

Thinking Local about Self-Driving Cars: A Local Framework for  
Autonomous Vehicle Development in the United States

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Master thesis submitted in partial fulfillment of the requirements for the degree of:

Master of Urban Planning

University of Washington  
2016

Committee:  
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Program Authorized to Offer Degree:  
Urban Design and Planning

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## ABSTRACT

### THINKING LOCAL ABOUT SELF-DRIVING CARS: A LOCAL FRAMEWORK FOR AUTONOMOUS VEHICLE DEVELOPMENT IN THE UNITED STATES

By Jacob A. Brett, 2016, 126 pgs.

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Once a feature from science-fiction movies and books, self-driving cars are now a reality on public roads throughout the United States. I argue that until extensive data and research on self-driving cars is made available to the public, a flexible, place-based framework should drive local development of autonomous vehicles. Through existing literature, I highlight how autonomous vehicles will create different benefits and costs in safety, energy use/emissions, employment, congestion, and the built environment. However, variation in spatial patterns will lead to different outcomes with self-driving cars across urban, suburban, and rural areas in the United States. I created a flexible local policy framework to analyze case studies in King County, Washington through demographic, geographic, and transportation data. These case studies are representative of urban, suburban, and rural areas throughout the county. Furthermore, I conclude that spatial variability in each community will influence how policy and planning shape the path for autonomous vehicle development. Through analyzing the fundamental differences between demographics, geography, and transportation behaviors in each study area, I conclude that local policymakers and planners should account for spatial variability when crafting tools to manage autonomous vehicle development in each neighborhood.

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## INTRODUCTION

The main goal of this project is to provide a resource for local planners and policymakers as they brace for the arrival of autonomous vehicles (AVs) in their communities. Self-driving cars may present multiple opportunities to address the negative externalities that conventional automobiles create in terms of safety, emissions & energy use, congestion, and the built environment. Some news articles suggest that self-driving cars are a threat to security and could collapse the American way of life, while others imply that AV technology could lead to the salvation of single occupancy vehicles and initiate a cultural revolution. However, it is too early to support either of these ideological positions - the existing literature suggests that self-driving cars will create a complex web of benefits and costs that will vary by location.

This thesis sets out to build a local framework that addresses the unique factors that will dictate and drive the development of AVs in the diverse communities of the United States. I construct this framework through extensive literature review, including a stakeholder analysis, an overview of benefits and costs of self-driving cars, and an assessment of several local policy tools & planning tools for AV development in local communities. The effects of self-driving cars will not be uniform – rather, various factors will dictate how self-driving cars influence local communities. In this thesis I review a variety sources and datasets in order to build a methodology around case studies. These case studies help put the benefits and costs of self-driving cars into context and provide measurable criteria that I use as benchmarks to compare local AV development in urban, suburban, and rural census tracts. Ultimately, this research is designed to help local policymakers and planners answer several questions:

- What are the various benefits & costs associated with self-driving cars?
- How will these benefits & costs impact different communities over time?

- Which factors (demographics, geography, transportation behavior) will influence AV development in my community?
- How can local policymakers and planners maximize the benefits and minimize the negative externalities of self-driving cars?

## **Thinking Local**

Policy and planning tools give local communities options for how they will implement AV technology. Each government entity has jurisdiction over different regions and administers different types of rules and regulations that will all potentially influence the development of AV technology in their own unique way. Differences in jurisdictional control of policy and planning will dictate the tools governments can use to address the benefits and costs of local AV development. No single tool will serve as the panacea of AV policy and planning. Policymakers and planners have a lot to consider when thinking local about self-driving cars. Townsend argues that the implementation timeframes tend to be overly optimistic conclusions about the benefits and costs of AV technology.<sup>1</sup> It will take time and money to change infrastructure and there will be some growing pains as society adapts to self-driving cars in the built environment.

As consumers begin purchasing self-driving cars as a means of personal transportation, local planners and policymakers will need to brace for change in the United States. Automated technology is on the rise and will create various benefits and costs that will fundamentally change transportation in the United States. Self-driving cars formally arrived on public roads in 2009, when Google rolled out its first iteration

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<sup>1</sup> Townsend, Anthony. "Re-Programming Mobility: The Digital Transformation of Transportation in the United States." The Scenarios. NYU Wagner Rudin Center for Transportation Policy and Management, 2014. Web. 28 Mar. 2016. < <http://reprogrammingmobility.org>>.

of autonomous technology in single occupancy vehicles.<sup>2</sup> This new technology holds the potential to vastly improve personal transportation, but may create certain negative externalities. An image of the self-driving Lexus RX450h is featured below.



**Figure 1: Google Testing Vehicle – Lexus RX450h with LIDAR sensor<sup>3</sup>**

Policymakers and planners will have opportunities to maximize the potential benefits and mitigate the negative externalities that self-driving cars create. The relationship between the costs and benefits of self-driving cars, as well as the externalities that they create, is still not entirely clear. Although many news stories attempt to sensationalize the effects of self-driving cars by projecting utopian or dystopian results, a closer analysis of the existing data reveals that it is still too early to

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<sup>2</sup> "Google Self-Driving Car Project." *Google Self-Driving Car Project*. Google, Inc., n.d. Web. 18 Apr. 2016. <<https://www.google.com/selfdrivingcar/where/>>.

<sup>3</sup> Zigterman, Ben. "Video: Google's Self-driving Car Is Closer than Ever to Becoming a Reality." *BGR*. N.p., 28 Apr. 2014. Web. 26 May 2016. <<http://bgr.com/2014/04/28/google-self-driving-car-update/>>.

make sweeping claims about self-driving cars. This new technology, although authorized for testing in some states, is not yet available for consumers. Without real consumer data, most predictions rely on or build off of speculative arguments. Furthermore, rules and regulations from various entities across the United States are creating a patchwork system with various layers of authority and inconsistencies from state to state.

Today, the rise of AV technology is challenging government authorities in the United States to create a regulatory environment that maximizes the benefits of self-driving cars, and minimize the negative externalities. In a series of patchwork laws, states lead the charge for AV policy reforms shortly after AV technology hit the roads. The regulatory environment for transportation in the United States is a blend of federal, state, and local policies, all of which will play a different role in the development of AV technology. Certainly, any nation would benefit from a comprehensive framework for AV technology would both guide and drive development in the field. However, policymakers in cities and municipalities will need to take a unique approach to local policy on AV development.

With the current layers of complexity associated with policy and planning around AV technology, RAND Corporation's Transportation, Space, and Technology Program released a comprehensive policy report on self-driving cars. This report overviews many of the costs and benefits of AV technology and asserts, "Careful policymaking will be necessary to maximize the social benefits that this technology will enable, while minimizing the disadvantages. Yet policymakers are only beginning to think about the

challenges and opportunities this technology poses.”<sup>4</sup> This in-depth report primarily focuses on policies at a national and state level. While Federal and State policy-makers will play a huge role in influencing these costs and benefits, local jurisdictions will also play an important role. AV technology is “spatially-variable” in that the unique local benefits and costs of self-driving cars, including all of the associated externalities, will vary by location and community. Local policy and planning will guide AV development across the nation as different communities and neighborhoods look for tools to address the local effects of self-driving cars on their own streets. A framework must be flexible enough to address the subtle difference between these localities in order to develop the best tools to maximize the benefits and mitigate the costs of self-driving cars. In my research, I develop a methodology to analyze the unique characteristics of three different communities in King County. Through my methodology, I demonstrate how these case studies are representative of urban, suburban, and rural spatial patterns and outline how these patterns will influence policy and planning for self-driving cars at a local level.

## KEY STAKEHOLDERS

Although the Rand Policy analysis is thorough, it identifies several areas of research that need improvement. Among these identified research categories, a local stakeholder analysis is still absent from the existing literature.<sup>5</sup> I identified three main

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<sup>4</sup> Anderson, James M., Nidhi Kalra, Karlyn D. Stanley, Paul Sorensen, Constantine Samaras, and Oluwatobi A. Oluwatola. *Autonomous Vehicle Technology: A Guide for Policymakers*. Santa Monica: RAND Corporation, 2016. *Autonomous Vehicle Technology A Guide for Policymakers*. RAND Corporation. Web. 1 Apr. 2016. <[www.rand.org/t/rr443-2](http://www.rand.org/t/rr443-2)>.

<sup>5</sup> Anderson, 2016.

stakeholder groups that will influence and direct the development of AV technology. Although self-driving technology will involve far more than three stakeholder groups, the government, consumers, and manufacturers will all play different roles in the development of AV technology at a local level.

## Government Policymakers and Planners

Policymakers and planners at the local, state, and federal level pass different types of regulations that dictate transportation laws in the United States. While the jurisdiction, authority, funding mechanisms, and infrastructure funding varies for each level of the government, policymakers at each level will need to coordinate their frameworks to generate comprehensive laws regarding AVs.

### Federal Government

The Federal Government develops rules at the national level through two primary agencies: the National Highway Traffic Safety Administration (NHTSA)<sup>6</sup> and the United States Department of Transportation (USDOT)<sup>7</sup>. Federal policymakers provide grants for individual states in localities and funds research and projects in transportation. Policymakers and planners at the federal level finance major infrastructure projects and manage the nation's highways, bridges, and tunnels through federal tax dollars.<sup>8</sup> The Federal Government also dictates national safety standards and is challenged to adapt many of the existing Federal Motor Vehicle Safety

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<sup>6</sup> "National Highway Traffic Safety Administration." *National Highway Traffic Safety Administration (NHTSA)*. US NHTSA, n.d. Web. 29 May 2016. <<http://www.nhtsa.gov/>>.

<sup>7</sup> "Department of Transportation." *Department of Transportation*. US DOT, n.d. Web. 29 May 2016. <<https://www.transportation.gov/>>.

<sup>8</sup> "Federal Highway Administration." *Federal Highway Administration*. US FHWA, n.d. Web. 29 May 2016. <<https://www.fhwa.dot.gov/>>.

Standards (FMVSS) to accommodate AV technology and innovative vehicle designs. For example, many FMVSS standards refer to a driver, the individual operating a vehicle, and the mechanisms they use to operate a vehicle, like break pedals, accelerators, and steering wheels. But fully autonomous vehicles do not need a driver and eliminate the need for break pedals and steering wheels. Innovations in federal policy, and in particular new language in the FMVSS, will create the potential for new vehicle designs that rely on automation, increase safety on the road, and improve comfort for passengers in AVs.<sup>9</sup>

The lead innovators would like to see a more consistent policy framework for self-driving cars at the federal level. Federal laws can potentially simplify the complexities associated with the network of jurisdictions by establishing consistent laws across the country. Federal Policy Tools like passenger requirements and emissions standards will establish basic tenants of operation for AV technology. However, the Federal government can influence AV development by funding infrastructure, research, and other state and local projects. While cooperation between these entities will be vital for the success of AV technology, differentiation in approaches by various local and state agencies is expected as they address the unique challenges in their region. The Obama Administration took the first steps at constructing national policy regarding AV implementation in 2016. In January of 2016, the Obama Administration proposed a

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<sup>9</sup> Kim, Anita, David Perlman, Dan Bogard, and Ryan Harrington. "Review of FMVSS for Automated Vehicles: Identifying Potential Barriers and Challenges for the Certification of Automated Vehicles Using Existing FMVSS." *U.S. Department of Transportation*. Volpe, Mar. 2016. Web. 11 Apr. 2016. <[http://ntl.bts.gov/lib/57000/57000/57076/Review\\_FMVSS\\_AV\\_Scan.pdf](http://ntl.bts.gov/lib/57000/57000/57076/Review_FMVSS_AV_Scan.pdf)>.

\$3.9 billion budget to research AVs over 10 years.<sup>10</sup> Just a few months later, the NHTSA and USDOT released a preliminary report on FMVSS for AVs. The report highlighted the need for fully automated systems and authorized the exploration of designs without human controls.<sup>11</sup>

## State Government

State Government also dictates and presides over AV development. States regulate transportation through state driving laws, and inspections requirements. States generate funding through tolls and taxes and can finance infrastructure development inside of the state. The National Conference of State Legislators released a study that overviews each law on automated vehicles passed and proposed in each state, most recently updated in April of 2016.<sup>12</sup> This study highlights the content and status of each state's bills but does not analyze how these policies will effect AV development. A description of the policies outlined is in Appendix A. Even since 2015, Many other states have proposed laws that regulate and expand AV technology development. Although many bills have failed, states are rapidly beginning to address some of the issues with AV technology. The following States have all attempted to pass legislation on self-driving cars. These bills have been adopted, are pending review, or failed to pass through the legislature and are labeled accordingly in each state.

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<sup>10</sup> "Secretary Foxx Unveils President Obama's FY17 Budget Proposal of Nearly \$4 Billion for Automated Vehicles and Announces DOT Initiatives to Accelerate Vehicle Safety Innovations." *Secretary Foxx Unveils President Obama's FY17 Budget Proposal of Nearly \$4 Billion for Automated Vehicles and Announces DOT Initiatives to Accelerate Vehicle Safety Innovations*. NHTSA & USDOT, 14 Jan. 2016. Web. 04 May 2016. <<http://www.nhtsa.gov/About+NHTSA/Press+Releases/dot-initiatives-accelerating-vehicle-safety-innovations-01142016>>.

<sup>11</sup> Kim, 2016.

<sup>12</sup> "Autonomous | Self-Driving Vehicles Legislation." *National Conference of State Legislators*. NCSL, 8 Apr. 2016. Web. 4 May 2016. <<http://www.ncsl.org/research/transportation/autonomous-vehicles-legislation.aspx>>.

Policymakers and planners at the state level control a wide range of tools through the individual state's Department of Transportation, which can lobby for and create laws in each state. State policymakers and planners are responsible for the construction and maintenance of state roads.

State policymakers are also responsible for ensuring that roads are safe across the state through statewide safety regulations, driving laws and vehicle inspection requirements. This financing comes from state taxes and tolls on state roads. In March of 2016, self-driving car proponents went to congress to address the patchwork nature of existing state laws that create a complex regulatory for self-driving cars. Google's technical leader of their self-driving car project, Chris Urmson, highlighted that nearly half of the states have introduced over 50 bills to regulate autonomous cars in issues like liability and testing. Urmson said, "If every state is left to go its own way without a unified approach, operating self-driving cars across state boundaries would be an unworkable situation and one that will significantly hinder safety innovation, interstate commerce, national competitiveness and the eventual deployment of AVs."<sup>13</sup>

### Local Government

At the local level, governments will develop a set of unique tools to address the benefits and costs of AV technology on their own communities. Policymakers and planners will develop rules, laws, and investment strategies for infrastructure. Local governments build and maintain local roads and act as managers for public transportation and public parking within their jurisdiction. Local governments will play

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<sup>13</sup> Bomey, Nathan. "Self-Driving Car Leaders Ask for National Laws." *USA Today*. Gannett, 15 Mar. 2016. Web. 04 May 2016. <<http://www.usatoday.com/story/money/cars/2016/03/15/google-alphabet-general-motors-lyft-senate-commerce-self-driving-cars/81818812/>>.

an important role in ushering in policies and creating new infrastructure that supports AV development and addresses any negative externalities with self-driving cars.

Local policymakers and planners have a variety of tools at their disposal that will influence AV development in the United States. These tools include right of way (ROW) management, parking policy, and congestion pricing. Localities dictate the amount parking available in their respective communities by directly providing public parking and through land use codes that dictate parking requirements for developers. Local jurisdictions like cities and municipalities fund these operations through a combination of taxes, permitting fees, and parking fees. These tools vary by locality as communities build their transportation policies around their unique demographics, geographies, and transit behaviors. Local policymakers and planners will weave a network of regulations across the United States that address the spectrum of local costs and benefits of AV technology in transportation.

## **Consumers**

The consumer is also a key stakeholder group that will grow with the arrival of self-driving technology. Access to Single Occupancy Vehicles (SOVs) will improve for several demographics as AV technology becomes mainstream. As a result of this new access, more cars will likely be on the road with passengers who are too young to drive, too old to drive (although no law prohibits the elderly from driving), or physically disabled.<sup>14</sup> This new access will provide mobility for isolated people and provide its own intrinsic benefit to society by creating transportation for everyone, rather than just those who are physically and mentally able to drive an SOV safely.

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<sup>14</sup> Anderson, 2016.

In spite of these benefits, the technology behind self-driving cars will not be free. Innovators are investing large amounts of money in research and development in order to create the technology behind self-driving cars, which relies on a series of sensors. These new sensors will increase the cost of the automobile. Private companies will pass along the research and equipment costs to the consumer.<sup>15</sup> AVs will be more expensive than traditional automobiles in the early onset, when the technology is still new. On December 4, 2015, The Washington Post reported that the current model for sensor equipment on a self-driving car costs around \$75,000, but that research is underway to develop a more cost-efficient system of LIDAR sensors under \$100.<sup>16</sup> This high initial cost will likely slow the integration process and potentially limit AV ownership for low-income individuals.

Throughout the implementation process, not all cars on the road will be automated. There will be a time period when consumers have the option to purchase either traditional automobiles with manual operations or automated vehicles. As a result, consumers will likely have different opinions and feelings on AV technology depending on their personal consumer decisions and their trust in the technology. A recent AAA study suggests that Americans are still hesitant to put their faith in AV technology, and roughly 75% of U.S. drivers would be afraid to let an AV drive itself with them inside of it. The study also showed that women and baby boomers would be more hesitant to use AV technology than men and millennials.<sup>17</sup> This study

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<sup>15</sup> Litman, Todd. "Autonomous Vehicle Implementation Predictions." *Implications for Transport Planning*. Victoria Transport Policy Institute, 10 Dec. 2015. Web. 11 Apr. 2016. <<http://www.vtpi.org/avip.pdf>>.

<sup>16</sup> McFarland, Matt. "The \$75,000 Problem for Self-driving Cars Is Going Away." *Washington Post*. The Washington Post, 4 Dec. 2015. Web. 11 Apr. 2016.

<sup>17</sup> "Fact Sheet: Vehicle Technology Survey." AAA Newsroom. AAA Automotive Engineering, 2016. Web. 4 May 2016. <<http://publicaffairsresources.aaa.biz/wp-content/uploads/2016/02/Automotive-Engineering-ADAS-Survey-Fact-Sheet-FINAL-3.pdf>>.

demonstrates how these demographic differences will likely influence adoption rates for AV technology. However, public opinion will change over time as the technology improves and more data becomes available. More importantly, consumers will play an important role in lobbying for local policies in their respective jurisdictions. In King County and Washington State, the minimum age for an intermediate driver's license is 16, with restrictions during the first year of issuance.<sup>18</sup> Individuals below the legal driving age will be able to ride in AV technology without the help of an adult, creating additional access to SOVs and additional VMTs on the road. A recent AAA study determined that Baby Boomers (82%) are more likely to be afraid to allow an AV to drive itself with them in it than younger generations (69%).<sup>19</sup>

### Shared Autonomous Vehicles

Ridesharing companies like Uber, Lyft, Car-to-Go, and Zipcar will use AV technology to better serve consumers who do not own a car or do not want to bring their own vehicle to their destination. These ridesharing companies use payment structures that charge customers for the cost of each ride. Pay-per-ride changes driving behavior by amortizing the cost of a car over the span of its life, including fuel and maintenance, and charging passengers on a per-ride basis. A system in which passengers are paying per use tends to show the passenger the real cost of driving,

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<sup>18</sup> "Steps to Getting Your First License: Teens 16–17 Years Old." *WA State Licensing (DOL) Official Site*. WA State Department of Licensing, n.d. Web. 06 May 2016. <<http://www.dol.wa.gov/driverslicense/teens.html>>

<sup>19</sup> "Fact Sheet: Vehicle Technology Survey." *AAA Newsroom*. AAA Automotive Engineering, 2016. Web. 4 May 2016. <<http://publicaffairsresources.aaa.biz/wp-content/uploads/2016/02/Automotive-Engineering-ADAS-Survey-Fact-Sheet-FINAL-3.pdf>>.

and typically reduces the desire to travel. Furthermore, they create an environment in which fewer cars can accommodate more individuals.<sup>20</sup>

Sharing vehicles will potentially decrease congestion and emissions by reducing the number of vehicles owned and operated on a regular basis. A shared economy of vehicles often refers to the taxi services and ridesharing systems, in which the vehicles in a fleet are actually owned by a company. The company amortizes the value of the vehicle, and users pay the fees on a per mile basis. Through these implementation models, the company allows individuals to use the vehicles without paying the upfront costs of purchasing the vehicle, but they pay a much higher cost per mile traveled. Shared ownership works well for individuals who do not want to own their own vehicle and are happy to pay for the vehicle only when using it. By using on-demand applications to summon a car, shared vehicles can optimize transportation for individuals who want the privacy of a single occupancy vehicle, but do not want to pay the upfront and maintenance costs of such a vehicle.

A University of Texas study used existing rideshare service models to address how a Shared Autonomous Vehicle (SAV) market would reduce the number of privately owned vehicles. The study extrapolated that for all 20,000 rideshare users in Austin, Texas, SAVs could reduce the fleet size to 1,700. Rather, one SAV could eliminate the need for 11 conventional rideshare vehicles. The study acknowledged the potential for further emissions savings by reducing the number of cold-starts per engine, but suggested that early implementation could increase congestion and VMTs because of

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<sup>20</sup> Sengupta, Raja, and Joan L. Walker. "Travel Feedback Meets the Cloud to Change Behavior." *Access*, 47.Fall (2015): 2-7. Web. 20 Apr. 2016. <<http://www.accessmagazine.org/wp-content/uploads/sites/7/2015/11/access47.finalreduced.pdf>>.

trips without passengers.<sup>21</sup> Litman breaks down the market for personal automobiles, conventional taxis, and shared vehicles into quantifiable economic decisions based on the annual costs. He argues that personal automobiles cost about \$4,000 per year plus \$0.20 per mile, Conventional taxis cost an average of \$2-3 per mile, and carsharing services typically cost about \$0.60-1.00 per mile. With those costs, conventional taxis tend to be more affordable for individuals who drive less than 2,500 miles per year and carsharing is more affordable than owning a vehicle for those who drive less than 6,000 miles annually. Through these costs, Litman argues that autonomous cars support carsharing as a cost effective alternative to owning a personal vehicle for those who drive under 6,000 miles per year, depending on cleaning and repair costs.<sup>22</sup>

The expansion of a shared vehicle market will have a resounding effect on local revenue streams. Auto sales taxes and parking fees help finance important government projects and infrastructure. If SAVs reduce car sales and alleviate the need for parking, than local governments will lose important funding streams. Ultimately, governments must examine how these different models of AV implementation will influence local revenue streams in the United States. Traditional automakers are also heavily invested in private vehicle ownership because it maximizes sales, and profits. Traditional Automakers are already creating their own AV technology but will still seek a distribution model that supports the bottom line in their business strategy. SAVs will potentially disrupt local government revenue sources and create competing

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<sup>21</sup> Daniel J. Fagnant and Kara M. Kockelman (2013), *Preparing a Nation for Autonomous Vehicles: Opportunities, Barriers and Policy Recommendations*, *Eno Foundation* ([www.enotrans.org](http://www.enotrans.org)); at [www.enotrans.org/wp-content/uploads/wpsc/downloadables/AV-paper.pdf](http://www.enotrans.org/wp-content/uploads/wpsc/downloadables/AV-paper.pdf).

<sup>22</sup> Litman, 2015.

distribution models between traditional automakers and innovators. Each stakeholder group is likely to advocate for a distribution model that best serves their interests.

## **Manufacturers**

Automobile manufacturers are the driving force behind the research and development of AV technology in the United States. These manufacturers are comprised of two subgroups, traditional automakers and innovators, that will each contribute to the advances in AV technology in the years to come. Traditional automakers have proven and established business models that thrive on conventional automobile sales. Although these traditional automakers dominated the vehicle market for over a decade, new technology and carsharing companies are emerging as pioneers in the development of AV technology. While there are important distinctions between traditional automakers and innovators, they both stand to benefit from a simplified and standardized regulatory system for their products.

### Traditional Automakers

Traditional automakers may view AV technology as both a threat and as a feature in their own automobiles. AV technology presents a potential threat to existing distribution models and creates new potential competitors for traditional manufacturers. AV technology will be a threat to traditional automakers if they cooperate with innovators who introduce the technology. In particular, AV technology introduces the potential for a new, shared-ownership model, in which self-driving cars operate like taxis. Under this model, individual ownership will drop as access to AV technology proliferates the market. As a result of shared ownership, traditional automakers will see a drop in car sales. Furthermore, if innovative companies develop their own cars instead of licensing their technology to traditional automakers, they will end up as competitors in the automotive industry. Nissan Motor Co. CEO Carlos

Ghosn addressed the competition between traditional automakers and the new technology companies, stating that, "the tech companies will take as much space as we are ready to abandon."<sup>23</sup> Traditional automakers will likely aim for distribution models that encourage private ownership and stimulate maximum sales. In that sense, traditional automakers are likely to use automation as a feature to boost sales, but will likely be hesitant to venture into a shared ownership model. In many cases, automakers already incorporate some levels of automation in their vehicles, like cruise control, automatic breaking, and lane correction.

### Innovators

Self-driving technology innovators are developing new strategies for automation and single occupancy vehicles. Through financial investment in AV research and development, these innovators are driving the technology breakthroughs for self-driving cars. These innovators are not typically associated with traditional automakers, although many traditional automakers are pursuing AV technology. Innovators can potentially benefit financially from AV technology if they license the technology to automakers, or if they develop their own automobiles with AV technology. In the United States, technology companies are leading the charge in AV development. The group of innovators brings a diverse set of expertise to the field of AV developers. Tech giants like Google, Apple, and Tesla are well established companies that launched their own self-driving car testing facilities or research operations in the United States. Uber and Lyft are two ridesharing taxi services that are heavily investing in

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<sup>23</sup> Greimel, Hans, and Gabe Nelson. "Japan Inc.'s 2020 Vision: Self-driving Cars on the Road." Automotive News. N.p., 2 Nov. 2015. Web. 21 Apr. 2016. <<http://www.autonews.com/article/20151102/OEM/311029963/japan-inc.s-2020-vision:-self-driving-cars-on-the-road>>.

automation as a means of developing a market for shared AVs while also addressing safety, liability, and cost reductions. The lines between innovator and traditional automaker are blending as more traditional automakers invest in AV technology. In April of 2016 Ford and Volvo, two traditional automakers, joined with Uber, Lyft, and Google to form the Self-Driving Coalition for Safer Streets, a lobbying group in the United States.<sup>24</sup> This lobby demonstrates that traditional automakers and innovators are willing to cooperate in order to advocate for policy reforms in the United States.



