UNIVERSITY OF OREGON

AVS IN THE PACIFIC NORTHWEST: REDUCING GREENHOUSE GAS EMISSIONS IN A TIME OF AUTOMATION

BASELINE REPORT | AUGUST 2018

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ADVISORY COMMITTEE

- Joanna Clark, Senior Transportation Policy Planner, City of Vancouver, British Columbia
- Evan Corey, New Mobility Program Manager, Seattle Department of Transportation, Oregon
- Peter Hurley, Senior Transportation Policy Planner, Portland Bureau of Transportation, City of Portland, Oregon

URBANISM NEXT TEAM

The Urbanism Next Team are the primary authors of this report.

- Nico Larco, AIA, Professor, Urbanism Next Center Director and Sustainable Cities Initiative Co-Director
- Amanda Howell, Program Coordinator
- Rebecca Lewis, PhD., Assistant Professor and SCI Research Director
- Becky Steckler, AICP, Urbanism Next Program Manager

ABOUT THE URBANISM NEXT CENTER

The Urbanism Next Center is a research center housed within the Sustainable Cities Initiative at the University of Oregon. It is a leading source for information about the potential impacts of emerging technologies — autonomous vehicles, e-commerce, and the sharing economy — on city development, form, and design and the implications for equity, health, the economy, the environment, and governance.

ABOUT THE SUSTAINABLE CITY INITIATIVE

The Sustainable Cities Initiative (SCI) is a cross-disciplinary organization at the University of Oregon that promotes education, service, public outreach, and research on the design and development of sustainable cities. We are redefining higher education for the public good and catalyzing community change toward sustainability. Our work addresses sustainability at multiple scales and emerges from the conviction that creating the sustainable city cannot happen within any single discipline. SCI is grounded in cross-disciplinary engagement as the key strategy for improving community sustainability. Our work connects student energy, faculty experience, and community needs to produce innovative, tangible solutions for the creation of a sustainable society.

TABLE OF CONTENTS

1

INTRODUCTION

01 | INTRODUCTION

ABOUT

BACKGROUND AND PURPOSE OF THIS REPORT

Autonomous vehicles (AVs) promise to significantly disrupt how we plan, fund, and operate transportation systems. While there are many questions still to be answered before AVs can safely and legally operate on North American roads, there is growing consensus that AVs may be as transformative to cities as the introduction of the car itself. Research and preliminary modeling suggest that the automation of passenger travel and delivery of goods could significantly change travel behavior and mode of travel, increase congestion, and increase sprawl (Harb, Xiao, Circella, Mokhtarian, & Walker, 2017; Clewlow & Mishra, 2017; Fehr & Peers, Undated; Zhang & Guhathakurta, 2016).

It's not all dire news, as technology — primarily the smart phone, computers, and apps that make it easier to travel or get goods delivered — also provide a number of opportunities to improve livability and equity. Technology can also help to manage negative impacts such as reducing the cost and increasing the convenience and comfort of transportation, creating the ability to price the use of the transportation system to fund infrastructure and manage demand, increasing the demand for electric vehicles, and much more. However, the ability to mitigate the negative impacts of AVs and realize the opportunities is dependent on the ability of governments from the federal to local level to create the policies, programs, and pricing for AVs to (Zhang & Guhathakurta, 2016) achieve environmental, land use, transportation, economic development, equity and other community goals.

While only a handful of cities have developed AV strategies and assessed potential impacts, no city has yet explored how AVs may influence city-led efforts to reduce greenhouse gas emissions (GHG). The policy decisions made over the next 10 years that shape the deployment of AVs will have significant repercussions for our communities as well as environmental repercussions related to greenhouse gas (GHG) emissions and adaptation to climate change.

