et al., (2016) is the only study that considers some built environmental elements and concludes that residents of urban areas are more likely to adopt.

The results of this study support Bansal et al., (2016) by displaying that areas with low accessibility (that have more similarity to rural areas in terms of built environment) have a lower rate of adoption for both types of AVs. Meanwhile, around 10% of survey respondents who are not located in urbanized areas, are excluded from analysis since rural areas are out of the scope of the study. However, the rate of adoption in rural areas is considerably lower than urbanized areas (25% for PAVs adoption and 20% for SAVs adoption). It is further evidence that confirms the results of previous studies.

The authors initial hypothesis was that residents of accessible areas would accept SAVs and the residents of the low accessible area would adopt PAVs. The results confirm the first hypothesis but reject the second one. Initially, the author hypothesized that PAVs adoption might be higher in suburban areas since the convenience of autonomous driving would be attractive for suburban residents that drive more than residents of compact areas. However, the results demonstrate that the rate of adoption of PAVs and SAVs are lower in suburbia and low-accessible areas and residents generally do not trust the AV technology. This can be due to the fact that residents of suburban areas are usually more conservative (Roy & Perrella, 2015). Consequently, they are less likely to adopt innovative changes in their travel behavior.

Moreover, the results strongly support the hypothesis that residents of more accessible areas would be more apt to use shared AVs. These findings can be justified by the results of previous studies that emphasize individuals residing in traditional districts prefer to use non-driving travel modes (Cervero & Duncan, 2003; Crane & Crepeau, 1998). Therefore, for these residents, autonomous cars and especially shared AVs are new non-driving travel modes. The significant impact of B-Factor on SAVs adoption and insignificant effect on PAVs adoption, expresses the fact that residents of accessible areas select sharing travel modes over private ones. The literature supports these findings where it shows the residents of transit-oriented development (TOD) area are more likely to use transit (Renne, Hamidi, & Ewing, 2017; Nasri & Zhang, 2018).

Considering the results, the author concludes that the decision of selecting autonomous technology is affected by both individual and environmental features. Therefore, built environmental and socio-demographics together make a more comprehensive picture of AVs adoption in the U.S.

5.6 Willingness-To-Pay (WTP)

This study also elevates the respondents' Willingness-To-Pay for four types of AVs. Based on the results, respondents are Willing To Pay an average of $2,227 (with a median of $1176) extra to purchase an AV. WTP for installing an autonomous driver-less system on the user's current car is $1,710 (with a median of $959).

Different surveys present different WTP and their results are relatively inconsistent. For instance, a study by Casley et al., (2013) surveys 450 university students and faculties, and finds most of them think that the automation feature will cost around $5,000 extra the car value, whereas the majority of them are only ready to spend approximately $1,000 for it. A recent study by Giffi et al., (2017) shows that the WTP for American residents has decreased by 30% from $1,370 in 2014 to $925 in 2016. Bansal & Kockelman, (2017) discover that around two-thirds of respondents are willing to pay more than $3,000 over the price of a conventional vehicle to buy a full automation vehicle. The WTP that the author gains in this study, is closer to these studies.

On the other hand, some studies express higher WTP. For instance, a survey by Daziano, et al., (2017) shows WTP of $4900 for residents of different American cities. Bansal & Kockelman, (2015) discovers that WTP to add connectivity and Level 4 automation were $67 and $5,857, respectively. Another study by Bansal et al., (2016) analyzes the opinion of 347 respondents from Austin, TX and concludes that the average WTP for adding Level 4 automation to their current vehicles is $7,253 which is considerably higher than WTP for adding Level 3 automation which is $3,300. Another study by Silberg et al., (2013) points out the median premium expenses that consumers are ready to spend for automation is $4,500.

Meanwhile, the author computes a new variable measuring what percentage of the annual household income is their WTP. It indicates that on average respondents are willing to spend 5.13% of their household income in excess to shop a PAV, and 6.6% of their income to install an autonomous system on their current vehicles.

AV Forms	Median	Mean	WTP/Income
Willingness-To-Pay extra in shopping for an AV	$1,176	$2,227.62	6.6%
Willingness-To-Pay for installing an autonomous system on the current car	$959	$1,710.54	5.13%.
Expected price of SAVs compared to human-driven Lyft/Uber	32%	%33.25	-
Expected price of ridesharing SAVs compared to human-driven Lyft/Uber	28%	%30.24	-

Table 19: Willingness-To-Pay for Different Types of AVs

WTP for SAVs: to make a better understanding of the price of SAVs for respondents, the survey asks participants to indicate their expectation of the costs of SAVs compared to human-driven car-sharing services (Imagine there would be a fleet of driverless taxis serving 24/7. What percentage of the price of human-driven Uber/ Lyft would you expect a driver-less taxi to cost?). Based on the results, on average the respondents would use SAVs options if an autonomous taxi costs 33.25% or less of the price of human-driven taxis, and a ride-sharing SAVs costs 30.24% or less of the human-driven taxis with ride-sharing.

5.6.1 Determinates of Willingness-To-Pay for SAVs

As shown in Table 22, Travel-preference index is the most significant element with a positive impact on WTP for SAVs. After, travel preference, tech factor and then race are the second, and third most effective elements.

Built environment factor affects WTP positively. It means that the inhabitants of more accessible areas are willing to pay more compared to other people. For every unit increase in accessibility, the Willingness-To-Pay surges by 0.172 unit.

Variables	coeff.	Std. Error	t-value	Sig.
Age 18-24	2.999	4.822	0.622	0.535
Age 55-64	-8.851	5.323	-1.663	0.098
Race	8.631	3.600	2.398	0.017
T-preference	0.291	0.065	4.462	0.000
B-factor	0.107	0.064	1.672	0.096
Tech-factor	0.172	0.069	2.491	0.013
Income	-3.639E-006	0.000	-0.115	0.909
Disabilities	6.029	5.124	1.177	0.240
Gender	-0.765	3.152	-0.243	0.808

Table 20: Statistical Model for WTP-SAVs

Surprisingly, income has a negative impact on WTP-SAVs although it is not significant. In the meantime, the negative, insignificant influence of income was unpredictable. The reason might be the mentality of the high-income residents that consider ride sharing as a beneath them. Gender (male) and age group of 55-64 are the other variables with negative and insignificant impacts. Oppositely, disabilities and the age group of 18-24 are the variables with positive and negligible influence.

In summary, a high level of technology familiarity, coupled with a deep fondness for non-driving travel modes, being White (Caucasian) and living in more accessible neighborhoods, are the characteristics of users who would pay more for using SAVs. The variables that affect SAVs adoption are similar to the variables that influence WTP for SAVs.

5.6.2 Determinates of Willingness-To-Pay for PAVs

Transportation preference, disabilities, age group, and tech-factor, are respectively the most significant variables on WTP-PAVs with positives effects. Conversely, an age group of 55-64 has a negative and significant effect.

variables	coeff.	Std. Error	t-ratio	Sig.
Age 18-24	**901.791**	**414.827**	**2.174**	**0.031**
Age 55-64	**-977.737**	**421.443**	**-2.320**	**0.021**
Race (White)	428.084	302.836	1.414	0.159
T-prefer	**18.940**	**5.474**	**3.460**	**0.001**
B-factor	7.297	5.387	1.355	0.177
Tech-factor	**13.038**	**5.888**	**2.215**	**0.028**
Income	0.000	0.003	0.095	0.925
Disabilities	**1249.436**	**444.827**	**2.809**	**0.005**
Gender (male)	128.780	266.293	.484	0.629

Table 21: Statistical Model for WTP-PAVs

These variables are parallel with the variables affecting PAVs adoption. It can be a sign that survey attendees answered the questions carefully that caused very similar results to the variables with similar character. Meanwhile, the insignificant influence of income on the Willingness-To-Pay is surprising.

5.7 Adoption Time of Late AV Adopters

Around 50% of the respondents indicated that they are not ready for accepting any form of AVs, and the question is, when the other half of the DFW area's society will be willing to accept this technology. Rogers, (1995) identified several personality characters that contribute to categorizing how users accept an innovation. Based on his theory, late adopters and laggards are the residents that have conservative behavior towards new technology. However, during this time, there might be some reasons that change their decision. In a survey question, the research evaluates these reasons. Table 24 demonstrates how the successful implementation of the technology will attract laggards. "Data showing the safety of the technology" is the priority for non-adopters. Afterward, widespread use and experience of family and friends are the factors that contribute to deploying AVs gradually. Bansal, et al., (2016) also shows that 50% of respondents will adopt AVs after their friends use AVs.

Priority	Time of Acceptance	Percentage
1	Data showing they are safe for passengers	31%
2	Data showing they are safe for other drivers and pedestrians	28%
3	Widespread use (more than 50% of drivers are using them)	12%
4	The positive experiences of my friends and family	43%
5	The positive opinions of my friends and family about AVs	30%
6	The chance to be one of the first people to own a driverless car	43%

Table 22: Prediction of Adoption Time for Late Adopters

5.8 Innovative Transportation Modes

This study also finds that the rate of public adoptions is higher for other innovative transportation modes compared to autonomous cars. The Hyperloop and Bullet Train are the most attractive innovative means for respondents. The average of acceptance for these technologies is 66.93% and 66.85% respectively. After those, the rate of acceptance for flying taxis is 57.25%. Moreover, the rate of acceptance for a mixed-transportation system of high-speed rail and autonomous taxis is 53.68%. This rate is considerably higher than the acceptance rate for autonomous taxis. Thus, integrating autonomous cars with other innovative transportation modes would increase the attraction of AVs for users. Likewise, the high rate of acceptance of the other innovative transportation modes compared to AVs is considerable and confirms that residents are not against all new transportation modes. Some respondents in interviews pointed out that since Bullet Train and Hyperloop move on stable rails, they have lower risks compared to AVs. Concurrently, the lower rate of AVs adoption compared to flying taxis (that the idea is in the initial stages of evaluation) is questionable.

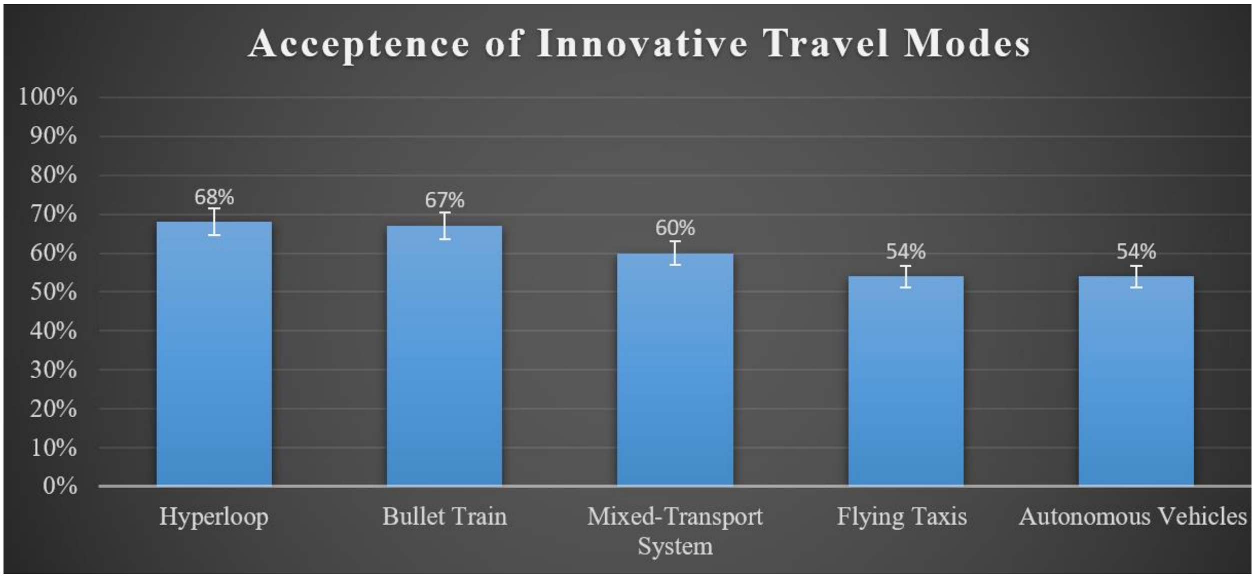


Figure 5-5: Public Acceptance of Innovative Transportation Modes

5.9 Regulations and Policy Considerations

Regulatory challenges are significant barriers to the deployment of AVs technology. Several gaps need to be addressed before making regulatory changes.

Besides considering the different technical aspects of AVs, policymakers need to know public perceptions regarding these controversial issues. Otherwise, the new regulations might not be a good fit for society and could result in potential problems for cities (Organisation for Economic Co-operation and Development, 2010). By interviewing over 200 transportation experts Underwood, et al., (2014) concludes that the policy community remains mostly unaware of AV technology.

This study found that the average agreement rate to the statement “An individual should be required to obtain a state-issued license to operate a driver-less vehicle legally” is 65.4%. Moreover, the agreement rate for the statement, “Governments should regulate how driverless vehicles are used" is 64.7%. As the results show, respondents expect the government to oversee how driverless vehicles are used. The users also prefer regulations that require AV users to be trained before using the technology.

Regarding the travel information of passengers (such as the addresses and locations to where passengers travel and the average mileage passengers drive annually), the majority of respondents (75.3%) want to have access to their own travel information while only 23.7% incline that the government could access to this information. Additionally, the percentage of respondents that are willing to share their travel information with research centers and automaker companies is 14.8% and 17.2%.

Although AVs drive in the same lanes with human-driven cars in European countries such as Greece and Finland, in the U.S. there are still concerns about the interaction of AVs with human-driven cars. The outcomes indicate that around 75% of participants prefer that AVs drive in dedicated lanes.

Statement	Mean	Median
An individual should be required to obtain a state-issued license to operate a driver-less vehicle legally	65.64	72.00
I expect the government to regulate how driverless vehicles are used	64.96	70.00
Legislation about driver-less cars affects my desire to purchase one	57.63	56.5

Table 23: Regulation Issues Surrounding AVs

Literature does not provide enough evidence on this topic. Based on the results of a study by Howard & Dai, (2014), 46% of respondents believe that self-driving cars should operate with conventional traffic, while another 38% believed in separate lanes, and 11% had no opinion.

