Land Use in a World of New Transportation Technologies

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16. Abstract
o prepare for the arrival of autonomous vehicles, the Los Angeles Department of City Planning is exploring land use strategies to optimize the potential safety and the environmental and access benefits of this new technology. Self-driving or autonomous vehicles have captured the imagination of many people, including transportation officials, the media, technology entrepreneurs and travelers. At the same time, this new technology is raising complicated questions related to ethics, liability, accessibility, and safety. Technology companies and auto manufacturers are testing this technology on our roads today. Although the technology is still in progress, advancements in self-driving technology are occurring rapidly. In order to capture the benefits and minimize the costs of autonomous vehicles, cities must take advantage of this testing period to prepare for an autonomous future. Autonomous vehicles have the potential to transform mobility in Los Angeles by providing populations previously unable or unwilling to drive themselves with access to vehicles, eliminating human error in traffic crashes, and increasing efficiency through connected vehicle technology; however, these benefits are not assured. In the absence of advanced preparation and planning, there may be unintentional adverse effects including increased sprawl, vehicle miles traveled, commute distance, and automobile-related pollution.

In this study, I draw on academic literature, analysis of city General and Comprehensive Plans, and phone interviews with planners to analyze the potential impact of autonomous vehicles on local land use. Based on these findings, I provide a set of recommendations for the City of Los Angeles to consider in shaping future land use policies. Local governments have limited control over the development and consumer response to this technology; however, it does wield significant control over the built environment through zoning regulations. By leveraging these tools, local governments can shape the future growth of their cities while reinforcing stakeholder goals and adapting existing infrastructure to take advantage of these new technologies.

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Land Use in a World of New Technologies

Executive Summary

To prepare for the arrival of autonomous vehicles, the Los Angeles Department of City Planning is exploring land use strategies to optimize the potential safety and the environmental and access benefits of this new technology. Self-driving or autonomous vehicles have captured the imagination of many people, including transportation officials, the media, technology entrepreneurs and travelers. At the same time, this new technology is raising complicated questions related to ethics, liability, accessibility, and safety. Technology companies and auto manufacturers are testing this technology on our roads today. Although the technology is still in progress, advancements in self-driving technology are occurring rapidly. In order to capture the benefits and minimize the costs of autonomous vehicles, cities must take advantage of this testing period to prepare for an autonomous future. Autonomous vehicles have the potential to transform mobility in Los Angeles by providing populations previously unable or unwilling to drive themselves with access to vehicles, eliminating human error in traffic crashes, and increasing efficiency through connected vehicle technology; however, these benefits are not assured. In the absence of advanced preparation and planning, there may be unintentional adverse effects including increased sprawl, vehicle miles traveled, commute distance, and automobile-related pollution.

In this study, I draw on academic literature, analysis of city General and Comprehensive Plans, and phone interviews with planners to analyze the potential impact of autonomous vehicles on local land use. Based on these findings, I provide a set of recommendations for the City of Los Angeles to consider in shaping future land use policies. Local governments have limited control over the development and consumer response to this technology; however, it does wield significant control over the built environment through zoning regulations. By leveraging these tools, local governments can shape the future growth of their cities while reinforcing stakeholder goals and adapting existing infrastructure to take advantage of these new technologies.

There are limited opportunities to observe and analyze autonomous vehicle use on public roads. Therefore, this study utilizes qualitative analysis to understand how cities around the U.S. are addressing the potential land use and travel behavior implications

of autonomous vehicles. I first draw on the growing body of research on autonomous vehicles to outline the projected costs and benefits of this new technology and highlight the key debates associated with this topic area. I then complement this research by compiling and reviewing the most updated versions of the General or Comprehensive Plan, the Land Use Element, and the Circulation Element for 40 of the largest U.S. cities. In these plans, I systematically searched for policies connecting land use and autonomous vehicles. To the best of my knowledge, no other study has attempted a comprehensive, systematic review of city policies related to autonomous vehicles and land use at this scale. I summarize this information, describing each city's approach to autonomous vehicles as well as identifying any strategies the city proposes to address the potential impacts. To supplement the analysis of documentary evidence, I conducted phone interviews with city staff members listed in the General Plan or Land Use and Circulation Elements. Interview questions explored each city's overarching approach to addressing autonomous vehicles and the specific policies that the city has considered in response to their state's enactment of AV-specific legislation.

From the research, I find that cities use different strategies to tackle the potential land use and travel behavior impacts of autonomous vehicles. These strategies, both broad and specific, include building relationships with policymakers at all levels of government in order to exchange knowledge, adapting existing infrastructure and zoning regulations to address concerns related to sprawl and congestion, using the dialogue around autonomous vehicles as a tool to achieve other city goals such as equity and sustainability, and reexamining the city's parking supply to identify opportunities for land reclamation.

The Los Angeles Department of City Planning is beginning to develop a longer-term strategy for addressing autonomous vehicles. Based on the findings from this research, I recommend that the City implement the following strategies:

1) The creation of a citywide task force in partnership with other city agencies to exchange knowledge and different perspectives on how to address the impending adoption of autonomous vehicles.

2) The incorporation of policies to reduce or eliminate parking requirements for new development in certain areas as part of its efforts to update the city's development code.

3) The inclusion of shared on-demand mobility options as potential programmatic measures in their efforts to update the existing TDM Ordinance to encourage the use of sustainable transportation modes and the shared use of autonomous vehicles.

Introduction

The arrival of self-driving or autonomous vehicles has captured the imagination of many individuals, including transportation officials, the media, technology entrepreneurs and individual travelers, while raising complicated questions about ethics, liability, accessibility, and safety. Technology companies and auto manufacturers are testing this technology on our roads today. For example, Cruise and Waymo, two veteran companies actively developing autonomous vehicle technology, had a combined total of almost half a million test miles on California roads between December 2016 and November 2017 (Neiger, 2018). To prepare for the arrival of autonomous vehicles, the Los Angeles Department of City Planning is exploring land use strategies to optimize the potential safety, environmental, and access benefits that could be realized by planning for this new technology.

Within the realm of transportation planning, much of the discussion around autonomous vehicles has focused on potential models of deployment as well as the safety, environmental, and land use implications potentially associated with widespread consumer adoption of this new technology. The literature on autonomous vehicles emphasizes three possible models of deployment: private ownership by individual households, private ownership of fleets by private operators, and public ownership of fleets by government agencies. The costs and benefits often associated with autonomous vehicles can vary greatly depending on the deployment model, the extent of deployment, the degree of consumer adoption, and the evolution of local, state, and federal regulatory environments over time. Scholars and technology enthusiasts, however, often assess these costs and benefits under the assumption of mass consumer adoption and the complete turnover of the existing vehicle fleet into fully autonomous vehicles. In viewing this technology in its fully realized state, researchers run the risk of failing to address anticipated impacts stemming from human-driven vehicles mixing with semi-autonomous and fully automated vehicles. In addition, the existing literature has generally been broad in its examination of the transportation impacts of autonomous vehicles. These broad generalizations about autonomous vehicles and their predicted effects on cities at large, however, overlook key differences in how autonomous vehicles potentially may affect different types of geographies and individuals.

This study examines the potential impact of autonomous vehicles on local land use and includes policy recommendations to address the potential negative effects of these impacts. I draw recommendations specifically for the City of Los Angeles, which has experienced a rapid expansion of new transportation technologies within the past decade (Los Angeles Department of Transportation, 2018). Autonomous vehicles have the potential to transform mobility in Los Angeles by providing populations previously unable or unwilling to drive themselves with access to automobility, eliminating human error in traffic crashes, and increasing efficiency through connected vehicle technology. In the absence of advanced preparation and planning, however, cities may see unintentional adverse effects including increases in vehicle miles traveled, sprawl, automobile-related pollution, and a growing jobs-housing imbalance with households choosing to live further away from jobs and services. Local governments have minimal control over the pace of technological development and consumer adoption. It can, however, use land use regulations to shape factors that influence how technology will be used. Local governments wield a substantial amount of control over the physical environment; they directly oversee zoning, land use composition, and street-level designs. By leveraging these tools, local governments can shape the future growth of their cities while also reinforcing stakeholder goals and adapting existing infrastructure to take advantage of these technological changes.

The Los Angeles Department of City Planning (DCP) is taking a proactive approach in this regard. It is exploring land use strategies that can be used to prepare the City of Los Angeles for the arrival of autonomous vehicles. Therefore, with the City's interest in mind, this project seeks to identify policies and design elements that consider how emerging technologies can lead to land use patterns that promote inclusivity, equity, and safety within the City of Los Angeles. The research required to develop these policies requires answers to the following research questions:

1) In what ways do cities expect new emerging mobility services to affect land use and vice versa?

2) What are cities doing to help shape the use of these new services through land use policies?

3) What factors influenced whether cities have included autonomous and connected vehicles in their plans?

Given the lack of publicly-available data and the fact that no autonomous vehicle testing is taking place in Los Angeles, this study employs qualitative analysis to understand how U.S. cities are addressing the potential land use and travel behavior implications of autonomous vehicles. I systematically reviewed the most updated

versions of the General Plan, the Land Use Element, and the Circulation Element for 40 of the most populated U.S. cities to identify the strategies cities are adopting to prepare for the deployment of autonomous vehicles. I focus specifically on strategies that address impacts to the built form. To supplement these data, I conducted 9 telephone interviews with city staff members who are listed within the 40 General Plans or Land Use and Circulation Elements. During the interviews, I asked a series of questions to learn more about the specific land use and design strategies cities are employing. Following the interviews, I analyzed the data by categorizing the responses based on elements of the built form (i.e. curb management, land reclamation, etc.) and recommended land use policies that are applicable to the Los Angeles Department of City Planning. To the best of my knowledge, no other study has attempted such a comprehensive, systematic review of city policies related to autonomous vehicles and land use at this scale.