**Figure 2: Google Testing Vehicle - Innovative Mode<sup>25</sup>**

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<sup>24</sup> Shepardson, David. "Google, Ford, Uber Launch Coalition to Further Self-driving Cars." *Reuters*. Ed. Bill Trott and Alan Crosby. Thomson Reuters, 26 Apr. 2016. Web. 29 Apr. 2016. <<http://www.reuters.com/article/us-autos-selfdriving-idUSKCN0XN1F1>>.

<sup>25</sup> "Google Self-Driving Car Project." *Google Self-Driving Car Project*. Google, Inc., n.d. Web. 11 Apr. 2016. <<https://www.google.com/selfdrivingcar/reports/>>.

## International AV Development

Although this paper primarily focuses on technology development in the United States, international companies all over the world will contribute to domestic AV development in the United States. In several different countries, tech companies and automakers are forging their own paths for self-driving cars, which will add to the progressive advances in the technology and the collective knowledge of the manufacturing stakeholder group. Although still under development, the Japanese tech company Robot Taxi, Inc. announced plans to use autonomous taxis for the 2020 Tokyo Olympics in order to transport athletes from their housing to the games.<sup>26</sup> In Japan, traditional automakers are also taking part in the AV movement. Toyota, Honda, & Nissan collectively announced plans to sell autonomous cars by 2020 that enable drivers to yield functionality to the car under certain circumstances.<sup>27</sup> Chinese companies Baidu, Inc., BAIC Group, and Chongqing Changan Automobile Co. have joined the race to develop self-driving cars in Asia. In fact, Bloomberg News reports that in 2016, Chongqing Changan Automobile Co. completed a 1200-mile road trip to test a self-driving car in China.<sup>28</sup> European automakers Daimler, Volvo and Volkswagen are also leading the development of AV technology in Europe.<sup>29</sup> In the United Kingdom, policymakers approved nationwide testing.<sup>30</sup> In order to compete with

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<sup>26</sup> "Tokyo 2020: The Olympics of the Future (INFOGRAPHIC)." *Futurism Tokyo 2020 The Olympics of the Future Comments*, 06 Apr. 2016. Web. 21 Apr. 2016. <<http://futurism.com/images/tokyo-2020-olympics-future/?src=home>>.

<sup>27</sup> Greimel, 2015.

<sup>28</sup> "Self-Driving Car Completes 1,200-Mile Roadtrip Across China." *Bloomberg News*. Bloomberg News, 17 Apr. 2016. Web. 20 Apr. 2016. <<http://www.bloomberg.com/news/articles/2016-04-18/china-s-changan-auto-completes-1-200-mile-autonomous-drive-test>>.

<sup>29</sup> Greimel, 2015.

<sup>30</sup> "UK to Allow Driverless Cars on Public Roads in January." *BBC News*. BBC, 30 July 2014. Web. 21 Apr. 2016. <<http://www.bbc.com/news/technology-28551069>>.

European and Asian companies, policymakers in the United States are challenged with creating a regulatory framework in which domestic AV development can thrive without ignoring the potential negative externalities.

These stakeholder groups will play a role in how AVs develop in the United States. Governments will provide the regulatory framework for self-driving cars. Manufacturers will build and develop self-driving cars that fit within the regulatory framework provided by the government and sell them to consumers. Each stakeholder group is vested in the outcome of self-driving cars in local communities. These outcomes can be defined in terms of benefits and costs in the United States.

## LITERATURE REVIEW

The existing literature on AV technology highlights the prospective benefits and costs associated with the implementation of self-driving cars on a large scale. AV technology has the potential to substantially change transportation in five categories: Safety, Congestion, Energy/Emissions, Employment, & Land use. Through these five categories, AV technology will incur benefits and costs that vary over time. During early implementation, AV users will be a minority. Early implementation will benefit AV users, but not necessarily have much of a net change in the public sphere. Yet as more self-driving cars take to the streets, the benefits and costs will gradually spill over into the general public. As self-driving cars become the norm during late implementation, the public externalities will magnify. Once all cars are fully autonomous, these benefits and costs will finally hit their maximum potential. Litman analyzed standard technology adoption rates and determined that full implementation is likely in the 2040s – 2060s, a

complete implementation timeframe of 25-45 years.<sup>31</sup> In spite of these projections, the complex relationship between implementation, adoption rates, and policy is still unclear.

Conventional driving imposes various costs on the driver and negative externalities upon the public. Individual costs of driving, like fuel, depreciation, and insurance, are all borne by the driver of an automobile. However, cars also contain external costs that are borne by the public, also known as “negative externalities.” Negative externalities, like congestion, pollution, and car accidents are very costly, but are distributed across taxpayers and other commuters. Rand estimates that the negative externalities of conventional driving cost 13 cents per mile for each additional driver on the road. The study extrapolates that “If a hypothetical driver drives 10,000 miles, she imposes \$1,300 worth of costs on others, in addition to the costs she bears herself.”<sup>32</sup> AV technology will address some of these externalities, but likely present entirely new problems along with their various benefits.

### **Precedent for Change: A Brief History**

Not too long ago, automobiles set the precedent for a massive shift in personal transportation in response to negative externalities from horses. Until the 1900’s, horses were the primary form of transportation across the United States. In addition to personal transportation, horses could haul freight and provide mechanical power. But by the late 1800’s, the problems were mounting. For one, horses were dangerous. Morris points out that horse-related fatalities per capita were significantly higher than the modern counterpart, the automobile. In the year 1900, New York City recorded

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<sup>31</sup> Litman, 2015.

<sup>32</sup> Anderson, 2016.

200 horse-related fatalities. Over a decade later in 2003, New York City recorded 344 auto-related fatalities with a significantly larger population, resulting in a per-capita decrease in fatalities of roughly 75%.<sup>33</sup>

Horses also created negative externalities in sanitation, including horse manure and urine, pests, disease, and noise pollution. Horses were expensive to maintain and died frequently, leading to further costs and sanitation issues. In 1880, New York City removed over 15,000 horse carcasses from the streets. In addition to the upfront cost of purchasing a new horse, consumers also needed horseshoes, saddles, a consistent source of food and water, and stabling overnight.<sup>34</sup> In 1898, world delegates met in New York City to attend an urban planning conference to address the negative externalities associated with their primary form of transportation.<sup>35</sup> Unfortunately, the delegates were stumped – nobody could conceive of a way to replace their primary form of transportation without a major technology innovation.

The new technology the delegates were looking for arrived in the 1900s: automobiles. When combined with smoother roads and new traffic laws, automobiles created a cleaner, faster, safer, and cheaper mode of transportation than horses. By 1912, traffic counts in New York showed that cars finally outnumbered horses.<sup>36</sup> Although cars were better in many ways, they still created their own externalities and a new set of problems for individual localities. As the United States prepares to adopt

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<sup>33</sup> Morris, Eric. *From Horse Power to Horsepower*. Spring 2007 ed. Vol. 30. N.p.: n.p., 2007. Access. University of California Transportation Center, 2007. Web. 21 Apr. 2016. <<http://www.uctc.net/access/30/Access%2030%20-%2002%20-%20Horse%20Power.pdf>>.

<sup>34</sup> Tarr, Joel A. "The Horse - Polluter of the City." *The Search for the Ultimate Sink: Urban Pollution in Historical Perspective*. Akron: U of Akron, 1996. 324-33. Print.

<sup>35</sup> Morris, 2016.

<sup>36</sup> Morris, 2016.

self-driving cars as a mainstream technology, policymakers and planners would be prudent to plan for the coming changes and consider how this major shift will impact everyday Americans in different localities.

## Defining Autonomous Vehicles

The first task for policy-makers at all levels in the government is to define AVs and to understand how the technology operates. In broad terms, self-driving cars are a type of AV that function with varying levels of independence without human interaction. Although other types of vehicles, like trains, planes, freight ships, and trucks & farming equipment, all stand to benefit from automation, this report primarily addresses the potential results of AV technology for SOVs. Through a combination of sensors and response systems, self-driving cars detect and report on road conditions, which allow the vehicle to navigate through obstacles and other drivers without the help of a human driver. This technology began as simple assistive features, but with the help of improvements in RADAR, LIDAR, ultrasonic sensors, infrared, cameras, and GPS, manufacturers are rapidly developing technology for true self-driving cars.<sup>37</sup> This innovative technology is constantly evolving and improving. Today, the sensors are sensitive enough to detect the differences between road surfaces, pedestrians, bikers, and other cars. To date, the technical definition of AV technology is tied to the extent of the automation. In the United States, policy-makers rely on two key definitions

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<sup>37</sup> Zuby, David S. "Driverless Cars, Cars That "Talk" to Each Other, Forward Collision Warning and More." The Promise and Reality of Crash Avoidance Technology. *Insurance Institute for Highway Safety*, 27 Apr. 2014. Web. 11 Apr. 2016. <[http://www.iihs.org/lifesavers/pdfs/LS\\_Promise%20and%20Reality%20of.pdf](http://www.iihs.org/lifesavers/pdfs/LS_Promise%20and%20Reality%20of.pdf)>.

established by the NHTSA<sup>38</sup> and the Society Automotive Engineers (SAE)<sup>39</sup>. Each defined these features through different levels of automation. The NHTSA breaks AV technology into 5 distinct categories:

**Level 0:** *No Automation* – In this level, the human driver is responsible for all aspects of dynamic driving task.

**Level 1:** *Function-specific Automation* – In level 1, some individual systems have assistive features, like steering and acceleration/deceleration, but human driver is still responsible for remaining aspects of dynamic driving task. Many cars already contain some basic function-specific automated features, like cruise control, automatic braking, and lane keeping safety features.

**Level 2:** *Combined Function Automation* – Level 2 combines and integrates multiple aspects from level 1. In this level, some systems are automated, but driver is still responsible for remaining aspects of dynamic driving task.

**Level 3:** *Limited Self-Driving Automation* – In level 3, the automated system oversees dynamic driving task, but human driver is expected to intervene upon request. In level 3, the human operator can completely cede control of the car to the automated system.

**Level 4:** *Full Self-driving Automation* – The last phase of automation is level 4, in which the automated system oversees all aspects of dynamic driving task under all conditions. The human operator is not expected to intervene with any aspects of the dynamic driving task.

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<sup>38</sup> "U.S. Department of Transportation Releases Policy on Automated Vehicle Development." *National Highway Traffic Safety Administration (NHTSA)*. US NHTSA, 30 May 2013. Web. 10 Apr. 2016. <<http://www.nhtsa.gov/About+NHTSA/Press+Releases/U.S.+Department+of+Transportation+Releases+Policy+on+Automated+Vehicle+Development>>.

<sup>39</sup> "Taxonomy and Definitions for Terms Related to On-Road Motor Vehicle Automated Driving Systems." *SAE International*. SAE International, 16 Jan. 2014. Web. 10 Mar. 2016. <[http://standards.sae.org/j3016\\_201401/](http://standards.sae.org/j3016_201401/)>.

Although the definitions used by the NHTSA and SAE are similar, SAE breaks level 4 into two categories to show that even with full automation, drivers may still need or want to intervene occasionally. These definitions outline various levels of automation in terms of the extent of automation and the role of the driver in the vehicle. For the purposes of this study, and its focus on the United States, I will refer to the NHTSA definition outlined above.

## Safety

Although the frequency of crashes is gradually declining with the introduction of new safety features, car accidents are still a major public health problem in the United States. In 2011, over 5.3 million automobile crashes occurred in the United States alone. Although the exact figures vary by source, these crashes resulted in over 2.2 million injuries and around 32,000 fatalities, not to mention billions of dollars in costs to individuals and the public.<sup>40</sup> Automobiles are a leading cause of death and injuries in the United States. However, new innovations, including some levels of basic autonomy, are making cars safer.

With the potential to reduce the number and severity of car accidents, safety is the main force driving the development of AVs. Google tracks its own AV fleet and releases monthly data reports on accidents. In February, Google claimed partial fault for the first time due to an accident with a bus on February 14<sup>th</sup> in Mountain View, California. This accident only caused minor damage and nobody was hurt during the event.<sup>41</sup> In 2015, Google's test cars averaged around 10,000-15,000 miles per week

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<sup>40</sup> Anderson, 2016.

<sup>41</sup> Howard, Bill. "Oh, the Humanity: Google Car Self-drives into a Bus...at 2 Mph | ExtremeTech." *ExtremeTech*. Ziff Davis, 1 Mar. 2016. Web. 11 Apr. 2016. <<http://www.extremetech.com/extreme/223844-oh-the-humanity-google-car-self-drives-into-a-bus-at-2-mph>>.

on public roads and have traveled over 1.498 million miles in autonomous mode.<sup>42</sup> Virginia Tech's Transportation Institute released a study called the *Automated Vehicle Crash Rate Comparison Using Naturalistic Data* that compared the crash rates of Google's self-driving cars to conventional automobiles. The study found that the crash rates for self-driving cars operating in autonomous mode were lower, even when the study controlled for crash severity. This data suggests that automated vehicles are already ahead of conventional automobiles in terms of safety. Most importantly, the study shows larger disparities in safety between AV technology and their conventional predecessors as accidents become more severe.<sup>43</sup>

Time and data will help researchers quantify the full safety benefits of self-driving cars. In the meantime, research studies paint an accurate picture of how much conventional cars cost in terms of safety. AAA breaks down the average costs of a car accident in the United States, including both the private costs to an individual and the public costs like congestion and fuel waste that result from a car accident.<sup>44</sup> The National Motor Vehicle Crash Causation Study by NHTSA breaks down the causes of each accident in the United States, 95% of which are caused by human error.<sup>45</sup> In order

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<sup>42</sup> "Google Self-Driving Car Project." *Google Self-Driving Car Project*. Google, Inc., n.d. Web. 11 Apr. 2016. <<https://www.google.com/selfdrivingcar/reports/>>.

<sup>43</sup> Blanco, Myra, Jon Atwood, Sheldon Russell, Tammy Trimble, Julie McClafferty, and Miguel Perez. "Automated Vehicle Crash Rate Comparison Using Naturalistic Data." *Virginia Tech Transportation Institute*. Google, Inc., Jan. 2016. Web. 11 Apr. 2016. <[http://www.vtti.vt.edu/PDFs/Automated%20Vehicle%20Crash%20Rate%20Comparison%20Using%20Naturalistic%20Data\\_Final%20Report\\_20160107.pdf](http://www.vtti.vt.edu/PDFs/Automated%20Vehicle%20Crash%20Rate%20Comparison%20Using%20Naturalistic%20Data_Final%20Report_20160107.pdf)>.

<sup>44</sup> Green, Michael. "AAA Study Finds Costs Associated With Traffic Crashes Are More than Three Times Greater than Congestion Costs." *News Room*. AAA, 3 Nov. 2011. Web. 12 Nov. 2015. <<http://newsroom.aaa.com/2011/11/aaa-study-finds-costs-associated-with-traffic-crashes-are-more-than-three-times-greater-than-congestion-costs/>>.

<sup>45</sup> "Traffic Safety Facts." *Critical Reasons for Crashes Investigated in the National Motor Vehicle Crash Causation Survey (2015)*: n. pag. NHTSA & USDOT, Feb. 2015. Web. Nov.-Dec. 2015. <<http://www-nrd.nhtsa.dot.gov/pubs/812115.pdf>>.

to account for these factors in conventional driving, various government entities pass regulations & standards, licensing, and insurance requirements.

Kirk Gosselin projects the economic cost of car accidents at nearly \$300 billion per year.<sup>46</sup> AVs hold the potential to reduce these costs considerably by reducing the magnitude of human error. The Insurance Institute for Highway Safety (IIHS) conducted a study that analyzed the prospects of expanding existing automated safety features. The study estimated that nearly a third of crashes and fatalities could be prevented if all vehicles had automated safety features like forward collision, lane departure, side view blind spot assistance, and adaptive headlights.<sup>47</sup> Follow up studies suggest that many of the crashes associated with distracted driving would be eliminated through higher levels of automation, but that these types of safety features sometimes take up to three decades to spread throughout a vehicle fleet.<sup>48</sup> Fully automated features have the potential to eliminate a large number of crashes associated with driver error. Alcohol impairment also causes a considerable amount of accidents in the United States. In 2011, roughly 39% of all crash fatalities involved alcohol use by at least one of the drivers.<sup>49</sup> Altogether, these safety features will make transportation safer in the United States.

More AV technology on the road will also enable new traffic management systems to improve safety. Specifically, communications from vehicle-to-vehicle and

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<sup>46</sup> Gosselin, Kurt M. "Navigating The Policy Landscape To Bring Autonomous Vehicle Legislation To Your State." *Quorum* (2015): 85-109. N.Y.U. Journal Of Legislation And Public Policy Quorum. N.Y.U. Journal Of Legislation And Public Policy, 4 Sept. 2015. Web. 20 Apr. 2016.

<sup>47</sup> Zuby, 2014.

<sup>48</sup> "Eyes on the Road: Searching for Answers to the Problem of Distracted Driving." *Eyes on the Road* 49.8 (2014): 1-11. *IIHS Status Report*. Insurance Institute for Highway Safety & Highway Loss Data Institute, 24 Oct. 2014. Web. 11 Apr. 2016. <<http://www.iihs.org/externaldata/srdata/docs/sr4908.pdf>>.

<sup>49</sup> Anderson, 2016.

vehicle-to-infrastructure also hold the potential to reduce car accidents and increase safety.<sup>50</sup> However, as each company develops its own safety measures, they will need to create systems that can interact across different companies and different types of technology. While the road is shared between automated and conventional drivers, the results may be mixed. As AV data becomes more available, policymakers and planners must take note of how safety interactions may differ between various stakeholders using the right of way. The government already uses a variety of tools that apply to AVs and protect the safety of people on the road.

### Regulations and Standards

Safety regulations and standards will set practical benchmarks through industry and government goals on AV development. Regulations are legally mandated requirements set by the government that dictate AV development through testing requirements, definitions, and vehicle standards. While many of these regulations are dictated at the state level, the NHTSA enacts Federal Motor Vehicle Safety Standards (FMVSSs) “that specify performance standards for a wide range of safety components, including specific crash test performance. Retroactively, the NHTSA can facilitate new standards through recalls and buybacks of old models in its New Car Assessment Program.”<sup>51</sup>

The Federal Government offers programs to reclaim old, faulty, and inefficient cars with a buyback programs or by issuing recalls. These programs expedite the

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<sup>50</sup> Knight, Will. "Car-to-Car Communication." *MIT Technology Review*. Massachusetts Institute of Technology, 18 Feb. 2015. Web. 04 May 2016. <<https://www.technologyreview.com/s/534981/car-to-car-communication/>>.

<sup>51</sup> Anderson, 2016.

implementation process when safety and health are concerned. Industry practices that dictate how a product should be designed are known as standards. Standards will dictate the type and strength of sensors, fuel efficiency, and horsepower for AVs. Standards set a baseline for performance and assure consumers that the product is effective. Simultaneously, standards set precedents for the automotive industry that are enforced by market conditions. Manufacturers change their products and prices to reflect the actual demand for higher standards.

### Licensing Requirements

Licensing requirements limit the pool of potential drivers to those who are old enough to use sound judgment and are physically able to operate a vehicle. State governments administrate licensing requirements and will hold the key to unlocking access to single occupancy vehicle use for relatively immobile groups like seniors, children, and the disabled. Without relaxing licensing requirements, these demographics will access to mobility with AV technology. Traditional definitions of a human driver will serve as an obstacle to AV development across the nation and merit review by state and federal policymakers. With self-driving cars, governments may shift licensing requirements to occupancy requirements for self-driving cars.

### Insurance / Liability Requirements

Through improvements in safety, insurance costs are likely to decrease along with the risk associated with driving. But In terms of liability, AV technology creates a complicated underlying issue of fault. Before cars are fully automated (Level 4), individual drivers will still be required to intervene in specific situations, but these transitions during the earlier phases of implementation will be dangerous for AV users and other individuals on the road. If a passenger is no longer responsible for the dynamic task of driving, then insurance providers will need to assign fault to another

party. Furthermore, if states adjust their unique definition of a driver to include autonomous driving systems, the driver at fault would not be a “person” by traditional standards. Moreover, insurers will need a legal precedent for establishing who or what was at fault in an AV accident. In the event of an accident caused by an autonomous car, insurance claims will need to differentiate between the liability of automakers who build the cars, the engineers that program the cars, and the passengers that own the cars. If state legislators move the burden of insurance to the manufacturers or programmers, they will increase the price of their vehicle. Alternatively, states may still require automobile owners to purchase a no-fault insurance to address these liability concerns.<sup>52</sup>

## Energy Use / Emissions

Automobile emissions contribute to pollution at many different levels. New emissions standards and engines (hybrid and electric) are making cars more efficient, but many negative externalities persist. The particulate matter, black smoke, benzene, and NO<sub>2</sub> released as a byproduct of fuel consumption creates air pollution. In addition to air pollution, automobile emissions create soil and water pollution as these particulates combine with other materials in the form of runoff. A study by the University of Washington examined GIS data to determine how these externalities disproportionately hurt minorities and other disadvantaged populations that live close to freeways. The study found that these groups experience worse health outcomes that correlate to auto emissions and proximity to freeways. These disadvantaged

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<sup>52</sup> Anderson, 2016.

populations end up paying for the negative externalities with their health, regardless of their driving behaviors.<sup>53</sup>

Automated vehicles can be programmed to drive more efficiently to cut down on fuel use and emissions like GHG, CO<sub>2</sub>, and air pollution because an increase in fuel efficiency leads to subsequent reductions in emissions. Platoons of cars driving in formation holds the potential to reduce drag on vehicles, drive at more efficient speeds, and eliminate unnecessary accelerating and breaking.<sup>54</sup> Even without platoons, AVs can be programmed to operate more efficiently to reduce energy use and emissions.

The potential savings may be limited early in the integration process on the roads. Fuel efficiency and emissions projections typically assert that all vehicles on the road will be fully autonomous. Yet this reality will not be possible until all individuals trade in their conventional vehicles much later in the implementation process. In the meantime, human drivers and automated driving systems must share the road. AVs will struggle to maximize fuel efficiency under existing traffic patterns and laws, which do not permit platoon formations because they are designed for human reaction speeds. But over time, these laws can evolve such that AVs will improve fuel efficiency and reduce emissions.

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<sup>53</sup> Bae, Christine, Gail Sandlin, Alon Bassok, and Sungyop Kim. "The Exposure of Disadvantaged Populations in Freeway Air-Pollution Sheds: A Case Study of the Seattle and Portland Regions." Sage Journals. University of Washington, 29 Jan. 2006. Web. 22 Apr. 2016. <<http://epb.sagepub.com/content/34/1/154.full.pdf+html>>.

<sup>54</sup> Frangoul, Anmar. "Self-driving Trucks Have Crossed Europe." Technology. CNBC, 07 Apr. 2016. Web. 11 Apr. 2016. <<http://www.cnbc.com/2016/04/07/a-platoon-of-self-driving-trucks-has-crossed-europe.html>>.

## Employment

Millions of jobs that are reliant on the conventional automobile will be at risk through AV development. Employers can reduce payroll costs by automating the task of driving. The US Bureau of Labor Statistics lists many different industries that rely on humans for the task of driving, including first responders, transit operators and bus drivers, truck drivers, taxi drivers, rail operators, and boat operators. In the country, truck drivers alone consist of over 2.3% of the total active workforce. Companies will undergo large-scale layoffs as driving becomes obsolete. Instead, these trucks will be programmed to drive at fuel-efficient speeds and will not need to stop for food or sleep. Taxi drivers and bus drivers, which consist of 0.3% & 0.37% of the workforce respectively, will also be laid off as employers opt for cheaper operating costs. In 2015, these industries and occupations contained over 3% of the workforce (about 4.7 million people), in the United States.<sup>55</sup>

Traditional automakers and manufacturers will also experience a loss in employment as alternative products reach consumer markets. While some employment will shift from one industry to the other, a shared car economy will potentially reduce the amount of cars bought and sold. This fundamental shift in the automotive industry will lead to higher unemployment in both sales and production. With such a large amount of people and industries dependent on conventional navigation systems, AV technology might drastically reduce domestic employment. However, in spite of these losses in employment, many other industries will rise from the ashes of the conventional automobile. As self-driving cars hit mainstream consumer markets, AV

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<sup>55</sup> "Bureau of Labor Statistics Data." *Databases, Tables & Calculators by Subject*. Bureau of Labor Statistics, n.d. Web. 1 May 2016.  
<[http://data.bls.gov/PDQ/servlet/SurveyOutputServlet?data\\_tool=latest\\_numbers&series\\_id=LNS14000000](http://data.bls.gov/PDQ/servlet/SurveyOutputServlet?data_tool=latest_numbers&series_id=LNS14000000)>.

technology will create new employment in the United States that includes new automakers, programmers, and manufacturers. However, if automakers outsource labor costs, many of these new jobs may end up overseas, instead of in the United States. The government occasionally provides job training assistance and also provides unemployment benefits to the public. More drastic measures might include a basic income for former employees and the general public as automation eliminates jobs in other sectors.

## Congestion

AVs will create both benefits and costs with respect to congestion in many major cities. The current scale of congestion on urban American roadways delays drivers and passengers, wastes fuel and time, and increases emissions. Researchers evaluate congestion by examining vehicle flows (VKT), the number of vehicles passing a point on a highway in a given hour.<sup>56</sup> Lindsey and Verhoef point out that infrastructure development has not kept pace with rising traffic volumes, resulting in a continuous increase in traffic congestion over the last several decades.<sup>57</sup>

Many studies debate whether self-driving cars will increase or decrease congestion due to the complex relationship between automation and transportation behavior. As individuals respond to the new mode of transportation, driving behaviors will shift. These shifts in behavior are typically quantified in vehicular miles traveled (VMTs). Although these changes will vary by individual and locality, the agglomerative

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<sup>56</sup> Parry, Ian W. H., Margaret Walls, and Winston Harrington. "Automobile Externalities and Policies". *Journal of Economic Literature* 45.2 (2007): 373-399. Web. 22 Apr. 2016. <<http://pubs.aeaweb.org.offcampus.lib.washington.edu/doi/pdfplus/10.1257/jel.45.2.373>>.

<sup>57</sup> Lindsey, Robin, and Erik Verhoef. *Traffic Congestion and Congestion Pricing*. Amsterdam: Tinbergen Institute, 2000. Tinbergen Institute. Web. 22 Apr. 2016. <<http://papers.tinbergen.nl/00101.pdf>>.

affects of these shifts will either increase or decrease the VMTs and congestion in specific communities.