The Cities of Portland, Oregon; Seattle, Washington; and Vancouver, British Columbia (Canada) (referred to as Portland, Seattle, and Vancouver throughout the rest of this document) have been at the forefront of thinking about how AVs will integrate into their cities, given the three cities' environmental and sustainability goals. In 2017, the cities partnered with the Carbon Neutral

Cities Alliance at the Urban Sustainability Directors Network (CNCA/USDN) on a collaborative project to better understand how each city is individually addressing policy issues related to AVs, as well as to develop common policies and strategies that help advance their climate goals.

The University of Oregon conducted research for the cities of Portland, Seattle, and Vancouver to understand how the deployment of autonomous vehicles may impact greenhouse gas (GHG) emissions. Based on the range of possible outcomes, the cities hope to better understand the policies and programmatic choices available to mitigate negative impacts of AVs and ensure that they can accomplish the goals stated in their climate action, land use, and transportation plans. By working together, each city hopes to learn from each other—as well as cities from across North America—to achieve their climate-related goals.

This report is the first of a two-phase project, both funded by the Bullitt Foundation. The Bullitt Foundation provided a grant to CNCA/USDN and subsequently to the Urbanism Next Center at the University of Oregon to fund research related to the impact of AVs on the Cities of Portland, Seattle, and Vancouver and their ability to successfully implement their climate action plans to reduce GHG emissions. Phase II is supported by a grant directly to the Urbanism Next Center and builds on Phase I to examine in greater detail a limited number of strategies and actions that the Cities could incorporate into their new mobility[1] strategies.

[1] New mobility is the term favored by many jurisdictions across the country to describe transportation that is newly enabled by technology, primarily the use of smart phones. This technology includes transportation network companies (like Uber and Lyft), micro-transit (like Chariot), bike share, scooter share, and potentially other modes of transportation that are enabled by smart phones or other electronic devices. AVs are expected to be included in the suite of technologies covered by new mobility when they are deployed in cities.

01 | INTRODUCTION

METHODS

The Urbanism Next Center at the University of Oregon conducted technical research and policy analysis in preparation for the facilitated workshop conversations with the partner cities in June and July of 2018. The purpose of the workshops was to share information among n cities and between different agencies within cities, to bring staff at each city up to speed on key topics related to AVs and GHG emissions, to discuss research and potential policy gaps, and to provide analysis for each of the cities so that development of new mobility strategies that include AVs incorporates climate action plan goals.

The Urbanism Next Center at the University of Oregon used the following methods to complete its work:

- **LITERATURE REVIEW.** With AVs only in the testing phase, there is limited quantitative information about the potential impacts of AVs on communities. Urbanism Next conducted a literature review related to the implications of AV impacts on GHG emissions, focusing on literature related to vehicle distance traveled, mode share, energy sources, land use/metropolitan footprint, and freight and goods delivery. The literature review focused primarily on rigorous academic, public sector, and private sector research.

- **POLICY ANALYSIS.** Urbanism Next reviewed key transportation policies and plans related to AVs for the Cities of Portland, Seattle, and Vancouver, as well as climate action plans and other relevant plans. In addition, Urbanism Next reviewed AV and new mobility documents from other North American cities. The policy review helped identify gaps inthe approach taken by each (or all) of the cities.

- **COMPARATIVE ANALYSIS.** Urbanism Next conducted a comparative analysis of the AV policy approach of each city compared to each other, other cities, and the literature to identify key topics, recurring focus areas, related/secondary impacts (such as social, economic, environmental, etc.), and how other cities propose to address these issues through policy, programs, and pricing.

- **FACILITATED WORKSHOPS.** The facilitated workshops provided the city staff an opportunity to learn from the research in the Baseline Report and informed the conclusions areas of further study in Section 4.