I first start with a literature review on the costs and benefits of autonomous vehicles, highlighting the implications of autonomous vehicles for land use, transportation, and travel behavior. I then summarize my methodology for collecting and analyzing the strategies that other cities have adopted to prepare for autonomous vehicles. Following this section, I discuss the preliminary findings from the review of cities' General Plans and from the interviews with city staff. Finally, based on these analyses, I conclude with a discussion of strategies that Los Angeles should consider in their efforts to prepare the City for autonomous.

Literature Review

Given that the current models of autonomous vehicles being tested are not fully operational, much of the discussion of autonomous vehicle technology and its impacts on existing transportation networks is theoretical. The purpose of this literature review is to differentiate between what is currently known about autonomous vehicle technology and what is purely speculation. I lay out the potential issues facing local governments and planners as they prepare for a future with autonomous vehicles. Likewise, I illustrate the uncertain regulatory and policy environment in which cities are making decisions.

The Society of Automotive Engineers (SAE) International (2018) created a classification system for vehicle automation that is based on the level of human involvement in driving tasks. Adopted by the U.S. Department of Transportation and the United Nations, this classification system is divided into six categories (Table 1). The term

'autonomous vehicle' typically refers to Levels 4 or 5 automation where the vehicle rather than the driver oversees all driving-related tasks.

Current debates amongst scholars focus on projected models of deployment and the potential benefits and costs related to safety, mobility, and land use implications. The literature emphasizes three possible deployment models for autonomous vehicles. The first model involves the private ownership of autonomous vehicles by individual households, or a continuation of the current consumer adoption model (Hawkins and Habib, 2018). The second model involves the private ownership of fleets of autonomous vehicles by private operators, similar to the ride-hailing networks managed by companies like Uber and Lyft (Hawkins and Habib, 2018). The third model involves the public ownership of autonomous vehicle or shuttle fleets by government agencies, which shares similarities with the operation of public transit systems (Hawkins and Habib, 2018).

Potential Benefits of Autonomous Vehicles

There is general agreement among academics that autonomous vehicles in their fully realized state can reduce collisions to some degree (Anderson et al., 2016). Nearly 40,000 automobile-related deaths occur each year in the U.S. (U.S. Department of Transportation, 2016). Human error accounts for approximately 90 percent of car crashes and 40 percent of fatal crashes (Fagnant and Kockelman, 2015). By removing the human element of driving and increasing the uniformity of vehicle movements through the urban environment, autonomous vehicles can reduce traffic collisions by as much as 90 percent with complete consumer adoption (Fagnant and Kockelman, 2015).

Proponents also claim that autonomous vehicles will increase mobility for non-driving populations, including seniors, children, people with disabilities, and people who are unable or unwilling to drive themselves (Litman, 2018). While this benefit may result in modest increases in automobile travel by formerly non-driving populations, it likely would improve their access to opportunities and services and enable greater independence (Sivak and Schoettle, 2015). If autonomous vehicles are deployed as a shared commodity, this may have notable impacts on the rate of car ownership amongst driving-age young adults (Litman, 2018). Adults between the ages of 25 to 34 are more likely to use on-demand ridesharing services such as Uber and Lyft than any other age group (Rayle et al., 2014). A recent study using data from the U.S. Census and the National Household Travel Survey also found that Millennials own 0.4 fewer

vehicles per household than the average Baby Boomer did at the same age (Knittel and Murphy, 2019).

Table 1. Levels of Vehicle Automation

LEVEL	AUTOMATION TYPE	EXAMPLE	DEFINITION
0	No Automation	No driving automation anywhere	Driver performs all driving tasks
1	Driver assistance	Adaptive cruise control	Driver performs majority of all driving tasks, but some driving assisted features may be included in vehicle design
2	Partial Automation	Adaptive cruise control AND braking	Driver performs majority of driving tasks and monitor changes to driving environments at all times, but vehicle has automated functions like steering and acceleration
3	Conditional Automation	Automated driving on congested freeway at low speeds	Vehicle performs a majority of all driving tasks, but the driver must be ready to engage with notice.
4	High Automation	Automated driving limited to defined area	Vehicle performs all driving tasks under all conditions
5	Full Automation	Automated driving everywhere	Vehicle performs all driving tasks under all conditions

Source: Society of Automotive Engineers (SAE) International, 2018.

Advanced sensor technology and cameras also may allow for autonomous vehicles to be spaced closer together than non-autonomous vehicles, which may increase highway capacity and throughput (Hawkins and Habib, 2018). Some scholars predict that the ability of autonomous vehicles to use roadway space more efficiently may result in significant lane width reductions, which would then catalyze a reclamation of land for uses other than the movement and storage of automobiles (Schlossberg, et al. 2018). Autonomous vehicles also may affect the amount of land needed for parking. On-street parking may be replaced with flexible loading zones which are better suited to facilitating the expected rise in curbside pick-ups and drop-offs; off-street parking facilities also might be repurposed (NACTO 2018).

In terms of travel behavior, some scholars predict that autonomous vehicles may significantly decrease the disutility, or travel time costs, associated with driving a vehicle (Fagnant and Kockelman, 2015; Berrada and Leurent, 2017; Trommer, et al 2016). This could translate to reduced commuting stress and improved productivity. Individuals who previously managed all driving tasks could, in theory, rest or complete work while traveling to their destination. According to several modeling studies that analyzed variables such as the value of time and the market penetration of both shared autonomous vehicles (SAV) and private autonomous vehicles (PAV), the value of time could play a significant role in determining long-term settlement patterns and the deployment model that consumers will adopt (Kim, et al. 2015; Thakur, et al. 2016).

Potential Costs of Autonomous Vehicles

It is important to note that many of the potential benefits associated with autonomous vehicles are not a by-product of the technology itself (Manville and Osman, 2018). The 'promise' of autonomous vehicles is contingent on many external factors such as the rate of consumer adoption, the model of deployment, the need for uniform vehicle standards, and the synchronization of federal and state regulations. Every potential benefit also may result in undesired and uncontrollable outcomes.

Scholars and technology enthusiasts who support autonomous vehicles for their proposed safety benefits often overlook the potential risks that come with new technologies. Computers often fail and small issues like malfunctioning sensors or cameras may result in serious safety issues that can lead to crashes (Koopman and

Wagner, 2017). In addition, passengers who feel safe in a vehicle often engage in riskier behavior (Millard-Ball, 2016). For instance, if drivers and passengers consider autonomous vehicles to be safe, they may reduce their use of seatbelts or may take greater risks while traveling. It is plausible that the potential safety benefits will increase as more people use autonomous vehicles; however, the safety benefits may not occur for years or even decades. Most households have made substantial investments in durable, personal automobiles. Many individuals also enjoy owning and driving their own personal vehicle (Choo and Mokhtarian, 2004). Therefore, a complete shift away from non-autonomous, internal combustion, privately-owned vehicles will take some time and may require federal involvement in making these vehicles commercially available.

Several statistical models that include land use, socio-demographic, and economic data show that autonomous vehicles are associated with increased vehicle miles travelled (VMT) and shifts away from active modes of travel (Soteropoulos et al., 2018). These shifts in travel behavior stem from some of the benefits created by autonomous vehicles. For instance, extending mobility options to previously non-driving populations will likely result in additional car trips and vehicle miles travelled (Fagnant and Kockelman, 2015). It also is plausible that population groups currently unable or unwilling to drive to shift away from more sustainable modes like public transit and carpooling with family and friends if autonomous vehicles offer greater flexibility in trip planning. Decreasing the disutility of driving also may result in lengthier, more frequent trips, thereby increasing VMT (Rice and Tomer, 2017). In urban areas, this trend could exacerbate congestion and induce sprawl since commuters may be more willing to travel longer distances to and from work (Anderson et al., 2016; Meyer 2017). Zhang (2018) examined the potential changes to residential location choice using current home location preferences and real estate records in Atlanta. He finds that even under the shared model of deployment, household residential location preferences change. Commuters may relocate to neighborhoods in connected, outer suburbs with better schools and more amenities due to projected reductions in commute cost (Zhang, 2018).

The impact of autonomous vehicles on congestion remains unclear. Optimists argue that AV's will increase roadway capacity with its ability to optimize spacing between itself and other vehicles. Increased capacity, however, creates an induced demand that will encourage more people to drive, thereby undermining any temporary improvements created by autonomous vehicles (Downs, 2004). Conversely, if consumers adopt a shared use model for autonomous vehicles, projected reductions in parking demand within urban centers may encourage the use of more sustainable travel options like carpooling or ridesourcing to downtown centers (Zhang et al., 2015).

People may shift to more sustainable, non-automobile modes when traveling to downtowns. Congestion will likely continue to be an issue, however, if parking consolidation occurs in the absence of policies such as congestion pricing. Zero-occupant autonomous vehicles may cruise if no parking is available near the owner's destination or if the owner wishes not to store their vehicle away from their destination (Thakur et al., 2016).