The private benefits of self-driving cars will encourage individuals to use single-occupancy vehicles more frequently than with conventional automobiles. These factors may increase VMTs and contribute to congestion.<sup>58</sup> Automated Vehicles present the opportunity for multitasking during a commute. With self-driving cars with automation of level 3 or higher, passengers don't need to drive and can instead dedicate their focus to leisure & work activities. Although individuals will still be confined to their vehicle, occupants can enjoy the privacy of a single occupancy vehicle without needing to remain attentive to the road. As a result, AV technology can reduce the cost of time spent in a single occupancy vehicle. In the United States, the Census Bureau measures commute time with respect to location and mode of transportation. Data from the American Community Survey helps put a number on the amount of time an individual may through multitasking in a single occupancy vehicle. Although this will directly save time for the passenger, this feature will make single-occupancy vehicles more attractive of an option in transportation and likely lead to an increase in VMTs and congestion.

Also, self-driving cars will create an environment in which individuals can theoretically send a car on a trip without a passenger. In a manually operated SOV, driving behavior is relatively standard. Individuals will drive to their destination, park their car, and return to the car when ready to go somewhere else. But with self-driving cars, rather than paying for parking, individuals may choose to send their vehicle home and have it return when they are ready to get back into the vehicle. This new scenario would double the VMTs in an individual trip. For shorter trips, AV users could send

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<sup>58</sup> Anderson, 2016.

their vehicle around the block or idle instead of parking. This type of behavior will add to VMTs, increase congestion, waste fuel, and increase emissions. In an individual household, sharing vehicles will increase congestion because one household may send a car on more trips without a driver, and subsequently increase VMTs for the household. A study by KPMG suggests that VMTs would potentially increase by 1 trillion annually to meet untapped demand and shifting driving behaviors.<sup>59</sup>

AVs can decrease congestion by using less of the right-of-way more efficiently without compromising safety. Fully autonomous vehicles with a faster reaction speed than human drivers can cruise in tighter formations, called platoons. However, the implementation process will present various challenges for policy-makers and planners. Before all cars are fully automated, AVs will be sharing the road with human-operated cars, and it will be difficult for AVs to maximize their potential benefits (many of which are predicated on every person using a fully automated system).<sup>60</sup> Without designated lanes, a fleet of AVs in a tight formation will create a moving obstacle on the road for human drivers. These formations may not be feasible until much later in the implementation process. Intersections will also merit review from policymakers and planners. An MIT study suggests that with complete implementation of fully autonomous cars, intersections will become obsolete because rather than coming to a complete stop, AVs could just navigate around each other.<sup>61</sup> These long-term benefits

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<sup>59</sup> Silberg, Gary, Thomas Mayor, Todd Dubner, Jono Anderson, and Leila Shin. "The Clockspeed Dilemma: What Does It Mean for Automotive Innovation?" KPMG, LLP, Nov. 2015. Web. 11 Apr. 2016. <<http://info.kpmg.us/content/dam/kpmg-im/automotive/auto-clockspeed-dilemma.pdf>>.

<sup>60</sup> Litman, 2015.

<sup>61</sup> Tachet, Remi, Paolo Santi, Stanislav Sobolevsky, Luis Ignacio Reyes-Castro, Emilio Frazzoli, Dirk Helbing, and Carlo Ratti. "Revisiting Street Intersections Using Slot-Based Systems." *PLOS ONE*: MIT Senseable City Lab, 16 Mar. 2016. Web. 04 May 2016. <<http://journals.plos.org/plosone/article?id=10.1371%2Fjournal.pone.0149607>>.

will not materialize without full implementation and high adoption rates. In the meantime, AVs will still benefit society by reducing car accidents, and in turn reducing crash-related traffic congestion.<sup>62</sup> Policymakers and planners will need to use existing tools and create new tools to prepare for the changes in transportation behavior that might increase congestion.

### Congestion Policy Options

Lindsey and Verhoef argue that congestion pricing is the most effective policy at reducing congestion on roadways. Congestion pricing is a tolling system that creates an additional cost for drivers. The price fluctuates based on the amount of congestion in order to reduce drivers during peak hours.<sup>63</sup> Congestion pricing directly charges the culprits of congestion by proportionately increasing the financial burden on additional drivers. As a result, congestion pricing forces these drivers to pay for use of the road. Many individuals choose not to drive during peak hours, which limits the extent of congestion. This policy effectively changes driving behavior, reduces congestion during peak hours, and raises revenue for local jurisdictions. Although these programs generate revenue, they are expensive to manage due to the high cost of the GPS technology and tagging to administrate the tolls. Congestion pricing in Germany is estimated to cost approximately \$500 per vehicle.<sup>64</sup> However, with automated systems improving and evolving on a regular basis, these costs are likely to decrease over time.

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<sup>62</sup> Anderson, 2016.

<sup>63</sup> Lindsey, 2016.

<sup>64</sup> "Congestion Pricing: A Primer." Federal Highway Administration. U.S. Department of Transportation, 31 July 2014. Web. 24 Apr. 2016. <<http://ops.fhwa.dot.gov/publications/congestionpricing/sec2.htm>>.

Congestion pricing is a local policy tool with different variations across the globe that can help mitigate a substantial increase in VMTs and traffic delays caused by AVs:<sup>65</sup>

**Variable Tolls:** Variable tolls set up a pricing scheme across an entire roadway, charging more during peak hours.

**Variable Lanes:** Variable lane congestion pricing provides benefits to high-occupancy vehicles (HOVs) through special lanes. When cars are not using HOV lanes, other drivers can opt to use these faster lanes and pay an additional toll fee.

**Cordon Pricing:** Cordon pricing is a form of congestion pricing that charges a fee to enter or drive within a congested area, usually adopted for busy city centers.

**Area-wide Pricing:** Area-wide pricing is a form of congestion pricing that establishes per-mile charges to capture the costs associated with Vehicular Miles Traveled. The State of Oregon is testing area-wide pricing as a means to replace fuel taxes. This program would assess higher charges during congested periods on high traffic road segments. Seattle also tested a similar charging system in the metropolitan area from 2005-2006. The Puget Sound Regional Council found that area-wide pricing successfully reduced congestion and created additional revenue for other projects.<sup>66</sup>

## The Built Environment

With the rise of autonomous technology, self-driving cars will create new opportunities to restructure the built environment and repurpose existing infrastructure. The automobile profoundly shaped urban form in the United States when Dwight Eisenhower passed the Federal Highway Act and created the Interstate

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<sup>65</sup> Congestion, 2014.

<sup>66</sup> Davis, Aubrey. "Traffic Choices Study - Summary Report." *Puget Sound Regional Council*. USDOT, Apr. 2008. Web. 4 May 2016. <<http://www.psrc.org/assets/37/summaryreport.pdf?processed=true>>.

Highway system. The policy put Americans to work and built an extensive road system that many people still use today. With the new highways system, ideas, money, and prosperity easily flowed across the United States. However, this infrastructure development act prioritized the automobile over other forms of transit in the United States, including public transit, walking, and biking.<sup>67</sup> This auto-based infrastructure development created a new generation of negative externalities like sprawl and low-density environments that increase the costs to provide public services.<sup>68</sup> Critics like James Kunstler assert that planners and traffic engineers emphasized wider roads and readily accessible parking lots at the expense of pedestrian environments and urban form. He suggests that these changes in urban form paved over the urban identity of the United States.<sup>69</sup>

In spite of the potential for built environment improvements, AV technology may encourage more sprawling development in the United States. As noted earlier, self-driving cars with automation at levels 3 and up will reduce the cost of time spent in an automobile because of multitasking and potentially spur commuters to live further away from job centers. Rand Corp suggest that, "Just as the rise of the automobile led to the emergence of suburbs and exurbs, so the introduction of AVs could lead to more dispersed and low-density patterns of land use surrounding metropolitan

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<sup>67</sup> Schwager, Dianne S., comp. "Consequences of the Development of the Interstate Highway System for Transit." *Research Results Digest 21* (1997): 1-22. Transit Cooperative Research Program. Federal Transit Administration, Aug. 1997. Web. 22 Apr. 2016. <[http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp\\_rrd\\_21.pdf](http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp_rrd_21.pdf)>.

<sup>68</sup> Bento, Antonio M., Maureen L. Cropper, Ahmed M. Mobarak, and Katja Vinha. "The Effects of Urban Spatial Structure on Travel Demand in the United States." *The Review of Economics and Statistics* 87.3 (2005): 466-78. MIT Press. Web. 22 Apr. 2016. <<http://www.econ.umd.edu/sites/www.econ.umd.edu/files/pubs/jc52.pdf>>.

<sup>69</sup> Kunstler, James Howard. *The Geography of Nowhere: The Rise and Decline of America's Man-made Landscape*. New York: Simon & Schuster, 1993. Print.

regions.”<sup>70</sup> Sprawl creates problems for local governments, which must then provide more services at a higher cost to individuals living further away from the urban core.

### Right of Way Management

Further down the road with full implementation of AV technology, self-driving cars will ultimately save space in the right of way with platoon formations, more efficient driving, and less congestion caused by car accidents. Planners are only just beginning to consider how this technology will affect the right of way in their long-range planning documents. A 2015 study by the National League of Cities searched for content on self-driving cars in local policies and long-range planning documents in the most populated cities and the largest cities in each state. Of the 68 local planning documents reviewed, only 6% addressed self-driving cars or autonomous technology. Most of these documents analyzed the sole issue of automobile congestion and prescribed increased SOV infrastructure.<sup>71</sup> The study revealed that local governments are only beginning to consider the implications of AV technology and potential shifts in personal transportation. Over time, research and public data will expand and give public officials a better sense of the real costs and benefits of self-driving cars.

As self-driving cars evolve from a concept into reality, policymakers and planners in the United States will need to understand the spectrum of benefits and costs and the implications on long-range planning for transportation infrastructure. The full spectrum includes single-occupancy vehicle infrastructure, public transit infrastructure, pedestrian

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<sup>70</sup> Anderson, 2016.

<sup>71</sup> DuPuis, Nicole, Cooper Martin, and Brooks Rainwater. "City of the Future: Technology & Mobility." National League of Cities. National League of Cities, n.d. Web. 26 Apr. 2016. <<http://www.nlc.org/Documents/Find%20City%20Solutions/Research%20Innovation/City%20of%20the%20Future/City%20of%20the%20Future%20FINAL%20WEB.pdf>>.

infrastructure, and biking infrastructure. Infrastructure investments are limited in their ability to reduce congestion because additional capacity is met with an increase in driving over the long run.<sup>72</sup> Instead of directly expanding the capacity of the road, policymakers and planners would be wise to invest in streamlining the existing SOV infrastructure to make AV technology more efficient and effective while mitigating any negative externalities that may result.

A study conducted by Gilles Duranton and Matthew Turner shows that adding lanes does little to curb congestion. Increasing the amount of lanes available for drivers typically reduces congestion in the short term, but these benefits usually erode as additional drivers take advantage of the newly available space on the road. Individual driving behavior determines the congestion rates in urban areas because more available lanes creates more capacity for cars. The fundamental law of road congestion highlights that additional capacity is met with a proportionate increase in driving.<sup>73</sup> Critics argue that auto-oriented development patterns have negative results on economic development, encourage sprawl, detract from alternative modes of transport, and create poor health and environmental outcomes.<sup>74-75</sup>

Public transit infrastructure often costs too much for smaller communities to finance or hits political roadblocks. In response these communities may turn to subsidized carsharing services with autonomous features. A publicly subsidized shared

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<sup>72</sup> Duranton, Gilles, and Matthew A. Turner. "The Fundamental Law of Road Congestion: Evidence from US Cities." *The American Economic Review* 6. 101. October (2011): 2616-652. Web. 22 Apr. 2016. <<http://pubs.aeaweb.org/doi/pdfplus/10.1257/aer.101.6.2616>>.

<sup>73</sup> Duranton & Turner, 2016.

<sup>74</sup> Rode, Philipp, and Graham Floater. "Accessibility in Cities: Transport and Urban Form." *The New Climate Economy* 3 (2014): 1-61. *The New Climate Economy*. London School of Economics and Political Science, Nov. 2014. Web. 25 Apr. 2016. <<http://newclimateeconomy.report/wp-content/uploads/2014/11/Transport-and-urban-form.pdf>>.

<sup>75</sup> Kunstler, 1993.

vehicle market already broke ground in the United States in Alamonte Springs, Florida. This jurisdiction repurposed funding to subsidize the cost of Uber by 20% for all trips beginning or ending in Alamonte Springs.<sup>76</sup> On-demand transportation systems are designed to increase access to transportation in communities that are not able to finance the construction of mass transit. They don't require the intense capital needed by traditional public transit infrastructure, but will rely on an increasingly aging SOV infrastructure that will need extensive repairs throughout the country.

Investments in alternative modes of transportation create more options for residents and take cars off the roads. With high ridership, transit investments provide many positive externalities in emissions, health, real estate value, and mobility.<sup>77</sup> Dedicated transit lanes and mass transit light-rail investments sometimes provide a faster alternative to single-occupancy vehicles on congested roads. In spite of these many benefits, Duranton and Turner illustrate how these investments in public transit fail to reduce congestion in the long-term because the temporary increase in capacity still follows the fundamental law of road congestion. The additional capacity from transit leads to a proportionate increase in drivers. The changes in driving behavior mitigate the gains in congestion created by transit.<sup>78</sup> Even though public transportation doesn't necessarily reduce congestion, it is still an important tool that promotes growth and serves as a vital method of transportation in dense urban

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<sup>76</sup> "The Newest Public Transportation In Town: Uber." The Industry. NPR, 9 Apr. 2016. Web. 20 Apr. 2016. <<http://www.npr.org/sections/alltechconsidered/2016/04/09/473422686/the-newest-public-transportation-in-town-uber>>.

<sup>77</sup> Litman, Todd. "Evaluating Public Transit Benefits and Costs: Best Practices Guidebook." (2015): n. p. Victoria Transport Policy Institute. Victoria Transport Policy Institute, 10 Dec. 2015. Web. 24 Apr. 2016. <<http://www.vtpi.org/tranben.pdf>>.

<sup>78</sup> Duranton and Turner. 2016.

environments. Public transportation may be cost-prohibitive for smaller communities with sprawling density or limited funding.

Bike and pedestrian investments, also known as active transit infrastructure, provide an alternative to driving and promote healthier behaviors within the community. These healthy transportation options only require a small amount of the available right of way and don't add much to traffic. Crosswalks, Shared lane markings, dedicated bike lanes, shared sidewalks, wider sidewalks, landscaping buffers, and bike-share systems all encourage more pedestrian and biking activity to varying degrees.<sup>79</sup> In dense communities with more proximate locations, active transit provides a legitimate transportation options within a community. However, if destinations in a community are too far to bike or walk conveniently, it may not be a practical alternative to driving. Independent from the investments in active transit, density, land-use mix and street design also influence the likelihood of walking.<sup>80</sup> Although non-motorized transit is considered a slow form of transit, data actually suggests that forms of non-motorized transit can be faster for short trips within 1 mile for walking and 3 miles for biking.<sup>81</sup> Studies indicate that investments in bike and pedestrian infrastructure lead to proportionate increases in active transit, which creates better health outcomes and

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<sup>79</sup> Milne, Andrea, and Maggie Melin. *Bicycling and Walking in the United States 2016 Benchmarking Report*. N.p.: n.p., n.d. Bike Walk Alliance. AARP, 2016. Web. 24 Apr. 2016. <[http://www.bikewalkalliance.org/storage/documents/reports/2016benchmarkingreport\\_web.pdf](http://www.bikewalkalliance.org/storage/documents/reports/2016benchmarkingreport_web.pdf)>.

<sup>80</sup> Ewing, Reid, and Robert Cervero. "Travel and the Built Environment." *Journal of the American Planning Association* 76.3 (2010): 1-30. Routledge, 11 May 2010. Web. 25 Apr. 2016. <<http://www.arch.utah.edu/cgi-bin/wordpress-metroresearch/wp-content/uploads/2013/09/Most%20Cited%20Articles/Ewing&Cervero.pdf>>.

<sup>81</sup> Litman, Todd. "Evaluating Active Transport Benefits and Costs." *Victoria Transport Policy Institute*. Victoria Transport Policy Institute, 23 Mar. 2016. Web. 24 Apr. 2016. <<http://www.vtpi.org/nmt-tdm.pdf>>.

generates economic benefit for communities. Their research concludes that these benefits outweigh the costs to provide active transit infrastructure.<sup>82, 83</sup>

### Parking Policy

Under the right regulatory environment, self-driving cars will change urban form in the United States. In the right locations, the urban land dedicated to parking can be repurposed for higher and better uses.<sup>84</sup> Currently, a large portion of valuable land in urban areas is dedicated to parking. Shoup analyzed parking in 41 major cities and concluded that approximately 31 percent of space in their central business districts was devoted entirely to parking.<sup>85</sup> Local governments influence parking policy through zoning and land use codes, the provision of public parking, and investments in public space conversions.

Zoning and land use codes establish standards for parking stall sizes and parking requirements for developers. Local communities will need less space for parking because passengers can exit vehicles at the destination rather than in a parking lot. Without allotting space for a driver to exit the vehicle, a self-driving car could park in a tighter spot. From this fact alone, a McKinsey Report details how individual parking

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<sup>82</sup> Litman, Todd. "Quantifying the Benefits of Non-Motorized Travel for Achieving TDM Objectives." *Victoria Transport Policy Institute*. Victoria Transport Policy Institute, 23 Mar. 2016. Web. 8 May 2016. <<http://www.vtppi.org/nmt-tdm.pdf>>.

<sup>83</sup> Campbell, Richard, and Margaret Wittgens. "The Business Case for Active Transportation: The Economic Benefits of Walking and Cycling." *Nacto.org*. Go for Green: The Active Living & Environment Program, Mar. 2004. Web. 8 May 2016. <[http://nacto.org/docs/usdg/business\\_case\\_for\\_active\\_transportation\\_campbell.pdf](http://nacto.org/docs/usdg/business_case_for_active_transportation_campbell.pdf)>.

<sup>84</sup> Anderson, 2016.

<sup>85</sup> Shoup, 2005.

stalls and lots could be reduced in size by 15%.<sup>86</sup> Self-driving cars can reduce the need for parking in urban centers. Unlike conventional automobiles, self-driving cars could drop passengers off at their destination and then park in a remote location further away from the urban core where land is more readily available. In order to promote a reduction in parking, localities can also reduce parking requirements on developers in zoning and land use codes. If all localities eliminate parking requirements, private automobiles will still need to park somewhere.

In urban areas where a shared vehicle economy is viable, self-driving cars could pick up another driver and continue to the next destination rather than parking. Full automation will allow for an easement in some parking requirements and a reduction in public parking, but private vehicle owners will still need a place to store their cars. AV owners can send their cars to park in nearby neighborhoods with a higher parking supply or cheaper parking rates, thus shifting the burden of parking to other communities. However, it is important to note that reducing the public parking availability will result in the loss of some municipal dollars from parking revenue. Even if tax revenues are created in place, reducing the parking supply could still create funding challenges for some localities in the short-term. Cities should adopt and update a comprehensive parking plan to address parking infrastructure over a 20-year period. This planning timeframe will allow policymakers to examine areas where parking reductions are possible.

The main problem associated with all of this urban parking is the cost. Parking costs include the price of the land, the cost to construct the parking, and the operating

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<sup>86</sup> Bertonecello, Michele, and Dominik Wee. "Ten Ways Autonomous Driving Could Redefine the Automotive World." Industries. McKinsey & Company, June 2015. Web. 11 Apr. 2016. <<http://www.mckinsey.com/industries/automotive-and-assembly/our-insights/ten-ways-autonomous-driving-could-redefine-the-automotive-world>>.

costs to repair and manage parking. Real estate values fluctuate across different locations and communities, but urban land for parking is typically in short supply and high demand. As a result, this land is often sold at a premium value. In contrast, rural areas with more land are typically associated with cheaper land values. The price of the land directly influences the cost of the parking per square foot. Construction costs for parking vary depending on the type of parking. Parking structures are expensive to construct and require additional costs to manage and operate the parking. At the turn of the millennium, above grade parking structures required \$150-200 of revenue per month (on average) in order to recover the capital and operating costs, and does not include the cost to purchase the land.<sup>87</sup> In some rare cases like airports, parking demand is high enough that the parking developer can make a profit on parking. However, very few situations permit a parking provider to pass this cost along to visitors, employees, and residents, without discouraging a trip to the destination.

The costs of public parking are often subsidized such that individuals pay for a fraction of the true cost of parking. Instead, the full costs of public parking are spread out among all members of the tax-paying public. In the private sector, parking providers like businesses and landlords subsidize parking costs and pass them on to consumers by increasing their prices. In the public realm, local governments subsidize the cost of parking with taxpayer dollars. They can also pass zoning ordinances to require parking in new developments. Developers are then responsible for providing parking and a means to subsidize the costs, like increasing rent. Although public parking provides a benefit to those who drive, it creates a negative externality that

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<sup>87</sup> Chrest, Anthony P., Mary S. Smith, and Sam Bhuyan. *Parking Structures: Planning, Design, Construction, Maintenance, and Repair*. 3rd ed. New York: Van Nostrand Reinhold, 1989. Print.

taxpayers address through an increase in taxes, regardless of whether or not they drive.<sup>88</sup> By eliminating some of this parking, local governments can eliminate the externalities associated with parking costs.

In terms of opportunity costs, parking options can be repurposed for higher and better uses. However, the type of parking structure will dictate the costs associated with any changes. Surface parking lots are ideal locations for new developments because developers will not need to tear down old buildings and parking structures could be rehabbed for low-income housing or storage facilities. Public Agencies can also purchase private lots for redevelopment, or redevelop existing public parking lots. Surface lots can be redeveloped into other public uses, like affordable housing, service centers, and community centers. Multi-story parking structures are also valuable, but structures will take longer to convert because demolition adds time and costs to the development process. Even so, in a strong real estate market, any available urban land is extremely valuable. Underground parking lots also add a layer of complexity: underground parking's potential is limited because it cannot accommodate many new uses with the exception of storage. Private vehicle owners may still desire nearby parking for convenience, and the costs to convert these lots in the interim may be cost-prohibitive.<sup>89</sup>

On-street parking is more complicated because size and shape of the parking spots accommodate few alternatives and revenue-generating uses. In terms of urban form, miniature parks also known as parklets are narrow enough to fit in on-street parking and will generate revenue for cities through permitting and an increase in sales

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<sup>88</sup> Shoup, 2005.

<sup>89</sup> Chrest, Smith, & Bhuyan, 1989.

tax revenue. Through public-private partnerships, local businesses can design and build parklets in the public right of way. For use of the space, the business pays permitting fees to use the public right of way.<sup>90</sup> Parklets provide additional outdoor space for businesses and serve as a cost-effective ways to activate street sidewalks. The cost of installing a parklet varies depending on the size, location, and design. In Seattle, the city government estimates that the total costs of design review, permitting, and construction at a range of \$15,000 - \$50,000. Although this cost may seem high, Seattle offers a variety of funding sources and resources to help defray the design and construction costs. However, these estimates do not include the costs to operate or maintain a parklet, and also exclude the cost to remove the parklet, if needed.<sup>91</sup> Parklets are just one particular way that local residents and business owners can repurpose parking to improve urban form in their locality.

## METHODOLOGY

The benefits and costs of AV technology will not be uniform across different localities with different spatial patterns. This spatial variability manifests in terms of different types of development patterns in urban, suburban, and rural localities. In order to measure the differences between urban, suburban, and rural localities, I evaluated these demographic, geographic, and transportation differences between three census tracts in King County. Differences in demographics, geography, and

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<sup>90</sup> "Parklet Handbook." Seattle Department of Transportation Parklet Handbook (2016): 1-49. Seattle Department of Transportation, Mar. 2016. Web. 24 Apr. 2016. <[http://www.seattle.gov/transportation/docs/parklets/Parklet\\_Handbook\\_DIN.pdf](http://www.seattle.gov/transportation/docs/parklets/Parklet_Handbook_DIN.pdf)>.

<sup>91</sup> Parklet, 2016.

transportation will change how individual communities feel the effects local AV development.

## Demographic Data Metrics

Demographic variability manifests in terms of the different people that reside in each locality. Based on the literature review findings, demographic differences in age, income, disability status, gender, age, and employment will all influence the role of AV technology in each study area. These factors, and differences between demographics within urban, suburban, and rural census tracts, will directly influence AV development in each locality. The specific criteria are explained below along with a quick demographic comparison table to highlight the differences between the selected census tracts.

### Population

I measured the population size in each tract in order to understand the magnitude of the demographics in each subarea. Furthermore, this statistic helps me analyze the proportions of other criteria on this list.<sup>92</sup>

### Income

Understanding Income level will help evaluate the general income of the neighborhood and whether or not a vehicle would be cost prohibitive relative to their income level.<sup>93</sup>

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<sup>92</sup> U.S. Census Bureau; American Community Survey, 2010-2014 American Community Survey 5-Year Estimates, Table B01003; generated by Jacob Brett; using American FactFinder. 30 Mar. 2016. <<http://factfinder2.census.gov>>.

<sup>93</sup> U.S. Census Bureau; American Community Survey, 2010-2014 American Community Survey 5-Year Estimates, Table S1901; generated by Jacob Brett; using American FactFinder. 30 Mar. 2016. <<http://factfinder2.census.gov>>.

### Employment in Transportation & Warehousing:

With the implementation of AV technology, employment in transportation will be at risk through automation. The census bureau breaks employment down by industry and occupation through categorical variables. This data consolidates warehousing and transportation sector jobs.<sup>94</sup>

### Physical Disability:

Individuals with physical disabilities will be able to use AV technology in spite of their disabilities whereas they are limited in conventional vehicles. Census data tracks how many individuals with disabilities live in a geographic location. Physical disability and old age are by no means exclusive demographics.<sup>95</sup>

### Age

Demographic differences in age will likely relate to the rates of AV technology adoption in different localities. While demographics will shift over time, an overview of different ages will help break down the cultural and legal differences between different age groups. Census data breaks down residents by age in each census tract: Individuals from 0-17 in each area will be unable to drive without many restrictions & individuals from 65 and up also struggle with more mobility issues.<sup>96</sup>

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<sup>94</sup> U.S. Census Bureau; American Community Survey, 2010-2014 American Community Survey 5-Year Estimates, Table DP03; generated by Jacob Brett; using American FactFinder. 30 Mar. 2016. <<http://factfinder2.census.gov>>.

