RETROFITTING THE HIGH DENSITY CITY FOR AUTONOMOUS VEHICLES: WASHINGTON, D.C.’S TEST CASE

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A capstone thesis paper submitted to the Executive Director of the Urban & Regional Planning Program at Georgetown University’s School of Continuing Studies in partial fulfillment of the requirements for Masters of Professional Studies in Urban & Regional Planning.

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ABSTRACT

At a time where research is new and technology is rapidly evolving, urban planners must accommodate the indeterminate impacts that connected and autonomous vehicles (CAVs) will have on roadways, streetscapes, and the built environment. CAVs are no longer a question of “if,” but of “when,” and while there is not an abundance of existing academic literature readily available as a resource for professional practice, applied research must explore new urban planning opportunities and practices. This paper argues that CAVs will drastically alter the urban fabric of the Chinatown neighborhood of Washington, D.C. through a repurposed streetscape built with the pedestrian in mind, with behavior altering shifts in transportation patterns and land use trends. In conclusion, this paper identifies a variety of planning strategies which will harness the impact of new technologies in furtherance of creating more livable cites and humanistic streetscapes.
KEYWORDS


RESEARCH QUESTIONS

How are current trends in connected and autonomous vehicles likely to impact transportation and design patterns in central cities?

How can the streetscape of Chinatown be reimagined through the introduction of connected and autonomous vehicles?

What impact can these reimagined streets have on the neighborhood’s cultural, historical, and educational institutions?
# TABLE OF CONTENTS

ABSTRACT .................................................................................................................. 01
KEYWORDS .................................................................................................................. 02
RESEARCH QUESTIONS .............................................................................................. 02
TABLE OF CONTENTS .............................................................................................. 03
LIST OF TABLES ........................................................................................................ 05
LIST OF FIGURES ...................................................................................................... 05
CHAPTER 1: INTRODUCTION .................................................................................... 06
CHAPTER 2: LITERATURE REVIEW ......................................................................... 07
  What are Connected and Autonomous Vehicles ...................................................... 08
  Why Do We Need CAVs? ....................................................................................... 10
  Additional Benefits of CAVs .................................................................................. 11
  Challenges of CAVs ............................................................................................... 19
CHAPTER 3: RESEARCH METHODOLOGY ............................................................... 27
  Literature Review .................................................................................................. 27
  Geospatial Analysis ............................................................................................... 28
  Case Studies ........................................................................................................... 28
  Modeling Study ...................................................................................................... 28
CHAPTER 4: CASE STUDIES .................................................................................... 29
  Waymo ...................................................................................................................... 29
  Boston, Massachusetts ............................................................................................ 31
  Las Vegas, Nevada .................................................................................................... 34
  Case Study Analysis ................................................................................................. 37
CHAPTER 5: CHINATOWN: WASHINGTON, D.C.’S TEST CASE .......................... 39
  A Neighborhood-based Approach .......................................................................... 39
  Selecting a Study Area ............................................................................................. 39
  Chinatown Analysis .................................................................................................. 41
  D.C.’s Commitment to an Autonomous Future ......................................................... 42
LIST OF TABLES

Table 2.1: Estimates of Annual Economic Benefits from AVs [CAVs] in the United States  ... 18

LIST OF FIGURES

Figure 2.1: Society of Automotive Engineers (SAE) Automation Levels .................................. 09
Figure 2.2: States with Enacted CAV Legislation ........................................................................21
Figure 2.3: Keeping Data Safe .....................................................................................................23
Figure 2.4: Hesitations Related to Purchasing a Self-Driving Vehicle ........................................26
Figure 4.1: City of Boston: CAV Testing Area ..............................................................................33
Figure 4.2: Application of CAV Technology in Freight and Private Auto: Waymo .....................38
Figure 4.3: Application of CAV Technology in Taxi and Private Auto: NuTonomy ......................38
Figure 4.4: Application of CAV Technology in Transit: Navya ...................................................38
Figure 5.1: Proximity of Chinatown to Other D.C. Attractions ....................................................40
Figure 5.2: Chinatown Boundaries ...............................................................................................41
Figure 5.3: Driverless Delivery Robots in Washington, D.C. .......................................................44
Figure 6.1: Percentage of Weekly Trips by Mode – 2016, 2013, 2010, 2007, and 2004 ..............46
Figure 6.2: How Reliable are Chinatown’s Roads? .....................................................................47
Figure 6.3: Present-Day Chinatown .............................................................................................54
Figure 6.4: Near-Future Chinatown, 2023 ..................................................................................55
Figure 6.5: Future Chinatown, 2038 ..........................................................................................56
CHAPTER 1: INTRODUCTION

“The implementation of autonomous driving needs a whole new rethinking. To really make it an attribute for society, we really need to think differently about where and when and how we implement this.” - Henrik Fisker, Automotive Designer

For over a hundred years, automobiles have transformed the way people move. These machines have enhanced lives by allowing us to go further, faster, and more comfortably than ever before, influencing where and how we live, work, and play. Although the automobile has been a driving force behind the manufacturing and shipping of goods in countries around the world, it has also been a driver of sprawl, congestion, and environmentally damaging emissions. However, over one hundred years later, a new generation of vehicles is emerging.

Today, a generation of connected and autonomous vehicles (CAVs) is operating on our city streets and is likely to proliferate all around the world. As with the first generation of automobiles, these vehicles will change the way we live, work, and play, while redefining the meaning of mobility with the potential for both positive and negative outcomes.

This paper operates under the premise that the implementation of this technology is no longer a question of “if,” but is inevitably a question of “when,” and will illustrate how the Chinatown neighborhood in Washington, D.C. has the potential to be transformed over a phased timeframe of CAV implementation. To strengthen this claim: 1) a series of urban planning recommendations grounded in comprehensive research, 2) acknowledging the differing opinions and trends in CAV implementation, 3) creating educated predictions concerning the future of Chinatown through application of this technology, and 4) act as a model to forecast the impact CAV technology will have on transportation and design patterns in central cities everywhere.

As later illustrated in this paper, my focus on CAV technology in the Chinatown neighborhood arose from a personal interest in the topic as well as Washington, D.C.’s
demonstrated commitment to exploring the impact of an autonomous future. This in-depth exploration of CAVs is the result of familiarity with the chosen study neighborhood and curiosity in the ways in which a mix of CAVs and the cultural, historical, and institutional land uses of the neighborhood could impact transportation patterns. Furthermore, a rooted interest in the public realm and the users’ experience of space has fostered much discussion pertaining to how Chinatown’s streets have the possibility to be transformed from both motorist and pedestrian perspective.

Ultimately, it is my goal to present predictions and recommendations in an unbiased manner through recognition of potential utopian and dystopian outcomes, while acknowledging the positive and negative hype resulting from this emerging technology. However, I will admit a degree of personal bias because I believe CAV technology has the potential to be significantly more successful and beneficial than shown by current events and research. Without current best practices and data to back it up, I understand where opposing and skeptical views are formed. It is these opposing views, absence of data, and relative young age of this emerging technology that makes such a controversial subject matter so interesting and vital to further explore.

CHAPTER 2: LITERATURE REVIEW

In order to make the case and realize the potential for connected and autonomous vehicles in Chinatown, it must first be understood what defines the technology, why the need for the technology exists, and what current literature, research, and public opinion says about them. This chapter presents a strong argument for their implementation, but also details the challenges and benefits of the technology while taking a detailed look at various broad opinions. It also presents
insight into policy challenges that cities across the country are dealing with in order to create effective, cohesive policy and respond to rapid changes in technology.

**What are Connected and Autonomous Vehicles?**

It is important to first acknowledge that by definition, “connected” and “autonomous” vehicles are two different entities. As such, the two technologies are not necessarily reliant on each other, but when combined, vehicular movement becomes even more efficient and safe.

**Connected Vehicles**

According to the Institute of Electrical and Electronics Engineers (IEEE), connected vehicle technology refers to the applications, services, and systems that connect a vehicle to its surroundings.\(^1\) Within a connected vehicle system, there are communication devices which allow for in-car connectivity with other systems present in the vehicle and enable connection of the vehicle to other external networks, applications, and services.\(^2\) Examples of these applications include everything from traffic safety and efficiency, parking assistance, roadside assistance, remote diagnostics, and Global Positioning System (GPS). In addition, interactive advanced driver-assistance systems (ADASs) technology is present within connected vehicles that include features such as adaptive cruise control, automatic braking, traffic warning integration, and blind spot monitoring systems. These features combine to provide valuable information about many different conditions of the road environment and serve to aid both the vehicle and driver in safe and efficient navigation.

**Autonomous Vehicles**

As defined by the U.S. Department of Transportation’s National Highway Traffic Safety Administration (NHTSA), fully automated, autonomous, or “self-driving” vehicles are “those in

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\(^2\) Ibid.
which operation of the vehicle occurs without direct driver input to control the steering, acceleration, and braking and are designed so that the driver is not expected to constantly monitor the roadway while operating in self-driving mode.” Recognizing that it is a broad term, SAE International (initially the Society of Automotive Engineers) developed a standard to define the various levels of automation and to create a sense of clarity and consistency as to what degree of driver interaction is needed in order for the vehicle to operate (see Figure 2.1). Clearly defining levels of automation also allows for ease of discussion of the topic across different states, automobile manufacturers, and other stakeholders.