Although technology companies and automakers are optimistic that Level 4 or 5 automation will arrive within the next decade, the commercialization and widespread adoption of self-driving vehicles within this time frame is unlikely. It remains unclear whether the benefits of autonomous vehicle deployment will outweigh the costs (Table 2). In the absence of available data, many of these predictions are speculative and rest on layers of underlying assumptions. As such, cities should expect the transition to autonomous vehicles to be slow and uneven.

Table 2. Summary of the Potential Benefits and Costs of Autonomous vehicles

FACTORS	POTENTIAL BENEFITS	POTENTIAL COSTS
Travel Behavior	Eliminated burden of driving	Increased VMT
Congestion	Reduced (shared)	Worsened (private)
Land Use	Densification (shared)	Sprawl (private)
Safety	Reduced traffic collisions	At risk of cybersecurity breach
Accessibility	Increased mobility for non-driving populations	Too expensive for certain populations
Environment	Reduced GHG emissions (electric, shared)	Increased GHG emissions (diesel, private)

Potential factors that may be impacted by autonomous vehicles can result in benefits or costs depending on the adopted deployment model.

Time Horizon for the Arrival of Autonomous Vehicles

The widespread adoption of autonomous vehicles depends not only on the development of the technology but also on the regulatory environment. So far, 29 states have enacted legislation and 7 states have issued executive orders supportive of autonomous vehicle testing and development while 14 states have yet to push forward any autonomous vehicle agenda (National Conference State Legislatures, 2018). These findings suggest that U.S. states are generally supportive of autonomous vehicle deployment; however, mass adoption and commercialization requires synergy between the technology and the legislative environment. For example, Audi, the first automaker to achieve Level 3 Automation with its commercially available 2019 Audi A8, restricted the semi-autonomous driving features to the European market (Audi, 2017). Audi cited concerns related to the patchwork of federal and state laws that could lead to future legal battles that the company hopes to avoid (Davies, 2018). Vehicles also must be approved for general commercial use and be made affordable to most travelers before autonomous vehicles will achieve significant market penetration. Since autonomous vehicle technology is still being developed, this may take several decades.

It is also important to remember that despite the tremendous progress made in the advancement of self-driving technology, autonomous vehicles are still limited to hyper-specific road and weather conditions. It likely will take many years before a fully autonomous vehicle can operate safely in mixed urban traffic or within dense urban environments where the variability of other road users also must be considered. Recently, Gill Pratt, the CEO of the Toyota Research Institute, stated that autonomous driving "is a wonderful goal but none of us in the automobile or IT industries are close to achieving true Level 5 autonomy" (Ackerman, 2017).

Taken altogether, the evidence suggests that time horizon for the deployment and widespread adoption of autonomous vehicles is unclear. Planners and local governments do not know how long they have to prepare for autonomous vehicles because the legislative environment and the technological development are both moving at different rates. Audi's cautious release of the 2019 Audi A8, however, suggests that deployment will be gradual. Local governments will need to prepare not just for the arrival of Level 4 or 5 vehicles but also for an intermediate period during which autonomous vehicles mix with the existing fleet of human-driven vehicles.

The Importance of Land Use in the Deployment of Autonomous Vehicles

Local governments have minimal control over the pace of technological development and the pace of consumer adoption; however, they can shape factors that influence how the technology will be used (Manville and Osman, 2017). Local governments wield a substantial amount of control over the physical environment; they directly oversee zoning, land use, and street-level designs. Autonomous vehicle developers heavily depend on the accurate mapping of the physical environment to improve how self-driving machines read, learn and predict a variety of possible driving conditions (National League of Cities, 2018). Consequently, local governments can leverage their land use control to shape the manner in which consumers will use autonomous vehicles.

The connection among land use, transportation, and travel behavior is one of the most heavily studied topics within the transportation planning literature (Cervero and Kockelman, 1997; Boarnet and Crane, 2001; Chatman, 2014); however, with a few exceptions, these studies rarely examine this relationship through the lens of autonomous vehicles. This project seeks to fill this void by studying how U.S. cities use land use policies to shape the future of autonomous vehicle use. The few existing studies on autonomous vehicles and land use focus heavily on the repurposing of parking lots and garages (NACTO, 2018). The notion of reclaiming and repurposing land previously devoted to the storage of personal vehicles, however, is anchored by the assumption that the ridesharing model will be adopted (Rice and Tomer, 2017). This is a very bold assumption because only a small percentage of trips currently are made using ridesharing (Rayle et al., 2014). Rather than leading with these assumptions, this study reviews different land use elements including but in addition to those related to vehicle storage. This study also is the first to focus on policies that can be specifically applied to the City of Los Angeles. Los Angeles is a prime location for analysis because it consists of diverse neighborhoods with varying densities and land uses that allow for robust comparisons across different land use patterns.

With regard to land use and transportation, the prevailing wisdom is that vehicle miles per capita is lower in dense, urban areas characterized by compact development (Glaeser and Kahn, 2002). Lower vehicle miles of travel in these neighborhoods is associated with the fact that dense urban centers make alternative modes such as walking, cycling, and transit easier while making driving more difficult (Chatman,

2009). Scholars characterize built environments that lack enough development density, land use diversity, street connectivity, and destination accessibility, which reflect existing, long-standing land use policies, as sprawling (Cervero and Ewing, 2017). Therefore, if cities continue to promote existing land use practices that facilitate automobile travel, such as the separation of different land uses and minimum parking requirements, sprawl will become more difficult to manage with the deployment of autonomous vehicles (Manville and Osman, 2018).

Data and Methods

The Los Angeles Department of City Planning is exploring land use strategies to optimize the potential safety, environmental, and access benefits that could be realized by planning for emerging transportation technologies like autonomous vehicles. This study seeks to understand how cities are addressing the expected arrival of autonomous vehicles in the absence of comprehensive federal and state legislation. The ultimate goal of this study is to shape land use policies that will harness the safety and access benefits of this new technology. Shaping these policies require addressing the following research questions:

1) In what ways do cities expect new emerging mobility services to affect land use and vice versa?

2) What are cities doing to help shape the use of these new services through land use policies?

3) What factors influenced whether cities have included autonomous and connected vehicles in their plans?

Data Limitations

As of October 2018, the California Department of Motor Vehicles had issued one permit as part of its Autonomous Vehicle Driverless Testing Permit[1]. Waymo, the sole permittee, has limited its testing to specific roads near its Mountain View campus. No testing is currently being done in the City of Los Angeles. I had considered observing ride-hailing trips as a proxy for autonomous vehicles because it is one of the three projected models of deployment. Also, ride-hailing trip characteristics, like average trip

[1] Driverless of Autonomous Vehicles, California Department of Motor Vehicles, https://www.dmv.ca.gov/portal/dmv/detail/vr/autonomous/auto

distance, trip purpose, and projected pick-up and drop-off frequencies, more closely resemble the trip characteristics that may be expected of autonomous vehicles. As with most emerging mobility technology, however, trip-level data or, more broadly, data organized into meaningful levels of aggregation, are not publicly available. Both the National and California Household Travel (CHTS) Surveys include questions related to ride-hailing usage; however, ride-hailing trip counts are combined with taxi trips. The CHTS also was conducted between 2010 and 2012, slightly before Lyft or Uber launched their ride-hailing service in Los Angeles, which may explain the low response rate to questions pertaining to ride-hailing.

Methodology

In the absence of available data and due to the inability to observe autonomous vehicles on public roads, this study utilizes qualitative analysis to understand how U.S. cities are addressing the potential land use and travel behavior implications of autonomous vehicles. I begin by compiling and reviewing the most updated versions of the General and Comprehensive Plans, the Land Use Elements, and the Circulation Elements for 40 of the most populated cities within the U.S. (Figure 1). To my knowledge, no other study has attempted a comprehensive, systematic review of city policies related to autonomous vehicles and land use at this scale. Appendix A includes the list of cities included in the sample. I focus specifically on General Plans and Comprehensive Plans for several reasons. First, they serve as a cities' blueprint for how and where they will grow over time. They also serve as a decision-making tool, containing policies that help guide zoning enforcement, transportation objectives, and future development. General and Comprehensive Plans typically have a time horizon of 10 to 25 years, during which technology and federal and state regulations on autonomous vehicle testing and safety guidelines will continue to develop.

Although I did not randomly select the sample, it is still nationally representative of U.S. cities. It includes large coastal cities, midsize cities, and several smaller Sunbelt cities. There are cities that have played a significant role in influencing state-level safety regulations as well as cities that have only just begun to consider the role that autonomous vehicles will play within their local transportation system. Although the sample is small (relative to all U.S. cities), it includes approximately 18 percent of the nation's population. I did not base the selection process on criteria related to autonomous vehicles. It was important to include not only cities that have a proven record of planning for emerging mobility but also cities that have yet to address these changes in transportation technology. From the latter group of cities, I hope to analyze

the gaps in knowledge that they identified as crucial to making informed planning decisions around emerging mobility.

I found the General Plans and their corresponding Land Use and Circulation Elements by searching through city-managed web pages. I then systematically reviewed each plan, searching for the following key terms:

- "Autonomous Vehicle"
- "Automated"
- "Connected Vehicle"
- "Self-Driving"
- "Technology"

I then summarize the information included in the General Plans that describe the city's approach to autonomous vehicles as well as any strategies they propose to address their potential impacts. I paid close attention to strategies that apply to specific elements of the built form, like reclamation of land currently used for parking.