<sup>95</sup> U.S. Census Bureau; American Community Survey, 2010-2014 American Community Survey 5-Year Estimates, Table S1810; generated by Jacob Brett; using American FactFinder. 30 Mar. 2016. <<http://factfinder2.census.gov>>.

<sup>96</sup> U.S. Census Bureau; American Community Survey, 2010-2014 American Community Survey 5-Year Estimates, Table DP05; generated by Jacob Brett; using American FactFinder. 30 Mar. 2016. <<http://factfinder2.census.gov>>.

## Gender

Gender differences will also affect the rates of AV technology adoption. The aforementioned AAA survey determined that women (81%) are more likely than men (67%) to be afraid to allow an AV to drive itself with them in it.<sup>97</sup> The American Community Survey breaks down gender by census tract.<sup>98</sup> This information demonstrates that adoption rates may be higher in areas with more men than women.

## **Geographic Data Metrics**

Geographic differences affect each community in terms of land area, population density, and urban form. Geographic data analysis helps build a profile of how self-driving cars will interact with the built environment. Land use and zoning tools help dictate and guide the urban form throughout a community. Planning and infrastructure development will also guide AV development through diverse geographic areas.

## Land Area

The size of each subarea will vary depending on the size of each census tract. The land area is different from the surface area in that it excludes any water bodies in each subarea, as they are not habitable by people. Controlling for land area size in each subarea will help to evaluate the proportions of ROW and parking lots in each tract.<sup>99</sup>

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<sup>97</sup> "Vehicle Technology Survey Fact Sheet." AAA Newsroom. AAA Automotive Engineering, 2016. Web. 20 Apr. 2016. <<http://publicaffairsresources.aaa.biz/wp-content/uploads/2016/02/Automotive-Engineering-ADAS-Survey-Fact-Sheet-FINAL-3.pdf>>.

<sup>98</sup> U.S. Census Bureau; American Community Survey, 2010-2014 American Community Survey 5-Year Estimates, Table S0101; generated by Jacob Brett; using American FactFinder. 30 Mar. 2016. <<http://factfinder2.census.gov>>.

<sup>99</sup> U.S. Census Bureau; American Community Survey, 2010-2014 American Community Survey 5-Year Estimates, Table GCT-PH1, B01003; generated by Jacob Brett; using American FactFinder. 30 Mar. 2016. <<http://factfinder2.census.gov>>.

## Population density

Population density will also vary in different localities depending on how many people live within each tract. Urban areas with higher density will undergo different a different spectrum of costs and benefits when compared to rural areas with lower densities. Population density calculations will help analyze the urban form on a per capita basis.<sup>100</sup>

## ROW Management

Individual localities provide right of way for their residents. Since the taxpayers must subsidize right of way development in order to address the maintenance and upkeep, it creates a negative externality in the public. I conducted an evaluation of the right of way that various localities provide to the public. I will analyze the quantity of right of way relative to the number of people and total area of each subarea. King County releases GIS data, which I used to quantify the total amount of ROW coverage in each census tract.<sup>101</sup>

## Parking

Across each subarea, off-street parking will serve as valuable land that cities can repurpose for higher and better uses. Off-street parking is documented in the King County Assessor Database as a present land use. By calculating the square footage of these lots through GIS, I can evaluate how parking will play a role in the place-based framework for AV development across the different subareas. Off-street parking consists of commercial lots and garages. Even though garages can occupy multiple

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<sup>100</sup> U.S. Census Bureau; American Community Survey, 2010-2014 American Community Survey 5-Year Estimates, Table GCT-PH1, B01003; generated by Jacob Brett; using American FactFinder. 30 Mar. 2016. <<http://factfinder2.census.gov>>.

<sup>101</sup> King County ROW Shapefile, 2012. *Esri ArcGIS*. 5 May 2016.

floors, providing additional parking, there value is still assessed in terms of the size of the lot. <sup>102</sup>

## Zoning

Zoning laws will vary across different localities. It is important to differentiate between zoning and land use laws in each locality, because these laws dictate different aspects of parking requirements. In many cases, because AV technology can potentially eliminate the need for parking in urban centers, zoning and land use are important for evaluating the regulatory environment for self-driving cars. Existing zoning laws may limit the potential to reduce parking in certain areas. A zoning assessment of each census tract will outline qualitative data that will influence AV development at a local level.

## **Transportation Data Metrics**

Variability in transportation behavior between the different study areas will also influence how AV technology creates costs and benefits in each respective community. Transportation behavior listed in the American FactFinder is part of the US Census Bureaus American Community Survey. I compared the mode of transportation and length of time during commutes out of each subarea to paint a picture of how the local communities get to work and how long it takes arrive at their respective destination. This data indicates the role of cars relative to other modes of transportation in each tract and the extent of how multitasking may save time for AV passengers.

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<sup>102</sup> King County Tax Assessor Data, 2012. *Esri ArcGIS*. 5 May 2016.

## Mode of Transportation

Current modes of transportation, as identified in the American Community Survey, will help to estimate the magnitude of self-driving cars given existing behavior patterns. The survey identifies numerous categories regarding the mode of transportation used by residents during their commute. The data for mode of transportation in each community is listed at the end of the section.<sup>103</sup>

## Commute Time

The average commute time for a census tract will illustrate the demand for an alternative mode of transportation. Individuals with longer commute times have more to gain from self-driving technology. Commute times in the census bureau are divided into time categories of 5 minutes.<sup>104</sup> I compressed these timeframes into 15 minutes intervals to make it easier to compare.

## **Case Study Selection**

After careful consideration, I selected tract 84 as an urban case study, tract 225 as a suburban case study, and tract 315.01 as a rural case study. Large differences across these census tracts illustrate why a spatial framework is imperative in assessing local AV development. Furthermore, these differences also highlight that a one-size-fits-all policy will not address the unique issues of self-driving cars in each community. By examining census tracts in urban, suburban and rural environments, I will compare different communities using standardized criteria. I elected to analyze 3 case studies in

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<sup>103</sup> U.S. Census Bureau; American Community Survey, 2010-2014 American Community Survey 5-Year Estimates, Table B08134; generated by Jacob Brett; using American FactFinder. 30 Mar. 2016. <<http://factfinder2.census.gov>>.

<sup>104</sup> U.S. Census Bureau; American Community Survey, 2010-2014 American Community Survey 5-Year Estimates, Table B08303; generated by Jacob Brett; using American FactFinder. 30 Mar 2016. <<http://factfinder2.census.gov>>.

one county to control for state and federal policies and assess how even within one county, policy and regulation may have a diverse array of effects on individual communities. Evaluating these neighborhoods through the same lens will demonstrate how spatial variability will influence policy and planning for self-driving cars in each respective community.

King County makes an ideal county to conduct a local analysis because it is one of three counties in the United States where Google is actively testing AVs on local roads. As of 4/5/2016, Google is testing in Kirkland, WA, Austin, TX, and Mountain View, CA.<sup>105</sup> I selected three case study census tracts in King County, Washington to demonstrate the different challenges faced by urban, suburban, and rural areas. King County data will be a useful comparison tool for evaluating and comparing local data to the county averages. Conclusions from these case studies can guide policymakers but are limited in their correlation to other counties. These urban, suburban, and rural census tracts illustrate the spectrum of local pressures and how they will relate to the costs & benefits with respect to various stakeholders in each community.

### Urban Spatial Patterns

Urban areas contain high population densities and serve as cultural, economic, or industrial centers for the surrounding areas. The US Census Bureau defines an urban area as "a continuously built-up area with a population of 50,000 or more. It comprises one or more places—central place(s)—and the adjacent densely settled surrounding area—urban fringe—consisting of other places and nonplace territory."<sup>106</sup> Because of

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<sup>105</sup> "Google Self-Driving Car Project." *Google Self-Driving Car Project*. Google, n.d. Web. 09 May 2016. <<https://www.google.com/selfdrivingcar/where/>>.

<sup>106</sup> "The Urban and Rural Classifications." *US Census Bureau* (n.d.): 12-1-2-24. *US Census Bureau*. US Census Bureau. Web. 26 May 2016. <<https://www2.census.gov/geo/pdfs/reference/GARM/Ch12GARM.pdf>>.

their density, urban areas often contain multiple modes of public transit and a mix of land uses. Urban areas tend to struggle with several driving forces for AV development in dense areas, including parking availability, parking costs, and congestion. In a recent Census Bureau study, the US population in cities or incorporated areas was listed at 62.7%, roughly two thirds of the total population.<sup>107</sup> Census tract 84 meets the standards for an urban census tract, although it lies outside of the central business district in the City of Seattle.

### Suburban Spatial Patterns

Suburbs will also serve as important grounds for the development of AV technology in the United States. Although there is no census bureau definition for suburbs, they are typically described in terms of density and urban form patterns.<sup>108</sup> Robert Moses spurred a school of thought that advocated for suburban development through the mid-20<sup>th</sup> century and played an integral role in the development of highway infrastructure and the sprawling suburban development patterns meant to provide refuge from the nearby dense urban environments.<sup>109</sup> Today, these suburbs are challenged with providing services and infrastructure over a large geographic area. Suburbs are usually located on the outskirts of urban areas and within commuting distance of jobs located at the urban core. Suburban development patterns are

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<sup>107</sup> Cohen, Darryl T., Geoffrey W. Hatchard, and Steven G. Wilson. "Population Trends in Incorporated Places: 2000 to 2013." *Census.gov*. US Census Bureau, Mar. 2015. Web. 8 May 2016. <<https://www.census.gov/content/dam/Census/library/publications/2015/demo/p25-1142.pdf>>.

<sup>108</sup> Forsyth, Ann. "Defining Suburbs." *Journal of Planning Literature* 27.3: 270-81. August 2012. Web. 10 April 2016. <[https://dash.harvard.edu/bitstream/handle/1/16139611/Forsyth\\_Defining\\_Suburbs2012.pdf?sequence=1](https://dash.harvard.edu/bitstream/handle/1/16139611/Forsyth_Defining_Suburbs2012.pdf?sequence=1)>.

<sup>109</sup> Eisenstadt, Peter R. *Rochdale Village: Robert Moses, 6,000 Families, and New York City's Great Experiment in Integrated Housing*. Ithaca, NY: Cornell UP, 2010. Print.

primarily residential but occasionally include some commercial and office space depending on the local zoning ordinances. Road networks in suburbs often include cul-de-sacs, large blocks, and disconnected road networks. I selected census tract 225 because it shares many of the aforementioned suburban development patterns and demonstrates the wide range of spatial variability between urban and rural areas across the county.

### Rural Spatial Patterns

Rural areas, although limited in population density, are numerous throughout the United States. Rural areas are the least dense type of development pattern in the spectrum, and often contain industrial and agricultural land uses with some light residential development. In Washington State, growth management policies limit development outside of the urban growth boundary. The census bureau refers back to the definition of urban in drawing the distinction between development patterns. It states that "territory, population, and housing units that the Census Bureau does not classify as urban are classified as rural." It asserts that the rural status is reserved for any "incorporated place or CDP with fewer than 2,500 inhabitants that is located outside of a UA." Incorporated places are local government entities with the authority to tax residents and provide services within a defined boundary. While this guideline helps to distinguish between rural and urban areas, it does not account for any other options like suburban developments. These distinctions are too rigid for the purpose of this study, which aims to show a range of development styles across the spectrum. For the rural case study, I selected census tract 315.01, which sits outside of the urban

growth boundary in King County. This tract is “rural” by census bureau standards and contains many of the rural development patterns listed above.<sup>110</sup>

## Data Sources

Quantitative data that demonstrates the spatial variability between urban, suburban, and rural communities is readily available to the public. In order to measure the various criteria in each locality, I used census data from the American Community Survey, GIS data, and zoning codes. These data sources are crucial for analyzing the costs and benefits at a local level. The data I will show are designed to illustrate a snapshot of self-driving cars in different localities. Due to the constantly evolving nature of AV technology, and the fluid relationship between geographic location and demographics, parking, and zoning over time, these sources should be regularly updated to reflect any changes over time.

### The American Community Survey

The ACS data is collected through the US Census Bureau. The data provides annual demographic information and 5 year summary estimates to provide an approximate analysis of population demographics over a wider range of time. These numbers are estimated through trends from data collected each year from 2009-2016. The ACS releases data to the public through a variety of tools, including downloadable data and geography selection through the American FactFinder. These tools allowed

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<sup>110</sup> U.S. Census Bureau; American Community Survey, 2010-2014 American Community Survey 5-Year Estimates, Table P2; generated by Jacob Brett; using American FactFinder. 30 Mar 2016. <<http://factfinder2.census.gov>>.

me to create a demographic profile for each of the selected census tracts and compare the AV development potential in each locality.<sup>111</sup>

### Map Data

King County releases Geographic Information Systems (GIS) data to the public. GIS allow researchers to map data and is integral for many layers of analysis in this study. The software also helped me analyze the land use data for the subareas. I used GIS software to calculate the right of way's surface area in each of the three subareas. GIS data allowed me to visually compare the differences in development patterns in each of the three case studies. Additionally, I used GIS software to visually depict data exports from King County, the City of Seattle, and the City of Kirkland. I used Esri ArcGIS software for the GIS analysis included in this report. Google Map Data & Street View imagery are also included in this report and are attributed under fair use.

### Local Zoning Codes

Zoning codes set important rules and guidelines for developers in terms of parking. These requirements are typically tied to the number of units and number of bedrooms in each unit. As the implementation of self-driving cars picks up speed over the coming years, these local jurisdictions may need to edit these zoning codes to relax or tighten parking requirements on developers, depending on the needs of the community. I examined the zoning codes of each local jurisdiction by using the city websites, GIS data, and by reading the details of the parking requirements across the

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<sup>111</sup> U.S. Census Bureau; American Community Survey, 2010-2014 American Community Survey 5-Year Estimates; generated by Jacob Brett; using American FactFinder. 30 Mar 2016. <<http://factfinder2.census.gov>>.

zones within each census tract. This data allowed for a comparative analysis between the zoning requirements in each of the three subareas.

### Data Limitations

The configuration of some datasets also presented some difficulties in the data analysis for Age, Industry/Occupation, and Parking. While individuals 17 and under are restricted or unable to drive, many senior citizens are very capable of driving. Although many seniors struggle with access to mobility, no laws prohibit driving due to age. These restrictions are connected to physical disabilities, which are also highlighted in the demographic information. Occupational statistics from the Bureau of Labor Statistics would be more useful than census data, but lack local information about jobs. The census data includes transportation and warehousing in the same category. Both industries are at-risk through automation, but it is too difficult to assess individual occupations without more detailed data. For future parking evaluations, I recommend that researchers develop a parking inventory for private and public parking lots and on-street parking. In each subarea, the parking analysis should include costs for hourly parking and residential permits. For off-street parking, in addition to measuring the hourly parking costs, a real estate analysis of private and public parking lots and structures will show development potential for these lots.

Localized case studies limit the scope and potential extrapolations of the study. Other case studies can illustrate how these effects may vary across different counties in the United States. The goal of this study is to demonstrate how local policy will influence AV development in terms of maximizing the potential costs and benefits. However, different regions will undergo their own process to evolve with the technology and new idea and solutions will form in different states across the nation. By other definitions, the case study census tracts I selected may not be representative

of urban, suburban, and rural areas. Outside of the census bureau definition, my selection criteria for census tracts relied heavily on visual comparisons of development patterns. I evaluated the geographic size of the census tracts, studied the road networks, and assessed the typical block sizes. The US census bureau, the source of the demographic data in this study, does not define suburban areas.

Because the technology is relatively new, the existing literature on self-driving cars is limited in both scope and breadth. Survey data is also limited because AV technology is only just emerging and not currently available to consumers. A well-designed survey could better gauge consumer interest in automated vehicles soon after the first models are made available to consumers, but the technology is still too new to accurately gauge implementation timeframes among specific demographics. Public opinion will shift as the technology evolves. In order to project the adoption rates of AV technology, researchers must regularly collect data that surveys demographic concerns and generates geographic profiles for regions, states, and metropolitan areas. As the technology behind self-driving cars becomes more affordable, new companies will compete in the AV markets and they will release more data to the public. Over time, these AV products are likely to become more specialized and differentiated to accommodate the various needs of future generations.

## **DATA ANALYSIS**

Below, I outline each of the selected study areas and highlight how their differences in demographics, geography, and transportation will drive local AV development in urban, suburban, and rural areas respectively. A one-size-fits-all solution won't address these fundamental differences between communities that dictate local policy and planning decisions. Even within King County in Washington,

the data suggests that differences between the case studies will play an important role in AV development. Policymakers and planners can better understand the differences between localities by examining case studies and evaluating how these case studies will respond to AV technology. Spatial variability will manifest in terms of how urban, suburban, and rural communities respond to the complex issue of AV development. I used the literature review and various data sources to inform the selection of specific metrics in demographics, geography and transportation.

As a rapidly growing region with considerable diversity in the United States, King County will provide useful data in how AV technology will develop in similar counties. However, similar studies in different counties would provide a better context for how localities will develop different approaches across the United States. This particular county is densely populated, diverse, and one of few counties in the United States with active testing for self-driving cars. In July of 2015, the American Community Survey estimated King County's population at 2,117,125, with a growth rate of 9.6% in the last year. This growth is staggering when compared to the US average of 4.1%.<sup>112</sup> I included a series of maps at the end of this section to show the differences in land use across the case study areas.

#### Urban Case Study Profile: Seattle, Tract 84

Seattle is King County's largest metropolitan area and ranks as the biggest city in the northwest region of the United States. Using Seattle as a case study will show how a dense city and its residents will be helped or hindered by AV development. Although all cities are different, they all try to address transportation, SOVs, and the

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<sup>112</sup> U.S. Census Bureau; American Community Survey, 2010-2014 American Community Survey 5-Year Estimates; generated by Jacob Brett; using American FactFinder. 30 Mar 2016. <<http://factfinder2.census.gov>>.

negative externalities associated with cars. This case study will examine one census tract in Seattle to compare with the other suburban and rural tracts. For this case study, I selected King County Census Tract 84 in Seattle's Capital Hill neighborhood. This tract contains mix of dense residential and mixed-use commercial development. One major border of this tract is Interstate 5, a multilane highway that runs through Seattle and separates this tract from the nearby downtown core.

#### Suburban Case Study Profile: Kirkland, Tract 225

I examined several census tracts with suburban development patterns throughout King County. The following areas all contain a mix of land use patterns that resemble suburban development: Redmond, Shoreline, Tukwila, and Kirkland. For this case study, I decided to examine census tract 225 in Kirkland, Washington. This particular census tract contains a blend of residential and commercial development in the southern end of the study area. Towards the north side of the tract, the area contains typical suburban development patterns, including larger blocks and cul-de-sacs. However, further towards the south, mid-rise residential developments provide substantial housing across the study area.

#### Rural Case Study Profile: Unincorporated King County, Tract 315.01

I referred to the King County government website when examining rural census tracts, which list several rural communities across the county. I examined census tracts in eastern King County, including Black Diamond, Carnation, Duvall, Maple Valley, North Bend, & Snoqualmie. After some deliberation, I selected tract 315.01 in unincorporated King County. This tract lies beyond the urban growth boundary and consists of several unincorporated mining towns and communities, including Franklin, Durham, Cumberland, Kanaskat, Palmer, & Cumberland. The urban growth boundary prevents development in rural areas like tract 315.01. This tract also takes up a very

large geographic area compared to the urban and suburban tracts and will demonstrate the differences in demographics and geography across the county.

The land use maps on the following pages highlight the diverse uses for land in the urban, suburban, and rural census tracts. These maps demonstrate how spatial variability looks from planning and zoning perspectives. The different colors indicate different uses. This aerial view for each census tract shows key differences in how land is used in different locations. Although it is difficult to put these differences into any one category, the following data analysis will articulate how these differences will set the course for local AV development.

### **King County Demographic Data Analysis**

Age, gender, physical disability, income and employment data all correlate to AV development in each study area. In King County, the total population is 2,008,997 people. 21.1% of the population is under 18 years old and 11.6% of the population is aged 65 and up. Together, these age groups add up to 32.7%, almost a third of the total population in King County. These population proportions help set a line of comparison for the census tract study areas. Across King County, the gender ratio is nearly even. 49.88% of the population identifying as male and 50.12% identifying as female. 9.6% of King County's population reported as disabled in some way. This demographic will potentially add 200,000 additional drivers and would increase VMTs significantly across the county. In King County, the median income is \$73,035. The mean income is significantly higher at \$98,867. The Census Bureau reports that individuals in transportation and warehousing comprise of 4.6% of the total workforce in King County. This figure does not indicate the number of jobs that will be eliminated in response to AV technology, but rather, the number of jobs that might be directly affected. Furthermore, it sets a line of comparison for each census tract.

# Census Tract 84

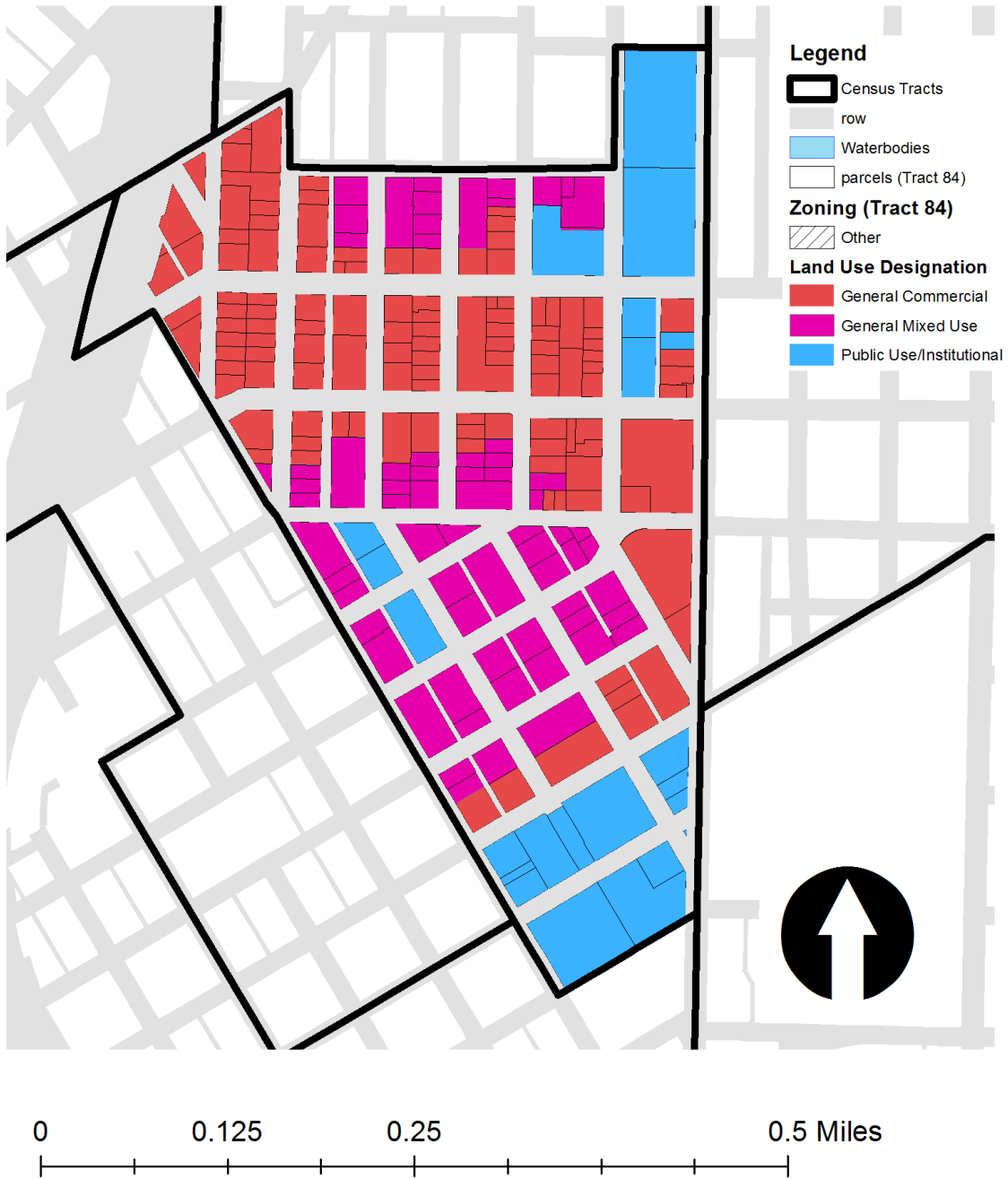


Figure 3: Urban Land Use Map - Census Tract 84 (King County Land Use, 2014)

# Census Tract 225

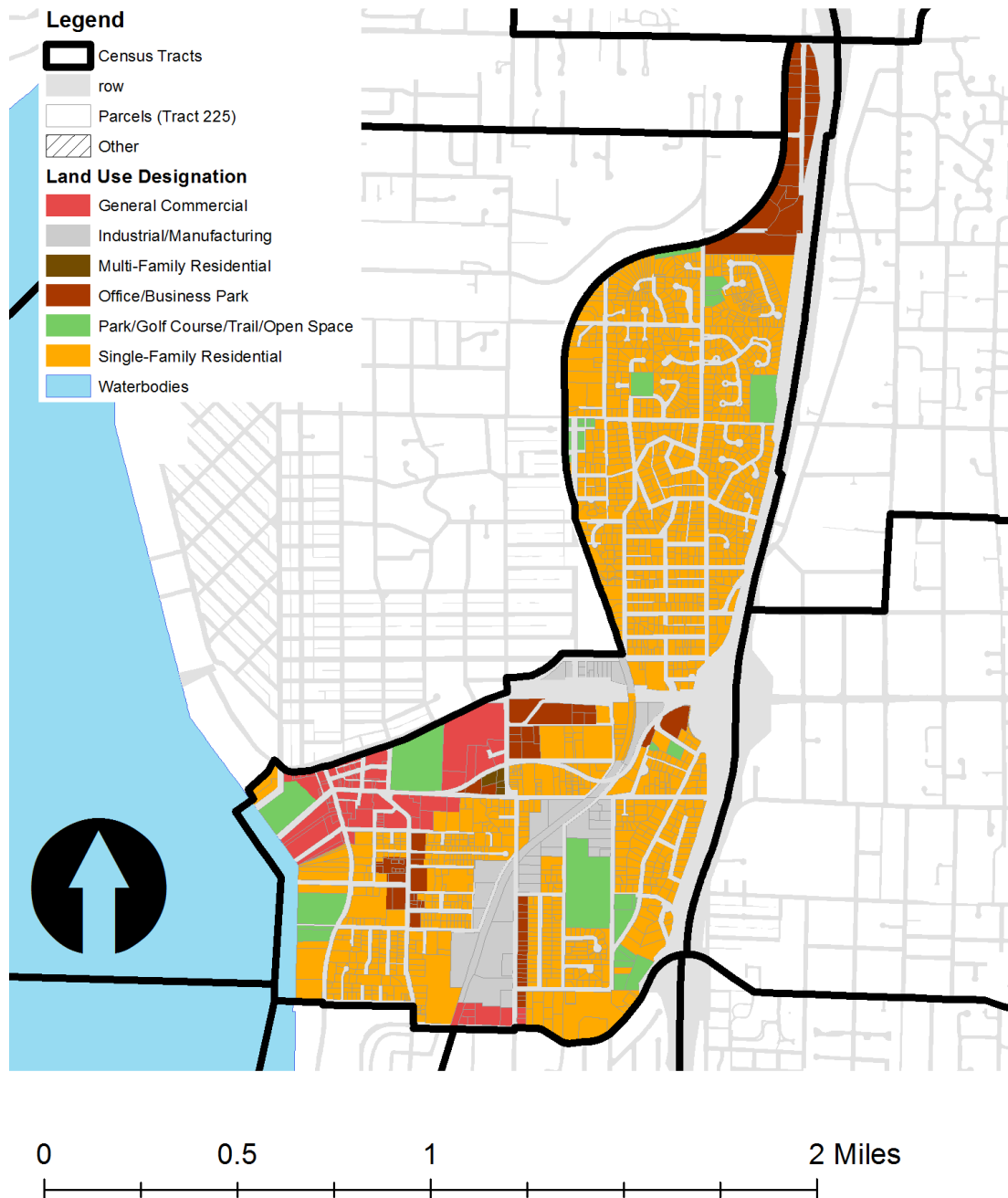


Figure 4: Suburban Land Use Map - Census Tract 225 (King County Land Use, 2014)