![Figure 2.1: Society of Automotive Engineers (SAE) Automation Levels](Source: National Highway Traffic Safety Administration)

Many people do not realize that several of these levels of autonomous vehicles already exist on our roadways. While many cars are still at a Level Zero, the newest and most advanced vehicles that are available to the general public are considered to be anywhere up to a Level Two. In a Level Two vehicle, the majority of the driving decisions are still left up to the driver,

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but these vehicles can maintain particular speeds and following distances, apply brakes in an
emergency, and follow curves in the road.\textsuperscript{4} It is important to note that other common features in
vehicles such as lane departure or forward crash warnings are still considered a Level Zero, as it
is up to the driver to physically respond to vehicle warnings.\textsuperscript{5} Level Four vehicles are currently
being used in pilot studies in Arizona.

\textit{Classification}

Connected and autonomous vehicles have similar implications for change in
infrastructure, streetscape design, and pedestrian behavior. For the purposes of this paper,
vehicles that are both connected and autonomous are referred to as CAVs.

\textit{Why do we need CAVs?}

According to a report released by the National Safety Council in February 2018, an
estimated 40,100 people were killed in automobile accidents in 2017.\textsuperscript{6} An additional 4.57 million
people were injured seriously enough to require medical attention in motor vehicle crashes that
same year, with costs to society totaling $413.8 billion.\textsuperscript{7} In 2016, the National Highway Traffic
Safety Administration reported that 37,461 people were killed in crashes on U.S. roadways,
which was a 5.6 percent increase from 35,485 deaths in 2015.\textsuperscript{8} Causes of these crashes and
fatalities include speeding, alcohol impairment, improper seatbelt use, drowsy driving, and

\begin{flushright}
\textsuperscript{5} Ibid.
\textsuperscript{7} Ibid.
\end{flushright}
distracted driving with the percentages of each increasing each year. With these factors in mind, it is hard to ignore the fact that 94 percent of serious crashes are due to human error, and not a vehicle malfunction.

These statistics say a lot about the current climate of our roadway systems. While enhanced safety features and vehicles with higher safety ratings continue to make their debut on the market, the number of pedestrian and other traffic related fatalities continue to rise. However, CAVs have the potential to save thousands of lives and reduce injuries by removing the element of human error from the crash equation. Removing human error will help to protect pedestrians and bicyclists with whom motorists may interact. Ultimately, it is the hope that motor-vehicle fatality rates (per person-mile traveled) could eventually approach those seen in aviation and rail travel, (about 1 percent of current rates), and that society could potentially see “crash-less cars.”

Additional Benefits of CAVs

While increasing safety appears to be the most obvious advantage of CAV implementation, other benefits include fostering a greater sense of independence, helping the environment, and making driving an all-around more reliable experience.

Increased Access and Mobility

Hindered mobility affects people in a range of different ways, including reducing overall independence and imposing limits on access to healthcare, education, employment, and leisure

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9 Ibid.
activities.\textsuperscript{13} Mobility limitations often result in social exclusion, which greatly impacts the older generation and persons with disabilities. In fact, in the United States alone, there are more than 49 million Americans over the age of 65 and 53 million people that have some form of disability.\textsuperscript{14} When you consider that in many places across the country, the ability to hold a steady job or live independently rests on the ability to drive, the implementation of CAVs could extend that degree of freedom to millions of others.\textsuperscript{15} In addition, a recent study sponsored by the Ruderman Family Foundation concluded that mitigating transportation obstacles for persons with disabilities would enable new employment opportunities for approximately 2 million individuals and save $19 billion annually in healthcare expenditures from missed medical appointments.\textsuperscript{16} For children too young to drive, much of the burden on the parent of running between sports practices, school, and home could be eliminated by implementation of CAV technology.

\textbf{Reduced Congestion and More Reliable Drive Times}

The implementation of CAVs has the potential to completely redefine the idea of vehicle ownership while expanding opportunities for vehicle sharing, resulting in more efficient traffic flow and reduced congestion due to fewer vehicles on the road.\textsuperscript{17} There are three main factors affecting congestion both positively and negatively as it pertains to CAV technology: a reduction in traffic delays due to a reduction in vehicle crashes, vehicle throughput enhancement, and


\textsuperscript{15} Ibid.


changes in total vehicle miles traveled (VMT).\textsuperscript{18} Transportation systems would become more reliable with reduced delays that result from vehicle crashes, while overall trips would experience less stop and go traffic as vehicles would be able to monitor and adjust speeds and following distances based on the volume of traffic on the road.

Ultimately, the ability of CAV technology to influence roadway congestion levels depends on short-, mid-, or long-term implementation. As such, the type of impact will depend on the level of autonomy enabled and the degree of CAV penetration in the market.\textsuperscript{19} For example, it is suggested that the long-term outlook for CAV is “paradoxically easier to forecast than the mid-term,”\textsuperscript{20} as within the mid-term (or even short term), there will be a mixed fleet of vehicles operating on the roads. When this is the case, there will be vehicles with no autonomous driving technology, vehicles capable of autonomous travel under certain conditions, and completely autonomous vehicles sharing the roadways.\textsuperscript{21} While this is still an entirely feasible scenario, the potential impact CAV technology could have on roadway congestion will be far less obvious than if all of the vehicles on the road were able to communicate with one another and adapt appropriately.

The exact outcomes are still uncertain as they pertain to VMT. In some cases, it is believed CAVs will lead to a decrease in VMT as vehicle sharing impacts the number of vehicles on the road. In other cases, CAVs are believed to project an increase in VMT, as families rely on one vehicle to make many trips to fulfill all of their needs. Generally, decisions on where to live are influenced by vehicle operating costs (such as depreciation, insurance, fuel, parking, and

\textsuperscript{18} Ibid.
maintenance) and driver commuting time.\textsuperscript{22} With CAV technology however, the opportunity cost of time spent in the vehicle would be greatly reduced, meaning passengers would be free to engage in other productive activities. As a result, people may choose to live farther away from their workplaces or take trips they would not have regularly taken given the reduction in opportunity cost.\textsuperscript{23} Likewise, families might choose to only rely on a single car since they will no longer have to drive it. In doing so, more demand is placed on the singular vehicle to make numerous trips between workplaces, school, and home, which would cause an overall increase in VMT.

\textit{Environmental Impacts}

It is important to note the potential impact CAV technology can have on the environment. It has been suggested by researchers from the Eno Center for Transportation that CAV technology could reduce fuel consumption in the transportation sector by smoothing out driving patterns and minimizing braking,\textsuperscript{24} in conjunction with the forecasted impact on congestion as discussed earlier. According to Eno Center’s 2013 analysis, there is a potential to increase fuel economy 23 to 39 percent with features such as adaptive cruise control (found on autonomous vehicles) working with other vehicle-to-vehicle communication systems of connected vehicles. In addition, it has been found that although VMT may increase, emissions per mile could still decrease when vehicles are able to communicate with infrastructure and therefore drive in a smoother manner. With this in mind, researchers have concluded that with a 20 percent reduction in accelerations and decelerations, CAVs would have the potential to consume 5 percent less


\textsuperscript{23} Ibid.

fuel.25 Once again, these benefits are largely dependent on the market penetration of CAV technology, but should be a large driving force behind its use and implementation.

Ultimately, these projected environmental impacts should be taken into great consideration as auto manufacturers and policy makers move forward with this technology. Going far beyond just fuel consumption (as all or many of these vehicles may be electric), CAV technology can help to pave the way for better air quality, cleaner cities, and healthier people.

Creation of Walkable Communities

In addition to advantages pertaining to vehicles and roadway capacity, CAVs have the potential to greatly enhance the public realm and improve the lives of urban residents by creating more walkable and livable communities. At the moment, many cities are planned in ways that cater to the interests of self-driving consumers and not to an environment focused on the public realm that would harness the potential of self-driving cars.26 While a concerning concept, this technology presents an opportunity to learn from the streetscapes of today and ensure that cities and transportation systems become more sustainable, efficient, and equitable moving forward into the future.

With the implementation of CAV technology, the city streets of the future have the potential to be designed for people, not primarily vehicles. Due to the fact that CAVs require less space than traditional vehicles, more space will be able to be dedicated to public amenities.27 These amenities, such as increased seating and gathering places, parklets, and other complete

street features, will help to make what once may have been the busiest downtown arterial street feel like a welcoming main street.

This is similar to Jane Jacob’s approach to urban planning, where pedestrians are the most important factor of successful cities.\(^{28}\) Even 50+ years ago, there was an identified need for wider sidewalks that would promote increased mobility and safety for city dwellers, and the benefit of replacing driving street area with walking streets or sidewalks was realized. Jacobs saw the benefit of designing cities with decreased demand for personal vehicles by increasing walkability and accessibility to public transit.\(^{29}\) Implementing these concepts will undoubtedly foster a greater sense of community within a city, in which more people are encouraged to get out and walk, interact, play, and repurpose the built environment. Although Jacobs would probably have never imagined that her idea of decreasing the need for private vehicles would be solved by cars that drive themselves, it is important to suggest that these are themes that have been around for a while and need to be incorporated into this new era of street design.

**Land Use Shifts**

One last benefit that is important to acknowledge—also related to the creation of more walkable communities—is the change in land use patterns that is projected to occur. In his work, *The High Cost of Free Parking*, Donald Shoup estimates that on average, 31 percent of the areas in a district are dedicated to parking spaces.\(^{30}\) CAV technology will ultimately decrease this need for parking spaces. Personal CAVs would now be able to navigate to an underground garage in the city or parking station located on the outskirts of town, while shared CAVs would be in continuous service going from one passenger to the next, not needing to be parked. This

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creates abandoned spaces in the hearts of cities free for other uses,\textsuperscript{31} such as complete street amenities or other building types. As a result, this will increase the density of central business districts (CBDs) and stimulate more urban growth. While the need for drop off and pick up areas will still exist, storage needs would be reduced allowing for new mixed-use development or open space to be enjoyed by the public.