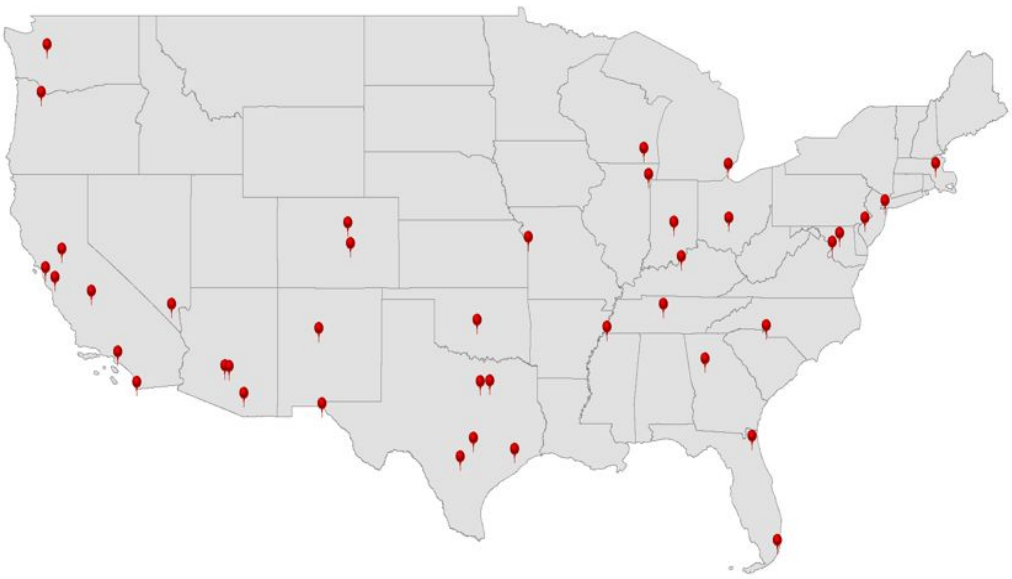

Figure 1. Sample of 40 Cities

Although the sample size is small, the sample is nationally representative of cities across the U.S. Large coastal cities, mid-size Sunbelt cities, and cities that have seen rapid population growth are all part of the sample.

To supplement these data, I conducted interviews with city staff members listed in the General Plan or Land Use and Circulation Elements. I specifically reached out to individuals who work for the city's Planning Department or Transportation Department. I reached out to at least one representative in all 40 cities via email in which I describe the purpose of the study and my research questions. In some cases, the individuals I initially reached redirected me to other team members or individuals in other departments.

I conducted the interviews in March and April 2019 via telephone. I asked each representative to provide a brief description of their role and to respond to six open-ended questions about how their organization is planning for or thinking about autonomous vehicles and land use. If a representative stated that their city had not considered autonomous vehicles in their future planning decisions, I asked questions to better understand why. I was able to interview 12 individuals from 9 cities. Each of the interviews lasted 20 to 30 minutes on average.

After I completed the interviews, I categorized these data based on elements of the built form. For example, for all cities that included autonomous or connected vehicles in their General Plan, I summarized findings for curb management and adaptive reuse parking strategies. I followed this same protocol for all cities that did not include autonomous or connected vehicles in their General Plan.

In the remainder of this report, I refer to interviewees by their department and their city. Appendix B includes the names and titles of interviewees who gave their consent to be identified.

Findings and Analysis

In reviewing the General and Comprehensive Plans of the 40 most populated U.S. cities and from the interviews with planning staff members, I found tremendous variation in the rate at which cities are working to address the potential transportation impacts of autonomous vehicles in their city. Some cities have developed detailed plans proposing changes to downtown parking requirements in anticipation of AV deployment. Some cities have had informal conversations with regional planning

bodies and other local agencies to learn and share knowledge. Other cities have done very little to plan for AVs.

In this section, I first discuss several trends that emerged in my review of the General and Comprehensive Plans. I then examine the correlation between the development of federal and state regulations and city-level policies. Finally, I discuss several land use policies that cities have either implemented or are considering to address the potential impacts of autonomous vehicles.

Review of General Plans

Twenty percent or 8 out of the 40 cities had General Plans that contained phrases like "Autonomous," "Automated," "Self-driving," "Technology," and "Connected Vehicle" as they relate to transportation. These 8 cities are Chicago, Indianapolis, Denver, Boston, Memphis, Portland, Albuquerque, and Colorado Springs. The 8 cities drafted or completed their General Plans or Comprehensive Plans within the past 2 years (Appendix A). Five cities are currently in the process of updating their General Plans while the remaining 27 cities had General Plans that did not include language specifically related to autonomous vehicles. Cities are required to update their General Plans periodically; however, few states are explicit in their expectations of how frequently cities must update their plans. As such, the inclusion of language on autonomous vehicles within a General Plan may not be the best indicator for assessing a city's preparedness for AV deployment.

To get a sense of the factors that prompt planners to consider autonomous vehicles in planning the future of their cities, I compared the date of each city's most updated General Plan, Comprehensive Plan, or individual elements and the year that their state drafted or enacted legislation related to autonomous vehicles. Since 2012, 28 states and the District of Columbia enacted legislation related to autonomous vehicles (NCLS, 2019). The eight cities that referenced autonomous vehicles within their General or Comprehensive Plans had updated these documents within one to two years of the date that their state had enacted legislation on autonomous vehicles. Seven of these eight cities adopted their General or Comprehensive Plan updates following state action. Among the cities within the sample that did not mention autonomous vehicles in their plans, 24 of them are in states that had taken some action on this issue. It is unclear to what extent policy development at the state level influences decision-making at the city level. Some cities may be waiting for policy development at the state level before making the commitment to address autonomous vehicles in their General Plans. This is understandable given that a General Plan update is a major

and, oftentimes, costly undertaking for both small and large cities. Many state bills are broad and focus primarily on standardizing definitions or providing guidance for preliminary testing in controlled settings (Table 3). The content of state legislation provides some insight as to why many of the General Plans that address AVs have been non-specific, especially with regard to potential land use implications.

Cities that included autonomous vehicle-related language in their General Plan, Land Use Element, or Mobility Element spoke generally about autonomous vehicles. These General Plans did not include detailed policies, guidelines, or metrics but demonstrated a clear intent to further their understanding of this new technology. Several cities, including Philadelphia, Chicago, and Indianapolis, view the anticipated deployment of autonomous vehicles as an opportunity to solidify their commitment to prioritizing existing city policies, which range from improving transit service to increasing mixed-use development.

Table 3. Autonomous Vehicle Enacted Legislation by State

BILL NO.	STATE	YEAR OF EARLIEST ENACTED LEGISLATION	POLICY FRAMEWORK
SJR 81	Alabama	2016	Request for Study, Definitions
2015-09*	Arizona	2015	Vehicle Testing, Operation on Public Roads
HB 1754	Arkansas	2017	Vehicle Testing
SB 1298	California	2012	Vehicle Testing,Operation on Public Roads
SB 213	Colorado	2017	Definitions, Vehicle Testing
SB 260	Connecticut	2017	Definitions, Request for Study
HB 1207	Florida	2012	Definitions, Vehicle Testing
HB 472	Georgia	2017	Insurance and Liability, Commercial Freight
HB 791	Illinois	2017	Vehicle Testing , Definitions
HB 1290	Indiana	2018	Definitions
SB 116	Kentucky	2018	Commercial Freight
HB 1143	Louisiana	2016	Definitions

HP 1204	Maine	2018	Vehicle Testing
	Massachusetts	2018	Cybersecurity, Vehicle Testing
SB 995	Michigan	2016	Definitions, Vehicle Testing
BILL NO.	**STATE**	**YEAR OF EARLIEST ENACTED LEGISLATION**	**POLICY FRAMEWORK**
HB 1343	Mississippi	2018	Definitions
LB 989	Nebraska	2018	Definitions, Vehicle Testing
SB 140	Nevada	2011	Operations on Public Roads
SB 2005	New York	2017	Vehicle Testing, Definitions
HB 469	North Carolina	2017	Commercial Freight, Definitions
HB 4059	Oregon	2018	Definitions
SB 1267	Pennsylvania	2016	Intelligent Transportation System Applications
HB 3289	South Carolina	2017	Commercial Freight
SB 598	Tennessee	2015	Definitions, Operation on Public Roads, Commercial Freight
HB 1791	Texas	2017	Vehicle Testing
HB 373	Utah	2015	Vehicle Testing
HB 494	Vermont	2017	Request for Study
17-02*	Washington	2017	Vehicle Testing
DC B 19-0931	Washington D.C.	2012	Definitions

Executive orders signed by state governors.** ***Source: National Conference of State Legislatures, Autonomous Vehicles/Self-Driving Vehicles Enacted Legislation (2019).