Therefore, the results of this study are significantly different from Howard & Dai, (2014). However, the method of data collection is considerably different in Howard & Dai study. Their respondents are limited to the visitors of a museum and the researchers show a short movie about AVs before answering the question. This might be the reason for the difference in outcome in that study.

However, the results of this study are matched with Silberg et al., (2013) that shows that it is more plausible for respondents to accept AVs when incentives like dedicated lanes for AVs are available. Dedicated lanes for AVs have been tested in some European cities like Lausanne, France for presenting the technology in the early stages (European Commission, 2016).

Although the respondents' viewpoint about dedicating lanes is conservative, their perception about the speed-limit for AVs shows more trust when 50.2% of participants believe that AVs should have the same speed-limit as human-driven cars. Even 16.1% trust AVs to have higher speed limit and only one-third of participants consider less speed limit for AVs.

Question	**Options**	**Responses**	
		Frequency	Percentage
Who can have access to travel information of AVs passenger	Government for security reasons	77	23.7%
	The auto-maker company	56	17.2%
	Research organizations (for purposes other than advertising)	48	14.8%
	Should be available to the passenger	244	75.3%
Can AVs drive in regular lanes or should they have dedicated lanes?	Dedicated Lanes	232	74.6%
	Regular lanes	79	25.4%
What is the speed limit for AVs	Less than human-driven cars	105	33.8%
	More than human-driven cars	50	16.1%
	Same as human-driven cars	156	50.2%

Table 24: Controversial and Liability Topics Around AVs

Additionally, around 58% of respondents point out that legislation about AVs affects their adoption, and around 65% think that the governments should interfere in regulating AVs, also people need to gain a license to be qualified to operate an AV. Accordingly, and there is a consensus on making restrictive regulations for AVs and giving the government continuous control over them.

5.9.1 Liability and Priority

The first controversial issue of AV regulation is reliability. As the results of these disadvantages section reveals, the reliability of this technology is a noticeable concern for users. Around 60% of respondents believe that driver-less car manufacturers and the manufacturers of the driver-less systems should be responsible in the case of car crashes. While respondents that state AV owners and the insurance companies should be liable are just 37.62% and 25.40% correspondingly. This shows that most users prefer for AVs to be in faultless shape when they come to the market and in the case of failure, the factories should take sole responsibility.

As the research disclosed in the AVs advantages section, decreasing insurance costs has high priority for the respondents in deciding to adopt AVs and it could be the reason that they do not pick insurance companies as responsible for AVs failure. They might be afraid that the costs of insurance would increase by giving the liability to the insurance providers.

A controversial ethical topic surrounding AVs is who has the priority to survive. In the case that an accident involving an AV is unavoidable, and has to pick between the car passengers and pedestrians, whom should it pick? The survey asks this question from participants. As Table 25 illustrates, the majority of respondents (54.3%) state that the priority of AVs should be saving the majority of people’s lives to convince them to use this technology. These results confirm the findings of a study by Bonnefon et al., (2016) that analyzes the reliability concerns surrounding driverless automobiles. It reveals meaningfully lower possibility of purchasing AVs products if the AV programming prioritizes the pedestrians to the car passengers.

Question	**Options**	**Responses**	
		Frequency	Percentage
Who should be responsible in the case that a driver-less car is involved in an accident?	Owner of the driver-less car	117	37.62%
	The driver-less car manufacturer	186	59.81%
	The insurance company	79	25.40%
	Manufacturer of the driver-less system	175	56.27%
Imagine an autonomous car cannot avoid an accident and has to prioritize between its passengers and pedestrians to save their lives. In which scenario you would like to use/buy a driver-less car?	Priority of the car should be saving the majority of people's lives	169	54.3%
	AVs should not have the right to make this decision. It should be random and unbiased	41	13.2%
	Passengers lives should always have priority	52	16.7%
	Pedestrians lives should always have priority	49	15.8%

Table 25: Perception Towards Liability and Priority Issues

5.9.2 Effects of AVs on other Travel Modes

The potential influence of AVs deployment on different travel modes is a complicated issue and cannot be entirely answered before the implementation of the technology. However, several studies presented hypotheses about these effects. For instance, Millard-Ball, (2016) applied game theory to assess the interactions between pedestrians and AVs, with a concentration on yielding at crosswalks and concluded that AVs would improve walking activities. Since AVs will be risk-averse, the model recommends that walkers will walk with impunity, and AVs may improve pedestrian-oriented urban districts. Pedestrian Supremacy is another theory that anticipates AVs will increase walking activities. Based on the first scenario pedestrians, and maybe bicycles will take over urban spaces. Pedestrians recognize that AVs will behave carefully in their presence, which leads to a self-supporting trend. Pedestrian activity reduces the speed of AVs, particularly on non-arterial roads, which, in turn, makes walking a faster alternative for further trips. Since it is problematic for AVs to penetrate central cities, they will drop off their users on an arterial road at the edge, before going to a peripheral parking area. This allows for more rise in urban density, which again adds to more walking activity (Millard-Ball, 2016).

This study tests these hypotheses by asking residents to imagine their lives with AVs and express their feelings about other transportation modes. The results indicate that only 33% agree that AVs would change their walking and transit usage behavior. The rate is even less for the private car ownership. Only 25% of respondents believe they would be ending car ownership after AVs deployment. It is affiliated with the results of surveying more than 500 people in Austin, TX that indicate 23% of participants prefer to reduce vehicle ownership (Zmud, 2016).

Mode	**Statement**	**Agreed (%)**
Walking	I feel more secure walking as a pedestrian knowing that the cars on the adjacent street are driver-less	27%
Transit	If there is a fleet of shared driver-less vehicles available to take me to the nearest bus/train stations**,** I will use transit more often	30%
Personal cars	When a network of driver-less taxis become broadly available, I will end my car ownership	21%

Table 26: AVs Impacts on Other Transportation Modes

5.10 Concluding Remarks

Evaluating the outcomes of the survey, the majority of the findings are expected, and few are surprising. To sum up, the following are the most considerable outcomes in analyzing the survey:

1. Private cars are the most common transportation mode in the DFW area. Car dominance not only influences residents' travel behavior but affects their travel preferences too.
2. Although private cars are far more popular than other transportation modes, the popularity of car-sharing is relatively low.
3. The public adoption rate of private AVs is higher than shared AVs (46.95% versus 34.73%). However, after considering the benefits & drawbacks of the AVs, the results change, and respondents adopt SAVs more than PAVs by 56.59% versus 45.34%.
4. Improving safety, enhancing mobility and decreasing car insurance costs are respectively the most important advantages of AVs for users.
5. Equipment failure, hacking vulnerability, and the cost of driver-less system installation are respectively the most significant concerns of users regarding AVs.
6. The results of measuring D-Variables show relatively low rate of index for all D-Variables. In other words, most respondents live in the area with low activity density, low land-use diversity, poor street connectivity, low accessibility to employment, and low transit proximity.
7. Built environmental elements positively affect AVs adoption. The effect is especially significant for SAVs adoptions and shows how increasing neighborhood accessibility leads to the higher chance of SAVs adoption. This might be due to the availability of transit services in these areas. People who frequently use transit, might have better perspective towards car-sharing and be more willing to share an autonomous car.

8. The residents of low accessible neighborhoods, indicate low adoption to both private and shared autonomous vehicles. It might be due to their mentality that shared AVs bring homelessness or crime to their neighborhoods.
9. Built environmental factors have no significant effect on PAVs adoption. It means that socio-demographic and travel preference factors are the factors that determine the adoption rate of private AVs.
10. In summary, the results of regression analysis indicate that male residents with higher technology familiarity, living in more accessible area, having disabilities, with non-driving preferences are the characteristics of the people that are ready to use SAVs and pay more for it. Moreover, White residents pay higher for SAVs services.
11. In brief, younger users (being in age group of 18-24) with high technology familiarity, and with non-driving travel preference are the characteristics of people who are more interested in buying a PAV and are willing to pay more for it. Moreover, the age group 55-64 considerably less likely to adopt PAVs.
12. Like the predations of game theory, the survey results show that the AVs development might promote walkability and transit although its effect is not considerable.
13. Most respondents believe that in the case of a car crashes, the AV manufacturers should be responsible and the priority of AVs should be saving the majority of people’s lives.
14. Respondents expect that the government should regulate AVs use and liability. They prefer AVs drive in dedicated lanes, have the same speed limit as human-driven cars, and the passengers’ trip information would be available only for the AV user/owner.
15. Autonomous vehicles have the lowest acceptance rate in DFW amongst other innovative transportation modes such as Hyperloop, high-speed rail and flying taxis.

16. Creating a mixed-transportation mode of AVs and Bullet Train increases the AVs adoption.
17. The dynamics that influence WTP are the same variables that stimulate AV adoption. Even income does not play a crucial role on the level of WTP.

6 Chapter 6: Conclusion and Policy Implication

This chapter provides a summary of the process of conducting this dissertation research and shows the main results of each chapter. Then, the author makes a conclusion, based on the results of the study and accesses the role of the built environment on adoption. Based on the results, the study implicates policies for cities regarding autonomous driving. Afterward, the author describes the limitations of the study and recommends several topics for the future studies.

6.1 Summary and Overview

Before presenting any new technology, measuring the public perception towards that technology is essential. Scholars believe that autonomous driving technology will revolutionize the current urban transpiration systems. However, the implementation of this fundamental change needs a broader public acceptance. Without a deep understanding of public perception towards the AV technology and preparing users for the new technology, the implementation of the technology will fail. To meet this need, several research works focus on exploring the public adoption of AVs. However, few works have focused on the factors that change adoption, and especially there is very little evidence of the effects of built environmental factors on AVs adoption.

This dissertation presents a cohesive argument for public adoption of self-driving cars. It also provides a detailed examination of how built environmental factors affect AVs adoption.

The research presents a comprehensive review of the literature on the topics of AVs effects on cities, AVs adoption, and the findings of surveys about AVs all over the nation. The results of literature review show numerous advantages of AVs besides the drawbacks that the technology might cause. Withal, the results of previous surveys reveal the relatively low rate of AVs adoption in the U.S. Based on the results of reviewing previous surveys and the experiences of the AVs implementation in Europe; the author designs a survey. Moreover, to distribute the survey, the author design a sample considering the most effective demographic features on adoption. According to the sampling, the survey is distributed in the study area, and data is collected. After collecting and cleaning the data, the author conducts the statistical analysis and find the variables that significantly influence AVs adoption.

The results of this study confirm that SAVs and PAVs are independent transportation modes. Results also show that the public adoption of PAVs is higher than SAVs, However educating residents about the features of AVs, considerably increases SAVs adoption.

Therefore, to achieve a better understanding surrounding public adoption, policymakers and AVs developers should consider two types of AVs adopters: PAVs adopters and SAVs adopters. Distinguishing these two modes will help AVs developers to present the right products to the right people and in the right place. As the findings indicate, residents of accessible areas are more likely to accept SAVs. Therefore, implementing a victorious SAVs fleet in these areas might increase the adoption rate of the people from other areas and the technology and will gradually expand SAVs network to the other neighborhoods.

The results alsoindicate that built environmental factors, and some socio-demographic elements play a vital role in adoption. The characteristics of the people who are more likely to adopt either form of AVs, are male and younger people (age group of 18-25 years old), residents who live in the more accessible neighbourhoods, residents with high technology familiarity (graduate education, tech-savvy, more experiences of autonomous features), citizens who prefer non-driving travel modes, and people with disabilities. Consequently, AVs developers should identify these groups of society and concentrate their investment on them.

Considering the most important advantages and disadvantages of AVs for residents helps us to interpret the adoption behaviors. There are safety issues on the top of the lists of pros and cons. The most considerable advantage of AVs for residents is road safety, while the highest concern of them is a hacking vulnerability. Subsequently, AV producers should think through this issue and prioritize safety features to others such as price, fuel economy, electric car engines, and car insurance.

An unexpected finding is the low rate of AV adoption compared to other innovative transportation modes that are not even tested. For example, flying taxis are in the initial stages of assessment, and they have not been publicly displayed. However, public adoption of flying taxis has the same rate of adoption as AVs with numerous showcases all over the nation. This emphasizes the fact that a relatively unsuccessful showcasing of this new transportation mode can cause a destructive effect on public trust.

The second most important advantages of AVs for residents is providing mobility for persons who do not drive. In addition to disabled residents, SAVs can provide transportation in the mobility-desert areas. Due to the considerably low price of SAVs compared to human-driven taxis, SAVs will eliminate the problems that ride-hailing drivers might create such as sexual harassment, assault, and racial discrimination. For instance, findings of a recent study that monitored 1,500 rides in Seattle, WA, and Boston, MA, reveal that there is a pattern of discrimination in peer transportation companies. African-American riders wait meaningfully longer for their Ubers, and the cancellation rate for black sounding names is over twice as frequent in comparison to white sounding names (Ge, Knittel, MacKenzie, & Zoepf, 2016). Furthermore, the results of a recent study indicate acceptance of sexual harassment at Uber will negatively impact consumers’ perception toward Uber's brand popularity (Griffith, Van Esch, &

Trittenbach, 2018). Therefore, SAVs could potentially provide safter and more reliable mobility services for racial minorities and women compared to human-driven car-sharing services.

Dedication of lanes to AVs is a controversial issue. Dedicating lanes to AVs will lead to fundamental changes in the road infrastructure and might increase traffic in the other lanes. However, based on the survey results, the majority of residents do not feel comfortable driving in the same lanes with AVs. Ignoring the request of the majority of residents will likely result in adverse outcomes on the public adoption. Therefore this is an issue that an urban planner should consider in planning for the cities. Showcasing the technology in the low-traffic streets that have the potential to dedicate a lane to AVs will improve trust to AVs and prepare the public to accept AVs in the regular lanes. Regarding the speed limit, the majority of residents believe that AVs can have the same speed limit as the other cars. This public perception provides more freedom for policymakers to determine the speed limit for AVs.