CAVs also have the potential to encourage increased suburbanization and sprawl as self-driving technology influences individuals and families to accept increased distance between home and their place of work. Looking for cheaper rent and home prices, the exodus to the suburbs introduces mega-commutes and higher vehicle miles traveled once again.

As with many of these benefits and drawbacks, the most obvious changes in land use will not be fully realized until long-term expectations of Level 5 CAV implementation are achieved. In the meantime, cities should be able to gradually see small changes in parking demand and utilization as this technology is rolled out.

**Summary of Benefits: An Economic Analysis**

Table 2.1: *Estimates of Annual Economic Benefits from AVs [CAVs] in the United States*\textsuperscript{32} is a complete estimated impact summary that suggests the economic benefits of CAV usage and ownership in the United States. The table operates at different market penetration levels (10 percent, 50 percent, and 90 percent) and assumes a $10,000 added purchase price at the 10 percent market penetration rate (that appropriately decreases as time goes on and the technology become cheaper). The study also takes into account monetary savings from the benefits that have been previously discussed, including reduced fuel usage, parking costs, and


time spent driving. Also included is a section of assumptions that outline the number of CAVs operating in the United States as well as percentages of benefits and their weight in making these predictions. While this table has been formulated based on predictions of future trends, it is a tool crucial to understanding the monetary value and impact CAVs can have on society and our wallets.

Table 2.1: Estimates of Annual Economic Benefits from AVs [CAVs] in the United States

<table>
<thead>
<tr>
<th>Source: Daniel J. Fagnant, Transportation Research Part A</th>
<th>Assumed market shares</th>
<th>10%</th>
<th>50%</th>
<th>90%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crash cost savings from AVs</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lives saved (per year)</td>
<td>1100</td>
<td>9600</td>
<td>21,700</td>
<td></td>
</tr>
<tr>
<td>Fewer crashes</td>
<td>211,000</td>
<td>1,880,000</td>
<td>4,220,000</td>
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<tr>
<td>Economic cost savings</td>
<td>$5.5 B</td>
<td>$48.8 B</td>
<td>$109.7 B</td>
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</tr>
<tr>
<td>Comprehensive cost savings</td>
<td>$17.7 B</td>
<td>$158.1 B</td>
<td>$353.4 B</td>
<td></td>
</tr>
<tr>
<td>Economic cost savings per AV</td>
<td>$430</td>
<td>$770</td>
<td>$960</td>
<td></td>
</tr>
<tr>
<td>Comprehensive cost savings per AV</td>
<td>$1390</td>
<td>$2,480</td>
<td>$3100</td>
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<tr>
<td>Congestion benefits</td>
<td></td>
<td></td>
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<tr>
<td>Travel time savings (M hours)</td>
<td>756</td>
<td>1680</td>
<td>2772</td>
<td></td>
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<tr>
<td>Fuel savings (M gallons)</td>
<td>102</td>
<td>224</td>
<td>724</td>
<td></td>
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<tr>
<td>Total savings</td>
<td>$16.8</td>
<td>$37.4</td>
<td>$63.0</td>
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<tr>
<td>Savings per AV</td>
<td>$1320</td>
<td>$590</td>
<td>$550</td>
<td></td>
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<tr>
<td>Other AV impacts</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parking savings</td>
<td>$3.2</td>
<td>$15.9</td>
<td>$28.7</td>
<td></td>
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<tr>
<td>Savings per AV</td>
<td>$250</td>
<td>$250</td>
<td>$250</td>
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<tr>
<td>VMT increase</td>
<td>2.0%</td>
<td>7.5%</td>
<td>9.0%</td>
<td></td>
</tr>
<tr>
<td>Change in total # vehicles</td>
<td>-4.7%</td>
<td>-23.7%</td>
<td>-42.6%</td>
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</tr>
<tr>
<td>Annual savings: Economic costs only</td>
<td>$25.5 B</td>
<td>$102.2 B</td>
<td>$201.4 B</td>
<td></td>
</tr>
<tr>
<td>Annual savings: Comprehensive costs</td>
<td>$37.7 B</td>
<td>$211.5 B</td>
<td>$447.1 B</td>
<td></td>
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<tr>
<td>Annual savings per AV: Economic costs only</td>
<td>$2000</td>
<td>$1610</td>
<td>$1760</td>
<td></td>
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<tr>
<td>Annual savings per AV: Comprehensive costs</td>
<td>$2960</td>
<td>$3320</td>
<td>$3900</td>
<td></td>
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<tr>
<td>Net present value of AV benefits minus added purchase price: Economic costs only</td>
<td>$5210</td>
<td>$7250</td>
<td>$10,390</td>
<td></td>
</tr>
<tr>
<td>Net present value of AV benefits minus added purchase price: Comprehensive costs</td>
<td>$12,510</td>
<td>$20,250</td>
<td>$26,660</td>
<td></td>
</tr>
</tbody>
</table>

Assumptions:
- Number of AVs operating in U.S.
- Crash reduction fraction per AV
- Freeway congestion benefit (delay reduction)
- Arterial congestion benefit
- Fuel savings
- Non-AV following-vehicle fuel efficiency benefit (freeway)
- VMT increase per AV
- % of AVs shared across users
- Added purchase price for AV capabilities
- Discount rate
- Vehicle lifetime (years)

Source: Daniel J. Fagnant, Transportation Research Part A
Challenges of CAVs

While CAVs present many opportunities and benefits pertaining to how we interact with our transportation systems and built environment, there are plenty of challenges that hinder their adoption. These challenges include purchase cost, purchase approachability, policy barriers, security concerns, privacy concerns, and general public misconceptions that arise from a misunderstanding of CAV technology.

The Cost of CAVs

In the midst of this new tech-savvy vision of the future of our cities, it would be irresponsible to not address the cost of adopting CAV technologies. The technology upgrades needed to implement such a system include the addition of new sensors, communication and guidance hardware, and software for each vehicle. As it stands today, the Light Detection and Ranging (LIDAR) systems currently installed on CAVs cost anywhere from $30,000 to $85,000 each, with additional costs anticipated for other sensors and software that will be required. In total, it is estimated that current civilian and military CAV applications cost over $100,000 per vehicle, which is grossly unaffordable to most Americans considering the average cost of a vehicle today is $33,560.

However, as with electric vehicles, greater affordability over time is promised, with the ability to produce LIDAR sensors at a cheaper rate, mass production, and advances in technology. In fact, many researchers estimate that with mass production capabilities, added

Costs may fall to between $50,000 and $25,000 (per CAV), perhaps reaching the $10,000 mark in 10 years.\textsuperscript{36}

Although cost is certainly a deterrent at the moment, it does not reflect a lack of interest in the technology. A recent survey conducted by J.D. Power and Associates suggests a ready and willing market in which 37 percent of people surveyed would “definitely” or “probably” purchase a vehicle with autonomous driving capabilities in their next vehicle; the share dropped to 20 percent when the additional $3,000 purchase price was taken into consideration.\textsuperscript{37} Just as a full market penetration will take time, so will the balancing of cost – but with mass production and evolving technology, it is certainly not out of the question for CAVs to reach a price point that is competitive with other standard vehicles on the road today.

\textbf{Policy Barriers}

One of the largest legal challenges facing automotive manufactures and policy makers today is the need to develop a framework and set of nationally recognized guidelines for CAV development and implementation usable across all 50 states and the District of Columbia. While it appears that at this time the certification of CAV use is generally up to the state, there needs to be additional solidified federal guidance to ensure there is continuity across the nation and eliminate policy uncertainty between states. Figure 2.2 illustrates the states that enacted some sort of CAV legislation and demonstrates where there are gaps across the country, such as the Midwest.


Some federal action does exist, however. In September 2017, the National Highway and Transportation Safety Administration (NHTSA) released its new federal guidance for Automated Driving Systems, *A Vision for Safety 2.0*, which is the latest guidance for automated driving systems in the states. While this guidance serves to clarify the role between federal and state governments, it does not come with a compliance requirement or enforcement mechanism.

As of 2017, 33 states have introduced legislation of some sort, although they lack consistency. For example, some states have enacted legislation that allows for CAV

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certification, while others allow for testing. Even so, most states have declined to set many specific restrictions or definitions and instead look toward their DMV to establish regulatory certification and provisional testing standards. Without clearly defined regulations, it will be difficult for CAV drivers to freely cross state borders with confidence that they are operating legally in fully autonomous mode in that state.

**Security and Privacy Concerns**

Other issues related to the implementation of CAVs are data security and privacy. Numerous questions arise such as what type of data will be shared and collected, with whom and in what ways it will be shared, what will it be used for, and who owns the data. As it stands today, much of the U.S. data ownership and control remains undefined as seen in the insurance industry. Some states have strict restrictions about what on-board data insurance companies can access in regards to crashes while others have no such regulation. This concept will be particularly tricky, especially when it comes down to providing CAV travel data, such as destinations, routes, and time of day to centralized and government controlled systems. Some of these systems rely on the data and use it in ways to advance technology and develop safer algorithms for the vehicles. However, without proper safeguards in place, this data could easily be misused by the private sector and/or government employees, be provided unfairly to law enforcement agencies for unwarranted monitoring and surveillance, or could lead to unwanted and targeted advertising.

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To mitigate this concern, some companies are already working on ways to anonymize vehicle data and aggregate it in a way that the data does not reveal drivers’ personally identifiable information. This concept has also been identified within the National Association of City Transportation Officials’ (NACTO) Blueprint for Autonomous Urbanism as illustrated below in Figure 2.3.

Developers will also need to be aware of electronic and cyber security as a whole and develop robust defense systems that will make security breaches and other crippling attacks more difficult. A system largely dependent on data exchange and interpretation over (essentially) a
cloud-based service requires the utmost security protocols. This ensures the safety and security of users trusting the system to deliver them from place to place.