From these plans, I identified several themes characterizing how cities are approaching autonomous vehicles and new transportation technologies. The most common theme ties autonomous vehicles to broader mobility initiatives. The City of San Jose, for instance, aims to guide future technological advances to meet the transportation needs of seniors, people with disabilities, and other vulnerable populations. San Jose is

specifically looking to find ways to reduce the cost of managing a city-run paratransit program, and believes that autonomous vehicles may be a cost-effective alternative. Several cities, including Denver and Austin would like to create strategies for incentivizing the shared use of vehicles, including autonomous vehicles, as a way to tackle congestion. Portland's General Plan outlines several policies demonstrating the city's commitment to improving curbside management and active transportation infrastructure, regardless of whether or not driverless vehicles are operating on their streets. This same theme is also mentioned in Philadelphia's updated Circulation Element. Philadelphia sees the deployment of autonomous vehicle as a catalyst for creating policies that will further reinforce its pedestrian-focused urban core. Several cities also call for greater collaboration with neighboring cities in their region and with state and national policymakers regarding autonomous vehicle safety and testing regulations. Chicago's General Plan, for instance, recognizes the need for greater coordination between all levels of government to create coherent policies.

In terms of land use, cities that included autonomous vehicle language in their General Plans focused on a number of themes, including optimizing existing infrastructure, improving curb management, and rethinking parking requirements for future development. Colorado Springs, for instance, foresees that parking within their downtown core will still be needed once autonomous vehicles are deployed, but is rethinking how parking garages and surface lots should be designed for adaptability. Indianapolis's General Plan includes policies that urge traffic engineers and planners to consider autonomous vehicle adoption for future streetscape projects. It also calls for feasibility studies that focus on the effects of removing parking minimums and adding parking maximums within the city's zoning code.

Although a large proportion of the sample includes cities that did not include any language on autonomous or connected vehicle in their most updated General Plans, several of them have utilized other mechanisms to plan for emerging mobility more broadly. I learned about alternative mechanisms by systematically searching each city's name in combination with the same set of keywords that were used when I reviewed each city's General or Comprehensive Plan. These cities are thinking of autonomous vehicles and its potential land use impacts in similar ways as cities that included language on autonomous vehicles in their General Plans. Washington D.C., Detroit, and San Francisco, for instance, created citywide task forces in coordination with other agencies including their public works, emergency response, fire and police departments, to exchange knowledge on this topic. In 2017, Austin developed its Smart Mobility Roadmap, which lays out their approach to planning for emerging mobility. Within this document, the city explores local land use policies that can enhance connected uses along key transit corridors and how new transportation technologies

may affect the city's equity, affordability and safety, and workforce but also.[2] This roadmap also prioritizes exploring opportunities to redevelop land for shared mobility use within neighborhoods near downtown and at regional mobility hubs. The City of Columbus' Smart Columbus program in partnership with an autonomous shuttle provider is developing safety standards for self-driving shuttles.[3] Smart Columbus is conducting a pilot with autonomous shuttle buses to offer residents and visitors a hands-on experience with self-driving technology.

Interviews with City Staff

To supplement the information included in the General and Comprehensive Plans, I interviewed planners from 9 of the 40 cities within my sample (Table 4). I spoke to planners from agencies that oversee different forms of planning including transportation planning, long-range planning, urban design, zoning, and historic preservation. I also had the opportunity to speak to staff level planners as well as department directors and managers. Appendix B includes the names and titles of the interviewees.

Cities with 'autonomous vehicles' in their General or Comprehensive Plan

The City of Albuquerque and the City of Colorado Springs both included language related to connected and autonomous vehicles in their comprehensive plans. While both cities view autonomous vehicle deployment as imminent, they also acknowledge that there is still so much uncertainty as to when it will arrive and the form it will take. Both cities are adopting smart city technologies to upgrade existing infrastructure. Colorado Springs is in the process of upgrading and redesigning street lights to bring safety benefits to road users. While city planners initially did not think about autonomous vehicles during the development of this project, the city sees these improvements as a way to optimize the capacity of its existing road network in anticipation of changes in transportation demand and technology, including

[2] City of Austin, Smart Mobility Roadmap (2017): http://austintexas.gov/sites/default/files/files/Smart_Mobility_Roadmap_-_Final.pdf

[3] Smart Columbus, Connected Electric Autonomous Vehicles Playbook (2017): https://smart.columbus.gov/Playbook-Assets/Connected-Electric-Autonomous-Vehicles-(CEAV)/Developing-a-Safety-Plan-for-Self-Driving-Shuttles/

autonomous vehicles. Albuquerque is looking to integrate 5G wireless technology into public infrastructure, which may involve replacing street lights and installing devices that communicate real-time data with roadways.

Table 4. City Interviews

CITY	AGENCY
Included AVs in General or Comprehensive Plan	
Albuquerque, NM	Planning Department
Colorado Springs, CO	Planning and Development
Excluded AVs in General or Comprehensive Plan	
Austin, TX	Planning and Zoning, Department of Transportation
Houston, TX	Planning and Development
Kansas City, MO	Planning Department
Nashville, TN	Planning Department
Oklahoma City, OK	Planning Department
San Francisco, CA	Planning Department
San Jose, CA	Department of Transportation

Planners from all 40 cities received an email to participate in an academic interview. 10 cities confirmed but 9 cities actually participated in the interviews. Interviews were conducted over the phone and lasted on average for 30 minutes.

In terms of land use, Albuquerque's City Council recently adopted their Integrated Development Ordinance, which explores the redevelopment of certain areas into mixed-use zones. Some of these development and zoning code changes target major transit corridors where nodes that were formerly zoned neighborhood commercial are

zoned for mixed use. In the discussion of potential land use impacts, the Albuquerque interviewee also mentioned the possibility of significant changes to the downtown parking supply and the distribution of parking structures. Specifically, the city foresees the relocation of parking structures to distant areas outside of the urban core on less valuable land. Albuquerque is currently exploring the development of the next generation of adaptive parking facilities.

During their interviews, both cities emphasized their commitment to advancing existing city goals and view autonomous vehicles as being one of many factors to help promote these goals. Colorado Spring's fundamental policy is rooted in the concept of efficiency. Rather than building or widening roads to meet changing travel demands, they aim to maximize the capacity of their current road supply. In contrast, the changes Albuquerque has made in their zoning code to prioritize mix-used development near transit corridors demonstrates a commitment to promoting sustainable mobility options. These overarching, citywide goals were not created in anticipation of autonomous vehicle deployment; however, they have the added advantage of being applicable to various planning environments, including ones that may or may not include autonomous vehicles.

Cities without 'autonomous vehicles' in their General or Comprehensive Plan

Although the remaining cities did not include autonomous vehicles in their General or Comprehensive Plans, there is consensus that autonomous vehicles are inevitable and that the time to prepare for their anticipated arrival is now. Several cities have adopted alternative mechanisms to the General Plan to explore policies and strategies that address autonomous vehicles. Austin's Transportation Department, for instance, developed the city's Smart Mobility Roadmap, which outlines their approach to addressing shared, electric, and autonomous vehicles. Kansas City and its regional Metropolitan Planning Organization (MPO) are working on a policy document that discusses their approach to autonomous vehicles. Oklahoma City recently completed and adopted several amendments to its current Comprehensive Plan and said there may be future opportunity to include autonomous vehicles in planning decisions. San Francisco's Planning Department in collaboration with the San Francisco Municipal Transportation Agency are working on a policy document that addresses Transportation Network Companies (TNCs) but also touches on autonomous vehicles.

Several interviewees also stressed that regardless of when or how autonomous vehicles are deployed, their main priorities are to advance their city's guiding

principles. Houston's approach to autonomous vehicles and to emerging mobility more broadly involves examining the different ways that emerging mobility can help to push forward the city's main objectives. Similar to Los Angeles, one of Houston's overarching goals is to encourage the use of more active and sustainable transportation options. To advance this goal, Houston's Department of Planning and Development is exploring potential changes to land use policies that have historically promoted suburban-style development. For instance, Houston has considered eliminating its generous setback requirement for development along major thoroughfares, which has enabled the creation of large surface lots in front of buildings. Houston is working to ensure that emerging mobility services promote rather than hinder their efforts to make Houston more livable and walkable. In 2017, several public agencies in San Francisco participated in a citywide initiative to outline guiding principles for addressing emerging mobility services and technology.[4] They developed 10 guiding principles that reflect existing city legislation and echo city objectives that have been and will continue to be in existence regardless of when and how autonomous vehicles are deployed. The Oklahoma City interviewee shared a similar sentiment. Oklahoma City has made significant investments in promoting Bus Rapid Transit on key travel corridors and are in the process of a code update to encourage TOD-style development at nodes along these corridors. Oklahoma City's representative believes that the increased densification of their urban core may encourage the shared use of autonomous vehicles or the adoption of autonomous shuttles; however, the city's existing priorities remain constant.

