**Observations from Autonomous Vehicle Testing in Phoenix,
Noteworthy Ways Existing Political Practices & Commuting Behaviors Will Affect
Planning for Self-Driving Vehicles**

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ABSTRACT

Political and social contexts affecting the planning for self-driving vehicles are explored through a mixed-methods case study of autonomous vehicle testing in Phoenix, Arizona. This thesis addresses the following five research questions: What are the public perceptions of self-driving vehicles? How common are self-driving vehicles within testing areas? What role will private firms creating autonomous driving technologies have in the planning for these vehicles? What role will public agencies have in supporting and regulating the use of self-driving vehicles? And are concerns of induced sprawl associated with driverless vehicles justified? The results produced five main findings. First, autonomous vehicles are popular in the Phoenix metropolis. Second, they are quite common in testing areas. Third, the developers of self-driving technologies are a major planner for these vehicles. Fourth, public planning for self-driving vehicles in the United States will follow the existing divisions of responsibilities across the various levels of government. And fifth, that the convenience provided by self-driving vehicles could incite sprawl within a one-hour commuting limit. Overall, these results indicate that the planning for self-driving vehicles will occur through existing political practices, and in response to persistent commuting behaviors. The practical and research ramifications of these findings are discussed, along with the enduring role of the car in American society. While the socially beneficial promises of self-driving vehicles are huge, planners must remember that they are essentially automobiles with similar potentials for sprawl and other effects harmful to cities and urban communities as their traditional counterparts.

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For my Mom,
Bobetta Jean Montilla,
Whose Voice Through the Phone Kept Me Focused,
Whose Voice is a Comfort of Home.

ACKNOWLEDGMENTS

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Observations from Autonomous Vehicle Testing in Phoenix,
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Self-Driving Vehicles

Part One
Introduction, Background, and Literature Review

A Waymo Autonomous Vehicle in Chandler, Arizona

Chapter 1
Introduction: The Now that Shapes the Future

We are at the dawn of a transportation revolution. The ongoing development of self-driving

vehicles will change how people travel. While there are still many questions concerning how these

technologies will be incorporated into society, it is time for planners to begin pondering how to

prepare for the transportation systems of the future. The promise of autonomous vehicles is huge.

They could potentially reconceptualize how the public views the use of automobiles. Widespread

use of self-driving vehicles may significantly reduce the number of deaths and injuries caused by

traffic accidents, and this change may lead to an expectation for near perfect transportation safety

(Fleetwood, 2017). However, use of autonomous vehicles may also redesign cities to the detriment

of marginalized communities, and to the public's health in general. Use of driverless cars could accelerate sprawl, leading to sedentary lifestyles while sapping urban cores of their residents and prosperity (Pettigrew, 2017; Vakharia, 2018). Nevertheless, autonomous vehicles are coming. Planners need to formulate solutions to mitigate these negative consequences while maximizing positive effects. Sadly, planners historically ignored or poorly incorporated new transportation technologies into cities, and few – if any – contemporary cities are prepared for the approaching changes (Guerra, 2016). The research presented here explores the current state of autonomous vehicle testing, and provides evidence for both the continued importance of existing political norms, and for self-driving vehicles' potential to fuel sprawl within the seemingly innate constraint known as Marchetti's Constant (Marchetti, 1994). Simply put, planning for self-driving vehicles will occur through existing political practices, and in response to persistent commuting behaviors.

Claiming that existing norms and practices will affect the future may seem like a trivial assertion, but when it comes to planning for self-driving vehicles, acknowledging the importance of existing political and behavioral standards is critical. Autonomous vehicles are often portrayed as a wholly new technology that will disrupt every facet of life. In actuality, autonomous vehicles are merely the next evolutionary phenotype of automobiles. Self-driving vehicles will utilize existing infrastructure, and will follow existing traffic laws. Likewise, planning for these vehicles will follow existing political conventions, and will be motivated by existing travel behaviors. Distinguishing these similarities provides planners with a guide for action. The successes and failures of past planning practices are well known, and identifying these practices could instruct future planners of the best means to plan for widespread use of driverless vehicles. In other words, while driverless vehicles may come with their own set of planning concerns beyond those of their traditional counterparts, these concerns will be accounted for through familiar or analogous means.

At this point in time, there are autonomous vehicle testing sites across the whole of the continuous United States. Department of Transportation designated testing sites range from San Diego to Pittsburgh. Testing is occurring on the campuses of the University of Wisconsin, the University of Michigan, the University of Central Florida, and elsewhere (Korosec, 2017). Furthermore, some states and cities have encouraged testing within their borders without federal designation, and in some of these places, autonomous vehicles are heavily tested on public roads.

While research into autonomous vehicles is now a major concern of many academic fields, planning has been reluctant to approach this topic from a political and social perspective. Instead, planning related research into autonomous vehicles has usually incorporated a design or engineering perspective (Chen, He, Yin, & Du, 2017; Gopalswamy, & Rathinam, 2018). The results of these studies have called for new technologies to be incorporated into highway infrastructure, or for the restructuring of roads. However, few studies have looked into the political methods planners will leverage to realize these suggestions, or examine the role autonomous vehicles are starting to have in society. Despite being in development, autonomous vehicles are already building a role within the communities they are tested in, and this role will surely affect the planning practice as the distribution of self-driving vehicles becomes extensive.

Therefore, the research presented here is principally an attempt to uncover some of the political and social contexts autonomous vehicles will shape and be shaped by. To achieve this end, this research attempts to inform the following questions: what are the public perceptions of self-driving vehicles, how common are self-driving vehicles within testing areas, what role will private firms creating autonomous driving technologies have in the planning for these vehicles, what role will public agencies have in supporting and regulating the use of self-driving vehicles, and finally, are the concerns of induced sprawl associated with driverless vehicles justified?

To answer these questions as best as possible, this research will focus on an area that has an unusually high number of autonomous vehicles in use. Ideally, governments in this area would have also taken policy actions to plan for these vehicles. While there are a few places that match these conditions, there is one area that stands out – Phoenix, Arizona.

The original research at the core of this thesis is a case study of the Phoenix metropolitan area concerned with investigating the area's brief history, and already entrenched relationship with autonomous vehicles. In 2015, the governor of Arizona signed an executive order instructing state agencies to facilitate the testing of autonomous vehicles on public roads (AZ Exec. Order No. 2015-09, 2015). Since then, Arizona has become a hotbed for the development of autonomous vehicles. Today, self-driving cars are currently tested in regular traffic often without any person present in the vehicle, and select residents of the Phoenix area are already hailing driverless minivans as they would a taxi (Randall & Bergen, 2018). Soon, anyone in the Phoenix area could take advantage of this technology, and planners should keep a keen eye on these developments to see what can be learned about how to plan for the use, and effects of driverless vehicles (Greig, 2018). In addition, there have been more traditional planning actions taken because of autonomous vehicles in Arizona as well. The local public transit authority recently teamed with Waymo, an autonomous vehicle developer, to provide connecting rides as part of the region's transit offerings, and the governor has appended his original executive order to require autonomous technologies to meet certain safety standards unnecessary in traditional vehicles (Randell & Bergen, 2018; AZ Exec. Order No. 2018-04, 2018a). The Phoenix area has more experience with self-driving vehicles on public roads than anywhere else, and is an ideal location to perform a case study.

The researcher broke this case study into four types of research methods. The first method was a Twitter content analysis gauging public perceptions of autonomous vehicles in the Phoenix

metropolitan area. The second was a set of observational studies occurring within the Phoenix metropolis. These observations measured how common autonomous vehicles are at Waymo's main testing site (Chandler, Arizona), identified ways private and public actors are planning for self-driving vehicles, and evaluated how well these vehicles drive in traffic. The results of these observational approaches inspired the third method, a survey exploring sprawl's connection to the potential convenience of self-driving vehicles. And fourth, to round out the case study, the researcher interviewed experts, and corresponded with a local political leader from Arizona. Furthermore, the researcher completed an in-depth literature review of autonomous vehicles and the Phoenix to complement these methods. As a whole, these methods produced a series of results informing the aforementioned research questions.

The results indicate that autonomous vehicles are very popular and common in the Phoenix area. They also show that the developers advancing these technologies are currently the primary planners for autonomous vehicles, and that public planning for self-driving vehicles will likely occur across the existing division of responsibility amongst local, state, and federal levels of government. Results also support self-driving vehicles' potential to instigate sprawl, as well as the one-hour commuting threshold postulated by Marchetti (1994).

In total, these findings indicate that the planning for self-driving vehicles will occur through existing political means, and in response to rigid commuting behaviors. Identifying these political and behavioral structures will assuredly help planners implement future planning actions, but the previously harmful results of these structures must also be accounted for. The division of planning between and across various governments has previously led to inefficient and inequitable transportation systems, and the convenience of the traditional automobile fundamentally changed nearly every American city to the advantage of already-privileged communities while wounding

poor and minority neighborhoods. Planning for self-driving cars and trucks provides planners with an opportunity to avoid the mistakes of the past, and to possibly correct them to some extent. It is imperative that planners comprehend the persistent role political and behavioral structures will have in the future, and must be ready to work through these structures aware of their pitfalls.

Self-driving vehicles will travel on existing infrastructure, will be planned through existing political norms, and will elicit commuting behaviors similar to those spurred by use of traditional automobiles. Existing situations should not be overlooked solely because vehicles will soon be autonomous. Planning's expertise for automotive travel provides the field with a proverbial leg-up when it comes to planning for self-driving cars on the urban and metropolitan scale. There is already a firm foundation of planning knowledge to rely upon. However, autonomous vehicles are noticeably different than any means of travel that has come before. While noting their similarities to existing cars is tremendously useful, planners must also know what makes vehicles autonomous, and how this capability could affect cities in both familiar and alien ways.

Chapter 2
Autonomy, Autonomation, and Sensing

There is a maelstrom of near-synonymous terminology dominating discussions of the future of automotive transportation. The terms self-driving, driverless, autonomous, and automated are bandied about as though there is no difference between them. While these terms are all related, they all refer to specific levels of capability, and some denote unique technological underpinnings. Despite these distinctions, the public will likely continue using these terms as equals. The synonymous nature of these terms comes from the fact that they all imply a common result from the user's perspective. No matter the term, some level of control is taken out of human hands.

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To establish a scale of driving responsibilities outside the user's control, the Society of Automotive Engineers (SAE) created a classification ladder of driving automation. In this hierarchy, the SAE outlines five levels of automation extending from vehicles that are fully controlled by a human driver, to vehicles that are fully automated with no human control (See Figure 1 on Page 8). According to this scale, one could purchase a level 2 vehicle from most car dealerships today, and some may argue that the "Navigate" feature available through Tesla's Autopilot system makes equipped cars level 3 vehicles. This feature takes nearly all driving tasks out of the user's control while on major highways, but requires the user to be able to take back control when prompted, or when the user deems necessary (Wattles, 2018). By conceptualizing driving automation as they have, the SAE gives developers a set of capabilities to aim for while also providing definitions the public can understand (Society of Automotive Engineers, 2018).

This scale also helps to clarify the distinctions between the terminology used when discussing autonomous/automated vehicles. As mentioned before, each term refers to specific levels of capability, while some also refer to unique processes and enabling technologies.

The term "driverless" technically refers to the most capable vehicles on the SAE scale. A driverless vehicle does not require a human to operate the vehicle in any condition whatsoever (Levinson, 2017). The term itself parallels the SAE's definition of a level 5 automobile. In contrast, a "self-driving" vehicle may be a level 5 automobile, but the terminology itself does not exclude the need for a backup, human driver. Therefore, self-driving vehicles are often thought of as level 4 automobiles or below (Levinson, 2017). Most developers strive for their vehicles to be level 5, but they will have to master self-driving status before users will accept them as truly driverless.

The terms "autonomous" and "automated" are differentiated more by the process in which these vehicles achieve self-driving status, than the terms "driverless" and "self-driving". Simply

put, autonomous vehicles are self-guided, without control from an outside source (Levinson, 2017). They are enabled by environmental sensors, and adaptive programming. Alternatively, nonlocalized automated vehicles are generally guided by some type of external control (Levinson, 2017). These vehicles are enabled by connectivity, and more rigid programming than their autonomous kin. While both types of vehicles could operate at level 5, automated vehicles are generally considered level 3 or 4 because of the potential loss of connection between a vehicle and its control (Levinson, 2017). If an automated car lost contact with its dispatcher, it would stop working, or would need a human to assume operations.

Figure 1
SAE Levels of Driving Automation
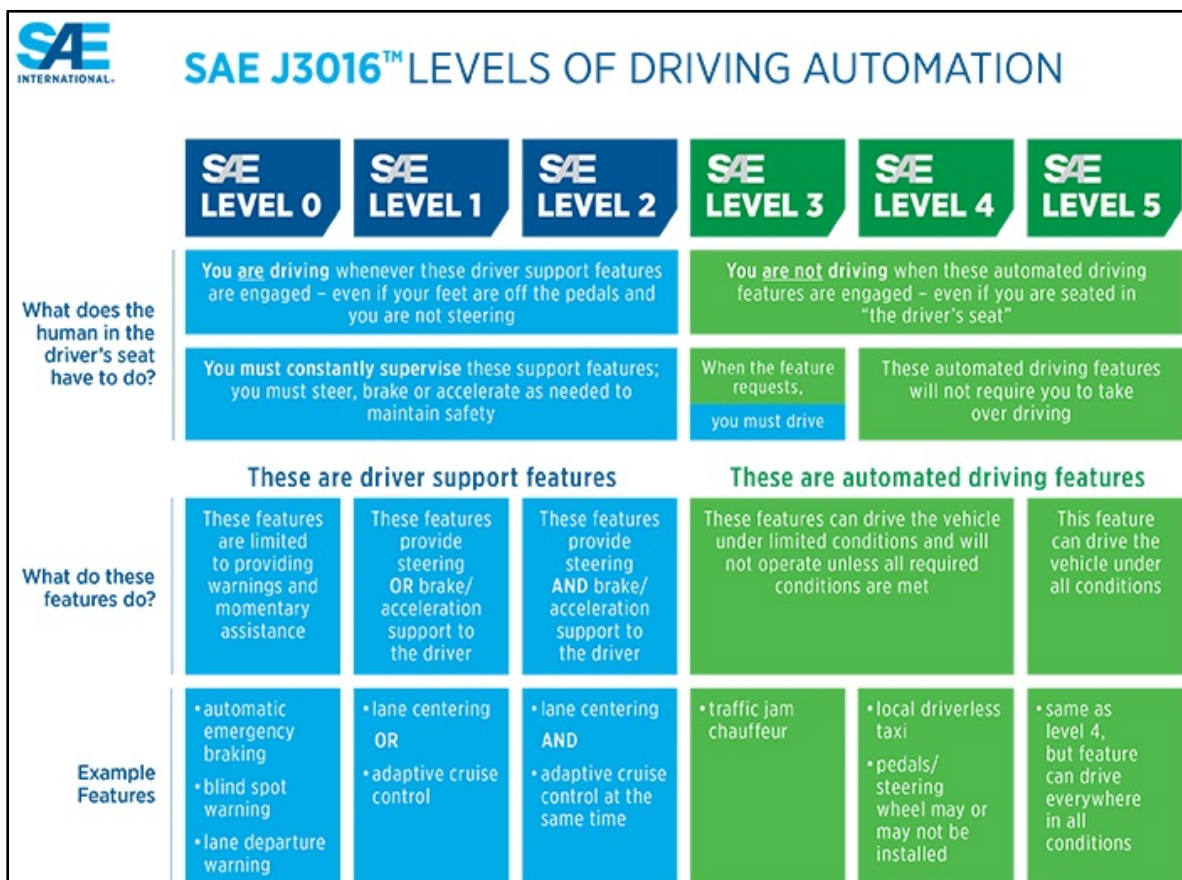
Figure Citation: Society of Automotive Engineers (2018, December 11). Levels of Driving Automation. *SAE International*.

In actuality, the vehicles currently being developed mix features of both autonomous and automated cars. This combination is necessary because it is better to be automated in some situations, and autonomous in others. To achieve both automated and autonomous potentials, a legion of components and software have been incorporated into these vehicles to ascertain where it is, what is around it, and what it should do next. These components can be generally classified as connectivity hardware or sensors, and the information they gather is organized and deciphered by some of the most cutting-edge computer programming in the world.

Self-driving vehicles rely on connectivity for a multitude of reasons. They utilize Global Positioning System (GPS) antennae to help determine where the vehicle is (Vakharia, 2018). They remain wirelessly connected to the internet to access highly accurate and constantly updating maps of their surroundings (Herrmann, Brenner, & Stadler, 2018, 101-4). They also retain cellular capabilities to report emergencies, or to facilitate occupants communicating with the outside world. These communication components may also allow vehicles to share information with each other directly, and potentially plan their movements in concert (Vakharia, 2018). In total, these connectivity components allow self-driving vehicles to acquire data they cannot generate themselves, and to share data from the sensors placed throughout its physical structure.

The other major type of physical component these vehicles rely upon is sensors. These sensors work together to create a comprehensive representation of the vehicle's surroundings with accurate distances, and velocities measured for all identified objects in the observable environment. To form this representation, each type of sensor provides a unique set of data that is combined and interpreted by software. As shown in Figure 2 (on Page 10), the types of sensors include cameras working in both the visual and infrared ranges of the light spectrum, radar units, Lidars units, and ultrasonic sonar units (Herrmann, Brenner, & Stadler, 2018, 95-6). Some sensors

of the same type are further delineated by their purpose. Some sensors are meant to sense objects nearby, while others are intended to sense objects further away. As an example, the primary Lidar unit on the vehicle's roof may be optimized to detect objects at greater distances than the other Lidar units located around the vehicle. Furthermore, different types of sensors can overcome the shortfalls of others. Cameras are often ineffectual in low light situations, but Lidar works well without ambient light (Dorazio, 2018). Simply put, each sensor has its own strengths and weaknesses, but by working together, the entire suite of sensors generates the data necessary to create an accurate representation of the vehicle's surroundings.

