Planning in the Face of Technological Innovation:

A Case Study of the San Francisco Bay Area's Handling of Autonomous Vehicles

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Abstract

Autonomous vehicles of varying levels are already a reality for several major U.S. cities. This technology has implications of an economic, ethical, and environmental nature, and will likely disrupt the landscape of city and regional transportation planning processes for years to come. This report builds upon existing literature on the predicted ramifications of autonomous vehicles to identify similarities and discrepancies between autonomous vehicle-related transportation planning documents for the San Francisco Bay Area and the personal perceptions of planners themselves. This is done via document and interview analyses, based on publicly available planning documents and the interviewing of four Bay Area planning professionals. The research problem and its findings are framed with the theory on the multi-level perspective on socio-technical transitions, as a way of understanding how a technological change comes about in society, particularly a technology which disrupts the current stable regime of the gas-powered automobile. The results of this study show that of the planning documents that cover autonomous vehicles, the content is predominantly in line with the viewpoints of the planners, most evidently on the themes of autonomous vehicle technology itself and its potential impacts on social equity and public transit. The future stable regime of a new smart and sustainable mobility paradigm can be one of an equitable, safe, efficient, and streamlined transportation system that leverages ICT to achieve regional goals, driven by a shift in the landscape that is sparked by the autonomous vehicle. In this new paradigm, it will not be the gas-powered automobile which characterizes the stable regime, but it will likely not be characterized by the autonomous vehicle either - rather, the autonomous vehicle must be but one well-functioning part of a revitalized entire transportation network.

Preface

This report has been written in connection to the 4th semester thesis requirements for the Master's in Urban Planning and Management program at Aalborg University. The research and writing was conducted from February 1st until June 7th, 2019. The report is structured as follows: the main body of the research report consists of an introduction with problem formulation, literature review, theoretical framework, methodology, an introduction to the San Francisco Bay Area region case study, results, discussion, and conclusion. The report ends with personal reflections on the research experience, and appendices, including an interview guide and more detailed research results.

The literature references are cited according to the APA style (author, date) within the text, with a full bibliography found at the end of the report. For sources with the same author and year of publication, the sources are distinguished within the text.

I would like to thank the many professors and support staff I've worked with in the Urban Planning and Management department over the last two years who have provided valuable guidance in the UPM program, as well as an additional heartfelt thanks to my supervisor, Malene Freudendal-Pedersen. I must also extend an additional thanks to the interview participants that served as a vital source of data collection in this research report. To these individuals from the Metropolitan Transportation Commission, Arup, and the University of San Francisco, I owe appreciation for a great learning experience in studying the topic of autonomous vehicles in the San Francisco Bay Area.

Any remaining errors are entirely my own.

Contents

List of Figures

List of Tables

List of Acronyms

- AAA — American Automobile Association
- ABAG — Association of Bay Area Governments
- ADAS — Advanced Driver Assistance Systems
- AI — Artificial Intelligence
- AV — Autonomous Vehicle
- BAAQMD — Bay Area Air Quality Management District
- BART — Bay Area Rapid Transit
- CAV — Connected and Automated Vehicle
- CBD — Central Business District
- CO2 — Carbon Dioxide
- DMV — Department of Motor Vehicles
- EPA — Environmental Protection Agency
- FMRP — Future Mobility Research Program
- GHG — Greenhouse Gas
- ICT — Information and Communication Technology
- IoT — Internet of Things
- MaaS — Mobility as a Service
- MLP — Multi-level Perspective
- MPO — Metropolitan Planning Organization
- MTC — Metropolitan Transportation Commission
- NHTSA — National Highway Traffic Safety Administration
- RTP or LRTP — (Long-Range) Regional Transportation Plan
- SFCTA — San Francisco County Transportation Authority
- SFMTA — San Francisco Municipal Transportation Agency
- SOV — Single Occupancy Vehicle
- VKT — Vehicle Kilometers Traveled
- VMT — Vehicle Miles Traveled

Chapter 1

Introduction

Today, more than half of the world's population lives in cities, and by 2050, 2.5 billion people, or 70% of the world's population, are projected to move to urban areas covering less than 2% of Earth's surface (United Nations, 2018). From economic vitality to people's well-being and way of life, the way in which we design and build our cities lies at the heart of these challenges. At the same time, urban growth and human behaviors formed from the time of the first and second Industrial Revolutions have contributed to a massive climate change, the effects of which are being felt all across the world. Increasing temperatures, more extreme weather patterns, and rising sea levels are but a few of the severe impacts that unsustainable human development has generated. Considering that transportation accounts for the environmental impact of 28% of U.S. greenhouse gas emissions (U.S. EPA, 2018b) and the interwoven nature of the transportation network into every city's framework and development in social well-being, sense of community, and connectedness, this makes for an intriguing area for a deeper study of its current trends, challenges, and possible solutions.

From around the period of the second Industrial Revolution, the U.S. was beginning to develop rapidly with the introduction of the automobile, mass manufacturing, and electricity. At the turn of the last century, the way in which cities were planned and designed transformed dramatically, as they catered to the personal vehicle. The revolution of the car made it more attractive for people to live further away from their jobs, given their greater freedom in mobility. However, the automobile, arguably more than anything else, changed our land use patterns, leading to urban sprawl, low density development, and more highways. Today, private car ownership levels have reached a high since 2008 (UMTRI, 2013), according to a study performed by the University of Michigan Transportation Research Institute. At the same time, public transit ridership decreased in 31 of 35 metropolitan areas in the U.S. in 2017 (Siddiqui, 2018), as was found by the New York-based TransitCenter advocacy group, using data from the U.S. Department of Transportation's National Transit Database. While many connected factors are at play such as temporary dips in fuel cost, increased teleworking, and the rise of alternative modes such as ridesharing, there is no doubt that there is a continued ripple effect of issues such as further pollution, traffic congestion, and mobility. These problems associated with urban sprawl continue in a feedback loop with current urban development trends. It is well documented in urban planning literature that catering to private car only exacerbates congestion and urban sprawl, resulting in the question of why traditional planning practices continue to invest in business-as-usual plans that are proven not to work. This necessitates a new paradigm of planning, from the way city planning problems are understood, to the methods and processes carried out to execute solutions.

Many governments around the world, from Songdo in South Korea, to Stockholm and London (Wakefield, 2013), are increasingly infusing technology into their city operations. Smart cities leverage technology to serve people, are built for users, and start with an information network designed to optimize resources and thereby promote sound, sustainable development. With applicability from public transportation and power supply to IT connectivity and citizen participation, smart cities cannot be achieved by a patchwork approach, but rather, by the adoption of well-thought-out incremental changes (Iqbal et al., 2018). Smart cities are hyper-connected cities, technologically equipped with the development of new technologies such as the internet of things (IoT) and artificial intelligence (AI) to offer a multi-faceted solution to improve the lives of their residents.

In the current age of exponential technological growth, we are entering a second revolution. Autonomous vehicles represent an "unknown" - they could be very beneficial to society, or detrimental. Will this technology help to reduce the number of cars on the road? Will it reduce GHG emissions? Can they work successfully in conjunction with public transit? What kind of cities do we want and how can AVs help us get there? There is extensive research and ongoing discussions surrounding the technological and ethical obstacles and implications of AVs, but there is minimal research on secondary impacts, namely, how AVs will impact our cities, communities, and way of life. How AVs may affect land use, what parts of the city we live in, neighborhood and street design, and mobility have far more significant and compounding effects than the addition of a new technology in isolation.

The metropolitan region of the San Francisco Bay Area in Northern California is a leading hub of technological innovation in the field of automated driving and AI (Marr, 2018), giving rise to new opportunities and applications of technology to improving the efficiency of transportation across this nine-county area. A major economy and driver for the Bay Area's recent exponential growth is Silicon Valley, located in the southern San Francisco Bay Area and which serves as a global center for high-tech innovation and development. With its dense concentration and reputation for entrepreneurship and technology, it can be seen why this region plays a major role in predicting the future growth of the Bay Area from a social, economic, and cultural standpoint (MTC, 2018). The unique setting of the intersection of an environmentally progressive city with the surrounding technology industry makes the Bay Area an interesting case to delve into how autonomous vehicles are perceived and planned for. Additionally, the planning profession is one which in dealing with long-lasting assets and infrastructure, is often typically characterized by business-as-usual practices which do not too largely deviate from the status quo. This report serves to make a comparative analysis between how autonomous vehicles are currently worked into long-range transportation planning efforts for the Bay Area and the perceptions of individual planners themselves. The methodology first consists of the analysis of publicly available documents concerning the current regional planning efforts around autonomous vehicles, followed by the collection of interviews with transportation planners in the Bay Area working directly with this issue. The overarching research question that this report aims to answer is as follows:

1.1 Research Question(s)

How does the current integration of autonomous vehicles into regional transportation planning strategies in the Bay Area compare to the personal perceptions of transportation plan-

ners directly working on autonomous vehicles in practice?

1.1.1 Research Sub-Questions

1. What are the focal points on the topic of autonomous vehicles in Bay Area regional transportation planning documents?

2. What are the focal points on the topic of autonomous vehicles as identified by Bay Area transportation planners involved in their planning and research?

3. What common or counteracting themes can be drawn between what is found in the regional transportation planning documents versus the perceptions of the individual planners?

Through addressing the questions and topics raised above, it is hoped that this report provides a perspective on the value of considering the potential of the role of the planner in future smart cities of which autonomous vehicles have a major presence. As AV technologies and the concept of smart cities advance and become more widely accepted, along with the evolution of contemporary planning practices, the findings of this study provide a simplified description and analysis of the possible challenges of implementing a technology such as AVs on a regional scale so that other agencies looking to test these technologies may do so with vigilance.

1.2 Structure of the Research Report

This research report is structured around a central research question and three sub-questions, as presented above. Following is the Motivations and Background for this research, describing the inspirations for this study and interest in delving into the topic of autonomous vehicles in regional transportation planning. The next chapter is the Literature Review, which bases off of existing literature on the relevant topics surrounding the research question, and is comprised of the following four sections: smart cities, the impacts of autonomous vehicles on transportation planning, governance and a sharing economy, and urban mobility change. Next is the Theoretical Framework, which focuses on the theory of the multi-level perspective on sustainable transitions to form the lens through which the methodology and analysis are based. Then, the Methodology chapter justifies the case study as the chosen research method, describing the data collection sources and analysis methods applied, as well as the research design.

Prior to the analytical portion of the report, a chapter on the San Francisco Bay Area is presented to give a brief overview of the region's characterizations of demography, economy, and transportation network. The Results chapter is the analytical portion of the research, broken into three sections corresponding to the three sub-questions above, and are identified as the sections of document analysis, interview analysis, and the comparisons between the findings of the two. Finally, the Discussion chapter reports on the summary of the results and their evaluation and interpretation in light of the relevant literature and theory, and the Conclusion provides a closing statement on the research, and comments on possible areas for further research.

Chapter 2

Motivations and Background

The mention of autonomous vehicles triggers imaginations of a fantastical future, where one can seamlessly go about their daily lives of commuting, traveling, and accessing services in a comfortable, efficient, and safe vehicle on an un-congested roadway, all while enjoying the economic and psychological benefits of abandoning private car ownership. While the realities of such an imagination are likely decades away, there is much research being done on the technological advancements and ethical implications of autonomous vehicles of various types in the near future. Despite this, there exist considerable gaps both in the academic sphere and in the public discourse of how the current research on autonomous vehicles is being addressed at city and regional levels. As with the original adoption of the automobile, the disruption of society, the urban, and people's way of life that autonomous vehicles will generate is amplified by the rapid pace of technological innovation today, coupled with global impending issues of climate change and limited natural resources. Autonomous vehicles have the potential of increasing roadway safety and transportation access for those unable to drive, and if planned for strategically, can help cities and regions to achieve Vision Zero and smart city goals. However, it is only with comprehensive, multi-disciplinary, and collaborative planning that autonomous vehicles will likely be implemented in such a way to realize such visions while mitigating the potential negative effects in our communities.

With these issues in mind, the inspiration for this research is to delve into how planning agencies are currently discussing a future Bay Area with autonomous vehicles. A typical comprehensive plan, or long-range plan, is intended to direct the growth and physical development of a community in the time frame of the next 20-30 years. The Metropolitan Transportation Commission (MTC) and Association of Bay Area Governments (ABAG) in San Francisco recently developed a new initiative, called Horizon, to explore the issues and challenges concerning Bay Area residents today, looking forward through 2050. With this initiative in mind, MTC and ABAG in 2017 finalized the Plan Bay Area 2040, which focuses on transportation and land use strategies for the nine-county San Francisco Bay Area for the next two decades, to grow the region into a more sustainable, equitable, and economically vibrant future. Given this forward-thinking and mission-driven regional plan, it interested me to understand how this plan includes autonomous vehicles in its vision and language. Further, how do transportation planners themselves perceive autonomous vehicles in the future Bay Area, and how do these views align with or differ from the publicized regional planning documents?

Chapter 3

Literature Review

The purpose of this chapter is to identify and explore the relationships between major concepts surrounding rising autonomous vehicle technologies and forward-thinking city and region urban development goals. In doing this, the chapter will establish the primary lines of inquiry of integrating autonomous vehicles in the field of regional transportation planning. This chapter is structured into four sections. In section one, the main outlines of smart cities are reviewed through four aspects: mobility, connectivity, security, and sustainability. In section two, the literature pertaining to the current developments in autonomous vehicle technologies is discussed with an eye toward examining, among others, issues of technological development and barriers, as well as the purported potential benefits and negative impacts. Section three outlines looks into the role of governance in autonomous vehicles examining the specific facets of equity and the current state of policy. Finally, in section four, it is outlined how urban mobility change comes about, specifically, a more smart mobility paradigm. This chapter ends with a final summary which describes the linkages between the four sections, with the second purpose of introducing the theoretical framework this research adopts.

3.1 Smart Cities

Today, rapidly evolving technologies in transportation and communication have begun to shape the pulses and pace of many cities and regions where the mission of sustainable development has driven changes in social, cultural, and economic life (Freudendal-Pedersen et al., 2019). There is no one comprehensive definition for what constitutes a "smart city", as there can be no single template for the framing of a smart city given the wide-ranging levels of urban development and characteristics of cities in the world (Albino et al., 2014). One possible reason for the ambiguity in definition of a smart city is that the term has been generally applied to two different types of "domains": "hard" domains such as buildings, natural resources, and mobility where Information and Communication Technologies (ICTs) can play a crucial role in the functioning of its systems, and "soft" domains such as culture, innovations in policy, and education where the uses of ICT are not usually conclusive (Albino et al., 2014). Therefore, in the assessment of the smartness of a city, an assessment should be customized to each city's vision and priorities.

In many modern cities, there has long been the production and use of large datasets as a result of ICT, that provide information about cities and their citizens, for instance in the form of government records, national censuses, and geomatic surveys (Kitchin, 2014). V. Albino et al. define a smart city as a city "where investments in human and social capital

and traditional transport and modern ICT communication infrastructure fuel sustainable economic growth and a high quality of life, with a wise management of natural resources, through participatory governance" (Albino et al., 2014,pg.6). It can be seen that it is in how ICT is used in conjunction with human capital to leverage growth and effect urban development to make a city "smart". For the purposes of this report, a smart city is defined as the application of a wide range of electronic and digital technologies in order to leverage ICT in a city's infrastructure to enhance innovation, city operations, and quality of life. This section of the literature review on smart cities is broken down into four points of focus identified as particularly important for the purposes of the case study on the San Francisco Bay Area: mobility, connectivity, security, and sustainability.

3.1.1 Mobility

Mobility is defined by Iqbal et al. as the moving of people, goods, and information effectively and efficiently (Iqbal et al., 2018), and can be seen as the lifeblood of our cities. Thus, smart cities must necessarily deal with the transportation network, where cities and regions are grappling with the challenge of taking a century-old public transport network and bringing it up to today's standards, while also embracing the technological changes emerging and transforming it into an inclusive, accessible public transport network that all people can access regardless of socio-economic class, geographic location, or physical capabilities. High quality and more efficient public transport which responds to a city's economic needs and connects labor with employment is considered a vital factor for city growth (Albino et al., 2014). Smart mobility then can be defined as the use of ICT in modern transport technologies to improve traffic in urban contexts. Smart city technologies are enabling more sustainable transport modes to become increasingly competitive, trending towards a shift away from dependence on the privately owned car (Newman and Kenworthy, 2015). It is evident that for many urban passengers, public transport only addresses one portion of their daily commuting necessities, as they are also increasingly making use of new options such as ridesharing, cycling, scooters, and demand-responsive travel modes in order to circumvent last-mile issues and public transport delays (Nisenson, 2017). Mobility as a Service (MaaS), is one smart city solution that is travel mode-agnostic, leveraging data to enable passengers to choose from and use multiple forms of transport as a packaged service. Other forms of new technologies that many cities have begun to introduce include autonomous vehicles, ridesharing, and car-on-demand schemes (Meila, 2018). These trends alongside disruptions in distributed power generation, urbanization, and investments in public transport are beginning to transform today's mobility systems.

Managing urban mobility is one of the most complex challenges cities face today, as smart transportation is not without its own obstacles. The digital information systems emerging in cities have the potential to evolve cities away from automobile dependence, or otherwise continue to perpetuate this dependence (Newman and Kenworthy, 2015). Even alternative transport options such as ridesharing is not always the best solution, as it does not always ensure optimal occupancy of vehicles and is often a source of conflict with regular local transport operators (Meyer and Shaheen, 2017). As well-designed transportation networks are a key factor in the economic welfare of major cities, the design and planning of these systems necessitates a quantitative understanding of traffic patterns and human behaviors (Silva et al., 2015). How mobility in future cities will look also depends on population

density, infrastructure, and the wealth of the inhabitants (Meyer and Shaheen, 2017). Additionally, it also hinges on the assimilation of technology trends, and how these work to their best ability in each city. Therefore, regardless of the level of technology a smart solution to mobility may advertise, there are repercussions such as continued dependence on fossil fuels, induced traffic congestion, and a greater wealth disparity caused by the difference in accessibility of mobility services that must also be considered.

Mobility in a smart city seems to be trending towards transportation as part of a sharing economy, where in lieu of paying separately for public transit tickets, shuttles, bike-sharing, and other forms of transit, consumers will be able to buy packaged mobility contracts from a variety of service providers (Zavyalova, 2017). Continuing along this trajectory, the concept of personally owning a vehicle and the necessity of a driver's license to operate one may become redundant. The autonomous vehicle is expected to be a major player in the new mobility era, in which carmakers and software providers compete for market dominance, which may bring about a further shift away from vehicles as owned assets (Krasniqi and Hajrizi, 2016). In this sharing economy, ridesharing in an AV could potentially provide an on-demand door-to-door service that is up to 60% cheaper than owning one's own car (Meyer and Shaheen, 2017). Advancements in technology for smart mobility are not limited to connected vehicles and AVs, however, as new systems where active transport, transit, and technology work cohesively together on a platform of optimized city design (Nisenson, 2017). For example, transport hubs in underserved urban communities designed to aggregate mobility options widen the benefits of transit-oriented development to more areas. Designed optimally, such hubs can increase accessibility to riders and reduce congestion by directing traffic away from intersections.

3.1.2 Connectivity

Connectivity can be seen as the foundation of a smart city, with real-time data about people, places, and their interactions collected on a large scale and stored on cloud servers to be analyzed and used to make better-informed planning decisions (Krasniqi and Hajrizi, 2016). A city cannot be considered "smart" unless it is connected, and this consists of a system that unites the utilization of ICT, an Internet of Things (IoT) network, and data analytics (Iqbal et al., 2018). The IoT is changing much about the world and urban areas we live in, where sophisticated sensors and chips embedded in the infrastructure and devices that surround us communicate with each other and generate valuable data (Iqbal et al., 2018). Park et al. broadly characterize IoT as the ability to provide valuable and useful information through diverse user devices through wireless and wired Internet networks (Park et al., 2018). Whether giving residents real-time updates on where to park or monitoring traffic incidents on freeways, it is the common IoT platform that brings diverse information together and provides the common language for the devices and apps to communicate with each other (hoon Kim et al., 2017). As the IoT becomes more prevalent and as more things become connected to the internet and each other, this will have significant implications for smart city development. In looking at connected and autonomous vehicles, there is a connected piece that requires both wireless and wired connectivity.

A smart city can be imagined as a future where vehicles talk to one another and to critical infrastructure. In the 1970s, electronics only made up 5% of a vehicle's content; today that portion has risen to 40% and increases (DSM Engineering Plastics, 2017). Cars' growing in-

telligence is becoming synonymous with digital connectivity, and to keep up with this trend, forward-thinking companies are developing new products with connectivity in mind. Connected vehicles aim to promote safer and more efficient driving through use of technologies such as collision avoidance systems, on-board GPS, and remote diagnostics (Fang, 2015). This connected vehicle technology can change our transportation system as we know it by enabling safe and networked wireless communications between vehicles, infrastructure, and personal communications devices. With the development of the autonomous vehicle, the IoT transforms the automobile industry, and vice versa, as software developers are provided a boost for innovation (Krasniqi and Hajrizi, 2016). Further benefits are achieved through connected transportation systems and vehicle-to-Vehicle (V2V) communications, enabling vehicles to "talk" to one another to minimize hazards and the potential for accidents. The National Highway Traffic Safety Administration (NHTSA) estimates that V2V technology could prevent more than half a million accidents and save more than 1,000 lives each year in the U.S. (NHTSA, 2016). While a future with fully autonomous vehicles may be decades away, the possibility of connected vehicles to promote safer roads, decrease traffic, and reduce GHG emissions makes a case for further development of these technologies.

A smart city is also characterized by its physical connectivity, enabling a more seamless and optimized environment for encouraging multi-modal behavior and shifts away from single-occupancy vehicle (SOV) reliance. In the U.S., issues in physical connectivity of mobility such as the first- and last-mile are being addressed with the assistance of local and federal active transportation programs in response to public demand (Government Accountability Office, 2018). As a result, many cities and metropolitan areas have made great improvements by facilitating walking, access to public transit, bicycling, and shared modes. However, the harsh reality is that for many people, driving as the main mode of commuting is still a necessity, whether in terms of cost, time, or the practicality of alternative modes. For this population, most cities' transportation networks are greatly fragmented, and the cost of re-creating the urban landscape for the automobile is prohibitive (Lioris et al., 2017). Thus, the smart city approach to this gap lies in the investment of funds into a more fully integrated transportation system using the provision of real-time data to travelers with streamlined electronic payments across various modes of transit to make traveling around the city cheaper, more efficient, and more convenient (Cardenas-Benitez et al., 2016).

3.1.3 Security

The delivery of services in a smart city requires the ability to understand the city and its moving parts and to gather data on the environment, infrastructure, incidents, and residents. Thus, a rise in the use of smart technology requires improvement of public and private security, data protection, and cyber-security (Mijac et al., 2017). However, with the benefits of the spread of the IoT, inevitably brings risks to data security and privacy. Some of the implications inherent to the IoT include vulnerability to hackers, concerns of user privacy, and uncertainty as to the entirety of what given devices and technology are capable of doing. According to AT&T's Cybersecurity Insights Report, 85% of enterprises are either in the process of or plan to utilize IoT devices (AT&T Business, 2019). Despite this, only 10% are confident in their capability to secure devices against hackers. Bibri argues that it is up to urban policy and governance practice associated with the "design, development, deployment, and implementation" of smart technologies to ensure security measures are prioritized (Bibri, 2018).

Regarding the security of smart mobility solutions, connected cars and autonomous vehicles can pose threats to privacy, not only from the data collected by the vehicles themselves, but also to physical safety of the passenger when not properly secured. A 2016 Spireon survey showed that despite an interest in connected cars among 1,000 participants, 54% of participants said they had not actually used connected car features (Spireon, 2016). Any attempt of unauthorized access, abuse of information, or malicious attack on infrastructures, people, or facilities can greatly compromise the integration of smart city solutions. In the end, the ability to secure the generation, delivery, and sharing of data requires organizations to continuously identify and monitor how that data should be used (Kirby, 2017). For AVs, it is not only the automobile manufacturers who hold the responsibility in guaranteeing security, but also the dealership, developers of aftermarket services, and even the customer.

3.1.4 Sustainability

Sustainability is a major pillar of smart cities, as sustainable practices involving critical issues of transportation, economic stability, and natural resource consumption drive the need for the innovative solutions that smart cities can offer. Cities inherently rely heavily on external resources, and the promotion of sustainability has often been interpreted through the advocacy of natural capital stocks (Albino et al., 2014). More recent interpretations of urban sustainability have promoted a more anthropocentric perspective, wherein cities are seen as needing to respond to the needs of its people through sustainable solutions for social and economic aspects (Turcu, 2013). In addition to sustainable planning of physical structures such as public transportation, parks, and streets, the IT infrastructure must also be designed to last and develop over time (Bibri, 2018). Thus, in order to handle global challenges in diverse fields of energy, transportation, and public health, the IT infrastructure must be tailored to promote collaboration across many different industrial and societal sectors.