When I asked which land use policies may be effective in addressing the potential transportation impacts of autonomous vehicles such as sprawl and congestion, the interviewees mentioned parking and curbside management. One of Oklahoma City's biggest concerns is how autonomous vehicles will affect the public right-of-way and the city's existing parking supply. Depending on the type of deployment and how people travel to downtown, they anticipate that current parking structures may see reduced use over time. In their current recode initiative, Oklahoma City is exploring the feasibility of easing parking requirements to accommodate the anticipated shift from vehicle storage to flexible pick-up and drop-off areas. Nashville has scaled back its parking requirements over the last decade, particularly in parts of the city that are walkable. While Nashville's Planning Department currently does not have a specific policy in place to encourage this practice, they anticipate that developers will move

[4] San Francisco Municipal Transportation Agency, Guiding Principles for Emerging Mobility Services and Technology (2017): https://www.sfmta.com/sites/default/files/reports-and-documents/2017/11/final_guiding_principles_emst_factsheet.pdf

toward designing adaptable parking structures that can be retrofitted for other uses in the future. Houston is exploring the possibility of reducing and reusing its surface parking lots for future infill development. However, they have not committed to developing a concrete policy; like most cities, they want to better understand how parking demand will change with the emergence of new transportation technologies. Austin's Transportation Department also is exploring policies related to curb management and easing parking requirements for new development. In their Smart Mobility Roadmap, for instance, the city includes the following land use and infrastructure recommendations:

- Allow for reduced or zero parking requirements with TDM or on-site access to shared mobility guarantees
- Unbundle parking costs from city building leases and purchases
- Encourage adaptable parking garages for future re-use as residential buildings, office spaces, and retail spaces
- Allow for shared parking between businesses

While these policies are not specific to autonomous vehicles, Austin's representatives believe they can help shape how travelers will use autonomous vehicles while still promoting the city's current objectives. Austin is also in the process of adopting a new Land Development Code, which looks to modify the city's minimum parking requirements in order to provide additional opportunities for future development and to reduce the impact of minimum parking requirements on new development.[5] The proposed code revisions would eliminate minimum parking requirements in areas that are within ¼ mile of activity centers, activity corridors, and transit priority networks, and would allow for parking structures to evolve over time as transportation patterns change.

Many interviewees would like to conduct pilot programs to better understand how travelers may respond to new technology. Houston is conducting a pilot program in partnership with Texas Southern University to test automated transit shuttles that will be used as campus circulators. This project aligns with the city's overarching goal of promoting high capacity transit options across the city. Planners in Kansas City have engaged in multiple conversations with their MPO on what an autonomous vehicle program will look like in their region and have identified several corridors for future

[5]Austin City Council, Land Development Code Policy Direction Memo (2019): http://austintexas.gov/sites/default/files/files/Communications/Council_Adopted_LDC_Policy_Direction_5.2.19.pdf

testing. Austin, considered to be the Kitty Hawk of driverless vehicles, is positioning itself as a testing ground for autonomous vehicles. The city is participating in an autonomous vehicle deployment platform called INRIX AV Road Rule[6] that enables cities to assign, validate, and manage traffic rules and restrictions for autonomous vehicles operating on public roads. The platform also lays the foundation for efficient and accurate data sharing between autonomous vehicles, their data providers, and Austin's Transportation Department. The City of San Jose's approach to autonomous vehicles is primarily focused on creating small-scale pilot programs to better understand how the technology works. The city created industry roundtables that involved several city agencies as well as representatives from technology companies who showed interest in wanting to pilot their autonomous vehicles in San Jose. This effort resulted in the creation of San Jose's Autonomous Vehicle Request for Information,[7] which invited companies to submit ideas for how to implement an autonomous vehicle pilot. According to the San Jose interviewee, the city wants to understand how constituents will respond to this technology before adjusting its land use policies and zoning code. That said, the city views autonomous vehicles as a tool to potentially free up land that is currently used for roads and parking to add additional housing. In its most recent General Plan, San Jose set targets for adding additional jobs in certain parts of the city to rebalance the number of jobs and housing within the city. They see autonomous vehicles as a possible opportunity to address this issue but did not have specific strategies in mind for how to do this.

The interviews with city staff show that cities are moving at different rates in their attempts to address autonomous vehicles: some have incorporated specific policies in their General or Strategic Plans while others have engaged in preliminary conversations with regional and state policymakers. Cities that included autonomous vehicles in their General Plans share similar approaches to addressing autonomous vehicles compared to cities that did not include autonomous vehicles in their General Plans. Many of my interviewees reported that their cities have taken advantage of the public attention around autonomous to reinforce existing city goals, which includes prioritizing mixed-use development along transit corridors, rethinking parking and curbside management, and adding technological improvements to existing road infrastructure. Cities also have developed mechanisms outside of the General or Comprehensive Plan

[6] City of Austin, Austin to Pilot INRIX Platform for Autonomous Vehicle Deployment (2018): http://www.austintexas.gov/news/austin-pilot-inrix-platform-autonomous-vehicle-deployment

[7] City of San Jose, Bid #1705-001 – RFI Pilot for Autonomous Vehicle Technology (2017): https://www.bidsync.com/bidsync-app-web/vendor/links/BidDetail.xhtml?bidid=2014573&roundId=null

to begin planning for and developing policies to prepare for the deployment of autonomous vehicles.

Recommendations

Although the City of Los Angeles's General Plan and Mobility Element do not mention autonomous or connected vehicles, the city has demonstrated its desire to take a more proactive role in addressing the potential impacts of autonomous vehicles. In 2017, Mayor Eric Garcetti was appointed the co-chair of the U.S. Department of Transportation's (U.S. DOT) Advisory Committee on Automation in Transportation. In 2018, Los Angeles City Council passed a resolution that allocated $1 million from its 2018-2019 budget to the Los Angeles Department of Transportation (LADOT) to explore modeling scenarios, engage with autonomous vehicle experts, and expand the city's efforts to test autonomous transit buses. Within that same year, LADOT released its Urban Mobility in a Digital Age Strategic Implementation Plan, which positioned the city as an active partner in the development of electric, shared, and autonomous vehicles. Most recently, Los Angeles City Council unanimously approved the city to apply for U.S. DOT's Automated Driving System Demonstration Grant, which provides up to $10 million to conduct autonomous vehicle testing with an emphasis on safety, data collection, and rulemaking.

For the past few years, the Los Angeles Department of City Planning has focused on updating several key planning documents, including its General Plan and Mobility Element; however, much of this work was set in motion before the Los Angeles City Council determined the city's position on autonomous vehicles. The Los Angeles Department of City Planning is now in the process of formulating its own approach to autonomous vehicles by shaping the city's land use policies. While it may be tempting to follow the hype of autonomous vehicles, it is important to remember that good planning principles are important regardless of the type of new transportation technologies that are deployed on city streets. Existing land use patterns serve as a reminder of the consequences that come from planning cities around the automobile. Rather than planning for autonomous vehicles, the findings from this study suggest that Los Angeles's Department of City Planning should consider how autonomous vehicles can serve the community's visions and goals for the future as set out in their General Plan. In this moment of rapid change and uncertainty, the Department of City Planning needs to adopt agile, flexible, and adaptable planning approaches that will enable them to respond quickly to changing environments. This may involve monitoring and adjusting plans and development codes based on performance, incorporating scenario

planning into their practice, and more frequent update cycles for existing planning documents.

In the past few years, the Department of City Planning has initiated a series of updates to several planning initiatives; these will play a key role in shaping future land development patterns and mobility in Los Angeles. These initiatives include modernizing the Transportation Demand Management (TDM) Ordinance and revamping the city's zoning code. With these current initiatives already underway, the City of Los Angeles has the unique opportunity to design policies that advance city goals and that shape how autonomous vehicles will be implemented in the future. In addition to incorporating AV-related policies in existing initiatives, the Department of City Planning should also consider creating and participating in a citywide task force to determine the city's policy position on autonomous vehicles.

Recommendation 1: Modernizing the Transportation Demand Management (TDM) Ordinance

California State Bill 743 requires CEQA transportation impact analysis to measure the environmental impacts of new development using changes in vehicle miles of travel (VMT), which is expected to be a better measure of the effects of land use on the transportation system than Level of Service (LOS). This shift from LOS to VMT better aligns with the State's goals of reducing GHG emissions, encouraging infill development, and improving public health through promoting active transportation options. Los Angeles's current, 25-year-old TDM ordinance features outdated mobility options that no longer reflect the changing transportation needs of Los Angeles residents. The existing ordinance provides incentives for ridesharing but does not account for emerging mobility services like ridesourcing, bikeshare, carshare, and the availability of real-time transit information. Therefore, the Department of City Planning in collaboration with the Los Angeles Department of Transportation (LADOT) is in the process of updating the ordinance to complement the recent update to SB 743.

The proposed ordinance will apply to new development projects that exceed certain thresholds based on the size of the development and the type of land use. Developers will select from a menu of programmatic and physical measures that reduce drive alone trips; these may include providing carshare and bikeshare memberships, transit subsidies, carpool incentives, parking pricing and cash out[8], and mobility hubs.

[8] California's Parking Cash-Out Law requires certain employers who provide subsidized parking for their employees to offer a cash allowance in lieu of a parking space. The intent of this strategy is to reduce vehicle

The Department of City Planning should include additional programmatic and physical measures that not only reflect the city's desired outcomes but are also adaptable to autonomous vehicle deployment. Autonomous vehicles make it possible to have zero-occupant vehicles, trips without any passengers. Therefore, policies need to be deployed with an eye towards minimizing these trips since they likely contribute to pollution and congestion while providing limited benefit. One possible programmatic measure can be the provision of ridesourcing memberships that are limited to pooled services like UberPool and Lyft Shared Rides. This policy would prioritize the shared use of ridesourcing, which may transition to an autonomous fleet in the near future. Several cities I interviewed are in the process of revamping their TDM strategy and have found ways to incorporate emerging mobility options into their programmatic measures. Austin's Smart Mobility Roadmap, for example, proposes permitting reduced or zero parking requirements if developers include TDM measures or on-site access to shared mobility options for new development projects. To implement this policy, the authors of Austin's Smart Mobility Roadmap propose that the city's code update allow for proactive TDM programs in place of parking requirements for certain developments.[9]

The City also could create and partially subsidize a Guaranteed Ride Home Program at large employer sites. To encourage ride sharing, employers could limit subsidies to any type of shared ride, which could be designed to be broad enough to include vanpool services, shuttles, and pooled ride sourcing. This programmatic measure can be complemented with the provision of flexible loading zones that can be used for commercial deliveries and passenger pick-ups and drop-offs. By limiting subsidies to only pooled rides, this program could potentially reduce the likelihood of zero-occupancy autonomous vehicle trips.