Figure 2
External Sensors on an Autonomous Vehicle
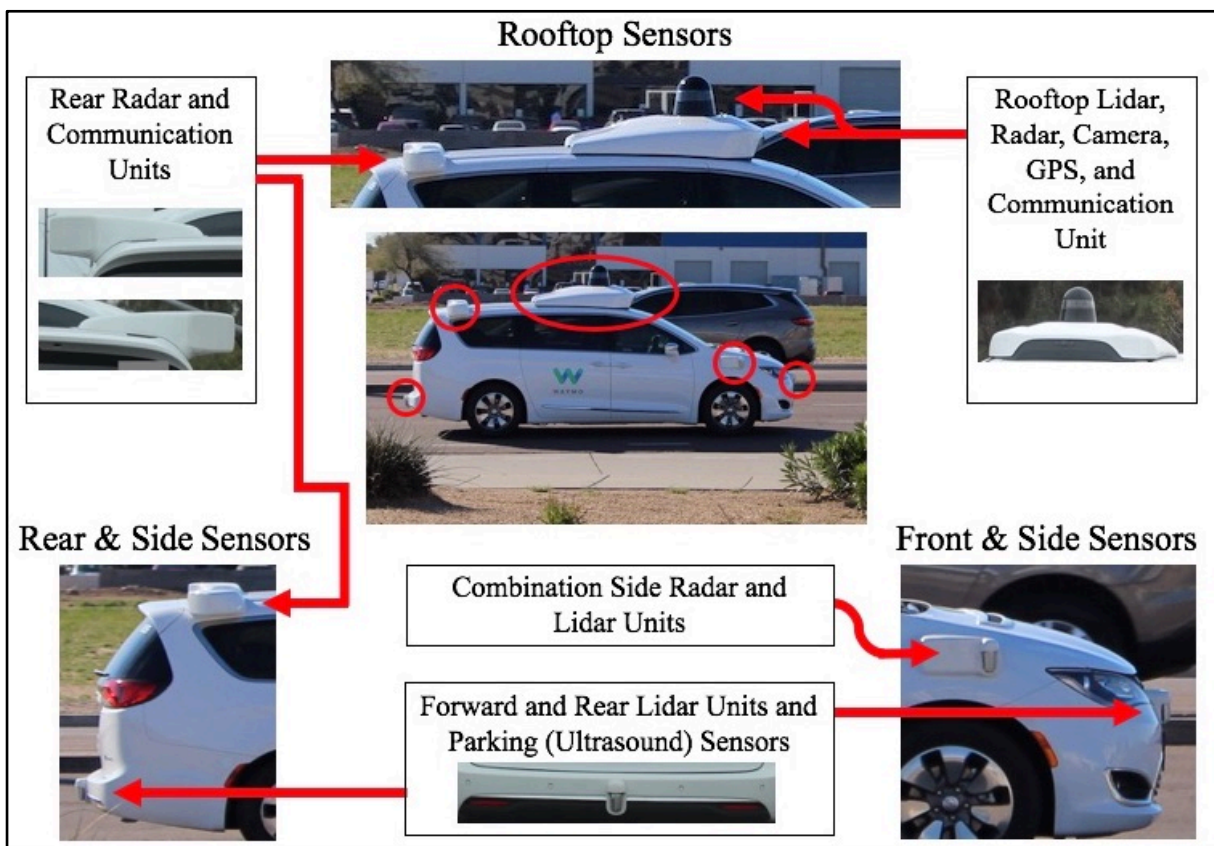
Figure Citation: Herrmann, A., Brenner, W., & Stadler, R. (2018). *Autonomous Driving: How the Driverless Revolution Will Change the World*. Bingley, England: Emerald. 95-6.
(Note: Images used in Figure 2 are from the author's collection)

Because of the ever-changing nature of sensing technologies, and the growing understanding of the limitations of existing sensors when applied to autonomous vehicles, self-driving cars will likely feature additional environmental sensors in the future. What exactly these sensors detect is as of now unknown, but they will likely be incorporated to produce more accurate representations of the vehicle's surrounding. For instance, some companies have called for thermal cameras to be installed in autonomous vehicles (Westbrook, 2018). While thermal cameras use infrared sensing technologies, they produce different images and different sets of data than other infrared cameras. In the future, the sensing needs of self-driving vehicles may call for new or previously unused types of sensors. Nevertheless, the goal of these sensors will remand the same: to produce the most accurate and detailed representation of the surrounding environment possible.

As an interesting aside, some have pointed out how these environmental sensors themselves may change the built environment of driving. Road signs, lane markings, and other directional cues along roads and highways were designed to be read by humans. There is a chance that these designs will need to change in order for them to become more easily detected by the sensors on self-driving cars (Vakharia, 2018). These conceivable changes may lead to a new set of standards for road signs and markings, and planners should know that these changes may occur.

The external sensors are without a doubt the more well-known and discussed sensing components of a self-driving vehicle, but there is another set of sensors hidden from the onlooker's eyes, monitoring the mechanical conditions of the vehicle itself. Within the wheel wells are sensors measuring steer angle and suspension dynamics. In the engine bay are dozens of sensors collecting powertrain data. Sensors gauging the chassis angle to both the horizon and to the roadway are located near the front of the vehicle, and scores of other sensors monitoring everything from acceleration, to wheel speed, to fluid levels are found in other places within the vehicle as well

(Herrmann, Brenner, & Stadler, 2018, 96-8). These internal sensors are required to provide the guidance software with vital information about the vehicle's location, performance, and heading. Without these internal sensors, crucial data for the self-operation of the vehicle would go unrecognized, and the software programmed to guide the vehicle could not fulfill its task.

While the sensors and communication hardware detect and collect information needed for the vehicle to operate without human intervention, it is an extremely complex set of programming that actually controls the vehicle by making predications based on the collected information. Within a central processing unit (or units) somewhere inside the vehicle, the data generated by the enabling sensors and external sources are interpreted by a program. First, this program recognizes all recognizable objects within the environment (Heaps, 2017). The program then assigns a set of predications to each object, and assigns probabilities to each predication. By using the GPS facilitated directions to determine the optimal path to its assign destination along with these sets of predications, the program determines when to slow down, when it is safe to turn, when it needs to accelerate, and so on. Machine learning algorithms then assess the accuracy of these predictions depending on the succeeding set of incoming data (Herrmann, Brenner, & Stadler, 2018, 96-102). These machine learning algorithms can revise the protocols calculating the aforementioned probabilities, and can program new conditions the vehicle must recognize and account for. This set of software is the actual driver of a self-driving vehicle. It is vastly sophisticated, and it is the principal aspect of self-driving cars that make them so potentially transformative.

As this software operates the vehicle, the data it is generating along with all the data from the sensors around the vehicle are being shared or stored for future use. Much like how an engine needs fuel without impurities, the software operating self-driving vehicles needs data without inaccuracies. By sharing the data generated by each vehicle, new and more accurate maps can be

produced, better prediction protocols can be written, and the use of self-driving vehicles can become more reliable (Vakharia, 2018; Herrmann, Brenner, & Stadler, 2018, 101-7). This data has an irreplaceable role in the development of autonomous vehicles. Unfortunately, the need to share it could leave it open to attack, sabotage, misuse, and unnecessary commercialization.

As with any new technology that generates terabyte upon terabyte of data, there are serious concerns over the safety and subsequent use of that data. Firstly, who owns this data? Is it the developer, the vehicle owner, the passengers? Is this data open for anybody to use? These questions must be answered to begin securing this immensely important information (Vakharia, 2018). The accuracy of this data is tied directly to physical safety. A single tampered line of data could create substantial consequences to an unsuspecting passenger, pedestrian, or to the occupants of another vehicle. Moreover, there is a distinct possibility that this data – regardless of its owner – may become commodified and sold by a third party wholly unrelated to the development, ownership, or use of a self-driving car. McKinsey and Company (2016) are already looking for ways to profit off the data generated by autonomous vehicles, and the public must determine when this type of business practice should be acceptable. These concerns are just a few of the ethical quandaries that may arise with regards to the data generated by self-driving vehicles. Like most contemporary technologies, the data they create can be a blessing or a curse, and ways to ensure that such data is shared and stored responsibly, safely, and without misappropriation must be established.

While the terms self-driving, driverless, autonomous, and automated all mean slightly different things, their meanings all share one aspect in common. They all refer to a vehicle that removes at least part of the driving responsibilities from human occupants. If fully successful, these vehicles would allow passengers to dedicate their attention elsewhere – at least temporarily. When thinking of cars, automation and autonomy may seem like concepts from a science fiction

movie, but these technologies are here. They are already being testing in some parts of the world. Whatever the public ends up calling these vehicles, one term will undoubtedly remain – the car. It may be autonomous, it may be driverless, but to the average individual, it will still be a car. No matter if they own it, share it, or hail it, a car is a car, and its uses will remain mostly the same.

Chapter 3
The Developmental History of Self-Driving Cars

The history of automobiles is a story of automation. Whether it be for propulsion, production, operation, or control, automation has always been a goal of car manufacturers. The first cars were intended to automate the propulsion of the carriage. Later, the Ford company utilized the assembly line to automate as much of the production of the Model T as possible. Through the course of the twentieth century, a series of small developments, such as the automatic transmission, and anti-lock brakes automated operational tasks that drivers were formally reasonable for. And today, dozens of developers are automating the act of controlling the direction and speed of the vehicle. The automobile is finally approaching what it was always meant to be, automated. This change may fundamentally alter how automobiles operates, but it will not change the automobile itself. Automobiles have always been about automation, and probably always will.

Concepts for automated control of automobiles date as far back as the 1920's. At the time, America's love affair with the car was blossoming. Automotive use in the United States was more common than in other countries, and safety concerns surrounding these vehicles began to percolate. To address these concerns, some visionaries (as well as science fiction writers) began discussing automated control (Herrmann, Brenner, & Stadler, 2018, 39). The exact technologies that would facilitate automation was unknown, but the idea that control of automobiles could be taken out of drivers' hands was born. In the following decades, rudimentary suggestions for

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automated control such as roadbed equipped wire guidance systems were theorized, but the technology to make such suggestions practical had yet to be developed (Herrmann, Brenner, & Stadler, 2018, 40). These concepts may have been too aspirational for their day, but other developments were laying the foundations necessary for the self-driving vehicles that now exist.

Figure 3
Development of Self-Driving Vehicle Technologies Timeline
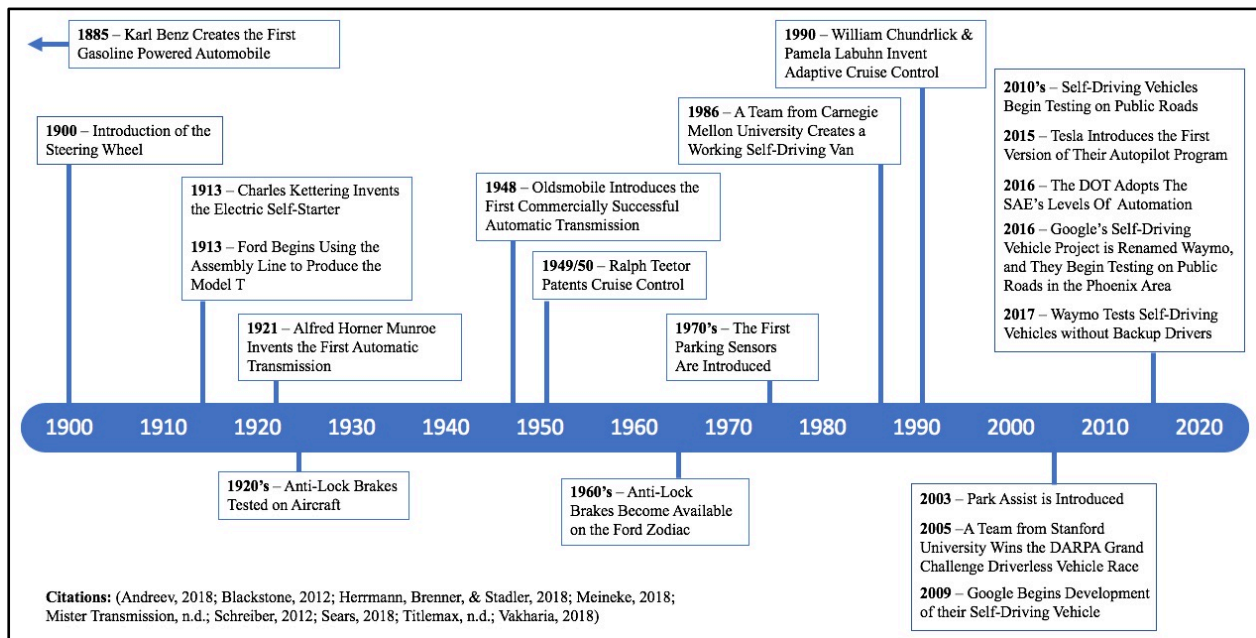
One could argue that the first step towards automated control was creation of the electric self-starter. Prior to the advent of the self-starter, drivers had to crank start their automobiles – often a highly physical and dangerous task (Schreiber, 2012). The self-starter allowed drivers to start their cars in a reliable and safe fashion. Much like the sensors and guidance programming of a contemporary self-driving vehicle, this simple electric starter, took over an aspect of the vehicle's operation. As shown in Figure 3 above, the electric self-starter was followed by a series of developments that each took control of some aspect of the vehicle's operation. Automatic transmissions took the task of shifting gears out of the driver's hands. Anti-lock brakes enabled

the vehicle to correct lock up without the driver anxiously pumping the brake pedal. Even recently, Tesla has developed automatically engaging turn signals to compensate for drivers who forget to indicate a lane change (Hyatt, 2018). Each of these inventions automated vehicular operation to some degree, and are utilized by the self-driving systems of today.

Some may claim these developments only facilitate operation of the vehicle without affecting the driver's level of control, but the creation of cruise control in the late 1940's shows how the process of automation with regard to vehicular control began decades ago. Cruise control sustains the speed of the vehicle at a rate set by the driver, allowing the driver the forgo operation of the throttle for some time (Vakharia, 2018). This feature undoubtedly assumes one aspect of the control of the vehicle: the maintenance of its speed. While there is some merit to the argument that control of the vehicle is defined by heading and speed alone, this argument ignores all the other tasks necessary to control heading and speed, such as gear selection. Regardless of one's view of what technologies automate the act of driving, the fact remains that the process of automation began long ago.

Building upon the advancements of the early and mid-twentieth century, a team from Carnegie Mellon University built the world's first self-driving road vehicle in 1986. This vehicle, a large van, was conceived as a mobile lab to test self-driving technologies (Reilly, 2016). It usually avoided public roads, and was quite slow, but it featured many elements seen in the self-driving cars of today. The van was outfitted with a collection of sensors gauging the environment, the ability for a backup driver to override self-driving mode, and high-performance computers assessing sensor data and ultimately guiding the vehicle. All the technological advancements discussed above may have been aimed in some way or another at automation, but this van was the first proof-of-concept. What was critically different between this van and all automobiles before it

was its sensing capabilities, and the level of computing power it utilized. At the time, this level of computing power required a large box van to contain it all, but computing power was already shrinking rapidly, and cellular data technology would soon be able to provide such computers with additional data about the environment. The movement towards self-driving vehicles was quickly accelerating, and by the mid-2000's, the federal government would encourage its progress, and major companies would begin playing a role in the development of driverless cars.

The next major step towards automation was the DARPA Grand Challenge. DARPA, the Defense Advanced Research Projects Agency, is a branch of the Department of Defense aimed at encouraging the development of technologies with military applications. It played a major role in the creation of the Internet, and would play a major role encouraging private corporations to develop self-driving vehicles. The DARPA Grand Challenge was effectively a race in the desert involving self-driving vehicles. The first event, held in 2004, produced no winner as not a single vehicle could reach its destination. However, the following year, a team from Stanford University claimed the Grand Challenge prize (Vakharia, 2018). DARPA held a third Grand Challenge in 2007 within a simulated urban environment (Herrmann, Brenner, & Stadler, 2018, 41). This final challenge was won by a team from Carnegie Mellon (a fitting victory for the home of the first self-driving van). While DARPA's challenge was won by university-based teams, it encouraged private manufacturers and firms to consider developing self-driving technologies. Soon Cisco, Google, Navya, Audi, Nauto, and other companies would all play a role building the technologies needed to mass produce self-driving vehicles (Herrmann, Brenner, & Stadler, 2018, 41-5). The DARPA Grand Challenge proved that self-driving vehicles could drive in all types of environments, and the private sector realized that these vehicles had the potential to be a major source of revenue.

Since the DARPA Grand Challenge, self-driving technologies have advanced faster than ever before. In the United States, these advancements have been led by three main developers; Alphabet (the parent company of Google), Uber, and Tesla. The branch of Alphabet responsible for their autonomous technologies was originally known as the Google Self-Driving Car Project, but it is now known as Waymo. Many experts believe that they are the true leaders of self-driving technologies, and they are the developers that this thesis is focused on (Neiger, 2018). Waymo is considered the most advanced self-driving vehicle developer for many reasons. They build their own hardware. Their parent company is one of the wealthiest firms in the world. Their self-driving vehicles have driven over 8-million miles of testing with over 24,000 miles added daily on public roads, and they have a strong partnership with the Fiat Chrysler family of vehicles as well as Jaguar (Neiger, 2018). Waymo began road testing in the early 2010's, and began testing on Phoenix metropolitan area roads without a backup driver in 2018 (Locklear, 2018). Late last year, they rolled out an experimental ride hailing service known as Waymo ONE, and will hopefully make this service available to anyone in the Phoenix area in the near future (Korosec, 2018). Waymo, is at the forefront of self-driving automobiles, but there are many trailing them. Dozens of companies are building their own self-driving technologies, and each is differentiating itself from the pack.

The companies involved in the development of autonomous vehicles are starting to establish unique business models relying on self-driving technologies. Waymo and Uber are pursuing ride-hailing services. Many manufacturers are formulating ways to preserve private ownership and daily use of their vehicles, and others are developing autonomous vehicles with specialized purposes. Volvo is approaching the development of self-driving vehicles in two ways, long-distance travel, and freight. In 2018, Volvo showcased a self-driving car with a fold out bed, luxurious seating, numerous screens/monitors/surfaces for entertainment and productivity, and a

pair of rendered passengers enjoying what appears to be sparkling wine (Gitlin, 2018; Walker, 2018). Volvo asserts that plane travel is an unenjoyable and tedious experience, and they bet that travelers of the future would rather ride in their comfortable self-driving sedan. At the same time, Volvo is developing self-driving trucks for localized freight movement. These trucks have no cabs, or anywhere else for passengers to sit, and are intended for use in, "…[P]orts, factory areas and mega-logistics centers… (Baptiste Su, 2018)." The variety of autonomous vehicles in development suggest that the self-driving vehicles of the future will be highly specialized, with some vehicles designed for every-day, private use within metropolitan areas, others designed for long distance travel, and others designed for ride-hailing services in highly urban cities. Much like how automation of manufacturing led to specialized machines, robots, and human jobs, automation of driving might lead to a spectrum of specialized vehicles each with a target market and environment.

The promise of the automobile has always been automation. For the last century, from the advent of the self-starter, to the testing of Waymo vehicles on public roads, the goal of the automobile has been to remove as much of the operational and guidance responsibilities from the hands of users as possible. The creation of self-driving capabilities may be the most transformative step in this process, but it is a step that would have not occurred without all the steps that laid before it. Autonomous vehicles may seem like the wave of the future, but it is a wave spawn from the rumblings of the past. The world is familiar with the automobile, and while the autonomous car will certainly change some aspects and ramifications of automotive use, these changes will occur because of decades of developments, not because of a singular event. Planners know how to plan – and how not to plan – for automobiles, and many of the practices of the past will still be relevant in the future. However, just because many places were designed for the use of cars does not mean that planners can sit idly as self-driving vehicles become widespread. On the contrary,

the development of these vehicles requires planners to step up, and to prepare the world for the coming autonomous tsunami. In no uncertain terms, self-driving vehicles will need to planned for, and their development provides an opportunity to plan in light of the mistakes of the past.

Chapter 4
Reasons to Plan for Self-Driving Cars

Some may argue that autonomous road vehicles do not need to be planned for because most American cities are already planned for traditional automobiles. While both types of transportation bare noticeable similarities, autonomous vehicles have both positive and negative potentials with regards to public health and the sustainability of dense, urban areas that traditional road vehicles simply do not. Well thought-out, advanced planning could support the positive effects of autonomous vehicles, while mitigating their negative outcomes. Figuratively speaking, widespread use of autonomous vehicles is a double-edged sword that all cities will be forced to wield. Planning actions could temper the effects of autonomous vehicles to best serve cities and their residents, and governments of all types should prepare for these vehicles now. Common use of self-driving cars could occur within a lifetime. Given their benefits to public health, planners should encourage the use of self-driving vehicles, but they must plan for them remembering the flaws of the planning practices of the past.