When ICT for cities is planned for new development today, it is typically done actor-by-actor or field-by-field, creating a patchwork of communication networks of various kinds with hindrances to collaboration or open competition(Isenhour et al., 2015). Truly smart cities are instead built on shared infrastructures, even for ICT. Much like a typical road infrastructure is built to carry vehicles of different kinds for varying purposes, an ICT infrastructure should be capable of serving many different actors and providing services and technology for a multitude of reasons; one of the most evident advantages to parallel systems is a lowered cos from development and construction, to deployment and even disposal (Bibri, 2018). This type of infrastructure enables an environment of innovation, where collaboration and competition is stimulated, and barriers for new actors to offer services are lowered significantly (Mijac et al., 2017). Thus, the leading issues of the smart sustainable city involve facets of everyday life and the processes that define a given urban problem, the interrelation of problems and solutions to the function of a dynamic city, and the issues that emerge in relation to current plans for possible improvements. The philosophy of sustainability in smart city planning requires systems thinking in order to deal with this complexity, as well as making citizens aware of upcoming changes by focusing on conscious behavioral change.

The mobility sector is a significant portion of the challenges cities face, as urban transformation coupled with aging infrastructure and its demand for capacity increases. With goals of reducing carbon emissions, fighting climate change, and seeking alternative energy

sources, many cities have begun to place a higher priority on active modes of transport as a trend of shifting urban space back to the people (Gehl, 2010). Smart sustainable cities take this a step further, leveraging ICT to match users with on-demand vehicles, enable sharing of products and services such as bicycles and scooters, and advancements in the synergy between land use, transport, and telecommunications systems (Meila, 2018). How true sustainable mobility will look on an everyday basis is characterized by mobility which is safer, more fluid, more convenient, more accessible, and friendlier to the environment. In the U.S., a national program for GHG emissions and fuel economy standards for passenger cars and trucks was developed jointly by the Environmental Protection Agency (EPA) and the National Highway Traffic Safety Administration (NHTSA) (U.S. EPA, 2018a) to enable the production of a new generation of clean vehicles. Researchers, planners, and financial institutions are also contributing to this debate (Arup, 2014). Many cities agenda for smart sustainable mobility is roughly based on three key concepts: First, encouraging soft travel modes such as walking and cycling, so people can easily switch between transport modes while also improving access to public transport. Second, improving connections between different types of transport by using a common ticketing system and smart information systems that optimize multi-modal journeys. And finally, designing vehicles that consume and pollute less, and are less dependent on fossil fuels (Iqbal et al., 2018).

3.1.5 Smart Cities Summary

In summary, smart cities, and more specifically, smart mobility is not only about technology. It is about leveraging technology to move people and goods in ways that are safer, more efficient, and more enjoyable than the systems we now have in place. The interconnections between mobility, connectivity, security, and sustainability are, as the preceding sub-sections have indicated, complex and deeply entangled with one another. Urban development strategies towards smart cities must take into account that the relationships are not fixed, but rather dynamic, and oftentimes highly unpredictable considering the factors of uncertainty among the relations between the economic, social, political, and environmental systems.

3.2 Impacts of Autonomous Vehicles on Transportation Planning

The U.S. population is expected to grow by 78 million people by 2060, crossing the threshold of 400 million by 2058 (Vespa et al., 2018), and to address this increased demand, it is essential to have greater collaboration in transportation planning. While the basic principles of urban and regional transportation planning has remained generally unchanged for decades, it has evolved into a more integrated process (Harding and Blokland, 2014). Transportation planning typically sets short, medium, and long-term planning goals of roughly 5-10 years, 10-20 years, and 20-30+ years, respectfully, and growth projections and land use are used as a basis for forecasting future transport demand (Bordenkircher et al., 2018). This demand is then used to determine the required transport initiatives that address issues for each of the included transport modes. The issue with this process is that future transport technology and modes are generally assumed to be the same as they are today, without factoring in the possible changes in travel pattern behaviors due to a disruptive change in transport technology, such as the introduction of autonomous vehicles. Much of the existing literature on AVs focuses on the technology itself, but as a technology still in the research and development

phase, there has not been ample research in how we plan for this eventuality in the future. With researchers predicting widespread adoption of autonomous vehicles within the next few decades, this will undeniably transform existing travel patterns, land uses, and the way people interact with their built environments.

In June of 2017, 10 of the top 11 car manufacturers in the world said they would have AVs to market by the year 2021 (Muoio, 2016). With the AV market crowding with a growing number of players, some of the top leaders in the market include Ford (Tovey, 2016), BMW (Etherington, 2017), Volvo (Gitlin, 2017), and Google (Marr, 2018). These vehicles will be commercially available within five years, and could be commonplace in ten to twenty years, which easily falls within our immediate to long-term planning horizons. While the deployment of AVs is no longer a question of "if", fully autonomous vehicle implementation will take time and is predicted based on the pattern of previous vehicle features such as cruise control, navigation systems, and airbags, all of which took a long time for wide-spread deployment (Krasniqi and Hajrizi, 2016). An autonomous vehicle can be defined as any vehicle with features that allow it to accelerate, brake, and steer with limited or no driver interaction (Krasniqi and Hajrizi, 2016). AVs can be divided into two different types: semi-autonomous and fully autonomous. Semi-autonomous cars can accelerate, brake, and steer, but a driver must be present and is still required to be in full control. A fully autonomous vehicle can drive from point A to point B without requiring any interaction from a driver, and is thus computer-driven. Further, the Society of Automotive Engineers has identified six levels of autonomous driving; figure 3.1 illustrates the range of autonomous driving levels classifying a car's capabilities. Many vehicles today are already being deployed with autonomous functionalities, such as self-parking or auto-collision avoidance features (Murtha, 2015). The U.S. government has adopted the SAE categories, which may mean that they will be used in the future for informing regulations on production and testing, labeling cars for consumers, and determining insurance rates. Most manufacturers will likely gradually phase in various levels of autonomy until fully autonomous vehicles are widely tested and embraced by the general public.

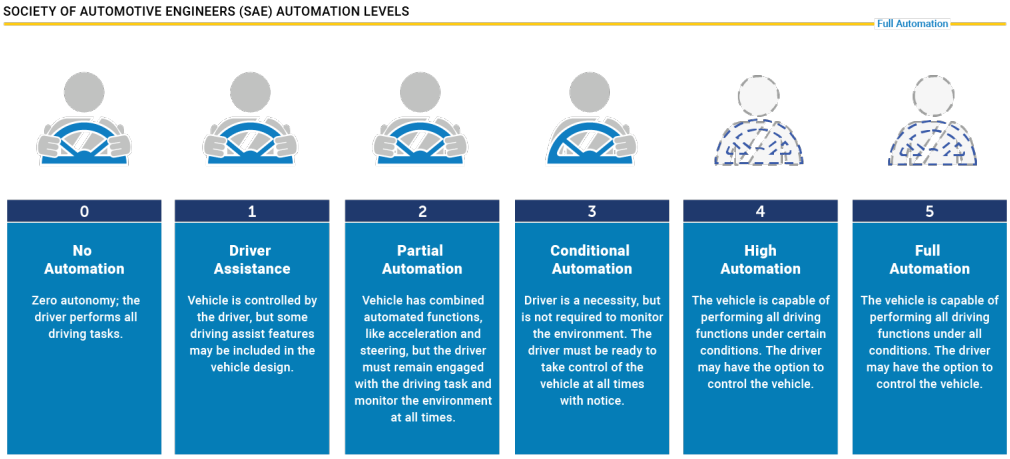

Figure 3.1: Five Levels of the Autonomous Vehicle. Source: (NHTSA, 2018)

The Google AV is an example of the powerful innovation synergies that develop quickly, with the potential to reduce the number of traffic accidents and loss of life. Schoettle and

Sivak have suggested that AVs could potentially reduce car ownership by 43% in the United States, not including the added potential benefit of influencing the overall need for a car once shared-travel options become more commonplace (Schoettle and Sivak, 2015). The International Association of Public Transport (UITP) published a policy brief stating that AVs must be shared fleets in order to work in tandem with public transport (UITP, 2017). In the exploration of the possible impact of shared autonomous vehicles on urban parking demand, Zhang et al. found that based on their simulation model, up to 90% of parking demand could be eliminated (Zhang et al., 2015). This brief also states that the roll-out of AVs can only be successful if governments and transport authorities take an active role now in integrating AVs into an effective public transport network. Potential impacts on travel and emissions, both positive and negative, remain under speculation, and further research is needed in this area. Table 3.1 outlines some of the main pros and cons of the introduction of AVs commonly discussed in literature.

Table 3.1: Potential Pros and Cons of Autonomous Vehicles

	Potential Benefits	**Potential Cons**
User Convenience	• Mobility for those who do not or cannot drive • Frees driver to make better use of travel time • Less driving-related stress with increased/faster travel • More efficient delivery systems • Ability to select vehicle appropriate for trip • Aid feeder service (first/last-mile)	• Encourages traveling and longer commutes, increasing congestion and GHG emissions if not electric AVs • Excludes those for whom it is not economically feasible compared to existing public transit/private car ownership • Works against public transit
Safety	• Fewer driver-at-fault traffic incidents • Improved conditions for walking and cycling	• Liability issues when accidents occur • Risk to data privacy and security
Capacity	• Roughly doubles road capacity • Less congestion • Faster emergency vehicle access • Better use of streets	• Induced travel may increase congestion • Decreased parking spaces leading to more roaming, zero-occupancy vehicles increases congestion
Parking	• Demand will be much less • Obsolete parking spaces can be repurposed and moved to less valuable real estate, i.e. outside the CBD	• Potential negative impact on capacity
Environmental	• Lesser GHG emissions if AVs designed to be electric	• Greater GHG emissions from induced travel
Cost	• Decreased operating cost of public transit (e.g., 54% of cost of operating a bus is the driver)	• Job Loss - need retraining programs for emerging technologies, bus/taxi/truck/delivery driver jobs
Policy \ Regulatory	• City and region-shaping will be influenced by AVs to reconsider land use, transportation, housing, and other sectors in a more comprehensive way	• Politics of algorithms - private companies might start lobbying for control, prioritize multi-occupant vehicles over single-occupant cars, ped/bike priorities • System needs to reflect good policy over politics

With many variables involved in the technological development of AVs, the potential implications are highly unpredictable in degree and benefit. For example, a widespread rollout of autonomous and electric public transit or fleet-owned AVs working in tandem with transit may greatly reduce vehicle miles traveled (VMT) as well as greenhouse gas emissions, having the subsequent benefits of greater passenger safety and a more efficient and accessible transit system (Arup et al., 2018). Conversely, AV usage dominated by TNCs utilizing fleet-owned and gas-powered AVs may significantly increase VMT due to the convenience of the service and the added freedom of making use of travel time not spent operating the vehicle, which would in turn increase GHG emissions and could contribute to further urban sprawl as people become more willing to live farther out from the city center.

It is important to note that while TNCs are often referred to as providing ride-sharing or ride-hailing services, these two terms are not interchangeable. Ride-sharing is synonymous with carpooling, referring to the process by which a rider shares a vehicle with other riders, while ride-hailing refers to the on-demand hailing of a vehicle by a rider, with the vehicle not being shared with any other riders or making any additional stops along the route to

the desired destination (Ecoland, 2018). Autonomous vehicles often symbolize a future city with improved public health, a growing economy, and greater equity, by giving those without the means to drive the opportunity to access various community services. However, with a technology that has the power to disrupt a decades-old and deeply embedded industry as the automobile, there is no doubt the adoption of AVs will have a significant impact on the livelihoods of lower and middle class workers who depend on jobs such as truck and taxi driving, transit operating, mechanics, and other positions supporting the automobile industry, which have historically been stable lines of work (Newman and Kenworthy, 2015).

3.3 Governance, Equity, and the Current State of Policy

Planning is an inherently political and democratic exercise, as it is a means by which society collectively decides what urban change should be like and how to achieve that vision involving a plurality of actors. In dealing with as complicated of a concept as smart mobility, this also involves the political perspective of how the benefits and negative externalities of such a transition will be governed (Finger and Audouin, 2019). The concept of moving away from the traditional hierarchy of government towards the more flexible and networked mechanisms of governance involve various actors and sectors, public and private, with interests and scopes of work at different scales. Docherty argues that in order for the currently imagined smart mobility transition to come about, it will require an equally extensive shift in the governance of mobility so that the "Smart Transition" delivers more public value (Dochertya et al., 2018). While governance may refer to a variety of different contexts in the political, economic, technical spectrums and so on, it can be characterized by the main three factors of politics (e.g., actors and their power), polity (e.g., policy processes and institutions), and policy (e.g., mechanisms and instruments) (Treib et al., 2007). The governance of urban mobility, which has experienced considerable changes in the past few decades, has been affected by several trends: 1) strengthening of lower levels of government, 2) increasing diversity, variation, and asymmetry in how regions are governed, and 3) increasing marketization of the public domain (Treib et al., 2007).

Geels notes that one of the characteristic factors of an environmentally-relevant transition is that strong input from the state is required as it is necessary in the changing of economic frame conditions (e.g. taxes, regulatory frameworks, subsidies) (Geels, 2011). Along these lines, managing transitions successfully also depends on the capability of the predominating governance system to dynamic circumstances, and that through "adaptive capacity" it can be identified what must be changed in regards to necessary changes in policy interventions, monitoring frameworks, and so on (Dochertya et al., 2018). A comparative case study by Lee et al. on the implementation of smart city concepts in San Francisco and Seoul Metropolitan City found that it is through the dynamic collaboration of public and private sector actors in their activities and resources through an open innovation platform that effective smart cities can emerge (Lee et al., 2013). This calls into question what role the state must take within these new networks to drive, facilitate, and dismiss various elements of the mobility system. Failure of the governance system to set a clear vision of underlying goals and foster innovation will risk the state being reduced to a piecemeal mode of governance (Dochertya et al., 2018).

State power in the transport sector is relatively weak in many U.S. cities where the private automobile remains the dominant mode of transport and the state has a small role in how mobility should be planned beyond the status quo. Docherty's 2018 analysis of the governance of smart mobility showed that we are already at a "critical juncture" for smart mobility, which is defined by Capoccia and Kelemen as a "relatively short period of time during which there is a substantially heightened probability that agents' choices will affect the outcome of interest" (Capoccia and Kelemen, 2007). In other words, given the rapid momentum of technological innovation, it may be that the window of opportunity is small for policy makers to have the optimal options for intervention in order to enact meaningful impact on the potential outcomes before a new mobility regime is established. Additionally, finding consensus and generating lasting and reliable decisions has become a major problem for democracies and their institutions.

Specific to shared mobility, another point of view is that data-driven governance, with its ability to produce a more flexible regulatory environment, will be a solution to the current regulatory gridlock in transportation policy and emerging shared mobility services. Voege states that this is achieved by allowing systems that contribute to the public good to be implemented in a safe, flexible environment, facilitating market uptake while also protecting public safety (Finger and Audouin, 2019). As AVs increasingly become part of the sharing economy and disrupting technologies, the role of policy makers in actively managing this transition has already begun. Much of the discussion regarding regulatory frameworks in the context of AVs focuses on the vehicles and the approval processes for ensuring road safety (Finger and Audouin, 2019). While vital, given the eventual integration of AVs with the existing transportation network which is often highly protected and regulated, mobility services must be regulated in parallel. Voege establishes that in order for data-driven governance to successfully move forward acceptance and approval for AVs, certain key principles must be taken into account in the regulatory frameworks: inclusion of all social groups, basis on sound economic principles, adaptability and monitoring of impact, reliance on efficient tools but remain technology-agnostic, and to be limited to correcting market failures.

3.3.1 Equity

Equity is a prominent issue in the vision of a smart and sustainable city, particularly in the realm of transportation, as equal possibility of access to and the use of public spaces and services is embedded in the concept of a liveable city. Much of the existing literature in the domain of transport is of an empirical nature, focusing on the topics of social justice and distributive justice, which looks at goods and how they are distributed among society (Bibri, 2018). These studies are mainly empirically driven, lacking a theoretical foundation of social justice - however, they do often highlight major disparities, for instance, in the contrast of public transport subsidies between generous subsidies dedicated to affluent neighborhoods and those of the inner-city poor (Jaramillo et al., 2012).

Planning with equity in mind requires new visions, strong leadership, and planning methods which allow the city to serve a democratic function where people experience social diversity while sharing the same space and future generation destiny (Behbahania et al., 2018). Wampler states that it is the direct incorporation of citizens into complex policy-making pro-

cesses that is the single most significant innovation in the "third wave" of democratization (Wampler, 2012). The term "social equity" can be understood as the dispersion of effects - namely, benefits and costs - and whether this is considered fair and suitable (Litman, 2011). This translates to increased accessibility to transportation mobility and options for disadvantaged communities such as older adults, the physically disabled, and ethnic minorities, regardless of socio-economic circumstances (Adorno et al., 2018). Transportation options, which must justly serve the entirety of the spectrum of users reflected in a community, raises the question of who uses them and who are excluded. Early applications of equity and justice in transportation planning and policy focused around environmental effects such as air quality, noise pollution, and safety (Adorno et al., 2018). Despite its importance in a well-functioning society, equity remains an issue which is often underplayed in regards to shared mobility, as early evidence has shown a disparity in the accessibility of such services of lower-income populations (Shaheen and Chan, 2016).

It is well documented that ridesourcing and shared mobility services are more likely to be used by younger, better-educated, and more affluent individuals (Mishra et al., 2017), and this has stemmed from an increasing trend of unequal access to ICT and the skills necessary to use it, extending to unequal access to smartphones and mobile data (Selwyn, 2004). A study of residents in Arlington, Texas aged 55 and older found that older adults who were "transportation-disadvantaged" experienced subsequent limited access to health care, goods, and other community services, as well as isolation from certain lifestyle habits and social networks (Adorno et al., 2018). In the analysis of how social equity is incorporated into the transportation plans of 18 metropolitan areas in North America, Manaugh et al. observed a general lack of explicitly stated social equity objectives and appropriate means of assessing their achievement, as environmental concerns are taken as a higher priority (Manaugh et al., 2015). While environmental and social justice issues are not mutually exclusive, it is important to note that there can exist trade-offs between these two sets of objectives. Addressing such issues can be challenging, as various definitions of equity exist among different schools of thought and economic systems, and the levels of impact of groups of people vary in their analysis; while a policy may seem to promote equity in one way, it can be inequitable if measured by another means. Labor issues are also under contention, as it is often unclear whether drivers should be regarded as independent contractors or as employees. Litman et al. propose a systematic framework based upon the three goals of determining distributable benefit, forming target groups, and selecting the favored social equity approach among different perspectives in order to help practitioners integrate equity into transportation modeling to better meet the needs of underserved communities (Behbahania et al., 2018). From the consumer's perspective, services such as ridesourcing serve different divisions of society, leading to repercussions of discriminating and risks to data privacy and security (Jin et al., 2018), showing that AVs also have potential to exacerbate issue of wealth disparity.

3.3.2 Current State of Policy

In 2017, 22 U.S. states introduced legislation on autonomous vehicles, and in 2018, 15 states enacted AV-related bills (of State Legislatures, 2019). On September 12, the National Highway and Transportation Safety Administration (NHTSA) released new federal guidelines for Automated Driving Systems (ADS). Building on NHTSA's 2016 guidance, "A Vision for Safety 2.0", is the latest guidance for automated driving systems to industry and the states

(of State Legislatures, 2019), with the purpose of providing best practices for incorporating safety-related components and aspects regarding ADSs into legislation. Traditionally, states regulate the driver while the federal government regulates the car (Bellon, 2017), but it can be seen how the rollout of AV technology does not fit neatly into the existing regulatory framework, as the traditional state-federal division of labor is hard to maintain when cars have no drivers. Therefore, if AVs are to be successfully integrated into the transportation network, then these policies must be carried down to the regional and local levels through comprehensive planning processes. When spearheaded locally, AVs have the potential to be a part of an integrated transportation system, and their effects, both positive and negative, on land use, infrastructure, and capital budgeting processes well thought-out and anticipatory. However, Guerra warns against planners failing to see the relationship between cities and a new transportation technology, either by misjudging autonomous vehicles or by seeing them as a solution for contemporary planning challenges of road congestion or climate change (Guerra, 2015).

Federal law (U.S. Code Title 23 Chapter 1 § 134 - Metropolitan Transportation Planning 2014) requires that MPOs develop long-range regional transportation plans with a minimum planning outlook of twenty years, and to update them every four years for regions with more than fifty thousand residents (Guerra, 2015). At the California state level, the California Department of Motor Vehicles (CA DMV) currently mandates for any vehicle tested on California roads, it must be retrofitted to account for a backup human driver, and that data related to disengagements of the AV technology be publicly available (Favaro et al., 2018). In the analysis of the disengagements data obtained from AV manufacturers testing on California roads from 2014 to 2017, Favaro et al. found that limitations existed in the wording and drafting of the requirements set by the CA DMV (Favaro et al., 2018). This shows one example of a gap between the regulatory language set by a state and the reality of AV testing, which could indicate insufficient collaboration between the public and private sectors. Fagnant and Kockelman note that the idea of perception has been known to drive policy, such as the perception that AVs are potentially dangerous due to the lack of a human driver (Fagnant and Kockelman, 2015). To account for liability, California law, for example, requires 20 seconds of sensor data storage prior to a collision in order to help establish fault (Center for Information and Society, 2012). With some 90% of vehicle crashes attributable to human error (Smith, 2013), another parameter that the CA DMV uses to establish AV testing in regards to safety is the mandatory submission of Autonomous Vehicle Collision Reports and Autonomous Vehicle Disengagement Reports (State of California DMV, 2019). However, with these current regulations, AV manufacturing companies testing in California are able to decide for themselves which disengagements are safety related, showing that while these metrics indicate the progression of the AV technology, they are of limited utility in regards to indicating safety, as each company gets to decide what counts as a reportable disengagement.

In the work by Anderson et al which outlines a guide for policymakers, the authors warn that "a hastily enacted mandate for sub-optimal technology could lead to enormous lost social welfare" (Anderson et al., 2014). With some boosting AVs as enhancing roadway safety by removing the variable of human error from the equation, it cannot be overlooked that with autonomous technology comes an increased risk of data security, privacy, and liability. Therefore, it is important that cities facilitate implementation of AVs so that the potential benefits are realized for all communities, while minimizing and mitigating the potential negative impacts. Fagnant and Kockelman recommend policy initiatives such as expanding

federal funding for AV research, the development of federal guidelines for AV certification at the state level, and the determination of appropriate standards for liability, security, and data privacy (Fagnant and Kockelman, 2015). While the progression of AV technology is likely to advance with or without legislative action at the federal level, the successful implementation of AVs depends heavily on them. Without federal guidance, states will continue to pursue their own testing and licensing requirements, which may lead to a discordant patchwork of regulations and requirements, particularly when considering issues of safety and data security.

3.4 Urban Mobility Change

A certain amount of creative destruction is necessary in order to make way for the next great innovative technology that moves society forward, and there is an active debate on how emerging technologies of AVs and the IoT will revolutionize individual and collective mobility. At the intersection of the subjects covered in the preceding sections lies what is a move away from the "old mobility" regime, rigidly constructed with private cars at its epicentre, towards a new kind of mobility (Zavyalova, 2017). For many decades, the prominence of the automobile and the path-dependent planning of managing transportation systems around it perpetuated the rigidity of the old mobility regime (Dochertya et al., 2018) . The new smart mobility paradigm has already begun to make strides by ridesharing services such as Uber and Lyft, transforming the way in which we perceive vehicles, routes, and travel, as well as travel planning and time. As cities develop in a manner that car ownership becomes less attractive and practical, the demand for individual freedom and flexibility grows in tandem (Bauman, 2000). Because mobility is a system, many different possible smart mobility futures exist, even with a limited number of technological innovations (Dochertya et al., 2018). Like any other socio-technical transition, this raises questions how to how a transition from one dominating paradigm of urban mobility to another is managed.

It took the span of several decades for the state to grapple with the challenges of managing the car and the numerous impacts of the initial adoption of the automobile on the economy, environment, and society, and so as the transition to the smart mobility paradigm has already begun, it is vital to include in the discussion how state action and public policy must change in this new phase led by the technology sector (Dochertya et al., 2018). As the values, cultures, and mentality of people vary across locations, ages, and socio-economic standing, so do travel behaviors. With the urban being a hotbed of demographic, economic, and infrastructural change, the relations between people and the urban landscapes in which they live and work are to a significant extent experienced through their means of travel. As a result, the modes of transportation one uses is a reflection of how one thinks and feels about the city, and choosing one mode over another also has a psychosocial aspect which goes beyond a rational, function-based decision. Over the last ten years, however, the concept of private car ownership as the only means to the socio-economic end of success has come under much criticism in an increasingly liquid society (Bardhi and Eckhardt, 2012). For planners, understanding how changes take form is essential, as planners are involved in diverse types of dynamics of change at the societal level, which are embedded in diverse systems. As with the Industrial Revolution, a major societal shift incorporates a spectrum of effects such as socio-technological and socio-political transitions, trending toward sustainable mobility, and a greater emphasis on a "just" city as social equity concerns become more pronounced.