Studies show that carshare programs can be an effective TDM measure for shedding vehicle ownership and reducing daily VMT, particularly for large residential developments (Tal, 2018; Cervero et al., 2006). To discourage the private ownership of autonomous vehicles, the Department of City Planning should consider reducing minimum parking requirements for developments that offer designated carsharing parking spaces and charging stations on site for their residents.

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commute trips and emission by offering employees the option of "cashing out" their subsidized parking space and taking transit, biking, walking, or carpooling to work.

[9] City of Austin, Smart Mobility Roadmap (2017): http://www.austintexas.gov/sites/default/files/files/Smart_Mobility_Roadmap_-_Final.pdf

Recommendation 2: Factor in AVs in PLAN re:code efforts

In the summer of 2013, the Department of City Planning initiated the PLAN re:code program, which involves a comprehensive revision of the city's zoning code. The PLAN re:code effort is nearing completion; however, the updated zoning code has not yet been adopted by the Planning Commission. The Department of City Planning should take this opportunity to integrate the parking-related programmatic measures proposed in the TDM ordinance update with PLAN re:code. By better managing the parking supply and complementing these efforts with robust transportation alternatives, cities can steer autonomous vehicle toward a shared-use model. Interviewees from all of the cities in my sample stressed better management of their parking supply as critical to mitigating the potential sprawl and congestion effects of autonomous vehicles use. Several cities who are also in the process of updating their zoning code, including Austin, Oklahoma, and Portland, have considered reducing or eliminating parking minimums for new development projects along key transit corridors. Inexpensive, excessive parking has been linked to increased driving and more drive-alone commutes (Shoup, 2005). This finding holds true for autonomous vehicle adoption. Therefore, I urge the Department of City Planning to consider eliminating parking minimums along key transit corridors and near transit-oriented developments. The Department of City Planning should also consider using the data collected from the Los Angeles Department of Transportation's (LADOT) Mobility Data Specifications (MDS)[10] tool to determine where shared mobility use is highest in the city and consider eliminating parking minimums in those areas. Cities that have removed parking minimums find that many new development projects include less parking than was previously required (Leimenstoll, 2017).

In addition to removing parking minimums along key transit corridors in the city, the Department of City Planning also should consider adjusting the code to promote shared parking between neighboring businesses. This change may involve allowing new developers to rent on and off-street parking spaces from nearby businesses. Shared parking policies allow complementary land uses to share a fixed supply of parking spaces rather than requiring more parking for different land uses. Promoting

[10] Mobility Data Specification (MDS) is a data and API standard that allows Los Angeles to gather, analyze, and compare real-time data from mobility-as-a-service (MaaS) companies. MDS is currently required for dockless bikeshare and e-scooter share providers participating in LADOT's One Year Dockless Mobility Permit Program, however, the intent is for MDS to be applied to all emerging mobility services, including autonomous vehicles.

shared parking encourages more efficient use of the existing parking supply while reducing the need to add additional parking. Shared parking policies provides some flexibility as cities monitor the development of AVs and their impacts to parking demand.

Establishing design guidelines for adaptive reuse parking structures also can provide flexibility that would allow the City to adjust its parking supply in accordance with changes to parking demand. The Department of City Planning should consider adjusting zoning and building codes to require parking garage developers to meet adaptability requirements. This may involve raising the minimum clearance heights for any newly constructed parking structures and adding requirements that ensure floors are level between ramps.

Recommendation 3: Create a citywide emerging mobility task force

To ensure that the City of Los Angeles provides a unified response to autonomous vehicles and to emerging mobility more broadly, the Department of City Planning should consider creating a citywide task force involving planners from other city agencies, engineers, police and parking enforcement officers, and community stakeholders to exchange different perspectives and information on the factors that they must consider when planning for autonomous vehicles. A special task force may help to ensure that future land use policies are in alignment with how other agencies are responding to emerging mobility. It also can create an opportunity for establishing citywide guiding principles that outline the city's overarching approach to addressing emerging mobility.

The creation of a citywide or region-wide task force came up frequently during my interviews with city staff and in my review of General Plans that did and did not include autonomous vehicle language. This desire for greater collaboration demonstrates the fact that autonomous vehicle deployment will affect all levels of government and across jurisdictions. During my interview with San Francisco's representative, we discussed the process that went into creating San Francisco's citywide Emerging Mobility Services and Technology Guiding Principles in 2017. Multiple agencies, community-based organizations, stakeholder groups, and on-demand mobility providers came together in a series of workshops to draft a set of principles that define San Francisco's approach to emerging mobility. Several agencies have since adopted these principles and have incorporated them into their planning. The San Francisco Municipal Transportation Agency (SFMTA) for instance, has applied

these Guiding Principles in their development and evaluation of their Powered Scooter Share Permit and Pilot Program.[11] Each guiding principle stems from existing city legislation that are managed by multiple city agencies. For example, the Transit principle stems from the city's Transit First policy, the Safety principle stems from the city's Vision Zero policy, and the Sustainability principle stems from the city's Climate Action Strategy.

Establishing a broad framework that shapes how the city as a whole approaches emerging mobility can serve as a means to reinforce existing city objectives. It also can help to ensure that the priorities of other agencies and departments are kept in mind if one agency conducts a pilot program or collaborates with an emerging mobility provider. A task force would make it easier to coordinate future infrastructure upgrades, pricing regulations, and policy recommendations. This policy framework can also communicate to providers the city's overarching goals and objectives as they relate to emerging mobility. This collaboration should extend to state and national policymakers too, so that the City of Los Angeles can play a more active role in helping to shape safety and testing standards.

Conclusion

Cities across the U.S. have adopted various strategies to understand and address the potential land use and travel behavior implications of autonomous vehicles. Although some cities are further along than others in creating city-level policies, the general consensus amongst cities is that the time to act is now, especially as the technology is still in early phases of development. Autonomous vehicles have the potential to transform mobility in Los Angeles by providing populations previously unable or unwilling to drive themselves with access to vehicles, eliminating human error in traffic crashes, and increasing efficiency through connected vehicle technology; however, these benefits are not a given. In the absence of advanced preparation and planning, we may unintentionally see the costs outweigh the benefits, including increases in vehicle miles traveled, sprawling development, increases in automobile-related pollution, and an exacerbated jobs-housing imbalance with people choosing to live further away from jobs and services.

[11] San Francisco Municipal Transportation Agency, Mid-Point Evaluation Appendix (2018): https://www.sfmta.com/sites/default/files/reports-and-documents/2019/04/powered_scooter_share_mid-pilot_evaluation_appendices_final.pdf

In our efforts to guide the City of Los Angeles's Planning Department in taking its first steps to prepare for autonomous vehicles, I analyzed the policies that other cities have considered in their most recent General or Comprehensive Plan updates and assessed their applicability to the City of Los Angeles. My recommendations call for incorporating shared on-demand mobility options as programmatic measures for the city's TDM Ordinance update. I also recommend that the City Planning Department update the development code to include the reduction or elimination of parking requirements for new development projects in certain parts of the city and create a citywide task force that will collaborate to address emerging mobility in the city. This study provides a starting point from which the City of Los Angeles's Planning Department may begin to plan for autonomous vehicles. Future investigations may involve performing feasibility studies on eliminating parking minimums for new developments in parts of downtown or conducting pilots that experiment with flexible curb zones that prioritize short-term loading over long-term, on-street parking.

Similar to other U.S. cities, the City of Los Angeles is working under an uncertain time horizon and with incomplete information. That said, in collaborating in this study, the City of Los Angeles has taken crucial first steps to not only learn about the potential impacts of this technology but also to explore strategies to address them.

References

Ackerman, E. (n.d.). Toyota Gill Pratt on the Reality of Full Autonomy. Retrieved from https://spectrum.ieee.org/cars-that-think/transportation/self-driving/toyota-gill-pratt-on-the-reality-of-full-autonomy

Anderson, J., Kalra, N., Stanley, K., Sorensen, P., Samaras, C., & Oluwatola, O. (2016). *Autonomous Vehicle Technology: A Guide for Policymakers*. RAND Corporation.

Cervero, R., & Ewing, R. (2010). Travel and the Build Environment: A Meta-Analysis. *Journal of the American Planning Association*, *76*(3), 265–294. Retrieved from https://www.tandfonline.com/doi/abs/10.1080/01944361003766766

Cervero, R., & Ewing, R. (2017). Does Compact Development Make People Drive Less? The Answer is Yes. *Journal of the American Planning Association*, *83*(1). Retrieved from https://www.tandfonline.com/doi/full/10.1080/01944363.2016.1245112

Chatman, D. (2009). Residential choice, the built environment, and nonwork travel: evidence using new data and methods. *Environment and Planning*, *41*, 1072–1089. Retrieved from https://journals.sagepub.com/doi/pdf/10.1068/a4114

Choo, S., & Mokhtarian, P. (2004). What type of vehicle do people drive? The role of attitude and lifestyle in influencing vehicle type choice. *Transportation Research Part A*, *38*(3), 201–222.