As the results of the study reveal environmental aspects of AVs is an attraction Subsidizing the price of SAVs rides can productively contribute to the expansion of the technology. In order to do that, SAVs developers can form partnerships with entities that follow environmental and social goals. For instance, since SAVs facilitate electric engines, SAVs developers can cooperate with the air quality entities in the area for implementing SAVs fleets and subsidizing the ride costs for residents. The approach can be especially in the DFW Metroplex that suffes from air polution.

6.2 Role of Built Environments in AVs deployment

An important finding of this study is the correlation between the built environment and shared AVs. As the results reveal, compact development can increase public adoption of SAVs and PAVs although the effect on PAVs is not significant. This can be a lesson for SAVs developers to consider analyzing built environment before deployment of SAVs services. Selection of the right place for initiating a SAVs fleet service areas is the key to succes. The successful performance of SAVs in accessible areas will increase trust in the technology in other areas and after some while, the authorities can expand SAVs services to another part of cities. Moreover, the successful performance of SAVs in the accessible neighborhoods might enhance the general trust in AV technology and improve the sales of private AVs.

As the study discusses in chapter 3, this experience of autonomous shuttle performance in the Europe confirms this issue. The successful performance of AV shuttles in seven European cities leads to a significant growth in public adoption in all cities. Even residents show in the survey that they prefer autonomous shuttles to human-driven shuttles.

Meanwhile, a partnership of SAVs developers with affordable housing entities can lead to development of compact development. According to the new definition of affordability that includes transportation cost, cities seek for new methods and policies to provide transit accessibility for affordable housing. Before expanding SAVs services, the authorities can provide incentives for housing developers to expand affordable houses according to the bases of compact development in the area. Afterward, the networks of SAVs will connect the residents of these houses to the employment centers (SAVs deployment before housing construction might increase land value and damage affordability of the houses).

AS the results indicate SAVs adoption in low accesible neighbourhoods. The cooperation of SAVs developers and city authorities improve the SAVs adoption by providing subsidized rides for the residents on mobility desert areas . SAVs services are flexible to deviate or travel off the standard fixed route and provide mobility for disadvantaged groups like the elderly, low-income laborers and disabled residents. SAVs can give services for the areas that are shrinking because of the lack of mobility. In mobility-desert areas, due to the low population density, the extension of human-driven transit is not a cost-effective solution. Operation of subsidized and regulated SAVs services might prevent families from moving out of these areas and revitalize these areas. For instance, replacing human-driven vanpooling with autonomous shuttle can reduce the costs of these services considerably through deleting the cost of drivers.

Finally, findings of this study are generalizable to other US cities with similar urban form so planners in these cities can apply the results to identify the neighborhoods that have a higher potential of AV acceptance.

6.3 Policy Implication

Creating policies and regulations for AVs is a big challenge for the deployment of the technology. Besides several aspects such as technical features of AVs, the infrastructure of cities, and current transportation policies, policymakers should consider public perception in order to create new rules.

Based on the results, the type of urban development can influence public adoption of SAVs. Therefore urban planners and policymakers can contribute in SAVs deployments by making land use policies that encourage compact development.

Based on the results of the study, the public is highly concerned regarding hacking vulnerability. Cities need to set regulations that supervise the AVs developers and strict standards to avoid any possible hacking. Policies that protect cyber-security are also necessary. There is a consensus among residents indicating that they would not like their travel information to be shared with any entities but themselves. Thus, regulations that assure users about the security of their travel information will improve trust in AVs.

The majority of the residents express that rules about AVs affect their decision to adopt the technology and they expect the government to regulate these for driver-less cars. Therefore, the government plays a crucial role in AVs deployment. Former U.S. President Barack Obama believes the role of government in AVs deployment should be as a conveyor. “The government should add a relatively light touch, investing heavily in research and making sure there’s a conversation between basic research and applied research. As technologies emerge and mature, then figuring out how they get incorporated into existing regulatory structures becomes a tougher problem, and the government needs to be involved a little bit more. Not always to force the new technology into the square peg that exists but to make sure the regulations reflect a broad base set of values. Otherwise, we may find that it’s disadvantaging certain people or certain groups.”

6.4 Limitations of the Study

This research dissertation is subject to several restrictions:

The first limitation of this research is the reliability of answers achieved from the survey questionnaire. Since the autonomous vehicle technology is not implemented on a large scale yet, some aspects of this system are not clear for respondents. Deployment of PAVs and SAVs in the city scale will show new aspects of this technology that may change the publics’ attitude either positively or negatively. Therefore, it is likely that some residents show mistrust in the survey, but after the implementation of the system in the real world, they might change their mind, or vice versa.

The second limitation of the study is that due to the high speed of technology improvement, it is difficult to predict the pace of technological progress. Therefore, it is likely that in the time of AVs implementation, there will be options for AVs that affect public acceptance that scholars have not predicted yet.

The third limitation of the research is about the methods of data collection. Although the initial plan of the study was conducting both online and paper-based surveys, the financial resources and time limitations change the method.

6.5 Research Contributions

The results of this research will shed light on AVs adoption by the public and, by extension, AV deployment. Academic researchers, urban planners, public policy makers, autonomous car producers, and car insurance agencies will utilize the findings. This study contributes to the current literature by meeting the need to research the potential impacts of urban form factors on the acceptance of self-driving vehicles.

The correlation that this study finds about the correlation between AVs acceptance and the urban form factors can be used as a guideline for the DFW urban planners to predict the process of SAVs deployment in this area. These results are also generalizable to other U.S. cities with similar urban form, to identify the neighborhoods that have a higher potential for SAV acceptance.

In order to make socially sustainable regulations, public policy makers must know the perception of the residents regarding policies surrounding upcoming technologies. The outcome of this investigation presents an outline of the public view toward policies concerning autonomous driving.

Additionally, driverless car manufacturers will use the outcome of this investigation to evaluate the market penetration of AV technology in the DFW area. Withal, AVs developers can use the findings of this study to help them predict the characteristics of neighborhoods in which residents have a higher likelihood of accepting this new technology. The preference of residents between

PAVs and SAVs and their Willingness-To-Pay for each form of AVs and the socio-demographic elements that affect public adoption are useful results of the study for AVs developers. Succinctly, the results of the study will be useful for academic researchers, urban planners, public policy makers, automakers, and insurance companies. The broad range of the applications of the results justifies the importance of conducting this investigation. Besides producing useful data, this survey will help to enhance public awareness about AV technology and educate the public about the benefits of SAVs.

6.6 Recommendations for Future Research

Throughout this work, the author has identified some opportunities for future studies that can be of help in realizing the efficient adoption of autonomous vehicle technologies.

- An issue that needs more attention for future studies is finding new financial resources after AVs arrive. A considerable portion of the income of the cities and budget for transportation projects come from traffic violation and the gas tax. However, AVs will almost eliminate driving violations and drastically decrease gas consumption. Therefore cities and transportation entities should explore new resources for their financial supplement.
- Subjects around AVs deployment and transportation equity need more attention in future studies.
- Another interesting topic that future studies can focus on is the potential influence of AVs deployment on real estate.

7 Bibliography

Alessandrini, A., Campagna, A., Site, P. D., Filippi, F., & Persia, L. (2015). Automated vehicles and the rethinking of mobility and cities. In *Transportation Research Procedia* (Vol. 5, pp. 145–160). https://doi.org/10.1016/j.trpro.2015.01.002

Alexander, D., & Gartner, J. (2014). Self-driving vehicles, advanced driver assistance systems, and autonomous driving features: Global market analysis and forecasts. Retrieved May 17, 2017, from https://www.navigantresearch.com

American Public Transportation Association. (2010). The benefits of Public transit: The rout to better personal health. *American Public Transportation Association*. Retrieved from http://www.apta.com/resources/reportsandpublications/Documents/better_health.pdf

Anderson, J. M., Nidhi, K., Stanley, K. D., Sorensen, P., Samaras, C., & Oluwatola, O. A. (2014). *Autonomous vehicle technology: A guide for policymakers*. Rand Corporation.

Asher, I. (2014). *Towards An Autonomous World: Making Sense of the Potential Impacts of Autonomous Vehicles*. Master's Thesis, Georgia Institute of Technology. Retrieved from https://smartech.gatech.edu/bitstream/handle/1853/51944/IsaacAsher_Towards an Autonomous World.pdf

Badland, H. M., Schofield, G. M., Witten, K., Schluter, P. J., Mavoa, S., Kearns, R. A., … McPhee, J. (2009). Understanding the relationship between activity and neighbourhoods (URBAN) study: Research design and methodology. *BMC Public Health*. https://doi.org/10.1186/1471-2458-9-224

Bandura, A. (1986). *Social foundations of thought and action: A social cognitive theory. PrenticeHall series in social learning theory*.

Bansal, P. (2015). OPERATIONS OF A SHARED AUTONOMOUS VEHICLE FLEET. *To Be Presented at the 94th Annual Meeting of the Transportation Research Board in Washington DC*. Retrieved from http://www.caee.utexas.edu/prof/kockelman/public_html/TRB15SAVsinAustin.pdf

Bansal, P., & Kockelman, K. M. (2017a). Are we ready to embrace connected and self-driving vehicles? A case study of Texans. *Transportation*, 1–35. https://doi.org/10.1007/s11116-016-9745-z

Bansal, P., & Kockelman, K. M. (2017b). Forecasting Americans' long-term adoption of connected and autonomous vehicle technologies. *Transportation Research Part A: Policy and Practice*, *95*, 512–293. https://doi.org/https://doi.org/10.1016/j.tra.2016.10.013

Bansal, P., Kockelman, K. M., & Singh, A. (2016). Assessing public opinions of and interest in new vehicle technologies: An Austin perspective. *Transportation Research Part C: Emerging Technologies*, *67*, 1–14. https://doi.org/10.1016/j.trc.2016.01.019

Barth, M., & Shaheen, S. (2002). Shared-Use Vehicle Systems: Framework for Classifying Carsharing, Station Cars, and Combined Approaches. *Transportation Research Record: Journal of the Transportation Research Board*, *1791*, 105–112. https://doi.org/10.3141/1791-16

Baum-Snow, N. (2007). Did highways cause suburbanization? *Quarterly Journal of Economics 122 (2): 775–805. Doi:10.1162/Qjec.122.2.775*. Retrieved from http://isites.harvard.edu/fs/docs/icb.topic1377262.files/Urbanization/Baum-Snow.pdf

Bednarek, J. R. D. (2001). *America's airports : airfield development, 1918-1947*. College Station: Texas A&M University Press. Retrieved from http://www.tamupress.com/product/Americas-Airports,1268.aspx

Bell, S. (1996). Learning with Information Systems: Learning cycles and information systems development. *European Journal of Information Systems*, *7*(2), 261–272. Retrieved from http://oro.open.ac.uk/20891/

Boarnet, M. G., & Crane, R. (2001). *Travel by design: The influence of urban form on travel*. Oxford University Press on Demand.

Boarnet, M. G., Greenwald, M., & McMillan, T. E. (2008). Walking, Urban Design, and Health: Toward a Cost-Benefit Analysis Framework. *Journal of Planning Education and Research*. https://doi.org/10.1177/0739456X07311073

Boer, R., Zheng, Y., Overton, A., Ridgeway, G. K., & Cohen, D. A. (2007). Neighborhood Design and Walking Trips in Ten U.S. Metropolitan Areas. *American Journal of Preventive Medicine*. https://doi.org/10.1016/j.amepre.2006.12.012

Bonnefon, J.-F., Shariff, A., & Rahwan, I. (2016). The social dilemma of autonomous vehicles. *Science*, *352*(6293), 1573–6. https://doi.org/10.1126/science.aaf2654

Brown, J. L. (2017). The Essential Guide to Writing Effective Survey Questions. Retrieved from http://www.uxbooth.com/articles/the-essential-guide-to-writing-effective-survey-questions/

Brown, J., Morris, E., & Taylor, B. D. (2009). Planning for Cars in Cities: Planners, Engineers, and Freeways in the 20th Century. *Journal of the American Planning Association 75 (2):*

161–77. Doi:10.1080/01944360802640016. Retrieved from http://diginole.lib.fsu.edu/islandora/object/fsu:207224/datastream/PDF/view

Brownson, R. C., Chang, J. J., Eyler, A. A., Ainsworth, B. E., Kirtland, K. A., Saelens, B. E., & Sallis, J. F. (2004). Measuring the Environment for Friendliness Toward Physical Activity: A Comparison of the Reliability of 3 Questionnaires. *American Journal of Public Health*. https://doi.org/10.2105/AJPH.94.3.473

Brownson, R. C., Hoehner, C. M., Day, K., Forsyth, A., & Sallis, J. F. (2009). Measuring the Built Environment for Physical Activity. State of the Science. *American Journal of Preventive Medicine*. https://doi.org/10.1016/j.amepre.2009.01.005

Burchell, R. (2015). Dallas-Fort Worth among top cities for urban sprawl.

Burghout, W., Rigole, P. J., & Andreasson, I. (2015). Impacts of Shared Autonomous Taxis in a Metropolitan Area. Retrieved from http://www.diva-portal.org/smash/record.jsf?pid=diva2%3A912176&dswid=7729

Burns, L. D., Jordan, W. C., & Scarborough, B. A. (2013). Transforming personal mobility. *The Earth Institute*, *431*, 432.