A new approach to the management of city investments is needed in order for planners and decision-makers to integrate smart and sustainable development goals into urban planning. The successful implementation of new technologies is reliant on the involved stakeholders and strong leadership, particularly in the collaboration between public and private sectors. The private sector is generally considered to be more efficient and flexible in attaining project objectives that are not necessarily in line with public interests (Przybylowski, 2018). Additionally, the behavior of stakeholders must be shaped based on clearly-defined objectives of the implementation of smart mobility in order to maximize the benefits of both sectors, thereby motivating efforts from both sides to pursue common interests (Przybylowski, 2018). Master planning has long been a fundamental tool for urban development and management, however, in recent years it has been found to have shortcomings due to the exclusion of certain community groups, target beneficiaries, and nongovernmental organizations from the process of public participation in planning (Giduthuri, 2015). Many urban areas are adopting planning strategies aimed to a more sustainable use of resources in order to achieve sustainable mobility - these policies are quite different in terms of costs and expected benefits, and the effects of these policies are difficult to anticipate on a purely intuitive basis, and sometimes the end result is contrary to intuitive expectations (Carteni, 2014). Carteni argues that in order to identify the right mixture of interventions to be implemented on the transport system, rationality is vital in the transportation planning process. Rationality refers to acting in the best possible way considering the aims and constraints. While a rational approach is not always the right alternative, it is likely closer to the best solution because it is more acceptable for public engagement and follows some of the minimum requirements of rationality (e.g., quantitative methods). Standard transport policies are not always "eco-rational" because these policies are very different in terms of costs and expected benefits, both at the global and local levels (Carteni, 2014).

In a sustainable mobility paradigm, there is a strong argument for increasing the scope of public discourse and empowering stakeholders through interactive and participatory governance processes. Banister argues that it is through the formation of broad coalitions - including specialists, academics, practitioners, policy makers, and so forth - that a true debate about sustainable mobility can occur, where there is a collective willingness to change and an acceptance of responsibility (Banister, 2008). In order to achieve sustainable mobility, the collective arguments by these coalitions must be powerful enough to overcome dependence on the car According to Efrussy, one of the characteristics of a good comprehensive plan is its value as a basis for making rational decisions, but not replacing the decision-making process (Efrussy, 2013). In the evaluation of planning documents of to what extent they address autonomous vehicles, it is vital to understand what the rationale is for planning, as well as the efficacy and results of previous plans, particularly in regards to technological changes.

3.5 Summary

Smart city development, often seen as analogous to sustainable urban development, is a current priority for many major metropolitan areas and cities, however, many cities lack the capacity and resources to achieve these ends. Smart mobility is one of the most challenging topics facing large metropolitan areas, as it involves not only environmental and economic aspects, but also the willingness of people to change their mindsets and behaviors away from deeply embedded transportation norms and values, all of which factor into the ability to

prompt urban mobility change. The idea of smart city development forms the basis for a new way of thinking about civilization and touches upon fundamental aspects of day-to-day way of life, with integration of a rising sharing economy which strays away from traditional private ownership models. In contemporary cities, quality of life is highly dependent on a safe, affordable, and efficient transportation system.

Mobility planning is a notoriously complicated task due to the complex and often contradictory factors and needs involved in the process, as well as additional difficulties posed by political and financial restraints. While it is a challenge to ensure smart mobility patterns which take into account a high level of stakeholder participation and the establishment of a detailed, complex, and comprehensive planning process, it is with the coordination of a common vision between social and economic sectors - for example, land management, transport, social policy, safety, and health - as well as between authorities that will enable the proposal of actions that improve the quality of life. The value in incorporating a more data-driven governance with autonomous vehicles also lies at the intersection of a sharing economy and disruptive innovation. The sharing economy movement includes new business models which allow for the use of shared vehicles, while the movement of disruptive innovation pertains to ride-hailing and ridesharing services offered by TNCs and the growth of platform-based mobility services such as MaaS. With the more robust data and utility infrastructure that autonomous vehicles will likely require, data-driven governance will allow for decision-makers to formulate sound decisions based on a real-time availability and abundance of data related to autonomous vehicle safety, equity, ridership, and economic impacts. Thus, the effective implementation of bringing about a disruptive urban mobility change such as autonomous vehicles requires the commitment of key stakeholders to leverage data to better understand the reasoning behind policy initiatives and to support legislative efforts to utilize autonomous vehicles for their benefits while also mitigating their negative impacts.

The next chapter presents the theoretical framework established for this research report. In order to answer the research question of *how does the current integration of autonomous vehicles into regional transportation planning strategies in the Bay Area compare to the personal perceptions of transportation planners directly working on autonomous vehicles in practice?*, the literature review has shown that while academic knowledge exists on the various facets of what an autonomous vehicle future may entail, there is understandably little research focused on the process of integrating autonomous vehicles specifically into transportation planning. This can be due to the inherent complexity of transportation planning problems, as they encompass numerous aspects of society, including certain institutions such as the planning profession and the political landscape, which do not vary significantly from year-to-year. Given this, it is understandable that there is no standard approach for addressing a disruptive technology such as autonomous vehicles in its integration into comprehensive planning processes, as they would require a considerable change in the way transportation planning problems are framed, approached, and acted upon in order for cities and regions to meet their long-term goals. Thus, based on the existing theory and research of what is already known, the following theoretical framework serves to show how this research informs the research questions and methodology.

Chapter 4

Theoretical Framework

This chapter is composed of the main theoretical and conceptual framework on which the analysis will be based. These themes are developed from studies taken from literature on previous research most relevant to the concepts of sustainable urban mobility, particularly concerning a disruptive force or technology.

4.1 Multi-level Perspective on Socio-technical Transitions

In the bringing about of social and technological changes in society essential for a more sustainable future, a richer understanding of how these changes come about is necessary. One theory concerning change that is relevant for addressing complex issues like climate change and transportation planning is the multi-level perspective (MLP) of sociological transitions, which provides insights into how one technology has transitioned into a radically new one to fulfill a social need. Planners are involved in a field that takes place in a complex network of many disciplines such as politics, sociology, and engineering, all of which are affected by the dynamics of change at the societal level. Due to the necessity of these various disciplines to work together and the political pressures that may hinder, stall, or support these efforts, transportation planning has often underestimated critical challenges facing urban planners, such as with the urban sprawl brought about by the accommodation of the automobile in the 1950s. Banister states that such challenges as the growth of faster and longer-distance travel can be explained by people's value of the activity at the destination and their minimization of the cost of travel (Banister, 2008). When diverse socio-technical system innovations change, oppose, or reinforce each other, transitions occur. While there is no single cause or driver to a certain transition, it is rather the existence of many processes occurring in multiple dimensions and levels that change simultaneously.

Figure 4.1 illustrates the multi-level perspective of Frank Geels, showing that socio-technical transitions occur when many dimensions reinforce each other in a cyclical manner in order to fill a social need. The stable socio-technical regime represents the normality of society, whereas the "landscape" refers to the intangible societal landscape of how people feel about a situation and the common discourse surrounding the technology being studied. Niche innovations are small radical changes that emerge to disrupt the stable regime but do not yet scale up to break through the durability of the stable regime. Changes in the landscape

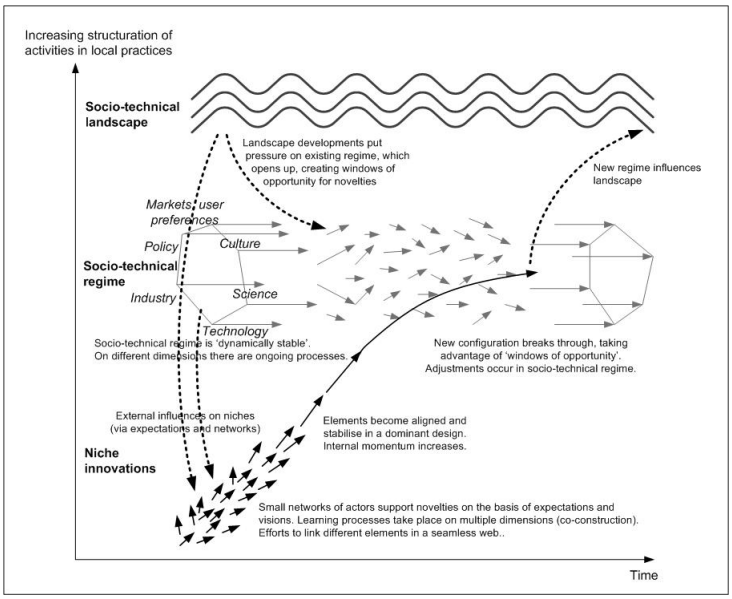

Figure 4.1: The Socio-technical Regime, Landscape, and Niche Innovations Required to Effect Change - Source: (Geels, 2011)

put pressure on the stable regime and create windows of opportunity for niche innovations to develop and compound on each other. The stable regime either adapts to, rejects, or is taken over by the niche innovations, over time leading to the eventual replacement of an old technology. The factors and interdependencies within this regime over time is what situates society into a locked dominant technological solution. Thus, in the application of this model to the automobile, it can be understood how the gas-powered automobile came to make up the stable regime in the United States. Through the niche innovation of the technology to evolve from the horse and buggy, coupled with the abundant and affordable fuel source of gasoline, and the capacity of land mass the United States had at its disposal to develop that reinforced each other to build what it now the predominant transportation infrastructure in the U.S., characterized by sprawling highways, low-density development, and congested urban centers. Additionally, the automobile industry and its suppliers are keen to conserve their investments, while their dominance over the market share inhibit new transport technologies from gaining a foothold.

In this research, the multi-level perspective model is applied to the new socio-technical transition of a shift to a more sustainable mobility paradigm - that of the autonomous vehicle. In this application of the MLP, the autonomous vehicle is the niche innovation which is posed to cause a disruption in the stable regime, which is currently dominated by the gas-powered automobile. The landscape will be defined as the general societal, political, and economic climate surrounding the automobile which currently maintain, if not support, continued car dependence for the unforeseen future. With the current stable regime being an unsustainable one due to its reliance on fossil fuel consumption and its hindrance to the realization of cities made for people, a sustainable mobility paradigm offers an alternative path to readdressing many of the urban and transportation planning issues present today. In order to create windows of opportunity for the niche innovation of autonomous vehicle technology to make meaningful breakthroughs into the stable regime, the landscape, which is constantly fluctuating in response to society's behaviors, perspectives, and beliefs on issues, must also change in a way that allows for the conversation of autonomous vehicles to gain traction at a

higher level. It follows that planners, whose profession lies at the intersection of serving the greater public as well as being at the will of political forces to a certain extent, are uniquely positioned to serve as a go-between on behalf of key decision-makers in planning processes, the public, and the impending technology of autonomous vehicles.

Figure 4.2 shows how in comparison to historical trends, consumption - particularly of new technologies - is adopted at a much quicker rate today. With preliminary adoption of autonomous vehicles able to begin with the current transportation infrastructure already in place today, it is likely that based on these trends of consumption, autonomous vehicles - once past the research and development phase - will follow a similar pattern once a certain level of affordability and availability is reached. This reinforces the significance of the potential role planners will play in ensuring that cities and regions are well equipped to handle a technology that will have undeniable impacts on human safety, equity, and mobility.

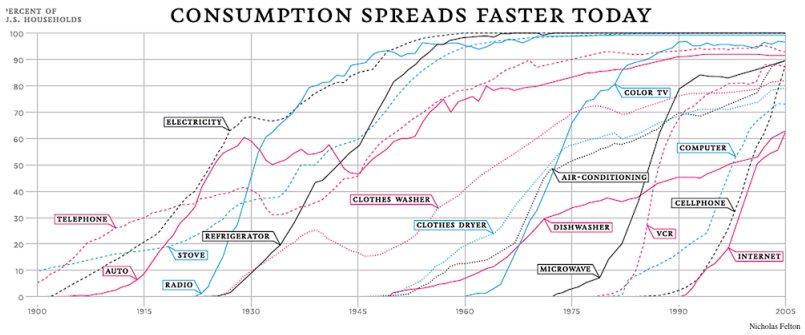

Figure 4.2: Consumption Trends Faster Today Source: (The New York Times, 2008)

With the application of the multi-level perspective model to the autonomous vehicle, the central idea of MLP is that a technology, such as an automobile, does not exist as a discrete entity. As the automobile became the dominant means of transport, the automobile developed interdependencies with social, technical, and institutional factors such as production, the supplied network, transportation infrastructure, regulation, and users. Figure 4.3 below illustrates Geels' conceptualization of basic fields and resources of socio-technical systems, showing that when considering an artifact, in this case the automobile, the artifact is interlinked between realms of production (e.g. the automotive industry), the distribution network (e.g. transportation infrastructure), and the application of the artifact (e.g. end users of the automobile). Each realm contains smaller fields of industry which enable the artifact to develop, be distributed, and provide a service to the consumer. With these interdependencies evolving with one another, the artifact of the automobile is able to mature, forming a stable socio-technical regime around it constituted of people working in the industry such as engineers and designers, and the general public on a wider scale who have come to rely on the car on an everyday basis. This makes way for a stable socio-technical regime which gravitates toward common assumptions, knowledge, beliefs, and behaviors about what are feasible and worthwhile transport solutions.

In addition to the societal norms and behaviors surrounding the automobile which constitute the stable regime, the built environment of transportation infrastructure is also relatively long-lasting and expensive to change. Even when alternative transport options are under consideration, the options are fairly limited to operating within the current infrastructure,

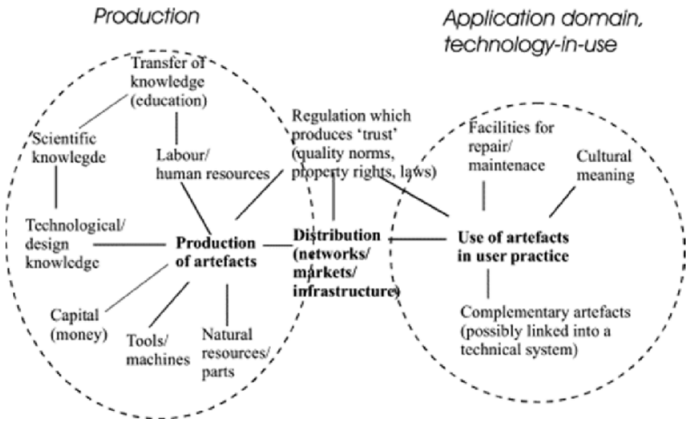

Figure 4.3: Social, Technical, and Institutional Interdependencies of the Artifact - Source: (Geels, 2004)

as deviating from the status quo would require a large upfront capital expense. Therefore, it is vital that key changes occur at the landscape level to spark riffs in the discourse and habits surrounding the automobile. In this research, the multi-level perspective model will be used from the perspective of studying the perceptions of individual transportation planners on autonomous vehicles, which contribute to the landscape of the automobile. Namely, in order for the current automobile-dependent transportation system to be disrupted, there must be some movement at the level of city and regional transportation planning, particularly within metropolitan planning organizations who must consider these types of future mobility technologies in long-range planning processes. This movement may be characterized, for example, by forward-thinking planners who believe it to be worthwhile to invest time in researching the possible impacts of autonomous vehicles on their regions' residents, despite the fact that it is a technology that is not yet fully realized.

The Results chapter of this report will provide the findings to the three sub-questions:

1. What are the focal points on the topic of autonomous vehicles in Bay Area regional transportation planning documents?

2. What are the focal points on the topic of autonomous vehicles as identified by Bay Area transportation planners involved in their planning and research?

3. What common or counteracting themes can be drawn between what is found in the regional transportation planning documents versus the perceptions of the individual planners?

Following the answers to these sub-questions, the theoretical framework of the multi-level perspective will be applied in the Discussion chapter, to provide an analytical look at the findings through the lens of this model.

Chapter 5

Methodology

This research depends heavily on assumptions and predictions concerning a future with autonomous vehicles. Given that there are no data on autonomous vehicles as a fully realized existing mode of transportation, the phenomenon cannot be studied directly. Therefore, this research is in the form of an exploratory, qualitative case study, with primary data gathered from planning documents, relevant planning journal articles, and interviews. Given the limitations of a phenomenon which is not yet present today, the aim of this research is to understand how regional transportation planners in the San Francisco Bay Area perceive autonomous vehicles as a future mobility option, versus what exists concerning autonomous vehicles in regional planning documents today. This chapter outlines the various methods used to carry out this research and is divided into three sections: section one defines the purpose of the use of the case study as the focal point of this research; section two describes the data collection sources and analysis techniques employed that contribute to the answering of each of the research sub-questions; section three is a discussion of the research design and addresses the issue of quality in research design and limitations.

5.1 The Case Study as a Research Method

A case study can be described as an inquiry which deals with a technically distinctive phenomenon comprised of many variables of concern, therefore relying on a variety of evidence and a theoretical framework which guides the data collection and analysis (Yin, 2009). Here, a "case" refers to an event, problem, process, program, or person. A case study typically concerns an empirical examining of a phenomenon within its real-life context when the boundary between the phenomenon and its context are not clearly discernible, where the researcher is excluded from that context (Yin, 2009). Thus, the researcher aims to have no influence on the phenomenon; this is in direct contrast from an experiment, wherein the researcher intends to have direct influence on the phenomenon. A case is also characterized by multiple sources of data, including a variety of qualitative data such as interviews, observations, documents, and artifacts (Silverman, 2006). This variety of data is necessary in order for the researcher to have a more in-depth understanding of the case. There are typically three types of case studies: 1) the single instrumental case, 2) the collective/multiple case, and 3) the intrinsic case study (Yin, 2009). As the collective case study enhances the reliability and validity of the data by using a wider variety of data, this allows the findings to become more full-bodied (Yin, 2009). However, while the benefits of a collective case study offer a more robust assembly of data and understanding of the findings, it is important to note that

simply widening the boundaries of the case study from a single case to multiple comparative cases does not necessarily correlate with the ability to more confidently make causal connections.

When considering the case study method, firstly, it was important to determine if a case study would answer the proposed research question surrounding the specific case, as defined previously. Next, the case or cases were identified, as well as what type of case study both best fit my interest and answered the research question. Then, it was necessary to select the depth of the case study: a holistic case study examines a case as a whole, while an embedded case study only examines certain aspects of a case. In this research, a single instrumental case study was used, therefore, the analysis of the data was structured as being categorized into distinct themes. In this step, assertions or interpretations of the meaning of the data were made. This last step also included making statements about the lessons learned about the case and what should be learned from the meaning of the data.

It was deemed that a case study method was appropriate for this research in order to answer exploratory questions of "what" and "why", regarding a contemporary phenomenon where I as the researcher strove to effect minimal impact on the events and relevant actors (Yin, 2009). As a multi-disciplinary practice that incorporates theories of social science, the study of city planning is very much context-dependent, and therefore required a more in-depth understanding of the environment of the case, as well as the documents and other qualitative data under analysis. Utilizing the case study also allowed me to get closely familiar to the primary sources of data throughout the research process (Flyvbjerg, 2004).

5.1.1 Focus of Study

The nine-county San Francisco Bay Area region in Northern California is home to 7.4 million inhabitants, covering approximately 7,000 square miles of land, composed of the three major cities of San Francisco, San Jose, and Oakland (see Figure 5.1 below). Located here are the headquarters of high-tech such as the prominent on-demand ridesharing companies Lyft and Uber, automotive and energy company Tesla, as well as Silicon Valley, an area of the Bay Area which has over the years solidified itself as the center of the computer industry and venture capital. Relative to the rest of the United States, California as a state has long been considered an environmentally progressive leader in pushing ambitious policies that have set the standard for others (Berkeley Political Review, 2018). Further, in April of 2018, the California Department of Motor Vehicles (DMV) began approving applications for autonomous vehicle testing without a driver and deployment (State of California DMV, 2018). Therefore, as an environmentally and socially conscious region, it is embedded in the major municipal and regional planning agencies' missions and visions that projects are planned with new mandates, advances in technology, and changing environmental conditions in mind. With its dense concentration and reputation for entrepreneurship and technology, it can be seen why this region plays a major role in predicting the future growth of the Bay Area from a social, economic, and cultural standpoint.

As the fourth-largest metropolitan area in the U.S., the Bay Area has more than two dozen operating public transit agencies, with passengers making more than 2 million trips per day in over 4,000 transit vehicles (MTC, 2018). Beginning in the dot-com boom of 2000,

Figure 5.1: San Francisco Bay Area's Nine Counties - Source: (PerryPlanet, 2010)

per-commuter congested delay increased by approximately 65%, while population and jobs increased by 15% and 12%, respectively (MTC, 2017). Therefore, while the Bay Area is heavily impacted by traffic congestion and its subsequent effects of pollution, public health, and the economy, this region of Northern California is also in a unique position to more proactively incorporate high technology-based solutions into its planning processes.

5.2 Data Collection Sources and Applied Analysis Methods

This section discusses the primary sources of data utilized during the course of the research, as well as a description of the analysis techniques used with each source. As qualitative data constitutes the basis of this research, the applied methods are of a variety of sources found to be relevant to the topic at hand.

5.2.1 Document Analysis

In this research, publicly available documents in the forms of plans, conference and meeting proceedings, and planning-related materials were analyzed as a method to comprehend the complex nature of autonomous vehicles in the Bay Area. The planning documents, which for the boundaries of this research are limited to regional plans and exclude municipality-specific plans, cover land use, transportation, diversity, and economic aspects, and are mainly gathered from 2013 onward. Relevant secondary source documents were all obtained online.

In order to identify the material most relevant and pertinent to advancing this research, the following were considered: relevance, authority, and currency. Relevance refers to the selected literature as contributing to the development of the issue, providing perspectives that can either be used in support of or against the research (Silverman, 2006). Authority refers to the credibility of the source, generally meaning that it is obtained from or recognized by experts of the field. Currency relates to whether the document is sufficiently recent to still

Table 5.1: Documents Chosen for Analysis

Document Title	Description	Corporate Author	Date	Source
Autonomous Vehicles Perspective Paper	Perspective Paper on AVs, part of the Horizon initiative. Contents include Executive Summary, Ch 1 (AVs in the Bay Area), Ch 2 (Preparing for AVs), Ch 3 (Next Steps) and Appendices.	Arup Group Ltd. MTC ABAG	June 26, 2018	https://mtc.ca.gov/digital-library/search/autonomous%20vehicles (MTC Digital Library)
Plan Bay Area 2040	A transportation and land use roadmap for future growth of the Bay Area - focused update of previous plan adopted in 2013	MTC ABAG	July 26, 2017	http://2040.planbayarea.org/reports
2017 and 2018 Final Joint Advocacy Program	Attachment listing issues, goals, and strategies of 2018 Advocacy Program	MTC	January 31, 2018	MTC Digital Library
Future Mobility Research Program - Update (meeting notes and presentation transcription)	MTC Planning Committee Agenda Item 5a from meeting on October 27, 2017 discussing research of MTC and partnering MPOs in California	MTC	October 27, 2017	MTC Digital Library
Toward a Shared Future: Strategies to Manage Travel Demand	Identifies high-impact policies to help manage travel demand and achieve VMT reductions while supporting Horizon's five Guiding Principles, as defined by Bay Area residents	MTC ABAG ICF International	September, 2018	https://mtc.ca.gov/our-work/plans-projects/horizon/perspective-papers
Futures Interim Report: Opportunities and Challenges	Interim milestone report to help guide a long-range regional plan for the Bay Area's future growth and investments. The report describes potential future challenges brought about by external forces while continuing the conversation about regional policies and investments to change the region's trajectory	MTC ABAG	March 15, 2019	MTC Digital Library

be recognized as a valid source (Silverman, 2006). As the topic of autonomous vehicles is relatively new, all of the documents used in this research were published in the last decade. Table 5.1 lists the documents chosen for the first phase of analysis, listing the title and description of each document, author(s), date of publication, and the source from which the document was obtained.

As publicly available documents are so readily available online, a thorough review of all documents relevant to the topic of this research were vital in gathering information to construct an overall view of the wider discussion of AVs in the current planning field in the San Francisco Bay Area. As shown in Table 5.1, case data were collected from secondary data-sources, including long-range regional plans, transportation committee meeting proceedings, and conference presentations. With the case study being bounded around the entire San Francisco Bay Area as a region, document collection excluded city- or county-specific planning documents. In the analysis of the documents, the guidelines listed in Table 5.2 were constructed and used, based on findings identified in the phase of the Literature Review.

The Document Background questions serve to provide a context for each document. This takes into account that all documents were created with an intent and intended audience in mind, which will color the content covered and language used in some manner. Questioning the point of view of a document factors in whether the author is an authority on the subject they discuss, as reliability and accuracy can be at risk if the source was not in a legitimate position to know this information. Further, the source may have implicit or explicit motives to lie, tell the truth, or to omit certain details. While with written documentation it is more difficult to gauge the tone or intent, it was important to keep in mind that in the political sphere of planning, direct or indirect political commentary may be used in a way that leads to bias, evokes satire or irony, or uses loaded language. As a researcher in a field with social science facets, it is also vital to consider that the source may be attempting to achieve an

Table 5.2: Document Analysis Checklist

Theme	Question
Document Background	1. What type of document is it?
	2. Who produced the document?
	3. When was the document produced?
	4. What is the point of view of the source?
	5. What kinds of information can we get from the document?
	6. Why does this document exist? What motivated the author to produce it?
Technology	7. What is said on the technology of autonomous vehicles?
AV Impacts	8. How does the document account for impacts of AVs on public transit?
	9. What are the effects on the regional transportation network?
	10. How does the document consider environmental impacts? (e.g. GHG emissions)
	11. How does the document consider effects on VMT?
	12. How does the document consider the relation of AVs with TNCs?
	13. How does the document consider the effects of the automation? (e.g. jobs lost)
	14. What is said regarding public safety?
	15. How does the document consider possible information technology safety and security concerns?
	16. What is said on the possibility of AV impact on electrification or use of electric vehicles (EVs)?
	17. How does the document consider impacts on social equity?
	18. How does the document consider land use changes due to AVs? (e.g. urban sprawl, repurposing land such as parking)
	19. How does the document address the increased demand for communications infrastructure necessary for AVs?
	20. How does the document consider the mitigation of the potential negative impacts of AVs?
Regulatory	21. How does the document include mentions of the regulation of AVs?
Other	22. What types of AV ownership models are considered?
	23. What types of partnerships and collaborations are mentioned regarding AVs?

agenda or to convey a certain idea. As publicly available information is necessarily edited and written in a specific manner, often to persuade the reader to perceive a topic in a certain way, it is likely that the source has omitted important information that must be taken into account before you an opinion is formed.