# Census Tract 315.01

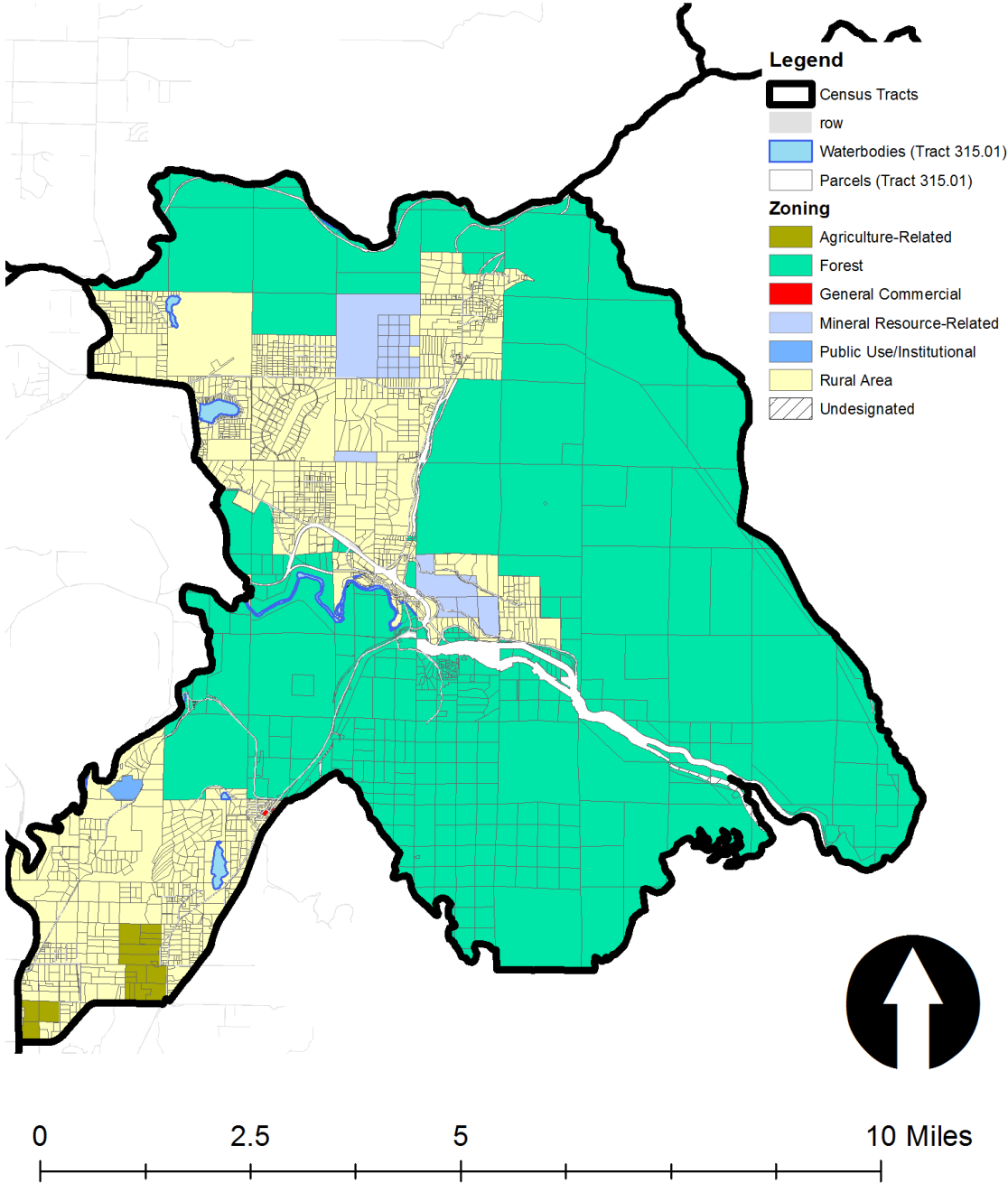


Figure 5: Rural Land Use Map - Tract 315.01 (King County Land Use 2014)

### Urban Demographic Data Analysis

The census estimates that 4,301 people live in this tract, which contains the smallest proportion of individuals in the two main age demographics that will experience an increase in access to mobility. Only 7.1% of the study area is 17 or under and only 9.5% of the population is aged 65 years old or older. This tract contains a relatively even split of men and women, with 51.78% of the population identifying as male and 48.22% of the population identifying as a female. Compared to the other study areas, this tract contains the most balanced gender ratio. In tract 84, only 10.03% of the population contains some physical disability. Although this proportion is lower than the other two study areas, it is still higher than the King County average. The area median income for census tract 84 is \$44,524, significantly lower than the area median income in the other subareas. The average income is much higher, at \$72,408, but still lower than the suburban and rural census tracts. With only 2.3% of the tract's total workforce, the employment in transportation and warehousing in urban census tract 84 is the smallest of the study areas.

### Suburban Demographic Data Analysis

With 7,335 people, this tract contains the largest population of the selected study areas. The demographic data supports increases in access to mobility for a large portion of the total population. Tract 225 in Kirkland contains the largest proportion of older residents to the general population, containing over 15.9% of the study area population. Individuals 17 and under are also a large demographic, with 16.6% of the study area population. In total, these two groups add up to 32.5% of tract population. This Kirkland census tract has 47.77% males and 52.23% females. This tract is the only study area selected with more females than males. Furthermore, 10.95% of the population in tract 225 reported as disabled in the study area. The area median income

for census tract 225 is \$97,997, the highest of the three tracts. The mean income also leads the census tracts at \$115,520. Through both metrics, this tract is the wealthiest of the subareas. Nearly 2.3% of the workforce in tract 225 works in these two industries. This proportion is the same as in the urban study area. These economic indicators show that residents in this tract have high incomes and will be relatively insulated from the economic forces driving AV benefits and costs. The high incomes will support private vehicle ownership, even if AVs price lower-income individuals out of the market.

### Rural Demographic Data Analysis

This tract contains 3,961 individuals, the fewest of the selected study area. This tract also contains many individuals with limited access to single-occupancy vehicles due to age. The census data shows that 18.2% of the residents are 17 and under and 11.3% of the residents are 65 and older. In total, 29.5% of the residents fit into these two categories. The gender ratio is unbalanced, with 54.92% of the total study area population identifies as male and 45.05% identify as female. The split between males and females in this tract is the widest of the three study areas. This tract also contains the largest portion of disabled respondents, with 15.36% of all respondents listing some type of disability. The presence of a group home for disabled residents would skew the data by creating an artificially high concentration of individuals with disabilities. I will examine GIS and mapping data to determine the presence of any facilities that may skew the data in the analysis section. Economic data will also factor in to the ability to purchase single occupancy vehicles during the era of self-driving cars and the employment in transportation & warehousing. The area median income for census tract 315.01 is \$78,581, a modest income just higher than the county median. The average income is \$88,517 a bit lower than the county average. Both income metrics rank the second highest of the three subareas. The rural census tract study area

(315.01) contains 6.9% of the workforce in transportation and warehousing. A much larger portion of individuals in this tract will experience the changes associated with AV technology.

## **King County Geographic Data Analysis**

Growth management practices across the state of Washington and in King County preserve rural land and promote higher density across existing urban areas. With 2,008,997 people in a land area of 2,115.57mi<sup>2</sup>, King County averages 949.62 people/mi<sup>2</sup>. This density demonstrates that although King County contains densely populated urban areas, it still consists of many rural areas that lower the average population density across the county. In King County, the right of way occupies 4.762% of the total land area. This total amounts to 2,808,555,348ft<sup>2</sup> of total ROW, and 1,397.99ft<sup>2</sup> of ROW per capita in the county. A total of 784 commercial lots and garages that provide parking to local communities. These lots combine to total 23,814,218ft<sup>2</sup>, a coverage ratio of 0.04%. King County provides zoning distinctions for parts of unincorporated King County without their own zoning designations. These designations vary depending on if the census tract is located within an urban growth area.

### Urban Geographic Data Analysis

King County Census Tract 84 has a population density of 28,673.33 people/mi<sup>2</sup>. With 4,301 people in a land area of 0.15mi<sup>2</sup>, this census tract is the densest of the sub-areas. This census tract contains 1,634,493 ft<sup>2</sup> of total right of way. Per capita, this tract contains the least amount of right of way, with only 380.02 ft<sup>2</sup> dedicated per individual. Although the per-capita numbers are relatively low, 39.09% of the subarea is dedicated to right of way. This tract contains the largest proportion of ROW to total land area, relative to the other tracts. If AV technology results in more efficient management of

the ROW, the existing ROW infrastructure can be streamlined and reduced. This tract contains extensive infrastructure to support parking for SOVs. It contains the most parking lots of the three subareas, with 22 parking lots and garages. These lots cover 243,312ft<sup>2</sup> in the tract, a coverage ratio of 5.818% across the entire land area.

Census tract 84 contains multiple zoning designations, including High-Rise (HR) zoning, Mid-Rise (MR) zoning, and Neighborhood Commercial (NC3P-85, NC3-65) zoning. Although many zones overlay this urban subarea, the tract is located within an urban village in Seattle. Urban villages get special zoning designations in Seattle to promote growth and create denser built environments. Among many other development benefits, this urban village zoning designation eliminates parking requirements for new developments in the study area.<sup>113,114</sup> The image below from Google Street View shows a streetscape of census tract 84 looking west on Pine Street. This streetscape contains extensive on-street parking in the urban tract and landscaping buffers on sidewalks.

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<sup>113</sup> City of Seattle. *Department of Construction and Inspections*. Online GIS application. n.d. Web. 6 Apr. 2016. <<http://web6.seattle.gov/DPD/Maps/dpdgis.aspx>>.

<sup>114</sup> City of Seattle Land Use Code. *Office of the City Clerk*. Table for 23.54.015. 23 July 2012. Web. 13 May 2016. <<http://clerk.seattle.gov/~scripts/nph-brs.exe?s1=&s3=117430&s4=&s2=&s5=&Sect4=AND&l=20&Sect2=THESON&Sect3=PLURON&Sect5=CBORY&Sect6=HITOFF&d=ORDF&p=1&u=%2F~public%2Fcbory.htm&r=1&f=G>>.



**Figure 6: View West on E Pine St & Bellevue Ave, Aug. 2015 (Google Street View, 2016)**

Beyond the limits of the subarea, the image shows downtown Seattle on the other side of Interstate 5. Large buildings cover roughly 38% of the urban tract when compared to the other subareas. The urban tract contains an average building size of 7,462 sq. ft, nearly triple the size of the buildings in the suburban tract. In all, 211 buildings cover 1.57 million ft<sup>2</sup> in the subarea.

High-rise buildings in this study area distinguish it from the other census tracts. The next image shows one such high-rise development over 20 stories tall, the First Hill Plaza on Spring Street. These high-rise buildings simply do not exist in the other census tracts.



Figure 7: First Hill Plaza on Spring St & Boylston Ave, Aug. 2015 (Google Street View, 2016)

# Census Tract 84

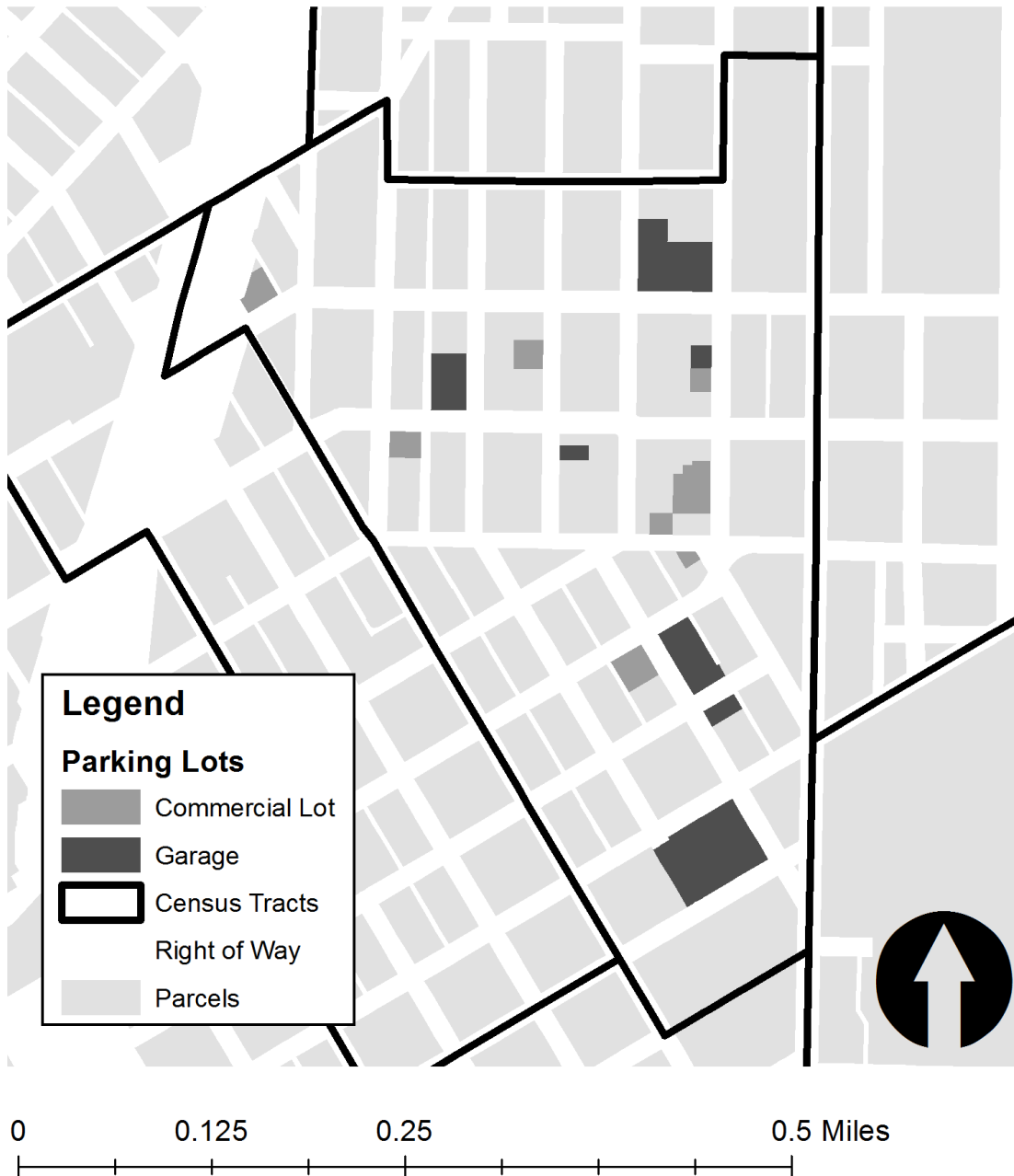


Figure 8: Parking Lot Map – Census Tract 84 (King County Tax Assessor, 2014)

# Census Tract 84

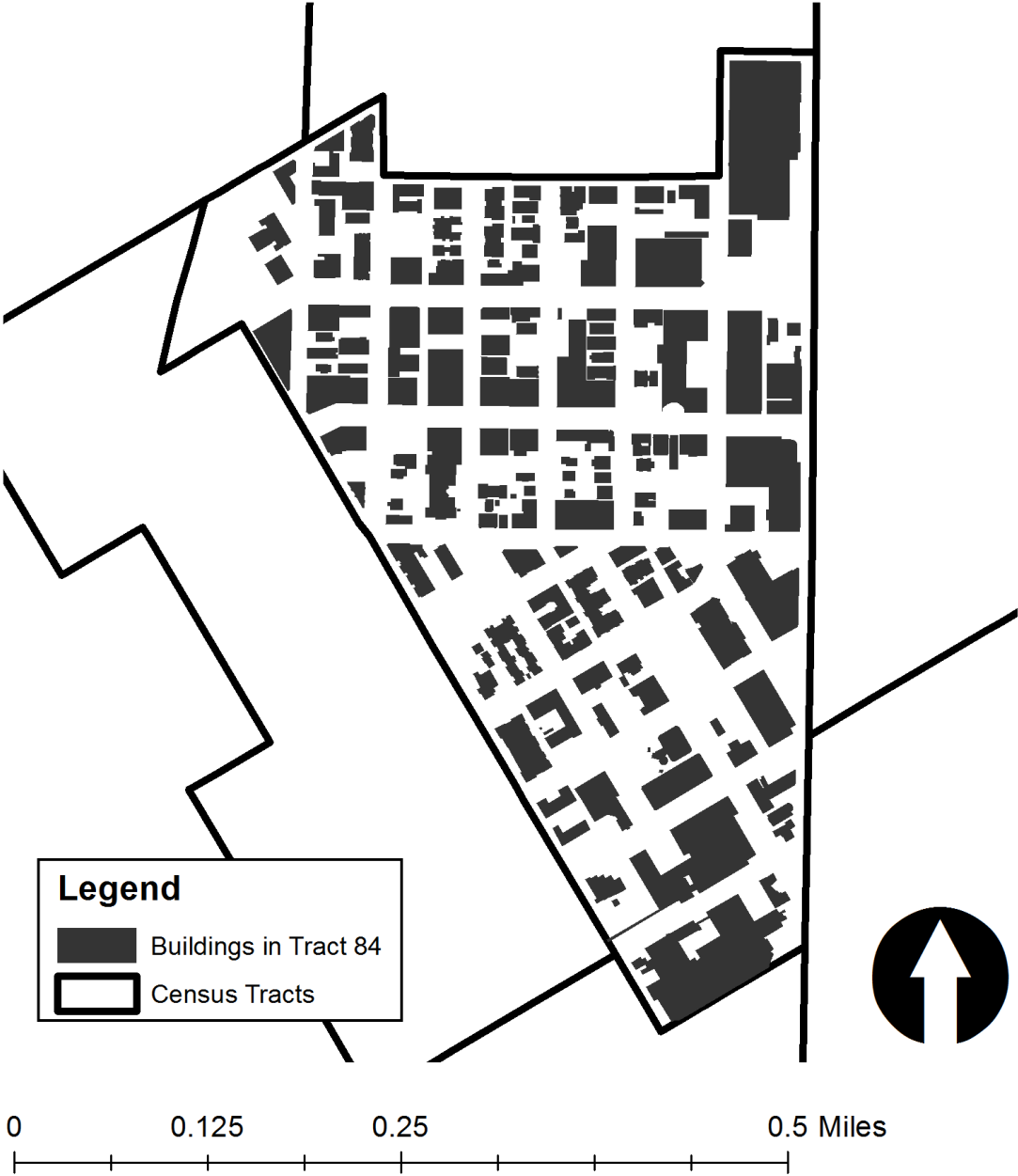


Figure 9: Urban Form in Census Tract 84 (City of Seattle GIS Portal, 2012)

## Suburban Geographic Data Analysis

King County Census Tract 225 has a population density of 5,023.97 people/mi<sup>2</sup>. With 7,335 people in Land area of 1.46mi<sup>2</sup>, this census tract has the second largest population density of the selected study areas and covers a geographic area nearly 10 times larger than the urban census tract. In this suburban census tract, the right of way occupies 7,717,920 ft<sup>2</sup> in total. This tract contains 1,052.20 ft<sup>2</sup> of right of way per capita, over twice the rate of the urban census tract. The right of way covers approximately 18.96% of the total area in the suburban census tract. This subarea contains 3 parking lots, which consist of a total of 64,889ft<sup>2</sup> of the entire census tract. The proportion of parking lots to the total land area in this tract is only 0.159%, significantly lower than in the urban area.

Parking requirements in Kirkland vary based on the zone and land use. Each zone contains different permitted land uses. The zoning code assigns parking requirements based on the use for each zone in the city. For residential uses, these parking requirements are assigned for each dwelling unit or bedroom. For commercial and some institutional uses, these requirements are assigned according to the square footage of a building's gross floor area. According to Kirkland zoning codes, the central business district contains a parking ratio of 1 stall per 350 ft<sup>2</sup> of gross floor area (125 ft<sup>2</sup> for restaurants). Industrial uses require 1 parking spot per 1000 ft<sup>2</sup> gross floor area. Commercial uses require 1 parking spot per 300 ft<sup>2</sup> gross floor area. For residential developments, low-density zones require up to 2 parking spots per unit, while medium & high-density zones require 1-2 parking spots per unit.<sup>115</sup> These high

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<sup>115</sup> City of Kirkland Land Use Code. CodePublishing. Chapter 15 – 50, 19 Apr. 2016. Web. 25 May 2016. <<http://www.codepublishing.com/WA/Kirkland/?html/KirklandZNT.html>>.

parking requirements provide an abundance of parking throughout the tract for individual property owners, and likely play a role in the subsequent lack of parking lots through the area when compared to the urban tract.

The image below shows one of the denser developments in the census tract, a mixed-use building with several commercial vendors below the Kirkland Central Condominiums. However, developments like this one are not typical in the study area.



**Figure 10: View South West at Kirkland Ave. & State St, Jun. 2015 (Google Street View, 2016)**

The 2,521 buildings in the study area cover roughly 6.925 million ft<sup>2</sup> - that adds up to a coverage rate of 17% of the study area. The average building size is much smaller in the suburban tract than the urban tract at only 2,747.21 ft<sup>2</sup> per building. Based on these ratios, there is substantial quantitative evidence that this tract is more sprawling than the urban case study. Tract 225 contains stereotypical features in suburban

development patterns. In the main residential area, the cul-de-sac streets contain a disconnected street grid that promotes privacy over the transportation network. The following image shows single-family developments in Highlands, a residential community within Kirkland and Census Tract 225.



**Figure 11: View East on NE 102 PL, Jun. 2015 (Google Street View, 2016)**

In this image, the right of way occupies a considerable amount of space for a small amount of people, yet provides extensive privacy for the tenants. This development pattern is typical in the northernmost portion of the study area and is easy to identify from an aerial view. This part of the rural tract is primarily single-family residential. However, there are important commercial and recreational areas in the southern portion of the tract.



**Figure 12: View North on Lake St. S, Jun. 2015 (Google Street View, 2016)**

As seen in the images above, several recreational areas in this tract abut Lake Washington to the west. This important natural amenity serves multiple metropolitan areas in King County. Although this figure shows some active transit infrastructure near the waterfront, it is not consistent throughout the entire study area. The solids and voids in this tract illustrate the suburban development patterns throughout the study area and indicate sprawling development.

# Census Tract 225

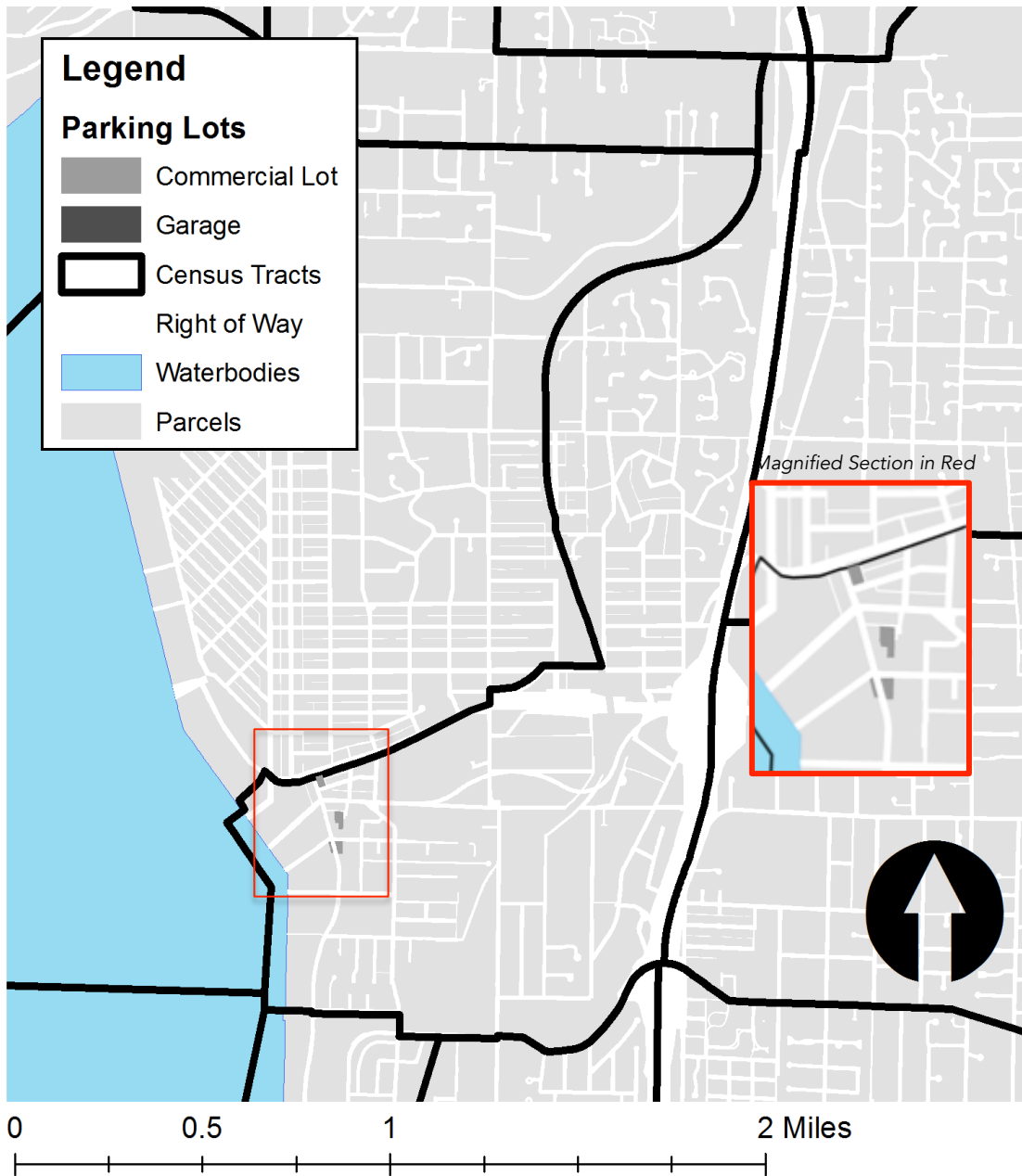


Figure 13: Parking Lot Map - Census Tract 225 (King County Tax Assessor, 2014)

# Census Tract 225



Figure 14: Urban Form in Census Tract 225 - Kirkland, WA (City of Seattle GIS, 2012)

The table below shows the building coverage in tract 225 relative to the urban tract.