The development of autonomous vehicles is transforming the concept of traffic safety, and planning should support this change. Janet Fleetwood (2017) of Drexel University writes, "From the vantage point of public health, the overarching goal [*of autonomous vehicles*] is to transform the current approach to automotive safety from reducing injuries after collisions to complete collision prevention (p.532)." Currently, traffic accidents account for 32,000 deaths, and more than 2 million injuries in the United States each year (Kalra, & Paddock, 2016, p.182). Autonomous

vehicles could eliminate most of these casualties. In the future, manufacturers will not advertise cars by emphasizing how safe they are during a crash. They will market them on how well they can detect, predict, and avoid collision risks. Some may challenge the assertion that all collisions are avoidable, but autonomous vehicles do not need to avoid all accidents to provoke this change in perception. Use of self-driving cars will likely lead to fewer collisions, and this difference will change how people, and the planning profession view traffic safety.

The most impactful way automation/autonomy will affect driving safety is by mitigating the effects of human error. Nearly 93% of all collisions are caused by human error, and researchers predict that approximately 90% of all accidents would be avoided if every vehicle was autonomous (Pettigrew, 2017, p.5). Nidhi Kalra and Susan Paddock of the RAND Corporation study the drawbacks to human control, and the importance of automation. They state, "…[A]utonomous vehicles are never drunk, distracted, or tired; these factors are involved in 41%, 10%, and 2.5% of all fatal crashes, respectively (Kalra, & Paddock, 2016, p.182-3)." People are often poorly suited to get behind the wheel. Day to day life is full of distractions and stressors which frequently cause the act of driving to be an afterthought. Use of autonomous vehicles removes the potential for human error, which could cut back on collisions, and ease the burden placed on medical services.

By shrinking the number of traffic collisions, the transition to widespread use of autonomous vehicles could improve the availability of emergency and rehabilitation services. Simone Pettigrew (2017) of Curtin University in Australia believes that autonomous vehicles will reduce automotive injuries, "…[F]reeing up… thousands of beds in hospitals and rehabilitation facilities (p.5)." Improvements to traffic safety caused by autonomous vehicles could allow hospitals to dedicate more resources to other types of injuries and disease. This change, albeit a secondary effect of autonomous vehicles, would advance public health nonetheless.

Pettigrew also points out that autonomous vehicles could improve the lives of people with physical or cognitive limitations. She argues that autonomous vehicles may provide the elderly and mobility-challenged with greater access to distant places and could help them socialize with their community as a whole (Pettigrew, 2017, p.5-6). Pettigrew (2017) states that dependence on caretakers, and social isolation are conditions tied to high mortality rates among the elderly and mobility-challenged, and autonomous vehicles could afford these people the means to create and maintain social connections (p.6). Social connections promote wellbeing, and autonomous vehicles could aid people with limited mobility sustain these connections, and live healthier lives.

Use of autonomous vehicles could also have substantial economic effects. Daniel Fagnant and Kara Kockelman (2015) estimate that the reduced costs from crash avoidance and other factors result in a single self-driving vehicle creating between $2,000 - $4,000 in annual economic benefit. At a 10% market share these vehicles could create $27 billion in annual economic benefit (Fagnant and Kockleman, 2015). These economic figures are promising, and are encouraging signs for the future of self-driving vehicles, but they should be a secondary concern after the aforementioned benefits to public health that widespread use of autonomous vehicles could create.

Autonomous vehicles' abilities to improve traffic safety and public health should be supported through planning, but these vehicles could also create problems that will need to be kept in check. Self-driving cars have the potential to be incredibly popular, which may result in congestion, higher rates of physical inactivity, and increased sprawl.

Planners and public health practitioners must realize that the proliferation of autonomous vehicles may promote traffic congestion. While many believe that autonomous vehicles will help reduce traffic at chokepoints and bottlenecks (Guerra, 2016, p.210), the popularity of autonomous vehicle may expand the use of automobiles in general. Pettigrew (2017) writes, "The convenience

and inclusivity of [*autonomous vehicles*] could result in an increase in the total number of kilometers travelled, placing upward pressure on congestion… (p.6)." The ease of operating a self-driving car may encourage (or allow) people to use personal vehicles who otherwise would not. The choice to use a car over other means of transportation is somewhat situational, and access to an autonomous vehicle could encourage people to use a personal vehicle in more situations.

American projections assessing the impact of autonomous vehicles on Vehicles Miles Travelled (VMT) support Pettigrew's assertion. These models predict an increase in VMT, coupled with reduced use of public transportation (Guerra, 2016, p.217). Despite the belief that autonomous vehicles will navigate through traffic more efficiently than human drivers, congestion will still likely increase due to the sheer number of vehicles on the road.

Growing reliance on personal vehicles may lead to unhealthier lifestyles as well. Autonomous vehicles could change people's behaviors for the worse by causing them to live more sedentary lives (Pettigrew, 2017, p.6). Current data on autonomous vehicles predicts reduced use of, "…[N]on-motorized modes [*of transportation*] (Guerra, 2016, p.217)." In short, people will be less likely to walk, bicycle, or engage in physical activity to travel if an autonomous vehicle is readily available (Guerra, 2016, p.219). Physical inactivity is already a major public health concern, and self-driving cars may only worsen this problem.

Self-driving vehicles may also stimulate sprawl. Use of autonomous vehicles will allow commuters to work or play while being driven to work, or to a night out on the town (Pettigrew, 2017, p.6). The ability to dedicate oneself to a non-driving task may allow for families and individuals to live further from the metropolitan core than they would if only conventional cars were available (Pettigrew, 2017, p.6). Suburban sprawl has been identified as a major factor in the decline of traditional cities during the mid-twentieth century, and is associated with the inequitable

distribution of socioeconomic opportunities (Pfeiffer, 2016, p.799). Sprawl has historically led to disadvantaged urban and minority neighborhoods, the wasteful use of energy, and other concerns that planners must combat. Autonomous vehicles many facilitate suburban sprawl, and strategies to relieve sprawl's negative health and socioeconomic effects will be needed.

Autonomous vehicles can improve traffic safety by reducing the number of collisions on the road, but they could also increase reliance on personal cars. Nevertheless, autonomous vehicles will soon be available to purchase, and cities will need to adapt. Planners must find ways to prepare cities for driverless vehicles, while concurrently managing the negative effects associated with this technology. Fully committing cities to the use of automobiles proved disastrous for many communities during the latter half the last century, and while planners should promote the use of self-driving cars today, steps must be taken to avoid a similar result. Many of the negative effects discussed above are the same negative effects caused by traditional automobiles. Decades of working with cars have provided planners with the means to limit these effects, and should employ these tactics while looking for new methods provided by autonomous vehicle technologies. Self-driving cars are coming. Planners could leave the planning for these vehicles up to private enterprise and chance, or they could plan for them to serve society in the best way possible.

Chapter 5
The Current State of Transportation Planning for Self-Driving Vehicles

Use of autonomous vehicles will become widespread over the next few decades, but as of now, few metropolitan areas are planning for this technology. Erick Guerra of the University of Pennsylvania recently examined how cities are preparing for autonomous vehicles. His results are shockingly worrisome. Guerra (2016) examined the Regional Transportation Plans (RTPs) for the 25 largest Metropolitan Planning Organizations (MPOs) in the United States, and found universal

ambivalence to the development of autonomous vehicles. He writes, "A review of the RTPs of the nation's twenty-five largest metropolitan areas finds that none has incorporated self-driving cars and only one mentions the new technology (Guerra, 2016, p.217)." In an interview completed in preparation for this thesis, Guerra now acknowledges that some MPOs have begun planning for self-driving vehicles. But there are others who have yet to begin preparing for their use. The development of autonomous vehicles is outpacing ongoing testing (Kalra, & Paddock, 2016, p.191). Highly-autonomous vehicles will be available for sale in a few short years. Metropolitan areas need to adapt to maximize the benefits of autonomous vehicles, but as of 2018, only a few major metropolises in the United States are planning for self-driving cars.

Given the positive health benefits of autonomous vehicles, cities and metropolitan areas should facilitate acceptance of self-driving cars. Swaminathan Gopalswamy and Sivakumar Rathinam (2018) of Texas A&M University state, "…[W]ith a 50% [*market*] penetration, autonomous vehicles [*could*] result in 9,600 lives saved per year, 1.9 million fewer crashes, $50 billion in economic savings, 1.6 billion hours saved in less time traveled, and 224 million less gallons of fuel consumed (p.1)." To achieve these benefits, 50% of automobiles on the road will need to be autonomous, and many believe that the best way to encourage adoption of this technology is to rethink how road systems operate (Chen, He, Yin, & Du, 2017, p. 45).

Many researchers have called for the implementation of autonomy-facilitating technologies into existing highways and roads. Gopalswamy and Rathinam (2018) point out that manufacturers currently bare all the responsibility for ensuring autonomous vehicles are as safe, and publicly beneficial as possible. They argue that all levels of government should become involved and retrofit existing infrastructure with technology that assists autonomous vehicles (Gopalswamy, & Rathinam, 2018, p.3). They believe that road systems should incorporate "Road-

Side-Units" outfitted with devices that monitor traffic-flow and other conditions. These units would then communicate with self-driving vehicles, providing them with information, or instructions intended to optimize safety and efficiency (Gopalswamy, & Rathinam, 2018, p.3-4). They call this theoretical system "Infrastructure Enabled Autonomy," and recognize that "Road-Side-Units" would initially be utilized solely on major highways and thoroughfares (Gopalswamy, & Rathinam, 2018). Autonomous vehicles would still need to be fully independent (or driven by humans) on smaller roads. Planners should be aware of this suggestion, and other similar systems. By incorporating technologies that facilitate autonomy along major roadways, cities can promote the transition to autonomous vehicles, while simultaneously maximizing their beneficial effects.

Some researchers have gone one step further and suggest driverless vehicle zones with similar roadside technologies. These suggestions are based on the belief that the only way to maximize the safety and efficiency of self-driving vehicles is to prohibit other vehicles from certain areas (Chen, He, Yin, & Du, 2017). All self-driving vehicles that enter these zones would be completely controlled by a centralized computer with access to all the sensory information generated by every vehicle, and every "Road-Side-Unit" within that zone (Chen, He, Yin, & Du, 2017, p. 45; Gopalswamy, & Rathinam, 2018). Such suggestions are based on the premise that a centralized system directing all vehicles will maximize traffic efficiency and safety, and planners should consider if these systems are appropriate for areas being planned for.

An added benefit of updating existing infrastructure with technologies that facilitate autonomy is the potential to counteract the added congestion caused by the growing number of autonomous vehicles. Having sensors capable of assessing congestion along roadways will allow autonomous vehicles to predict reoccurring congestion patterns (Chen, He, Yin, & Du, 2017;

Gopalswamy, & Rathinam, 2018). Overtime, autonomous vehicles as a whole may be able to predict, and avoid congestion causing situations despite the large number of vehicles on the road.

Planners should encourage the installation of autonomy-enabling technologies along major roads and highways to maximize the benefits of autonomous vehicles, but these enhancements will not mitigate the negative effects of these vehicles alone. To mitigate the adverse effects of the vehicles of tomorrow, planners must also utilize proven and novel policies to restrict sprawl.

To restrict sprawl, and the growth of sedentary lifestyles caused by the adoption of autonomous vehicles, new and existing developments could incorporate "smart growth" principles. "Smart growth" is an urban design paradigm that calls for the construction of compact, mixed-use areas with access to quality public transportation, and ample open space near city centers (Durand, et al, 2011). This combination of design elements encourages density and healthier lifestyles. Research shows that "smart growth" promotes physical activity (Durand, et al, 2011), and density counterbalances sprawl. Autonomous vehicles could fuel sprawl and sedentary lifestyles, and planners could temper these effects with "smart growth" developments.

However, there are still doubts that these suggestions could combat the negative effects of self-driving cars if they are privately owned. Some believe that the only way to calm the negative effects of driverless technologies is to implement them in shared vehicles or public transit.

One possible solution to combat the growth of VMT and the potential sprawl predicted with the use of autonomous vehicles is to transition away from private vehicle ownership and to a ride-hailing model (Vakharia, 2018). Autonomous ride-hailing (or ride-sharing) is a system where people who need transportation could hail an autonomous vehicle to take them to their destination. This system is slightly less convenient than private vehicle ownership, and may encourage less vehicular use and more trips with multiple passengers. It may also lead to reduced demand for

parking. Instead of a private vehicle remaining parked all day between commutes, a shared vehicle could be used in a string of hailed trips (Vakharia, 2018). Waymo has been testing such a system in Phoenix using volunteered participants for nearly a year now, and the company plans to roll out a commercial venture offering such a service to everyone in the Phoenix area within a few months (Greig, 2018). Waymo is even partnering with Walmart and other retailers to encourage people to forgo their private vehicle for shopping trips by offering free or discounted rides. (LeBeau, 2018). Ride-hailing is a promising way to reduce VMT and sprawl, but it is untested, and comes with significant doubts whether it could be implemented nationwide.

Simply put, ride-hailing may not be viable in every city, and may require major policy changes or even subsidization to be effective at reducing VMT and sprawl. There are serious doubts whether smaller cities could support a commercial autonomous ride-hailing system, and some areas are too rural to even consider them at all. In these areas, private vehicle ownership will probably remain. Furthermore, car manufacturers have a desire to maintain a transportation market based on private vehicle ownership (Vakharia, 2018). They want to sell a car (or two) to every household. Ride-hailing services may even block certain areas for more profitable ones if left to their own devices. For ride-hailing to function properly in most cities, policies will need to change, and authorities may need to subsidized them to ensure they operate in equitable ways.

Another proposed suggestion to combat the VMT and sprawl caused by self-driving technologies is to make public transit autonomous. Peter Calthorpe, a noted urbanist, believes that private use of self-driving cars will increase congestion. He contends that the best use of this technology is to implement autonomous bus routes and other forms of driverless public transit (Markoff, 2018). Such technologies are already in use in Istanbul, Barcelona, Rome and even on the L-train in New York (The Daily Sabah, 2018). Incorporating driverless technologies into bus

routes would expand the applicability of these technologies considerably, and may even lead to denser, more-urban inner suburbs. Moreover, Denny Zane of MoveLA, a transit advocacy group, believes that driverless busses could urge housing developments along transit corridors, and these routes would in-turn draw new and existing residents away from private vehicle use (Markoff, 2018). The possibilities created by autonomous transit are vast, and may restrict VMT and sprawl.

While there is an ever-growing agreement over the need for autonomy-facilitating infrastructures within road systems, and for solutions to restrict the sprawl widespread use of self-driving vehicles may create, there is a lack of research when it comes to the role of public policy in planning for self-driving vehicles. Thankfully, some state and local governments have already regulated the use of autonomous vehicles to some extent. Planning for autonomous vehicle may have only just begun, but there are emerging opportunities to examine and assess public policies governing their use. By exploring these policies now, suggestions for future practices may be discovered. Planning should investigate the policy implications of the widespread use of self-driving vehicles now, and there is no better place to do so than in Phoenix.

Chapter 6
The History of Phoenix, Arizona, and its Ties to the Development of Self-Driving Technologies

At first glance, the Phoenix area may seem like an odd place to test self-driving vehicles. It does not have a rich history of automotive testing and manufacturing like Detroit, nor is it the tech-mecca that is Silicon Valley. In the eyes of developers, Phoenix is an ideal place to test self-driving vehicles not because of a single factor, but because it has the right mix of conditions. Phoenix provides year-round sunshine that allows for daily testing in predictable conditions. Similar to most American cities, it anchors a metropolitan area with swaths of suburbs. While not

as concentrated as California's Bay Area, the Phoenix area is home to a dense talent pool of tech firms and highly trained workers. And probably most importantly, Arizona's government provides a supportive and welcoming environment for self-driving technology developers. These conditions have convinced Waymo, Uber, and other companies to test their vehicles in the Phoenix area, and mutually beneficially relationships are developing between some of these firms and the local area. However, testing in the Phoenix area has also led to some disconcerting traffic accidents, and even one death. Despite these incidents, Arizona has remained the American epicenter for self-driving vehicle testing, and will likely remain so into at least the near future. Phoenix offers developers a constructive mix of testing conditions, and it is unlikely for this mix to change anytime soon.

Most of Arizona's population growth occurred after World War II. During the War, the Phoenix area was selected as a training site for pilots and other military personnel (C-SPAN 2016; Rex, 2000). After the war, the area attracted many former trainees because of its weather, and the low cost for homes. Like most of the United States, large planned suburbs were constructed around the then-minuscule downtown of Phoenix. These incoming residents fueled the area's growth as a burgeoning manufacturing center, and established the area's general design as a mostly suburban metropolis (C-SPAN 2016; Rex, 2000). The area has remained primarily suburban to this day, but the area's economic focus on manufacturing shifted to technology during the 1980s.

The Phoenix area's weather and suburban design encourages the testing of self-driving vehicles in their own ways. At their current stage of development, self-driving vehicles need to be tested as much as possible. While these vehicles need to be tested in inclement conditions as well, there is a benefit to testing in an area with reliably warm and dry weather. In Phoenix, self-driving vehicles can be tested 24 hours a day, 365 days a year. Waymo and other developers chose to test

in Phoenix because they could continuously test vehicles with few interruptions due to weather, and this ability could allow their technologies to prove themselves as quickly as possible.

Furthermore, testing in a primarily suburban environment serves as a proxy to the design of most American metropolises. To paraphrase David King, professor of urban planning at Arizona State University who was interviewed as part of the research for this thesis, "More American cities are like Phoenix than like Manhattan." American cities are more often a mass of suburbs with a small urban core, than a large urban core with few suburbs. Testing self-driving vehicles in the Phoenix area prepares these vehicles for most American cities better than testing in New York City, or within San Francisco. Autonomous vehicles will have to be tested in dense urban areas to work successfully in such areas, but such areas are rare in the United States. Testing in a majorly suburban metropolis prepares self-driving vehicles for areas where they will be used most often. Hence, it makes sense for developers to choose to test in the Phoenix area.

The Phoenix area also provides developers with a vibrant tech scene to recruit employees and to establish business partnerships. In the 1980's, Intel and Motorola opened major operation centers in the Phoenix area. The establishment of major tech companies in the Phoenix area was followed by the creation of new Arizona-based start-ups such as Infusionsoft and WebPT (Camacho, 2018). By 2010, the Phoenix area had become known for its work in sensing technologies, and for its prominent tech scene. It soon acquired the nickname, "The Silicon Desert (Coxhead, n.d.)." Phoenix is an attractive place for tech companies because it offers lower operational costs and a rich talent base supported by existing firms and universities. These benefits allow self-driving technology developers to find well-trained individuals with experience in fields related to autonomy such as sensing, communication, and advanced programming (Camacho, 2018; Coxhead, n.d.). The Phoenix area also provides these developers with opportunities to form

partnerships with other tech firms. Phoenix may not be Northern California, but operating in the Phoenix area offers tech companies many of the same benefits nonetheless.

The final element that has made Phoenix a great place for autonomous vehicle testing is a supportive state government. In 2015, Arizona Governor, Doug Ducey, released an executive order requiring state agencies to facilitate the testing of self-driving vehicles on public roads in the state. (AZ Exec. Order No. 2015-09, 2015). This executive order mandated that no laws be established for self-driving vehicles beyond those regulating traditional vehicles. He augmented his original order in early 2018 to allow for the testing of self-driving vehicles without a back-up driver (AZ Exec. Order No. 2018-04, 2018a). Interestingly enough, this order created a regulation that does not apply for traditional vehicles; autonomous vehicles must be able to come to a safe stop before disengaging autonomous mode if there were ever a technical malfunction with the vehicles autonomous capabilities. Finally, the governor issued a third executive order later on in 2018 that created the Institute for Automated Mobility (AZ Exec. Order No. 2018-09, 2018b). This institute is intended to foster stronger relationships between the Arizona universities and autonomous vehicle developers, and to help maintain Arizona as a capital for self-driving vehicle developers.