Captain, S. (2017). Uber’s Flying Taxis Will First Take To The Skies In Dallas-Fort Worth And Dubai. Retrieved May 10, 2017, from https://www.fastcompany.com/40411555/ubers-flying-taxis-will-first-take-to-the-skies-in-dallas-fort-worth-and-dubai

Casley, S., Jardim, A., & Quartilli, A. (2013). A Study of Public Acceptance of Autonomous Cars. Retrieved from https://web.wpi.edu/Pubs/E-project/Available/E-project-043013-155601/unrestricted/A_Study_of_Public_Acceptance_of_Autonomous_Cars.pdf

Center for Disease Control(CDC). (2011). Behavioral Risk Factor Surveillance System (BRFSS). Retrieved May 24, 2017, from https://www.cdc.gov/BRFSS/

Center for Disease Control and Prevention(CDC). (2007). No Title. Retrieved January 6, 2018, from https://www.cdc.gov/healthyplaces/terminology.htm

Cerin, E., Leslie, E., Toit, L. du, Owen, N., & Frank, L. D. (2007). Destinations that matter: Associations with walking for transport. *Health and Place*. https://doi.org/10.1016/j.healthplace.2006.11.002

Cervero, R., & Duncan, M. (2003). Walking, bicycling, and urban landscapes: evidence from the San Francisco Bay Area. *American Journal of Public Health*, *93*(9), 1478–83. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/12948966

Cervero, R., & Kockelman, K. (1997). Travel demand and the 3Ds: Density, diversity, and design. *Transportation Research Part D: Transport and Environment*, *2*(3), 199–219. https://doi.org/10.1016/S1361-9209(97)00009-6

Chatman, D. G. (2005). How the built environment influences non-work travel: Theoretical and empirical essays. *Dissertation Abstracts International, A: The Humanities and Social Sciences*, 4205. Retrieved from https://queens.ezp1.qub.ac.uk/login?url=http://search.proquest.com/docview/61611104?accountid=13374%5Cnhttps://ezproxy1.qub.ac.uk:8443/resserv/QUEEN?genre=dissertations+&+theses&issn=&title=How+the+built+environment+influences+non-work+travel:+Theoretical

Chen, T. D., Kockelman, K. M., & Hanna, J. P. (2016). Operations of a shared, autonomous, electric vehicle fleet: Implications of vehicle & charging infrastructure decisions. *Transportation Research Part A: Policy and Practice*, *94*, 243–254. https://doi.org/10.1016/j.tra.2016.08.020

Childress, S., Nichols., B., Charlton., B., & Stefan, C. (2015). Model to Explore Possible Impacts of Automated Vehicles. *Presented at 94th Annual Meeting of the Transportation Research Board, Washington, D.C.*

Cisco Systems. (2013). Cisco Customer Experience Research Automotive Industry Global Data. Retrieved from http://www.cisco.com/c/dam/en_us/about/ac79/docs/ccer_report_manufacturing.pdf

CityMobil Consortium. (2006). *CityMobil evaluation framework, Deliverable D5.1.1 of CITYMOBIL project*.

CityMobil Consortium. (2010). Field Trial B ex-ante evaluation report. Retrieved July 25, 2017, from http://www.citymobil-project.eu/site/en/consortium.php

CityMobil2. (2015). Cities demonstrating automated road passenger transport. Retrieved April 30, 2017, from http://www.citymobil2.eu/en/

CityMobil2. (2016). CityMobil2 Lessons learned and results, (314190). Retrieved from http://www.citymobil2.eu/en/upload/cityMobil2 leaflet 2016 v_02.pdf

Cole, S. (2001). Dare to Dream: *Bringing Futures into Planning*. *Journal of the American Planning Association*, *67*(4), 372–383. https://doi.org/10.1080/01944360108976246

Continental. (2015). It’s Mine. Yes to Mobility, Insight and Outlook 2015 Continental Mobility Study, Technical Report. Retrieved from http://report.contionline.com/report2014/service/download/docs/mobility_study_2015_en.pdf

Coogan, P. F., White, L. F., Adler, T. J., Hathaway, K. M., Palmer, J. R., & Rosenberg, L. (2009). Prospective study of urban form and physical activity in the black women's health study. *American Journal of Epidemiology*. https://doi.org/10.1093/aje/kwp264

Couclelis, H. (2005). Where Has the Future Gone?' Rethinking the Role of Integrated Land-Use Models in Spatial Planning. *Environment and Planning A 37 (8): 1353–71. Doi:10.1068/ A3785*. https://doi.org/10.1068/a3785

Crane, R., & Crepeau, R. (1998). Does neighborhood design influence travel?: A behavioral analysis of travel diary and GIS data. *Transportation Research Part D: Transport and Environment*, *3*(4), 225–238. https://doi.org/10.1016/S1361-9209(98)00001-7

Danise, A. (2015). Women Say No Thanks to Driverless Cars, Survey Finds; Men Say Tell Me More. Retrieved July 28, 2017, from https://www.nerdwallet.com/blog/insurance/survey-consumer-fears-self-driving-cars/

Daziano, R. A., Sarrias, M., & Leard, B. (2017). Are consumers willing to pay to let cars drive for them? Analyzing response to autonomous vehicles. *Transportation Research Part C: Emerging Technologies*, *78*, 150–164. https://doi.org/10.1016/j.trc.2017.03.003

Denver Regional Council of Governments. (1993). *Suburban Mobility Design Manual*. Denver, CO, 1993, p. 26.

Department of Transportation(DOT). (2016). Fiscal Year 2016 Budget Highlights | Department of Transportation. Retrieved April 27, 2017, from https://www.transportation.gov/mission/budget/fiscal-year-2016-budget-highlights

Duncan, D. T., Aldstadt, J., Whalen, J., Melly, S. J., & Gortmaker, S. L. (2011). Validation of walkscore® for estimating neighborhood walkability: an analysis of four US metropolitan areas. *International Journal of Environmental Research and Public Health*. https://doi.org/10.3390/ijerph8114160

Duranton, G., & Turner, M. A. (2011). The Fundamental Law of Road Congestion: Evidence from US Cities. *The American Economic Review 101 (6): 2616–52*, *101*(6), 2616–2652. https://doi.org/10.1257/aer.101.6.2616

European Commission. (2016). CITYMOBIL2 Report Summary. Retrieved from http://cordis.europa.eu/result/rcn/177967_en.html

Ewing, R. (1996). *Best Development Practices - Doing the Right Thing and Making Money at the Same Time*. Chicago, IL: American Planning Association.

Ewing, R. (1998). Pedestrian and Transit-Friendly Design. *In Third National Conference on Access Management. Fort Lauderdale, FL: U.S. Department of Transportation Federal Highway Administration.*

Ewing, R., & Cervero, R. (2001). Travel and the Built Environment: A Synthesis. *Transportation Research Record: Journal of the Transportation Research Board*, *1780*, 87–114. https://doi.org/10.3141/1780-10

Ewing, R., & Hamidi, S. (2014). *Measuring Sprawl 2014*. *Smart Growth America*. https://doi.org/10.1111/j.1728-4465.2014.00390.x

Ewing, R., Hamidi, S., & Grace, J. B. (2016). Compact development and VMT — Environmental or some of both ? *Environment and Planning B: Planning and Design*, *43(4)*, 737–755. https://doi.org/10.1177/0265813515594811

Fagnant, D. ., & Kockelman, K. (2014). Preparing a nation for autonomous vehicles: opportunities, barriers and policy recommendations for capitalizing on self-driven vehicles. *Transportation Research Board*.

Fagnant, D. ., & Kockelman, K. (2015). Preparing a nation for autonomous vehicles: opportunities, barriers and policy recommendations. *Transportation Research Part A: Policy and Practice*, *77*, 167–181. https://doi.org/10.1016/j.tra.2015.04.003

Fagnant, D. ., & Kockelman, K. (2016). Dynamic ride-sharing and fleet sizing for a system of shared autonomous vehicles in Austin, Texas. *Transportation*, 1–16. https://doi.org/10.1007/s11116-016-9729-z

Fagnant, D., & James, D. (2014). The future of fully automated vehicles : opportunities for vehicle- and ride-sharing, with cost and emissions savings. *Transportation*.

Fagnant, D., & Kockelman, K. (2014). The travel and environmental implications of shared autonomous vehicles, using agent-based model scenarios. *Transportation Research Part C*, *40*, 1–13. Retrieved from http://www.ce.utexas.edu/prof/kockelman/public_html/TRB14SAVenergy_emissions.pdf

Feskens, R., Hox, J., Lensvelt-Mulders, G., & Schmeets, H. (2007). Nonresponse Among Ethnic Minorities: A Multivariate Analysis. *Journal of Official Statistics, Vol. 23, No. 3, 2007, Pp. 387–408*.

Financial Times. (2017). Uber venture prepares to test flying taxis by 2020. Retrieved May 10, 2017, from https://www.ft.com/content/76056b28-297a-11e7-9ec8-

168383da43b7?emailId=5900200a79a3ca00040adf62&segmentId=22011ee7-896a-8c4c-22a0-7603348b7f22

FluidSurveys Team. (2015). Survey Priming –How Your Question Order is Giving Your Survey Bias. Retrieved June 2, 2018, from http://fluidsurveys.com/university/survey-priming-question-order-giving-survey-bias/

Frank, L., Bradley, M., Kavage, S., Chapman, J., & Lawton, T. K. (2007). Urban form, travel time, and cost relationships with tour complexity and mode choice. *Transportation*, *35*(1), 37–54. https://doi.org/10.1007/s11116-007-9136-6

Frank, L. D., Sallis, J. F., Conway, T. L., Chapman, J. E., Saelens, B. E., & Bachman, W. (2006). Many pathways from land use to health: Associations between neighborhood walkability and active transportation, body mass index, and air quality. *Journal of the American Planning Association*. https://doi.org/10.1080/01944360608976725

Furman, B. (2014). Automated Transit Networks (ATN): A Review of the State of the Industry and Prospects for the Future. Retrieved from http://transweb.sjsu.edu/PDFs/research/1227-automated-transit-networks.pdf

Ge, Y., Knittel, C., MacKenzie, D., & Zoepf, S. (2016). Racial and Gender Discrimination in Transportation Network Companies. *NBER Working Paper Series*, (22776), 1–38. https://doi.org/10.3386/w22776

Giffi, C., Vitale, J., Robinson, R., & Pingitore, G. (2017). The race to autonomous driving Winning American consumers’ trust. *Deloitte University Press*. Retrieved from https://dupress.deloitte.com/content/dam/dup-us-en/articles/3565_Race-to-autonomous-driving/DR20_The race to autonomous driving_reprint.pdf

Giles-Corti, B., Bull, F., Knuiman, M., McCormack, G., Van Niel, K., Timperio, A., … Middleton, N. (2013). The influence of urban design on neighborhood walking following residential relocation: Longitudinal results from the RESIDE study. *Social Science & Medicine*, *77*, 20–30. https://doi.org/10.1016/j.socscimed.2012.10.016

Glanz, K., & Kegler, M. C. (2007). *Environments: Theory, Research and Measures of the Built Environment*.

Glanz, K., Sallis, J. F., Saelens, B. E., & Frank, L. D. (2007). Nutrition Environment Measures Survey in Stores (NEMS-S). Development and Evaluation. *American Journal of Preventive Medicine*. https://doi.org/10.1016/j.amepre.2006.12.019

Global Driving Risk Management. (2011). Human error accounts for 90% of road accidents | Driver Risk Management Solutions | AlertDriving. Retrieved May 1, 2017, from http://channel.staging.alertdriving.com/home/fleet-alert-magazine/international/human-error-accounts-90-road-accidents

Goodman, M. (2017). Forget The High Speed Rail—This Dallas Company Wants the Hyperloop. Retrieved August 14, 2017, from https://www.dmagazine.com/frontburner/2017/04/forget-the-high-speed-rail-this-dallas-company-wants-the-hyperloop/

Griffith, D. A., van Esch, P., & Trittenbach, M. (2018). Investigating the mediating effect of Uber’s sexual harassment case on its brand: Does it matter? *Journal of Retailing and Consumer Services*, *43*, 111–118. https://doi.org/10.1016/j.jretconser.2018.03.007

Guerra, E. (2015). When Autonomous Cars Take to the Road, Be ready; it may happen soon. Retrieved June 12, 2017, from https://www.planning.org/planning/2015/may/autonomouscars.htm

Guerra, E. (2016). Planning for Cars That Drive Themselves: Metropolitan Planning Organizations, Regional Transportation Plans, and Autonomous Vehicles. *Journal of Planning Education and Research*, *36*(2), 210–224. https://doi.org/10.1177/0739456X15613591

Haboucha, C. J., Ishaq, R., & Shiftan, Y. (2015). User preferences regarding autonomous vehicles: Giving up your private car. *IATBR 2015 - WINDSOR*. Retrieved from http://www.iatbr2015.org.uk/index.php/iatbr/iatbr2015/paper/view/28

Hamidi, S., Ewing, R., & Renne, J. (2016). How Affordable Is HUD Affordable Housing? *Housing Policy Debate*, *26*(3), 437–455. https://doi.org/10.1080/10511482.2015.1123753

Handy, S., Cao, X., & Mokhtarian, P. (2005). Correlation or causality between the built environment and travel behavior? Evidence from Northern California. *Transportation Research Part D: Transport and Environment*, *10*(6), 427–444. https://doi.org/10.1016/j.trd.2005.05.002

Harper, C. D., Hendrickson, C. T., & Samaras, C. (2016). Cost and benefit estimates of partially-automated vehicle collision avoidance technologies. *Accident Analysis and Prevention*, *95*, 104–115. https://doi.org/10.1016/j.aap.2016.06.017

Hayes, B. (2011). Leave the Driving to It. *American Scientist. 99: 362-366.* Retrieved from http://www.americanscientist.org/libraries/documents/201189112848657-2011-

09Hayes.pdf

Health Canada Division of Childhood and Adolescence. (2002). Natural and Built Environments. Ottawa: Health Canada. *Natural and Built Environments. Ottawa: Health Canada*.

Howard, D., & Dai, D. (2014). Public Perceptions of Self-driving Cars: The Case of Berkeley, California. *Prepared for the 93rd 40 Annual Meeting of the Transportation Research Board*.