**Table 1: Built Environment in Census Tract 225 (City of Kirkland GIS, 2016)**

<b>Built Environment</b>	<b>Tract 84</b>	<b>Tract 225</b>
Building Coverage	38%	17%
# of Buildings	211.00	2,521.00
Avg. Size	7,462.37	2,747.21
Total Building Envelope (sq. ft.)	1,574,561.53	6,925,705.00

### Rural Geographic Analysis

King County Census Tract 315.01 has a population density of 63.55 people/mi<sup>2</sup>. With 3,961 people in land area of 62.33 mi<sup>2</sup>, this census tract has the lowest population density of the selected study areas. It covers a geographic area over 400 times larger than the urban census tract. In this rural census tract, the right of way occupies 2,903,294 ft<sup>2</sup> in total. Per capita, each individual living in the tract receives 732.97 ft<sup>2</sup> of right of way, just under twice the per capita rate of the urban census tract, but still less than the suburban tract. The right of way covers only 0.167 % of the total area in this census tract, by far the least of the three study areas. This subarea contains no parking lots.

Zoning in Unincorporated King County does not call for specific parking requirements.<sup>116</sup> The limitations based on the urban growth boundary in King County caps density at a spatial level thus directly limiting the development potential in this tract. Unfortunately, without the specialized and well-funded city governments, spatial data is limited in Unincorporated King County. Building footprints are not yet mapped for this census tract. Visually, the large parcels and extensive zoning for forestry suggests that the building coverage in the rural subarea is substantially smaller than the

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<sup>116</sup> Unincorporated King County Land Use Code. King County, Title 21A Zoning. 14 Apr. 2016. 25 May 2016. <[http://www.kingcounty.gov/council/legislation/kc\\_code/24\\_30\\_Title\\_21A.aspx](http://www.kingcounty.gov/council/legislation/kc_code/24_30_Title_21A.aspx)>

urban and suburban tracts. In contrast, the rural area has vast open spaces and only two minor development areas.

Although this subarea is lacking in building data, Google’s Street View imagery presents a vivid picture of the urban form and natural environment in this rural census tract. The image below shows a street view from Kanaskat-Palmer State Park, the only state park in the selected study areas. This preservation of open space and serves as a vital amenity for the local residents and visitors.



**Figure 15: View South East Cumberland Kanaskat Rd, Sep. 2015 (Google Street View, 2016)**

The next image shows one of the “denser” areas in the rural census tract – even as a denser part of this tract, the predominant uses for agriculture and extensive forestry are clearly evident. Typical housing units are one or two story single-family houses on very large lots. These dwelling units are strictly regulated in the King County Zoning Codes that limit the number and size of dwelling units throughout the census tract.



Figure 16: View North at Kanaskat Kangley Rd. SE & SE Courtney Rd, Sep. 2012 (Google Street View 2016)

The image below shows what the denser developments look like with terrain, roads, and forestry from an aerial view. This view shows that although the tract contains some clusters of housing, the vast majority of the tract consists of trees and other natural



Figure 17: Urban Form in Census Tract 315.01 – Kanaskat, WA (Google Map Data: DigitalGlobe 2016)

features. Another part of the rural study area with some level of proximate development is located in the town of Cumberland, Washington. This part of the tract is slightly denser than in Kanaskat, but still features many typical rural development patterns, including large lots separated by farms and forests.



Figure 18: View North at SE 354<sup>th</sup> St, Sep. 2012 (Google Street View 2016)

The image above depicts the main commercial development in the census tract, including a small grocery store for residents. (This commercial area is visible in Figure 5 as a small red dot in the southeast corner of the study area.)

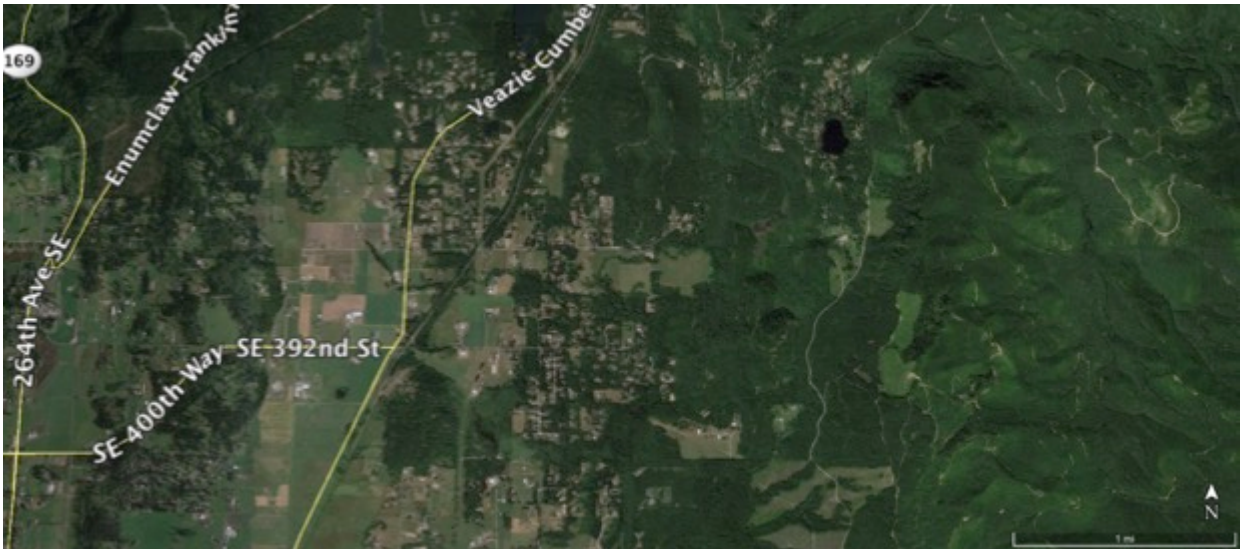


Figure 19: Urban Form in Census Tract 315.01 - Cumberland, WA (Google Map Data: DigitalGlobe 2016)

## King County Transportation Data Analysis

King County residents use a number of modes of transportation on their regular commute to work. Census data shows that the predominant mode of transportation across the county is by car, truck, or van. Of these individuals, 68.96% drove alone, thus contributing to many negative externalities associated with SOVs. The two least popular forms of transportation are walking (4.99%) and taxi/bike/other (2.9%). Commute times in King County vary widely, but the most popular commute time frame (17.18%) is from 30-34 minutes. Shorter commutes were also common, but there was no clear dominant commute time across the county.

### Urban Transportation Data Analysis

In this urban census tract, single occupancy vehicles and solo driving behaviors are rare. Only 24.23% of the population uses cars, trucks, or vans and over one third (33.46%) of the population uses public transportation. Compared to the other tract and the county averages, the respondents use public transit as a primary mode of transportation in census tract 84. Additionally, 37.21% of the population walks to work. This proportion is over 28 times higher than in the suburban tract and over 17 times higher than the rural tract. Proximity to important amenities enables residents to walk to destinations from the study area. It is also worth noting that this tract contains the largest proportion of residents that listed taxi/bike/other for their commute.

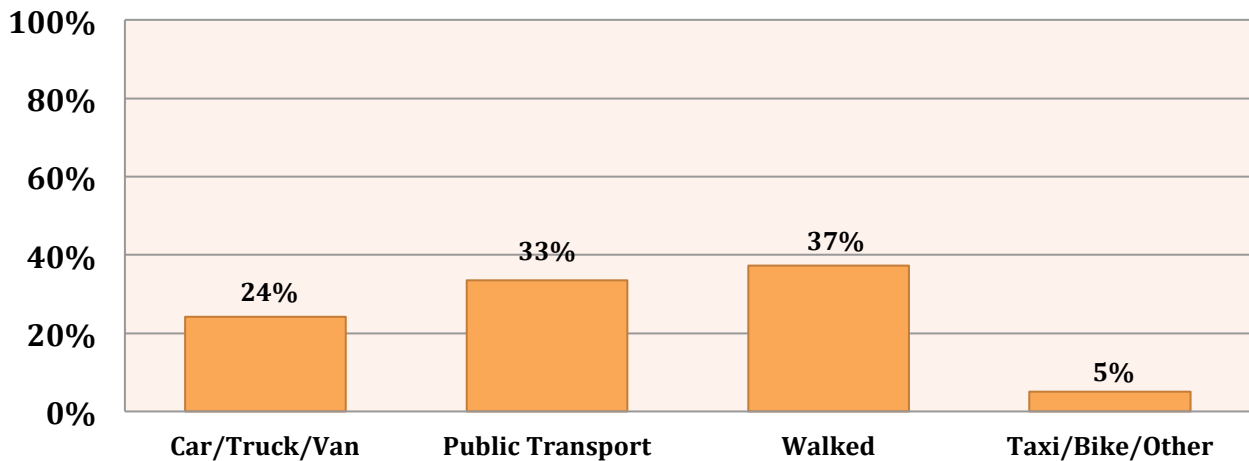


Figure 20: Mode of Transportation – Census Tract 84 (US Census, 2010-2014)

The most popular commute time in the Capital Hill census tract is the 20-24 minute range. Commute times trend on a shorter side for this census tract. It has the largest percentage of commuters in the under 5 minute range due to the close proximity of residential and commercial developments in the neighborhood. This tract

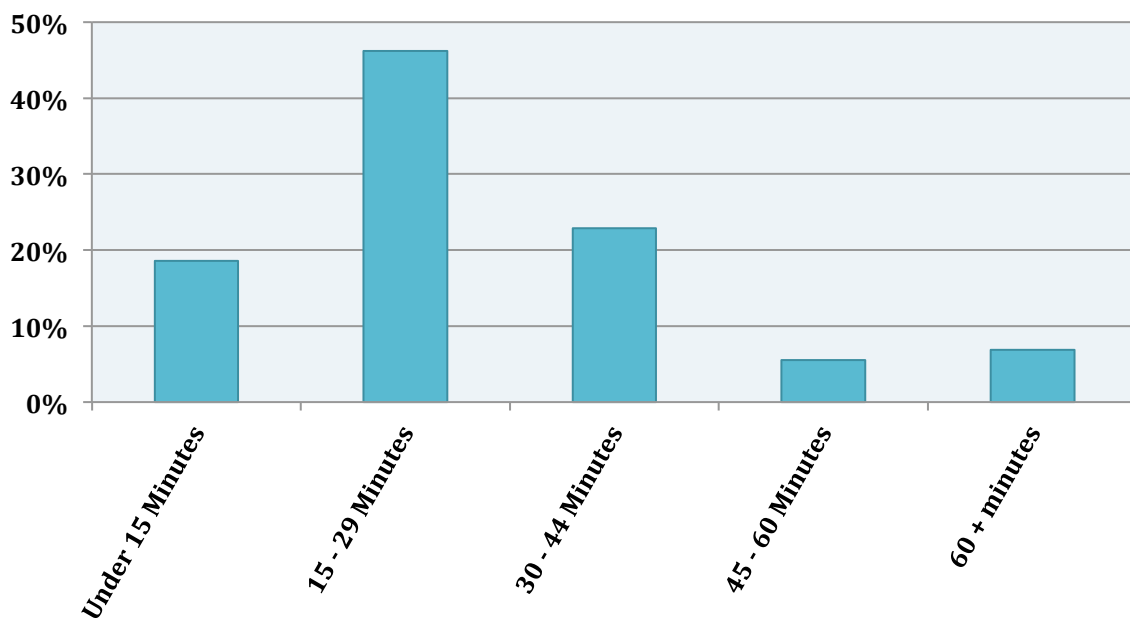


Figure 21: Commute Times in Census Tract 84 (US Census 2010-2014)

supports slightly longer commute times than the suburban tract, but they share similar rates across the board.

Suburban Transportation Data Analysis

In the suburban census tract, 86.81% of respondents claim to commute in a car, truck or van, a much larger demographic than in the urban census tract. Of those respondents, 82.25% drove alone. Public transit use and walking are less significant modes of transportation in the suburban tract than in the urban tract (84). Public transportation use in tract 225 stands at 10.23%, a 20 percent reduction, while walking is down to 1.29%, a reduction by over 35%. The large use of cars throughout this tract indicates that if SOV use remains high with the arrival of self-driving cars, this suburban

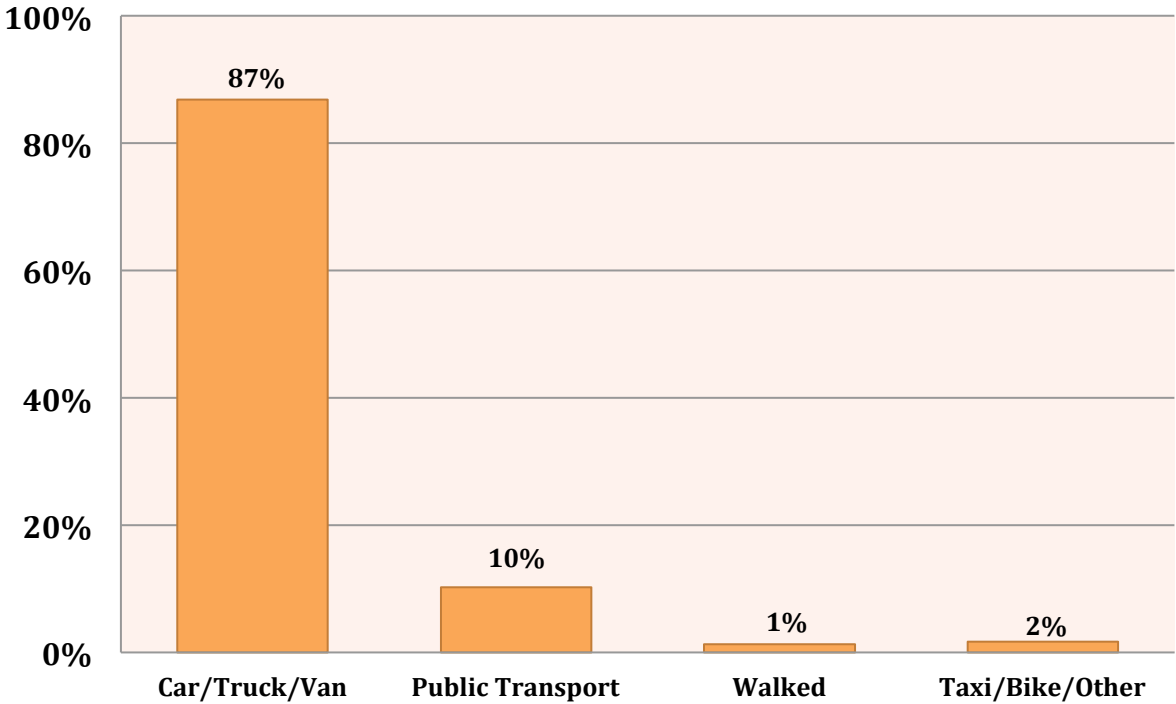
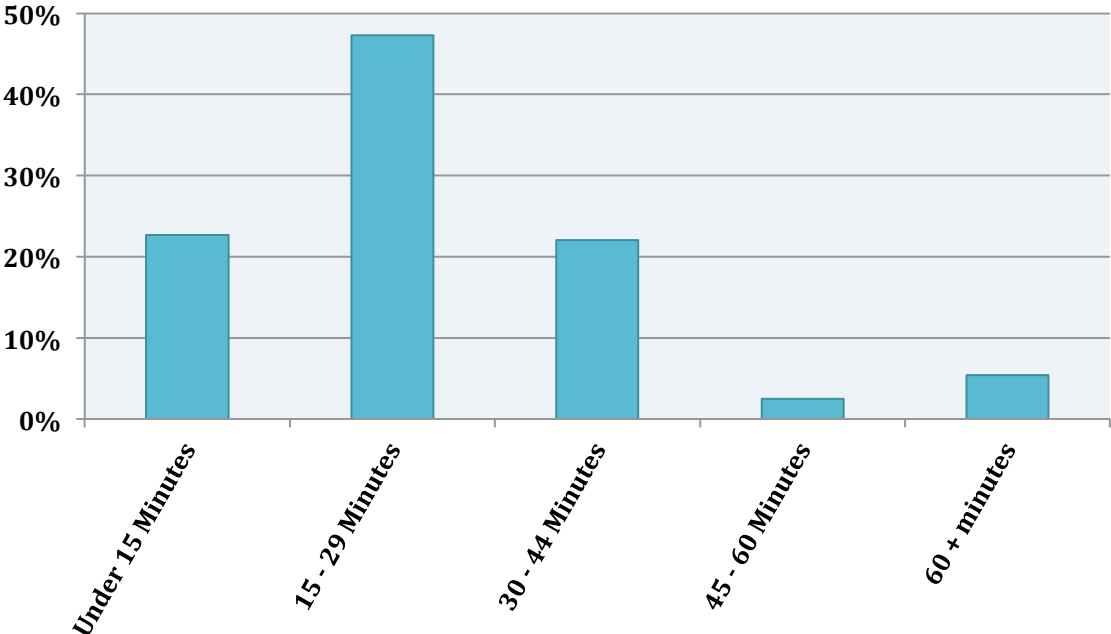


Figure 22: Mode of Transportation - Census Tract 225 (US Census, 2010-2014)

area will undergo both positive and negative externalities associated with high AV use.

Commute times in this Kirkland census tract are similar to tract 84 in Seattle. However, the leading commute time is slightly shorter at 15-19 minutes. Tract 225 contains the fewest 90+ minute commutes among the subareas. The shorter commute times suggest that residents in this tract will save less time from multitasking than the residents in the rural tract. With the high per-capita right of way figure in this tract, it is not a surprise that commute times are quick. The issues raised in the literature review suggest that this built environment in suburban areas favors automobiles at the expense of pedestrians.



**Figure 23: Commute Times in Census Tract 225 (US Census, 2010-2014)**

Rural Transportation Data Analysis

In comparison, transportation modes and times in tract 315.01 are relatively unique. Over 95% of residents use a car and over 88% of those drove alone. None of the respondents used public transportation in order to get to work, indicating that public transit does not adequately serve this area. Due to the lack of density, it

wouldn't be financially feasible to serve this remote area. In spite of containing only just over 2% of respondents, more individuals walk to work in the rural tract than in the suburban tract. The complete chart of modes and proportions is listed at the end of this section.

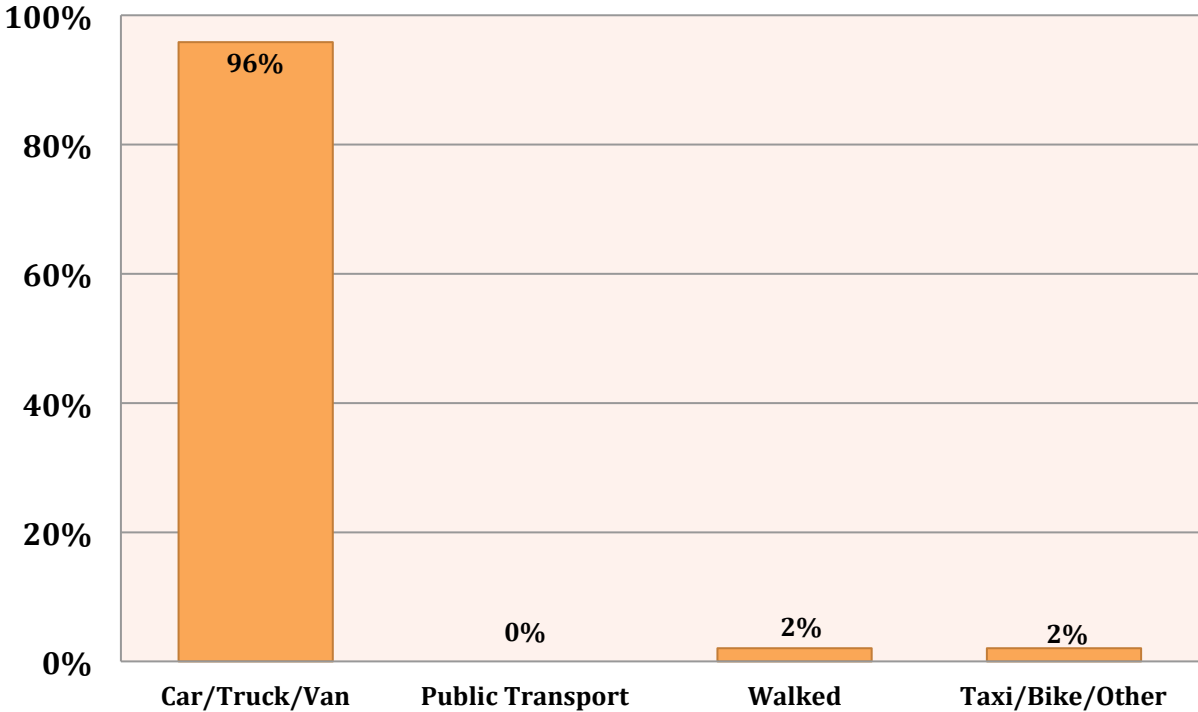


Figure 24: Mode of Transportation - Census Tract 315.01 (US Census, 2010-2014)

Census tract 315.01 presents a stark contrast to the urban and suburban census tracts – the leading commute time is much longer at 45-59 minutes. The other tracts' main cluster of commute times trended below 30 minutes. Over 13.66% of this tract spends over an hour getting to work. According to the census data, this tract also leads the others in the commute duration of 90 minutes or longer. Longer commute times indicate that individuals will save a large amount of time with multitasking in self-driving cars and will likely serve as a driving force for personal vehicle sales. The large

variability in this data suggests that the distance between home and work is much further in rural areas than for urban and suburban areas.

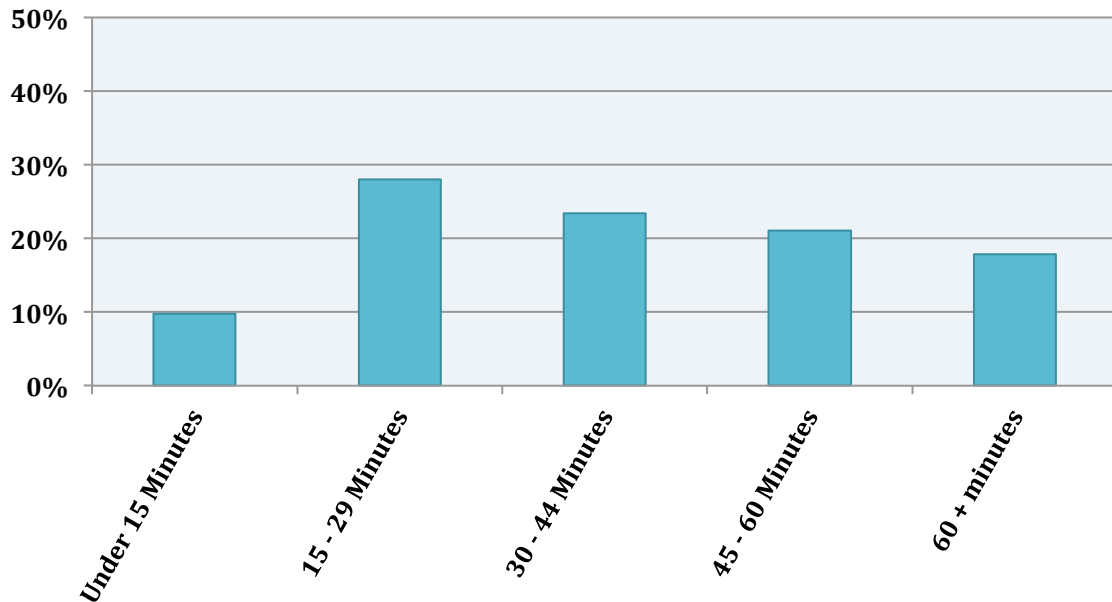


Figure 25: Commute Times in Census Tract 315.01 (US Census, 2010-2014)

## RESULTS & IMPLICATIONS

Ultimately, local governments will make a decision to invest in AV technology based on the needs of the communities they represent. While federal policy may ultimately guide national AV development, the existing network of state and local policies will continue to weave a complicated web of jurisdictional control over self-driving cars. This network will potentially stagnate the development of AV technology in individual localities by making rules difficult to follow for manufacturers and consumers. These complexities will hamper the development of this potentially beneficial technology. The various benefits and costs of self-driving cars, as well as new

implementation models like SAVs, will drive the development of AV technology. Regardless of a national policy framework, some key responsibilities in addressing AV benefits and costs will fall to local governments.

### Local Demographic Implications

Demographic data will influence the market for AVs in different localities. Markets with larger percentages of young people and the elderly will see a steeper rise in VMTs. Furthermore, men and millennials are more likely to ride in a self-driving car than baby-boomers and women respectively. Income levels will effect an individuals ability to afford the technology when it becomes mainstream. As a result, tracts with higher incomes will likely see more private vehicle ownership of self-driving cars. From an economics perspective, communities with high proportions of jobs in transportation will be faced with high unemployment if drivers become obsolete. These demographic factors will have profound implications across each study area.