On the heels of Governor Ducey's first executive order concerning self-driving vehicles, Waymo, Uber, and other developers began testing in the Phoenix area. In late 2016, Waymo set up a testing center in Chandler, Arizona, a city in the southeast suburbs of Phoenix (Woods, 2016). To celebrate this occasion, the governor took a symbolic first ride in a self-driving van (See Figure 4 on Page 33). The company was assuredly lured to the area in part by the governor-mandated pro-autonomous vehicle stance, and since commencing operations in Chandler, Waymo has been generally supported by most local politicians (Marshall, 2018). Yet autonomous vehicle testing has not had a perfect record in Arizona, and there are concerns that regulations have been too lax.

Figure 4
Governor Doug Ducey and Waymo's Director of Operations, Jennifer Haroon, After a Symbolic Ride in a Waymo Vehicle Celebrating the Company's Decision to Test in the Phoenix Area

Figure Citation: Wallace D. (2016). Photograph from Waymo Launch Event. From Woods, A. (2016, December 15). Governor Ducey Taken for a Driverless Ride in Google's Waymo. *Arizona Central*.

Both Waymo and Uber vehicles have been involved in traffic accidents since they began testing in Arizona. The most notable of these accidents was the tragic, and likely avoidable death of Elaine Herzberg. In March 2018, Herzberg was crossing a major road in Tempe when an Uber self-driving vehicle collided with her (Somerville, 2018). She would later die in a local hospital of her injuries. The Uber vehicle was occupied by a backup driver, Rafaela Vasquez. Unfortunately, Vasquez was allegedly distracted by her smartphone streaming a television show (Laris, 2018).

Uber was immediately ordered to halt testing by Governor Ducey, and would eventually stop testing autonomous vehicles in Arizona on a permanent basis (Davies, 2018). Waymo has also been involved in numerous accidents in the Phoenix area, but most of these accidents were found to be caused by the driver of the other vehicle (Marshall & Davies 2018; Bosnjak, 2018).

These accidents coupled with Ducey's permissive stance on regulating self-driving vehicles has led some to question Arizona's autonomous vehicle guidelines. While his order to facilitate self-driving vehicle testing has undoubtedly enticed developers to test in his state, many fear that Ducey's order to limit regulations introduces a safety hazard. Consumer Watchdog, a non-profit advocacy group, state that Ducey's policies create, "[T]he wild west of robot car testing (Neuman, 2018)." These criticisms basically claim that Ducey lured developers to Arizona by creating a lawless frontier. With these criticisms are growing in volume, some restrictions have been placed on self-driving vehicles – most notably the requirement for autonomous vehicles to come to a complete stop before leaving autonomous mode if a technical problem arises. However, Arizona is likely to avoid regulations to keep the state a welcoming place for autonomous vehicle developers. Whether or not such restraint will endure is a question left for another occasion, but there are doubts that a politically hands-off approach to autonomous vehicle testing is ideal.

Arizona probably has the best mix of conditions for autonomous vehicle development. Its climate allows for near-continuous testing. Its economy has produced a condensed source of tech employees and potential business partners, and its politicians support the testing of self-driving vehicles on public roads. These conditions have drawn developers to the state, and research-minded planners should keep an eye on Arizona to identify autonomous vehicle trends that appear in this setting. Arizona has produced a great environment for testing autonomous vehicles, making the state a great place to study from the planning perspective as well.

Part Two
Methods and Limitations
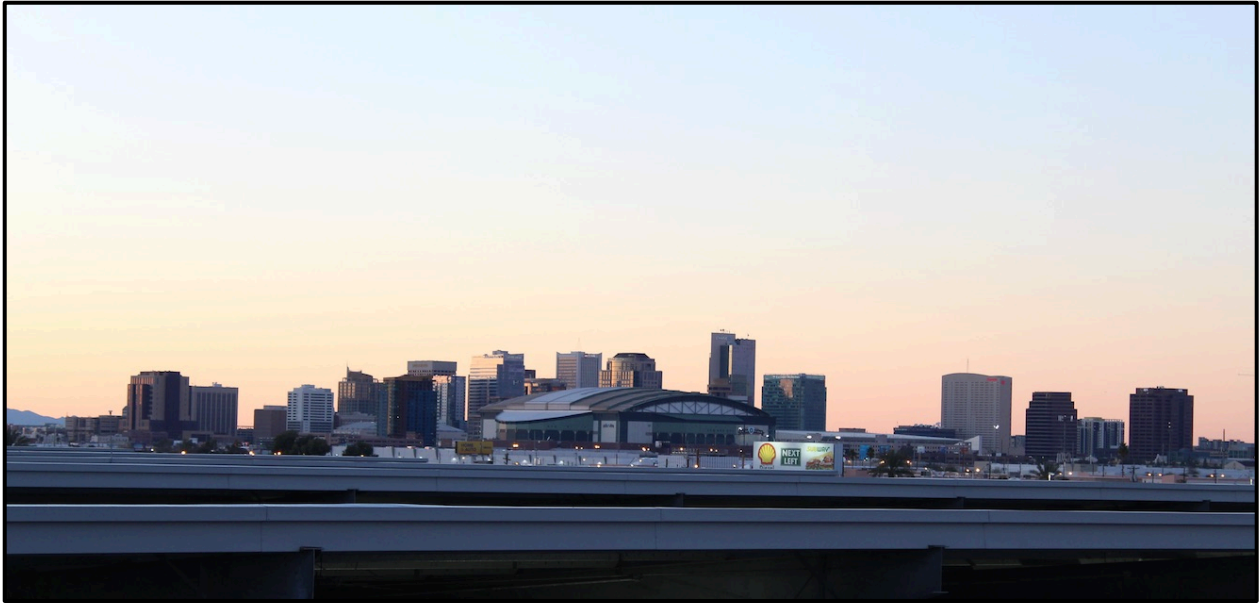
The Phoenix Skyline at Dusk

Chapter 7
Methods Overview: A Case Study of Phoenix

In broad terms, this thesis strives to uncover details of how planners will plan for self-driving vehicles. This research – by its very nature – is speculative. There are no publicly-available datasets with the necessary information to analyze. Furthermore, there are very few self-driving vehicles currently on the road. Because of these limitations, completing this research will require a method that produces its own data, focuses on an area with an established history of self-driving vehicle testing, and is as comprehensive as possible. A mixed-method case study of autonomous vehicle testing in the Phoenix area fulfills these requirements, and allows for this thesis to address multiple research question. In an ideal situation, robust data concerning the planning ramifications of self-driving vehicles would be readily available, but since it is not, the best way to complete this research is through a case study of the Phoenix area, and its relationship with autonomous vehicles.

The methods of this case study were tailored to address the following five research questions: (1) what are the public perceptions of self-driving vehicles, (2) how common are self-driving vehicles within testing areas, (3) what role will private firms creating autonomous driving technologies have in the planning for these vehicles, (4) what role will public agencies have in supporting and regulating the use of self-driving vehicles, (5) and are concerns of induced sprawl associated with driverless vehicles justified? By concentrating on these questions, this thesis will produce a through depiction of the current state of the development self-driving vehicles especially in regards to the social meaning these vehicles have with local communities, as well as indications of the political dynamics, and concerns that may influence or motivate future planning actions.

To address these questions, this case study is broken into four main methods. The first method completed was a regional analysis of Twitter content following the news that Waymo would begin offering a self-driving ride hailing service within a few months. The second method was a series of observational studies that took place in the Phoenix metropolitan area in early February, 2019. The third method was a commuting survey tasked with examining the potential effects driverless vehicles may have on sprawl. The fourth and final method, was a series of interviews with academic and journalistic autonomous vehicle experts, as well as a set of email correspondences with a political leader from the Phoenix metropolitan area.

Each of these methods was intended to stand alone. They were also intended to be complementary. In general, the purpose of a case study is to produce an in-depth analysis of a situation of interest. The comprehensive nature of this current study comes from both the strength of each individual method, and their synergistic aspects. These methods were designed to answer one or more of the research questions on their own, but as a whole, these methods were designed to examine the potential planning implications of self-driving vehicles as holistically as possible.

Chapter 8
Twitter Content Analysis

The first method employed was a Twitter content analysis intended to gauge public perceptions in the Phoenix metropolitan area of autonomous vehicles and autonomous vehicle developers. This method was inspired by a method utilized by Justin B. Hollander and Henry Renski (2015), and was originally performed as part of an assignment for the *Urban Data and Informatics I* class at Columbia University. This method allowed the researcher to measure public perceptions in the Phoenix area before visiting it, and helped shape the ensuing focus of this thesis.

On November 13, 2018, Waymo created a news storm by announcing that they planned to launch a commercial ride-hailing venture utilizing autonomous vehicles within the next few months, and were hopeful that it would be up and running by the end of the year (Randall, 2018). On the heels of this news story, the researcher used Twitter's Application Program Interface (API) to measure the public's reaction to this announcement in the Phoenix area as defined by a 68.5-mile radius around Phoenix's city hall (see Figure 5 on Page 38). This radius was chosen because it captured an area slightly larger than the Phoenix metropolitan area. The Phoenix metropolitan area is estimated to be 14,566 square miles large, and a radius of 68.5 miles produces a circle with an area of 14,741 square miles (Sperling's Best Places, n.d.). By utilizing a search area larger than the metropolitan area, most if not all geocoded tweets from the entire metropolis were collected.

Between November 18th and 19th, 2018, the researcher gathered geocoded tweets mentioning four topics over a 7-day period beginning at 12:01AM GMT on November 12th, and ending at 11:59PM GMT on November 18th. The four topics searched for were "Waymo", "Uber", the term "Autonomous", and "Valley Metro" (the Phoenix area's public transit authority). The researcher then analyzed the content of these tweets, identifying tweets that were overtly positive or negative about the topic searched for. The researcher also identified which tweets mentioned

the news discussed above, and which tweets mentioned self-driving vehicles. With each tweet

scored for their content, the researcher analyzed the entire set of tweets using descriptive statistics

producing reasonable findings informing the research questions presented in the previous chapter.

Figure 5
68.5 Mile Radius Search Area Around Phoenix City Hall
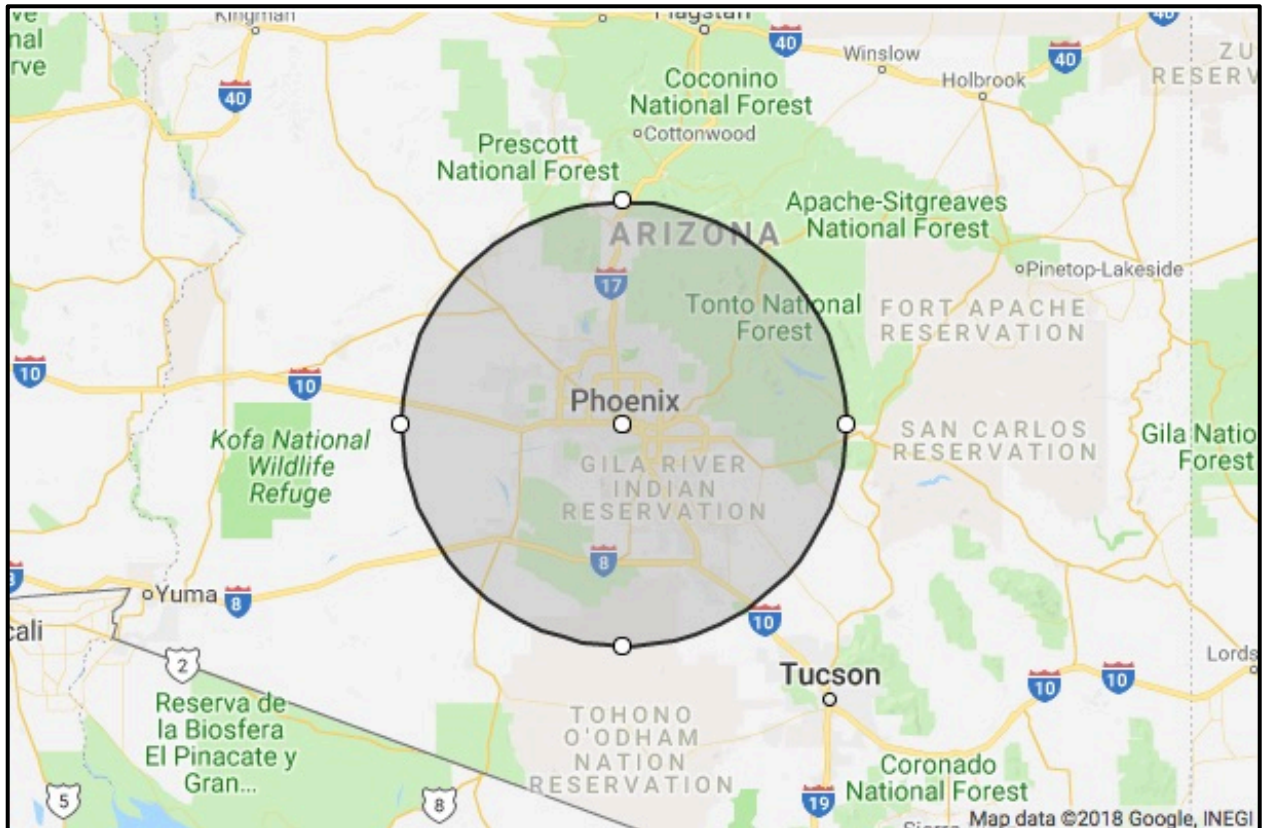
Figure Citation: Map Developers (n.d). Draw a Circle [Web Application]. *Map Developers*.
(Note: Application utilizes Google Maps for underlying map images)

Overall, 789 tweets were collected. The search term "Uber" produced 476 tweets.

"Autonomous" produced 130 tweets. "Valley Metro" originally produced 95 tweets, but this set

of data was eventually excluded (See the Limitations section on Page 39). And "Waymo" produced

88 tweets. The researcher was pleased with the large number of tweets collected, and was confident

that the datasets made up of these tweets would provide for meaningful findings.

Limitations

As with all research, this study was limited in some noteworthy ways. First, Twitter users are not a representative sample of all residents of the Phoenix area. Intuitively, it is reasonable to believe that Twitter users would be more favorable to new technologies than the population as a whole. Second, Twitter users can block geocoding capabilities, which means that some tweets relevant to this study may not have been collected. Third, the data for the local transit authority, Valley Metro, had to be excluded due to an extremely low number of relevant tweets. Of the 95 tweets collected that mentioned "Valley Metro," most were using the term to refer to the "Valley Metropolitan Area," not the transit authority. In total, only 13 of the 95 gathered tweets actually discussed the public transit authority. Because of the low number of collected tweets, and the potential analytical errors created by the two uses of the term "Valley Metro," all the data collected by the use of "Valley Metro" as a search topic was excluded. Likewise, a small number of tweets gathered for other topics were irrelevant to this study, such as "Autonomous" tweets discussing robot workforces. Finally, using a 68.5-mile search radius around Phoenix's city hall was somewhat arbitrary. Ideally, this study would have searched an area with the exact shape and size of the metropolitan area, but Twitter's API searches are limited to circular geographic areas as defined by a radius around a designated point, or by bounding boxes as defined by the location of northeast and southwest corners (Hollander & Renski, 2015). The researcher chose to use a circle instead of a box because the shape of the Phoenix metropolitan area fits better into a circle.

It should be noted that this method originally involved other forms of analysis not included in this thesis. The frequency of tweets per day, and the number of politicized tweets were measured to satisfy the aforementioned assignment for the *Urban Data and Informatics I* class. Neither of these methods are reviewed here because their operational foci are outside the scope of this thesis.

Chapter 9
Observational Methods

Observations in the Phoenix area were performed every day between Thursday the 7th, and Sunday the 10th of February, 2019. These observations were funded by a stipend provided by Columbia University, and utilized a rental car to visit sites of interest, and to monitor Waymo autonomous vehicles driving on public roads. The goals of these observations were to assess how well autonomous vehicles integrate into existing urban/suburban landscapes, and to identify any changes prompted by their use. These observations can be broken down into three overarching types: site observations examining the built environment, vehicular observations focused on the movements of Waymo vehicles, and a frequency observation measuring how common Waymo vehicles are in their host suburb, Chandler. These observations afforded the researcher with firsthand knowledge of how these vehicles function, and their place in the Phoenician community.

Site Observations

Observations began by visiting Walmart locations in the southeastern suburbs of Phoenix. Waymo recently partnered with Walmart to provide rides to and from Walmart locations (LeBeau, 2018). Thus, the researcher believed that they could find indications of Waymo's presence at Walmart locations. The third Walmart visited was the Supercenter on West Chandler Boulevard and North Country Club Way in Chandler. The locations visited earlier (in Tempe and Mesa) showed no indications of Waymo use, but this location in Chandler was actively used by Waymo vehicles. Upon arriving at this location, the researcher spotted a Waymo vehicle exiting the parking area. Furthermore, there were a set of four parking spots clearly reserved for Waymo vehicles as indicated by signage (See Figure 6 on Page 41). The researcher visited this location multiple times over four days, and on each visit spotted at least one Waymo vehicle in use. However, this was the

only Walmart location that the researcher observed Waymo use at. In total, the researcher visited six Walmart locations (all in Chandler, Tempe, or Mesa), and the location at 3460 West Chandler Boulevard was the sole location with observed Waymo activity or signage.

Figure 6
Signage for the Waymo Reserved Parking/Pickup Area at a Walmart in Chandler, AZ

The researcher also visited multiple Valley Metro light rail stations looking for indications of Waymo's presence in the area. In 2018, Waymo partnered with Valley Metro to provide connecting rides to and from their light rail stations (Randell & Bergen, 2018). Unfortunately, the researcher found no indications of Waymo use at the stations visited, or indications of the partnership between Waymo and Valley Metro besides a Waymo vehicle driving parallel to the

light rail tracks near Arizona State University in Tempe. Despite the lack of evidence for Waymo use near light rail stations, visiting these stations provided some useful observations nonetheless.

To the surprise of the researcher, the Valley Metro stations they visited were all well used and had easy pedestrian access as well as banks of shared bikes and scooters nearby. Furthermore, the researcher observed these bikes and scooters in heavy use – particularly near the university. The development of Arizona over the latter half of the 20th century resulted in car dependent cities, but the use of alternative transportation around Valley Metro stations indicate that transit and alternative forms of transportation are viable modes of travel in certain situations in Phoenix.

In totality, the researcher traveled throughout the Phoenix area looking for notable signs of Waymo use. They found that Waymo vehicles are used more in the southeastern suburbs compared to other locations in the metropolitan area. Chandler, the home of Waymo's operation center, has a particularly high number of Waymo vehicles on the road. With these observations in mind, the researcher decided to focus subsequent observations on Chandler, and neighboring communities.

Vehicular Observations

The researcher also monitored the operations of Waymo vehicles by following them on public roads. Most of these observations began after spotting a Waymo vehicle in operation while the researcher was traveling in their rental car along West Chandler Boulevard. The researcher would then change course to follow the Waymo vehicle, beginning the observation. Additional observations began at the aforementioned Walmart on West Chandler Boulevard, and some observations began by waiting for a passing Waymo vehicle at the exit of an unused parking lot on 56th Street in Chandler. When a Waymo vehicle passed, the researcher would drive out of the lot and follow the vehicle. Eight of these observations were performed. Six were performed during the day, and two were performed at night. Every observation began in Chandler, and six

observations ended in a different municipality. Of the two observations the ended in Chandler, one culminated at the Waymo operations center (See Figure 7 below), while the other ended at a local shopping center. Six observations lasted less than ten minutes, one lasted about 15 minutes, and one observation was called off after 20 minutes.