Downs, A. (2004). *Still Stuck in Traffic: Coping with Peak-Hour Traffic Congestion*. Washington D.C.: Brookings Institution.

Fagnant, D., & Kockelman, K. (77). Preparing a nation for autonomous vehicles: opportunities, barriers, and policy recommendations. *Transportation Research Record: Journal of the Transportation Research Board*, (77), 167–181.

Fagnant, D., & Kockelman, K. (2015). Preparing a Nation for Autonomous Vehicles: Opportunities, Barriers and Policy Recommendations for Capitalizing on

Self-Driven Vehicles. *Transportation Research*. Retrieved from https://www.cae.utexas.edu/prof/kockelman/public_html/TRB14EnoAVs.pdf

Glaeser, E., & Kahn, M. (2013). Sprawl and Urban Growth. In *Handbook of Urban and Regional Economics* (Vol. 4, pp. 2481–2527). ELSEVIER Ltd. Retrieved from http://www.econ.brown.edu/Faculty/henderson/sprawl.pdf

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

Hawkins, J., & Habib, K. (2018). Integrated models of land use and transportation for the autonomous vehicle revolution. *Transportation Reviews*, *39*(1: Long Term Implications of Automated Vehicles), 66–83.

Heinrichs, D. (2016). Autonomous Driving and Urban Land Use. *Springer*, *Autonomous Driving*. Retrieved from https://doi.org/10.1007/978-3-662-48847-8_11

Henaghan, J. (2018). *Preparing Communities for Autonomous Vehicles*. American Planning Association.

Knittel, C., & Murphy, E. (2019). Generational Trends in Vehicle Ownership and Use: Are Millennials Any Different? *National Bureau of Economic Research*. Retrieved from http://www.nber.org/papers/w25674

Litman, T. (2018). *Autonomous Vehicle Implementation Predictions: Implications for Transport Planning*. Victoria Transport Policy Institute.

Los Angeles Department of Transportation. (2018). *LADOT Strategic Implementation Plan* (p. 1).

Manville, M., & Osman, T. (2018). *An Outcome-Based Approach to Technological Change for Local Governments: A Report to the South Bay Council of Governments (White Paper)*.

National Association of City Transportation Officials (NACTO). (2018). *Blueprint for Autonomous Urbanism*. Retrieved from https://nacto.org/publication/bau/blueprint-for-autonomous-urbanism/

National Conference of State Legislatures. (2019). Autonomous Vehicles / Self Driving-Vehicles Enacted Legislation. Retrieved from http://www.ncsl.org/research/transportation/autonomous-vehicles-self-driving-vehicles-enacted-legislation.aspx

Perkins, L., Dupuis, N., & Rainwater, B. (2018). *Autonomous Vehicle Pilots Across America: Municipal Action Guide*. National League of Cities. Retrieved from https://www.nlc.org/sites/default/files/2018-10/AV%20MAG%20Web.pdf

Rayle, L., Dai, D., Chan, N., Cervero, R., & Shaheen, S. (2016) Just a better taxi? A survey-based comparison of taxis, transit, and ridesourcing services in San Francisco. *Transport Policy*, 168–178.

Rice, A., & Tomer, A. (2017, October). How will autonomous vehicles transform the built environment? Retrieved from https://www.brookings.edu/blog/the-avenue/2017/10/16/how-will-autonomous-vehicles-transform-the-built-environment/

Shoup, D. (1997). *The High Cost of Free Parking* (Vol. 17). Journal of Planning Education and Research, 3-20.

Society of Automotive Engineers. (2018). Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles. Retrieved from https://www.sae.org/standards/content/j3016_201806/

Soteropoulos, A., Berger, M., & Ciari, F. (2018). Impacts of automated vehicles on travel behavior and land use: an international review of modeling studies. *Transport Review,* 1464-5327.

Tal, G. (2018). *Evaluating the Effect of Car-Sharing: Exploring the Gap between What We Know vs. What We Need to know and Its Effect on Optimism Bias*. UC Davis: Institute of Transportation Studies.

U.S. Department of Transportation. (2016). *2016 Fatal Motor Vehicle Crashes: Overview*. NHTSA's National Center for Statistics and Analysis

Appendix A. Sample of 40 Cities

CITY	PLAN TYPE*	YEAR UPDATED	PLAN INCLUDES AV'S	PLAN EXCLUDES AV'S
New York, NY	N/A**	N/A	N/A	N/A
Los Angeles, CA	G	2015		
Chicago, IL	C	2018		
Houston, TX	G	2015		
Philadelphia, PA	C	2011		
Phoenix, AZ	C	2015		
San Antonio, TX	C	2016		
San Diego, CA	G	2008		
Dallas, TX	C	2006		
San Jose, CA	G	2011		
Austin, TX	C	2012		
Jacksonville, FL	C	2016		
San Francisco, CA	G	1996		
Indianapolis, IN	C	2018		
Columbus, OH	C	2014		
Fort Worth, TX	C	2017		
Charlotte, NC	C	2010		
Seattle, WA	C	2005		
Denver, CO	C	2019		

El Paso, TX	C	2012		
Detroit, MI	M	2009		
Washington D.C., MD	C	2011		
Boston, MA	C	2017		
Memphis, TN	C	2019		
Nashville, TN	C	2015		
Portland, OR	C	2018		
Oklahoma City, OK	C	2017		
Las Vegas, NV	C	2000		
Baltimore, MD	M	2006		
Louisville, KY	C	2019		
Milwaukee, WI	C	2010		
Albuquerque, NM	C	2017		
Tucson, AZ	G	2013		
Fresno, CA	G	2014		
Sacramento, CA	G	2015		
Kansas City, MO	C	1997		
Long Beach, CA	G	1989		
Mesa, AZ	G	2014		
Atlanta, GA	C	2016		
Colorado Springs, CO	C	2018		

*** C = Comprehensive Plan, G = General Plan, M = Master Plan**

**** City of New York has Strategic Plan but does not have a citywide Comprehensive or General Plan**

Appendix B. Interviewees

CITY	AGENCY	INTERVIEWEE	TITLE, DIVISION
Included AVS in General or Comprehensive Plan			
Albuquerque, NM	Planning Department	David Campbell	Director
Colorado Springs, CO	Planning and Development	Carl Schueler	Planning Manager, Comprehensive Planning
Excluded AVs in General or Comprehensive Plan			
Austin, TX	Planning and Zoning	Greg Guernsey	Director
Austin, TX	Department of Transportation	Jason JonMichael	Assistant Director, Smart Mobility
		Christina Willingham	Division Manager, Smart Mobility
Houston, TX	Planning and Development	Jennifer Ostlind	Assistant Director
Kansas City, MO	Planning Department	Kyle Elliott	Division Manager, Long-Range Planning and Preservation
		Joseph Blankenship	Planner
Nashville, TN	Planning Department	Michael Briggs	Manager, Multimodal Transportation Planning
Oklahoma City, OK	Planning Department	Lakesha Dunbar	Transportation Program Planner
San Francisco, CA	Planning Department	Wade Wietgrefe	Principal Planner, Environmental Planning Division
San Jose, CA	Department of Transportation	--*	--*

***Interviewee did not provide permission to include their name and title.**

Appendix B. Interviewees

Introduction

As part of my senior capstone project, I have partnered with UCLA and the City of Los Angeles's Planning Department to explore potential land use policies that can help the city of Los Angeles prepare for the anticipated arrival of autonomous vehicles. I just finished a review of the General Plans of the 40 largest U.S. cities and want to interview you about whether, how, and why your agency has incorporated or not incorporated autonomous vehicles into the official General or Comprehensive Plan. I am also interested in discussing any other mechanisms through which you consider self-driving cars. The two research questions I am hoping to address for this project are as follows:

1. In what ways are new emerging mobility services expected to affect land use and vice versa?

2. What are cities doing to help shape the use of these new services through land use policies?

As part of this interview, I will ask you a series of questions. The interview should take no longer than 30 minutes though this may fluctuate depending on how the discussion unfolds. Let me know if any information is sensitive. I should also note that your name will be excluded from the body of the report but if you are okay with it, it will be included in the Appendix section of the report—is that okay?

Could you describe your role in your department?

Questions for cities with General or Comprehensive Plan that include language on AV's

1. Is there discussion about autonomous vehicles at your organization?

2. What do you and your organization think the impacts of autonomous vehicles will be on travel behavior in the next 20 to 30 years?

3. Are there mechanisms through which your organization considers autonomous vehicles?

4. Have state and federal legislation regarding autonomous vehicles influenced your organization's approach to planning for autonomous vehicles in anyway? If yes, how so?

5. What do you and your organization think the impact of autonomous vehicles will be on land use?

6. What are some policies you and your organization are exploring in addressing potential impacts to land use?

Questions for cities with General or Comprehensive Plan that exclude language on AV's

1. Is there discussion about autonomous vehicles at your organization?

2. What do you and your organization think the impacts of autonomous vehicles will be on travel behavior in the next 20 to 30 years?

3. What do you and your organization think the impact of autonomous vehicles will be on land use?

4. Do you have any other mechanisms in place (such as technical reports) to consider autonomous vehicles?

5. Has it had any concrete influence on plans or investments?

6. What are some questions that your organization may like to have answered before considering planning for autonomous vehicles?