Only one broad question on Technology was included, as autonomous vehicles are still deeply in the research and development phase. For the purposes of this report, it was chosen to focus only on technology as it pertains specifically to transportation planning of autonomous vehicles. The section of document analysis questions on AV Impacts include themes covering social equity, relations to public transit, public safety, data security, and impacts on land use. These questions were formulated based on preliminary research performed during the Literature Review, where it was identified what are the uncertainties that arise from a future with autonomous vehicles. The intent was to provide the flexibility of an explanatory answer to each question for each document. Not all documents addressed all questions posed, as the type of document ranged from committee meeting transcriptions to long-range regional plans. The aim was to analyze all documents as a comprehensive whole, in order to illustrate they focal points most emphasized in these publicly available documents.

5.2.2 Interview Analysis

From gaining a wider sphere of knowledge on the general discussion of autonomous vehicles in regional transportation planning, the second applied method of interviewing was used to generate data on a smaller field within the case study. In-person interviews were conducted with planners identified as contributing to the current discussion of the integration of AVs in the San Francisco Bay Area. These interviews were a vital portion of the data, as the collection of responses from primary sources allowed for minimal skewing of information - which can be often present when information passes through various media - and allowed for the participants to speak in their own voice and terms, and to express their thoughts and feelings freely in a comfortable environment. This gives interviews an added benefit in contrast to documents, which are static sources of information that may be missing further context or be misinterpreted with no chance for clarification.

Typically, the aim in a sampling design for an interview study is to identify key individuals who have knowledge of or experience with the phenomenon of interest that they are willing to speak about (Lee et al., 2013). The goal is breadth and attaining a broad range of perspectives across a spectrum, rather than representativeness. The sample size varies depending on the complexity of the inquiry and is determined by theoretical saturation, or the point at which no new concepts emerge from the data (Lee et al., 2013). In this research, in lieu of sampling, San Francisco Bay Area regional planners and professionals with planning backgrounds were specifically sought out, as the topic of research is addressed by a small niche of planners within the boundaries of the case study. Therefore, the interview participants reached out to were chosen strategically, given their position in planning for the San Francisco Bay Area and involvement with AV-related projects. In the in-depth interviews conducted, there was no set path for the interview, although an Interview Guide was created beforehand in order to ensure that certain key topics were covered (see Appendix), such as environmental factors, impacts on social equity, and relations to public transit. From these interviews it was learned how each individual perceived the future incorporation of autonomous vehicles in a planning context, as they pertained to various themes informed by the document analysis.

A total of four interviews were conducted: three in-person interviews with regional transportation planners in the public and private sectors, and one phone interview with an academic with previous planning experience. The interviews lasted between 40 minutes to an hour and were conducted in April and May of 2019. While using the Interview Guide as a reference, there was open opportunity for a back and forth exchange between the researcher and interview participants, giving a chance for the posing of follow-up questions that touched on new topics as they arose, or for the clarification of responses. This approach also allowed me to delve deeper for additional information, making connections between different points in the interview in order to gain a more comprehensive understanding of the participant's perceptions, motivations, and rationales. The aim of the interviews was twofold: to hear what focal points were most prominent in the discussion of AV implementation in a private setting, and to query the rationales behind autonomous vehicle initiatives. While the document analysis had already been completed prior to the interviews, the questions asked were phrased in general terms, so as to give the interviewee the chance to answer freely in their own words. In order to maintain anonymity throughout the text, I opted to exclude the names of any interviewees in the body of the paper. In the Results section of the paper, the reader may match the names of the interviewees with the organizations listed in Table 5.3.

Table 5.3: Interview Participants and Roles with Autonomous Vehicles

Interview Participant	Organization	Areas of Expertise
Planner A	Metropolitan Transportation Commission	Principal planner focusing on long-range planning and policy; managed Plan Bay Area 2040 and its Environmental Impact Report; MTC lead on Future Mobility Research Program; initial interest with AVs on how they affect long-range planning
Planner B	University of San Francisco School of Management	Background as both planner and engineer, as well as more recently academia, focusing on intersection of technologies and cities; previous experience in urban planning, economics, and information systems; focused on industry side of AVs
Planner C	Arup	Senior transportation planner, focusing on transportation technology with AVs as specialization; intelligent mobility; disaster resilience
Planner D	Metropolitan Transportation Commission	Principal planner also working with Association of Bay Area Governments (ABAG); project manager for the upcoming long-range regional plan, which has 2 components: Horizon and Plan Bay Area 2050

The in-depth interview methods used were inspired by Kvale and Brinkmann, performed as semi-structured interviews allowing for a degree of deviance from the prepared interview guide (Kvale and Brinkmann, 2008). The interview guide served more as a framework for the interviewer, rather than boundaries for the participants. Therefore, it was not a structured script that must be followed in a standard way every time, but instead a guidance to be used in facilitating the conversation and delve into relevant subjects that the participants may not have considered prior to the interview. The interview guide used in this research was constructed to contain a list of main questions and probes that help the interviewee understand the intent of the question. Questions were open and non-directive, based upon the principle of qualitative methods being exploratory in nature and non-directional (Kvale and Brinkmann, 2008). It is the responsibility of the researcher to maintain as objective a stance as possible in the posing of the questions, proactively minimizing the risk of reliability by avoiding influencing responses, such as by asking leading questions or conveying one's own view, implicitly or explicitly (Kvale and Brinkmann, 2008). This was kept in mind when performing the interviews, as well as the importance of thinking in broad, non-judgmental terms, encouraging the respondent to give both positive and negative statements.

Coding and NVivo In the analysis of the interview findings, NVivo 12 was used, as the use of software is increasingly seen as the standard to qualitative data analysis. In order to organize large amounts of data from the conducted interviews and support transparency, NVivo was used to help organize and analyze the transcripts of the interviews in order to explore and evaluate the social phenomena of this study. As a tool which provides structure to a large amount of messy non-numerical data and supports rigorous systematic analysis, NVivo was chosen due to its functionality as an organized filing system where one can quickly search and locate material, as well as its user-friendly and flexible design to facilitate commonly used qualitative techniques. In the analysis of the collected data, NVivo simplified the determination of arising themes, as well as the examination of relationships between the data. In the final stage of analysis, visualizations were constructed from the data in various forms to represent the findings.

The coding process in NVivo was conducted by beginning with importing the interview transcripts into the NVivo platform. Once imported, the first step before coding was to

read the transcript freely and broadly without any biases or assumptions, in order to spend time with the data. Next, initial codes and properties were created with the first transcript, bringing that initial code structure to all transcripts. The chosen codes referred to words or short phrases that were found to represent the essence or key attributes of a portion of the interview narrative. Here, a code structure arose from the process of organizing the interview data into groups that were alike, composed of emerging codes characterizing the properties of paragraph-by-paragraph analysis or taking several phrases or sentences at a time. This code structure was then revised in an iterative form, moving back and forth between individual and group level reviews of the interview transcripts, editing the codes in order to accommodate various perspectives in the analysis. Ultimately, the final goal was to create a final code structure that was then applied to the whole data set systematically so that it ended with a comprehensive, fully coded set of narrative data that could then be analyzed at more complex levels. Below is the final code structure that emerged from the interview data:

1. AV Impacts
    - Environmental
    - Land Use
    - Partnerships
    - Public Safety
    - Social Equity
    - Technology
    - Transit
2. Challenges
3. Mobility
4. Ownership Models
5. Planner Role
6. Regional Effects
7. Regulation and Policy

5.3 Research Design

The methodology used in this research is of a dominantly inductive nature, although not purely inductive. The use of a theoretical framework prior to the data analysis serves to help conceptualize key themes relating to the phenomenon of this research later on in the Discussion chapter. However, this theoretical framework was not applied in the initial phase of the qualitative data analysis, as the objective of the data analysis rooted in grounded theory was to optimize the discovery of emerging themes in an unbiased manner. As a study with aspects in the social sciences, a post-positivist or constructivist stance was taken in this research in which it is assumed that social phenomena are produced through social interactions (Farthing, 2016). The social constructivist perspective leads to a level of interpretivism (Bickman and Rog, 2009), both in the understanding of key themes such as the role of the planner in attaining smart mobility solutions, as well as in the analyses of the qualitative data collected. Ontological assumptions are necessarily made by the researcher from the onset of the report, shaping the observations and understanding of the world based on how reality is perceived. Therefore, it is inevitable that the framing of the research contains a degree of subjectivity. A number of assumptions underpin the research, based on philosophical arguments of the nature of what sorts of things are thought to exist (ontology) and what

there is to know about these things (epistemology) (Farthing, 2016).

Inspiration for the topic of the planning perspective of autonomous vehicles on transportation planning stemmed from the unique environmental, technological, and social environment of the researcher's location of residence. With firsthand experience of the perceived troubles with the current public transportation system, unwanted trends of private car ownership, and the attractive new idea of the technology of autonomous vehicles, it was determined during preliminary research that while much research is dedicated to the viability of the technology itself and the ethical ramifications of AVs, there was minimal discussion as to how the new technology of AVs is currently perceived and discussed by planners. In finding that much of the academic discussion was based upon the technology itself and the ethics of the use of artificial intelligence, it was found that further research would benefit those wanting to know of the logistics on the local level of the actual implementation of such a technology, particularly, how this concept is perceived and discussed among planning professionals. Thus, while this research overall aims to contribute to the academic literature available on this subject, it is hoped that any revelations emerging from the data will also serve to benefit planners who are currently or will soon be dealing with the complexity of autonomous vehicles in their cities. The framing of the research was a necessarily selective process where it was determined that the focus of the study would be on the the perspectives of transportation planners themselves who are currently dealing with the potential implementation of AV technology in the San Francisco Bay Area region. Transportation and urban planning in San Francisco is a regional issue, and so in setting the bounds of the research, it was necessary to consider the close relations between the major cities and counties that constitute the Bay Area region.

5.3.1 Research Questions and Supporting Analyses

How does the current integration of autonomous vehicles into regional transportation planning strategies in the Bay Area compare to the personal perceptions of transportation planners directly working on autonomous vehicles in practice?

5.3.2 Research Sub-Questions

1. What are the focal points on the topic of autonomous vehicles in Bay Area regional transportation planning documents?

2. What are the focal points on the topic of autonomous vehicles as identified by Bay Area transportation planners involved in their planning and research?

3. What common or counteracting themes can be drawn between what is found in the regional transportation planning documents versus the perceptions of the individual planners?

Table 5.4 illustrates the research question and underlying sub-questions, as well as the document collection source and analysis method applied to answer each.

Sub-questions one and two are of a descriptive approach, where the former relies on data collected through means of publicly available resources online, and the latter depends on

Table 5.4: Methods for Answering of Research Question and Sub-questions

Research Question *What, if any, is the discrepancy between the personal perceptions of the implementation of autonomous vehicles in the San Francisco Bay Area, versus what is documented in the plans themselves?*	**Data Collection Source**	**Analysis Method Applied**
Sub-question 1 *What are the focal points on the topic of autonomous vehicles in regional planning of the San Francisco Bay Area?*	**Documents:** Plans, research articles, conference and committee meeting proceedings, news articles	**Document Analysis:** Document analysis checklist to identify focal points as found in documents
Sub-question 2 *What are the focal points on the topic of autonomous vehicles in regional planning of the San Francisco Bay Area, as identified through one-on-one interviews with planners involved in AV planning and research?*	**Interviews:** One-on-one in person or over phone	**Interview Analysis:** Coding in NVivo of transcribed interviews
Sub-question 3 *What common or counteracting themes can be drawn regarding how planners talk about AVs?*	**Qualitative data** from answering of sub-questions 1 and 2	**Comparison of findings** from sub-questions 1 and 2

the anecdotal accounts of San Francisco transportation planning professionals through interviews.

Sub-question three is of an explanatory nature, with a point of departure based on the document and interview transcript analyses conducted in the answering of the first two sub-questions. Here, comparisons are made between the findings of the document and interview analyses, to identify common and unshared themes which emerged from the data.

5.3.3 Quality of the Research

Much of case study research design concerns collecting information about the world in some sort of structured, socially accepted manner. What determines a socially approved method are the following key questions of the quality of research: reliability, validity, and generalizability.

Reliability
Reliability refers to the degree to which a research instrument produces consistent results, where "instrument" is another word for a given data collection method (Shipman, 1997). In qualitative research, the researcher must try to combat potential subject error by not becoming wound up in the specific way that an interviewee may respond to a series of questions, but rather what they talked about in a general sense (Kvale and Brinkmann, 2008). Conducted at any other time, interviewees' responses may change the results in a significant manner, not because anything is changing in the world, but simply because people change from day to day. Further, there is a large number of uncontrollable variances and differences in the contextual environment of autonomous vehicles, which will inevitably affect the reader's interpretation of this research's results. Therefore, it is noted that the interviews do not have a high degree of replicability, as a repeated interview at a later point in time, even with the same participants and questions, will yield different perceptions and answers.

Validity
The second key question concerns whether the evidence reflects the reality under investi-

gation, and if it is a true reflection of what is actually going on. In social science research particularly, the notion of reality - in this concept of quality, we have to take on trust that there is some kind of situation out there in the world that we are trying to measure or capture, which exists independently of the researcher (Farthing, 2016). The question then becomes whether the results extracted from the research match up to that reality (positivism). A separate way of thinking which contrasts positivism is constructivist, arguing that in fact the world is created by us (Farthing, 2016). A piece of research can be valid, doing the right things, but it can be unreliable if it produces different results with every iteration.

Generalizability
Concerning the generalizability of research, the researcher must ask themselves what relevance the results have beyond the situation investigated (Shipman, 1997). Given that the field of autonomous vehicles is still in its infancy and the small sample of planners interviewed in this research, it is advised not to generalize these results to apply to a larger sample size. All interviewees were asked to speak personally, so while the interviewees' responses themselves cannot be applied to other contexts, emerging themes from those responses may rather indicate a common perspective on the case study phenomenon.

5.3.4 Limitations

A few major limitations effect this research, the first being the use of the case study as a research methodology. Foremost, the researcher may not have the time to devote to a robust description and analysis of a phenomenon. The amount of description, analysis, or summary material is dependent on the researcher and the available resources and time, making decisions as to how to report a story, how much to compare with other cases, how much to generalize, and so on (Stake, 2005). Another downside in the use of the case study is that the supporting methodological choice and reasoning is more difficult to justify. As this research focuses on one sample that is the planning practices in the San Francisco Bay Area, the findings from this sample must be generalizable and applicable to some degree to the larger phenomenon of the growing use of AVs in urban areas. Secondly, document analysis alone is not always sufficient to form the basis for a complete research project (Bryman, 2008), as documents themselves are not capable of expressing the nuances, disagreements, or other forms of misinterpretation or error that are often involved in their creation. A further limitation of this study has been the lack of historical context from previous generations of plans and methods in the Bay Area. It was difficult to determine with confidence such issues as the extent of the political and institutional support for innovative vehicle technologies, to what extent the strategies of AV integration represented a significant shift in planning toward a more sustainable paradigm, or whether they represented a form of branding or publicity to enhance the competitive profile of the region.

Chapter 6

The San Francisco Bay Area Region

San Francisco, officially known as the City and County of San Francisco, is the cultural, commercial, and financial hub of Northern California. As the 13th most populous city in the United States and the fourth-most populous in California, there are approximately 885,000 residents (U.S. Department of Commerce, 2018) covering an area of about 45 square miles (120 sq km) (US Census Bureau, 2010) as of 2017 (US Census Bureau, 2017). As of 2017, it was the seventh-highest income county in the United States, with a per capita personal income of $119,868 (Bureau of Economic Analysis, 2018). As of 2018, San Francisco is the highest rated American city on world liveability rankings (Mercer, 2018).

6.1 Race and Ethnic Groupings

San Francisco has a minority-majority population, as non-Hispanic whites comprise less than half of the population (US Census Bureau, 2005), As of the 2010 census, the ethnic makeup and population of San Francisco included: 390,387 whites (48%), 267,915 Asians (33%), 48,870 African Americans (6%), and others. There were 121,744 Hispanics or Latinos of any race (15%). In 2010, residents of Chinese ethnicity constituted the largest single ethnic minority group in San Francisco at 21% of the population. Between the years of 1990 and 2000, the number of foreign born residents increased from 33% to nearly 40% (Pamuk, 2004). During this same time period, the San Francisco Metropolitan area received 850,000 immigrants, ranking third in the United States after Los Angeles and New York (Pamuk, 2004).

6.2 Education, Households, and Income

Of all major cities in the United States, San Francisco has the second-highest percentage of residents with a college degree, with over 44% of adults having a bachelor's degree or higher (Bizjournals, 2006). San Francisco ranks third of American cities in median household income with a 2009 value of $81,136 (US Census Bureau, 2011). An emigration of middle-class families has left the city with a lower proportion of children than any other large American city (Sankin, 2012). While the city's poverty rate is 12% lower than the national average (US Census Bureau, 2009), homelessness has been a chronic problem for San Francisco since the early 1970s (Torrey, 1997). The city of San Francisco has been dramatically increasing expenditure directed to alleviate the homelessness crisis: spending jumped by $241 million in 2016-17 to total $275 million, compared to a budget of just $34 million in the previous

year (Graff, 2018).

6.3 Economy

According to academic Rob Wilson, San Francisco is a global city, characterized by its ethnic clustering, network of international connectivity, and convergence of technological innovation (Pamuk, 2004). Global cities are considered to be complex and require a high level of talent as well as large masses of low wage workers. A divide is created within the city of ethnic, typically low-class neighborhoods, and expensive ones with newly developed buildings. This in turn creates a population of highly educated, white collar individuals as well as blue-collar workers, many of whom are immigrants, both of which are drawn to the increasing number of opportunities available (Sassen, 2016). Competition for these opportunities pushes growth and adaptation in world centers. An estimated 10 percent of San Francisco residents were in poverty in 2017, with older residents (65 years of age and over) more likely to being in poverty than other age groups (Mercer, 2018). Poverty rates also vary by race and ethnicity; most notably, Black and African American residents experience poverty at nearly three times the average rate (City and County of San Francisco, 2019).

Since the 1990s, San Francisco's economy has diversified away from finance and tourism towards the growing fields of high tech, biotechnology, and medical research (Waters, 2009). Technology jobs accounted for a mere one percent of San Francisco's economy in 1990, growing to 4% in 2010 and an estimated % by the end of 2018 (Warburg, 2014). San Francisco became an epicenter of Internet start-up companies during the dot-com bubble of the 1990s and the subsequent social media boom of the late 2000s (Selna, 2008). Since 2010, San Francisco proper has attracted an increasing share of venture capital investments as compared to nearby Silicon Valley, attracting 423 financings worth $4.58 billion in 2013 (Garland, 2014). The Great Recession had a profound effect on inter-regional traffic volumes, halting two decades of steady growth. Up until 2006, the Bay Area witnessed significant growth in traffic entering from neighboring counties, contributing to regional congestion challenges. The recession reversed this trend from 2006 through 2012, but the resurgent Bay Area economy has since powered growth in traffic for three years in a row (MTC, 2017).

6.4 Bay Area Transportation Network

The demand for mass transit continues to grow, in response to the ongoing trends in increased employment in the Bay Area's central business districts (CBDs), strong underlying population growth in the inner and outer metropolitan area, and subsequently, traffic congestion in the key transport corridors. Even as new forms of mobility emerge into the market, the region is also experiencing an increase in competition for scarce road space. How the region connects a mass public transport solution to a wider, on-demand, and more complex set of mobility solutions will likely be central to the future of the liveability of the region. Yet today, the trains and trams are full during peak commute times, dwell times are increasing, and commuting times are increasing. The Bay Area's dynamic economy and well-developed transportation system give workers access to jobs located in numerous places within the region's 7,000-square-mile territory. Overall, 65 percent of Bay Area workers hold jobs in

the same county they live in (MTC, 2017). In addition to these intra-regional commute patterns, the Bay Area experiences a net inflow of nearly 120,000 people who commute into the region each day for work (MTC, 2017).

6.4.1 Cycling and Walking

Cycling is a popular mode of transportation, with 74,000 residents commuting by bicycle per day (SFMTA, 2011). Ford GoBike, previously named Bay Area Bike Share at its inception, launched in August 2013 with 700 bikes in downtown San Francisco, selected cities in the East Bay, and San Jose with a specific objective of providing connections to local and regional rail systems. The San Francisco Municipal Transportation Agency and Bay Area Air Quality Management District are responsible for the operation with management provided by Motivate (Bialick, 2017). A major expansion started in 2017 along with a rebranding as Ford GoBike (Ford GoBike, 2017). Annual bicycle counts by the MTA in 2010 showed the number of cyclists at 33 locations had increased 58% from the 2006 baseline counts (SFMTA, 2010).

Pedestrian traffic is a major mode of transport: in 2015, Walk Score ranked San Francisco the second-most walkable city in the United States (Said, 2011). San Francisco has significantly higher rates of pedestrian and bicyclist traffic deaths than the United States on average. In 2013, 21 pedestrians were killed in vehicle collisions, the highest since 2001 (Examiner Staff, 2012), which is 2.5 deaths per 100,000 population - 70% higher than the national average of 1.5 deaths per 100,000 population (NHTSA, 2013).

6.4.2 Public Transportation

32% of San Francisco residents use public transportation for their daily commute to work, ranking first on the West Coast and third overall in the United States (Christie, 2007). The San Francisco Municipal Railway, known as Muni, is the primary public transit system of San Francisco and is the seventh largest transit system in the United States (SFMTA, 2008). The system operates a combined light rail and subway system, the Muni Metro, as well as large bus and trolley coach networks (San Francisco Chronicle, 2008). Additionally, it runs a historic streetcar line as well as cable cars (San Francisco Chronicle, 2008), which has been designated as a National Historic Landmark and are a major tourist attraction (San Francisco Beautiful, 2007). Short- and long-term ridership trends indicate an ongoing shift in transit demand away from local bus services and toward regional rail systems: while ridership on rail systems has grown steadily over the decades, bus ridership has dropped significantly. On a per-capita basis, ridership on Bay Area buses has fallen by one-third since 1991 (MTC, 2017). Given that the majority of Bay Area transit trips take place on buses - rather than trains - this has played a major role in the overall per-capita decline in regional transit use (MTC, 2017). Table 6.1 below lists the transit agencies, nine counties, and major partner agencies that constitute the San Francisco Bay Area.

Bay Area Rapid Transit, a regional Rapid Transit system, connects San Francisco with the East Bay through the underwater Transbay Tube (San Francisco Chronicle, 2008). Another commuter rail system, Caltrain, runs from San Francisco along the San Francisco peninsula

Table 6.1: Bay Area Transit Angencies and Partners

Transit Agencies	**Association of Bay Area Governments Member Counties**	**Other Partner Agencies**
Alameda-Contra Costa Transit District	County of Alameda	Bay Area Air Quality Management District (BAAQMD)
Central Contra Costa Transit Authority	County of Contra Costa	San Francisco Bay Conservation and Development Commission (BCDC)
City of Union City Transit Division	County of Marin	San Francisco Municipal Transportation Agency
City of Santa Rosa?	County of Napa	California Highway Patrol (CHP)
Eastern Contra Costa Transit Authority	City and County of San Francisco	California Department of Transportation (Caltrans)
Golden Gate Bridge, Highway and Transportation District	County of San Mateo	Metropolitan Transportation Commission (MTC)
Livermore/Amador Valley Transit Authority	County of Santa Clara	Federal Agencies
Marin County Transit District	County of Solano	
Napa Valley Transportation Authority	County of Sonoma	
Peninsula Corridor Joint Powers Board		
Petaluma Municipal Transit		
San Francisco Bay Area Rapid Transit District		
San Francisco Bay Area Water Emergency Transportation Authority		
San Francisco Municipal Railway		
San Mateo County Transit District		
Santa Clara Valley Transportation Authority		
Solano County Transit		
Sonoma County Transit		
Western Contra Costa Transit Authority		

to San Jose. San Francisco Bay Ferry and Golden Gate Ferry operates to points in Oakland, Alameda, South San Francisco, Marin County, and Solano County. San Francisco was an early adopter of car-sharing in America, with the non-profit City Carshare opened in 2001 (Getaround, 2019), closely followed by Zipcar (Zipcar, 2019). To accommodate the large amount of San Francisco citizens who commute to the Silicon Valley daily, companies like Google and Apple have begun providing private bus transportation for their employees from San Francisco locations south to the tech start-up hotspot. These buses have quickly become a heated topic of debate within the city, as protesters claim they block bus lanes and delay public buses (McBride, 2013). Transit asset condition performance varies widely in the Bay Area: for example, while none of the light rail vehicles are past their useful life, 50-80% of longer-distance service-providing commuter and heavy rail vehicles are (MTC, 2017). However, with new BART trains already in service and plans for electric Caltrain locomotives expected to be implemented in 2022, regional performance in this area is expected to improve in future years. Despite this, nearly a quarter of the Bay Area's maintenance facilities are deemed to be in poor or failed condition by federal performance standards.