Figure 7
Images from the Waymo Operations Center in Chandler, AZ

Since these observations occurred while driving, and driving presents the risk for accidents, the researcher followed four rules to minimize accident risks. The first and most important rule was to avoid note taking while driving. Notes were written only after an observation was complete and the car was parked. Second, no unusual driving actions were taken to follow a Waymo vehicle under observation. As an example, during the course of one observation, the street light began to change from green to yellow. The researcher's rental car was about 30 yards behind the Waymo vehicle being observed. The Waymo vehicle easily made the light before it changed to red.

However, the only way the rental car could make the light would be to heavily accelerate. Following the guidelines laid out by the second rule, the researcher decided to end the observation and came safely to a stop at the now red light. The third rule was to end an observation if the Waymo vehicle enters a residential area. Entering a residential area could lead to research notes containing the personal information of Waymo users such as approximations of their addresses. Therefore, all observations that progressed into residential areas were ended immediately. The forth and final rule stated that no observation would last more than 20 minutes. The researcher conducting these observations had never visited the Phoenix area before. Restricting observations to 20 minutes or less ensured that they would not venture too far from the Chandler area.

As discussed in the prior paragraph, one observation ended following rule two, while another observation ended following rule four. Two more observations ended when the Waymo vehicle entered a residential area in line with rule 3. One ended at the Waymo operations center, and the remaining three observations all ended at commercial destinations.

These observations produced four main results. First, locating Waymo vehicles to observe was very easy in Chandler, and the area around their operations center was often buzzing with activity (See Figure 8 on Page 45). Second, every Waymo vehicle observed had a backup driver. Third, these vehicles drive well, and predictably with one notable exception. During two observations, a Waymo vehicle came to a complete stop when the vehicle in front of it turned right into a parking area while in motion. A human driver would usually slowdown in this situation, but not stop (unless the vehicle in front takes longer than expected to turn). Fourth, the researcher observed a pair of Waymo vehicles nearly collide with a pedestrian (this observation will be discussed at length in Chapter 13). In total, these observations indicate that Waymo vehicles may not yet ready for widespread use despite driving well in most situations.

Figure 8
Activity Outside the Waymo Operations Center

Frequency Observation

To quantify how common operational Waymo vehicles are in Chandler, the researcher performed a simple frequency study at the intersection of West Chandler Boulevard and 56th Street in Chandler (See Figure 9 on Page 46). This intersection was chosen because most Waymo vehicles would need to pass through it on the way to or from Waymo's operations center. This intersection was initially identified through an article by Ryan Randazzo (2018b), a writer for *Arizona Central*. In the article, he mentions that the intersection is near the operations center. During the Vehicular Observation study, the researcher followed a Waymo vehicle to the operation center and can confirm its proximity to the intersection. The intersection is almost exactly one mile north of the operations center. This corner is also near a highway junction, and is a major node for travelers entering or exiting Chandler. It also provided an unobstructed and protected viewing area for the researcher to safely measure the number of Waymo vehicles passing through the intersection.

Measuring how common active Waymo vehicles are in Chandler, the researcher counted the number of Waymo vehicles passing through this intersection during two 30-minute periods. The researcher performed this study between 10:15 and 10:45 AM on Friday, February 8th, 2019,

and between 3:05 and 3:35PM on Saturday, February 9th , 2019. Performing this count twice made

the overall study more representative of the average conditions in Chandler. The two time periods

were chosen because one is a busy travel period immediately after a weekday morning rush hour,

and the other is a very quiet travel period in the middle of a weekend afternoon. Observations

lasted 30 minutes due to scheduling constraints. Both counts were performed from the same

vantage point (shown approximately in Figure 9 below).

Figure 9
Waymo Vehicles at the Corner of 56th Street and West Chandler Boulevard in Chandler, AZ

To provide a metric to compare the frequency of active Waymo vehicles against, the

researcher also counted the number of Ford F-Series trucks that passed through the same

intersection during the same time periods. Ford F-Series trucks were used as a comparison for two

reasons. First, they are likely the most common type of personal automobile in the country. For

each of the last 36 years including 2018, Ford F-Series trucks have been the highest selling vehicle

in the United States (Zhang, 2018). Using them as a comparison is advantageous because it allows

researchers to compare the frequency of Waymo vehicles in Chandler to the frequency of a very

common make of vehicle. Second, the researcher is very familiar with F-Series trucks and can easily identify them apart from other makes and models. The researcher kept counts for both types of vehicles through tally marks, and noted when multiple vehicles were waiting at the intersection.

Limitations

All observational methods are subject to errors rooted in the observer. It is possible for the observer to unwittingly ignore relevant information, or unwittingly overemphasize truly extraneous information. In this circumstance, the researcher had never visited Arizona before, and had never seen a high-level, self-driving vehicle in person. There may have been some important observations that were overlooked because of the researcher's lack of familiarity with the area or the act of driving amongst self-driving vehicles. Furthermore, all of these observations assume that the vehicles were in self-driving mode. Every observed vehicle had a back-up driver, and while there were occasions when the hands of the back-up driver were seen away from the steering wheel, there is no way to verify all of the observed Waymo vehicles were driving autonomously.

The most pressing concern of the Site Observations is that it may not have been thorough enough. Although much of the Phoenix area was explored, the researcher quickly decided to focus on the southeastern suburbs exclusively. While there were noticeably fewer Waymo vehicles operating in other parts of the metropolis, conducting more in-depth observations across the entirety of the Phoenix area would of likely produced at least some additional, useful information.

Ideally, the researcher would have completed more than eight Vehicular Observations. While the existing set of observations produced meaningful results, more observations would possibly illuminate trends in the driving functions of Waymo vehicles that went unseen.

Finally, the frequency observation would preferably take place on each day of the week, and during multiple time periods. Counts should occur during rush hours, in the middle of the

night, during the early afternoon, and across all other time periods as well. The only way to gauge the typical frequency of active Waymo vehicles in Chandler as accurately as possible is to measure their frequency across various time periods. Unfortunately, the researcher was only in the area for four days, and had to allocate most of their time to other observations.

In total, most of the limitations of these observational methods were related to the limited time available to the researcher in Arizona. The researcher had only four days in the Phoenix area to complete all of the observations described above. If this case study is repeated, weeks should be allocated to perform all the tasks described above.

Chapter 10
Commuting Survey

While designing the research methods for this thesis, many colleagues and friends of the researcher (as well as other individuals) expressed their unwillingness to change their commuting habits when discussing self-driving vehicles. These comments inspired the researcher to contemplate if Marchetti's Constant would hold in the case of self-driving vehicles. Marchetti's Constant is a theory that humans share a, "…[Q]uintessential unity of traveling instincts around the world, above culture, race, and religion… which gives unity to the considerations relative to the history and future of traveling, and provides a robust basis for forecasts in time and geography (Marchetti, 1994, p.75)." Marchetti states that his contemporary, Yacov Zahazi, noticed how people travel approximately one hour a day or less on average. This observation led Marchetti to conduct a series of anthropological studies measuring the daily travel habits of cultures across the world, and across thousands of years of human history. His findings support Zahazi's observations, and led to a theory with extreme relevance to current and future commuting habits. In simple terms, Marchetti's Constant is the amount of time any one person is willing to travel (or commute) on the

average day, and that amount is one hour regardless of culture or historical setting. For this current study, exploring the relevance of Marchetti's Constant to self-driving vehicles allows the researcher to discern whether or not the use of self-driving vehicles will affect sprawl.

One of the aspects of self-driving vehicles that many worry will encourage sprawl is enabling passengers – including the would-be-driver – to engage in tasks unrelated to the operation of the vehicle (Pettigrew, 2017, p.6). To examine if this capability will inflate commuting time, and in-turn promote sprawl, the researcher created a three-question survey (See Table I below). The first question asks if the respondent lives, or has lived in the Phoenix area. The second question is intended to see if the ability to engage in tasks unrelated to driving could inflate people's willingness to commute longer. And the third question is intended to see if the ability to engage in tasks unrelated to driving could inflate people's willingness to commute over an hour each day.

Table I
Survey Questions

Question #	Question Content
1	Have you ever, or do you currently live in the Phoenix Metropolitan Area?
2	If you had a self-driving car that enabled you to dedicate your full attention to tasks unrelated to the operation of the car, would you be willing to commute for a longer time during both daily commutes than you currently do?
3	If you had a self-driving car that enabled you to dedicate your full attention to tasks unrelated to the operation of the car, would you be willing to commute for longer than 1 hour during both daily commutes?

A web version of this survey was created on *SurveyMonkey*, an online survey collection platform, and a link was generated to direct respondents to a web page where they could complete the survey. Respondents were recruited through a posting on the *r/Tempe* subreddit, a web community with a common interest in Tempe, Arizona within the larger *Reddit* social media platform (https://www.reddit.com/r/Tempe/). The moderators of the subreddit approved of a

request for respondents before the researcher posted the link to the survey. Additional respondents were recruited through a request on *Facebook*, and within 7 hours, 70 individuals completed the survey. Please note, *SurveyMonkey* blocks IP addresses from accessing the survey more than once.

The survey was taken down after 7 hours because conversations about the survey began spreading through the *r/Tempe* subreddit. While these conversations were generally positive about the survey, they also had the potential to influence the survey responses of future respondents.

Limitations

There are three main limitations to this survey. First is the potential of a response bias. Recruiting respondents online is always risky, particularly through social media sites such as *Reddit* and *Facebook*. When given the opportunity to complete a survey, people sometimes try to skew resulting data by responding in ways they think will support their beliefs or personal causes.

The second major concern is the ambiguous wording of the third question. The use of the phrase, "during both daily commutes," could either be interpreted as, "during both daily commutes combined," or as, "during both daily commutes individually." It was the intention of the researcher to convey the first meaning. The reason why "during both daily commutes" was used in question three was because it mirrored the wording of the second question where its meaning is far less ambiguous. In the future, this survey should have the third question reworded as, "If you had a self-driving car that enabled you to dedicate your full attention to tasks unrelated to the operation of the car, would you be willing to commute for longer than 1 hour each day?"

The final limitation to this survey method was the short time frame the survey "was live" on *SurveyMonkey*. If this survey had a few days, or even a week to recruit respondents, then it could have been completed by many more people, ultimately strengthening the results. Unfortunately, the survey had to be taken down when it was to avoid potential outside influence.

Chapter 11
Expert Interviews and Correspondences

The final method utilized for this case study was a series of expert interviews, and a set of email correspondences with a political leader from the Phoenix area. The researcher believed these communications would round out the larger case study by collecting insights from individuals with direct knowledge of self-driving vehicles and/or the Phoenix area. These individuals highlighted aspects of self-driving vehicles the researcher would have ignored without their contribution.

During the course of research for this thesis, the researcher contacted 22 individuals seeking interviews. These individuals included academic experts, political leaders from the Phoenix area, journalists who had covered the testing of self-driving vehicles in Arizona, and developers working on these vehicles. Sadly, only 4 people agreed to be interviewed, and one declined an interview but provided useful insights via email. While most of the targeted groups were ultimately represented, not a single developer agreed to communicate about the matter. Contributors and their credentials are listed in *Table II* below, and they were all recruited through contact information found on university, newspaper, or municipal websites, or through referral.

Table II
List of Experts Consulted

Contributor	Type of Communication	Current Position	Credential (The Reason They Were Consulted)
Ed Finn	Interview	Founding Director for the Center of Science & the Imagination, and Associate Professor at Arizona State University	He researches and writes about the social ramifications of self-driving vehicles and lives in AZ
Erick Guerra	Interview	Assistant Professor, University of Pennsylvania Weitzman School of Design	He researches and writes about transportation planning including self-driving vehicles
David King	Interview	Assistant Professor, Arizona State University School of Geographic Sciences & Urban Planning	He researches and writes about transportation planning including taxis and ride-hailing services and lives in AZ
Christian Price	Email Correspondences	Mayor of the City of Maricopa, Arizona	He is a political leader from the Phoenix area
Ray Stern	Interview	Journalist working for the *Phoenix New Times*	He journalistically covers autonomous vehicle testing in the Phoenix area

The completed interviews followed a semi-structured paradigm where the researcher asked both a combination of prewritten questions as well as questions thought up in the moment and asked in response to the participant's comments. Most of the questions dealt with potential planning concerns or planning actions related to self-driving vehicles, but some questions dealt with other matters such as the public's reaction to self-driving vehicle testing in Arizona. All responses were open-ended. Each interview was completed over the phone, and took between 15 and 30 minutes. A complete list of interview questions is provided in Appendix A on Page 97**.**

While this interview method was not as extensive as initially hoped, it was still informative. Many of the results of other methods were strengthen or elaborated on by the statements of the individuals interviewed or corresponded with. In total, these communications helped the researcher comprehend issues surrounding self-driving vehicles previously unnoticed, and eventually informed the findings of this thesis by providing richer context and corroboration to the results.

Limitations

Interviews are always susceptible to a handful of biases either originating within the interviewer or the interviewee. All of the questions were written by the interviewer, and their wording may have unintentionally influenced the interviewee to respond a certain way. Furthermore, all responses were analyzed by the interviewer (the researcher) and their beliefs could skew the meaning or applicability of the responses from what was meant by the interviewee.

Alternatively, the interviewee may try to support one of their beliefs through their responses. Interviewees could also lie, or present information they are unsure about with certainty. The use of interview methods always comes with the risk of these potential biases, but for this thesis, the researcher believes that these individuals responded to the questions honestly and candidly, and views their responses as credible and useful information.

The Border Between Chandler and Phoenix, Arizona

Chapter 12
Findings Overview: Planning for Self-Driving Cars will be shaped by Existing Political Practices and Commuting Behaviors

Each of the methods described above was designed to answer one or more of the research questions. Furthermore, each method produced noteworthy results supporting the findings of other methods. Looking at the results individually, and as a whole, two major themes arise. First is the importance of existing political norms, and second is the persistent nature of commuting habits.

Overall, the case study of autonomous vehicles in the Phoenix area produced five main findings each responding to one of the aforementioned research questions. The first and second findings demonstrate how autonomous vehicles are popular and common in the Phoenix area. The

third finding indicates that planning for self-driving vehicles is currently handled primarily by their developers. The fourth finding shows how public planning for self-driving vehicles will likely occur across the existing governmental divisions amongst local, state, and federal levels of government. And the final finding highlights how existing commuting behaviors will likely persist particularly with regards to Marchetti's Constant (Marchetti, 1994).

The strength of existing political norms is shown in both the planning efforts of the developers of self-driving vehicles, and how public planning for these vehicles has occurred through the hierarchical division of government. In contemporary western society, neoliberal opposition to regulation has become a major obstacle for planning. Such resistance has led to the controversial practice of private companies planning the built environment for their products and services. Evidence for such planning is present in the results presented here. Additionally, the division of governmental power across various levels of government has led to each level assuming a distinct role in the planning and regulation of automobiles. The results below suggest that these distinct roles will persevere as the United States transitions to more common use of self-driving vehicles. Recognizing the strength and application of these political norms to the testing of self-driving vehicles indicate that they will be key features of the planning for autonomous vehicles.

Finally, the results of this thesis show ways that existing commuting behaviors will continue to be relevant for future planning. The most important way existing commuting behaviors will influence the use of self-driving vehicles is the one-hour commuting limit postulated by Marchetti (1994). There is evidence that this commuting limit has influenced travel for millennia, and the results discussed below indicate that it will continue influencing travel as individuals begin to use self-driving vehicles. Moreover, commuters use automobiles as more than just a means of transportation. During his interview, David King pointed out how people store items for multiple

tasks in their vehicle such as parents storing equipment for their children's activities, or a university student storing clothes in their car's trunk. The personal vehicle has many uses to the commuter. Their cars are not just means of conveyance. They are part-transportation, part-living room, and part-closet (sometimes part-dining room as well). Commuters will want to use automobiles in these ways, and these persistent desires could affect how people use self-driving vehicles.

The results discussed below inform five major findings, but there are two overarching themes across the entirety of the results. Existing political practices will have a major impact on the future planning for self-driving vehicles, and current commuting habits will influence their use.

Chapter 13
Autonomous Vehicles are Thought of Positively in Phoenix, but are not yet Ready for Widespread Use

The first research question sought to assess public perceptions of self-driving vehicles in the Phoenix area. According to the results of the Twitter content analysis, residents of the Phoenix area express more positive opinions about both autonomous vehicles and Waymo than they do negative opinions. However, there are also indications that residents differentiate between autonomous vehicle developers, and that they do not view all developers as highly as Waymo.

As shown in Table III on Page 56, Phoenix area Twitter users posted more overtly positive tweets about Waymo and autonomous vehicles than overtly negative tweets. Out of the 88 tweets that mentioned Waymo, 11.36% expressed overtly positive sentiments about the brand while only 1.14% expressed overtly negative sentiments. Most of the tweets containing the word "Waymo" reported the news that the developer would soon offer a driverless ride-hailing service and expressed no overtly positive or negative sentiments. Similarly, more tweets mentioning the term "autonomous" were overtly positive than negative. However, very few tweets mentioning the term "autonomous" expressed any sentiments. Like tweets mentioning Waymo, most of the tweets

containing the word "autonomous" reported on a recent news story concerning autonomous vehicles with a neutral perspective. Nevertheless, the Twitter results in their entirety indicate that more Twitter users in the Phoenix area have positive opinions about Waymo and autonomous vehicles than negative opinions. This finding suggests that public perceptions about Waymo and autonomous vehicles are more positive than negative, and there are additional findings within the Twitter content analysis results that paint a fuller, more nuance portrait of public perceptions.

Table III
Twitter Content Analysis Results

Search Topic	Total # of Tweets	# Overtly Positive	% Overtly Positive	# Overtly Negative	% Overtly Negative	# with Self-Driving Vehicle Content	% with Self-Driving Vehicle Content
Waymo	88	10	11.36%	1	1.14%	71	80.68%
Uber	476	7	1.47%	56	11.76%	3	0.63%
Autonomous	130	2	1.53%	1	0.77%	113	86.92%

One of the most important findings of the Twitter content analysis is how the results indicate that Twitter users in the Phoenix area differentiate between AV developers. This differentiation is seen in the dissimilar ways Twitter users refer to Waymo and Uber. 80.68% of all tweets mentioning Waymo discussed autonomous vehicles in some way. In contrast, only 0.63% of tweets mentioning Uber discussed these vehicles. This result indicates that Twitter users in Phoenix generally consider Waymo an autonomous vehicle company, but not Uber. Furthermore, the results indicate that Phoenix area residents show more affinity to Waymo than Uber. As shown in the Table III above, tweets mentioning Waymo were more positive than tweets mentioning Uber, and tweets mentioning Uber were more negative than those mentioning Waymo.

The results of this study indicate that Phoenix area residents are generally in favor of self-driving vehicles, specifically those tested and operated by Waymo. However, less than half of all the tweets examined discussed the topic of "Waymo" or "Autonomous". The majority of all tweets were about "Uber". This finding shows that Uber is a far more recognized brand in Phoenix than Waymo. While Waymo is less discussed (and thusly less recognized as a brand) compared to Uber, Waymo is almost universally discussed among Twitter users as an autonomous vehicle developer. Conversely, Uber is still mainly considered a human-driven ride-hailing or food-delivery company. Simply put, Waymo is thought of positively as an autonomous vehicle developer, and Uber is thought of negatively as a taxi/delivery service.