**General Misconceptions and Broad Opinions**

To summarize this literature review and form an unbiased viewpoint in which predictions and recommendations are being made, it is important to look at the big picture and survey common misconceptions influencing the varied and divided opinions pertaining to the implementation of CAV technology. Some of these misconceptions include:

- **Misconception #1:** It will take decades until most of the vehicles on the road are capable of autonomous driving and this is nothing to worry about in my lifetime.

- **Misconception #2:** Self-driving cars are controlled by classical computer algorithms (if-then rules)

- **Misconception #3:** Self-driving cars need to make the right ethical judgment.

- **Misconception #4:** Self-driving cars will only increase congestion in cities

- **Misconception #5:** CAVs must be 100 percent perfect before being deployed, or else they are simply not safe enough and there’s no way anyone should step foot in one.

As demonstrated in this literature review, there are many sides to each misconception, resulting from a lack of testing data and implementation. For instance, levels of CAVs are already on our roadways, and there is a lack of definitive evidence proving that implementation will definitely increase or decrease congestion levels. As for misconception #3 regarding the ethical judgments of these vehicles, opponents must consider how often a vehicle is going to face a scenario in which it is forced to veer off the road, endangering nearby pedestrians. In essence, issues with CAVs being able to correctly make life or death ethical decisions are approached
inappropriately. These dilemmas are based upon the idea that there is a right decision to be made (where there is no right decision possible) instead of realizing that CAVs will function appropriately as long as they are able to avoid making any wrong decisions in the first place.

To address misconception #5, that the technology must be 100 percent perfect before being deployed, it should be acknowledged that CAV driving is not (and never will be) perfect, but neither are human drivers. In order for CAVs to work, they do not need to prevent all accidents or be perfect 100 percent of the time, they just need to be better than us.

However, it is important to acknowledge how these misconceptions are encouraging wavering or unsure opinions from the general public. Previously in this review, it was discussed that although the current high cost of this technology is a deterrent at the moment, there is still interest in its development (*The Cost of CAVs*, p.23). At the same time, it has been found that interest and confidence are on the decline from where they have been; that may be a generational occurrence, as seen in the review of J.D. Power and Associates survey and a study conducted by the MIT AgeLab and New England Motor Press Association. For example, the MIT AgeLab study found that while approximately one third of the younger adult sample (under 45 years) were somewhat open to full automation, older drivers were more likely to only endorse being comfortable with systems that assist the driver and do not require them to give up control. In comparing data from 2016 and 2017, there was a proportional shift away from comfort with full

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47 Ibid.
automation; across all age ranges, a lower proportion of respondents were interested in full automation when compared to 2016. Figure 2.4 illustrates a summary of factors cited by respondents as the reason they would “never purchase a car that completely drives itself.”

As illustrated, discomfort with the “loss of control” was the most cited hesitation, while a “mistrust in the technology,” “fear of it never working perfectly,” and feeling that self-driving cars are “unsafe” were other commonly mentioned factors. Until something can be done to help ease these fears, it is an unfortunate reality of public opinion CAV proponents are up against and will have to mitigate.

Help or hinder? Accept or reject? Unfortunately, these are questions that will not be fully answered until there is a larger percentage of vehicles equipped with CAV technology operating

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48 Ibid.
on our roadways. While society’s sense of uncertainty is surely warranted, it would be unfair to write-off this revolutionizing technology, especially considering the ways in which we can redefine the public realm. Moving forward, it is paramount that automobile manufacturers, policy makers, and the general public respect differences, but keep an open mind about the uncertain timeframe that it may take to fully unleash this technology. After all, the switch from horse-drawn carriage to the first automobiles didn’t happen overnight either.

CHAPTER 3: RESEARCH METHODOLOGY

This paper acknowledges that CAV technology is a relatively new field of study and will use a combination of a literature review, case studies, and quantitative and qualitative research/data analyses to present proper planning recommendations for the use of CAVs in the Chinatown neighborhood. Most importantly, this paper is grounded in the location-specific cultural, historical, and educational elements that give CAV technology relevance to the Chinatown neighborhood and uses these elements to anchor research.

Literature Review

The literature review is a key tool for understanding what CAV technology is, what popular opinion is, and how uncertain the implementation of this technology is. Having completed a review of current research and public opinion, it is clear that these varied views must be taken into consideration collectively in order to allow for appropriate urban planning recommendations to be made by studying all sides of the argument.
Geospatial Analysis

Geospatial information systems (GIS) are used to compare and analyze current transportation trends in the Chinatown neighborhood, such as dynamics of metro, ride sharing, and private vehicle usage to those of other neighborhoods in the area as well as to make informed predictions about the future.

Case Studies

Although the actual implementation of CAV technology is still within development stages and is undergoing trial runs, testing has recently moved out of labs and onto the streets. In recognizing that data and real world applications are limited, this paper has compiled a typology of case studies based upon ways in which CAV technology has been implemented: industry based innovations, city agenda-focus, and non-profit application. These studies represent typical ways in which implementation could take place in Chinatown and the different ways the neighborhood (or any city) could strive to achieve their safe and smart city goals.

Modeling Study

It remains unclear exactly when rollout of this technology will take place and how long it will be before CAVs represent a large portion of the vehicle fleet. Loose predictions range from 5 to 50 years for the full conversion to autonomous vehicles, with industries such as freight or public transit being closer to deployment than private passenger cars. In order to be able to make appropriate and targeted predictions and assumptions, a timeframe must be established under which CAV technology is assessed. For the purposes of this study, a two-timeframe approach has been selected: a 5-year (2023) approach and a 30-year (2048) approach. These ranges were chosen in order to take into consideration tiered industry rollouts and will also be effective in showcasing the infrastructure differences visible now and in the near- and far-future.
A modeling study has been conducted to better understand the differences in these approaches and visualize the impact CAV implementation will have on urban street design and the public realm. The study uses the current typical street alignment in Chinatown to compare it with proposed near-future (2023) and far-future (2048) approaches. These models and their proposed alignments will be based off of an extensive review of benefits and challenges of CAV implementation as well as what is known today about locations where testing is already taking place.

CHAPTER 4: CASE STUDIES

The following case studies serve to represent typical ways in which CAV technology has penetrated the urban street fabric across the country and highlight means by which CAVs could be introduced into Chinatown. Each city or company has been selected with regard to what role the government has in its implementation and for what entity it is being piloted for: transit, freight, or private auto. It is especially important to examine these case studies as some of the first examples of CAV integration. These valuable lessons should be taken into consideration to better prepare cities and neighborhoods like Chinatown for implementation.

Case Study 1: Waymo

Piloting for: Private Automobile, Freight

Waymo was founded in 2009 as the Google Self-Driving Car Project and rebranded to its current name in late 2016 as a subsidiary of Google’s parent company, Alphabet Inc.⁴⁹ With a goal to transform mobility by making it easy and safe for people and things to move around, Waymo’s self-driving vehicle fleet has test driven over 5 million miles (mostly on city streets),

Mainly based in the California - Arizona region of the U.S., Waymo has also piloted small projects in Washington, Michigan, Georgia, and Texas.

Starting in 2009 with a challenge to drive fully autonomously over ten uninterrupted 100-mile routes in their Toyota Prius vehicles, it took only months before Waymo met and rose above the challenge, driving autonomously at a magnitude never seen before. In just four years, the company had self-driven more than 300,000 miles, added additional vehicles to their fleet, and began to allow employees to test the technology on highways for work and weekend trips. It was at this point in 2012 that the company began to move their technology off of smaller, closed routes and took it to complex city streets, adding pedestrians, cyclists, and other unpredictable factors into the equation. Three years later, the world’s first fully self-driving ride on public roads debuted in Austin, TX; a situation with no driver, no steering wheel, and no pedals.

From the name change in 2016 to today, Waymo continues pushing forward with CAVs. In 2017, they added a self-driving Chrysler Pacifica Hybrid to their fleet – the first vehicle built on a mass-production platform with a brand new, fully integrated hardware suite that was specially designed for the purpose of full autonomy. Today, Waymo is continuing to operate their Early Rider program in the Phoenix metropolitan area, where they are looking for volunteers to use their self-driving minivans to go places they frequent, while providing valuable feedback to the Waymo team to help shape our autonomous future.

Additionally, as recent as February 2018, Waymo was granted transportation network company (TNC) status by the state of Arizona. With this new TNC status, Waymo will be able to start charging riders for its autonomous services, which will be accessible through a computer

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or an app and would be comparable to Uber and Lyft. The company has also already committed
to the autonomous semi-truck market and is looking to use its vehicles for last-mile types of
deliveries.53 These trucks arrived in Atlanta, Georgia at the end of March 2018 to begin a pilot
program in which they carry cargo bound for Google’s data centers. This program is unlike the
minivans in Arizona as the trucks currently have highly trained drivers present in the cabs to
monitor systems and take over control if the need arises.54

In all, this is an example of a private company taking the lead on CAV implementation
and extending itself to a wide variety of states to create test programs and expand the reach of
autonomous driving capabilities. The next case study, Boston, Massachusetts, is an example of a
city government taking the initiative to fulfill their own “Vision Zero” in which they are relying
on different CAV technology groups to get the job done.