Huang, L., Stinchcomb, D. G., Pickle, L. W., Dill, J., & Berrigan, D. (2009). Identifying Clusters of Active Transportation Using Spatial Scan Statistics. *American Journal of Preventive Medicine*. https://doi.org/10.1016/j.amepre.2009.04.021

IndexMundi. (2013). Texas Average Commute Time by County. Retrieved from https://www.indexmundi.com/facts/united-states/quick-facts/texas/average-commute-time#map

Ipsos MORI. (2014). *Automated vehicles: what the public thinks*. Retrieved from http://www.sciencewise-erc.org.uk/cms/assets/Uploads/Automated-Vehicles-Update-Jan-2015.pdf

Isserman, A. M. (1985). Dare to Plan: An Essay on the Role of the Future in Planning Practice and Education on JSTOR. Retrieved April 30, 2017, from https://www.jstor.org/stable/40112237?seq=1#page_scan_tab_contents

J.D. Power. (2012). Vehicle Owners Show Willingness to Spend on Automotive Infotainment Features, Technical Report, Westlake Village. Retrieved from http://www.jdpower.com/sites/default/files/2012049-uset.pdf

J.D. Power. (2013). 2013 U.S. Automotive Emerging Technologies Study | J.D. Power. Retrieved July 26, 2017, from http://www.jdpower.com/press-releases/2013-us-automotive-emerging-technologies-study

J.D. Power. (2015). Power Reports: Consumer Preference for Collision Protection Technologies Paves the Way for Autonomous Driving Apple CarPlay vs. Google Android Auto? It Depends on Your Phone. Retrieved from http://www.jdpower.com/sites/default/files/2015044 Tech Choice Study (FINAL).pdf

James, P., Troped, P. J., & Laden, F. (2013). Chapter 50 – The Impact of the Built Environment on Health. *Women and Health (Second Edition)*, 753–763.

Jeihani, M. (2013). *Development of a Framework for Transit-Oriented Development (TOD).*

Karaseitanidis, G., Lytrivis, P., Ballis, A., Amditis, A., & Raptis, O. (2013). Trikala Local transport plans reviewed and automated road transport system assessment. *Citymobil2 SEVENTH FRAMEWORK PROGRAMMEF*, *D9.1 Local*, 1–78.

Khan, M., Kockelman, K. M., & Xiong, X. (2014). Models for anticipating non-motorized travel choices, and the role of the built environment. *Transport Policy*, *35*, 117–126. https://doi.org/10.1016/j.tranpol.2014.05.008

Kockelman, K., Boyles, S., Stone, P., Fagnant, D. ., Patel, R., Levin, M. W., … Li, J. (2016). An Assessment of Autonomous Vehicles: Traffic Impacts and Infrastructure Needs. Final Report (FHWA 0-6847-1). *Center for Transportation Research the University of Texas at Austin*. Retrieved from http://library.ctr.utexas.edu/ctr

Kornhauser, A., Chang, A., Clark, C., Gao, J., Korac, D., Lebowitz, B., &, & Swoboda, A.

(2013). Uncongested Mobility for All: New Jersey's AreaWide aTaxi System. *Princeton University*. *Princeton, New Jersey*. Retrieved from http://orfe.princeton.edu/~alaink/NJ_aTaxiOrf467F12/ORF467F12aTaxiFinalReport.pdf

KPMG, & CAR. (2012). *Self-Driving Cars: The Next Revolution*. *Ann Arbor, MI.*

Krueger, R., Rashidi, T. H., & Rose, J. M. (2016). Preferences for shared autonomous vehicles. https://doi.org/10.1016/j.trc.2016.06.015

Kyriakidis, M., Happee, R., & de Winter, J. C. F. (2015). Public opinion on automated driving: Results of an international questionnaire among 5000 respondents. *Transportation Research Part F: Traffic Psychology and Behaviour*, *32*, 127–140. https://doi.org/10.1016/j.trf.2015.04.014

Levin, M. W., & Boyles, S. D. (2015). Effects of Autonomous Vehicle Ownership on Trip, Mode, and Route Choice. *Transportation Research Record: Journal of the Transportation Research Board*, *2493*, 29–38. https://doi.org/10.3141/2493-04

Levine, J., Zellner, M., Shiftan, Y., Alarcon Arquero de, M., & Diffenderfer, A. (2013). *Effects of automated transit, pedestrian and bicycling facilities on urban travel patterns*. Retrieved from https://taubmancollege.umich.edu/sites/default/files/files/effects-of-automated-transit-pedestrian-and-bicyling-facilities-on-urban-travel-patterns.pdf

Li, F., Fisher, K. J., Brownson, R. C., & Bosworth, M. (2005). *Multilevel modelling of built environment characteristics related to neighbourhood walking activity in older adults*. *J Epidemiol Community Health*. https://doi.org/10.1136/jech.2004.028399

Li, T., & Kockelman, K. M. (2016). Valuing the Safety Benefits of Connected and Automated

Vehicle Technologies. *Transportation Research Board 95th Annual Meeting (No. 16-1468)*. Retrieved from https://www.caee.utexas.edu/prof/kockelman/public_html/TRB16CAVSafety.pdf

Lin, J., & Long, L. (2008). What neighborhood are you in? Empirical findings of relationships between household travel and neighborhood characteristics. *Transportation*. https://doi.org/10.1007/s11116-008-9167-7

Litman, T. (2015). Autonomous Vehicle Implementation Predictions Implications for Transport Planning. *Traffic Technology International*, 36–42. Retrieved from www.vtpi.org/AVIP_TTI_Jan2014.pdf

Litman, T. (2016). Parking Management Strategies, Evaluation and Planning. *Victoria Transport Policy Institute. Victoria, B.C.* Retrieved from http://www.vtpi.org/park_man.pdf

Litman, T. (2017). *Autonomous Vehicle Implementation Predictions Implications for Transport Planning*. *Victoria Transport Policy Institute*. Retrieved from www.vtpi.org/AVIP_TTI_Jan2014.pdf

Litman, T., & Steele, R. (2017). Land Use Impacts on Transport, How Land Use Factors Affect Travel Behavior. *Online TDM Encyclopedia, Victoria Transport Policy Institute*, 88. https://doi.org/10.1007/978-3-642-54876-5

Lofland, J., & Lofland, L. H. (1995). Analyzing Social Settings: A Guide to Qualitative Observation and Analysis 4th Edition. *Belmont, CA: Wadsworth*. Belmont, California: University of California, Davis. https://doi.org/10.1177/089124196025003006

Lu, Y., & Tang, J. (2004). Fractal dimension of a transportation network and its relationship with urban growth: A study of the Dallas-Fort Worth area. *Environment and Planning B: Planning and Design*, *31*(6), 895–911. https://doi.org/10.1068/b3163

McCormack, G. R., Giles-Corti, B., & Bulsara, M. (2008). The relationship between destination proximity, destination mix and physical activity behaviors. *Preventive Medicine*. https://doi.org/10.1016/j.ypmed.2007.01.013

McIntyre, L. J. (1999). (1999). *The practical skeptic: Core concepts in sociology. Mountain View, CA: Mayfield Publishing.*

McLeroy, K. R., Bibeau, D., Steckler, A., & Glanz, K. (1988). An ecological perspective on health promotion programs. *Health Education Quarterly*. https://doi.org/10.1177/109019818801500401

Mearian, L. (2013). Self-driving cars could save more than 21,700 lives, $450B a year | Computerworld. Retrieved May 1, 2017, from http://www.computerworld.com/article/2486635/emerging-technology/self-driving-cars-could-save-more-than-21-700-lives-450b-a-year.html

Millard-Ball, A. (2016). Pedestrians, Autonomous Vehicles, and Cities. *Journal of Planning Education and Research*, 0739456X1667567. https://doi.org/10.1177/0739456X16675674

Mujahid, M. S., Diez Roux, A. V., Morenoff, J. D., & Raghunathan, T. (2007). Assessing the measurement properties of neighborhood scales: From psychometrics to ecometrics. *American Journal of Epidemiology*. https://doi.org/10.1093/aje/kwm040

Myers, D., & Kitsuse, A. (2000). Constructing the future in planning: constructing the future in planning: a survey of theories and tools. *Journal of Planning Education and Research 19*

(3): 221–31. Doi:10.1177 /0739456X0001900301. Retrieved from http://priceschool.usc.edu/files/documents/masters/research/JPER_Future.pdf

Nair, S., Koymans, A., Malhéné, N., Debord, N., Graindorge, M., Boesch, M., & Camacho-hübner, E. (2013). La Rochelle City Study Matthieu, (1), 1–131.

Nasri, A., & Zhang, L. (2018). Multi-level urban form and commuting mode share in rail station areas across the United States; a seemingly unrelated regression approach. *Transport Policy*. https://doi.org/https://doi.org/10.1016/j.tranpol.2018.05.011

National Highway Traffic Safety Administration. (2013). Preliminary Statement of Policy Concerning Automated Vehicles, National Highway Traffic Safety Administration. Retrieved July 31, 2017, from https://www.nhtsa.gov/

National Highway Traffic Safety Administration. (2016). *Preliminary Statement of Policy Concerning Automated Vehicles*. Retrieved from https://one.nhtsa.gov/Research/Crash-Avoidance/Automated-Vehicles

National Highway Traffic Safety Administration (NHTSA). (2008). National Motor Vehicle Crash Causation Survey: Report to Congress. Retrieved from https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/811059

National Highway Traffic Safety Administration (NHTSA). (2012). Traffic safety facts early estimate of motor vehicle traffic fatalities in 2012. Retrieved from https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/811741

Nissan. (2014). The Future Is Now: Nissan Advances Plans to Have Commercially Viable Autonomous Drive Vehicles on the Road by 2020. Retrieved April 30, 2017, from https://www.nissanusa.com/blog/autonomous-drive-car

North Central Texas Council of Governments(NCTCOG). (2011). *Mobility 2035: the metropolitan transportation plan for north central texas program and project selection*. Retrieved from http://www.nctcog.org/trans/mtp/2035/documents/Mobility2035StandardPresentation.pdf

O'Sullivan, S., & Morrall, J. (1996). Walking Distances to and from Light-Rail Transit Stations. *Transportation Research Record: Journal of the Transportation Research Board, 1538,* 19–26. https://doi.org/10.3141/1538-03

Open Roboethics initiative. (2014). Autonomous Cars Archive. Retrieved July 31, 2017, from http://www.openroboethics.org/category/autonmous_cars/

Organisation for Economic Co-operation and Development. (2010). *Regulatory Policy and the Road to Sustainable Growth*. Retrieved from https://www.oecd.org/regreform/policyconference/46270065.pdf

Owen, N., Humpel, N., Leslie, E., Bauman, A., & Sallis, J. F. (2004). Understanding environmental influences on walking: Review and research agenda. *American Journal of Preventive Medicine*. https://doi.org/10.1016/j.amepre.2004.03.006

Renne, J., Hamidi, S., & Ewing, R. (2017). Transit commuting, the network accessibility effect, and the built environment in station areas across the United States. *Research in Transportation Economics Volume 60, December 2016, Pages 35-43*.

Riva, M., Gauvin, L., Apparicio, P., & Brodeur, J. M. (2009). Disentangling the relative influence of built and socioeconomic environments on walking: The contribution of areas homogenous along exposures of interest. *Social Science and Medicine*. https://doi.org/10.1016/j.socscimed.2009.07.019

Rodríguez, D. A., Evenson, K. R., Diez Roux, A. V., & Brines, S. J. (2009). Land Use, Residential Density, and Walking. The Multi-Ethnic Study of Atherosclerosis. *American Journal of Preventive Medicine*. https://doi.org/10.1016/j.amepre.2009.07.008

Rogers, E. M. (1995). *Diffusion of innovations*. *Macmillian Publishing Co.* https://doi.org/citeulike-article-id:126680

Roman, K. (2016). Shared autonomy - Feasability study for shared usage of autonomus vehicles in rural regions. Retrieved April 27, 2017, from https://forschung.boku.ac.at/fis/suchen.projekte_suchergebnis

Roy, J., & Perrella, A. M. L. (2015). Rural, Suburban and Urban Voters: Dissecting Residence Based Voter Cleavages in Provincial Elections. *Canadian Political Science Review V, ol. 9, No.*

Saelens, B. E., & Handy, S. L. (2008). Built environment correlates of walking: A review. *Medicine and Science in Sports and Exercise*. https://doi.org/10.1249/MSS.0b013e31817c67a4

Salent, P., & Dillman, D. (1996). How to conduct your own survey. *Journal of Marketing Research*.

Sallis, J. F., Frank, L. D., Saelens, B. E., & Kraft, M. K. (2004). Active transportation and physical activity: Opportunities for collaboration on transportation and public health research. *Transportation Research Part A: Policy and Practice*, *38*(4), 249–268.

https://doi.org/10.1016/j.tra.2003.11.003

Sallis, J. F., Owen, N., & Fisher, E. B. (2008). *Ecological models of health behavior*. *Health Behavior and Health Education: Theory, Research, and Practice*. https://doi.org/10.7326/0003-4819-116-4-350_1

Schoettle, B., & Sivak, M. (2014). *A survey of public opinion about autonomous and self-driving vehicles in the U.S., the U.K., and Australia*. Michigan. Retrieved from https://deepblue.lib.umich.edu/bitstream/handle/2027.42/108384/103024.pdf?sequence=1&isAllowed=y

Schoettle, B., & Sivak, M. (2015). *Motorists' Preferences for Different Levels of Vehicle Automation*. *The University of Michigan Transportation Research Institute Ann Arbor, Michigan 48109-2150 U.S.A.* Michigan. Retrieved from https://deepblue.lib.umich.edu/bitstream/handle/2027.42/114386/103217.pdf?sequence=1&isAllowed=y

Seapine Software. (2014). Study finds 88 percent of adults would be worried about riding in a driverless car. Retrieved July 29, 2017, from https://www.thestreet.com/story/12300610/2/study-finds-88-percent-of-adults-would-be-worried-about-riding-in-a-driverless-car.html

Segal, M., & Kockelman, K. M. (2016). Design and implementation of a shared autonomous vehicle system in austin, Texas. *Journal of Urban Planning and Development*. Retrieved from http://www.caee.utexas.edu/prof/kockelman/public_html/TRB16SAVDesign.pdf

Shanker, R., Jonas, A., Jain, P., Ying, Y., Devitt, I. S., Monahan, J., … Hoshino, R. (2013).

Autonomous Cars: Self-driving the New Auto Industry Paradigm. *Morgan Stanely Research,*. Retrieved from https://orfe.princeton.edu/~alaink/SmartDrivingCars/PDFs/Nov2013MORGAN-Stanley-blue-paper-autonomous-cars：-self-driving-the-new-auto-industry-paradigm.pdf

Shapiro, G. (2016). Imperfect Self-Driving Cars Are Safer Than Humans Are. *The Wall Street Journal*.