These outcomes suggest that autonomous vehicle services pioneered by Waymo in markets outside of Phoenix may be more welcomed than those pioneered by Uber. Uber has established a controversial reputation that Waymo has yet to accrue. Moreover, Uber started out as a ride-hailing company, not an autonomous vehicle developer. Therefore, the popularity & excitement surrounding autonomous vehicle technologies may benefit the Waymo brand more than Uber. Nevertheless, the manner in which local laws will change to facilitate or limit Uber's or Waymo's operations will probably depend on how their reputations progress over the next few years. Uber needs to improve and evolve their image, while Waymo needs to become more well-known.

In addition, responses from the expert interviews support the main finding from the Twitter content analysis. There is consensus amongst interviewees that public perceptions in Phoenix are generally pro-autonomous vehicles. Most interviewees were directly asked about public opinions of autonomous vehicles in Phoenix, and all responded that the public is mostly in favor of them. David King described the Phoenician public's sentiments concerning autonomous vehicles as, "cautiously optimistic." However, a few interviewees questioned whether sentiments would

remain positive as more vehicles enter testing. While public opinions about autonomous vehicles may be positive currently, there are still questions about their readiness for widespread use.

Some of the most noteworthy results from the observational methods have to do with how well the Waymo vehicles drive on public roads. During the majority of observations, the vehicles drove very well. However, there were occasions that seemed to puzzle the vehicles. Furthermore, two Waymo vehicles nearly collided with a pedestrian, and the two vehicles acted very differently.

Figure 10
Two Waymo Vehicles Nearly Collide with a Pedestrian

During a Vehicular Observation, the researcher saw an incident involving two Waymo vehicles and an individual in the street. The Waymo vehicle under observation was immediately behind another Waymo vehicle driving south on 56th Street in Chandler. Both Waymo vehicles were heading back to the operations center about a mile down the road. About three-quarters of a mile away from the operations center, a pedestrian paced within the center turning-lane. The two Waymo vehicle were in the left lane, within feet of the individual. While the researcher slowed down and took unaimed photographs of the situation (see Figure 10 above), the first Waymo vehicle passed the pedestrian without slowing down or changing course. The second Waymo

vehicle slammed on its breaks, before slowly passing the individual. It must be noted that while the second Waymo vehicle slowed down considerably, it never came to a complete stop.

The difference in how these two vehicles handled this near collision highlights how prepared autonomous vehicles are for widespread use. Despite their popularity in the Phoenix area, these vehicles are not yet ready. One of the biggest questions stemming from this incident was if the backup driver in the second Waymo vehicle engaged the breaks, or if it was the vehicle's programming. Regardless, the difference in the way these two vehicles responded to an admittedly unpredictable pedestrian is striking. Neither vehicle handled the situation perfectly, and one did not even respond to the collision risk at all. In general, Waymo vehicles drive very well. But this generality must become near ubiquity before these vehicles are ready for driving risks, and before Waymo is ready to risk its positive reputation. Thankfully, it seems that Waymo realizes that testing is far from over. The presence of a backup driver in every observed Waymo vehicle indicate Waymo's level of confidence in their vehicles. They trust them in most situations, but not all.

Unfortunately, development pressures may drive a developer to forgo their responsibilities for headlines. Elon Musk often makes grand claims about the new capabilities of Tesla vehicles, and the company markets these technologies in ways that some assert overstate their capabilities. In fact, many experts, politicians, and regulatory agencies have told Tesla to stop using the term "Autopilot" to describe its self-driving technologies (Eisenstein, 2018). Waymo has done a good job maintaining its responsibilities as a new user of public roads, but they must continue to do so as business and profitability pressures exponentially mount.

In summary, the results of the Twitter analysis indicate that Waymo and autonomous vehicles are thought of positively in the Phoenix area. However, Waymo's autonomous vehicles are not yet ready for widespread use, and their popularity will be challenged in the years to come.

Pressures from investors for profits may lead to a disregard of developer responsibilities, and the public's own expectations for these vehicles may be too high. While the public in Phoenix is currently in favor of these vehicles, very, very few people have actually ridden in one.

Chapter 14
In Chandler, Autonomous Vehicles are Commonplace

The second research question asked: how common are self-driving vehicles within testing areas? The results from the frequency observation show that autonomous vehicles are as common in Chandler as the highest selling vehicle in the United States, Ford F-Series trucks. This observation implies that these vehicles could quickly become commonplace in areas where developers test their vehicles, or where self-driving ride-hailing services operate.

As shown in Figure 11 below, more Waymo vehicles passed through the intersection of West Chandler Boulevard and 56th Street during the first of two frequency observations. During this period, 26 Waymo vehicles crossed the intersection, compared to only 21 F-Series trucks

Figure 11
The Number of Waymo and F-Series Vehicles Crossing Through the 56th St. and West Chandler Blvd. Intersection Between 10:15 & 10:45AM on Friday, Feb. 8th, 2019
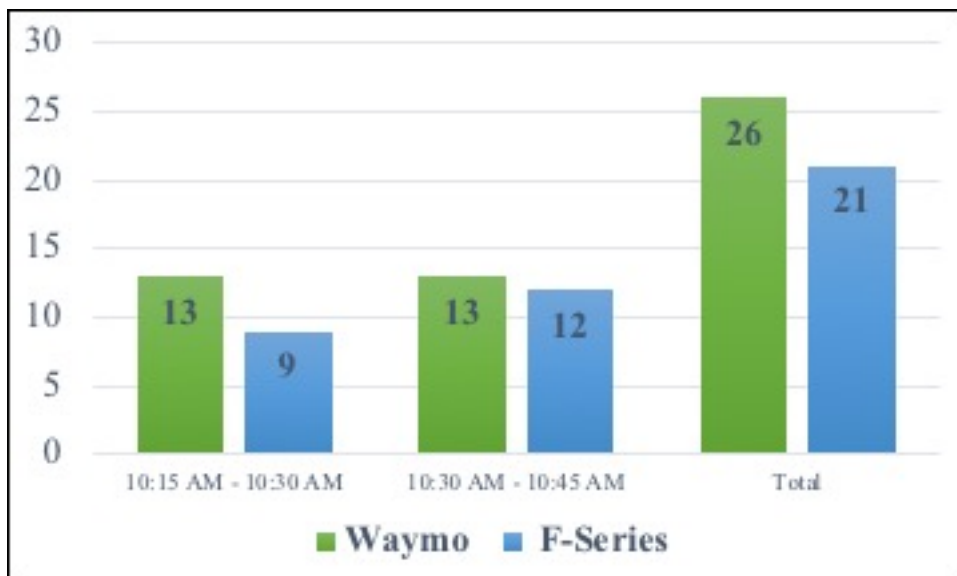
However, during the second frequency observation the following day, slightly more F-Series trucks passed through the intersection than Waymo vehicles. As shown in Figure 12 below, during this frequency observation, 18 F-Series trucks crossed the intersection compared to only 16 Waymo vehicles. Overall, fewer vehicles of either type passed through the intersection during the second frequency observation, and the researcher noted that the intersection was seemingly less busy during this period compared to the first frequency observation.

Figure 12
The Number of Waymo and F-Series Vehicles Crossing Through the 56th St. and West Chandler Blvd. Intersection Between 3:05 & 3:35PM on Saturday, Feb. 9th, 2019
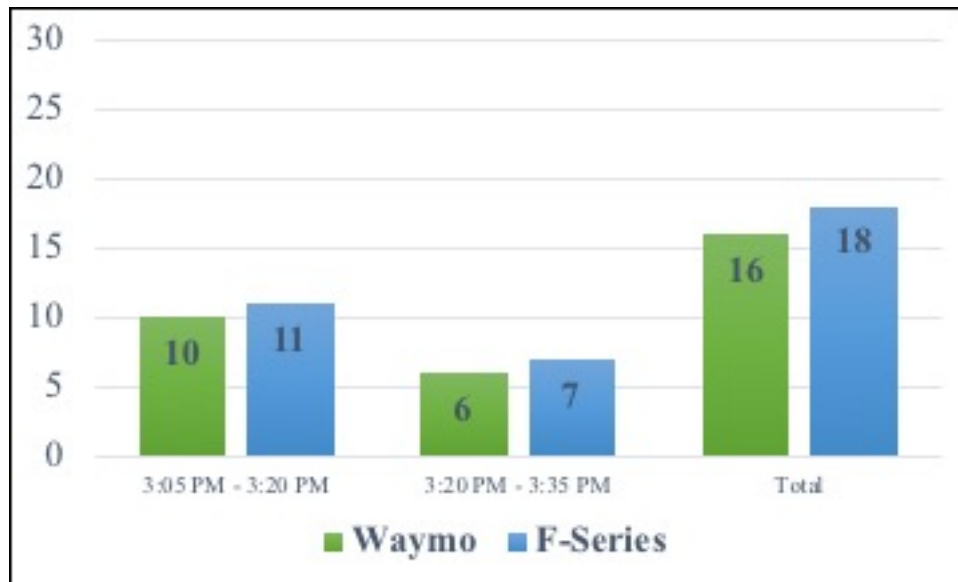
While more Waymo vehicles passed through the intersection in the combined results of both observations (42 Waymo vehicles compared to 39 F-Series trucks), these results do not necessarily suggest that Waymo vehicles are more common than F-Series truck in Chandler. The second frequency observation occurred during a typically quieter travel period than the first frequency observation. If both observations occurred during equally busy periods, then the results may be reversed, or equal amounts of both types of vehicles may have crossed the intersection.

Because of these possibilities, it would be irresponsible to say that one type of vehicle is more common than the other in Chandler. However, both types of vehicles were shown to be almost equally frequent during both observations. More Waymo vehicles crossed the intersection during the first observation, and more F-Series trucks crossed the intersection during the second observation, but on both days, the less frequent type of vehicle was only slightly less frequent than the more frequent type. In other words, while the results fail to indicate which type of vehicle is more common in Chandler, they do indicate that both types of vehicles are nearly as common. This finding answers the second research question, and highlights how common self-driving vehicles can become in areas with autonomous vehicle testing and/or commercial services.

Waymo began testing in the Phoenix area less than two and half years ago, and autonomous vehicles have already become very common in Chandler. As metropolises are chosen as test sites, and as driverless ride-hailing services open in new cities, autonomous vehicles could quickly become commonplace. Admittedly, Waymo vehicles are not as common in downtown Phoenix, or other parts of the metropolitan area as they are in Chandler. But their ever-presence in Chandler shows how certain areas of other metropolises may become. Waymo, and other developers will need physical operation centers in these metropolises, and the communities that host these centers may see autonomous vehicles become as commonplace as Ford F-Series trucks. The potential for self-driving vehicles to quickly become commonplace is real, and this potential could spread fast.

Chapter 15
Private Developers are a Major Source of Planning for Self-Driving Vehicle

The third research question considered the role the private firms creating autonomous driving technologies have in the planning for self-driving vehicles. Results from the site observations and expert interviews indicate that these firms are currently the primary planners for

self-driving vehicles, and that they will likely be a major source of planning for these vehicles in the future. Private companies planning the built environment for their goods and services is often controversial. While such planning allows local governments to allocate their time and money elsewhere, it usually comes with some amount of disregard to non-company interests, and inefficiencies in the designs or enforcement of policies related to the privately-generated plans.

Most of the experts interviewed agree that the primary planners for self-driving vehicles in Arizona are currently the developers creating them. Governor Ducey has fostered a lax regulatory environment in Arizona when it comes to self-driving vehicles, and the developers have utilized this environment to their benefit. This dearth of regulations, along with favorable public opinions have provided developers with wide-reaching abilities to plan for the vehicles they are creating. As Ray Stern stated during his interview, as of right now, "They [*the developers*] have the power." These developers have leveraged this power in a multitude of ways, but the most obvious examples are physical indications of their planning efforts within the built environment, and the influential relationships these companies have established with political leaders.

During the site observations, the researcher found indications of planning actions led by Waymo in the form of parking spaces reserved for Waymo vehicles at a Walmart in Chandler. These spaces were clearly signed, and preferentially close to the entrance of the store. The spaces were reserved because of a partnership formed between Waymo and Walmart (LeBeau, 2018). These spaces allow for Waymo users to pick-up ordered items quicker, and encourage Waymo users to shop at Walmart. These signs do not seem to negatively impact their surroundings, but it is still noteworthy that no public agencies had input into the details of this agreement. These spaces, and related signage are examples of planning actions led by a developer of autonomous vehicles, but they are not the only examples of developer-led planning, nor are they the most troublesome.

Even before Uber began testing on roads in Arizona, they ensured that they would have the ear of Governor Ducey. Through their influence, they convinced the governor to forego pursuit of certain taxi rules as applied to ride-hailing services, had him send out a pro-Uber tweet akin to an advertisement, and even sought a seat on a self-driving vehicle oversight committee (Harris, 2018). The relationship Uber developed with Ducey allowed them to plan, or at least attempt to plan for their vehicles through their influence over the governor. This type of influence is highly disconcerting, especially since Ducey's relationship with Uber only came to light after the death of Elaine Herzberg. Uber's relationship with the governor led some to question if Ducey's executive orders mandating a lack of regulations for self-driving vehicles were shaped by Uber. No matter the amount of influence Uber had on his executive orders, Uber efforts to plan for their vehicles by influencing the governor is more than apparent. It is unclear to what extent this influence succeeded, but planners should be wary of corporate attempts to plan through political influence. Suspicious relationships between private companies and powerful politicians are quite common, are always worthy of scrutiny, and often call for legal action.

Most of the interviewees agree that private influence over the planning for self-driving vehicles is likely to continue, but there were notable downsides to such planning practices that were evident in the site visits. One of the biggest weaknesses of private planning is its lack of perceived and real authority. Despite the existence of clearly marked Waymo-reserved parking spaces at Walmart, few vehicles respected the limitations placed on these spots. As shown in Figure 13 on Page 65, non-Waymo vehicles often parked in the Waymo reserved parking area. Likewise, the researcher observed Waymo vehicles using regular parking, leaving the Waymo reserved parking spots unused. Neither Waymo nor Walmart have much authority to punish individuals who violate how these spaces are used. These spaces are not parking spaces required

by law such as disabled or expecting-mothers parking. There are no legal ramifications for unauthorized parking in them. Walmart would likely tow an abandoned vehicle parked in a Waymo reserved space after a certain amount of time, but they cannot ticket such a vehicle as a town could ticket a car violating disabled parking regulations. There are numerous downsides to private planning, and one of the biggest drawbacks is its lack of legal authority.

Figure 13
A Non-Waymo Vehicle (the Red Truck) Parked in a Waymo-only Parking Space
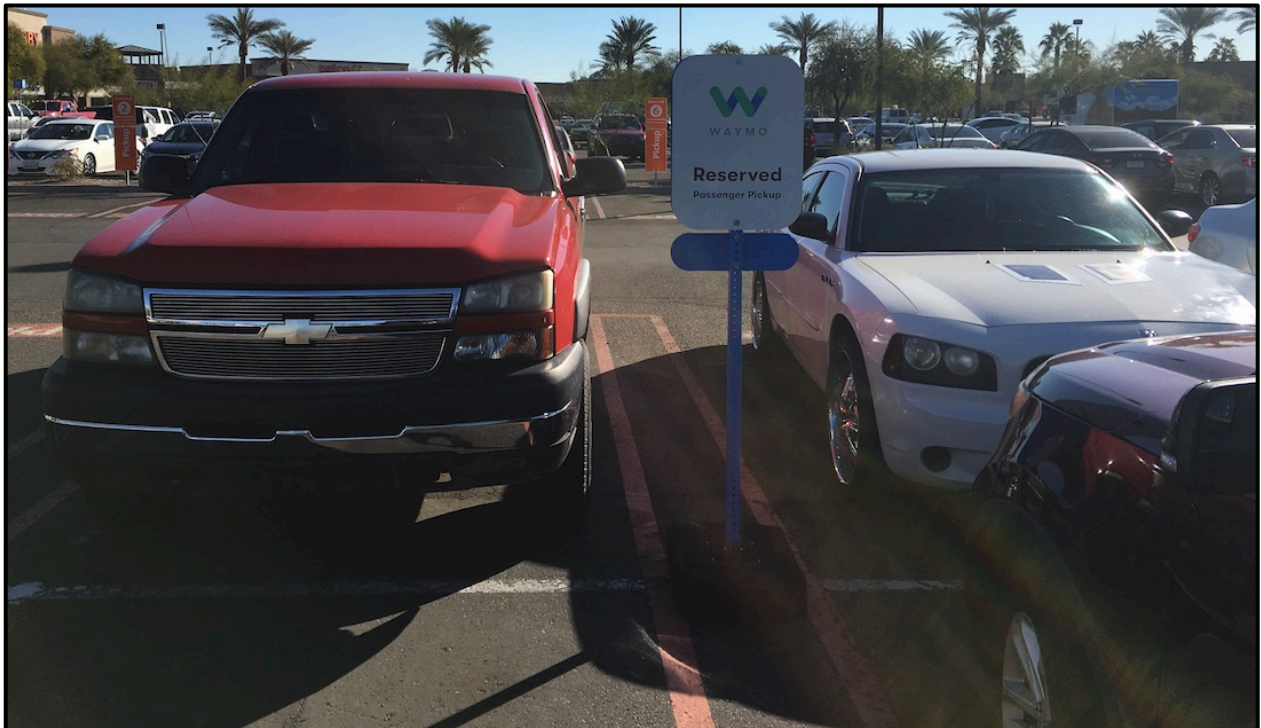
Some have wondered if the involvement of private firms in the planning for autonomous vehicles will also lead to more privately-owned transportation infrastructure. In 2018, Elon Musk unveiled a tunnel underneath Los Angeles built by his tunneling venture, The Boring Company. The tunnel, while complete, was merely a short 1.14-mile proof of concept (McFarland, 2018). It showed that highly automated, and especially equipped vehicles could safely travel through a narrow tunnel with limited inputs from a driver. Inspired by Los Angeles' notoriously bad traffic,

Musk intends to build a full-length tunnel soon, and to allow Tesla users, and drivers of other especially equipped cars to use the tunnel as an escape from gridlock (presumably for a toll).

Despite Musk's desires to build traffic tunnels underneath major cities, the experts interviewed for this thesis generally believe that autonomous vehicle developers want public agencies to remain in charge of road infrastructure. Most of the interviewees acknowledge that the use of autonomous vehicles could lead to more privately-owned transportation infrastructure, but they hesitate to state that private owned transportation infrastructure will become commonplace. In fact, Ed Finn believes that the benefits self-diving vehicles receive from public infrastructure may be a source of conflict between public and private entities. As use of self-driving vehicles necessitate implementation of new technologies along roads and highways (such as the "Road-Side-Units" called for by Gopalswamy and Rathinam (2018)), private firms may be asked to fund public infrastructure. However, it is in the best interests of these companies to avoid infrastructural responsibilities as much as possible. Finn points out that road infrastructure has always been the responsibility of state and local governments, and that the developers will likely wish to leave these responsibilities to public agencies going forward. In short, while the developers and manufacturers of self-driving vehicles will likely try to influence infrastructure planning, they will also be reticent to assume costly responsibilities such as the construction or maintenance of them.

Existing evidence shows that the developers of autonomous vehicles are currently the leading planners for self-driving vehicles. The influence of private planning will likely continue as self-driving vehicles become widespread. Unfortunately, private planning has notorious pitfalls such as a lack of legal authority to enforce planning actions, and the ethical concerns that come with private companies influencing politicians or the built environment. As self-driving vehicles become widely used across the country, local governments and planning agencies will need to

scrutinize and work with private firms attempting to plan for the vehicles or services they sell. These companies may be able to provide resources local governments would have a difficult time affording, but they may also attempt to plan spaces in their self-interests alone.