**Case Study 2: Boston, Massachusetts**

**Piloting For:** Taxi, Private Automobile

“Zero deaths, zero injuries, zero disparities, zero emissions, zero stress,” 55 is the vision
of Boston’s transportation departments and their hope for the near future. Unlike the first case
study, which was powered by a private company, CAV testing and implementation in Boston is
born from the city’s desire to tackle their transportation agenda by launching their own program.
Boston residents told the government they wanted their transportation system to embody three

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values: safety, access, and reliability, as part of the city’s Go Boston 2030 planning campaign. The program looks to create safer streets and increased vehicular/transportation access for the aging population and those looking for better access to public transportation.\textsuperscript{56}

Boston currently has testing partnerships with three different technology groups: nuTonomy, Inc., which is a 2013 MIT spin-off technology startup company that makes software to build self-driving cars and autonomous mobile robots,\textsuperscript{57} Optimus Ride, another MIT spin-off company that develops self-driving technologies that enable efficient, sustainable, and equitable mobility solutions that is currently designing Level 4 systems for their vehicle fleets,\textsuperscript{58} and Aptiv (formerly Delphi), an UK based global automotive parts technology company that is pushing the power of new urban mobility.\textsuperscript{59}

Although the official testing facility for the city’s CAV program is essentially all of Boston, the government has chosen to take a very graduated approach. Initially, the three companies the city has partnered with have been very much constrained in the time, place, and manner of their testing. Figure 4.1 illustrates the initial on-street testing areas (Raymond Flynn Marine Park) all partners are approved for and the expanded area (South Boston Waterfront) nuTonomy has recently been able to expand to. Initial on-street testing has been limited to just a few blocks within the Innovation District, but once test plan milestones are met, the potential to expand to about 1,000 acres of the South Boston Waterfront becomes available.

\textsuperscript{56} Ibid.
Before these companies are even allowed to take to the streets, they must first adhere to strict off-street standards developed by the city, including the ease of manual takeover from autonomous mode, the functionality of emergency braking and stopping, and basic driving capabilities such as being able to safely stay within a lane.\textsuperscript{60} In addition, testing is only permitted during good weather and daylight hours.\textsuperscript{61} At the end of each quarter, each company submits a formal report outlining concepts such as specific routes and locations driven, crash reports (if applicable), scenarios where the safety driver had to take control, and lessons learned. There are currently only quarterly reports for the year 2017 freely available on the city of Boston’s website, as this is a newly initiated program.

Along with these three technology companies, Boston is committed to working with the Commonwealth of Massachusetts, MassPort, additional research institutions in the area, and two

\textsuperscript{61} Ibid.
major additional partnerships: the World Economic Forum and Transportation for America. The partnership with Transportation for America and their Smart City Collaborative is a key connection and way to share ideas, data, and best practices with various cities across the country who are trying to accomplish similar goals.

Once this program is fully established and the strength of these partnerships is harnessed, it will be interesting to see how these pilot programs evolve into on-demand ride services without a safety driver and how far the test boundaries will be expanded throughout the city. The city’s desire to advance its transportation agenda into an autonomous future is an exciting trend that other cities can look to for advice and best practices.

*Case Study 3:* Las Vegas, Nevada

**Piloting For:** Transit

In terms of the near-future implementation of this technology, the aspect of transit rollout is predicted to be the first targeted use in a truly autonomous fashion. Some cities, like Las Vegas, have acknowledged this trend and have concentrated their pilot programs specifically for transit. As discussed here, the research and testing has been done; Las Vegas is on the brink of being able to fully release their vehicles to the public, much sooner than previously thought.

Nevada became the first U.S. state to adopt laws specifically permitting the operation of CAVs in 2011. Since then, the state has only strengthened its commitment to the technology with the passage of additional legislation including Assembly Bill 69 in June 2017. This bill updates existing statutes to permit the testing and commercial public deployment of CAVs

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thereby supporting innovation, promoting competition, and helping to ensure that Nevada remains the leader in the future of CAVs.\textsuperscript{63}

To build upon the city’s commitment to an autonomous future, the Las Vegas City Council recently established the Innovation District in the city’s urban core to concentrate smart city technology infrastructure investment. This new district is now the home of new transportation infrastructure and mobility technologies, acting as a hub for partnerships with autonomous vehicle/mobility companies and fostering smart city technology firms.\textsuperscript{64} The city has been hailed as an ideal location for CAV testing since the climate and urban area is conducive to year-round deployment and has a concentration of urban scenarios such as a highly mixed physical-capability population, high levels of pedestrian and vehicle traffic 24 hours a day, and roadways with a variety of physical characteristics.\textsuperscript{65}

Committing to an autonomous future is not only a promise made by the city and its leadership, it is a regional and statewide operation, with policies enacted to further mobility. The city has placed more than 123 lane-miles of fiber optic cable, allowing for the implementation of CAVs throughout the core of the city.\textsuperscript{66}

In order to bring CAVs into the Innovation District, Las Vegas partnered with Keolis, a global leader in operating public transportation systems, and NAVYA, a French company specializing in the development of innovative, smart, and sustainable mobility solutions such as

their driverless electric vehicle dedicated to first- and last-mile transit. NAVYA developed their autonomous bus, ARMA, in France in late 2015 and has been testing in seven different countries around the world including the MCity Testing Facility at the University of Michigan in 2016. The ARMA came to Las Vegas for the first time during the January 2017 Consumer Electronics Show and just days later was launched as the first completely autonomous, fully electric shuttle ever to be deployed on a public roadway in the United States.67 During its week-long pilot, the public was able to take free test rides of the vehicle which occurred on streets between Las Vegas Boulevard and Eighth Street in regular traffic.68 In November 2017, NAVYA launched an expansion to their two-week experiment in order to survey rider attitudes towards CAVs - a yearlong project along the same route - that is currently taking place.

Due to the success of this ongoing project, NAVYA and Keolis returned to the 2018 Consumer Electronics Show in Las Vegas to introduce AUTONOM CAB. This is the first robo-taxi service to operate in the United States. This vehicle, with no cockpit, steering wheel, or pedals, is able to carry up to six passengers and is capable of speeds up to 55 mph; for now it will be limited to around 30 mph as it conforms to the local speed limits within the urban areas it will be traveling.69 The AUTONOM CAB is available as either private or shared service and is accessible through a dedicated smartphone application allowing users to request a ride, open and close the doors, and complete their journey. First piloted during the Consumer Electronics Show, ongoing testing will continue to follow the ARMA plan.

68 Ibid.
Case Study Analysis

In order to be able to make any sort of educated predictions or policy recommendations concerning the potential CAVs hold for the Chinatown neighborhood, it was imperative to gain an understanding of the early stage of the current technological development and its various uses. The three case studies presented in this research represent diversity in the way the technology is being tested and utilized (see Figures 4.2-4.4) as well as different approaches both cities and companies are taking in order to get CAVs on the road. The Waymo case study is an example of industry-based innovation and a private company looking to expand its services across many cities in different ways. Alternatively, the Boston and Las Vegas case studies illustrate the ways in which cities are looking to remain leaders of the smart city and CAV revolution through their intricate work with policy and the utilization of partnerships with other technology companies that are at the top of their field. Collectively, the three case studies demonstrate the powerful potential CAVs hold, illustrating the need for partnerships and policies that other cities can model as they look to implement the technology. As early testers of CAVs, it will be vital for other cities and neighborhoods to consider lessons learned and the scale at which the technology was first implemented in order to advance their own transportation goals. Although these case studies illustrate the ways in which CAVs are being tested for human transportation purposes, this discussion would not be complete without acknowledging other entities, such as the industrial sector and application in which the technology could be used. While not completely applicable to the Chinatown neighborhood at this time, these are valuable opportunities for testing and furthering of the capabilities of CAV technology.
Figure 4.2: Application of CAV Technology in Freight and Private Auto: Waymo
Source: Waymo

Figure 4.3: Application of CAV Technology in Taxi and Private Auto: NuTonomy
Source: Forbes

Figure 4.4: Application of CAV Technology in Transit: Navya
Source: Navya
CHAPTER 5: CHINATOWN: WASHINGTON D.C.’S TEST CASE

A Neighborhood-based Approach

A concept so large must start small. To propose the idea of CAV technology adoption in a specific neighborhood is a large proposition, but one that has lead to invaluable lessons and feedback with the potential to transform our autonomous future. As illustrated in Boston and Las Vegas’ case study approach, starting at a neighborhood and localized scale is beneficial for planners to be able to monitor, control, and respond to the effects of early CAV implementation. A small-scaled approach allows for a level of familiarity to be achieved. Knowing the wants, needs, and assets of a neighborhood may help the technology thrive within the particular area. Once this technology has demonstrated itself successfully in the specific area, it becomes a valuable tool to educate the general public on this topic.

For the purposes of this study, it was necessary to select a specific neighborhood in which particular needs and existing issues could be identified. While choosing a small geographic area may make it harder to fully test the technology in terms of available area to pilot, selecting an entire city for an early implementation study would make it difficult to control or model potential outcomes. The utilization of a neighborhood within a city that has already demonstrated its commitment to an autonomous future is the ideal scenario to ensure growth, opportunity, and the means for expansion beyond the boundaries of a neighborhood.