Excluding individuals who work from home, over 3.7 million Bay Area workers must find a way to travel to their jobs each workday. Their choice of mode of transportation, departure time, and trip origin and destination all play crucial roles in determining the ultimate door-to-door travel time (MTC, 2017). The cumulative result of these daily decisions is reflected in the average commute time for the region; increasing congestion and longer-distance commutes to job centers in San Francisco and Silicon Valley have contributed to this trend, with 15% having extreme commutes of more than one hour each way (MTC, 2017). Commuters choosing to drive alone spend 29 minutes getting to work, while those choosing transit log an average commute time nearly twice as long at 51 minutes (MTC, 2017). The longer transit commute times are not surprising considering nearly two-thirds of transit commuters work in San Francisco. Given congestion in San Francisco and its related impacts on Muni, as well as long-distance commutes on BART, Caltrain and express buses from other counties, it is difficult for these commuters to get to work in 30 minutes or less, resulting in above-average travel times for transit users.

6.4.3 Private Car Ownership and Use

While three-quarters of residents still drive to work, the share of residents making this choice has declined by over 6 percentage points since 2000 (MTC, 2017). This trend accelerated in recent years, powered primarily by growth in both public and private transit, as well as active modes like walking and biking. In contrast, the decline in share of auto-commuters in 2016 was mostly attributable to growth in telecommuting. This reflects congested conditions both on the roads and aboard transit vehicles, making telecommuting increasingly attractive. As a result, the share of Bay Area telecommuters in 2016 was higher than any year on record (MTC, 2017). While past years have seen significant annual growth in congested miles traveled, traffic congestion did not notably get worse in 2016 compared to the previous year, despite a booming economy and corresponding growth in jobs and population. According to the American Automobile Association (AAA), the average cost of owning and operating a car is $706 per month, including expenses such as annual maintenance and repair, insurance, and parking (Edmonds, 2018).

6.5 SF Bay Area Development Trends

Statistics on car-free households and numbers of vehicles per household for cities is one method of assessing a city's reliance on cars. In a 2015-2016 calculation by the Census American Community Survey, it was estimated that the number of households without vehicles decreased from 31.2% in 2015 to 29.9% in 2016; alternatively, the number of vehicles increased from 1.07 to 1.10, respectively (Census American Community Survey, 2019). According to the 2018 San Francisco Mobility Trends Report by the SFMTA, San Francisco is expected to add another 200,000 new residents and 150,000 new jobs by 2040 (SFMTA, 2019b). Further investment in the sustainable modes will further the city's efforts to achieving its new goal of 80% of all trips taken by sustainable modes by 2030 and net zero greenhouse gas emissions by 2050 (SFMTA, 2019b). Since 2010, San Francisco residents' use of bikes has increased six percent, while use of mass transit (BART, Muni, and Caltrain combined) has increased five percent, in contrast to a national trend that has seen mass transit use decline across the United States (SFMTA, 2019b). Conversely, mass transit use is down since 2002. In 2003, the city saw a sudden, sharp decline of over 60,000 rides per week and has never reached previous highs since, even as the population increases. In line with the estimated increase in private car ownership calculated by the Census American Community Survey vehicular traffic entering the city is up 27 percent since 2010, with the total number of vehicles registered in the city having grown by six percent, adding 26,000 more vehicles (SFMTA, 2019b).

On the subject of ride-hailing apps, the report states that approximately 45,000 Lyft and Uber drivers are active in the city, noting that they account for about half of the total increase in congestion in San Francisco between 2010 and 2016, with population and employment responsible for the other half (SFMTA, 2019b). Currently, approximately 45% of the city's GHG emissions are due to transport, and San Francisco has an ambitious greenhouse gas emissions target of net zero emissions by 2050 (SF Environment, 2019). Between 1990 and 2016, San Francisco's carbon footprint was reduced by 30% while population increased 20% and the GDP (gross domestic product) increased 111% (SF Environment, 2019). The city's progress towards its climate goals proves it is possible to reduce greenhouse gas emissions while still growing the economy. Emissions from the transportation sector have decreased 2% below 1990 levels, largely due to higher fuel efficiency standards and more "clean" vehicle

fuels mandated by the State of California. With a long history of climate change policy marked with major milestones such as AB 32 which mandated a return to 1990 levels of greenhouse gas emissions by 2020 (California Air Resources Board, 2014), and the passing in 2006 of the largest cap-and-trade system in the nation, California has built a reputation for advocating for stricter state environmental regulations than those mandated by the federal government. Further, the 1970s Clean Air Act allowed California to regulate the overall fuel efficiency of car manufacturers' fleets (Berkeley Political Review, 2018).

6.6 Sustainable and Smart City Goals, Plans, and Visions

As a finalist in the Smart City Challenge, San Francisco was awarded 11 million dollars dedicated to projects for reducing transit travel time, emergency vehicle response time, and traffic incidents (Funk and Deininger, 2018). The city plans to use these funds to conduct research on six projects, including smart traffic signaling and the deployment of autonomous shuttle buses to serve intra-island trips on Treasure Island. With more than half of all trips in San Francisco made using public transit, city leaders have selected transportation as the focal point of their plans (Funk and Deininger, 2018).

To reach these goals, the city has created roles within city government to foster innovation. Specifically, the city hired its first Chief Data Officer (CDO) in response to citizens wanting clear data privacy rules. The CDO strives to strike a balance between protecting residents' privacy rights and concerns, and the need for data to fuel smart city policy and pilot programs. The city is focused on stakeholder engagement and encourages residents to submit proposals to the Mayor's Office of Civic Innovation. Having a centralized hub allows for the prioritization of resources and collaboration necessary to meet the city's aspirations of becoming a smart city.

Additionally, San Francisco has allocated a portion of its Department of Transportation funds for its SFpark project, which uses wireless sensors to create smarter parking management through demand-responsive pricing (SFMTA, 2019a). Installed in 8,200 on-street spaces in the piloted areas, the sensors can adjust prices in real time depending on the number of spaces available. This feedback is sent to app-users who can easily locate the closest available parking spot. SFpark has helped reduce traffic miles and greenhouse gas emission by 30 percent in the areas where the pilot was launched (SFMTA, 2019a).

Chapter 7

Results

7.1 Document Analysis

Of the six planning documents analyzed, only one, Plan Bay Area 2040, had no mention of any of the 17 analytical themes. Table 7.1 tallies the number of documents shown to mention each of the themes with significance. Table 7.2 shows a summary of all documents, the score assigned to each depending on whether or not any significant mention of an analytical theme was mentioned, and a list of all themes each document touched upon.

Table 7.1: Themes Covered per Document

Theme	Docs	Theme	Docs
Technology	5	Electric vehicles	3
Public transit	5	Social equity	5
Regional network	4	Land use	3
Environment	3	IT infrastructure	3
VMT	4	Negative impact mitigation	3
TNCs	4	Regulation	3
Automation impacts	1	Ownership models	4
Public safety	4	Partnerships	3
Data security	3		

The Autonomous Vehicles Perspective Paper came out on top with the highest score possible, having addressed all 17 analytical themes throughout the document. This was not surprising, as this document originated with the intent of exploring a variety of aspects related to the effect of autonomous vehicles on the San Francisco Bay Area's future trajectory of regional growth. As a collaborative effort between the regional transportation planning agencies MTC and Association of Bay Area Governments (ABAG), and the private firm Arup Group Ltd., the purpose of this paper was to consider questions and potential solutions of a disruptive technology that fall out of the traditional regional planning process. The concepts within the document ranged from the establishment of guiding principles of affordability, connectedness, diversity, health, and vibrancy, as they pertained to autonomous vehicles, to potential strategies with the aim of reaping the benefits of autonomous vehicles, while mitigating their negative implications.

The second-highest scoring document was the transcribed presentation of the Future Mobility Research Program (FMRP), which used a point-of-departure of the Autonomous Vehicles

Table 7.2: Document Analysis Findings: Themes Covered

Document	Score	Themes Covered
Autonomous Vehicles - Perspective Paper	17	Technology, public transit, regional network, environment, VMT, TNCs, automation impacts, public safety, data security, EVs, social equity, land use, IT infrastructure, negative impact mitigation, regulation, ownership models, partnerships
Plan Bay Area 2040	0	
2017 and 2018 Joint Advocacy Program	8	Technology, public transit, environment,public safety, social equity, IT infrastructure, regulation, partnerships
Future Mobility Research Program - Update	14	Technology, public transit, regional network, environment, VMT, TNCs, public safety, data security, EVs, social equity, negative impact mitigation, regulation, ownership models, partnerships
Toward a Shared Future: Strategies to Manage Travel Demand - Perspective Paper	11	Technology, public transit, regional network, VMT, TNCs, public safety, data security, social equity, land use, negative impact mitigation, ownership models
Futures Interim Report: Opportunities and Challenges	10	Technology, public transit, regional network, VMT, TNCs, EVs, social equity, land use, IT infrastructure, ownership models,

Perspective Paper. Thus, it is expected that the themes addressed in this transcription of a presentation of the FMRP and its work cover many of the same themes as the Perspective Paper. This presentation was given with the intent of informing the Bay Area planning committee of the accomplishments, findings, and future research plans of the FMRP.

The documents Toward a Shared Future and Futures Interim Report had comparable scores of eleven and ten points, respectively. The former document was composed of eight strategies for a more mobile Bay Area with a horizon of 2050, with particular focus on the fair pricing of mobility and the reduction of VMT demand by improving the reliability, convenience, and cost of other modes of transportation. The Futures Interim Report read as a sort of continuation of the Plan Bay Area 2040, describing potential future challenges that the Bay Area region will face, and what regional policies and investments are relevant in the discussion of the region's projected growth.

The 2017/2018 Joint Advocacy Program attachments were understandably the lowest-scoring documents, as they were documents specific to two meetings of the MTC Legislation Committee, the responsibilities of which are to recommend MTC legislative policy and represent the Commission in the legislative process. These documents briefly mentioned autonomous vehicles as they pertained to issues of social equity, regulation, and future infrastructure needs.

Tables 7.3 and 7.4 have compiled the content of the five documents (initially six, minus the Plan Bay Area 2040 found to contain no themes), organized by each analytical theme in the form of a question. The findings can be summarized as follows, and serve to answer this report's first sub-question of identifying the focal points on the topic of autonomous vehicles in the regional planning of the San Francisco Bay Area:

1. **Technology:** With the Bay Area in a unique position to leverage its technological innovation, diversity, and economy as its resources, the region can take advantage of the opportunities of AVs while mitigating against the potential risks. Two key themes of opportunity and uncertainty arise from the technology.

2. **Public Transit:** Public transit remains crucial with or without AVs. At its best, AV tech can work in parallel with transit to support and increase transit ridership by reducing cost and increasing flexibility, accessibility, and connectivity. AVs could hurt or help traffic congestion, so consideration of fleet-ownership is crucial.

Table 7.3: Document Analysis Findings Descriptions by Theme

Theme	Question	Document Analysis Findings
Technology	7. What is said on the technology of autonomous vehicles?	• Bay Area is uniquely situated to take advantage of opportunities and mitigate against risks, due to it being home to tech innovation, regional planners already preparing for a future with AVs, and the diversity of the region which allows for piloting/modeling that other communities can learn from • MPOs have an opportunity to be more proactive with emerging technologies • Bay Area jurisdictions' efforts to test/deploy AVs should be supported • Two key themes of opportunity and uncertainty arise from AV technology
AV Impacts	8. How does the document account for impacts of AVs on public transit?	• Even with embracing of EVs, public transit remains crucial • AV tech can work in tandem with transit to provide flexible, cost-effective services while offering connectivity to high-capacity, long-distance bus and rail and reducing congestion • Transit agencies can replace low-frequency fixed routes with more frequent demand-responsive transit in low-density areas; support first/last-mile connections • AVs competing with transit may cause ridership to fail and exacerbate congestion; if used, it is crucial that AVs are fleet-owned • Growth should be focused in priority development areas to support transit ridership
	9. What are the effects on the regional transportation network?	• AVs could influence how we plan, design, build, and operate cities • AV impacts will differ significantly across Bay Area between higher-density urban areas and lower-density, lower-amenity urban areas • AVs could create big challenges for region's capacity-constrained transportation network, in particular, improvements to regional gateways
	10. How does the document consider environmental impacts? (e.g. GHG emissions)	• AVs are an environmental wildcard - could support or undermine environmental efforts to achieve GHG emissions reduction targets. Survey findings predict -50% to +100% change in GHG emissions • If EVs, AVs could improve local air quality and noise pollution • Should engage in regulatory/legislative efforts related to AVs in order to accelerate environmental benefits
	11. How does the document consider effects on VMT?	• Surveys predict 5-40% increase in VMT, due to induced trips and longer trips • Non-driving populations may have increased access to independent car travel • Zero-occupancy vehicles will likely circulate • VMT reduction and encouragement of shared services is only achievable with comprehensive approach where transportation options are seamless and far-reaching, and transportation and land use development are planned together
	12. How does the document consider the relation of AVs with TNCs?	• Shared AVs would allow abandonment of private car ownership • TNCs could provide insight into market interest and regulatory response to AV services • Furthers demand for curbside passenger loading, exacerbating conflict with bicyclists, parked cars, transit vehicles, etc.
	13. How does the document consider the effects of the automation? (e.g. jobs lost)	• AVs could disrupt social fabric with significant impacts on labor markets • Could cause rapid job loss or shifts to other occupations • Potential mitigation strategies: 1) strengthen capacity for training programs to expand opportunities for workers, 2) pilot AV applications that could spur new job opportunities, 3) target job clusters on industrially-zoned land for production, distribution, and repair
	14. What is said regarding public safety?	• Survey findings predict 40-90% increase in safety, reducing human error in driving and contributing to Vision Zero goals • Should engage in regulatory/legislative efforts for AVs to accelerate safety benefits; support federal

3. **Regional Network:** AVs could present challenges for the region's already capacity-restricted transportation network, and the repercussions of AVs will differ significantly across the various densities of the region.

4. **Environment:** AVs could support or undermine efforts to meet GHG emissions reduction goals. AVs that are electric vehicles would be a vital mitigation strategy for this.

5. **VMT:** Zero-occupancy vehicles will likely circulate, and VMT will likely increase, due to induced trips, longer trips, and more non-driving persons with increased access to individual car travel. VMT reduction is only achievable if land use and transportation are planned in tandem.

6. **Transportation Network Companies:** Shared AVs would allow for the abandonment of the private ownership model, but will have the adverse effect of furthering the demand for curbside passenger loading space, conflicting with other motorists, bicyclists, transit vehicles, etc.

7. **Automation Impacts:** AVs could significantly disrupt labor markets, causing rapid job loss or shifts to other occupations.

8. **Public Safety:** 40-90% increase in safety predicted, with the reduction of human error in driving, contributing to Vision Zero goals of no collisions. However, uncertainty with

the sophistication of the technology creates the potential for unsafe street conditions for all roadway users.

9. **Data Security:** AV technology creates new challenges for cyber attacks and other safety risks to data privacy and security.

10. **Electric Vehicles and Electrification:** Low-cost electric AVs can make mobility more affordable, but will require new infrastructure for charging. Unless AVs are predominantly electric, they will likely increase GHG emissions.

11. **Social Equity:** AVs should accelerate equity benefits, with identified Communities of Concern being of particular focus in overcoming inaccessibility, inequitable service, and discrimination. AVs may create an exclusive, costly service that does not benefit all residents.

12. **Land Use:** Transportation and land use must be planned together. With a potential 90% reduction in the demand for parking, these spaces must be considered for repurposing.

13. **IT Infrastructure:** AV technology will likely require additional investments in utility infrastructure, as digital infrastructure and supportive data standards create the foundation for mobility innovation.

14. **Negative Impact Mitigation:** AV impacts have their associated opportunities and risks. The Perspectives Paper in particular has a mitigation strategy for each of the main perceived risks.

15. **Regulation:** The novelty of AV technology may result in a patchwork regulation by multiple diverse government agencies. A TNC case study showed that specific local jurisdiction (e.g. over curb use) may empower municipalities to enact regulation in addition to state laws.

16. **Ownership Models:** The documents mentioned autonomous vehicles as shared vehicles such as those utilized by TNCs, privately owned vehicles, and as fleet-owned vehicles.

17. **Partnerships:** Coordination between state and local actors can lead to valuable funding support. The Future Mobility Research Program is a partnership between 4 California MPOs to pool agency resources and benefit from a consistent framework, collaborative research, and to streamlines processes. There should also exist partnerships between Bay Area cities and counties, transit agencies, the business community, and other transportation organizations.

Table 7.4: Document Analysis Findings by Theme (continued)

		vehicle safety standards • Technology has potential to create unsafe street conditions for all roadway users
	15. How does the document consider possible information technology safety and security concerns?	• Technology has potential to create more insecure data • Should consider new safety risks, such as cyber attacks and other privacy concerns • Potential mitigation strategies: 1) mandate data transparency on all vehicles with appropriate privacy protections, 2) reduce hacking vulnerability
	16. What is said on the possibility of AV impact on electrification or use of electric vehicles (EVs)?	• Low-cost EV AVs will make mobility more affordable • Until EVs dominate the market, AVs will likely increase GHG emissions • Influx of EVs will require new infrastructure for charging
	17. How does the document consider impacts on social equity?	• Should engage in regulatory/legislative efforts for AVs to accelerate equity benefits • Communities of Concern face accessibility challenges, inequitable service, and discrimination • AVs could create exclusive, expensive services that do not benefit all residents • Strategy: mandate provision of mobility services with transparent reporting, subsidize public transit innovations, prioritize AV service to serve Communities of Concern • Shared AVs have unintended impacts and increased cost of transportation alienates those with lesser means
	18. How does the document consider land use changes due to AVs? (e.g. urban sprawl, repurposing land such as parking)	• Cost of development associated with changing needs for parking are factored into regional land use modeling • Transportation, goods delivery, and land use development must be planned together • Parking demand could drop as much as 90% - repurpose for infill development
	19. How does the document address the increased demand for communications infrastructure necessary for AVs?	• AV future will require reinvestments in utility infrastructure • Digital infrastructure and supportive data standards create foundation for mobility innovation • Strategy: support development of industry-wide data sharing protocols, real-time data infrastructure, defining data needs
	20. How does the document consider the mitigation of the potential negative impacts of AVs?	• AV implications have their associated opportunities and risks • Priority strategies should address mitigation of risks - specifics listed out in Perspective Paper
Regulatory	21. How does the document include mentions of the regulation of AVs?	• Regulatory responses can help mitigate projected increases in VMT • TNC case study showed that specific local jurisdiction (e.g. over curb use) may enable municipalities to enact regulation in addition to state laws • Novelty of AV tech may result in regulation by multiple diverse government agencies
Other	22. What types of AV ownership models are considered?	• Shared use, privately owned, fleet-owned
	23. What types of partnerships and collaborations are mentioned regarding AVs?	• Coordination between state/local actors can lead to valuable funding support • FMRP partnership between 4 MPOs to pool agency resources and benefit from consistent framework, collaborative research, and streamline process • Should partner with Bay Area cities/counties, transit agencies, business community, and other transportation organizations

7.2 Interview Analysis

Through the interviews conducted with each of the four individuals listed in Table 5.3, responses were collected on various topics pertaining to autonomous vehicles, as listed in the Interview Guide (see Appendix). The transcripts were then coded in NVivo, yielding a second set of analytical themes generated from the interviewee's responses. The findings can be summarized as follows, and serve to answer this report's second sub-question of identifying the focal points on the topic of autonomous vehicles in the regional planning of the San Francisco Bay Area, as identified through one-on-one interviews with planners involved in AV planning and research:

1. **AV Impacts:**

   - **Environmental:** Considering the environmental impacts of AVs, the discussion was largely dominated by concerns regarding greenhouse gas emissions, with climate change and resilience to a lesser degree. Three planners valued the importance of the potential impact AVs may have on city or regional goals for GHG emissions reductions and to be in line with climate action plans, while Planner B had minimal concerns for emissions, as it was believed that electrification is a much larger trend occurring within the automotive industry. Planner B foresees a major shift away from fossil fuels at a rapid pace, with the concern perhaps becoming how energy is produced from an electrification standpoint.
   - **Land Use:** On the topic of how AVs may affect land use, two planners noted how increased AV usage could free up parking spaces for repurposing for other

uses. This is a topic that is front and center for Planner C, who has clients wondering whether building parking is a smart investment, considering the monetary cost. Planner B noted that although there is a small segment of the city planning community that recognizes a shift towards having a different approach to transportation planning and how it relates to land use, a bigger problem is that many planners do not recognize the urgency that society faces in terms of climate, and the linkages between transportation and housing. Planner D spoke of land use from the standpoint of AVs being one possible solution to the first/last-mile problem, which is inherently a land use problem. In that sense, AVs are a secondary solution to a land use problem.

- **Partnerships:** All planners supported the value in establishing partnerships across sectors, whether it be between academia, the public sector, autonomous vehicle developers, or TNCs. Planner A hopes to leverage the collaboration between the four major MPOs in California to continue with the Future Mobility Research Program, as well as for MTC as an agency to support and participate in discussions with outside agencies. Three planners made mention of the obstacles in establishing close partnerships with the private sector and industry, typically because the companies developing AV technology are highly competitive and are often hesitant to disclose information. It is hoped that TNCs in the future will partner with agencies to advance social equity efforts and first and foremost meet the needs of the people. Planner B states that as studies have shown, rideshare as a serve has dramatically improved service for low-income and minority populations that have been traditionally underserved and redlined by transit. Using this as a case, it is believed that more and more partnerships between private and public will be seen.

- **Public Safety:** It was a unanimous belief that by reducing the human factor from driving, AVs present a large opportunity for safer roadways toward meeting Vision Zero goals and to produce a more streamlined and efficient highway system. However, new types of safety concerns also arise, from safety of pedestrians and cyclists sharing the roadway with AVs, to the concept of safety inside the AV itself if a shared ride. Planner C adds the concern for the need for safety from rider data being misused, such as data relating to private and personal information.

- **Social Equity:** Social equity was a resounding issue for Planners A, C, and D, where it was stated that AVs should be used as an opportunity to rethink how under-served populations could achieve the same levels of mobility as wealthier populations. From the equitable pricing of AVs by subsidization, to leveraging AVs to address first/last-mile problems, AVs should enable mobility, not make it an exclusive or isolating service, which may be achievable particularly if AVs are fleet-owned. Planner C remarks that equity is something that is foundational and fundamental to many planning problems, although not for AV developers, who are not working on accessible vehicles, for example, but rather retrofitting standard cars to have AV functionality. While the is understandable as AVs are still in the research and development phase, Planner C urges that industry integrate the equity of these systems earlier on. Planner B expressed little concern that the social equity dimension would be a significant issue in the future, citing the success that ridesharing has had in serving low-income and minority populations by offering an economically feasible solution to mobility obstacles.

- **Technology:** Much of the planners' responses regarding AV technology was characterized by uncertainty in the possible pros and cons. Planner A expressed cautious optimism about the ability for AVs to promote liveable and accessible communities, with many of the potential impacts relying on what ownership models dominate the market. There is a feeling on the public side that the message that AVs will be a savior to many current transportation problems is of a concern, which aligns with Planner D's comment that there exists a gap between the reality of where the technology stands versus the public perception. MTC as an agency is exploring the risks that AVs would pose in various future scenarios, with significant expected increases in VMT and other risks. The pros mentioned by the planners included the potential for AVs to: reduce vehicle collisions, support transit ridership, reduce GHG emissions with electric AVs, advance social equity, increased mobility for those lacking mobility or the ability to drive, and increased value of time spent traveling in the vehicle. The cons mentioned included the potential of AVs to: increase GHG emissions, compete with transit, exclude low-income and minority populations, urban sprawl, continued auto-dependency, and increased risks to bicyclists and pedestrians.
- **Transit:** AVs as one solution to supporting transit ridership, whether by working as a first/last-mile option, or increasing night time services to make up for transit that cannot operate for long hours in the evenings. One concern brought up by Planner A is the potential for induced travel if a more efficient transportation system equated to less congestion, bringing the issues back to square one. Planner B considered a future in which connectivity is more integrated with mobility, where AVs serve as one option in a suite of travel options, which are optimized and timed in parallel to link to whatever type of transit system. This necessitates a connectivity between providers of autonomous fleets, owners of autonomous vehicles, and operators of transit systems. Planner C echoes the hope for a more connected system; a future in which there is no difference between what is today called transit versus private mobility. Planner D asserts that the BART system in particular will fare well in a world of AVs, while local transit systems serving short trips may not do so well if AVs make it easier for first/last-mile connections. AVs can make for the opportunity to eliminate unproductive transit service and replace it with systems of small, autonomous shuttles right-sized vehicles for those environments.

2. **Challenges:** The challenges expressed by Planner A are those of: managing the public expectations of what AV technology is capable of, partnering with industry because the technology changes at a rapid pace and oftentimes confidential, as well as the ability to evaluate what the success of an AV rollout might look like. Planner B is concerned with the issue of how energy will be produced from an electrification standpoint, the data infrastructure that AVs will require, and the skills that planners will require in the future to manage large sets of unique TNC or autonomous ride data. Planner C was most concerned about public safety and the social equity aspect, while Planner D notes how AV technology will likely be introduced incrementally over a longer period of time, while the economy and other variables are changing simultaneously, tangling the problem further.