<div style="text-align:center">

Chapter 16
Public Planning for Self-Driving Vehicles in the United States will Follow the Existing
Division of Responsibilities Across Federal, State, and Local Lines

</div>

Complementing the third research question, the fourth asked: What role will public agencies have in supporting and regulating the use of self-driving vehicles? The recent history of autonomous vehicle policy, expert interviews, and communications with Arizona politicians indicate that public planning for self-driving vehicles will follow the existing division of responsibilities across the various levels of government. Planners must recognize that the creation of policies concerning autonomous vehicles will mirror the policymaking practices for traditional vehicles. In other words, some of the policies affecting self-driving vehicles will be made at the federal level, some will be written at the state level, and others will be created by the local levels of government. Planners must comprehend that different planning actions can be accomplished by different levels of government. In short, planners will plan for self-driving vehicles through every level of government because the actions viable through one level may not be viable in others.

Planning for autonomous vehicles will need to navigate these divisions much like the planning efforts for traditional automobiles. During his interview, Erick Guerra stated that the safety standards surrounding these vehicles will be set by the higher levels of government (mainly by the federal government and somewhat by state governments), while the management of roads and lanes will be handled by the lower levels. David King conceptualizes these divisions in a similar way. He states that the federal government will regulate vehicles, while the state and local

governments will regulate physical space. These divisions are divisions set by enumerated authorities and precedent. They represent not only the way vehicles will be planned for, but also the way they have been planned for. These political structures are very rigid, and they look upon autonomous vehicles and traditional automobiles in much the same way.

The presence of these divisions is already noticeable in policy actions related to self-driving vehicles. As an example, in 2018, the federal Department of Transportation (2018) released a set of standards for self-driving vehicles including safety guidelines. Moreover, the state of Arizona has opened it roads to autonomous vehicles as mandated by Governor Ducey's executive orders (AZ Exec. Order No. 2015-09, 2015; No. 2018-04, 2018a; No. 2018-09, 2018b). Lastly, local governments have begun regulating space as well. In response to Waymo's growing presence, Chandler changed their zoning codes to allow for up to a 40% reduction in the minimum parking requirements in exchange for construction of a passenger loading zone (Larco, 2018). The regulatory divisions between the levels of government discussed by Guerra and King are clearly noticeable in these examples. The federal government released safety guidelines for autonomous vehicles, while the state of Arizona and Chandler regulated their roads and parking lots. These divisions will likely remain as planning for self-driving vehicles moves forward, and it will be the responsibility of planners to traverse these divisions as wisely as possible.

Planning actions will occur on all levels of government, but it must be noted that actions on higher levels of government are more applicable (and generally more powerful) than those on lower levels. While Chandler has taken planning actions in response to Waymo's operations, most local governments in Arizona have not. In these areas, the actions taken on the state level hold the most sway. The relevance of state actions in these areas is confirmed by Christian Price, the Mayor of Maricopa, Arizona. Maricopa is a small exurb of Phoenix located to the southwest of Chandler.

The city occasionally sees an autonomous vehicle, but it is not an area with extensive testing. In a set of email correspondences, Mayor Price indicates that the area as a whole is involved with self-driving vehicles, but his city has yet to take any policy actions regarding them. He states, "…[W]e have been following the State's lead on giving policy leeway on autonomous vehicles as we learn to share the road with this new technology." In this case, state policy is the sole public planning action regarding self-driving vehicles affecting the municipality. As such, state policy is very strong. It has authority across Arizona, and could even nullify local laws in certain cases. Thus, planners must remember that the division of responsibilities across levels of government not only separate types of actions, but also define how broadly applicable, and strong the action is.

Existing divisions between federal, state and local levels of government will continue to have a major influence on planning for automobiles as they become driverless. Familiarity with these divisions should help planners organize their actions, but these divisions have often been problematic, and disastrous for some communities. While the federal structure allows local areas to plan for their wants and needs, it also facilitates the use of planning as a tool of prejudice and injustice. Despite these issues, these divisions will remain influential. Planners must be aware of the type of actions that can be taken on each level of government, and must remember the historical failings of these divisions to effectively plan for autonomous cars.

Chapter 17
Multi-Tasking Enabled by Travel in Autonomous Vehicles May Contribute to Sprawl Conforming to Marchetti's Constant

The fifth and final question was: are concerns of induced sprawl associated with driverless vehicles justified? The results from the commuting survey suggest that passenger multi-tasking enabled by travel in autonomous vehicles could induce sprawl, but that this sprawl would be limited by innate desires to commute less than one hour each day. A majority of survey respondents

indicated that they would be willing to commute longer than they currently do if they had a self-driving vehicle enabling them to perform tasks unrelated to driving. However, a majority of survey respondents also said that they would not be willing to commute more than one hour if they had the same vehicle. These results indicate that autonomous vehicles could promote sprawl, but that this sprawl would conform to the instinctive one-hour limit postulated by Marchetti (1994). In total, this finding suggests that worries over sprawl caused by autonomous vehicles are justified, especially since widespread use of self-driving vehicles could accelerate commuting speeds.

Most respondents stated that they would be willing to commute for a longer time if they had a self-driving vehicle. As shown in Figure 14 below, of the 70 individuals who completed the survey, 67% said that they would be willing to commute for a longer time than they currently do if they had a self-driving vehicle that allowed them to perform tasks unrelated to driving.

Figure 14
Distribution Chart of Responses to Question 2
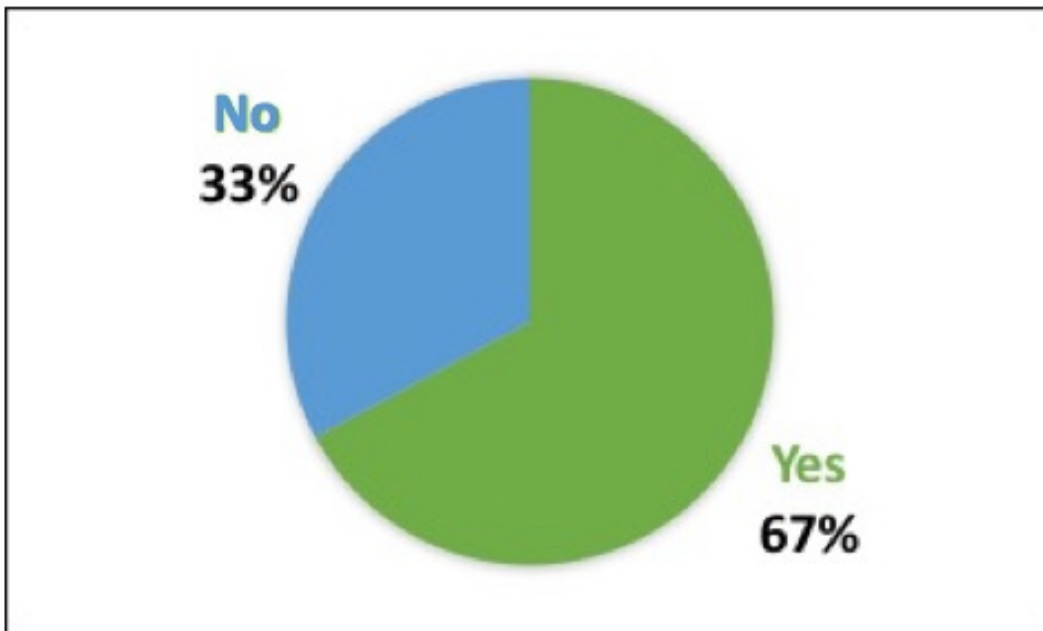
"If you had a self-driving car that enabled you to dedicate your full attention to tasks unrelated to the operation of the car, <u>would you be willing to commute for a longer time</u> during both daily commutes than you currently do?"

This result indicates that the convenience of autonomous vehicles could enable additional sprawl. If individuals are willing to commute more than they currently do, then they may choose to live in housing that is cheaper, or more desirable, yet further away from their workplace. By itself, this finding is worrisome. Sprawl has had a deleterious effect on American cities, and this result suggests that use of autonomous vehicles could lead to a new wave of sprawl. However, this finding is not the sole result of this survey. Other results suggest that the use of autonomous vehicles will conform to existing, inborn desires that restrict sprawl.

In contrast to the previous result, most respondents stated that they would not be willing to commute for more than one hour if they had a self-driving vehicle. As shown in Figure 15 below, 68% of all respondents stated that they would not be willing to commute for more than one hour if they had a self-driving vehicle allowing them to focus on tasks unrelated to operating the vehicle.

Figure 15
Distribution Chart of Responses to Question 3

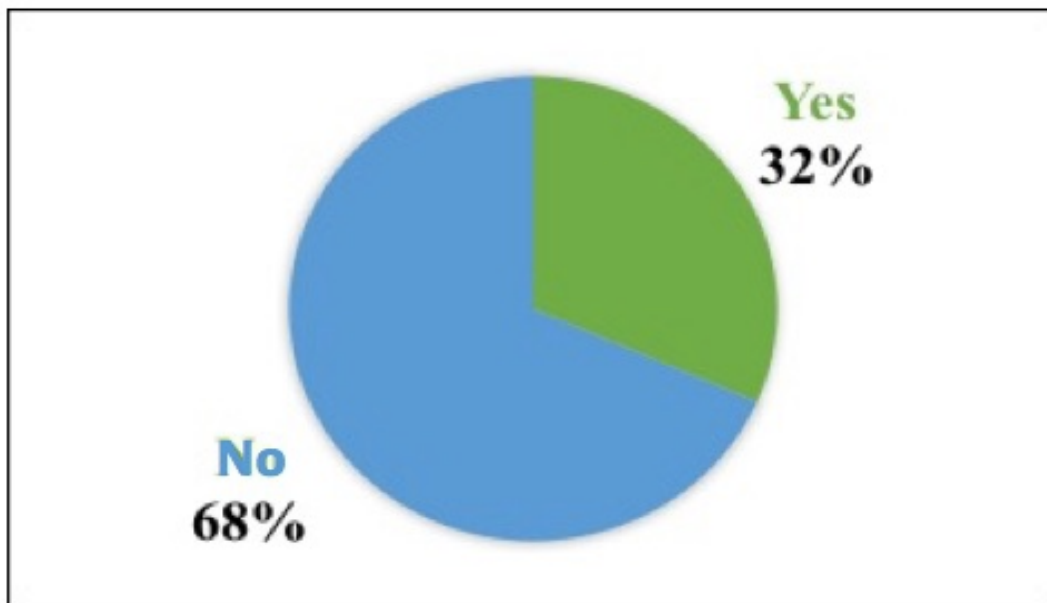*"If you had a self-driving car that enabled you to dedicate your full attention to tasks unrelated to the operation of the car, <u>would you be willing to commute for longer than 1 hour</u> during both daily commutes?"*

This result supports the findings of Marchetti 's (1994), but does not affect the underlying meaning of the previous result. The ability to multi-task while riding in an autonomous vehicle could produce sprawl. While the later finding suggests that this sprawl would be limited by desires to restrict commuting to approximately one-hour, it does not impact self-driving vehicles' potential to create sprawl within one-hour of daily commuting. This finding is also based on a temporal threshold. What happens if use of autonomous vehicles speeds up commuting?

Autonomous vehicles' potential to stimulate sprawl is fundamentally tied to their potential to improve commuting speeds. Whether or not autonomous vehicles improve commuting speeds has yet to be seen. Some experts are torn about how these vehicles will impact congestion. They believe that self-driving vehicles could predict and avoid congestion better than human drivers, but that their popularity may lead to more vehicles on the road increasing VMT, and hence congestion (Guerra, 2016; Fagnant and Kockleman, 2015). It is impossible to reliably predict how autonomous vehicles will impact commuting speeds within metropolitan areas, but the prospect of them increasing commuting speeds has been identified. If their use increases commuting speeds, then their ability to generate sprawl is enhanced. If commuters can travel further within an hour total commuting time, then they are more likely to live further away from where they work.

The risk for these vehicles to produce sprawl is real both because, and in spite of existing commuting habits. People already commute large distances in their cars, but they do not want to commute more than one hour even if their cars drive for them. However, much like how suburban amenities may convince people to live further from work, multi-tasking enabled by self-driving vehicles may coax people to commute more than they would otherwise. Ultimately, commuters are not deterred by sprawl. They are deterred by time, and self-driving vehicles' capacity to instigate sprawl will be mostly determined by their impact on commuting speed.

Part Four
Discussion and Conclusion

Suburban Sprawl Southeast of Phoenix, AZ

Chapter 18
Legacies to Act Upon

Numerous legacies – both physical and social – will affect planning for self-driving vehicles. Self-driving vehicles will operate over existing infrastructure, and occupy the same spaces as traditional automobiles. They will have similar uses, and be viewed by the public in many of the same ways. The results of this thesis indicate that the planning for self-driving vehicles will occur through the same political practices that planned for traditional vehicles, and in response to commuting behaviors that predate automobiles. Therefore, physical and social legacies may affect planning for self-driving vehicles more than any other form of transportation, and the development of self-driving vehicles provides planners the opportunity to plan with knowledge of the failures of the past. The negative effects of sprawl, the unchecked growth of suburbs, and

American overreliance on personal vehicles were all encouraged by planning actions related to traditional automobiles. As planners begin the prepare for use of self-driving vehicles, these unfortunate legacies of planning must serve as warnings to avoid shaping the world for automobiles alone.

Probably the most impactful legacy that will affect the planning for self-driving vehicles in America is the social meaning of cars in the United States. While discussing the place technologies form in society, historian David Nye (1992) states, "A machine's social reality is constructed, and emerges not only through its use as a functional device, but also through its being experienced as part of many human situations which collectively define its meaning (85)." In the United States, cars have already developed meanings through their archetypal role in numerous situations. One of many American teenage rites of passage is testing for a driver's license. Wedded couples place "just married" signs on the back of their car. The road trip is an American pastime, and tailgating from the back of vehicles is a part of American Football culture. In the United States, cars have a social place in most situations, and have become icons of freedom. They are engrained into many people's ways of life, and people often cannot imagine life without them. People become emotionally attached to cars. They named them. The automobile has a near sacred place in American society, and its meanings to millions of Americans are likely to remain the same.

Self-driving capabilities may become the most radical change ever to the automobile, but the social meanings of automobiles will persevere. People will still use vehicles to get around and commute. Many people will still want to use them as extension of one's home. As David King mentioned, people will still want to use cars to carry and store items related to everyday life. People will probably still tailgate out of them (they might even tailgate more if the car can drive itself

home). The social meanings of personal vehicles are well established in the United States, and planners will need to be cognizant of these meanings as they plan for self-driving vehicles.

These meanings may make certain planning goals more difficult to achieve, but the existence of these social meanings also give planners an advantage. As an example, automobiles' social meanings may hamper efforts to transition to shared-ownership, or ride-hailing models of automobile use. The built environment and social norms of many American cities have been designed around private car ownership. To transition to models limiting private ownership would require reconfigurations of space as well as changes to social practices. In car-centric cities, such as Miami, Florida and Los Angeles, California, high schools are designed with large parking lots for students and staff to use. In many cases, students use cars as refuge during the school day for friends to congregate away from prying eyes. Some students may also need a car because it is the only form of travel direct enough to take them to their afterschool job. Transitioning car-centric cities to a model of automobile use heavily limiting private ownership would require drastic changes to both the design of such schools, and the social norms that have developed here. The parking lot would need to be reconfigured to allow for more quick pick-ups and drop-offs. Students and staff would need to accept the disappearance of their cars from school property. Students would no longer be able to congregate around their vehicles, or store items in their trunks. Reliably scheduled alternatives will need to be established for students who had driven to work after school, or the economic pressures compelling students to work will need to change. The social meanings cars have formed in the United States permeate nearly every aspect of life. These meanings are engrained into American culture, and will make some planning actions much more difficult.

However, recognizing these social meanings may also facilitate planning for self-driving vehicles. Commuting behaviors are heavily related to the social meaning of automobiles. People

often use their vehicle to stop and chat at coffee shops, or cafés on their way to work. Likewise, some people go grocery shopping, or stop at a hair salon/barbershop on their way home. These behaviors are in-effect social rituals woven into the act of commuting. Even commuting itself can be viewed as a social ritual in that large parts of American society share the common struggle of highway traffic. While the means of travel may become autonomous, these rituals will likely remain the same, and recognizing them may help planners prepare for self-driving vehicles.

These social legacies are incredibly powerful, but they are not the only legacies future planners will need to deal with. The political legacies of past planning will also play a role in the planning for self-driving vehicles, and these legacies provide advantages and drawbacks as well.

Understanding the political legacies of traditional automobiles could aid planners as they plan for self-driving automobiles. The political practices through which traditional automobiles were planned for will be some of the practices that will plan for autonomous vehicles. In the past, car manufacturers played a major role planning for their vehicles. Today, the developers of autonomous vehicles have been a major planner for self-driving vehicles. Furthermore, the division of responsibilities across the various levels of government were followed while planning for traditional vehicles, and the same divisions will be maintained while planning for the vehicles of the future. Awareness of the role private companies have had, and will have in the planning for automobiles provides planners with potential avenues for planning. Likewise, knowledge of the capabilities of each of level of government can direct planners to viable planning options.

Yet these practices are not without their shortcomings. The influence of private firms has historically been problematic. Few private firms plan outside their self-interests even if such planning harms the greater good. Probably the most lurid example of a car manufacturer's influence on transportation planning is General Motors (GM) involvement in the dismantling of

public transit services in Los Angeles, and other major cities beginning in the 1930's (Klein, 1996). GM did not care about the well-being of these cities, or of their communities, or residents when they invested in companies purchasing streetcar lines intending to close them. General Motors wanted to sell cars, and knew that limiting transit options would stimulate automotive sales.

Furthermore, the divisions among different levels of government have historically led to discrimination and injustice. Sadly, local municipalities operating outside the oversight of state or federal governments have often used planning as a tool of prejudice. In the early 1970's, Mt. Laurel, New Jersey instituted zoning regulations that effectively prohibited poor families – specifically African Americans – from living in the township. While Mt. Laurel's zoning regulations were eventually deemed unconstitutional by the New Jersey Supreme Court, similarly prejudicial zoning ordinances still exist nationwide (Southern Burlington County…, 1975). Equally bigoted motivations guided state and municipal planners' decisions on where to locate highways, garbage dumps, and sewage treatment plants. Unsurprisingly, these blights were typically placed in poor and minority neighborhoods. The political norms that shaped past planning have resulted in inequitable, and unjust legacies. These same political practices will shape the planning for self-driving vehicles. Planners need to remember how they can lead to the exploitation of public amenities, or purposeful injustice, and must tailor their plans to avoid these outcomes.

In light of these unjust and unequal legacies, planners must view the development of self-driving vehicles as an opportunity to plan aware of these past failures. The planning practice has many mistakes to correct, and not all of them are repairable, but they all can positively influence future planning. Planning solely for the automobile led to a destruction of inner cities. Sprawl drew wealth from urban centers and redistributed it to the determent of already disadvantaged communities (Pfeiffer, 2016). Prejudice has directed planning efforts, and planners must now plan

so as to combat prejudice, sprawl, inequity, and decay. Past failures must inspire planning for self-driving vehicles, and they must also serve as lessons to avoid similar mistakes. Some of the risks associated with self-driving vehicles were outcomes of traditional vehicles as well. In other words, planning with the results of past planning actions in mind will help guide future planners.