01 | INTRODUCTION

LIMITATIONS

It bears repeating that AVs have not yet been deployed for commercial use in cities though several cities are conducting pilot projects. It is difficult to predict exactly what impacts AVs will have on cities. That said, operations of transportation network companies and other companies that offer “mobility as a service” or transportation on demand, give us a clue to how AVs may impact cities. Cities around the world are exploring transitioning from individual ownership of vehicles as a primary source of transportation to mobility as a service (MaaS). In MaaS, consumers purchase only the transportation they need but can choose from a suite of options including vehicles, bikes, scooters, and transit. AVs, which may be much less expensive for riders and much more responsive to their needs, will likely magnify and alter these outcomes in ways we can and cannot imagine. While Urbanism Next staff did their best to anticipate how these changes will impact climate action plans, we will inevitably get some information right and some information wrong.

In addition, few decision-making bodies have adopted much more then general principles or guidance for the development of new mobility and AV regulations. While many transportation departments are currently assessing the impacts, conducting public outreach, and describing policy tradeoffs, there are no “best practices” related specifically to AVs because cities are still developing policies and regulations.

Lastly, this report focuses exclusively on the potential impacts of AVs on transportation and land use and how they may contribute to increased or decreased GHG emissions. However, there are a range of other issues to consider, including equity and workforce impacts, and a variety of additional ways that AVs could have ecological impacts. For instance, a reduced need for parking could lead to the redevelopment of previously impervious surfaces into green spaces, which would have environmental benefits. While the full range of impacts are not explored in depth in this report, they are nonetheless important to consider and additional research is necessary to better understand the myriad impacts that AVs could have on cities.

01 | INTRODUCTION

IMPORTANCE OF SOCIAL EQUALITY

Historically, it has been all too common for disadvantaged populations to pay a disproportionate share of the costs for public policies and not receive their fair share of the benefits. The City of Portland's "Climate Action Through Equity" Report (City of Portland and Multnomah County, 2016) states that impacts from climate change, such as heat-related and respiratory illnesses, disproportionately impact disadvantaged communities as they often live in communities with fewer trees and greenspace. Disadvantaged populations may not receive timely information about extreme weather events or be aware of resources that can make them more comfortable or even save their life, and climate action investments and programs have not historically served disadvantaged populations as well as higher income populations. The City of Seattle's New Mobility Playbook describes how new mobility services could lead to more inequity by marketing in only one or two languages, providing services that are unaffordable to low income populations, providing services in limited locations that don't include communities of color or low-income neighborhoods, don't accommodate children, people with disabilities, pay options for the unbanked, and other barriers.

Policy makers, including those in Portland, Seattle, and Vancouver, understand that they must take a proactive approach to understanding the impacts of proposed policies and ensure that all residents share in the co-benefits. All three cities acknowledge the need to incorporate social equity considerations into AV policies, programs, and pricing mechanisms. The City of Seattle's New Mobility Playbook, the strategic document that provides guidance on the development of new mobility, including AV policies, has incorporated social equity throughout the document, and includes the goal of making a more equitable transportation system by increasing access to employment, making improvements to the transit system, analyzing data to identify unseen biases, offering subsidies to those most in need, creating new, better, paying technology jobs, and creating incentives and regulations to "make sure the system serves everyone." (City of Seattle Department of Transportation, 2017)

Increasingly, many communities are taking proactive steps to decrease inequities and injustices. Many cities have adopted equity plans to ensure that the policies they adopt do not have disparate impacts. These plans

Climate equity ensures the just distribution of the benefits of climate protection efforts and alleviates unequal burdens created by climate change. This requires intentional policies and projects that simultaneously address the effects of and the systems that perpetuate both climate change and inequity.

—2015 City of Portland and Multnomah County Climate Action Plan

provide a framework for cities to use as they develop AV policies that address existing systemic inequities and ensure that AV policies don't create new ones. If a city doesn't have an equity plan of its own yet in place, it should refer to one of the many equity impact assessments available for guidance, such as the King County 2015 Equity Impact Review Process (King County, 2016). This review process provides guidance on how institutions should evaluate proposed actions, regardless of topic.

This review process suggests that the following distributional, process, and cross-generational equity issues should be addressed in all policies:

- **DISTRIBUTIONAL EQUITY.** Fair and just distribution of benefits and burdens to all affected parties and communities across the community and organizational landscape.