3. **Mobility:** Similar to the social equity aspect, all planners see a potential in the benefit AVs could bring to addressing mobility needs, from accessibility needs to the need for

more convenient, frequent, and safer services. Planner D notes the potential to disrupt how public transportation operates in lower-density environments by offering more flexible routing, as traditional fixed-route transit often does not work well. Planner B expressed concern for the over-assumption of shared mobility, which those in the planning and engineering professions assume based on certain behavioral and demographic trends that are in fact oppositional to fundamental behavioral economic trends.

4. **Ownership Models:** All planners spoke with the possible impacts of AVs heavily relying on what ownership models dominate. The cost of privately versus publicly owned AVs would skew the perspectives of many of the impacts listed above; Planner B asserts that the market will eventually lead to individuals owning their own private self-driven car, and the question will become how to create an optimized shared network between these owners, transit system owners, and providers of autonomous fleets. Planner C states that with a fleet-managed mobility, system, the ability exists to not only apply programs and policies much more deeply than with individual drivers, but also to cultivate the service for the individual. Planner D also states the additional benefit of fleet-owned AVs being the potential to accelerate EV adoption, which currently is not moving along the trajectory that California wants.

5. **Regional Effects:** Planner A speaks of MTC's role as being from a high-level perspective in what AVs mean to the larger, broader goals for the region, rather than how the AVs will actually operate and function. Some Commissioners have expressed an interest in AVs and what their potential implications are on local planning, with some of the opinion that AVs will come quickly and something should be done now, while others are wondering how AVs can be incorporated into general planning aspects for their cities, noting that some of these general plans are not updated very often. The topic of AVs could present an opportunity for MTC to learn and collaborate, and help spread the message to others that may have less resources than San Francisco an other larger cities across the region. One of Planner B's larger fears of the regional impact was that AVs become so cheap and convenient that it leads to even more congested roads full of people taking autonomous rides. Planner C had the optimistic perspective that AVs could present the change to think differently from how community and transportation planning historically have catered to the private car, specifically, to change how people pay for mobility. Planner D made a similar statement of the need for planners to stay ever vigilant to ensure the same mistakes as the first wave of the automobile era in the 1950s are not made again. AVs were one of the reasons MTC is working on Horizon, one of the two components of the long-range regional plan for the Bay Area. In an environment with uncertainty from AVs climate change, and economic and political shifts, the way in which long-range planning was done had to be re-designed. With the AV industry being headquartered in the Bay Area, its success or failure could interact with the region's economy.

6. **Regulation and Policy:** Planner A states that MTC does not yet have a strategy on how it fits into promoting or helping to regulate AVs, as it is often dependent upon what the cities are interested in doing and how they plan to regulate their own streets and curbs, which MTC does not often get to weigh in on. It is linked back to the equity perspective that if AVs could be regulated to the point they could be electric and cheap, this would be a great opportunity for many users. Planner B, noting the speculative nature of predicting the future regulatory climate, assumes that more and

more regulation and barriers for AVs to enter the market will arise, which will be an impediment to low-income minority populations. In this situation, it should be encouraged to have as many providers of AV services as possible to drive down the cost to provide a service that is as affordable as possible. Planner B also states that every community is increasingly facing pressure from the state and federal government to regulate things they feel are within their purview at the local/neighborhood-level to regulate. This trend towards centralization of policy, and what people are calling preemption of local communities, is going to continue. Planner C states that the federal government has thus far taken a neutral but encouraging stance on the AV industry, and expects that states will continue to patchwork make their own systems regulating licensure and pilot program development; the federal government will likely come in with safety requirements, while city governments regulate the curb and flow of traffic. Planner D states that each type of agency has a different role to play - for MTC, it is to understand what AVs might entail and to inform policymakers about investments and policies and how they may change in a world of AVs. While there is little current regulation of AVs, particularly at the national level, Planner D is interested to see what California and other states that have AV testing on public roads proceed to do and how regulatory action may be spurred in these environments.

7. **Planner Role:** All planners stated having participated in publicly speaking on autonomous vehicles, whether at planning conferences, with the general public at large, or in regional planning committee meetings. Planner A as a principal planner with MTC has had a role of engaging in discussions with industry leaders and politicians throughout the region, with the aim of having a high-level discussion on the potential implications of AVs. It is a concern for Planner A that AVs may be a polarizing issue for some, similar to TNCs, and this polarization could result in loss in great opportunities. It is the role of the planner to think about AVs in the right away and make them work for the communities we envision, and not only how we plan for AVs to be in communities. MTC has heard in previous public meetings of long-range planning efforts that there is much interest from community members in terms of what future investments may not be needed in a future with AVs. In Planner A's opinion, MTC's stance message can be to serve as a platform or the opportunity to promote awareness and understanding of what some of the issues surrounding AVs are, and getting back to understanding who may use them and who may be left out of these systems. Planner D states that it is incumbent on planners to address society's problems of today of gridlock and crowded transit, but also be forward-looking about things that the public may not imagine in the next two to five years. Planner B, having a background in planning, engineering, and economics, has pushed research on AVs with attempting to spur a public dialogue in the Bay Area, as well as internationally. Their role has been to facilitate a multi-sector dialogue about the future of cities with AVs and to develop management strategies for future technologies. Planner C focuses on transportation technology with a specialization in AVs, helping local projects in the Bay Area as well as globally to shape business and policy around transportation technology and intelligent mobility.

Figure 7.1 summarizes each of the interviewed planners' most frequently covered themes, with the horizontal bars representing each theme as an approximate percentage of the planners' entire responses. Planners A, C, and D talked at length about the role of the planner, whether regarding their personal experiences or speaking more generally, while this theme

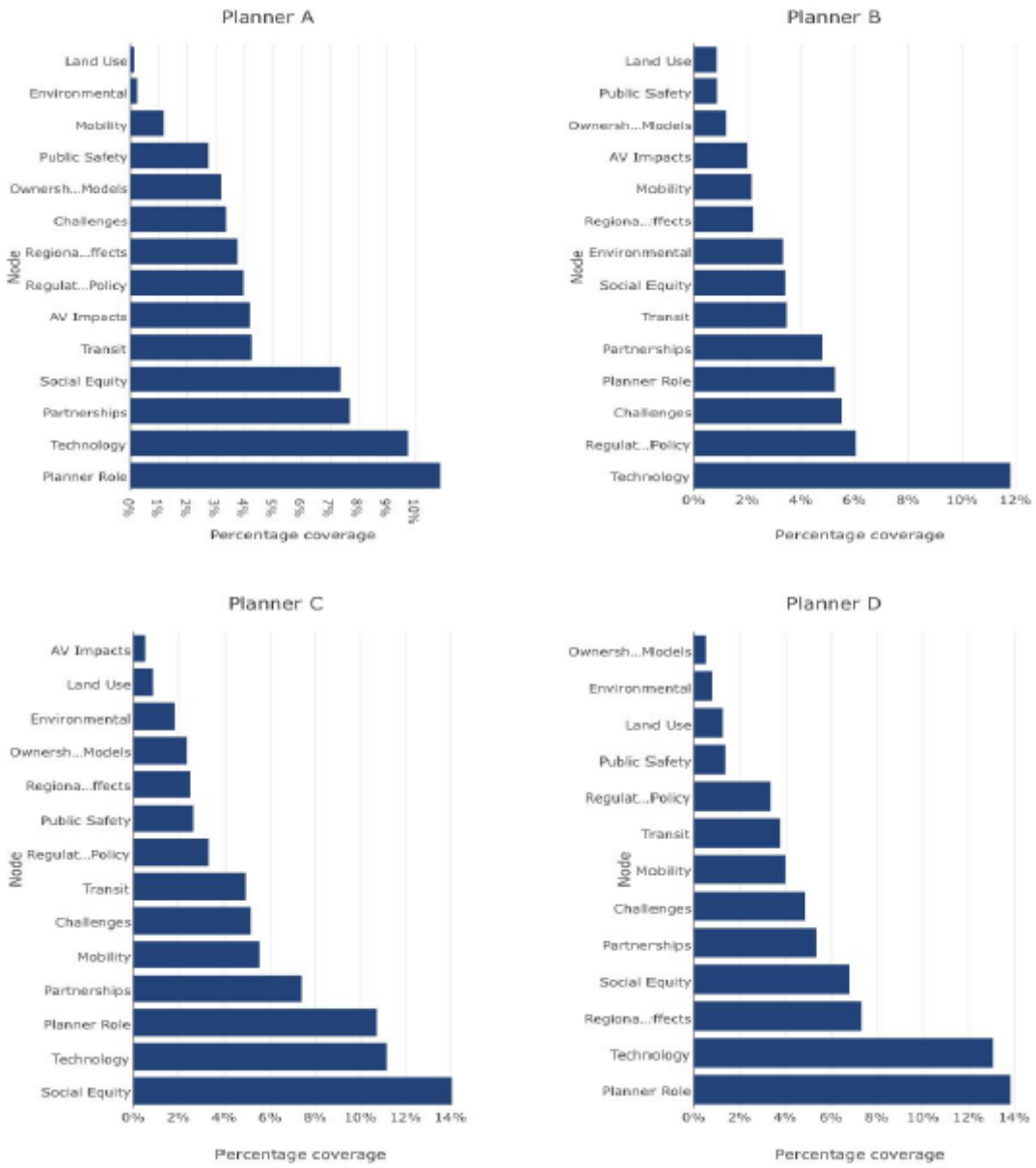

Figure 7.1: Themes Covered by Planners by Percentage Coverage of Responses

came in fourth highest percentage coverage for Planner B. This is likely due to the fact that Planner B's current role weighs more heavily on the side of academia. Planners A, C, and D also similarly spoke at length about autonomous vehicle technology, social equity concerns, and the importance of partnerships between the public and private sectors, while Planner B had more to say on the topic of regulations and policy, as well as the challenges surrounding autonomous vehicles. The themes least covered were those concerning land use and environmental impacts, as well as public safety and ownership models. This is not surprising, as all planners expressed that many aspects of autonomous vehicle technology is highly speculative, and therefore not much could be said on the foreseeable outcomes of these themes.

7.3 Comparisons

With the findings of the document and interview analysis in mind, I have attempted to draw some comparisons between the two sets of data in terms of their content and weighing of themes.

Table 7.5 shows that the themes of data security, electric vehicles, IT infrastructure, negative impact mitigation, and automation impacts were evident in the analysis of the documents (blue) but not majorly in the interviews, while the themes of the planner role, mobility, and public safety (red) were evident in the interview findings but were not significantly present in the documents. The table lists the major themes derived from each source of data, in order of the most evidently mentioned themes in the top row, with decreasing emphasis moving down the table.

Table 7.5: Common and Unshared Themes Between Document and Interview Analysis

Document Findings	Interview Findings
Technology, Public Transit, Social Equity	Planner Role, Technology
Regional Network, TNCs, VMT, Ownership Models	Social Equity, Public Transit
Environment, Data Security, Electric Vehicles, Land Use, IT Infrastructure, Regulation, Partnerships, Negative Impact Mitigation	Mobility, Regional Effects, Regulation and Policy
Automation Impacts	Land Use, Environment, Public Safety, Ownership Models

It can be seen that the themes of most significance that are shared between the two data sources are those of autonomous vehicle technology, social equity, and public transit. On the topic of technology, both the documents and interview respondents expressed an optimistic uncertainty on the possible pros and cons of an autonomous vehicle presence in the Bay Area, and in this sense were similar. One of the interviewees commented on believing there to be a gap in knowledge between the reality of where autonomous vehicle technology stands versus the public's perception. This is an example of the type of perspective not evident in the documents themselves, but may color the way a planner frames the issue. The documents and interview responses were overwhelmingly similar in their consideration of social equity concerns, with the common hopes and aims of accelerating equity benefits, minimizing discrimination and inequitable services, and prioritizing future autonomous vehicle services for identified Communities of Concern. On the theme of public transit, the document findings emphasized the importance of public transit, even with the embracing of AVs. The documents largely discussed how AVs could work in tandem with transit, while also mentioning the consequences of the potential for their competition with each other. The interview finding similarly advocated for the use of AVs in support of transit, specifically as one option to providing first/last-mile solutions, increasing night time services, and a more integrated transportation network. Following is a discussion of the results in light of the Literature Review and Theoretical Framework of the multi-level perspective of socio-technical transitions.

Chapter 8

Discussion

Earlier in this report, identified were the relevant existing academic literature pertaining to the topic of autonomous vehicles as laid out in the presented research question and sub-questions. The review was divided into the sections of: a) smart cities, b) the impacts of autonomous vehicles on transportation planning, c) governance, equity, and the current state of policy, and d) urban mobility change. In light of what was already known about the research problem being investigated, this chapter is structured with two main aims: 1) to explain any new understandings or insights that emerged as a result of the study of the problem, and 2) to interpret and describe the significance of the research findings with the applied lens of the theoretical framework of the multi-level perspective model.

8.1 Understandings and Insights

The document and interview findings unanimously show how the autonomous vehicle will be a future reality for the Bay Area, serving as a rapidly evolving smart city solution - specifically, one that could enable improvements in mobility, connectivity, security, and sustainability. However, these four aspects of smart cities have been ones not historically planned for in consideration of each other, but rather, as distinct entities. It is only relatively recently that the electric vehicle has become a fully-fledged and affordable option to the gas-powered automobile, and the internet did not exist just a few decades ago. Likewise, sustainability was not at the forefront of many city and region-wide planning initiatives until the topic of climate change became a resounding global issue in the last decade. Autonomous vehicles represent an impending disruptive technology that touches upon all of these aspects, and will similarly require a novel way of planning for them. Both the document and interview analyses show that for the Bay Area, autonomous vehicles are very much seen as an opportunity to preemptively make the right planning decisions from before their inception, by making a substantial shift in the way long-term transportation planning processes are approached. This is most evident in the comprehensiveness of the Horizon Perspective Paper on Autonomous Vehicles, which attained a perfect score in its covering of the most common themes on the topic. From its identification of various future scenarios, to its consideration of possible impacts and strategies for negative impact mitigation, this document showed the support and planning efforts being put towards developing a new way of comprehensive transportation planning for the region.

While neither the documents nor the interviewees covered the topic of governance or regulation at length, the Autonomous Vehicle Perspective Paper was the culmination of a

collaborative effort between the public and private sector, namely the Metropolitan Transportation Commission and Arup, Ltd. The paper is aimed to be utilized by the MTC, with its establishment of the Future Mobility Research Program, to inform future policy on how autonomous vehicles may dramatically alter the Bay Area's trajectory. Interview respondents from the MTC described their personal experiences in stakeholder engagement and public involvement, particularly in the consideration of the future-scenario planning process. Additionally, all interviewees spoke highly in favor of a closer partnership between the public and private sectors, especially with the developers of AV technologies. Their comments on the importance of the governing of AV technology to be distributed among the industry and the public sector alike show that the personal perceptions of the planners interviewed are in line with the emerging concepts of more flexible and networked mechanisms of governance involving a variety of actors and sectors.

Social equity was a theme at the forefront of both the document and interview analyses. It was recognized in the documents that the Bay Area has a process for identifying Communities of Concern in the region, which is intended to represent a cross-section of populations that could be considered disadvantaged or vulnerable in regards to both current conditions and potential impacts of future growth. The region has an objective to advance equity by promoting access to housing, jobs, and transportation for at-risk residents. Despite that academic literature has shown ridesourcing and shared mobility services to be more likely used by younger, better-educated, and affluent individuals, the research findings have shown that for the Bay Area, autonomous vehicles are hoped to be used as a springboard for promoting a more equitable transportation network. Of note is that while the Plan Bay Area 2040 had no mention of autonomous vehicles and was thus virtually nonexistent from the Results chapter of this report, it does explicitly state social equity objectives and appropriate means of assessing their achievement. Lastly, it can be said that the from the document and interview analyses, there is a strong sense of the Bay Area moving toward a more sustainable mobility paradigm, evident in its support and engagement in public discourse, empowering of stakeholders through participatory governance activities, and inventive approach to its traditional long-range planning processes. In addition to the inclusion of environmental, economic, and equity aspects, the planning documents analyzed and the personal views of the planners interviewed are largely in agreement with each other. The interviewees' responses displayed a willingness and eagerness to shift the mindset of planning away from deeply embedded transportation norms and values, trending toward the achievement of region-wide goals of equity, diversity, and growth for the region, accelerated by smart mobility solutions.

8.2 The Multi-level Perspective Lens

The findings of the document and interview analyses showed that the contents of each data source were largely in line with each other (Table 7.5), particularly on the themes of technology, public transit, and social equity. In addition to the data source findings being in agreement with each other rather than contention, all documents when considered together comprehensively covered the main points of concern, as were identified in the development of the Document Analysis Checklist. The Autonomous Vehicles Perspective Paper, which scored the highest, served as a document that cautiously informs the reader of an impending technology, weighing various possible outcomes, rather than intending to sway the reader to fully support autonomous vehicles or otherwise. Through the analysis, all documents

appeared to first and foremost educate the reader, while also acknowledging the uncertainty of the technology and advocating for further funding and research in the area. For the interviewees, three of the planners had similar viewpoints and shared their most emphasized themes, while the last planner who is currently working in academia had more of a focus on the foreseeable challenges and effects on the region. On a higher level, all planners shared the viewpoint that the autonomous vehicle will be a significant force to be reckoned with in time, and that the technology should be leveraged to achieve social equity goals and spur a more connected, efficient transportation network.

The Theoretical Framework on the multi-level perspective on socio-technical transitions presented a method of understanding how a societal change comes about. This research was conducted on a technology that is not yet fully realized, but when a reality, will be a major contender as a niche innovation to disrupt the decades-old stable regime of the gas-powered automobile. It was established in this earlier chapter that what constitutes the landscape is the intangible societal landscape of how people generally feel about a technology and the common discourse surrounding it. Planners, who are in a profession which lies at the intersection of various disciplines such as politics and sociology, are one key piece of this landscape, with a unique power to interface between key decision makers and the the general public. This research's findings have shown that for the four planning professionals interviewed, there was much emphasis on the topics of autonomous vehicle technology, the importance of public-private sector partnerships, and social equity concerns. Considering that previous literature has shown a lack of explicitly stated social equity objectives in the transportation plans of major metropolitan areas in North America (Manaugh et al., 2015) and the growing academic conversation around governance of smart mobility, the interviewees' responses clearly exhibit a contemporary way of framing and addressing planning problems in the Bay Area.

With the publishing of the Autonomous Vehicles Perspective Paper as one hallmark of the new Horizon initiative, its creation and the discourse surrounding it and the Bay Area's long-term planning is one that can be seen as moving the region towards a new paradigm of planning. In this new paradigm, it will not be the gas-powered automobile which characterizes the stable regime, but it will likely not be characterized by the autonomous vehicle either. What the documents and interview findings have shown is that the autonomous vehicle will not be a new dominating force that replaces the conventional car, and shouldn't. In order to avoid making the same mistakes as were made to catering toward the private car and perpetuating dependency on an automobile, the autonomous vehicle must be one well-functioning part of a revitalized entire transportation network. Therefore, while the future autonomous vehicle in whatever form it takes - whether autonomous bus, shuttle, or other application - will represent a novel type of artifact with new requirements for its production and use, the fact that it will operate alongside existing transportation modes within current infrastructure means that it cannot be studied in isolation. The future stable regime of a new smart and sustainable mobility paradigm can be one of an equitable, safe, efficient, and streamlined transportation system that leverages ICT to achieve regional goals, driven by a shift in the landscape that is sparked by the autonomous vehicle.

As the next Plan Bay Area 2050 is published, further research findings are made on the possible impacts of AV technology, and planners continue and widen the discourse on the topic, these actions cumulatively put pressure on the current stable regime. Subject to the rapid

pace of technological innovation, these pressures are likely to affect society's dominant values and beliefs, creating windows of opportunity for more innovations in the autonomous vehicle industry to gain traction. However, if the niche innovation is not robust and mature enough when the opportunity arises, it will not be able to take advantage of it - therefore, timing and regulatory restrictions are critical. If the niche innovation is mature enough, it may compete with the regime, such as autonomous electric vehicle ridesharing against human-operated ridesharing cars. Alternatively, the innovation may be incorporated into the regime as a way of relieving the landscape pressure, such as autonomous shuttles providing a more efficient first/last-mile service. This latter adoption may over time drive the incumbent regime into a new trajectory, for example, further prompting electric shuttle development.

Examining different theories of change is important, and the multi-level perspective models shows that it is not merely market forces or strides in research and development that encourage or restrain radical innovations. Rather, it is an interdependent network of infrastructural, socio-economic, and institutional variables that form innovation and socio-technical transitions. By understanding how social and technological change regarding autonomous vehicles occurs, we can broaden ideas to create changes in planning policy, practices, and communities for a more smart and sustainable future.

Chapter 9

Conclusion

This study has attempted to understand through various themes the perception of the future implementation of autonomous vehicles as an innovative, technological, and smart city solution. The study wove these themes into a framework, through which a case study was conducted on the San Francisco Bay Area of the potential integration of autonomous vehicles in the region. Of the six planning documents analyzed, one received a top score of 17 out of a possible 17 points on the themes covered, three had scores of 10 points or above, one scored 8 out of 17 points, while the Plan Bay Area 2040 received a score of zero. It is not entirely surprising that the regional long-range plan had virtually no mention of autonomous vehicles, as the purpose of the plan was to set forth a vision of actionable items to achieve regional goals, whereas autonomous vehicles remain too speculative of an area to be able to make valuable statements in this context. The Horizon Perspective Paper on Autonomous Vehicles, the highest scoring document, filled this gap as it is a document also published by a division of MTC in addition to support from the private firm Arup, to serve as an exploratory resource. The most commonly covered themes addressed by the documents were those of autonomous vehicle technology, the relation of AVs to public transit, and social equity concerns. This is promising, as explicitly stated social equity objectives are not commonplace in many metropolitan transportation plans. The least covered themes were those of the potential impacts of autonomous vehicle technology on job loss or a major shift of occupations from the automotive industry. However, given the high degree of uncertainty surrounding the issue, it is likely that neither the documents nor the interviewees chose to delve too deeply into speculative territory, especially when concerning the potential impacts of a large group of people's livelihoods. All planning documents analyzed were published within the last two years, and with work on the upcoming Plan Bay Area 2050 expected to begin in August of 2019, it may be that this state-mandated, integrated long-range transportation and land use plan will incorporate better coverage of the autonomous vehicle issue based on the findings from Horizon's Perspective Papers and future research.

This research began with the hypothesis that long-range planning documents and the perceptions of transportation planners in the Bay Area alike would not address a future of autonomous vehicles as one that is in need of urgent preparation. A review of six long-range planning documents related to autonomous vehicles in the Bay Area and the responses gathered from four planners actively working on autonomous vehicles in some capacity finds that the planners are in fact very much in a preparatory mindset, with each individual dedicated to various facets of the issue, from transportation technology, to promoting a multi-sector discourse, to envisioning distinct scenarios for a Bay Area in which autonomous vehicles

are a reality and a presence. Uncertainty surrounding the potential impacts and timing of autonomous vehicles was the single unifying theme among the documents and the planners' responses, however the Horizon Autonomous Vehicles Perspective Paper adequately undertook this challenge by providing an exploratory look at the possible ways in which AVs could be leveraged to meet regional goals, as well as what mitigation strategies could be employed to counteract the foreseeable negative impacts. In addition to the collaborative research being done on AVs by the Future Mobility Research Program, the interviewed planners are actively engaged in stakeholder engagement, publicly speaking about AVs at panels and conferences, and all see a significant value in establishing a closer public-private partnership.

Autonomous vehicles are not only a transportation issue, but are an issue which touch upon numerous aspects of city and regional development, as well as societal factors of equity, human behavior, and public safety and health. Considering this, if the topic of autonomous vehicles is one that is only a conversation among people who work in the transportation field, there is a danger of recreating the same mistakes as those that came with the automobile era of the 1950s. This conversation must include individuals and agencies interested in housing, community development, and economic development. In urban areas increasingly driven by smart city and smart region ideals, policy decisions that do not consider AV technology may have wide-reaching and costly consequences for this impending change. As AVs will change not only the way we travel, but people's way and quality of life, planners are uniquely situated in the landscape of transportation and mobility to enable the conversation to be inclusive to partnerships and proactive in pursuing social equity efforts, so that the windows of opportunity in which AVs will permeate the future status quo will have their benefits maximized to contribute to achieving larger, regional goals.

9.1 Future Research Areas

The findings of this research have been difficult to generalize due to the minimal availability of autonomous vehicle-related regional cases in academic literature. The research is limited in that it emerges from examination of only one region, the San Francisco Bay Area. To further refine and verify this framework, it would be interesting to see how the individual cities and counties that make up the Bay Area perceive a future with autonomous vehicles, as bringing the issue to this smaller scale will generate new perspectives and concerns about AV technology. As autonomous vehicles touch upon numerous aspects of urban development and society, any tangential area could be delved into, such as the impacts on land use. For example: with the rise of autonomous vehicles will likely come more available land use from obsolete parking spaces - how will cities continue to maintain their infrastructure with reduction in budgets from reduced property value?

Chapter 10

Reflections

This research provided a valuable opportunity to study how individual transportation planners concerned with the regional growth of the San Francisco Bay Area perceive the future presence of autonomous vehicles. The overarching atmosphere around the topic of autonomous vehicles was one of uncertainty, which echoed throughout the mentions of autonomous vehicles in the various planning documents studied. It was a relief to see that while autonomous vehicles were not included in the current long-range Plan Bay Area 2040 which was adopted in 2017, the Autonomous Vehicles Perspective Paper by MTC, ABAG, and Arup was quite extensive, the findings of which will inform regional transportation and land use planning for the region moving forward.