Selecting a Study Area

To best demonstrate the predicted impact the implementation of CAV technology will have on infrastructure, street design, and pedestrian behavior, the Chinatown neighborhood in Washington, D.C. has been selected as a model area in which outcomes were studied and envisioned. With the heart of the neighborhood centered at 7th and H Streets, it is strategically
situated between the Walter E. Washington Convention Center and the Capital One Arena. It is located above the third busiest Metrorail station in the region.\textsuperscript{70} As a downtown entertainment destination, the Chinatown neighborhood is located centrally to D.C. landmarks that attract millions of visitors annually (see figure 5.1) and is home to a variety of cultural, historical, and institutional land uses (see figure 5.2). It attracts thousands of visitors and provides employment and living space for locals. This represents numerous land use opportunities for infrastructure, transportation, and commuting patterns to be altered through the introduction of CAV technology. These are the reasons that the neighborhood was chosen as a representative sample area that would produce findings that could realistically be assumed for other areas with similar location and contextual influences.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{map.png}
\caption{Proximity of Chinatown to Other D.C. Attractions}
\label{fig:map}
\end{figure}

\footnotesize
Source: Esri

**Chinatown Analysis**

Based upon lessons learned and themes gathered from case study analyses, the Chinatown neighborhood is an appropriate and viable location for a piloting study to take place. As demonstrated in Las Vegas, the Chinatown neighborhood climate and urban area would be conducive to year-round deployments with a concentration of diverse urban scenarios. Particularly advantageous to the neighborhood is the referenced proximity to additional high-volume destinations that could influence more visitors to the neighborhood and D.C.’s commitment to an autonomous future.
Chinatown is a frequent site for public gatherings with more than 30,000 people crossing through its streets daily.\textsuperscript{71} Many visitors try to avoid 7\textsuperscript{th} and H Streets due to the congested sidewalks, traffic volume, and lack of street level activation by the cultural and commercial assets.\textsuperscript{72} Street level activation (the condition of the environment and activities on the ground that make the area interesting), and the advantages it would bring for business, is a major asset not yet fully taken advantage of. This is partially due to current street design, which does not allow for an excess of pedestrian public space. In addition to these missed opportunities, Chinatown is lagging behind in the transformation and improvement taking place throughout the rest of Downtown Washington, D.C. streets such as: new paving standards enhancing both the roadway and sidewalk character, new reinvestment in public spaces, and the existence of sidewalk cafes. In present day Chinatown, it is common to see inconsistent paving patterns, limited sidewalk cafes, obstructed sidewalks, poorly placed bus stops, and limited (to no) street furniture.\textsuperscript{73} While there have been efforts to mitigate some of these issues (such as the creation of the Chinatown Public Realm Plan), these are obstacles that have the potential to be resolved as we plan for a new generation of CAV operation and consider the effect implementation might have on the pedestrian scale problems plaguing the neighborhood.

\textit{D.C.’s Commitment to an Autonomous Future}

The District’s recent commitment to advancing into an autonomous future combined with the thriving tourist and business hubs make the Chinatown neighborhood an ideal study area for CAV implementation. The tremendous visibility inherent with being the nation’s capital drives the need to be on the edge of new technology and a desire for innovative solutions to the

\textsuperscript{72} Ibid.
\textsuperscript{73} Ibid.
problems that plague the city. Mayor Bowser announced on February 12, 2018 new efforts to explore an autonomous vehicle program. This program was created through the establishment of the Interagency AV Working Group, whose purpose is to proactively prepare the District for AV technologies and ensure that development will benefit District residents and visitors.74 The working group is comprised of various District agencies focused on transportation, disability rights, environmental issues, and public safety. In addition, the Bowser Administration partnered with the Southwest Business Improvement District to release a Request for Information for a CAV pilot program on 10th Street Southwest at L’Enfant Plaza. This stretch from Independence Avenue to The Wharf is seen as an ideal candidate for a CAV pilot program because of its manageable daily vehicle volume.

Furthermore, the capital oversaw the launch of the world’s largest urban AV freight pilot in March 2017. This program, which had oversight by the District Department of Transportation, introduced Starship Technologies’ driverless delivery robots in Logan Circle and around the 14th Street NW neighborhood (see Figure 5.3). These delivery robots provide last-mile deliveries between local businesses and residential customers with plans to expand beyond the Logan Circle/14th Street corridor in the future.

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The District has demonstrated a commitment to examining what an autonomous future could look like and has already begun to study the impact and potential scenarios throughout the city. In fact, D.C. is one of only 63 cities around the world considered a pilot city, while 32 other cities are preparing (meaning they have looked into the regulatory, planning, and governance issues), but have not started planning, according to Bloomberg Philanthropies and the Aspen Institute.75 Examining the streetscape and pedestrian level scale of potential impact of CAV technology serves to further the District’s existing transportation goals and remain an innovator in pioneering this technology.

CHAPTER 6: RESEARCH ANALYSIS AND FINDINGS

Now that it is understood where, why, and how early implementation of CAV technology has taken place, and what some of the issues and assets that make Chinatown the ideal test case are, this study examines the impact that CAVs may have on specific elements within the Chinatown neighborhood. In prior examinations of the pros, cons, and early implementation...

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strategies of CAV technology, it was made clear which specific elements of the neighborhood must be looked into further in order to fully understand potential consequences for the area, as well as what recommendations should be made in order to be most effective for Chinatown. These elements: mode choice, curb usage, streetscape characteristics, and land use patterns, are examined in order to predict how current trends will influence the transformation of the neighborhood as the result of CAV implementation.

**CAV Impact On: Mode Choice**

Commuting trends and vehicular traffic congestion in Washington, D.C. are among the worst in the nation. Nearly three-quarters of the District’s workforce commutes into the city and approximately one-third of District residents work outside of the District, contributing significantly to the congestion.\(^76\) Although driving alone is still the primary choice of transportation, overall driving has declined, while the percentage of workers within the District choosing to telework has risen. The rate of carpooling continues to drop, but mass transit, biking, and walking statistics increased through 2016\(^77\) as depicted in Figure 6.1.

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\(^77\) Ibid.
Figure 6.1: Percentage of Weekly Trips by Mode – 2016, 2013, 2010, 2007, and 2004
Source: National Capital Transportation Planning Board’s *State of the Commute*

Although these are District-wide trends in a regional study, the effects of heavy dependence on personal vehicles are apparent in examining congestion and the reliability of Chinatown’s main collector and intersection, 7th and H Street. The following series of images have been compiled from the District Department of Transportation’s District Mobility Project, a tool used to visualize multimodal transportation system performance within the District. These images study reliability within the Chinatown neighborhood using the planning time index. The planning time index is the ratio of travel time during the worst conditions to the time required to make the same trip at uncongested speeds. Greener shades on the map (representing a score of 1) mean the trip time is consistent from day to day, whereas the darker red streets (representing

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higher scores) mean the variation from day to day is greater and more time needs to be built into an overall trip to ensure that you will arrive at your destination on time.\footnote{DDOT. 2016. “Reliability.” District Mobility in Washington D.C. District Department of Transportation. https://districtmobility.org/stories/reliability.}

**Figure 6.2: How Reliable are Chinatown’s Roads?**

Source: District Mobility

Analysis of these images shed light on the congested street character present daily throughout the main streets of Chinatown. From early morning to late at night, the planning time index value remains at upwards of 3 or more, meaning that on a daily basis, one passing through the area can expect major congestion and will consistently need to build in extra time to ensure
they remain on time. The congested roadway character, coupled with congested sidewalks, has
the possibility to create an environment that some may wish to avoid.

Mass transit, including metro rail, train, and bus, is the second most commonly used
mode of transportation for the District (Figure 6.1). Recent issues plaguing the metro rail system,
including delays, malfunctions, and maintenance, have forced riders to build extra time into their
commutes. Mass transit users are the least satisfied with their mode of transportation.\(^{80}\) Although
this dissatisfaction exists, metro rail is one of the primary modes of transportation for Chinatown.
The Gallery Place-Chinatown metro station, located in the heart of the neighborhood, is the third
busiest station within the rail system and handles over 22,000 weekday passenger boardings on
average.\(^{81}\) This station provides convenient access to the Capital One Arena, the National
Galleries, the Convention Center, the Spy Museum, as well as local dining, retail, and other
cultural attractions. The city buses circulating through Chinatown are also plagued by delays as
they sit in the congested streets of the neighborhood.

In addition to public transit and private car, Capital Bikeshare has three stations located
within the neighborhood; it is not uncommon to see Limebikes, the new dockless bike-share
program that has made its way to the District, scattered throughout the streets. Ride-hailing
services, such as Uber and Lyft, are also very prominent in the area, with Capital One Arena and
the Convention Center ranking among the top destinations for both services in 2017.\(^{82}\)

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the-commute-region/.


\(^{82}\) Siddiqui, Faiz. 2017. “Uber and Lyft Name Top D.C.-Area Ride Destinations of 2017.” The
1981495400.html?refid=easy_hf.
With so many ways to access the neighborhood, it is difficult to predict how CAV implementation will affect each mode, especially in the context of near- and far-future timeframes. As a neighborhood with known traffic issues, there is a definite need to rethink how vehicles flow throughput. Many speculate mass transit usage will drastically decline as more people depend on the availability of CAVs. Others argue that due to the currently excessive costs of CAV technology, transit usage will remain the same or increase as CAVs become a first- and last-mile asset instead of a primary mode of transportation.

Considering CAV implementation is projected to occur over a tiered timeframe, the impact it has on mode choice and transportation trends will also occur gradually. It is over this timeframe the true effects on congestion will be apparent. While additional congestion could be an outcome of CAV implementation, the integration of technology in the vehicles would have the potential to help monitor and control traffic more effectively, in part re-inventing the meaning of congestion. At the same time, rollout of the technology could operate in a way that would decrease public transit use, like metro rail. Either way, cities should begin to think about how to best leverage these assets in ways each can operate without harming the other. CAV technology has great potential to redefine the meaning of congestion and alter commuting patterns for all.