Shigematsu, R., Sallis, J. F., Conway, T. L., Saelens, B. E., Frank, L. D., Cain, K. L., … King, A. C. (2009). Age differences in the relation of perceived neighborhood environment to walking. *Medicine and Science in Sports and Exercise*. https://doi.org/10.1249/MSS.0b013e318185496c

Silberg, G., Manassa, M., Everhart, K., Subramanian, D., Corley, M., Fraser, H., … Ready, A. W. (2013). Self-Driving Cars: Are we Ready? *Kpmg Llp*, 1–36.

Siu, V. W., Lambert, W. E., Fu, R., Hillier, T. A., Bosworth, M., & Michael, Y. L. (2012). Built environment and its influences on walking among older women: Use of standardized geographic units to define urban forms. *Journal of Environmental and Public Health*. https://doi.org/10.1155/2012/203141

Thayer-Hart, N., & Jennifer Dykema, Kelly Elver, Nora Cate Schaeffer, J. S. (2010). SURVEY FUNDAMENTALS A GUIDE TO DESIGNING AND IMPLEMENTING SURVEYS. *University of Wisconsin Survey Center*.

Tientrakool, P., Ho, Y.-C., & Maxemchuk, N. F. (2011). Highway Capacity Benefits from Using Vehicle-to-Vehicle Communication and Sensors for Collision Avoidance. *Presented at*

Vehicular Technology Conference, IEEE, 2011. Retrieved from https://pdfs.semanticscholar.org/db00/a24d0980bd977dac7de7fed56b19785b6c68.pdf

TransForm. (2014). *Why Creating And Preserving Affordable Homes Near Transit Is A Highly Effective Climate Protection Strategy*.

U.S. Department of Transportation. (1998). *Snohomish County Transportation Authority, A Guide to Land Use and Public Transportation, Technology Sharing Program*.

U.S. Survey Research. (2014). Questionnaire design. *PEW RESEARCH CENTER*,. Retrieved from http://www.pewresearch.org/methodology/u-s-survey-research/questionnaire-design/

Underwood, S. E., Marshall, S., & Niles, J. (2014). *Automated, Connected, and Electric Vehicles An Assessment of Emerging Transportation Technologies and a Policy Roadmap for More Sustainable Transportation*. Retrieved from http://graham.umich.edu/media/files/LC-IA-Final-Underwood.pdf

United States Census(USC). (2016). Tarrant County, Texas. Retrieved May 11, 2017, from https://www.census.gov/quickfacts/table/PST045216/48113

United States Census (USC). (2016). 2016 American Community Survey. Retrieved from https://www.census.gov/newsroom/releases/archives/american_community_survey_acs/cb12-r22.html

US Bureau of Transportation Statistics. (2009). Number of U.S. Aircraft, Vehicles, Vessels, and Other Conveyances. Retrieved from https://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/national_transportation_statistics/html/table_01_11.html

US Census. (2010). American Community Survey (ACS). Retrieved from https://www.census.gov/programs-surveys/acs/

Valle, M. (2016). Autonomous cars: Will you be a co-pilot or a passenger? Retrieved April 26, 2017, from http://www.insurance.com/auto-insurance/claims/autonomous-cars-self-driving.html

Vallet, M. (2014). Autonomous cars: Will you be a co-pilot or a passenger? | Insurance.com. Retrieved April 26, 2017, from http://www.insurance.com/auto-insurance/claims/autonomous-cars-self-driving.html

Van Arem, B., Van Driel, J., & Visser, R. (2006). The Impact of Cooperative Adaptive Cruise Control on Traffic-Flow Characteristics. *Journal of IEEE Transactions, Intelligent Transportation Systems, Vol 7, 2006, Pp. 429-436*. https://doi.org/10.1080/03081060.2013.870791

Villalon, L., & Leclair, C.-A. (2004). [A participatory approach for the prevention of type 2 diabetes for francophone youth of New Brunswick]. *Canadian Journal of Dietetic Practice and Research : A Publication of Dietitians of Canada = Revue Canadienne de La Pratique et de La Recherche En Dietetique : Une Publication Des Dietetistes Du Canada*, *65*(1), 15–21. https://doi.org/10.3148/65.1.2004.15

Vujanic, A., & Unkefer, H. (2011). *Consumers in US and UK Frustrated with Intelligent Devices That Frequently Crash or Freeze, New Accenture Survey Finds | Accenture Newsroom*. Retrieved from https://newsroom.accenture.com/subjects/cloud-computing/consumers-in-us-and-uk-frustrated-with-intelligent-devices-that-frequently-crash-or-freeze-new-accenture-survey-finds.htm

W. Bowes, M. G., & Noxon, and G. (1991). *Guide to Transit Considerations in the Subdivision Design and Approval Process, Transportation*.

Walker Smith, B. (2013). Human error as a cause of vehicle crashes | Center for Internet and Society. Retrieved April 29, 2017, from http://cyberlaw.stanford.edu/blog/2013/12/human-error-cause-vehicle-crashes

Yeager, D. S., Krosnick, J. A., Chang, L., Javitz, H. S., Levendusky, M. S., Simpser, A., & Wang, R. (2011). Comparing the accuracy of RDD telephone surveys and internet surveys conducted with probability and non-probability samples. *Public Opinion Quarterly*, *75*(4), 709–747. https://doi.org/10.1093/poq/nfr020

Young, J. (2014). *U.S. Automotive Emerging Technologies Study Results, Technical Report, McGraw Hill Financial*.

Zhang, W., Guhathakurta, S., Fang, J., & Zhang, G. (2015). Exploring the impact of shared autonomous vehicles on urban parking demand: An agent-based simulation approach. *Sustainable Cities and Society*, *19*, 34–45. https://doi.org/10.1016/j.scs.2015.07.006

Zmud, J., Sener, I. N., & Wagner, J. (2016). *Consumer Acceptance and Travel Behavior Impacts of Automated Vehicles*. *Final Report*. Retrieved from http://d2dtl5nnlpfr0r.cloudfront.net/tti.tamu.edu/documents/PRC-15-49-F.pdf

8 APPENDIX: Survey Questions

Q1 My name is Hamid Hajjafari, and I am a researcher at the University of Texas at Arlington. I am requesting your participation in a UT Arlington research study about driver-less cars. A driverless car is a robotic vehicle that is designed to travel between destinations without a human operator.

You must be at least **18 years old** to participate. Qualtrics Panel will inform you about the exact amount and type of payment that you will receive for your participation. There are no perceived risks for participating in the study and you can quit the survey at any time you want. Any identifiable information will be kept confidential with access limited to the research team. If you have any questions about the study, please contact me at hamid.hajjafari@uta.edu. For questions or concerns, contact the UTA Research office at 817-272-3723 or refulatoryservice@uta.edu By clicking on the button below, you indicate your agreement to participate in this online survey.

○ Agree

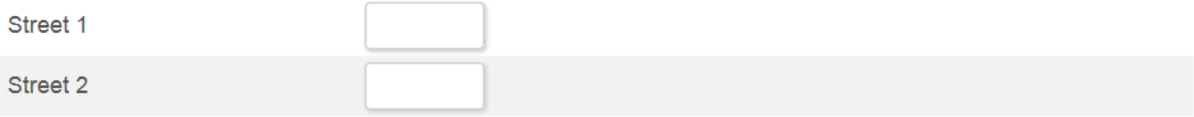
○ Disagree

Q2 Please provide the following information about where you reside.

County at which you reside (Dallas, Tarrant, Collin, Denton, Ellis, Rockwall, Kaufman).

Zip code at which you reside.

Q3 Please provide the nearest intersection to where you reside.



Street 1

Street 2

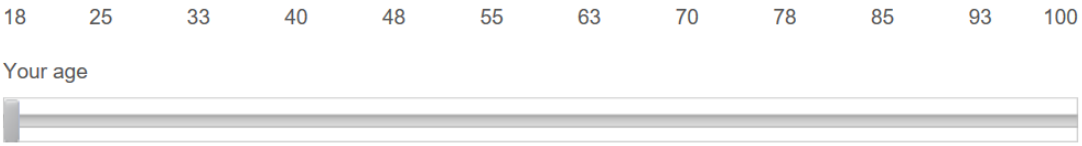
Q4 What gender do you identify with?

○ Male (1)

○ Female (2)

○ Other (3)

Q5 What is your age?



18 25 33 40 48 55 63 70 78 85 93 100

Your age

Q6 With which racial or ethnic group do you most identify?

- ○ American Indian or Alaska Native (1)
- ○ Asian (2)
- ○ African American (3)
- ○ Hispanic (4)
- ○ Native Hawaiian or Pacific Islander (5)
- ○ White (Non-Hispanic) (6)
- ○ Other (7)

Q7 What is the highest level of education you have completed?

- ○ Less than high school (1)
- ○ High school diploma (2)
- ○ Associate's degree (3)
- ○ Bachelor's degree (4)
- ○ Graduate or professional degree (Master's/ Ph.D. or equivalent) (5)

Q8 Please indicate your estimated annual household income (Not individual)

Q9 Do you rent or own your current residence?

○ Rent (1)

○ Own (2)

Q10 What kind of residence do you live in?

○ Single family house (no shared walls with any neighbors) (1)

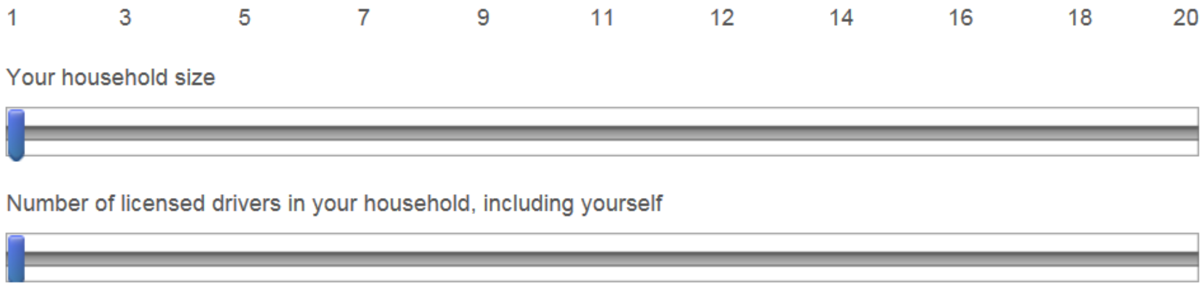
○ Town house (attached house) (2)

○ Multi-family house (3)

○ Apartment (4)

○ Dormitory or other institutional housing (5)

Q11 Please indicate the following information about your household.



Your household size

Number of licensed drivers in your household, including yourself

Q12 What is your current level of employment?

○ Employed full-time (1)

○ Employed part-time (2)

○ Not currently employed (3)

○ Retired (4)

○ Full-time student and don't work (5)

Q13 Which statement describes your familiarity with technology? (Please check all that apply)

☐ I am a tech-savvy person

☐ I complete errands such as shopping, paying bills and registrations using online technology

☐ I own a smart phone

☐ I know how to use self-checkout/In-car navigation system/Digital photography

☐ I can do basic internet tasks like checking emails

☐ I need someone to help me navigate the internet

Q14 Do you have any physical or mental disabilities that seriously limit or prevent you from doing any of the following? (Please check all that apply)

☐ Driving a vehicle (1)

☐ Driving a vehicle on the freeway (2)

☐ Walking outside the home (3)

☐ Riding a bicycle (4)

☐ Using public transit (5)

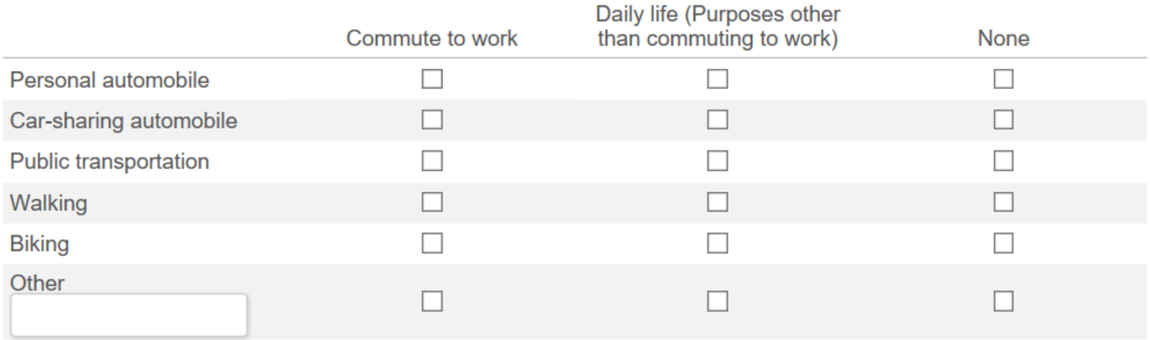
☐ No disabilities (6)

End of Block: Demographics

Start of Block: Travel Behavior

Q15 Which transportation modes do you use for commuting to work and for other purposes?

(Please check all that apply)



	Commute to work	Daily life (Purposes other than commuting to work)	None
Personal automobile	☐	☐	☐
Car-sharing automobile	☐	☐	☐
Public transportation	☐	☐	☐
Walking	☐	☐	☐
Biking	☐	☐	☐
Other ☐	☐	☐	☐

Q16 Do you currently own or lease a car?

○ Own (1)

○ Lease (2)

○ Non (3)

Skip To: Q21 If Do you currently own or lease a car? = Non

Q17 What kind of insurance coverage do you have for your current vehicle ?

○ Liability (1)

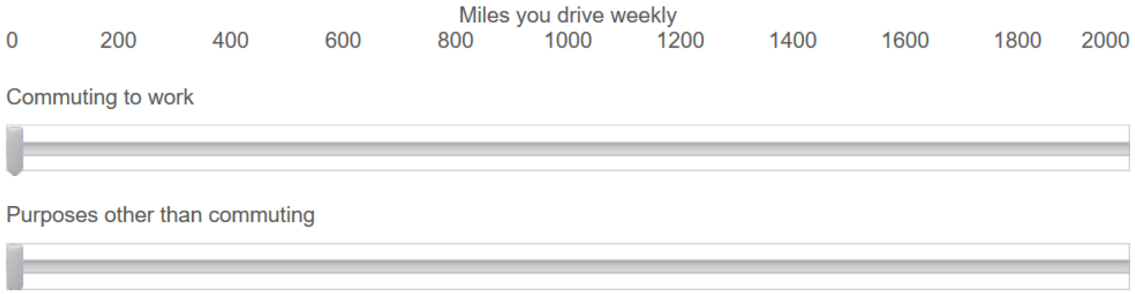
○ Full-coverage (2)

○ Comprehensive (3)

○ Other (4)

○ None (5)

Q18 How many miles would you say you drive during an average week for commuting and non-commuting purposes?