Given more time, I would have liked to have interviewed more and a wider variety of planners, such as those working at municipal agencies within the Bay Area who are actively working on integrating autonomous vehicles into transportation planning. While this research focuses on the viewpoints of planners, it also would have been worthwhile to interview other stakeholders involved in the autonomous vehicle movement, including those in industry, the regulatory side, and engineers. Gaining a perspective from such individuals would help to illustrate a more comprehensive and current understanding of the status quo. As all interviewees in this research spoke in favor of a more collaborative public-private partnership, it would be particularly intriguing to learn of how autonomous vehicle developers view this idea.

Finally, a comparative case study could show how the technological, economic, and regulatory environments of multiple regions through the United States differ in their handling of planning for autonomous vehicles. In particular, as state agencies work to develop policies and regulations related to public safety, it would be interesting to see how various metropolitan planning organizations leverage their resources and strengths to meet their goals for regional development.

Bibliography

Adorno et al., 2018. Gail Adorno, Noelle Fields, Courtney Cronley, Rupal Parekh and Karen Magruder. *Ageing in a low-density urban city: transportation mobility as a social equity issue*. Ageing & Society, 38, 296–320, 2018.

Albino et al., 2014. Vito Albino, Umberto Berardi and Rosa Maria Dangelico. *Smart Cities: Definitions, Dimensions, Performance, and Initiatives*. Journal of Urban Technology, pages 1–19, 2014.

Anderson et al., 2014. James M. Anderson, Nidhi Kalra, Karlyn D. Stanley, Paul Sorensen, Constantine Samaras and Oluwatobi A. Oluwatola. *Autonomous Vehicle Technology: A Guide for Policymakers*. Rand, 2014. ISBN 978-0-8330-8437-8.

Arup, 2014. Arup. *Future of Highways*, Arup Foresight + Research + Innovation, 2014.

Arup et al., 2018. Arup, London Transport Museum, Gowling WLG and Thales. *Rethinking Urban Mobility*, Arup, 2018.

AT&T Business, 2019. AT&T Business. *Cybersecurity Insights.*, 2019. URL `https://www.business.att.com/solutions/family/cybersecurity/cybersecurity-report.html`. Visited on 6-5-2019.

Banister, 2008. David Banister. *The Sustainable Mobility Paradigm*. Transport Policy, 15, 73–80, 2008.

Bardhi and Eckhardt, 2012. Fleura Bardhi and Giana M. Eckhardt. *Access-Based Consumption: The Case of Car Sharing*. Journal of Consumer Research, 39(4), 881–898, 2012.

Bauman, 2000. Zygmunt Bauman. *Liquid Modernity*. Oxford: Polity Press, 2000. ISBN 0745624103.

Behbahania et al., 2018. Hamid Behbahania, Sobhan Nazaria, Masood Jafari Kangb and Todd Litman. *A conceptual framework to formulate transportation network design problem considering social equity criteria*. Transportation Research Part A, pages 1–13, 2018.

Bellon, 2017. Tina Bellon. *Autonomous Vehicle Regulation Highlights Federal vs. State Divide*, 2017. URL `https://www.insurancejournal.com/news/national/2017/09/19/464721.htm`. Visited on 4-9-2019.

Berkeley Political Review, 2018. Berkeley Political Review. *Turning the Golden State Green: California's Reputation as an Environmental Savior*, 2018. URL `https://bpr.berkeley.edu/2018/03/07/turning-the-golden-state-green-californias-reputation-as-an-environmental-savior/`. Visited on 3-6-2019.

Bialick, **2017**. Aaron Bialick. *Ford GoBike Launches, Bringing Bike-Share to New SF Neighborhoods*, 2017. URL `https://www.sfmta.com/blog/ford-gobike-launches-bringing-bike-share-new-sf-neighborhoods`. Visited on 3-26-2019.

Bibri, **2018**. Simon Elias Bibri. *Smart Sustainable Cities of the Future: the Untapped Potential of Big Data Analytics and Context-Aware Computing for Advancing Sustainability.* Springer, 2018. ISBN 978-3-319-73980-9.

Bickman and Rog, **2009**. Leonard Bickman and Debra J. Rog. *The SAGE Handbook of Applied Social Research Methods.* Sage Publications, Inc, 2009. ISBN 9781412950312.

Bizjournals, **2006**. Bizjournals. *The brainpower of America's largest cities*, 2006. URL `https://web.archive.org/web/20060701071804/http://www.bizjournals.com/specials/pages/12.html`. Visited on 3-26-2019.

Bordenkircher et al., **2018**. Brandon Bordenkircher, Riley O'Neil and C. Scott Smith. *Managing the Sharing Economy: Municipal Policy Responses to Homesharing. Ridesharing, and Bikesharing in Illinois.* Illinois Municipal Policy Journal, 3(1), 17–48, 2018.

Bryman, **2008**. Alan Bryman. *Social Research Methods.* Oxford University Press, 2008. ISBN 9780199202959.

Bureau of Economic Analysis, **2018**. Bureau of Economic Analysis. *Personal Income by County, Metro, and Other Areas*, 2018. URL `https://www.bea.gov/data/income-saving/personal-income-county-metro-and-other-areas`. Visited on 3-26-2019.

California Air Resources Board, **2014**. California Air Resources Board. *Assembly Bill 32 Overview*, 2014. URL `https://www.arb.ca.gov/cc/ab32/ab32.htm`. Visited on 6-2-2019.

Capoccia and Kelemen, **2007**. Giovanni Capoccia and Daniel R. Kelemen. *The Study of Critical Junctures: Theory, Narrative, and Counterfactuals in Historical Institutionalism.* World Politics, 59(3), 341–369, 2007.

Cardenas-Benitez et al., **2016**. Nestor Cardenas-Benitez, Raul Aquino-Santos, Pedro Magana-Espinoza, Jose Aguilar-Velazco, Arthur Edwards and Aldo Medina Cass. *Traffic Congestion Detection System through Connected Vehicles and Big Data.* Sensors, 16, 1–26, 2016.

Carteni, **2014**. Armando Carteni. *Urban Sustainable Mobility. Part 1: Rationality in Transport Planning.* Transport Problems, 9(4), 39–48, 2014.

Census American Community Survey, **2019**. Census American Community Survey. *Vehicle Ownership in U.S. Cities Data and Map*, 2019. URL `https://www.governing.com/gov-data/car-ownership-numbers-of-vehicles-by-city-map.html`. Visited on 3-26-2019.

Center for Information and Society, **2012**. Center for Information and Society. *Automated Driving: Legislative and Regulatory Action*, Center for Information and Society, 2012.

Christie, **2007**. Les Christie. *New Yorkers are top transit users - More than half ride subway or bus to work*, 2007. URL https://money.cnn.com/2007/06/13/real_estate/public_transit_commutes/index.htm. Visited on 3-26-2019.

City and County of San Francisco, **2019**. City and County of San Francisco. *Poverty in San Francisco*, 2019. URL https://sfgov.org/scorecards/safety-net/poverty-san-francisco. Visited on 3-26-2019.

Dochertya et al., **2018**. Iain Dochertya, Greg Marsdenb and Jillian Anableb. *The governance of smart mobility*. Transportation Research Part A, 115, 114–125, 2018.

DSM Engineering Plastics, **2017**. DSM Engineering Plastics. *Designing the latest in electrical and electronics for vehicles*, 2017. URL https://www.dsm.com/markets/engineering-plastics/en/industry/automotive/electronics-electrical.html. Visited on 3-11-2019.

Ecoland, **2018**. Ecoland. *Ride-hailing vs. Ride-sharing: The Key Difference and Why It Matters.*, 2018. URL https://www.ecolane.com/blog/ride-hailing-vs.-ride-sharing-the-key-difference-and-why-it-matters. Visited on 5-19-2019.

Edmonds, **2018**. Ellen Edmonds. *Your Driving Costs*, 2018. URL https://newsroom.aaa.com/auto/your-driving-costs/. Visited on 3-26-2019.

Efrussy, **2013**. Alan Efrussy. *A Guide to Urban Planning in Texas Communities*, American Planning Association: Texas Chapter, 2013.

Etherington, **2017**. Darrell Etherington. *BMW's self-driving car will aim for full Level 5 autonomy by 2021*, 2017. URL https://techcrunch.com/2017/03/16/bmws-self-driving-car-will-aim-for-full-level-5-autonomy-by-2021/. Visited on 3-19-2019.

Examiner Staff, **2012**. Examiner Staff. *Contentious House transportation bill delayed by GOP*, 2012. URL https://www.sfexaminer.com/news/contentious-house-transportation-bill-delayed-by-gop/?oid=2678662. Visited on 3-26-2019.

Fagnant and Kockelman, **2015**. Daniel J. Fagnant and Kara Kockelman. *Preparing a nation for autonomous vehicles: opportunities, barriers and policy recommendations*. Transportation Research Part A, 77, 167–181, 2015.

Fang, **2015**. Yuguang Fang. *Connected Vehicles Make Transportation Faster, Safer, Smarter, and Greener!* IEEE Transactions on Vehicular Technology, 64(12), 5409–5410, 2015.

Farthing, **2016**. Stuart Farthing. *Research Design in Urban Planning - A Student's Guide*. SAGE Publications Ltd, 2016. ISBN 978-1-4462-9445-1.

Favaro et al., **2018**. Francesca Favaro, Sky Eurich and Nazanin Nader. *Autonomous vehicles' disengagements: Trends, triggers, and regulatory limitations*. Accident Analysis and Prevention, 110, 136–148, 2018.

Finger and Audouin, **2019**. Matthias Finger and Maxime Audouin. *The Governance of Smart Transportation Systems: Towards New Organizational Structures for the Development of Shared, Automated, Electric and Integrated Mobility*. Springer, 2019. ISBN 978-3-319-96525-3.

Flyvbjerg, **2004**. Bent Flyvbjerg. *Phronetic planning research: theoretical and methodological reflections*. Planning Theory & Practice, 5(3), 283–306, 2004.

Ford GoBike, **2017**. Ford GoBike. *Grab an ebike and Go*, 2017. URL `https://www.fordgobike.com`. Visited on 3-26-2019.

Freudendal-Pedersen et al., **2019**. Malene Freudendal-Pedersen, Sven Kesselring and Eriketti Servou. *What is Smart for the Future City? Mobilities and Automation*. Sustainability, 11(221), 1–21, 2019.

Funk and Deininger, **2018**. Kyle Funk and Niki Deininger. *Five Innovative Examples of Smart Cities in the U.S.*, 2018. URL `https://bipartisanpolicy.org/blog/five-innovative-examples-of-smart-cities-in-the-u-s/`. Visited on 3-6-2019.

Garland, **2014**. Russ Garland. *As Bay Area Investment Shifts North, Institutional Venture Partners Opens San Francisco Office*, 2014. URL `https://blogs.wsj.com/venturecapital/2014/02/27/as-bay-area-investment-shifts-north-institutional-venture-partners-opens-san-francis` Visited on 3-26-2019.

Geels, **2011**. Frank W. Geels. *The multi-level perspective on sustainability transitions: Responses to seven criticisms*. Environmental Innovation and Societal Transitions, 1, 24–40, 2011.

Geels, **2004**. Frank W. Geels. *From sectoral systems of innovation to socio-technical systems: Insights about dynamics and change from sociology and institutional theory*. Research Policy, 33, 897–920, 2004.

Gehl, **2010**. Jan Gehl. *Cities for People*. Island Press, 2010. ISBN 978-87-92420-11-4.

Getaround, **2019**. Getaround. *City CarShare is now powered by Getaround*, 2019. URL `https://p.getaround.com/city-carshare`. Visited on 3-26-2019.

Giduthuri, **2015**. Viswanadha Kumar Giduthuri. *Sustainable Urban Mobility: Challenges, Initiatives and Planning*. Current Urban Studies, 3, 261–265, 2015.

Gitlin, **2017**. Jonathan M. Gitlin. *Volvo's autonomous Drive Me research project gets underway*, 2017. URL `https://arstechnica.com/cars/2017/01/volvos-autonomous-drive-me-research-project-gets-underway/`. Visited on 3-19-2019.

Government Accountability Office, **2018**. Government Accountability Office. *Public Transit Partnerships: Report to the Committee on Banking, Housing, and Urban Affairs, U.S. Senate*, U.S. Government Accountability Office, 2018.

Graff, **2018**. Amy Graff. *UN expert on San Francisco homelessness: 'I couldn't help but be completely shocked'*, 2018. URL `https://www.sfgate.com/bayarea/article/Leilani-Farah-UN-rapporteur-homelessness-SF-CA-12519117.php`. Visited on 3-26-2019.

Guerra, **2015**. Erick Guerra. *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, 2015.

Harding and Blokland, **2014**. Alan Harding and Talja Blokland. *Urban Theory: A Critical Introduction to Power, Cities and Urbanism in the 21st Century*. SAGE Publications Ltd, 2014. ISBN 978-1-4462-9451-2.

hoon Kim et al., **2017**. Tai hoon Kim, Carlos Ramos and Sabah Mohammed. *Smart City and IoT*. Future Generation Computer Systems, 76, 159–162, 2017.

Iqbal et al., **2018**. Kashif Iqbal, Muhammad Adnan, Sagheer Abbas, Zahid Hasan and Areej Fatima. *Intelligent Transportation System (ITS) for Smart-Cities using Mamdani Fuzzy Inference System*. International Journal of Advanced Computer Science and Applications, 9(2), 2018.

Isenhour et al., **2015**. Cindy Isenhour, Gary McDonogh and Melissa Checker. *Sustainability in the Global City - Myth and Practice*. Cambridge University Press, 2015. ISBN 978-1-107-07628-0.

Jaramillo et al., **2012**. Ciro Jaramillo, Carmen Lizarraga and Alejandro Luis Grindlay. *Spatial disparity in transport social needs and public transport provision in Santiago de Cali*. Journal of Transport Geography, 24, 340–357, 2012.

Jin et al., **2018**. Scarlett T. Jin, Hui Kong, Rachel Wu and Daniel Z. Sui. *Ridesourcing, the sharing economy, and the future of cities*. Cities, 76, 96–104, 2018.

Kirby, **2017**. Shaun Kirby. *Securing IoT With Automated Connectivity Management: Lessons Learned From the Connected Car*. Big Data Quarterly, pages 6–8, 2017.

Kitchin, **2014**. Rob Kitchin. *The real-time city? Big data and smart urbanism*. Geojournal, 79, 1–14, 2014.

Krasniqi and Hajrizi, **2016**. X. Krasniqi and E. Hajrizi. *Use of IoT Technology to Drive the Automotive Industry from Connected to Full Autonomous Vehicles*. International Federation of Automatic Control, pages 269–274, 2016.

Kvale and Brinkmann, **2008**. Steinar Kvale and Svend Brinkmann. *InterViews: Learning the Craft of Qualitative Research Interviewing*. SAGE Publications, Inc, 2008. ISBN 978-0761925422.

Lee et al., **2013**. Jung Hoon Lee, Marguerite Gong Hancock and Mei-Chih Hu. *Towards an effective framework for building smart cities: Lessons from Seoul and San Francisco*. Technological Forecasting & Social Change, pages 80–99, 2013.

Lioris et al., **2017**. Jennie Lioris, Ramtin Pedarsani, Fatma Yildiz Tascikaraoglu and Pravin Varaiya. *Platoons of connected vehicles can double throughput in urban roads*. Transportation Research Part C, 77, 292–305, 2017.

Litman, **2011**. Todd Litman. *Evaluating Transportation Equity: Guidance for Incorporating Distributional Impacts in Transportation Planning*. Victoria Transport Policy Institute, 2011. ISBN 92-807-2507-6.

Manaugh et al., **2015**. Kevin Manaugh, Madhav G. Badami and Ahmed M. El-Geneidy. *Integrating social equity into urban transportation planning: A critical evaluation of equity objectives and measures in transportation plans in North America*. Transport Policy, 37, 167–176, 2015.

Marr, **2018**. Bernard Marr. *Key Milestones Of Waymo - Google's Self-Driving Cars*, 2018. URL `https://www.forbes.com/sites/bernardmarr/2018/09/21/key-milestones-of-waymo-googles-self-driving-cars/#6a309b5b5369`. Visited on 3-19-2019.

McBride, **2013**. Sarah McBride. *Google bus blocked in San Francisco protest vs gentrification*, 2013. URL `https://www.reuters.com/article/us-google-protest-idUSBRE9B818J20131209`. Visited on 3-26-2019.

Meila, **2018**. Alexandra Dana Meila. *Sustainable Urban Mobility in the Sharing Economy: Digital Platforms, Collaborative Governance, and Innovative Transportation*. Contemporary Readings in Law and Social Justice, 10(1), 130–136, 2018.

Mercer, **2018**. Mercer. *Quality of Living City Ranking*, 2018. URL `https://mobilityexchange.mercer.com/Insights/quality-of-living-rankings`. Visited on 3-26-2019.

Meyer and Shaheen, **2017**. Gereon Meyer and Susan Shaheen. *Disrupting Mobility*. Springer, 2017. ISBN 978-3-319-51601-1.

Mijac et al., **2017**. Marko Mijac, Darko Androcec and Ruben Picek. *Smart City Services Driven by IoT: A Systematic Review*. Journal of Economic and Social Development, 4(2), 40–50, 2017.

Mishra et al., **2017**. Gouri Shankar Mishra, Patricia L. Mokhtarian, Regina R. Clewlow and Keith F. Widaman. *Addressing the joint occurrence of self-selection and simultaneity biases in the estimation of program effects based on cross-sectional observational surveys: case study of travel behavior effects in carsharing*. Transportation Research Part D, pages 1–19, 2017.

MTC, **2018**. MTC. *Nine Bay Area Counties — What Is MTC? — About MTC*, 2018. URL `mtc.ca.gov/about-mtc/what-mtc/nine-bay-area-counties`. Visited on 3-6-2019.

MTC, **2017**. MTC. *Time Spent in Congestion*, 2017. URL `www.vitalsigns.mtc.ca.gov/time-spent-congestion`. Visited on 3-6-2019.

Muoio, **2016**. Danielle Muoio. *These 20 companies are racing to build self-driving cars in the next 5 years*, 2016. URL `https://www.businessinsider.in/These-20-companies-are-racing-to-build-self-driving-cars-in-the-next-5-years/articleshow/55926299.cms`. Visited on 3-19-2019.

Murtha, **2015**. Suzanne Murtha. *Autonomous vs connected vehicles – what's the difference?*, 2015. URL `https://www.atkinsglobal.com/en-gb/angles/all-angles/autonomous-vs-connected-vehicles-whats-the-difference`. Visited on 4-10-2019.

Newman and Kenworthy, **2015**. Peter Newman and Jeffrey Kenworthy. *The End of Automobile Dependence: How Cities are Moving Beyond Car-Based Planning*. Island Press, 2015. ISBN 9781518217937.

NHTSA, **2013**. NHTSA. *2012 Motor Vehicle Crashes: Overview*, U.S. Department of Transportation, 2013.

NHTSA, **2018**. NHTSA. *The Full Road to Automation*, 2018. URL `https://www.nhtsa.gov/technology-innovation/automated-vehicles-safety`. Visited on 4-17-2019.

NHTSA, **2016**. NHTSA. *Proposed rule would mandate vehicle-to-vehicle (V2V) communication on light vehicles, allowing cars to 'talk' to each other to avoid crashes*, 2016. URL `https://one.nhtsa.gov/About-NHTSA/Press-Releases/ci.nhtsa_v2v_proposed_rule_12132016.print`. Visited on 3-11-2019.

Nisenson, **2017**. Lisa Nisenson. *The Pace of Change: Why do Walking and Biking Still Matter in an Autonomos Future?* Inside the Industry, pages 21–24, 2017.

of State Legislatures, **2019**. National Conference of State Legislatures. *Autonomous Vehicles — Self-driving Vehicles Enacted Legislation*, 2019. URL `http://www.ncsl.org/research/transportation/autonomous-vehicles-self-driving-vehicles-enacted-legislation.aspx`. Visited on 4-9-2019.

Pamuk, **2004**. Ayse Pamuk. *Geography of immigrant clusters in global cities: a case study of San Francisco*. International Journal of Urban and Regional Research, 28(2), 287–307, 2004.

Park et al., **2018**. Eunil Park, Angel P. del Pobil and Sang Jib Kwon. *The Role of Internet of Things (IoT) in Smart Cities: Technology Roadmap-oriented Approaches*. Sustainability, 10, 1–13, 2018.

PerryPlanet, **2010**. PerryPlanet. *Bay Area Regions Map*, 2010. URL `https://commons.wikimedia.org/wiki/File:Bayarea-map.svg`. Visited on 4-17-2019.

Przybylowski, **2018**. Adam Przybylowski. *Sustainable urban mobility planning: Gdynia city case study*. Economics and Law, 17(2), 195–209, 2018.

Said, **2011**. Carolyn Said. *S.F., Oakland in top 10 most walkable U.S. cities*, 2011. URL `https://www.sfgate.com/business/article/S-F-Oakland-in-top-10-most-walkable-U-S-cities-2354150.php`. Visited on 3-26-2019.

San Francisco Beautiful, **2007**. San Francisco Beautiful. *Report on San Francisco's Cable Cars*, San Francisco Beautiful, 2007.

San Francisco Chronicle, **2008**. San Francisco Chronicle. *Bay Area Traveler: Transportation Information*, 2008. URL `https://web.archive.org/web/20080830051722/http://sfgate.com/traveler/guide/transportation/publictrans.shtml`. Visited on 3-26-2019.

Sankin, **2012**. Aaron Sankin. *Families Flee San Francisco: City Has Lowest Percentage Of Kids Of Any Major U.S. City*, 2012. URL `https://www.huffingtonpost.co.uk/2012/03/09/families-flee-san-francisco_n_1335639.html?guccounter=1`. Visited on 3-26-2019.

Sassen, **2016**. Saskia Sassen. *The Global City: Enabling Economic Intermediation and Bearing Its Costs*. City & Community, 15(2), 97–108, 2016.

Schoettle and Sivak, **2015**. Brandon Schoettle and Michael Sivak. *Potential Impact of Self-Driving Vehicles on Household Vehicle Demand and Usage*. The University of Michigan Transportation Research Institute, 2015.

Selna, **2008**. Robert Selna. *New jobs, houses spur S.F. population in 2007*, 2008. URL `https://www.sfgate.com/bayarea/article/New-jobs-houses-spur-S-F-population-in-2007-3284112.php`. Visited on 3-26-2019.

Selwyn, **2004**. Neil Selwyn. *New Media and Society*. Journal of Transport Geography, 6 (3), 341–362, 2004.

SF Environment, **2019**. SF Environment. *San Francisco's Carbon Footprint*, 2019. URL `https://sfenvironment.org/carbonfootprint`. Visited on 3-27-2019.

SFMTA, **2011**. SFMTA. *2011 Bicycle Count Report*, City of San Francisco, 2011.

SFMTA, **2010**. SFMTA. *City of San Francisco 2010 Bicycle Count Report*, City of San Francisco, 2010.

SFMTA, **2019a**. SFMTA. *About*, 2019. URL `http://sfpark.org/about-the-project/`. Visited on 6-2-2019.

SFMTA, **2008**. SFMTA. *DRAFT FY 2008 SRTP for Public Review*, City of San Francisco, 2008.

SFMTA, **2019b**. SFMTA. *San Francisco Mobility Trends Report 2018*, San Francisco Municipal Transportation Agency, 2019b.

Shaheen and Chan, **2016**. Susan Shaheen and Nelson Chan. *Mobility and the Sharing Economy: Potential to Overcome First- and Last-Mile Public Transit Connections*. eScholarhip, 2016.

Shipman, **1997**. M. D. Shipman. *The limitations of social research*. London: Longman, 1997. ISBN 9780582311039.

Siddiqui, **2018**. Faiz Siddiqui. *Falling transit ridership poses an 'emergency' for cities, experts fear*, 2018. URL `https://www.washingtonpost.com/local/trafficandcommuting/falling-transit-ridership-poses-an-emergency-for-cities-experts-fear/2018/03/20/ffb67c28-2865-11e8-874b-d517e912f125_story.html`. Visited on 5-6-2019.

Silva et al., **2015**. Ricardo Silva, Soong Moon Kang and Edoardo M. Airoldi. *Predicting Traffic Volumes and Estimating the Effects of Shocks in Massive Transportation Systems*. Proceedings of the National Academy of Sciences, 112(18), 2015.

Silverman, **2006**. David Silverman. *Interpreting Qualitative Data*. Sage Publications, Inc, 2006. ISBN 9781412922456.

Smith, **2013**. Bryant Walker Smith. *Human Error as a Cause of Vehicle Crashes*, 2013. URL http://cyberlaw.stanford.edu/blog/2013/12/human-error-cause-vehicle-crashes. Visited on 4-10-2019.

Spireon, **2016**. Spireon. *What Consumers REALLY Want in a Connected Car – Explained in 1 Infographic*, 2016. URL https://www.spireon.com/the-connected-car-explained-in-1-infographic/. Visited on 3-11-2019.

Stake, **2005**. Robert E. Stake. *Qualitative cast studies. In N.K. Denzin & Y.S. Lincoln (Eds.) The Sage handbook of qualitative research (3rd ed.).* Thousand Oaks: Sage, 2005. ISBN 9781412906449.

State of California DMV, **2018**. State of California DMV. *Driverless Testing of Autonomous Vehicles*, 2018. URL https://www.dmv.ca.gov/portal/dmv/detail/vr/autonomous/auto. Visited on 3-6-2019.