**CAV Impact On: Curb Usage**

One aspect that will be difficult to fully explore prior to full rollout of the technology, is the impact the CAVs will have on parking supply and demand. It is speculated that if automobiles become shared mobility resources that are on the road rather than sitting in a
parking lot or garage for most of the day, parking demand will dramatically decrease.\textsuperscript{83} Conversely, if CAVs become private mobility resources, parking demand might drop less dramatically than if it were a shared mobility resource, although the space required to store private vehicles would still shrink.\textsuperscript{84}

These ideas have great implications for the Chinatown neighborhood, where on-street parking and garages hug the sidewalks and are always full and costly. In response to research that found that D.C. drivers spend an estimated 65 hours a year searching for parking,\textsuperscript{85} the District Department of Transportation recently tested ParkDC, an initiative to manage and regulate curbside and parking assets in Chinatown and the neighboring Penn Quarter neighborhood.\textsuperscript{86} This parking meter rate adjustment encompassed roughly 1,000 on-street parking spots between the two neighborhoods and was part of a pilot project to improve parking availability through demand-based pricing. The ultimate goals were to reduce time spent searching for parking, freeing up desirable spaces more often, providing better parking information, and reducing congestion. However, regardless of the time of day, drivers in the neighborhood would be paying more for parking on average. For the commuter who relies on these garages every day, this is a costly expense that will continue to rise year after year.

Alternatively, imagine what the streetscape could look like if the demand for these parking spots wasn’t there and what it could do for our wallets. Reduced parking needs would

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\textsuperscript{84} Ibid. \\
\textsuperscript{86} “ParkDC -- Demand-Based Pricing.” 2017. District Department of Transportation. DDOT. https://ddot.dc.gov/page/parkdc.
\end{flushright}
dramatically free up significant public and private space, both on the streets and within buildings. While there will still be a need (especially during early implementation) for on-street parking as well as drop-off and pick-up zones, the additional sidewalk space gained could be re-purposed for pedestrian scale amenities, such as parklets, café spaces, and additional retail space. Although the 10+ parking garages surrounding the Chinatown neighborhood are largely underground and do not utilize above ground space for vehicle storage, this valuable and costly underground space could be retrofitted into storage facilities for businesses, thus freeing up above-ground space. Some of the parking garages could also be kept solely for CAV charging and storage instead of sending the vehicles to the peripherals of the city to wait until they are requested again. For cities with a large number of above ground parking facilities, these could be retrofitted into apartment or condo housing options in the future.

Although only time will tell, it is not difficult to imagine a Chinatown without street parking and garages. Gone will be the days of increased congestion due to visitors searching for parking or backed up of lines of vehicles waiting to get into a garage. Ultimately, the money and space saved by repurposing this highly valued land has great potential to reinvent the Chinatown neighborhood with a new focus on the pedestrian rather than the driver behind the wheel.

**CAV Impact On: Streetscape Characteristics**

As alluded to earlier, Chinatown’s streetscape is lacking many of the elements that make it an ideal, safe, and welcoming space for pedestrians. Sidewalks are narrow and cluttered; retail is unable to take advantage of any space beyond their front door. Congestion on the streets creates congestion on the sidewalks as pedestrians are unable to cross at crosswalks at times due to the back up of traffic. Bicyclists must travel in the streets with no dedicated bike lanes. Additional congestion is created because of unfamiliarity with street parking regulations,
especially time of day. CAV implementation has the potential to rework the streetscape to a more pedestrian friendly environment.

With CAV implementation, Chinatown has the potential to gain a typical street configuration; currently there is not one. For instance, parts of H Street are 6 lanes wide (with the outer lanes used for parking at certain times of the day) while 7th Street is 5 lanes (including a dedicated parking lane on one side and variable parking lane on the other). Adjacent side streets are generally one lane in either direction with parking on either side. Planning for CAVs would require for a more uniform street layout in order for traffic to flow smoothly. While near-future scenarios might require a dedicated lane for CAVs, it is the hope in a far-future scenario the two can co-exist. An even better solution would be a 100 percent saturation of CAV technology in the Chinatown neighborhood.

With the reduction in number of lanes and lane widths, there is the potential for more space to devote to pedestrians. Wider sidewalks are more inviting, have the capability to move more people at one time, and would be particularly helpful in the areas surrounding the Capital One Arena, where volumes of pedestrians exiting after events force adjacent roads to be shut down. Additionally, the numerous shops and restaurants that line the street would have the ability to move beyond their front doors and out onto the sidewalks to better connect with passersby.

The new sense of walkability and shared streetscape that can evolve with CAV implementation may even result in the rise of multiple downtowns, or a series of walkable hubs. Since Chinatown is so close to City Center and Downtown D.C., there is great potential in this instance to bridge the gap between the two and create a stronger relationship between these neighborhoods allowing people to flow between the two more quickly and freely.
CAV Impact On: Land Use

To sum up the impact that CAV technology can have on the Chinatown neighborhood, one must look at current and future land use patterns. Although changes in land use patterns may be more apparent in areas not as densely built up as Chinatown, there is still the potential for change. In Chinatown’s case, the largest shift in land use will occur on the street with the elimination of parking and the emergence of new public space in its place. Elsewhere in cities with larger above ground parking garages, a more apparent change will be noticed as these structures are either torn down or repurposed. Either way, cities must think about zoning and the way in which parking standards are set in current zoning codes to allow for flexibility within minimum parking requirements.

Although not a focus of this study, it is important to acknowledge the land use shifts that may also take place outside of the dense, urban city setting. As mentioned previously, CAVs may increase commuter willingness to travel longer distances to and from work. Consequently, households and businesses may choose to locate themselves farther away from the urban core in order to find more affordable rent or home prices. This acts as an incentive for urban sprawl and low-density urban development. This in turn could potentially create increased traffic and congestion.

Illustrating Overall Projected Changes

This examination has demonstrated that CAV technology will greatly influence transportation and design patterns not just in Chinatown, but in central cities everywhere. It demonstrates the need for planners to look beyond the fact there will be self-driving vehicles operating on our roadways to the impact on pedestrian interaction with the environment.
Just as it is difficult to determine the extent of impacts on traffic congestion, parking, etc., it is equally challenging to predict when the rollout of CAV technology may take place and how it will alter streets visually. In order to bridge the gap between mere concepts and actual change, a series of illustrations have been created to help visualize the potential for transformation of the Chinatown streetscape and public realm as the result of tiered CAV implementation.

Figure 6.3: Present-Day Chinatown
Source: Sarah Diehl

The above illustration is a depiction of present-day Chinatown at the main intersection of 7th and H Street NW. This intersection was chosen for its existing street character, high volumes of both pedestrian and vehicular traffic, and its role as a main arterial street for the neighborhood. Variable on-street parking, uneven lanes in either direction, and narrow, crowded sidewalks, the current alignment of the streetscape and are elements that will be most visually impacted within this study.
It is predicted transit will most likely be the first roll out of CAV technology, as demonstrated in case studies and other early pilot programs across the country. Therefore, it is reasonable to picture Chinatown five years from now with some of these transit-orientated elements. Near-future Chinatown is characterized by dedicated lanes, specifically for transit with emphasis on CAV. Consequentially, streetlights and traffic lights have been upgraded to work with CAV systems. In addition, protected bike lane infrastructure has been added as an opportunity to alter streetscape alignments in a way benefiting other active modes of transportation. Most notably, all on-street parking has been eliminated as a means to add bike infrastructure and begin to expand the sidewalk space.
A fully autonomous Chinatown of the future features a completely re-imagined streetscape where the pedestrians are the priority and can interact more freely with the street. Acting as a refuge for pedestrians crossing the road, the central median allows for additional opportunities for pedestrians to safely cross the street instead of depending solely on corner crosswalks. In addition, reducing lane widths to the minimum and adding dedicated drop off and pick up zones along the corridor has allowed for increased pedestrian space within the sidewalk, including areas for seating and other street level activation by neighborhood businesses. This 20-year approach also illustrates the removal of all traffic signals and relies on connected infrastructure to move CAVs efficiently and safely.

**Modeling Analysis**

Many elements of this study, especially the timeframe or feasibility of elements, could be perceived as far-fetched. However, in the midst of so many unknowns, it is important to make
these bold predictions that start conversations and influence Chinatown neighborhood groups and D.C. government officials to think about what preparatory measures they can introduce and how implementation of CAV technology will transform their neighborhood. While it may be hard to imagine the complete removal of street parking in 5 (or even 20) years, the point of this study is to illustrate how drastically different the streetscape and public realm can be with the introduction of CAV technology and how it can be done in a tiered approach.

For Chinatown in particular, these potential shifts in transportation patterns should be an exciting time for those who interact with the neighborhood, whether it be the local resident, the worker who commutes into the neighborhood everyday, or the out-of-town guest who is just there for a visit. The cultural, historical, and educational institutions that call the neighborhood home are sure to also feel the effects as increased means of access has the potential to bring in more patrons.

There is much to be done to prepare Chinatown (or any neighborhood) for the rollout of CAV technology. In order to take advantage of these potential benefits, it is vital that Chinatown take these studied trends into consideration in future planning efforts of the neighborhood.

CHAPTER 7: URBAN PLANNING RECOMMENDATIONS

*The District of Columbia will have a world-class transportation system serving the people who live, work, and visit the city. The transportation system will make the city more livable, sustainable, prosperous, and attractive. It will offer everyone in the District exceptional travel choices. –Vision, moveDC 2014: “The District of Columbia’s Multimodal Long-Range Transportation Plan”*

The development and implementation of CAV technology in the next 20 years will bring the potential of immense changes to Chinatown’s transportation systems and urban fabric. Acknowledging that the neighborhood (and cities in general) is currently built to cater to the
interests of self-driving consumers rather than to maximize the benefit of autonomy, there is much work that can and will need to be done now to ensure implementation occurs in a way immediately beneficial for all. To best accommodate CAV technology as a viable form of commuting, Chinatown and the District Department of Transportation will need to consider an overhaul of streetscape design guidelines and think about how this technology can most efficiently fill in the gaps and integrate itself with the existing transit infrastructure.

Furthermore, although there is a lack of cohesive legislative action concerning CAV implementation and testing at the federal level, it has not hindered the advancement of the technology. This causes additional disparity, inconsistency, and confusion between cities and states that are forming their own policies. This issue will need to be addressed to ensure CAVs can operate from one state to the next.