Sprawl is one of the potential risks associated with self-driving vehicles that was also a result of traditional vehicles. Planners have extensive experience with sprawl, and have formed numerous ways to combat it. When asked for ways to restrict the potential sprawl and increased VMTs associated with self-driving vehicles, the experts interviewed for this thesis gave numerous recommendations. David King suggested taxing distance traveled. Erick Guerra proposed congestion charges, and updated parking requirements. Ed Finn recommended building a culture of walkable neighborhoods. All of these suggestions combat sprawl in different ways, but they all combat sprawl regardless if it was caused by use of traditional vehicles, or use of self-driving vehicles. The results of this thesis support the belief that widespread use of self-driving vehicles could lead to sprawl, but planners already have means to combat sprawl at the metropolitan level. Planning's experience addressing past mistakes will provide ways to address some of the risks associated with widespread use of self-driving vehicles, but there are other potential outcomes to autonomous driving that planning has no experience with at all. Still, the history of planning for automobiles will provide useful methods and inspirations to plan for self-driving vehicles.

Autonomous vehicles designed for long-distance, intercity travel are one of the most interesting aspects of the development of self-driving technologies. Whereas self-driving vehicles within metropolitan areas may be constrained by congestion, traffic signals, and speed limits appropriate for populated areas, self-driving vehicles traveling between cities are abetted by open roads, easy to update infrastructure, and high-speed limits. Self-driving vehicles designed for

everyday use will likely be a central focus for transportation planners, but autonomous vehicles designed for long-distance travel will also create their own set of planning concerns. Conversely, they may also bring some social benefits. These vehicles may create better rural mobility in areas poorly served by trains or air travel. They may also be a more environmentally friendly way to travel than airplanes. Long-distance self-driving vehicles could be an incredibly helpful form of intercity travel, and planners should be excited to learn as much about these vehicles as possible.

Self-Driving vehicles could also transform cities in ways traditional vehicles did not. In an article for the MIT Technology Review, Ed Finn (2018) points out how a societal shift towards autonomous ride-sharing and hailing could transform urban economies, and environments built around car ownership. Not only are many cities designed for private vehicle use, but many local businesses rely on car ownership as well. Moving away from car ownership would thoroughly transform the physical and economic landscapes of these places.

Even if high levels of car ownership remain, autonomous vehicles may still transform cities. Finn (2018) points out how autonomous delivery-vehicles may provide new business opportunities and even new social practices around communal delivery locations. These changes may be resisted at first, but some may be beneficial. Reducing local economies' dependence on car ownership could create a more resilient and diversified market, and building social bonds through communal delivery practices could create strong neighborhoods. Self-Driving vehicles may change cities in ways older automobiles did not, but many of these changes could be beneficial, and others may be dealt with using practices employed previously on similar problems.

Some wholly new problems will also arise. Many planners are worried that empty self-driving cars may be ordered to circle cities waiting for travelers to hail their services, or to avoid parking restrictions. This practice could become an unnecessary source of congestion, and a

grievous waste of energy. Sadly, projections about such scenarios from the University of California, Santa Cruz utilizing game theory suggest that the owners and operators of self-driving vehicles are likely to order empty vehicles to loop with no passengers in them rather than park (Staff Writers, 2019). During his interview, David King stated that empty vehicle travel will need to be limited in some way. Thankfully, existing planning actions such as congestion pricing may help restrict empty vehicle travel (Staff Writers, 2019). However, new practices may also need to be developed. The development of self-driving technologies will assuredly create new challenges and opportunities for planners, yet the legacy of past planning actions will still remain relevant.

The motivations, methods, designs, and outcomes of the planning practices related to traditional automobiles have provided planners with numerous legacies to act upon. Admittedly, some of these legacies are among the profession's greatest shames, but all of these legacies can inform future planning actions. Planners should be hopeful. The development of self-driving vehicles provides planners with an opportunity to address some of the failures of the past, while also improving traffic safety, and bolstering public health in general. But planners will not rectify past mistakes by allowing self-driving vehicles to be planned by private interests alone. Planners must lead, and must prepare for these vehicles in ways that maximize their positive benefits, while minimizing their negative outcomes. Planning for self-driving vehicles has begun, and cities are already being shaped by new planning actions. Planners must ensure that the legacies of these current and future actions empower communities, and make better places for people to live.

Chapter 19
Tying Results Together, & Their Combined Ramifications

When taken together, the results of this thesis suggest that use of self-driving vehicles could spread very quickly in the United States due to an enabling political climate made up of business-

friendly norms and an eager public. Waymo and autonomous vehicles in general are thought of positively in the Phoenix area, and similar sentiments could pressure politicians into supporting the testing of self-driving vehicles within their jurisdictions. Such a facilitating political environment will likely allow developers to engage heavily in the planning for these vehicles resulting in environments prone to sprawl. When jointly analyzed, the results of this thesis are both worrisome and motivating. Self-driving vehicles could impact cities very quickly after localized testing or use begins, and the speed of their geographic expansion could result in swift manifestation of both their adverse and constructive effects.

Probably the single most shocking result of this thesis was the speed in which autonomous vehicles have become commonplace in Chandler. Waymo began testing in Chandler in December 2016, and they have already become very common in the area. In less than two and a quarter years, Waymo's autonomous vehicles went from nonexistent, to prevalent, and Waymo has yet to maximize their operations in the Phoenix area. They still only serve a select few users who have enrolled in the company's "Early Rider" program. If they made their services available to anyone in the Phoenix area, then the metropolitan presence of their vehicles will likely mirror their pervasiveness in Chandler. Similar outcomes could occur in other areas, and the popularity of Waymo and autonomous technologies will likely facilitate their proliferation.

As shown by the results of the Twitter analysis and discussed by interviewees, autonomous vehicles are thought of positively in the Phoenix area, and such sentiments could empower politicians to enable the testing of self-driving vehicle within their jurisdictions. Public perceptions are incredibly important within democratic societies, and at the current moment, there may not be a more exciting business venture in the eyes of the American populous than self-driving automobiles. This dynamic, coupled with how American political structures tend to favor business

interests, signal the potential for self-driving vehicles to be welcomed in an increasingly large expanse of the country. Politicians from other areas of the United States may adopt Arizona's permissive stance to self-driving vehicles encouraging private firms to plan for these automobiles. The net result of these outcomes could be the widespread adoption of self-driving vehicles in areas not prepared for them. This lack of preparedness could result in hasty, and single-minded planning.

The speed in which the testing and use of autonomous vehicles could spread may result in planning solely focused on enabling the transition to self-driving vehicles. Along with rapid expansion, the popularity of self-driving vehicles may entice states and cities to change zoning codes, or to transform transportation infrastructure in light of autonomous technologies. While some of the changes will be called for, others may ultimately harm urban communities. Rushed and myopic planning could result in plans focused on encouraging the use of self-driving vehicles. Given the popularity of autonomous vehicles, and the common political practices of the United States, it is not hard to believe that a local municipality could redirect funding from public transit projects in order to pay for new high-tech highways intended to maximize the efficiency of self-driving cars. These outcomes become more salient with the role autonomous technology developers have, and are likely to retain with regards to planning for self-driving vehicles.

Yet autonomous vehicles are not likely to be universally beneficial if handled in this way. Many are concerned that these vehicles could lead to negative social effects including increased sprawl, and the results of this thesis' commuting survey support these apprehensions. Dedicating new planning efforts to autonomous vehicles without inclusion of other modes of transportation is likely to be the best practice in only a small handful of situations, and planners must be allowed to review and consider all alternatives before committing to any plan. Unfortunately, the speed in which self-driving vehicles could spread may resulted in hurried and overenthusiastic action.

However, the results of this thesis point to one dynamic that could impede this spread: the reputation and familiarity of the autonomous technology developer entering the area. The Twitter analysis showed that Uber is not thought of as an autonomous vehicle developer, nor are they thought of positively. Uber introducing autonomous vehicle testing in a local area is not as likely to be as highly welcomed as Waymo or another developer. Conversely, the same Twitter analysis indicates that Waymo is not as well-known as Uber. If Waymo builds the public's awareness of their brand, while maintaining the public's enthusiasm for their technologies, then the speed in which they could spread their footprint may be faster than even their growth in Chandler.

The most important cross-cutting trend within the results of this thesis are indications of the facilitating political environment the development of self-driving vehicles is operating in. The public is optimistic about autonomous automobiles, and existing political norms support emerging businesses. Synergistically, the results suggest that the presence of self-driving vehicles could spread throughout this country faster than planning can account for. On one hand, these vehicles could have transformative positive effects on cities, leading to a revolution in traffic safety. On the other hand, these vehicles could also fuel suburban sprawl, promoting inescapable car culture and unhealthy lifestyles. The speed these vehicles could become commonplace may lead to cities overcommitting to them, leaving such areas vulnerable to their toxic effects. Slowing the spread of these vehicles is not likely to be successful, so planners must begin to prepare for them now, or else risk the results of hastily formulated plans shaped by overzealous politicians and constituents.

Chapter 20
Opportunities for Research

Autonomous vehicles have unique features that make them stand out from a research perspective. The same features also make them stand out to the average onlooker. These features

enable self-driving vehicles to safely navigate their environments, but they also create volumes of data that can be used to advance the study of many planning concerns. Autonomous vehicles create numerous ramifications for research, and these ramifications both enable and call for new investigations. In short, use of self-driving vehicles will create new, and enhance existing research methods, while also creating new phenomena that will need to be investigated.

The most immediate impact self-driving vehicles will have on research is the unfathomably large sets of data they will create. This data will include precise measurements of the both the natural and built environments wherever self-driving vehicles travel, and could be used for research into everything from traffic density, to mode choice, and to the impacts of weather and street designs. They amount of data that could become available to planners is immense, and this voluminous mine of information may be a treasure trove of knowledge.

Autonomous vehicles' ability to continuously generate many forms of data may also enhance existing research methods as well. In 1999, sociologist Robert Sampson pioneered a research method that has been very important for academic planners (Sampson & Raudenbush, 1999). Systematic Social Observations (SSO) is a structured observational study method that has been used to reliably measure public disorder and other social phenomena. Originally, observations were made in person, either walking or travelling some other way along city streets. However, Sampson later amended the method to take advantage of new technology. Instead of scoring the environment in-person, researchers score the environment through the images provided on Google Street View (Odgers, Caspi, Bates, Sampson & Moffitt, 2012). Waymo is owned by the same company as Google, and the images Waymo vehicles are taking of the built environment could one day provide frequent updates to Street View images. These vehicles could also produce accurate three-dimensional representations of environments thanks to their Lidar units. Frequently

updating Street View images paired with 3D representations of physical space could improve the reliability and broaden the applicability of SSOs along with other research method.

Self-driving vehicles will have an immense impact on research methods, but they also create phenomena that need to be studied. Some already identifiable avenues for research are the effects of long-distance autonomous vehicles, the rise of autonomous vehicle bullying, and ways to prevent rampant empty-car travel. Researching these issues now will help prepare planners looking for ways to optimize the uses of self-driving automobiles.

Long-distance travel is one of the ways that autonomous vehicles may be used in a different manner compared to traditional vehicles. Using self-driving vehicles to travel between cities is a very promising application of autonomous driving. However, very little is known about the potential effects of this type of travel. Long-distance travel in self-driving vehicles may help reduce the overwhelming emissions related to air travel, but is this reduction enough to lower the overall environmental impact? This type of travel has great potential, but it needs to be studied before planners commit to changing intercity infrastructure.

One of the most curious trends related to self-driving vehicles are the recent incidents of abuse and bullying directed at Waymo vehicles. Vandals have slashed the tires of Waymo vans. People have thrown rocks at them, and forced them off the road. A resident of Chandler recently threatened a vehicle with his gun, and Waymo drivers have been harassed multiple times. Over the last two years, the Chandler police have documented over twenty incidents of abuse or bullying towards Waymo vehicles (Randazzo, 2018a). As of right now, there are no reliable explanations for this phenomenon. Some of the experts interviewed stated that it may be related to the public's distrust of robots and automation, while other thought it may be related to an assumption that the targeted Waymo vehicles were without passengers. These explanations are just conjecture, but

research directed at this phenomenon could produce answers. The bullying of self-driving vehicles is an interesting turn of events, particularly since these vehicles are well thought of, and popular.

A final aspect of autonomous vehicles that needs to be investigated are ways to regulate empty-car travel. As mentioned before, the effects that empty self-driving vehicles could have on congestion and energy use may be calamitous. It is imperative for planners to begin formulating ways to restrict empty-vehicle travel. However, ideal restrictions will not be easy to implement. Some empty-car travel will be necessary to enable deliveries as well as autonomous ride-hailing services, but too many empty-cars on the road could create problems. A way to prevent cars that would otherwise be parked from travelling without passengers is called for, and planners should begin researching potential solutions as soon as possible.

The use of self-driving vehicles has many ramifications for research. These vehicles will enable new ways to conduct investigations, will improve on existing methods, and will create new phenomena to be studied. However, all of these ramifications are dependent on a sensible level of data transparency. Right now, Waymo and other autonomous vehicle developers withhold all the data they have collected, but for self-driving vehicles to aid research as much as they can, self-driving vehicle developers, manufacturers, and eventually regulators will need to keep their data as transparent as possible. Personal privacy will of course dictate some limitations to this transparency. Even so, a resulting dataset that is comprehensive while respecting personal privacy would be transparent enough to advance future research.

Chapter 21
Conclusion: Demystify the Self-Driving Car

One of the most worrisome aspects of the current state of self-driving automobiles is the status they already have. Simply put, these vehicles are popular. Driverless vehicles have great

potentials with regards to public health, but planners cannot overcommit to them. In the past, planners redesigned many cities for the near-exclusive use of automobiles destroying their vibrancies. In the near future, planners may be pressured to redesign cities again – this time for self-driving vehicles. Self-driving vehicles are so highly regarded, and so popular that they present planners with an all-too-familiar risk. The automobile was highly popular in America and promised to make travel easier and safer. Highway networks were highly popular in America and promised to make travel easier and safer. And now, self-driving vehicles are promising to make travel easier and safer, and planners will be called up to redesign the built environment for them. In the public's eyes, autonomous vehicles are miraculous, and while these vehicles could lead to great advances in transportation and health, they are not a panacea curing all of the world's problems. Planners need to demystify the self-driving car. The public must realize that overcommitting to these vehicles could be devastating. Self-driving vehicles will certainly be part of future transportation systems, but overreliance on them would be repeating past mistakes.

New technologies are often buoyed by an optimistic yet unfamiliar public. Noted author and futurist Arthur C. Clarke recognized the mesmerizing presence new technologies could have in the public imagination. In *Profiles of the Future*, he famously states, "Any sufficiently advanced technology is indistinguishable from magic (Clarke, 1973)." People become enthralled with new technologies. A combination of imagined and real possibilities coupled with a lack of understanding make new technologies seem more important and powerful – more magical – than they actually are. These perceptions inflate expectations for these technologies, and could convince some people to rely on these technologies without a well-rounded conceptualization of them.

Self-driving vehicles are currently in a phase where aspects of them are perceived and described as magic. Writers covering self-driving vehicles often equate the sensing and processing

capabilities of self-driving vehicles to magic (Kerr, 2017). Eric Adams (2018), an automotive journalist, describes public perceptions of self-driving vehicles as an expectation for magic. These expectations combined with public optimism for self-driving vehicles could coerce planners to repeat the mistakes of the past. Planning for traditional automobiles were spurred by similar expectations and levels of optimisms, and these dynamics led to planners deforming cities for cars.

In the 1950's, traditional automobiles and their enabling infrastructures were portrayed as magic in popular media. Like many magazine ads, an old Jeepster (Jeep) advertisement from Willy's-Overland Motors (1950) in Toledo, Ohio tells viewers how, "There's magic under the hood." Likewise, television shows and movies began to show cars as a solution to many of life's tasks. The perception of cars soon transitioned to a highly advanced piece of technology, but at the same time, highways and Interstates started to become magical in the eyes of the public. The passage of the National Interstate and Defense Highway Act of 1956 captured the imagination of the American people to such a degree that Walt Disney Studios dedicated an entire episode of the Disneyland show to the development of highways. This film labels the highways of the future as "Magic Highways (Kimball, 1958)." Fittingly, this film also portrays mid-century concepts for driverless cars. These magical perceptions of automobiles and highways convinced the public, politicians, and planners to redesign cities and the entire country around automobiles. This commitment to automobiles has been beyond catastrophic, and the current perceptions of self-driving vehicles should alert planners to the potential to repeat the same mistakes again.

To avoid overcommitting cities to the use of self-driving vehicles, planners must demystify the self-driving vehicle in the eyes of the public. They must warn the public of the pitfalls of traditional automobiles, and remind them that self-driving vehicles are just the newest form of

personal vehicle. Public discourse needs to move away from portraying these vehicles as wholly new technologies, and must focus on how they are another type of a familiar machine.

Planning for self-driving vehicles will occur through existing political practices, and in light of persistent commuting behaviors. These are elements that existed when traditional cars were planned for, and they are elements planning for autonomous vehicles will need to deal with as well. With the development of self-driving vehicles, the planning profession has been given an opportunity to address some of its prior mistakes. Planning must remember its failures, and must not overcommit to automobiles once again. The profession must acknowledge that self-driving automobiles will be a major aspect of future transportation, but they will not be the most appropriate form of travel for every neighborhood or environment. At this moment, public perceptions and expectations for self-driving vehicles are very high. Yet self-driving automobiles are not supernatural. They are far from magic. They can be understood, and planning's knowledge of them begins not with an illusion, but with the tangible legacies traditional automobiles have created. Planning can succeed where it has failed in the past. The profession has learned from its errors and is ready to plan for a better society. A healthier, and more equitable world can be planned for, and self-driving vehicles could become a powerful tool to reach this end.

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APPENDIX A: Interview Questions

(Note: Interviewees were asked between 6 to 11 questions chosen based on their expertise. The questions listed below were asked to at least one interviewee.)

Has there been any indication of increased planning efforts from Metropolitan Planning Organizations, City, States, or any other level of government?

How would you describe the residents' of the Phoenix area stance on autonomous vehicles, are most people in favor of testing them in the area, are opinions mixed, or are most people against them?

Why do you think people are starting to "bully" these vehicles like throw rock at them or jump in their way?

Has there been any local political backlash to Governor Ducey's pro-autonomous-vehicle-testing stance? Is this backlash mainly coming from Democrats?

Do you believe the use of traditional vehicles will be limited in any way in order to maximize the safety of self-driving vehicles (or to encourage their use)?

Will there be any public backlash to potential limitations on the use of traditional vehicles?

Do you think issues surrounding autonomous vehicle related policies could become politicized?

Some experts are concerned that autonomous vehicles could create some planning problems such as greater VMT (vehicle miles traveled), suburban sprawl, or sedentary lifestyles. In your opinion, what are some promising ways cities/planners/developers could combat these possibilities? Do you believe there may be some legal or policy ways to combat these issues?

Who do you believe is actually leading the planning for self-driving vehicles in Arizona, is it public agencies or the private companies developing these technologies?

Who do you believe will lead the planning for self-driving vehicles as they become more commonplace; public agencies, private companies, or some other party?

Could self-driving vehicles lead to more widespread private-ownership of transportation infrastructure?

What role will public transit have in a world populated by self-driving vehicles? What role will self-driving vehicles have in public transit?

Driverless vehicles could affect American cities with pronounced reliance on private automobiles. Do you believe any of these changes could lead to physical reorganization of hoe car-centric American cities are laid out?

APPENDIX B: Works Consulted

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