State of California DMV, **2019**. State of California DMV. *Testing of Autonomous Vehicles with a Driver*, 2019. URL https://www.dmv.ca.gov/portal/dmv/detail/vr/autonomous/testing. Visited on 4-10-2019.

The New York Times, **2008**. The New York Times. *Consumption Spreads Faster Today*, 2008. URL https://archive.nytimes.com/www.nytimes.com/imagepages/2008/02/10/opinion/10op.graphic.ready.html. Visited on 4-17-2019.

Torrey, **1997**. E. Fuller Torrey. *Deinstitutionalization: A Psychiatric "Titanic"*, 1997. URL https://web.archive.org/web/20140720013649/https://www.pbs.org/wgbh/pages/frontline/shows/asylums/special/excerpt.html. Visited on 3-26-2019.

Tovey, **2016**. Alan Tovey. *Ford plans mass-market self-driving cars within five years*, 2016. URL https://www.telegraph.co.uk/business/2016/08/16/ford-plans-mass-market-self-driving-cars-within-five-years/. Visited on 3-19-2019.

Treib et al., **2007**. Oliver Treib, Holger Bähr and Gerda Falkner. *Modes of governance: towards a conceptual clarification.* Journal of European Public Policy, 14(1), 1–20, 2007.

Turcu, **2013**. Catalina Turcu. *Re-thinking sustainability indicators: local perspectives of urban sustainability.* Journal of Environmental Planning and Management, pages 695–719, 2013.

UITP, **2017**. UITP. *Autonomous Vehicles: Potential Game Changer for Urban Mobility*, 2017. URL https://www.uitp.org/news/autonomous-vehicles-urban-mobility. Visited on 3-19-2019.

UMTRI, **2013**. UMTRI. *Has motorization in the U.S. Peaked?*, 2013. URL http://www.umtri.umich.edu/our-results/publications/has-motorization-us-peaked. Visited on 5-6-2019.

United Nations, **2018**. United Nations. *68% of the world population projected to live in urban areas by 2050, says UN*, 2018. URL https://www.un.org/development/desa/en/news/population/2018-revision-of-world-urbanization-prospects.html. Visited on 5-6-2019.

US Census Bureau, **2010**. US Census Bureau. *FactFinder*, 2010. URL https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?src=bkmk. Visited on 3-26-2019.

US Census Bureau, **2017**. US Census Bureau. *QuickFacts - San Francisco County, California; UNITED STATES*, 2017. URL https://www.census.gov/quickfacts/fact/table/sanfranciscocountycalifornia,US/PST045217. Visited on 3-26-2019.

US Census Bureau, **2011**. US Census Bureau. *San Francisco County, California*, 2011. URL https://web.archive.org/web/20110713075807/http://quickfacts.census.gov/qfd/states/06/06075.html. Visited on 3-26-2019.

US Census Bureau, **2009**. US Census Bureau. *2005-2009 American Community Survey 5-Year Estimates*, 2009. URL https://web.archive.org/web/20110103041948/http://factfinder.census.gov/servlet/ACSSAFFFacts?_event=&geo_id=05000US06075&_geoContext=01000US%7C04000US06%7C05000US06075&_street=&_county=san%2Bfrancisco&_cityTown=san%2Bfrancisco&_state=&_zip=&_lang=en&_sse=on&ActiveGeoDiv=&_useEV=&pctxt=fph&pgsl=050&_submenuId=factsheet_1&ds_name=null&_ci_nbr=null&qr_name=null&reg=null%3Anull&_keyword=&_industry=. Visited on 3-26-2019.

US Census Bureau, **2005**. US Census Bureau. *Historical Census Statistics On Population Totals By Race, 1790 to 1990, and By Hispanic Origin, 1970 to 1990, For Large Cities And Other Urban Places In The United States*, 2005. URL https://www.webcitation.org/69hd5KAIE?url=http://www.census.gov/population/www/documentation/twps0076/twps0076.html. Visited on 3-26-2019.

U.S. Department of Commerce, **2018**. U.S. Department of Commerce. *QuickFacts: San Francisco County, California*, 2018. URL https://www.census.gov/quickfacts/sanfranciscocountycalifornia. Visited on 3-26-2019.

U.S. EPA, **2018a**. U.S. EPA. *Regulations for Greenhouse Gas Emissions from Passenger Cars and Trucks*, 2018. URL https://www.epa.gov/regulations-emissions-vehicles-and-engines/regulations-greenhouse-gas-emissions-passenger-cars-and. Visited on 3-13-2019.

U.S. EPA, **2018b**. U.S. EPA. *Fast Facts on Transportation Greenhouse Gas Emissions*, 2018. URL https://www.epa.gov/greenvehicles/fast-facts-transportation-greenhouse-gas-emissions. Visited on 5-6-2019.

Vespa et al., **2018**. Jonathan Vespa, David M. Armstrong and Lauren Medina. *Demographic Turning Points for the United States: Population Projections for 2020 to 2060*, United States Census Bureau, 2018.

Wakefield, **2013**. Jane Wakefield. *Tomorrow's cities: Do you want to live in a smart city?*, 2013. URL https://www.bbc.com/news/technology-22538561. Visited on 5-6-2019.

Wampler, **2012**. Brian Wampler. *Participation, Representation, and Social Justice: Using Participatory Governance to Transform Representative Democracy*. Polity, 44(4), 666–682, 2012.

Warburg, **2014**. Jennifer Warburg. *Forecasting San Francisco's Economic Fortunes*, 2014. URL `https://www.spur.org/news/2014-02-27/forecasting-san-francisco-s-economic-fortunes`. Visited on 3-26-2019.

Waters, **2009**. Rob Waters. *Biotech Jobs Germinate as San Francisco Diversifies Economy*, 2009. URL `https://web.archive.org/web/20151016080842/http://www.bloomberg.com/apps/news?pid=newsarchive&sid=a0OqYCnyJ8eY`. Visited on 3-26-2019.

Yin, **2009**. Robert K. Yin. *Case Study Research: Design and Methods, Fourth Edition*. Sage Publications, Inc, 2009. ISBN 978-1-4129-6099-1.

Zavyalova, **2017**. Anna Zavyalova. *To Have and Have Not: Exploring Grammars of Sharing in the Context of Urban Mobility*. Ethnographic Praxis in Industry Conference Proceedings, 2017.

Zhang et al., **2015**. Wenwen Zhang, Subhrajit Guhathakurta, Jinqi Fang and Ge Zhang. *Exploring the impact of shared autonomous vehicles on urban parking demand: An agent-based simulation approach*. Sustainable Cities and Society, 19, 34–45, 2015.

Zipcar, **2019**. Zipcar. *The Story of Zipcar*, 2019. URL `https://www.zipcar.com/about`. Visited on 3-26-2019.

Appendix A

Interview Guide

Q#	Hypothesis	Theme of Question	Question
1	None	Provide comfortable, non-threatening way into the interview; locate the person in the organization from his/her own perspective; gain a sense of their role in the larger process	Let's start by giving a brief introduction and having you describe what you do here.
2	None	Planner role in discourse of technological disruption	What has been your role thus far in the public or political discourse surrounding AVs in the Bay Area?
3	Issues - Potential widening of wealth disparity, induced miles driven by AV cars Positive effects - Enhancement of multi-modal access, greater safety for pedestrians and motorists	Pros and cons of AVs from a planner's perspective	What are the main issues that concern you? What are the foreseeable positive effects?
4	AV buses and light rail could make public transit more affordable and reliable; conversely more AV automobiles will increase congestion for public transit unless public transit gets prioritization on roadways	Disruption of current public transportation infrastructure	How do you expect AVs to work in relation to public transit?
5	Will affect zoning ordinances and other types of regulations, as well as existing parking lots. With extra space comes the need to make decisions on how we repurpose those spaces.	Planning process - vision versus reality	How do you predict that AVs will be worked into current comprehensive planning processes? If this differs from what you envision, how do they differ?
6	More widespread branding of plans and policies to include themes such as climate change, reclamation of the city from cars back to people, and outreach to disadvantaged groups	Changes in planning paradigm, particularly caused by a socio-technical transition	Given the exponential rise in technology, social media, and awareness of environmental concerns (and others) in the last decade - in your career lifetime, have you experienced any widespread shift in the values or morals that planners incorporate into practice?

7	There have been efforts, both through traditional process of committee and city hall meetings, as well as through social media	Explore efforts broadly conceived, both formal and informal, of public and stakeholder involvement	Have there been efforts to preemptively involve the public, whether NGOs or the general wider public, to be involved in the planning of a future Bay Area with AVs?
8	The closest similarity to the socio-technical disruption of AVs is the original adoption of the automobile, the main difference now being we now have infrastructure in place which is difficult and expensive to change	Gives a sense for the dynamics of the institution, how well change is received/initiated, processes for implementing improvement	Is the topic of AVs analogous to any other disruption in the past? How do you see its imminent implementation differing from any other urban planning challenge before?
9	Too much regulation may stifle innovation, whereas not enough may cause more dangers than benefits	Legislation and regulation of new mode of transit with new safety and ethical implications	How do you see regulation/legislation of AVs evolving in parallel with the technology of AVs?
10	I predict that MTC collaborates with other Bay Area transportation agencies to the extent of discussing the financial side of planning projects, but minimal coordination of specific regional strategies to achieving long-term goals	City/municipal and regional partnerships in city and regional urban/transportation planning	How does MTC collaborate with other transit agencies, as Bay Area transportation is a regional network?
11	This will be an issue that will not be prioritized in the discussion until much further on, when the problem is amplified through the voice of the public	Socio-economic equity	How do you expect AVs to serve areas that are currently underserved, whether by public transit or where it is not economically feasible to regularly use other means such as ridesharing?
12	Through the establishment of various data points regarding GHG emissions, rates of car ownership, safety of motorists and pedestrians, public transit ridership, average commute time, etc.	Quantification of a complex solution to a complex, wicked problem	How does one evaluate success of the incorporation of AVs on a wider scale?

Appendix B

Document Analysis Results

Q#	Autonomous Vehicles - Perspective Paper [Horizon Paper]	Plan Bay Area 2040	2017 and 2018 Joint Advocacy Program	Future Mobility Research Program - Update (meeting notes and presentation transcription)	Toward a Shared Future: Strategies to Manage Travel Demand - Perspective Paper [Horizon Paper]	Futures Interim Report: Opportunities and Challenges [Horizon Paper]
1.	First in a series of Perspective Papers which contribute to Horizon, a regional initiative exploring a variety of external forces that have the potential to dramatically alter the region's trajectory	Long-term regional transportation, land use, and	Attachments to agenda items of two meetings of the Legislation Committee, which recommends MTC legislative policy and oversees the Commission's public information and participation programs	Planning committee update on the joint research efforts of CA's 4 largest MPOs	Perspective paper	Interim milestone report to help guide a long-range regional plan for the Bay Area's future growth and investments.
2.	Arup Group Ltd., MTC, ABAG	MTC, ABAG	MTC	MTC	MTC, ABAG, ICF	MTC, ABAG
3.	June 26, 2018	July 26, 2017	December 22, 2016 and January 31, 2018	October 27, 2017	September 2018	March 15, 2019
4.	Collaborative effort between Arup, a private design, engineering, and business consultation firm and MTC, a public regional transportation planning agency	Collaborative effort between ABAG, a Bay Area regional planning agency of local governments, and MTC	Proponents for the advocacy of disadvantaged and minority groups	Presented by Adam Noelting - principal planner with MTC working directly in FMRP	Collaborative effort between ABAG, MTC, and ICF International, a global consulting and technology services company	Collaborative effort between ABAG, a Bay Area regional planning agency of local governments, and MTC
5.	Presents a set of potential planning strategies for the Bay Area to seize the opportunities and meet the challenges that AVs are likely to introduce. This paper is the first in a series of Perspective Papers that contribute to Horizon, a regional initiative exploring a range of external forces that have the potential to fundamentally alter the region's trajectory.	Updated long-range Regional Transportation Plan and Sustainable Communities Strategy for the SF Bay Area. Discusses goals, proposed growth pattern, supporting transportation investment strategy, and key actions needed to address ongoing and long-term challenges	The issues, goals, and strategies prioritized annually as pertaining to state- and federal-level support needed for various transportation programs, tasks, initiatives, etc.	Knowledge required of established consultant panel; 3 procurement focuses; interview findings of modeling assumptions for fully AVs to inform the regions; next steps	Proposal of eight strategies for a more mobile Bay Area by 2050, focusing on pricing mobility fairly and reducing the demand for vehicle travel by improving the reliability, flexibility, convenience, and cost of other modes	Describes potential future challenges brought about by external forces, while continuing the conversation about regional policies and investments to change the region's trajectory
6.	To explore challenging questions that traditionally have been outside the regional planning process. Uses an approach of developing strategies not constrained fiscally or politically.	Document exists as limited and focused update of the region's previous integrated transportation and land use plan, Plan Bay Area, adopted in 2013	To make known to the Legislation Committee the legislative priorities for each year	To inform the Bay Area planning committee of accomplishments, findings, and future plans of FMRP	Meant to explore strategies that help to achieve regional goals and start the discussion to determine the final set of strategies for Plan Bay Area 2050. Uses an approach of developing strategies not constrained fiscally or politically.	To explore pressing issues and possible challenges Bay Area residents may face through 2050 due to disruptive technologies, rising sea levels, economic booms and busts, political volatility, and other external forces.

Q#	Autonomous Vehicles - Perspective Paper [Horizon Paper]	2017 and 2018 Joint Advocacy Program	Future Mobility Research Program - Update (meeting notes and presentation transcription)	Toward a Shared Future: Strategies to Manage Travel Demand - Perspective Paper [Horizon Paper]	Futures Interim Report: Opportunities and Challenges [Horizon Paper]
7.	Bay Area is uniquely situated to take advantage of opportunities and mitigate against risks AVs present, due to 1) Bay Area being home to tech innovation; 2) some of region's governmental and non-governmental organizations are already planning for a world with AVs; 3) diversity of region can allow for the piloting and modeling of policies that other communities can replicate. Survey findings predict 3 - 13 years until Level 5 AVs available for use.	In partnership with entities listed in Q22 below, support Bay Area jurisdictions' efforts to test and deploy CAVs	Two key themes of opportunity and uncertainty arise from technology of AVs. MPOs have an opportunity to be more proactive when it comes to emerging technologies, and to address the uncertain future of AVs, FMRP performed 22 expert interviews to foresee how AVs might influence travel behavior in the Bay Area. May see automation sooner in moving of goods rather than personal vehicles because they operate huge fleets and can make significant impact on market share.	The dynamic and fast pace of technological innovation opens opportunities to make the transportation system more efficient, effective and equitable.	Considers 3 Futures of "More Limited" 10% AV, 10% telecommute share; "Widespread" 95% AV, 30% telecommute share, and "Widespread" 75% AV, 15% telecommute share. Increased travel times would make it possible to be productive while commuting
8.	Shared AV services could introduce a transit renaissance with improved demand-responsive services. Lower operating costs could enable transit agencies to replace low frequency fixed routes with more frequent demand-responsive transit in low density Areas. However, If mobility services are effective, they may compete with transit, potentially causing ridership to fall, exacerbating the already lower viability of off-peak services and routes in low-density geographies.	In partnership with entities listed in Q22 below, include the goal of supporting improved transit access.	Public transit will change considerably with high utilization of AVs, but will still play a role. AVs will compete with public transit services in areas with relatively low capacity and low frequency services. However, AVs could also be complementary to high capacity transit, as a first- and last-mile solution.	AV technology can be integrated into transit systems in mid-to-low density areas to provide flexible and cost-effective services that connect residents to high-capacity, long-distance bus and rail corridors. AV tech has potential to reduce highway congestion or increase it. Encouraging travel with services that are part of a fleet, including public transit are necessary to achieve a reduction in the vehicles on the road.	Even with high penetration of AVs, public transit remains crucial element in region's transportation system. Growth focused in priority development areas helps to support transit ridership.
9.	Fundamentally, AVs could influence how we plan, design, build, and operate cities. Survey findings predict 0-45% increase in roadway capacity. AVs could worsen congestion with more induced travel and empty vehicle circulation. Priority strategies: Double down on high- capacity bus and rail corridors; Innovate suburban transit with autonomous, on-demand microtransit		Impacts will differ significantly across the region between higher density urban areas with more amenities, versus lower density, lower amenity urban areas. MPOs need to support programs and projects that ensure wide benefits among all users of the transportation system.	Free AV services, in vehicles appropriately sized for ridership demand, could feed into rail and expanded high- capacity express bus services to improve mobility and accessibility throughout the Bay Area	AVs could create huge challenges for the region's capacity-constrained transportation network. Will require reinvestments in utility and transportation infrastructure, in particular, improvements to regional gateways to accommodate significant growth in demand
10.	AVs seen as an environmental wildcard, as it has potential to support or undermine climate and environmental protection efforts. Survey findings predict -50 to +100% change in GHG emissions. Automotive land uses with high noise and air pollution tend to be in Communities of Concern. Reduced congestion and shift to EVs could improve local air quality and reduce noise issues.	Engage in regulatory / legislative efforts related to CAVs with the aim of accelerating their environmental benefits.	FMRP research aims to inform assumptions for region's plans to achieve passenger GHG emissions reduction targets. Literature findings show -50% to +100% change in GHG emissions		
11.	Survey findings predict 5- 40% increase in VMT. Non-driving populations will likely have increased access to independent car travel. Empty vehicles will likely travel the streets. Lower per-mile costs with demand-responsive mobility services and lower value of travel time (i.e., driving time can be productive) will likely induce demand. Goods movement trends are indicating more, faster deliveries.		Interview findings: AVs will likely induce trips, increase VMT, increase capacity, and generate longer trips. Literature findings show potential 5-40% increase in VMT.	VMT reduction and encouraging travel in shared services can only be accomplished through a comprehensive approach where transportation options are seamless and ubiquitous; driving costs are not subsidized as they are now; and transportation, goods delivery and land use development are planned together.	In a Future where AVs do not become widely popular, zero-occupancy vehicles will not be a significant issue. Conversely, wide use of shared AVs allow a significant share of Bay Area residents to abandon private car ownership and reduce VMT
12.	TNCs could provide insight into market interest and regulatory response to AV services. Demand for curbside passenger loading has grown substantially more pronounced, particularly in downtowns and other high-demand activity centers. This demand is exacerbating curbside conflict among bicyclists, delivery vehicles, transit vehicles, and parked cars.		MTC, SCAG, SANDAG, and the San Francisco County Transportation Authority (SFCTA) submitted a funding application to Caltrans for a grant to collect and analyze data from TNC services' passengers and drivers. TNC services require a mobile phone and credit card to access, as well as the cost of service itself - research into who is being served?	Pricing could be reduced for residents choosing to pool with others in either their own vehicle or a ridehail service (both of which could be autonomous by 2050)	Shared AVs allow a significant share of Bay Area residents to abandon private car ownership and reduce VMT
13.	AVs could disrupt the social fabric with major impacts on labor markets. Potential to reduce transportation and logistics operating costs, but also cause rapid job loss or a shift to other occupations. Priority strategies: Strengthen the capacity of training programs to expand opportunities for workers; Target job clusters on industrially-zoned land for production, distribution, and repair; Pilot innovative AV applications that could spur new job opportunities				
14.	Survey findings predict 40- 90% increase in safety. Significant reduction in human driving error could save lives. AVs allow for a new, expanded Vision Zero program. Priority strategies: Cap speed limits in downtowns,	Engage in regulatory/legislative efforts related to CAVs with the aim of accelerating their safety benefits. Support strong federal vehicle safety standards.	FMRP strives toward performance targets related to public health. Literature findings show 40-90% potential increase in safety with use of AVs. From the industry perspective, looking at moving toward zero accidents on roadways	AV technology has potential to create unsafe street conditions for all roadway users.	

	neighborhoods				
15.	New forms of safety and security risk may be introduced with hacking and cybersecurity vulnerabilities of CAV transportation systems. Priority strategies: Develop "bounty program" to reduce hacking vulnerability. Strategy: Mandate data transparency on all vehicles with appropriate privacy protections, potentially via a third-party aggregator.		Considering new safety risks including new cyber attacks or other privacy concerns	AV technology has potential to create more insecure data.	
16.	If AVs are EVs, electricity source will be a consideration, as the use of nonrenewable sources of electricity could present other risks. Undoubtedly, an influx of electric AVs to the fleet will require new infrastructure for charging vehicle autonomy could accelerate the shift to cleaner electric vehicles, EVs could improve air quality. Priority strategies: Mandate that all AVs are EVs and invest in the necessary infrastructure		Until EVs dominate the market, AVs will likely increase GHG emissions. Uncertainty of future AV fleets will be electric versus combustion engine, whether it's a -50% to +100% increase in GHG emissions		Low-cost autonomous EVs will make mobility more affordable
17.	AVs could disrupt the social fabric with major impacts on equity and access to opportunity. Today, Communities of Concern face numerous challenges related to accessibility including long waits and travel times and unreliable service for transit. Historically, these communities have faced inequi- table service and discrimination across all modes, most recently with TNCs such as Uber and Lyft. Review of major policy reports throughout the world have shown that to varying degrees, most reports recognize the importance of equity. Common equity-based policies include workforce preparedness, public engagement, and neighborhood coverage or geographic access programs and planning efforts. Priority strategies: Mandate equitable provision of mobility services with transparent reporting; Subsidize public transit innovations, replacing fixed route transit in some Communities of	Engage in regulatory/legislative efforts related to CAVs with the aim of accelerating their equity benefits.	FMRP strives toward performance targets related to equity. Further research will be looking at who is being served, as TNC services for example rely on a mobile phone, which has a cost premium. Another indicator of inequality would be drivers choosing not to pick up / drop-off in certain areas; must be ensured that communities are always being served.	AV technology has potential to create exclusive, expensive services that do not benefit all residents.	Shared AVs have unintended impacts and increased cost of transportation results in those with the least means experiencing the greatest impacts. Those same groups may benefit, however, from autonomous EVs.
	Concern; Prioritize AV mobility services or programs for that serve Communities of Concern.				
18.	AVs could impact housing preferences and cost and location of new construction. AVs could facilitate sprawl, increasing travel costs. Priority strategies: Repurpose off-street parking for infill development; Retain or strengthen urban growth boundaries to control greenfield development			Encouraging travel with services that are part of a fleet (scooters, bikes, transit, cars) will need to be integrated into transport- ation and land use policy and planning. Transportation, goods delivery and land use development must be planned together. When all vehicles are fully autonomous, parking demand could drop by as much as 90 percent.	Cost of development associated with the changing needs for parking provision in a Future with AVs is factored into Bay Area land use modeling
19.	Review of major policy reports throughout the world have shown that digital infrastructure and supportive data standards create the foundation upon which mobility innovation is made possible. Without clear data policies, inno- vation in support of communities – stalls. All reports make at least base- line mention of the need to support digital infrastructure. Strategy: Support the development of industry-wide data sharing protocols, defining data needs with appropriate privacy principles to provide real-time infrastructure, congestion, and pricing data to connected vehicles.	In partnership with entities listed in Q22 below, support access to critical data for transportation and land use planning and operational purposes			AV future will require reinvestments in utility and transportation infrastructure
20.	Bay Area is uniquely situated to take advantage of opportunities and mitigate against the risks that AVs present. Report organized to list out AV implications with their associated opportunities and risks, and priority strategies, which address mitigation of risks		VMT taxes, congestion charging, subsidies, and other regulatory responses such as dedicated lanes for high-occupancy shared AVs can help mitigate projected increases in VMT. FMRP is trying to account for both opportunities and risks.	Tolling highways and bridges in the Bay Area could encourage more shared use of AVs, limiting VMT growth that might result from AVs and ridehail services. Pricing and incentives to increase pooling will be critical to preventing a significant increase in congestion.	
21.	TNC case study showed that specific local jurisdiction (e.g., over curb use) may enable municipalities to enact regulation in addition to state laws. The disruptive and novel nature of new mobility services can defy clear classification, resulting in their regulation by multiple diverse government agencies.	At the state level, monitor and engage in legislation and regulations to facilitate deployment of connected and autonomous vehicles. At the federal level, support strong federal vehicle safety standards while also preserving the ability of state/local agencies to continue to set policies governing the operation of vehicles on highways and local roads, regardless of whether they are	VMT taxes, congestion charging, subsidies, and other regulatory responses such as dedicated lanes for high-occupancy shared AVs can help mitigate projected increases in VMT. Question of transit has more to do with politics than anything else - BART is an automated system, but doesn't run as one because of regulations and labor law.		

		driven manually or autonomously			
22.	AVs are likely to be applied to one of four use cases: private mobility services, goods movement, public transit, and privately owned vehicles.		Shared versus owned	Shared use	Shared use
23.	Case study findings showed that coordination between state and local actors can lead to valuable funding support. Integration of multiple private partners into a single program can offer mobility services that are not dependent on one solitary company. Strategy: Establish a city- or regional-scale data sharing pilot program in collaboration with private industry partners.	Partner with Bay Area cities and counties, transit agencies, the business community, and other transportation organizations	FMRP is collaboration between four largest MPOs in California - MTC, SANDAG (San Diego), SCAG (Southern CA), and SACOG (Sacramento). This partnership pools agency resources and streamlines contracts in order to share and benefit and creates a consistent framework, and the products of this research are intended to inform our regional transportation plans and sustainable community strategies.		