Q19 How many cars have you purchased or leased in the past ten years? (0 means no car)

Q20 Have you experienced any driving aids features in your time driving? (Select all applicable to you)

- ☐ Automatic cruise control (1)
- ☐ Navigation system (2)
- ☐ Blind-spot detection (3)
- ☐ lane-departure warning (4)
- ☐ Collision avoidance systems (5)
- ☐ Parking assist (6)
- ☐ Autopilot (7)
- ☐ None (8)

Q21 How often do you use on-demand private car services, such as Uber or Lyft?

○ Every day (1)

○ At least once a week (2)

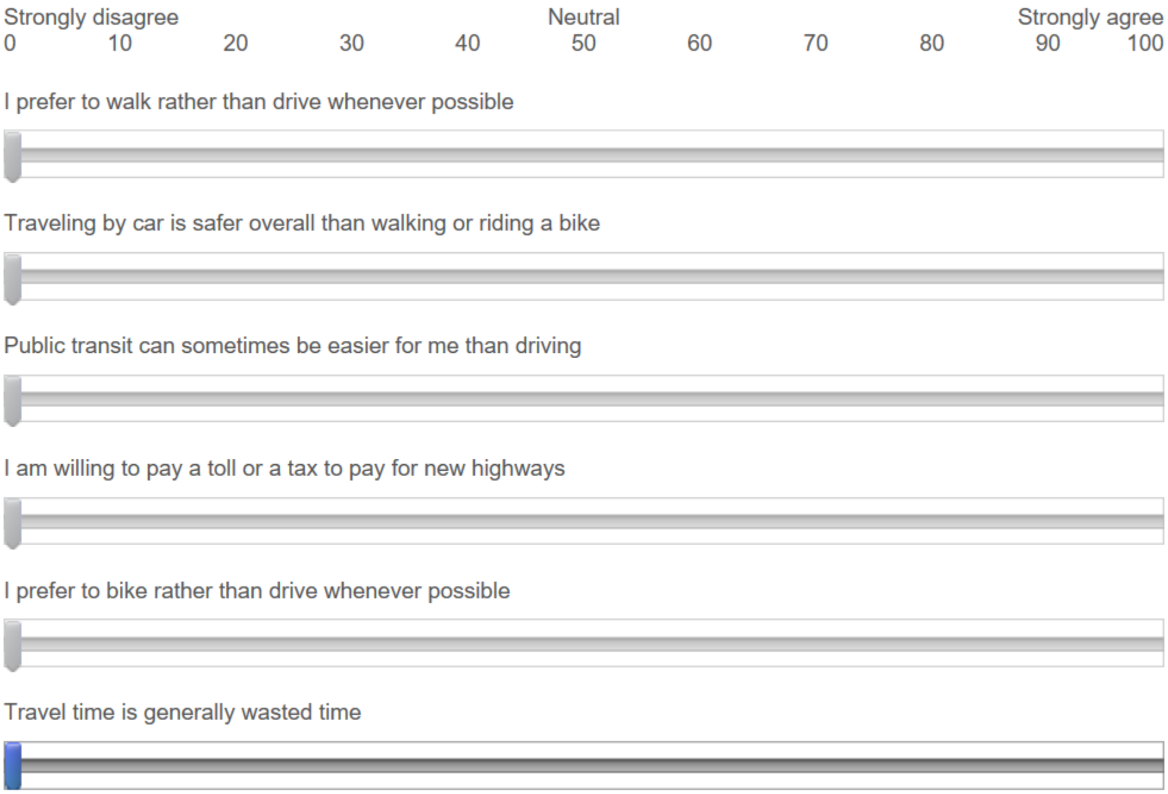
○ Between 1-3 times a month (3)

○ Less than once a month (4)

○ Never used them (5)

Q22 We would like to know a little about your preferences with respect to your **daily travel**.

Please indicate the extent to which you agree or disagree with each of the following statements on a scale from “strongly disagree” to “strongly agree.” There are no right or wrong answers; we only want your opinions.



Strongly disagree Neutral Strongly agree

0 10 20 30 40 50 60 70 80 90 100

I prefer to walk rather than drive whenever possible

Traveling by car is safer overall than walking or riding a bike

Public transit can sometimes be easier for me than driving

I am willing to pay a toll or a tax to pay for new highways

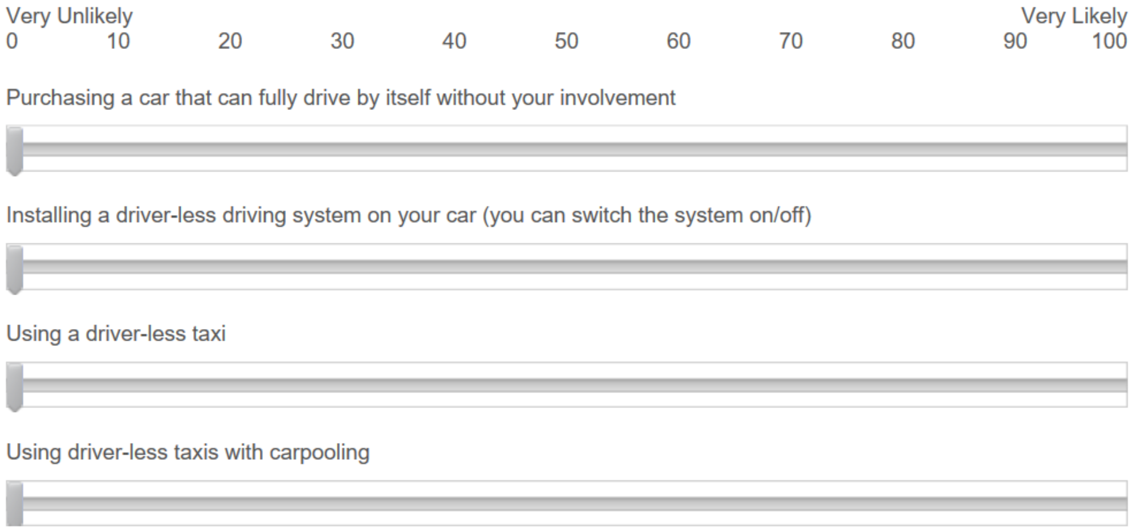
I prefer to bike rather than drive whenever possible

Travel time is generally wasted time

End of Block: Travel Behavior

Start of Block: Perceptions toward driver-less cars

Q23 Imagine driver-less vehicles become available for purchase by consumers and are legal. What is the likelihood that you would purchase or use a car that can fully drive by itself without your involvement? (0 means I would not use this form of driver-less technology.



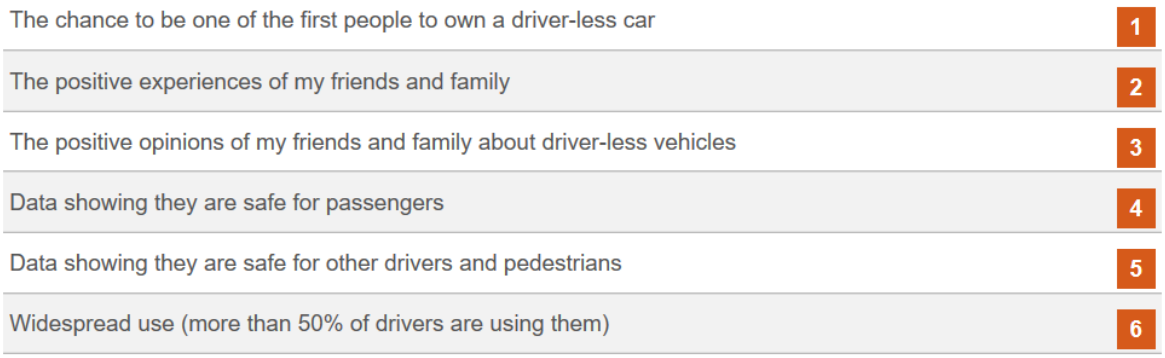
Purchasing a car that can fully drive by itself without your involvement

Installing a driver-less driving system on your car (you can switch the system on/off)

Using a driver-less taxi

Using driver-less taxis with carpooling

Q24 Imagine driver-less cars become available for purchase by consumers and are legal. What would matter most to you in deciding to purchase one? Please drag and drop to arrange the following sentences, with the most important at the top and the least important at the bottom.



The chance to be one of the first people to own a driver-less car 1

The positive experiences of my friends and family 2

The positive opinions of my friends and family about driver-less vehicles 3

Data showing they are safe for passengers 4

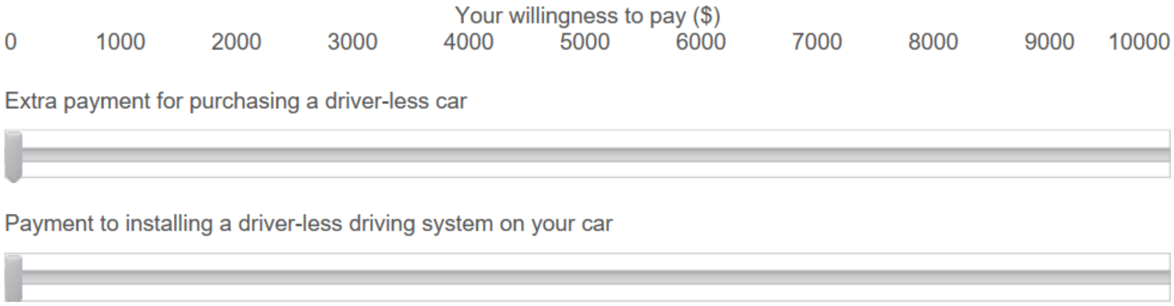
Data showing they are safe for other drivers and pedestrians 5

Widespread use (more than 50% of drivers are using them) 6

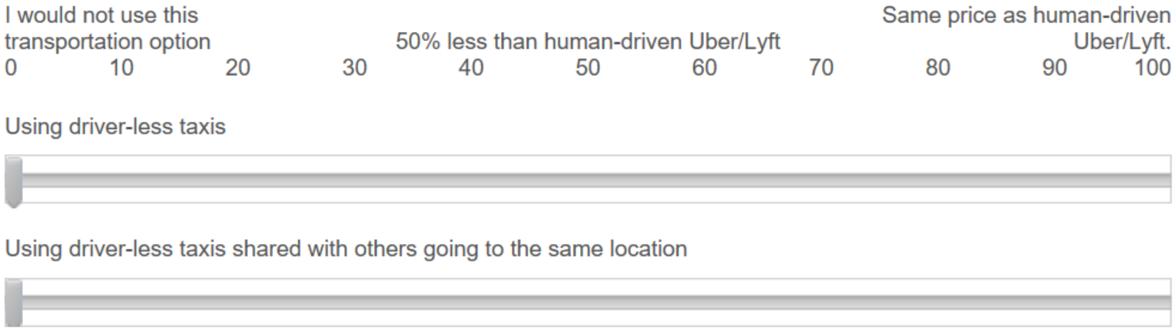
End of Block: Perceptions toward driver-less cars

Start of Block: Willingness-To-Pay

Q25 How much more than the base vehicle price would you be willing to spend to purchase a driver-less car and how much would you pay for installing a driver-less driving system in your current car (0 means I would not buy an autonomous car/ would not have this system installed)



Q26 Imagine there would be a fleet of driverless taxis serving 24/7 with a considerably lower price compared to typical taxis because the cost of a driver is eliminated. What percentage of the price of human-driven Uber/ Lyft would you expect a driver-less taxi to cost? (0 means I would not use this transportation option, 50 means 50% less than human-driven Uber/ Lyft and 100 means the same price as human-driven Uber/Lyft.



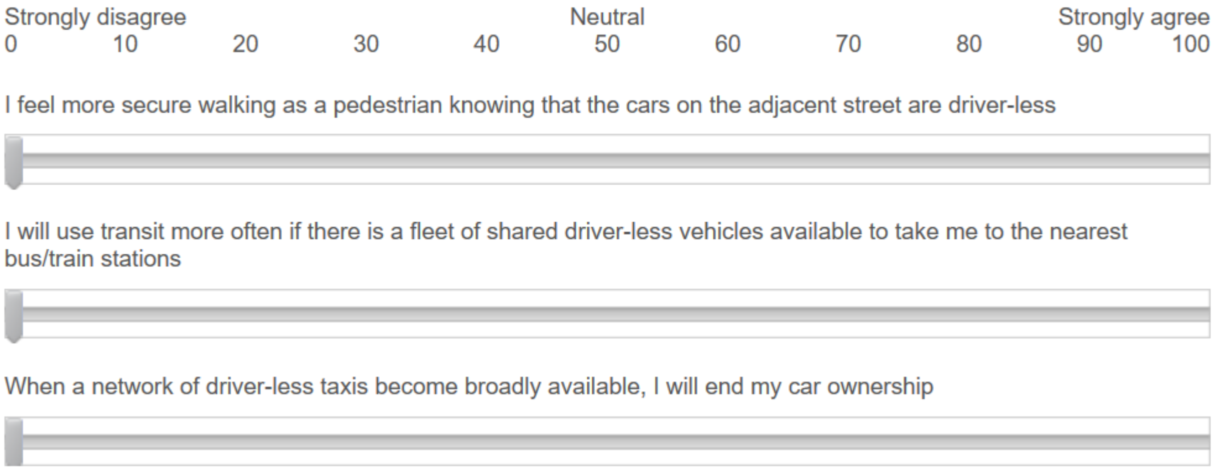
I would not use this transportation option
50% less than human-driven Uber/Lyft
Same price as human-driven Uber/Lyft.
0 10 20 30 40 50 60 70 80 90 100

Using driver-less taxis

Using driver-less taxis shared with others going to the same location

---

Q27 To what extent do you agree with the following statements?