**Table 2: Demographic Data Analysis (US Census, 2010-2014)**

<b>Demographics</b>	<b>King County Average</b>	<b>Census Tract 84</b>	<b>Census Tract 225</b>	<b>Census Tract 315.01</b>
<b>Age</b>				
0-17	21.10%	7.10%	16.60%	18.20%
18-64	67.30%	83.40%	67.50%	70.50%
65+	11.60%	9.50%	15.90%	11.30%
Median Age	37.1	31.0	42.1	44.0
<b>Gender</b>				
Men	49.88%	51.78%	47.77%	54.92%
Women	50.12%	48.22%	52.23%	45.08%
<b>Physical Disability</b>	9.60%	10.00%	10.90%	15.40%
<b>Income (Mean)</b>	\$73,035.00	\$44,524.00	\$97,997.00	\$78,581.00
<b>Income (Median)</b>	\$98,867.00	\$72,408.00	\$115,520.00	\$88,517.00
<b>Employment: Transportation &amp; Warehousing</b>	4.60%	2.30%	2.30%	6.90%

### Local Geography Implications

Higher population densities will change AV development implementation in each study area. A higher density creates incentives for both the driver and the public in terms of shared AVs and supporting faster adoption rates. High ROW and parking coverage rates indicate the high potential to repurpose land with higher and better uses. As demonstrated in the table below, geography will directly influence how self-driving cars interact with people in different built environments.

**Table 3: Geographic Data Comparison (US Census, 2010-2014)**

<b>Density</b>	<b>King County Average</b>	<b>Census Tract 84</b>	<b>Census Tract 225</b>	<b>Census Tract 315.01</b>
Total Population	2,008,997	4,301	7,335	3,961
Total Land Area (mi <sup>2</sup> )	2,115.57	0.15	1.46	62.33
Total Land Area (ft <sup>2</sup> )	58,978,706,688	4,181,760	40,702,464	1,737,660,672
Population Density (ppl/mi <sup>2</sup> )	949.62	28,673.33	5,023.97	63.55
<b>Right of Way</b>	<b>King County Average</b>	<b>Census Tract 84</b>	<b>Census Tract 225</b>	<b>Census Tract 315.01</b>
Total ROW (ft <sup>2</sup> )	2,808,555,348	1,634,493	7,717,920	2,903,294
ROW per Capita	1,397.99	380.03	1,052.20	732.97
ROW / Land Area	4.762%	39.086%	18.962%	0.167%
<b>Parking</b>	<b>King County Average</b>	<b>Census Tract 84</b>	<b>Census Tract 225</b>	<b>Census Tract 315.01</b>
Number of Lots	784	22	3	0
Parking Lot Coverage (ft <sup>2</sup> )	23,814,218	243,312	64,889	0
Parking Lots / Total Land Area	0.04%	5.818%	0.159%	0%

### Local Transportation Implications

When analyzing the different subareas, it becomes clear that urban environments are less reliant on SOVs and that commutes are much longer in rural areas. In remote rural areas, residents lack the same basic transportation infrastructure in urban areas and subsequently lack alternatives to SOVs. These key differences in transportation behavior are expressed in the table and figures below.

Table 4: Mode of Transportation during Commute (US Census, 2010-2014)

Mode of Transportation for Commute	King County Average	Census Tract 84	Census Tract 225	Census Tract 315.01
Car/Truck/Van	79.58%	24.23%	86.81%	95.83%
<i>Drove Alone</i>	68.96%	21.65%	82.25%	88.60%
<i>Carpooled</i>	10.62%	2.58%	4.55%	7.23%
Public Transport	12.54%	33.46%	10.23%	0.00%
Walked	4.99%	37.21%	1.29%	2.08%
Taxi/Bike/Other	2.90%	5.09%	1.67%	2.08%

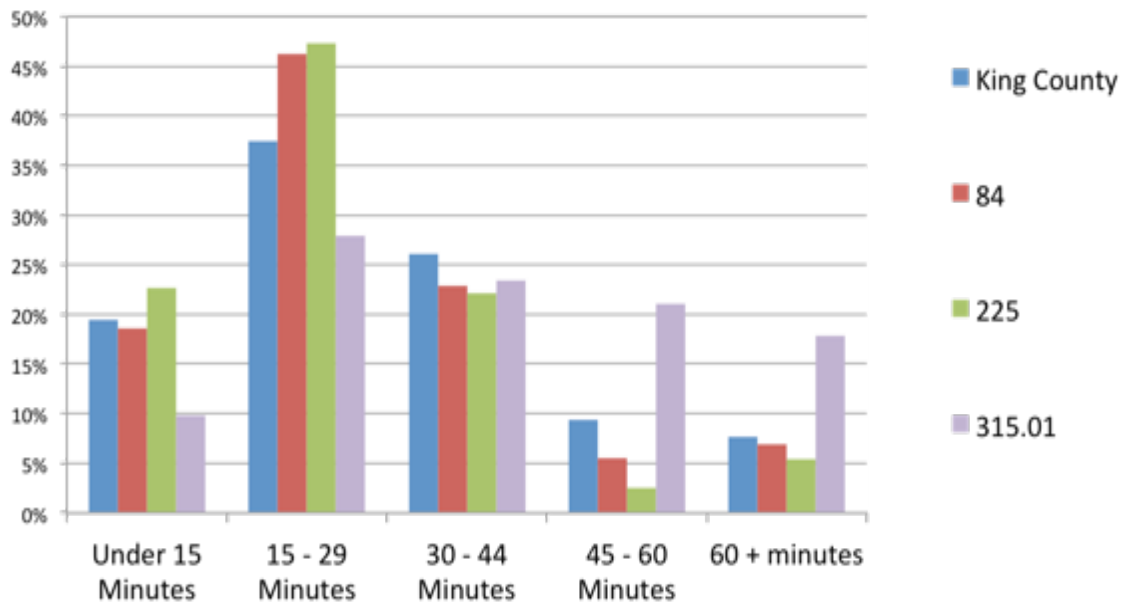


Figure 26: Commute Time Comparison (US Census, 2010-2014)

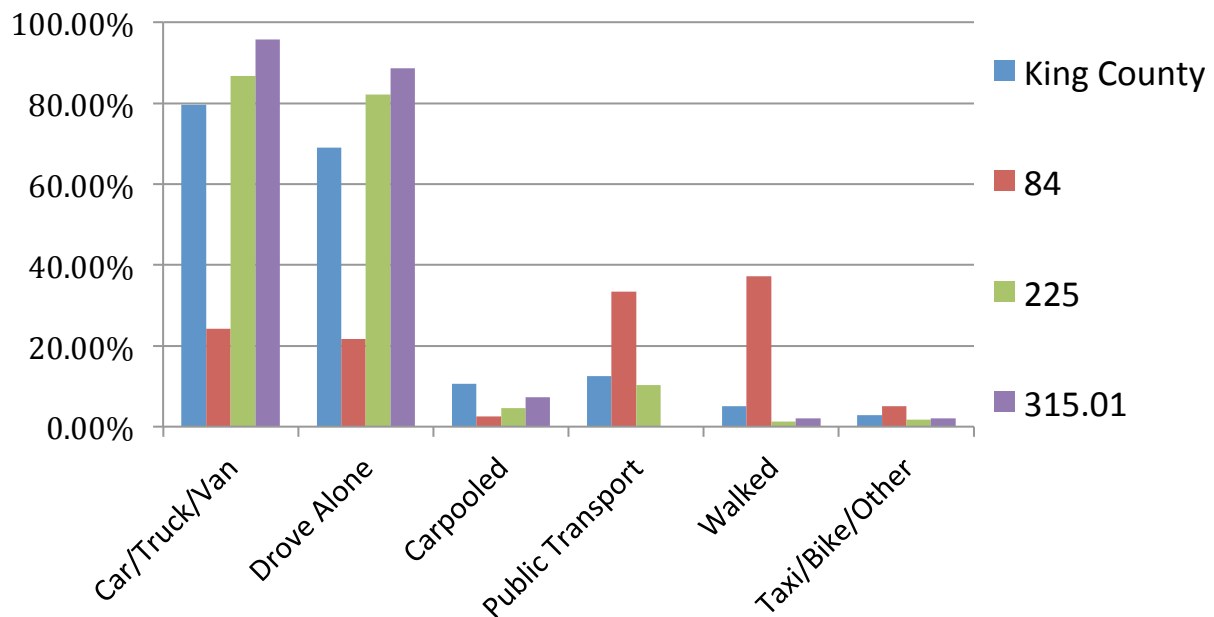


Figure 27: Histogram - Modes of Transportation during Commute (US Census, 2010-2014)

### County Implications

Although King County primarily served as a means of comparison in this study, it also oversees its own transportation policy and planning entity, King County Metro. King County Metro will play an important role in preparing for AV development in each community and financing projects across the county. Self-driving cars, and in particular a shared autonomous vehicle market, will disrupt the primary funding mechanism for King County Metro. Until 2000, King County Metro financed its projects and programs through a motor vehicle excise tax. But King County residents voted to replace this excise tax on automobile sales with general sales tax financing and a supplementary increase in sales tax. This funding mechanism is volatile because it is contingent on

economic conditions that generate high sales-tax revenue in the county.<sup>117</sup> But with the potential for a SAVs market and subsequent reductions in car ownership, AV technology may disrupt this business model that thrives on tax revenue from auto sales. From 2009 – 2015, the great recession in the United States caused a shortfall of approximately \$1.2 billion. Policymakers addressed this funding shortfall by increasing fares, cutting services, and increasing sales tax. Today, 50-60% of King County Metro's operating revenue comes from sales tax.<sup>118</sup> Other funding sources for King County Metro include grants, fares, property tax, interest, payments from sound transit, and other operations. Given the prospective reductions in sales tax revenue from SAVs, policymakers and planners will need to get creative to finance improvements for transit in the region.

## Urban Implications

Adoption rates and additional VMTs will dictate implementation in this urban subarea. Immediate private benefits for AV users, like multi-tasking during traffic and alleviating parking needs, will expedite adoption rates in urban areas like Tract 84. Congestion will be a primary incentive for AV development in urban areas given the high population densities and limited ROW per capita. The presence of younger demographics will also spur the growth of AVs in this subarea, but not in the sense of access to mobility. In the long run, a shared vehicle economy is highly viable, given the density and existing service availability of ridesharing in the subarea. Additional VMTs will create negative externalities throughout this subarea, but Seattle contains

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<sup>117</sup> "Metro Transit's Finances: An Overview." *King County Metro*. King County Metro, Feb. 2014. Web. 10 May 2016. <<http://metro.kingcounty.gov/am/reports/2014/metro-transit-finances-overview-02-03-14.pdf>>.

<sup>118</sup> "Financial Sustainability." *Our Funding*. King County Metro, n.d. Web. 11 May 2016. <<http://metro.kingcounty.gov/am/future/our-funding.html>>.

the financial resources for infrastructure improvements in the right of way. This urban tract will contribute the smallest proportion of new riders through increased access. Many individuals in this census tract use alternative forms of transportation during their commute, such as walking, biking, and public transit - the presence of strong alternatives to SOVs may slow AV implementation in this subarea.

Congestion pricing, ROW management, and parking policies will all serve policymakers and planners as they prepare for the future with automated vehicles. Congestion is a likely policy option for Seattle, even though it places additional costs on commuters. Area-Wide Pricing throughout Seattle would address many major concerns about AV development and increases in VMTs or congestion. By adding costs to the driving behaviors that create negative externalities, area-wide pricing can limit some of the behavioral changes that would increase congestion. Some of these individuals may be low-income, and lack access to transit or lower-cost transportation into the city. AV technology presents high opportunities to repurpose the ROW in census tract 84. The ROW in this tract covers nearly a third of the urban area. This subarea contains many modes of transportation, including buses, bicycle infrastructure, and a streetcar track on its eastern border. With substantially higher public transit use than the other tracts, local policymakers and planners must consider the fiscal implications of a SAV market in Seattle because a reduction in auto sales will decrease excise tax revenue. Parking policy will also be important for this census tract with high population density and limited public parking. Multiple lots in this subarea will be valuable locations to repurpose for housing or institutional services. The urban village overlay allows new developments to forgo parking requirements in zoning law. However, areas outside of the urban villages may see a subsequent increase in parking to accommodate residents and employees closer to the urban core who do not want to pay for parking in high cost areas. Individual parking lots may consider selling their lots

under increasing development pressures and a potential decrease in parking demand and utilization in urban commercial areas. The large commercial presence and residential density creates opportunities for public-private partnerships to create revenue in the subarea.

## **Suburban Implications**

Private benefits and additional VMTs will drive AV implementation across the suburbs. Suburban demographics and income support AV development. Suburban consumers will benefit from both the private benefits and externalities associated with self-driving cars. Over the long term, AVs will incur many short-term benefits for users, like safety, productivity during congestion, and fuel savings. However, shifts in driving behavior will create many negative externalities in the short term, including additional VMTs and potentially worse congestion. Based on the income of the residents, Kirkland probably contains the financial resources needed to make infrastructure improvements in the right of way. Although income levels would support private vehicle ownership in this tract, a shared vehicle economy is viable in the subarea over the long run. The area is still dense enough to support ridesharing, and existing ridesharing services are already available. AV technology will increase VMTs in this subarea. It contains the largest amount of new potential drivers that lead to an increase in VMTs. In terms of driving behavior, AV technology will increase VMTs across the subarea. Single-occupancy vehicles are a primary form of transportation, and will spur additional VMTs for smaller trips and commutes in the subarea. Parking in the subarea is plentiful, and will not be a primary incentive for additional VMTs. Households may choose to own fewer vehicles, which will lead to an increase in individual trips and VMTs.

Congestion pricing, ROW management, and parking policy reform are all viable policy tools in this subarea. Congestion pricing won't be necessary for trips within the

subarea, but specific roads might benefit from this additional transportation cost. Congestion pricing would not be politically popular in Kirkland among residents and employees, but may address some of the neighborhood's traffic needs during rush hour. Some major arterials in this large subarea may benefit from dedicated AV lanes. Throughout this census tract, the ROW occupies a considerable amount of space. By promoting narrower streets across the suburban tract over a long period of time, the subarea can promote alternative modes of transportation like walking, public transit, and biking infrastructure. This census tract is a prime example of how automobile infrastructure creates negative externalities and disrupts urban form. Repurposing the ROW for other uses will help reduce congestion over the long run, but will take time to develop. The zoning policy calls for 1-2 parking spots per unit, leading to more parking in this tract than the other subareas.<sup>119</sup> Parking policy reform in the zoning will help spur the parking benefits of self-driving cars.

## Rural Implications

Rural areas with low population density and less congestion will benefit from some private benefits. The largest benefit of AV technology will be productivity for individuals with long commutes. But without major congestion or parking issues, the financial cost of AV technology may outweigh the immediate benefits. Although King County contains the financial resources to make infrastructure improvements in the right of way, these investments are unlikely to occur in remote areas in unincorporated King County where population density is low. The county would probably use those funds for higher-priority infrastructure projects inside of the urban growth boundary.

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<sup>119</sup> City of Kirkland Land Use Code. CodePublishing. Chapter 15 – 50, 19 Apr. 2016. Web. 25 May 2016. <<http://www.codepublishing.com/WA/Kirkland/?html/KirklandZNT.html>>.

A shared vehicle economy is not likely in rural areas. Ridesharing services are not currently available in the subarea and are unlikely to arrive in the near future because the subarea is not dense enough to support the market. Additionally, incomes may be high enough to support private car ownership. The introduction of AV technology in rural subareas will lead to additional VMTs in individual households, but will not lead to worse congestion within the subarea, which still contains a large amount of ROW per person. This subarea contains many senior citizens and children who will benefit from additional mobility. These groups will add to VMTs if driving age limits and restrictions are alleviated. Trips within the subarea are unlikely to create additional VMTs to the same degree as the urban and suburban subareas due to the availability of free parking and land with limited development potential.

The policy spectrum in rural areas is severely limited by funding availability. The county would need to administrate any congestion based pricing scheme due to the tracts unincorporated status; however, there isn't enough congestion to merit a significant change in rural areas like tract 315.01. Even so, the lack of alternative modes of transit make SOV infrastructure important in this subarea. Most of the distances within the subarea are too far to walk and public transit does not serve this low-density census tract. Parking policies are not as relevant in rural areas like tract 315.01 due to the massive expanse of land area and basic limitation on development outside the urban growth area. Parking demand is not as important of an issue in many rural areas with abundant land and limited development potential. Without a change in zoning and subsequent increase in density, parking policies will hold little value in rural areas.

## CONCLUSIONS & REFLECTIONS

The literature review and case studies suggest that spatial variability will change how self-driving cars affect urban, suburban, and rural areas. My methodology selects key characteristics identified by existing literature to analyze across the three different census tracts in King County. But researchers still need more data to make extrapolations and predictions about AV outcomes in the United States. To expand this methodology across the state, researchers can classify all tracts within a state as urban, suburban, or rural and generate more case studies. The data will agglomerate trends in individual communities and help policymakers and planners draw more conclusions about the spatial variability of AV technology in Washington. Even after this information is scaled to the state, researchers will need more data on how people respond to AVs on local roads. The relationship between driving behavior and AV technology is still unknown because self-driving cars are not yet available to the public. Data collection will be paramount to understand the relationship between AV technology and local communities.

### Ownership Models & Adoption Rates

Ownership models and adoption rates for the technology are too distant to predict. SAVs will shift transportation behavior by reducing car ownership rates and altering people's perception of the cost of a trip in an SOV. SAVs amortize the cost of a car and charge riders accordingly throughout the life of the vehicle. This pricing model will discourage unnecessary trips in an SOV. SAV markets are less feasible for rural areas because too few potential clients live in too large of an area. We still don't know how quickly individual demographics will adopt self-driving cars. Faster adoption rates among any particular demographic will play a role in how quickly local governments need to start preparing for AVs. Initial studies suggest that women and

baby boomers will be less inclined to use AV technology. However, these studies are based on survey data for a technology that isn't currently available to consumers. This public opinion will likely shift over time as more data is available and the technology becomes more available to consumers. While the expense of owning an AV may be cost-prohibitive for low-income individuals, the technology will likely become cheaper over time.

## **Policy Decisions**

Policies can actively influence transportation by adding costs or restricting behaviors that perpetuate negative externalities. In particular, these types of policies can address AV externalities in transportation behavior. For example, congestion pricing adds costs to individuals who contribute to congestion and will encourage AV owners to limit trips without passengers. Restrictions are also effective at mitigating these externalities. With AVs, occupancy requirements are one type of restriction that will reduce VMTs with limit increases in congestion. These types of policy decisions will change how AVs influence local transportation behaviors and add another layer of complexity to the spatial variability framework.

## **Spatial Variability**

Suburbs are unique in that they contain financial resources to administrate local change for AVs and enough relative density to make these investments worthwhile for the public. Additionally, the heavy reliance on the SOV in suburban communities will make this spatial pattern an important testing ground for AVs and data collection transportation behavior. Most rural communities, particularly in unincorporated King County, lack the financial resources to make major infrastructure improvements for self-driving cars. The per capita return on the investment will be too small to justify the expense. Urban areas contain the financial resources, but also contain a number of

other transportation options, including biking, walking, and extensive public transportation.

## **Benefits & Costs Over Time**

Moving forward, policymakers and planners should evaluate the effectiveness of the tools they use to address AVs over time. In the short term, not everyone will own or use an AV regularly. In the long term, self-driving cars might replace all conventional cars in the United States and create new opportunities for policy and planning interventions. Benefits and costs in safety, congestion, emissions, employment, and the built environment will all shift as more individuals transition to self-driving cars. Safety, one of the driving forces behind AV development in the United States, will undoubtedly improve over time as AV technology becomes more reliable. The shift among other benefits and costs are less obvious. In the short run, while AVs share the road with conventional automobiles, congestion may increase. Also, an increase in VMTs per capita could prove disastrous for communities with bad congestion. Yet over the long term, as more AVs take to the road, new vehicle-to-vehicle and vehicle-to-infrastructure management tools can help policymakers and planners reduce this congestion. Emissions results are unclear: AV technology will allow cars to drive more efficiently, but driving behaviors may still increase VMTs, emissions, and energy use. In employment, experts anticipate layoffs in auto manufacturing and transportation sector jobs across the country. Although employment gains in programming and electronics sectors are expected, many blue-collar truck drivers will still be without employment. Additionally, changes in the built environment will take time to finance and construct. Suburban and urban areas will be able to make many changes to the built environment in the long term, but rural areas will struggle to finance major infrastructure projects in the ROW and in parking. The table below summarizes the benefits and costs of AVs in

the short and long term and presents time-sensitive policy and planning interventions to help guide local governments:

**Table 5: Benefits & Costs Over Time**

	<b>Time Frame</b>	<b>Spatial Implications</b>	<b>+ / -</b>	<b>Intervention</b>
<b>Safety</b>	Short Term	Reduction in Severe Accidents for AV users in all spatial environments.	+	Safety Standards, Insurance & Liability Policies
	Long Term	Large reduction in accidents in all spatial environments.	+++	Government Buyback Programs for conventional vehicles
<b>Congestion</b>	Short Term	Primarily in urban areas, congestion will be worse in the short term. New drivers & transportation behavior increase VMTs.	---	Congestion Pricing, dedicated AV Lanes
	Long Term	New vehicle-to-vehicle & vehicle-to-infrastructure improvements allow cities to mitigate congestion, but the complete relationship between congestion & AVs is unclear. Congestion is unlikely in rural areas.	?	Vehicle-to-Vehicle & Vehicle-to-Infrastructure Investments
<b>Emissions / Energy Use</b>	Short Term	AV cars become more efficient than conventional automobiles in all areas	+	Standards & Regulations regarding efficiency & AVs
	Long Term	All vehicles are equipped with efficient driving systems that minimize environmental impacts in all areas	+++	Government Buyback Programs for conventional vehicles
<b>Employment</b>	Short Term	Some commercial truck-driving jobs are automated, leading to a reduction in employment	-	Job Assistance & Retraining Programs

	Long Term	Programming and manufacturing jobs are outsourced, nearly all transportation-related jobs are automated	- - -	Basic Income (Automation will impact many other jobs)
<b>Built Environment</b>	Short Term	Added VMTs make any substantive changes difficult or unfeasible for human drivers	-	Parking Easements
	Long Term	Parking burden shifts away from urban areas towards less dense suburbs, cities begin to repurpose ROW & parking for higher uses – AV owners may ultimately decide to move further away from urban centers, triggering sprawl	?	Major infrastructure investments

## Discussion

It is still too early to make a value judgment about whether self-driving cars are good or bad for the United States. Even though the outcomes are not set in stone, local policy and planning must now face the realities of self-driving cars. The spatial variability framework suggests that the benefits and costs of AV technology will vary in different places. Although there are no simple answers to the research questions I proposed at the beginning of this analysis, there is plenty of room to expand upon the lessons learned. It is still too early to make bold predictions or value judgments about self-driving cars. However, as more data and research about AV testing becomes readily available to the public, policymakers and planners can gain a better understanding of the local issues driving AV development. In the meantime, thinking

local about self-driving cars means using data to consider the various factors that will drive local AV development in urban, suburban, and rural areas across the United States.

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## APPENDIX B: Glossary of Terms

AV(s) – Autonomous Vehicle(s)

FHA – Federal Highway Administration

FMVSS – Federal Motor Vehicle Safety Standards

FTA – Federal Transit Administration

GIS – Geographic Information Systems

NHTSA – National Highway Transit Safety Administration

ROW – Right of Way

SAE – Society for Automotive Engineers

SAV(s) – Shared Autonomous Vehicle(s)

SOV(s) – Single Occupancy Vehicle(s)

USDOT – U. S. Department of Transportation

VMTs – Vehicular Miles Traveled

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## APPENDIX D: ROW Measurements

### Census Tract 84

- ROW Total:
  - ROW Per Capita: **(380.02 ft<sup>2</sup> / person)**
    - $1,634,493 \text{ ft}^2 / 4,301 \text{ people} = 380.02$
  - ROW / Total Area: **39.09%**
    - $1,634,493 \text{ ft}^2 / 4,181,760 \text{ ft}^2 = 39.09\%$
  - Area: 0.15 mi<sup>2</sup>

### Census Tract 225

- ROW Total: 7,717,920 ft<sup>2</sup>
  - ROW per capita: (1,052.20 ft<sup>2</sup> / person)
    - $7,717,920 \text{ ft}^2 \text{ ROW} / 7,335 \text{ people}$
  - ROW / Total Area: (18.96%)
    - $7,717,920 \text{ ft}^2 \text{ ROW} / 40,702,464 \text{ ft}^2 = 18.96\%$
  - Area: 1.46 mi<sup>2</sup>

### Census Tract 315.01

- ROW Total: 2,903,294 ft<sup>2</sup>
  - ROW per capita: **(732.97 ft<sup>2</sup> / person)**
    - $2,903,294 \text{ ft}^2 / 3,961 \text{ People}$
  - ROW / Total Area: **(0.16%)**
    - $2,903,294 \text{ ft}^2 / 1,737,660,672 \text{ ft}^2 = 0.16\%$
  - Area: 62.33mi<sup>2</sup>

## APPENDIX E: State Laws as of 4/14/2016

### Alabama

AL S 178<sup>120</sup> – In 2016, Alabama began working on legislation to authorize AVs on public roads. The law sets testing and approval requirements for the Alabama State Law Enforcement Agency. Also, the law introduces specific insurance and licensing requirements for AVs. The law is pending in the Senate Committee on Transportation and Energy.

### Arizona

Although Arizona did not pass any law in the legislature, it passed an Executive Order to “undertake any necessary steps to support the testing and operation of self-driving vehicles on public roads within AZ.” This nearly complete authorization of self-driving cars will spur development in the state. The order also establishes a Self-Driving Vehicle Oversight Committee. The order was successfully passed in August of 2015.

### California

CA SB 1298 (2012) – This California bill provides a statewide definition for autonomous vehicles. The bill also requires the Department of the CA Highway Patrol to adopt safety standards and performance requirements to ensure safe operation and testing of autonomous Vehicles on the public roads in CA. This bill was successfully enacted in 2012.

CA A 1592 – California has also has pending legislation (A 1592<sup>121</sup>) to authorize the Contra Costa Transportation Authority to conduct a pilot project to test autonomous vehicles without standard driving features like a steering wheel, brake and acceleration pedals, or an operator.

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<sup>120</sup>Autonomous | Self-Driving Vehicles Legislation." *National Conference of State Legislators*. NCSL, 8 Apr. 2016. Web. 4 May 2016.