Ultimately, successful implementation of CAV technology will depend on responsible planning efforts, a strong vision, meaningful partnerships, and regulatory action by the Chinatown neighborhood. This section outlines high-level recommendations that Chinatown should be considering over the short- and long-term to ensure the potential of CAV implementation is captured now and in the years to come.

**Structure and Organization**

First and foremost, it is important to recommend the establishment of the Chinatown neighborhood as a dedicated testing zone (for near-future implementation), and the creation of a CAV taskforce that would represent the neighborhood within the larger governmental structure. Both are recommendations that can be considered by the neighborhood immediately and would be particularly helpful in gaining traction and support for CAV technology in Chinatown.
A Dedicated Testing Zone

Until there is more widespread penetration of CAV technology throughout Washington, D.C. and the surrounding regions, it will be important to be able to contain CAV testing within specific boundaries. Chinatown could have the means to designate specific testing and monitoring grounds and can implement lessons learned from Boston, Massachusetts. Although a drastic amount of resources and effort would have to go into limiting regular vehicular traffic and effectively rerouting the rest while this testing took place, many valuable lessons would be able to be learned through the interaction of CAV with the diverse elements of the neighborhood. Ultimately these boundaries would be lifted, but are necessary to most effectively monitor performance and other safety metrics during the testing period.

CAV Taskforce

To best represent the needs, wants, and concerns of the neighborhood and have a stronger voice within D.C. government, a Chinatown specific CAV taskforce should be established within the Interagency AV Working Group that the mayor of D.C. recently established. This taskforce would represent the neighborhood’s best interests and could be made up of stakeholders including community, cultural, arts, neighborhood organizations and institutions, residents, ANC Commissioners, Chinatown business owners, merchants, property owners, developers, and members of the Downtown Business Improvement District (BID). Their input would be especially beneficial in making design and testing decisions that require a more intimate understanding of the neighborhood. The government could use the taskforce to educate the public about CAV technology and the benefits and challenges of its implementation in the neighborhood.
**Partnership Recommendations**

One of the most valuable lessons learned from the examination of case studies is the value of partnerships and the immense resources they can provide for a city. Similar to how the city of Boston created testing partnerships with multiple technology companies, research institutions, and other large scale agencies to develop policy goals, testing scenarios, and share ideas and best practices, the Chinatown neighborhood should look to establish similar connections to advance their goal of having a world class transportation system.

The District’s commitment to an autonomous future and the plethora of innovative technology hubs in the nation’s capital allow for a variety of opportunities. Strengthening Chinatown’s relationship with the District Department of Transportation (DDOT) and the Interagency AV Working Group (including the Office of the Deputy Mayor of Planning and Economic Development, and D.C. Office of Planning) is a fundamental way to bring these new technologies into the neighborhood. Establishing strong ties to the activity created at the Southwest Waterfront and the CAV pilot zone is another valuable way to share ideas, data, and partnerships and perhaps one day encourage the creation of a broader testing zone connecting the two areas.

Additionally, partnerships with specific CAV developers and manufacturers are vital to maintain a sense of consistency and to be able to track performance measures within the testing process. For example, the neighborhood could partner with Local Motors, an innovative mobility company dedicated to shaping the future for the better with their work with CAV technology. Currently, they have a sales and demonstration facility in the National Harbor and are testing Olli, their driverless shuttle that was the first to integrate the advanced cognitive computing
capabilities of IBM Watson. Local Motors would also have the potential to bring many valuable partnerships with them, including General Electric, HP, Airbus, IBM, the U.S. Army, Shell, Peterbuilt, and Siemens.

The specialized expertise, data, and background that partners can bring with them is invaluable. It will be of the utmost importance for Chinatown to take advantage of these opportunities, both locally in D.C. and across the country, especially in a field that is new and in the developing stages.

Policy Recommendations

Respecting the relative age of the technology, the varying degree of interest of states, and the number of stakeholders who have embedded themselves within the world of CAV technology across the country, it is important to acknowledge the need of cohesive policy – and the current lack of it. While much of the innovation and rollout of CAV technology comes from the private sector, it is public policy and regulation which will be needed to ensure the District’s inclusivity, accessibility, and sustainability goals are achieved as it pertains to CAV implementation.

A common fear of CAV implementation is the effect it will have on the rest of the transportation industry and the car-related revenue Chinatown counts on. While there is the potential for the decline of revenue, policymakers and Chinatown can lessen the fiscal impact by instituting policies and taxes that would mitigate this decline. This includes:

1) Vehicle Miles Traveled (VMT) Tax: charged specifically to CAVs to make up for the missing gasoline tax revenue. In doing so, this would discourage zero-occupancy or even single occupancy vehicles from roaming the streets or making unnecessary trips.

2) **Right-of-Way Tax:** also a specific charge for CAVs, this tax would monetize the right-of-way road space and would encourage ride-sharing behavior by charging for the use of space.

3) **Connected Tax:** a tax specifically important in early stages of implementation, this would charge users a fee to connect to the wireless infrastructure allowing vehicles to communicate between themselves and their surroundings.

These taxes would encourage a change from thinking of cars as a consumer good to that of a utility that can be tracked and paid for. As a result, these elements become politically feasible and sustainable ways to fund new infrastructure.

In addition, there would need to be additional discussion of CAV implementation in Chinatown’s (and the District’s) prominent planning documents. Nowhere in the District’s current Comprehensive Plan (or its proposed amendments at the time) are policy or design guidelines for future implementation mentioned. A separate policy should be included to ensure that CAVs advance the plan’s vision and principles, while maximizing potential benefits and minimizing threats. Furthermore, in order for Chinatown to become a testing site for CAV technology, implementation principles should also make their way into neighborhood specific documents such as the *Chinatown Cultural Development Small Area Plan* (published and updated in 2009) and the *Chinatown Public Realm Plan* (completed in 2012). Although not specific transportation plans, CAV implementation should be integrated into these plans as a way to delve into design and how the dynamics of the space might change in response.

**Urban Design Recommendations**

As demonstrated, the planning for the implementation of CAV technology must be done with the pedestrian in mind. Building upon the need for Chinatown to rethink its urban structure
from the viewpoint of a visitor, there are a variety of urban planning recommendations the neighborhood should consider to greatly improve pedestrian comfort, safety, and allow the streetscape to better handle a greater number of visitors. Some of these recommendations are considered to be near-future goals, while others will be best realized when there is greater CAV penetration on the streets. Urban design recommendations influenced by CAV implementation include:

1) **Safety as the Top Priority**: Chinatown’s redesigned streets of the future should be accessible for all street users and characterized by reduced number of lanes and lane widths. This can be accomplished by consistent curb ramps, evenly paved surfaces, and areas for refuge, such as medians within the wider streets. Bike infrastructure should be treated equally with protective measures where necessary. In addition, pedestrian drop off and pick up zones should have appropriate barriers to protect the pedestrian from moving traffic.

2) **Rebalance of the Right of Way and Additional Mobility**: Chinatown should capitalize on the reality that CAVs will be able to move more people on less congested streets. Instead of planning for a roadway expansion, the neighborhood should plan on reallocating that street space to active modes of transportation and pedestrian needs, such as bicycle infrastructure and expanded sidewalks. Additionally, Chinatown should offer flexible and affordable mobility options with the reallocated street space. This would include the needs of all communities, including those who are walking, biking, relying on fixed transit, or ridesharing.

3) **Real Time Street Management**: Chinatown must capitalize on the opportunities to manage their streets using new advancements in technology. By utilizing real-time right-
of-way management and vehicle occupancy pricing mechanisms, the neighborhood will be able to incentivize shared transportation over single-occupancy vehicles and in turn provide additional public spaces.

4) **Heritage Preservation:** The Chinatown neighborhood has a rich history and strong desire to display its cultural roots. Any implementation of CAV technology should strive to enhance the neighborhood’s visual and cultural identity by maintaining existing patterns that celebrate the heritage through signage, paving patterns, streetscape elements, and public art opportunities. Community groups within the neighborhood should take advantage of new street geometry and look for opportunities to host dynamic events and gatherings that utilize the new street space available for increased pedestrian use.

Active collaboration, communication, and a desire to balance streetscape outcomes with pedestrian needs will be key for the transformation of Chinatown into the neighborhood of the future. With proper policy planning and partnerships with state of the art innovation labs, utilizing Chinatown as a testing ground for CAV technology will prove to be successful and precedent-setting as the neighborhood gives new meaning to mobility.

**CHAPTER 8: CONCLUSION**

This paper has successfully identified a variety of planning strategies that will harness the impact of CAV technologies within central city neighborhoods. Chinatown was used as a model for the transformative impact these technologies can have on transportation and urban design patterns, however these recommendations, design ideals, and transportation outcomes can be taken into consideration and sought after by other central cities. By reimagining the existing
streetscape of the Chinatown neighborhood in 5- and 20-year approaches, pedestrians have been prioritized and the welfare of the community improved. Respective of the neighborhood’s cultural identity and established institutions, it has also been demonstrated how CAV technologies can maintain and enhance the unique identity of Chinatown by promoting access and providing enhanced public spaces.

Although CAVs are an evolving technology filled with uncertainties as to their planning and implementation, it is important for cities to think beyond constraints and instead toward the beneficial ways in which the existing urban fabric can be transformed. In order to create livable, walkable, and more sustainable cities of the future, a paradigm shift must occur in which urban design favors the pedestrian over traditional, human driven vehicles. This new focus on CAV technology to minimize the impact the vehicle has on the pedestrian experience within a central city neighborhood will prove to be a valuable approach to urban and regional planning strategies of the future.
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