Strongly disagree
Neutral
Strongly agree
0 10 20 30 40 50 60 70 80 90 100

I feel more secure walking as a pedestrian knowing that the cars on the adjacent street are driver-less

I will use transit more often if there is a fleet of shared driver-less vehicles available to take me to the nearest bus/train stations

When a network of driver-less taxis become broadly available, I will end my car ownership

End of Block: Willingness-To-Pay

Start of Block: Regulations

Q28 Imagine a driver-less car is involved in an accident and due to a system error, the driver-less car is at fault. Who should be responsible, in your opinion? (You can select more than one)

- ☐ Owner of the driver-less car (1)
- ☐ The driver-less car manufacturer (2)
- ☐ The insurance company (3)
- ☐ Manufacturer of the driver-less system (4)
- ☐ I’m not sure (5)

Q29 As a potential user of driver-less cars, who are you comfortable with having access to your information such as the addresses and locations to where you travel and the average mileage you drive annually? (You can select more than one option)

- ☐ Government for security reasons (1)
- ☐ The auto-maker company (2)
- ☐ Research organizations (for purposes other than advertising) (3)
- ☐ Should be only available to me and people I determine (4)

Q30 Do you prefer that driver-less cars drive in dedicated lanes or in the regular lanes?

○ Dedicated Lanes (1)

○ Regular lanes (2)

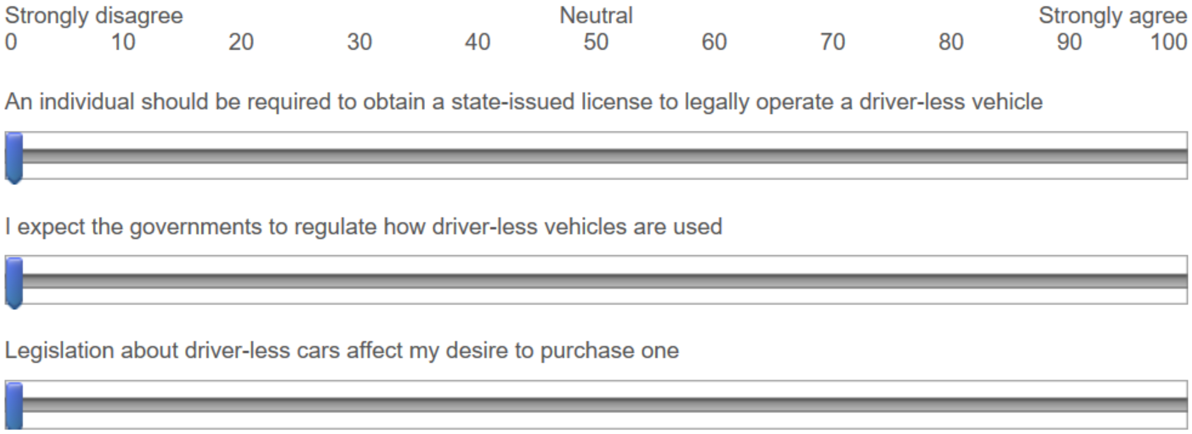
Q31 Imagine the city decides to regulate speed limit for driver-less cars. What speed limit do you prefer for driver-less cars as a potential driver-less car passenger?

○ Less than human-driven cars (1)

○ More than human-driven cars (2)

○ Same as human-driven cars (3)

Q32 Please indicate your opinions regarding the following statements.



Strongly disagree Neutral Strongly agree

0 10 20 30 40 50 60 70 80 90 100

An individual should be required to obtain a state-issued license to legally operate a driver-less vehicle

I expect the governments to regulate how driver-less vehicles are used

Legislation about driver-less cars affect my desire to purchase one

Q33 Imagine an autonomous car cannot avoid an accident and has to prioritize between its passengers and pedestrians to save their lives. It is a controversial issue about who should have priority. In which scenario you would like to use/buy a driver-less car?

○ Passengers lives should always have priority (1)

○ Pedestrians lives should always have priority (2)

○ Depends on the situation, the priority of the car should be saving the majority of people's lives regardless if they are passengers or pedestrians (3)

○ Driver-less cars should not have the right to make this decision. It should be random and unbiased (4)

Q34 Please indicate the importance of each advantage of driverless cars for you (The benefits are still uncertain, but I want you to mark which potential benefits would be the most important to you with the progression of driver-less technology).

Very unimportant Neutral Very important
0 10 20 30 40 50 60 70 80 90 100

Safety (By decreasing 90% of crashes caused by human errors)

Impacts on traffic

Decreasing parking need (a driver-less car can drop you off and park itself)

Reduced time driving

Fuel Economy

Decreasing the stress of driving

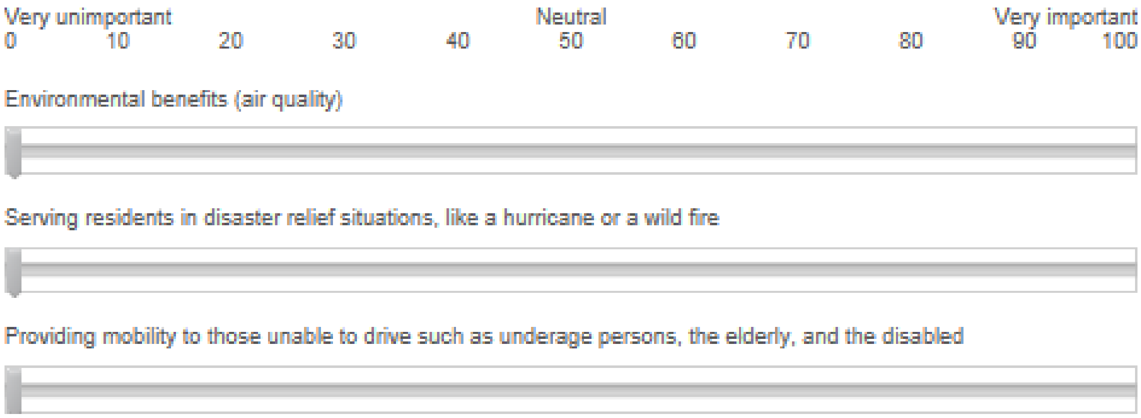
Ability to do activities while riding in a driver-less car

Decreasing the cost of car insurance

24/7 on-demand, door-to-door services of shared driver-less fleet taxis (faster than current services)

Facilitate electric cars

Q35 On a scale from 0-100, please indicate your opinion about the importance of each advantage of driver-less vehicles for your city/community



Environmental benefits (air quality)

Serving residents in disaster relief situations, like a hurricane or a wild fire

Providing mobility to those unable to drive such as underage persons, the elderly, and the disabled

Q36 On a scale from 0-100, please indicate how concerned you are about the following potential problems with a driver-less vehicle

Not concerned at all Neutral Very concerned

0 10 20 30 40 50 60 70 80 90 100

Equipment failure

Legal liability

The system being hacked

Privacy gap

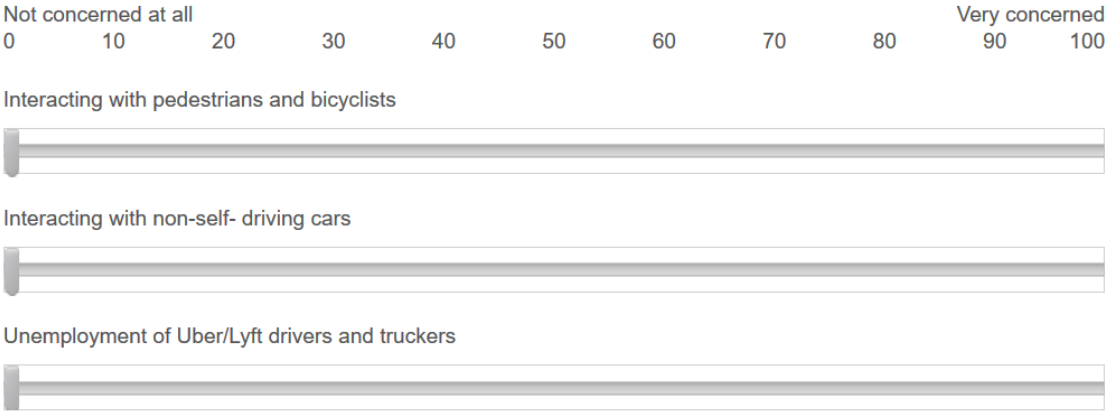
The high cost of driver-less system installation

Learning to use the new technology

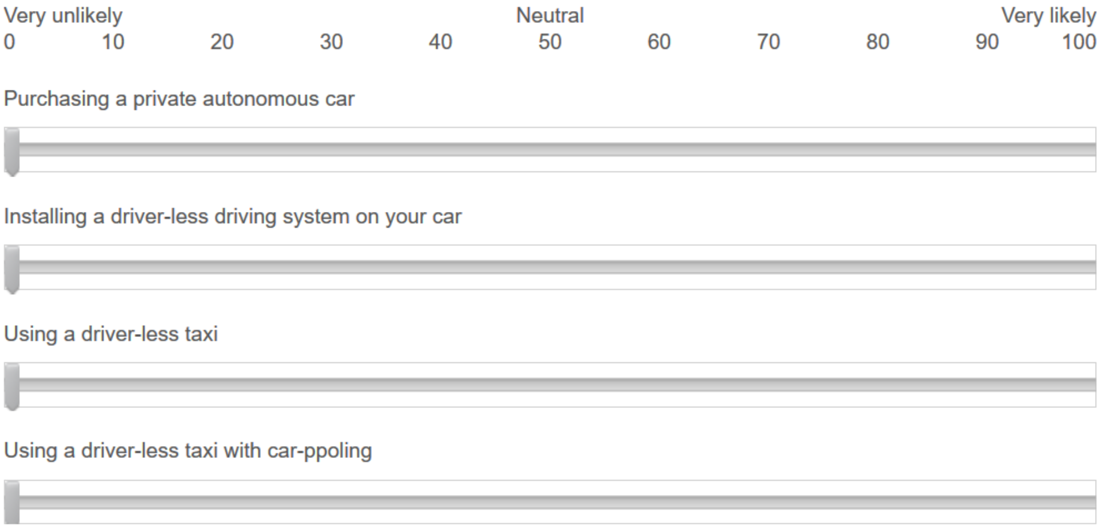
Losing the joy of driving

Lack of full control

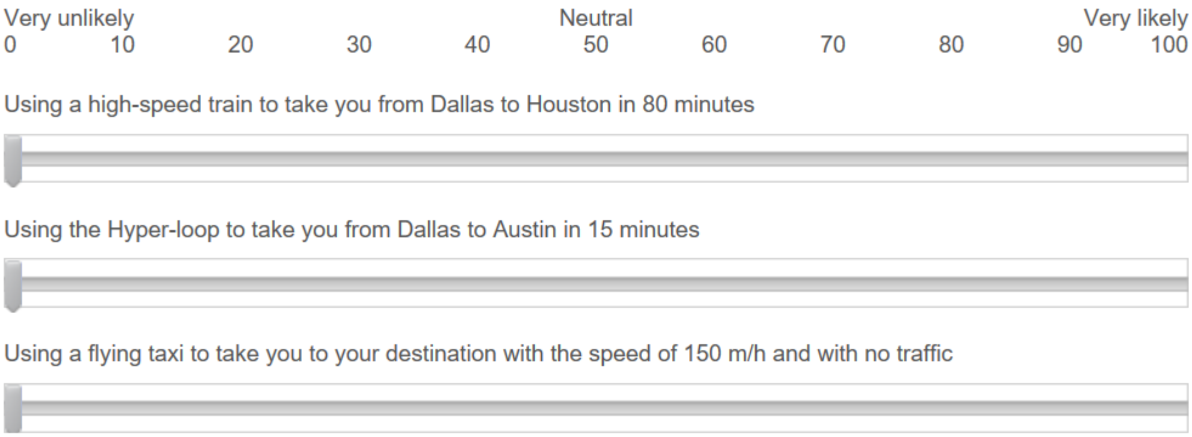
Q37 Concerns about cities and communities


Not concerned at all
Very concerned
0 10 20 30 40 50 60 70 80 90 100
Interacting with pedestrians and bicyclists
Interacting with non-self- driving cars
Unemployment of Uber/Lyft drivers and truckers

Q38 After considering the benefits and concerns, how likely are you to use the following driverless transportation options (as they become available)?


Very unlikely
Neutral
Very likely
0 10 20 30 40 50 60 70 80 90 100
Purchasing a private autonomous car
Installing a driver-less driving system on your car
Using a driver-less taxi
Using a driver-less taxi with car-ppoling

Q39 The Dallas-Fort Worth area is a hub for innovative transportation modes such as high-speed trains, the Hyperloop, and flying taxis. Imagine each of these technologies becomes available. What is the likelihood that you would use them? (0 means I would not use this form of driver-less technology

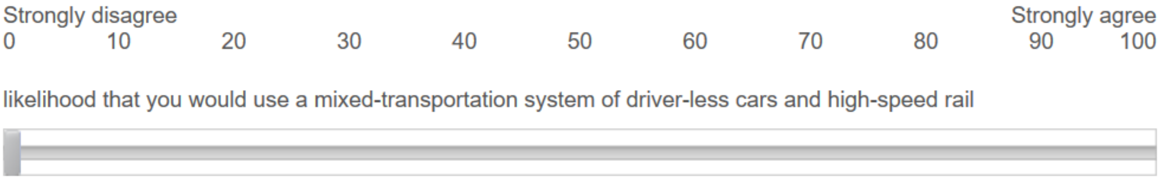


Using a high-speed train to take you from Dallas to Houston in 80 minutes

Using the Hyper-loop to take you from Dallas to Austin in 15 minutes

Using a flying taxi to take you to your destination with the speed of 150 m/h and with no traffic

Q40 Imagine driverless cars would make a transportation system in partnership with a high-speed rail? (You can book a trip from your house to a specific place in Houston, and the system will provide you with all of the transportation). What is the likelihood that you would use this system (0 means I would not use this transportation system).



likelihood that you would use a mixed-transportation system of driver-less cars and high-speed rail