<[https://custom.statenet.com/public/resources.cgi?id=ID:bill:AL2016000S178&ciq=ncsl6&client\\_md=5c72d089cebe326577882daf639f1dc0&mode=current\\_text](https://custom.statenet.com/public/resources.cgi?id=ID:bill:AL2016000S178&ciq=ncsl6&client_md=5c72d089cebe326577882daf639f1dc0&mode=current_text)>.

<sup>121</sup>Autonomous | Self-Driving Vehicles Legislation." *National Conference of State Legislators*. NCSL, 8 Apr. 2016. Web. 4 May 2016.

<[https://custom.statenet.com/public/resources.cgi?id=ID:bill:CA2015000A1592&ciq=ncsl6&client\\_md=f00cf9422e2fe7ad0b63da8fddfebf6e&mode=current\\_text](https://custom.statenet.com/public/resources.cgi?id=ID:bill:CA2015000A1592&ciq=ncsl6&client_md=f00cf9422e2fe7ad0b63da8fddfebf6e&mode=current_text)>.

CA S 431 – Another pending California bill (S 431<sup>122</sup>) would limit how close vehicles can follow each other and specifies the number of vehicles permitted in a caravan or motorcade. This law would impact the benefits of driving in formation.

### **Connecticut**

CT HB 6344 (2015) – In 2015, Connecticut’s house failed to pass a bill that raised concerns for AV tech, but allowed the use of AVs in Connecticut for testing purposes.

### **Florida**

FL HB 1207 (2012) / FL HB 599 (2012) – These successful pieces of Florida legislation define “autonomous vehicles” and “autonomous technology.” It also declares legislative intent to encourage the safe development, testing and operation of motor vehicles with autonomous technology on public roads of the state and finds that the state does not prohibit or specifically regulate the testing or operation of autonomous technology in motor vehicles on public roads. Furthermore, these bills authorize a person who possesses a valid driver's license to operate an autonomous vehicle, specifying that the person who causes the vehicle’s autonomous technology to engage is the operator. They also authorize the operation of autonomous vehicles by certain persons for testing purposes under certain conditions and require an instrument of insurance, surety bond or self-insurance prior to the testing of a vehicle.

The bill directs the State Department of Highway Safety and Motor Vehicles to prepare a report recommending additional legislative or regulatory action that may be required for the safe testing and operation of vehicles equipped with autonomous technology, to be submitted no later than Feb. 12, 2014. These bills were successfully passed in 2012.

FL HB 7027 (2016) – This Florida bill permits operation of autonomous vehicles on public roads by individuals with a valid driver license. This bill eliminates the requirement that the vehicle operation is being done for testing purposes and removes a number of provisions related to vehicle operation for testing purposes. Furthermore, it eliminates the requirement that a driver be present in the vehicle and requires

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<sup>122</sup>Autonomous | Self-Driving Vehicles Legislation." *National Conference of State Legislators*. NCSL, 8 Apr. 2016. Web. 4 May 2016.  
<[https://custom.statenet.com/public/resources.cgi?id=ID:bill:CA2015000S431&ciq=ncsl6&client\\_md=03facdae246b3fe893e8c5a05833cff1&mode=current\\_text](https://custom.statenet.com/public/resources.cgi?id=ID:bill:CA2015000S431&ciq=ncsl6&client_md=03facdae246b3fe893e8c5a05833cff1&mode=current_text) >.

autonomous vehicles to meet applicable federal safety standards and regulations. This bill was successfully passed in 2016.

FL H 7061<sup>123</sup> - This pending Florida bill defines autonomous technology and driver-assistive truck platooning technology. It also requires a study on the use and safe operation of driver-assistive truck platooning technology and allows for a pilot project upon conclusion of the study.

## **Georgia**

GA SB 113<sup>124</sup> - Georgia unsuccessfully attempted to pass a law in 2015 that would have created a new class of motor vehicles to be known as autonomous vehicles and sets various rules regarding their operations. The law defined autonomous technology and autonomous vehicle and specifies requirements to operate an autonomous vehicle. It also permits for the operation of self-driving cars on public highways and allowed for state regulations of autonomous vehicles. The bill also would have allowed for testing in the state. A more controversial aspect of the bill would have provided indemnity to vehicle manufacturers in certain instances.

## **Hawaii**

HI S 630<sup>125</sup> - In 2016, Hawaii failed to pass a bill (S 630) that allows a person who possesses a valid Hawaii driver license to operate an autonomous motor vehicle that employs autonomous technology. The bill defined autonomous vehicle and autonomous technology, but required certain safety features and specified certain conditions for safety testing.

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<sup>123</sup>Autonomous | Self-Driving Vehicles Legislation." *National Conference of State Legislators*. NCSL, 8 Apr. 2016. Web. 4 May 2016.

<[https://custom.statenet.com/public/resources.cgi?id=ID:bill:FL2016000H7061&ciq=ncl6&client\\_md=e19b283b50431dbba852164fd0560f61&mode=current\\_text](https://custom.statenet.com/public/resources.cgi?id=ID:bill:FL2016000H7061&ciq=ncl6&client_md=e19b283b50431dbba852164fd0560f61&mode=current_text)>.

<sup>124</sup>Autonomous | Self-Driving Vehicles Legislation." *National Conference of State Legislators*. NCSL, 8 Apr. 2016. Web. 4 May 2016.

<[https://custom.statenet.com/public/resources.cgi?id=ID:bill:GA2015000S113&ciq=ncl6&client\\_md=19d59f58a7d51d8977723cf05c4125c7&mode=current\\_text](https://custom.statenet.com/public/resources.cgi?id=ID:bill:GA2015000S113&ciq=ncl6&client_md=19d59f58a7d51d8977723cf05c4125c7&mode=current_text)>.

<sup>125</sup>Autonomous | Self-Driving Vehicles Legislation." *National Conference of State Legislators*. NCSL, 8 Apr. 2016. Web. 4 May 2016.

<[https://custom.statenet.com/public/resources.cgi?id=ID:bill:HI2015000S630&ciq=ncl6&client\\_md=f17f46c63e49c23dd24e28f5ce9d3957&mode=current\\_text](https://custom.statenet.com/public/resources.cgi?id=ID:bill:HI2015000S630&ciq=ncl6&client_md=f17f46c63e49c23dd24e28f5ce9d3957&mode=current_text)>.

HI HB 1458 – In 2015, Hawaii’s House also failed to pass a bill. The bill would have allowed AVs to operate on any road in the state under certain requirements. The bill would also permit the testing of AVs on any road. However, the bill failed to make it through the first crossover deadline

HI HB 632 – In 2015, Hawaii’s House started work on a bill that authorizes the testing and operation of autonomous vehicles in the state of Hawaii. This bill requires the State Department of Transportation to establish an application and approval process and report annually to the Legislature. It also makes an appropriation for the process. The bill is currently pending in carryover.

## **Idaho**

ID SB 1108 – In 2015, Idaho failed to pass a bill to amend and add to existing law to address AVs. The Idaho bill would have provided insurance requirements, requirements for testing AVs, and provided that AVs shall meet federal standards and regulations. The bill would set requirements for AVs before testing or operation on public roads within the state. It would have provided an exemption from liability for manufacturers and dealers and opened all highways for testing. The bill failed when congress adjourned session.

## **Illinois**

IL H 3136<sup>126</sup> - In 2015, Illinois introduced a bill through the house. After multiple carryovers, this bill to create the Automated Motor Vehicle Study and Report Act. Although the act is still pending, it will have a resounding impact on AV development in the state. An earlier iteration of the bill (IL HB 3136) addressed many other safety regulations regarding the authorization of testing. It also establishes a definition for automated motor vehicles and commissions a feasibility study by the Secretary of State. The bill is pending in the Senate for a third reading.

## **Maryland**

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<sup>126</sup> Autonomous | Self-Driving Vehicles Legislation." *National Conference of State Legislators*. NCSL, 8 Apr. 2016. Web. 4 May 2016.

<[https://custom.statenet.com/public/resources.cgi?id=ID:bill:IL2015000H3136&ciq=ncl6&client\\_md=cb82987d2b76892a0295eafda945bd86&mode=current\\_text](https://custom.statenet.com/public/resources.cgi?id=ID:bill:IL2015000H3136&ciq=ncl6&client_md=cb82987d2b76892a0295eafda945bd86&mode=current_text)>.

H 8<sup>127</sup> / S 126<sup>128</sup> - In 2016, Maryland attempted to pass a bill in both the house and the senate. The bill would have developed a task force to assess best practices for self-driving vehicles. This legislation failed in both the house and senate. Similar bills were also put out in in both branches of the State Legislature in 2015 (MD HB 172 / MD SB 778), but those bills failed as well.

## **Massachusetts**

MA H2977<sup>129</sup> - In 2015, Massachusetts began working on a house bill. The bill would authorize AVs without active controls or monitoring by a human operator. The bill's status is pending review in the state's Joint Committee on Transportation.

MA S 1841<sup>130</sup> - This bill was introduced in 2015. It would define Automated Vehicles for the state and also allow their operation on public roads if they adhere to various safety standards. The bill is currently pending in the state's Joint Committee on Transportation.

## **Michigan**

MI S 169 (2013) – Michigan successfully passed a bill in 2013 to define the terms "automated technology," "automated vehicle," "automated mode," and "operator." The bill expressly permits testing of automated vehicles by certain parties under certain conditions, addresses liability of the original manufacturer of a vehicle on which a third party has installed an automated system, and directs the State Department of Transportation with Secretary of State to submit a formal report by Feb. 1, 2016.

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<sup>127</sup> Autonomous | Self-Driving Vehicles Legislation." *National Conference of State Legislators*. NCSL, 8 Apr. 2016. Web. 4 May 2016.

<[https://custom.statenet.com/public/resources.cgi?id=ID:bill:MD2016000H8&ciq=ncl6&client\\_md=336bdca4c5a0b08391d8fca5d992c942&mode=current\\_text](https://custom.statenet.com/public/resources.cgi?id=ID:bill:MD2016000H8&ciq=ncl6&client_md=336bdca4c5a0b08391d8fca5d992c942&mode=current_text)>.

<sup>128</sup> Autonomous | Self-Driving Vehicles Legislation." *National Conference of State Legislators*. NCSL, 8 Apr. 2016. Web. 4 May 2016.

<[https://custom.statenet.com/public/resources.cgi?id=ID:bill:MD2016000S126&ciq=ncl6&client\\_md=037e54ce695a0d4106e8df5c07619cc6&mode=current\\_text](https://custom.statenet.com/public/resources.cgi?id=ID:bill:MD2016000S126&ciq=ncl6&client_md=037e54ce695a0d4106e8df5c07619cc6&mode=current_text)>.

<sup>129</sup> Autonomous | Self-Driving Vehicles Legislation." *National Conference of State Legislators*. NCSL, 8 Apr. 2016. Web. 4 May 2016.

<[https://custom.statenet.com/public/resources.cgi?id=ID:bill:MA2015000H2977&ciq=ncl6&client\\_md=b22de1a8d0e4a1df407869c38c738dbc&mode=current\\_text](https://custom.statenet.com/public/resources.cgi?id=ID:bill:MA2015000H2977&ciq=ncl6&client_md=b22de1a8d0e4a1df407869c38c738dbc&mode=current_text)>.

<sup>130</sup> Autonomous | Self-Driving Vehicles Legislation." *National Conference of State Legislators*. NCSL, 8 Apr. 2016. Web. 4 May 2016.

<[https://custom.statenet.com/public/resources.cgi?id=ID:bill:MA2015000S1841&ciq=ncl6&client\\_md=4723a882cc70ae879ec8bfa086aaa753&mode=current\\_text](https://custom.statenet.com/public/resources.cgi?id=ID:bill:MA2015000S1841&ciq=ncl6&client_md=4723a882cc70ae879ec8bfa086aaa753&mode=current_text)>.

MI SB 663 (2013) – Another successful bill passed in 2013 limits the liability of vehicle manufacturers for damages in a product liability suit resulting from modifications made by a third party to an automated vehicle or automated vehicle technology under certain circumstances. It is important to note that many traditional automobile manufacturers in the United States are based out of Michigan.

### **Mississippi**

MS SB 2676 – Mississippi failed to pass a law authorizing the use of AVs in the state. This bill would have defined autonomous technology and Autonomous Vehicles. It also would have provided for the state control over the safety and licensing for AV technology.

### **Missouri**

MO HB 924 – Missouri attempted to permit the testing of driverless motor vehicles through August 28, 2018. However, the bill failed as the legislative session adjourned.

### **Nevada**

NV AB 511 (2011) – In 2011, Nevada authorized the operation of autonomous vehicles and issued a driver’s license endorsement for operators of autonomous vehicles. It defines “autonomous vehicles” for the state and directs the State Department of Motor Vehicles (DMV) to adopt rules for license endorsement and for operation, including insurance, safety standards and testing.

NV SB 140 (2011) – This bill, passed in 2011, prohibits the use of cell phones or other handheld wireless communications devices while driving in certain circumstances, and makes it a crime to text or read data on a cellular phone while driving. It permits use of such devices for persons in a legally operating autonomous vehicle. These persons are deemed not to be operating a motor vehicle for the purposes of this law.

NV SB 313 (2013) – Nevada also passed a bill in 2013 that requires an autonomous vehicle that is being tested on a highway to meet certain conditions relating to a human operator. This bill requires operators to possess a proof of insurance and prohibits an autonomous vehicle from being registered in the state, or tested or operated on a highway within the state, unless it meets certain conditions. It also provides that the manufacturer of a vehicle that has been converted to be an autonomous vehicle by a third party is immune from liability for certain injuries.

## **New Jersey**

NJ A 554<sup>131</sup> - This bill would require self-driving vehicles to be equipped with an ignition interlock device. This bill's status is pending.

NJ A 851<sup>132</sup>/ S 343<sup>133</sup> - Another bill directs the Motor Vehicle Commission to establish licensing endorsements for AVs. This bill's status is also pending.

## **New York**

NY AB 31<sup>134</sup> - (2016) – New York State drafted legislation in 2015. The bill would provide for and regulate operations in the state. The bill would also permit the testing of AV technology in the State (A 31). It is currently pending carryover and under review in the Assembly Committee on Transportation.

## **North Carolina**

NC SB 600<sup>135</sup> / NC HB 782 – In 2015, North Carolina's Senate and house began working on bills to begin exploring the feasibility of AV technology in the state. The law defined autonomous vehicles as a vehicle capable of operating with full autonomy as determined by the SAE standard. It would direct the division of Motor Vehicles to study the impacts of AVs in North Carolina. It also proposes a probe to explore backup safety

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<sup>131</sup> Autonomous | Self-Driving Vehicles Legislation." *National Conference of State Legislators*. NCSL, 8 Apr. 2016. Web. 4 May 2016.

<[https://custom.statenet.com/public/resources.cgi?id=ID:bill:NJ2016000A554&ciq=ncl6&client\\_md=07524b3c49bc78df5ff20dc1d54079c5&mode=current\\_text](https://custom.statenet.com/public/resources.cgi?id=ID:bill:NJ2016000A554&ciq=ncl6&client_md=07524b3c49bc78df5ff20dc1d54079c5&mode=current_text)>.

<sup>132</sup> Autonomous | Self-Driving Vehicles Legislation." *National Conference of State Legislators*. NCSL, 8 Apr. 2016. Web. 4 May 2016.

<[https://custom.statenet.com/public/resources.cgi?id=ID:bill:NJ2016000A851&ciq=ncl6&client\\_md=df169b4f3bbfe424d271a83d5ea3a575&mode=current\\_text](https://custom.statenet.com/public/resources.cgi?id=ID:bill:NJ2016000A851&ciq=ncl6&client_md=df169b4f3bbfe424d271a83d5ea3a575&mode=current_text)>.

<sup>133</sup> Autonomous | Self-Driving Vehicles Legislation." *National Conference of State Legislators*. NCSL, 8 Apr. 2016. Web. 4 May 2016.

<[https://custom.statenet.com/public/resources.cgi?id=ID:bill:NJ2016000S343&ciq=ncl6&client\\_md=ee866a4f570135b1708aa1dcc283fab4&mode=current\\_text](https://custom.statenet.com/public/resources.cgi?id=ID:bill:NJ2016000S343&ciq=ncl6&client_md=ee866a4f570135b1708aa1dcc283fab4&mode=current_text)>.

<sup>134</sup> Autonomous | Self-Driving Vehicles Legislation." *National Conference of State Legislators*. NCSL, 8 Apr. 2016. Web. 4 May 2016.

<[https://custom.statenet.com/public/resources.cgi?id=ID:bill:NY2015000A31&ciq=ncl6&client\\_md=dfa652b8a0024c888002eb0f8d3b8138&mode=current\\_text](https://custom.statenet.com/public/resources.cgi?id=ID:bill:NY2015000A31&ciq=ncl6&client_md=dfa652b8a0024c888002eb0f8d3b8138&mode=current_text)>.

<sup>135</sup> Autonomous | Self-Driving Vehicles Legislation." *National Conference of State Legislators*. NCSL, 8 Apr. 2016. Web. 4 May 2016.

<[https://custom.statenet.com/public/resources.cgi?id=ID:bill:NC2015000S600&ciq=ncl6&client\\_md=a3cf1b9e7f536feb2daf52b0e4fd2303&mode=current\\_text](https://custom.statenet.com/public/resources.cgi?id=ID:bill:NC2015000S600&ciq=ncl6&client_md=a3cf1b9e7f536feb2daf52b0e4fd2303&mode=current_text)>.

features in the event of a critical system failure. These bills are still pending in the general assembly

### **North Dakota**

ND HB 1065 (2015) – This bill provides for a study of autonomous vehicles. Includes research into the degree that automated motor vehicles could reduce traffic fatalities and crashes by reducing or eliminating driver error and the degree that automated motor vehicles could reduce congestion and improve fuel economy. The bill was successfully passed in 2015.

### **Oregon**

OR SB 620 – This bill would have established a process for certifying manufacturers for purposes of testing, selling or operating autonomous vehicles on highways of state. It prescribes vehicle and operator requirements for autonomous vehicles. However, the bill failed when it died in congress.

### **Tennessee**

TN SB 598 (2015) – This bill prohibits local governments from banning the use of motor vehicles equipped with autonomous technology. The bill was passed in 2015.

TN SB 2333 (2016) – This bill replaced TN H 2173 (2015)<sup>136</sup> in 2015 and would allow a motor vehicle to be operated, or to be equipped with, an integrated electronic display visible to the operator while the motor vehicle's autonomous technology is engaged. The Senate approved this bill in 2016.

TN H 1564<sup>137</sup> / S 1561<sup>138</sup> These bills would establish a certification program for AVs and develop a tax structure based on VMTs. The bill is currently under review in the House Committee on Finance, Ways & Means. In the Senate, the bill is scheduled for review.

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<sup>136</sup> Autonomous | Self-Driving Vehicles Legislation." *National Conference of State Legislators*. NCSL, 8 Apr. 2016. Web. 4 May 2016.

<[https://custom.statenet.com/public/resources.cgi?id=ID:bill:TN2015000H2173&ciq=ncsl6&client\\_md=8a210409aec168f68aec47312eff61a8&mode=current\\_text](https://custom.statenet.com/public/resources.cgi?id=ID:bill:TN2015000H2173&ciq=ncsl6&client_md=8a210409aec168f68aec47312eff61a8&mode=current_text)>.

<sup>137</sup> Autonomous | Self-Driving Vehicles Legislation." *National Conference of State Legislators*. NCSL, 8 Apr. 2016. Web. 4 May 2016.

<[https://custom.statenet.com/public/resources.cgi?id=ID:bill:TN2015000H1564&ciq=ncsl6&client\\_md=eb828842c99042bca1364cfb3f228e0c&mode=current\\_text](https://custom.statenet.com/public/resources.cgi?id=ID:bill:TN2015000H1564&ciq=ncsl6&client_md=eb828842c99042bca1364cfb3f228e0c&mode=current_text)>.

## **Texas**

TX HB 933 – This bill related to AV development and border security, since Texas shares a border with Mexico. This bill failed as session adjourned.

TX SB 1167 – This bill regarding autonomous motor vehicles also failed as session adjourned. Details are unclear.

TX HB 3690 – This bill would have allowed the State Department of Transportation to regulate AV development in the state, but it failed as session adjourned.

## **Virginia**

VA H 1372<sup>139</sup> - In 2016, state lawmakers in Virginia tried to pass a bill on AVs. The bill attempted to define the differences between autonomous vehicles and piloted vehicles but law failed to pass the house.

## **Utah**

UT HB 280 (2016) – This bill requires a study related to autonomous vehicles, including evaluating NHTSA and AAMVA standards and best practices. It seeks to evaluate appropriate safety features and develop regulatory strategies and recommendations. This bill passed the house in 2016.

## **Washington DC**

DC B 19-0931 (2012) – This bill defines "autonomous vehicle" as "a vehicle capable of navigating District roadways and interpreting traffic-control devices without a driver actively operating any of the vehicle's control systems." It requires a human driver "prepared to take control of the autonomous vehicle at any moment." Furthermore, it restricts conversion to recent vehicles, and addresses liability of the original manufacturer of a converted vehicle. This bill passed in 2012.

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<sup>138</sup> Autonomous | Self-Driving Vehicles Legislation." *National Conference of State Legislators*. NCSL, 8 Apr. 2016. Web. 4 May 2016.

<[https://custom.statenet.com/public/resources.cgi?id=ID:bill:TN2015000S1561&ciq=ncsl6&client\\_md=d22d439db0eb69c693a5ea7b975b77b0&mode=current\\_text](https://custom.statenet.com/public/resources.cgi?id=ID:bill:TN2015000S1561&ciq=ncsl6&client_md=d22d439db0eb69c693a5ea7b975b77b0&mode=current_text)>.

<sup>139</sup> Autonomous | Self-Driving Vehicles Legislation." *National Conference of State Legislators*. NCSL, 8 Apr. 2016. Web. 4 May 2016.

<[https://custom.statenet.com/public/resources.cgi?id=ID:bill:VA2016000H1372&ciq=ncsl6&client\\_md=cf6fe6e7c4196817406da63582d98087&mode=current\\_text](https://custom.statenet.com/public/resources.cgi?id=ID:bill:VA2016000H1372&ciq=ncsl6&client_md=cf6fe6e7c4196817406da63582d98087&mode=current_text)>.

## **Washington**

WA HB 2106<sup>140</sup> - In 2015, Washington lawmakers in the house began crafting legislation to regulate testing. The bill would prohibit vehicle testing within specific boundaries. It is pending review in the House Committee on Transportation.

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<sup>140</sup> Autonomous | Self-Driving Vehicles Legislation." *National Conference of State Legislators*. NCSL, 8 Apr. 2016. Web. 4 May 2016.

<[https://custom.statenet.com/public/resources.cgi?id=ID:bill:WA2015000H2106&ciq=ncsl6&client\\_md=842c28dc319e8ff0a9600220c44e56f4&mode=current\\_text](https://custom.statenet.com/public/resources.cgi?id=ID:bill:WA2015000H2106&ciq=ncsl6&client_md=842c28dc319e8ff0a9600220c44e56f4&mode=current_text)>.

## APPENDIX F: Congestion Pricing

Variable tolls set up a pricing scheme across an entire roadway. In this type of toll, individuals must pay more money to use the road during peak hours. This type of congestion pricing changes behavior because individuals use the road at different times to avoid peak toll hours.<sup>141</sup> Variable lane congestion pricing provides benefits to high-occupancy vehicles (HOVs) in the form of HOV lanes. However, when HOV lanes are underutilized, other drivers can opt to use these faster lanes and pay an additional toll fee. These High Occupancy Toll (HOT) lanes help commuters who are constrained by the time they must arrive at their destination.<sup>142</sup> Much like High-occupancy vehicle lanes are designed provide a faster means of transportation for carpoolers, dedicated AV lanes would potentially provide a better means for implementation in the early phases integration on US roads.

Cordon pricing is a form of congestion pricing that charges a fee to enter or drive within a congested area. Usually adopted for busy city centers, cordon pricing is usually structured as a flat fee. In 1975, Singapore introduced a version of cordon pricing, and upgraded to a fully automated system in 1998. Other cities to introduce this pricing structure include London (2003) and Stockholm (the first half of 2006 on a trial basis).<sup>143</sup>

Area-wide pricing is a form of congestion pricing that establishes per-mile charges to capture the costs associated with Vehicular Miles Traveled. The State of Oregon is testing area-wide pricing as a means to replace fuel taxes. This program

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<sup>141</sup> Congestion, 2014.

<sup>142</sup> Congestion, 2014.

<sup>143</sup> Congestion, 2014.

would assess higher charges during congested periods on high traffic road segments. Seattle also tested a similar charging system in the metropolitan area from 2005-2006.<sup>144</sup> The Puget Sound Regional Council evaluated how area-wide pricing changed travel behavior on the roadway during that time period and found that the policy successfully reduced congestion and created substantial revenue for other projects.<sup>145</sup>

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<sup>144</sup> Congestion, 2014.

<sup>145</sup> Davis, Aubrey. "Traffic Choices Study - Summary Report." *Puget Sound Regional Council*. USDOT, Apr. 2008. Web. 4 May 2016. <<http://www.psrc.org/assets/37/summaryreport.pdf?processed=true>>.

## APPENDIX G: Full Commute Times Table

Commute Times	King County Average		Census Tract 84		Census Tract 225		Census Tract 315.01	
	Estimate	%	Estimate	%	Estimate	%	Estimate	%
Less than 5 minutes	17,829	1.84%	79	2.72%	13	0.36%	36	2.08%
5 to 9 minutes	64,044	6.62%	203	6.99%	330	9.05%	35	2.03%
10 to 14 minutes	106,537	11.01%	257	8.85%	484	13.27%	98	5.67%
15 to 19 minutes	138,528	14.32%	553	19.04%	959	26.30%	256	14.81%
20 to 24 minutes	152,058	15.71%	636	21.89%	526	14.43%	149	8.62%
25 to 29 minutes	71,887	7.43%	153	5.27%	240	6.58%	78	4.51%
30 to 34 minutes	166,278	17.18%	431	14.84%	469	12.86%	99	5.73%
35 to 39 minutes	36,008	3.72%	99	3.41%	181	4.96%	172	9.95%
40 to 44 minutes	50,303	5.20%	134	4.61%	155	4.25%	133	7.70%
45 to 59 minutes	90,357	9.34%	160	5.51%	92	2.52%	364	21.06%
60 to 89 minutes	55,247	5.71%	97	3.34%	136	3.73%	236	13.66%
90 or more minutes	18,636	1.93%	103	3.55%	61	1.67%	72	4.17%
<b>Total:</b>	<b>967,712</b>		<b>2,905</b>		<b>3,646</b>		<b>1,728</b>	