- **PROCESS EQUITY.** Inclusive, open and fair access by all stakeholders to decision processes that impact community and operational outcomes. Process equity relies on all affected parties having access to and meaningful experience with civic and employee engagement, public participation, and jurisdictional listening.

- **CROSS-GENERATIONAL EQUITY.** Effects of current actions on the fair and just distribution of benefits and burdens to future generations of communities and employees. Examples include income and wealth, health outcomes, white privilege, resource depletion, climate change and pollution, real estate redlining practices, and species extinction.

Another important resource that provides specific guidance on equity in mobility is The Greenlining Institute's Mobility Equity Framework (Creger, Espino, & Sanchez, 2018). This document outlines three overarching goals related to transportation equity: 1) increase access to mobility 2) reduce air pollution, and 3) enhance economic opportunity. It also identifies twelve mobility equity indicators that can be used to weigh the benefits and burdens of a particular strategy or plan during an equity analysis.

Every community will need to adapt its equity strategy to respond to the unique circumstances of affected populations and the policies under consideration. It was not within the scope of this project to conduct a comprehensive equity assessment or process to incorporate equity components related to GHG emissions and the development of AV policies. But it is important is to understand that there are very real threats that emerging technologies present to disadvantaged populations and that cities should create a comprehensive process for the consideration and adoption of AV policies that mitigate the threats and realize co-benefits for all residents.

ORGANIZATION OF THIS REPORT

The rest of this report is organized into the following sections:

- **SECTION 2. FRAMEWORK FOR THINKING ABOUT AVS AND GHG EMISSIONS.** This section provides an overview of anticipated changes to the built environment and transportation system from the roll out of AVs that could result in GHG emissions increasing or decreasing. The literature review focuses on research related to vehicle distance traveled, mode share, energy sources, land use/metropolitan footprint, and freight/goods movement.

- **SECTION 3. POLICY AND PLAN REVIEW RELATED TO GREENHOUSE GAS EMISSIONS AND AUTONOMOUS VEHICLES.** This section begins with a brief overview of the Cities of Portland and Seattle's Climate Action Plans, and Vancouver's Greenest City Action Plan and identifies the land use and transportation strategies that will be most relevant when crafting new mobility strategies. An overview of Portland, Seattle, and Vancouver's policy and programmatic approaches and strategies being developed for new mobility in the context of adopted climate action plan goals follows. This section then goes into greater detail on specific land use and transportation topics and how other North American cities are regulating AVs, especially related to mitigating potential negative impacts related to GHG emissions.

- **SECTION 4. POLICY AND PROGRAMMATIC OPPORTUNITIES TO MANAGE GHG EMISSIONS THROUGH AV-RELATED IMPLEMENTATION STRATEGIES.** Informed by the findings from the literature and policy reviews, this section presents a series of objectives, strategies, and actions that could be undertaken to proactively address the potentially negative impacts that emerging technologies and in particular, autonomous vehicles, could have on greenhouse gas emissions.

2

FRAMEWORK FOR THINKING ABOUT AUTONOMOUS VEHICLES AND GREENHOUSE GAS EMISSIONS

ABOUT

Because AVs are currently on city streets on a limited basis, research that examines the potential impacts of AVs remains speculative. However, research on more well-established topics such as travel behavior and vehicle distance traveled, shared mobility, fuel efficiency, and land use provides important guidance. This literature review draws upon academic literature as well as more recent industry reports, which offer preliminary findings on the impacts of emerging technologies like transportation network companies (TNCs), e.g., Uber and Lyft, on travel behavior, and the built environment. The following topics are included in the literature review:

- **VEHICLE DISTANCE TRAVELED:** Using conventional fuel sources, an increase in vehicle distance traveled increases greenhouse gas (GHG) emissions. AVs have the potential to increase overall vehicle distance traveled due to changes in overall demand, land use patterns and segregation of uses, and availability of other modes, to name of few. While there are multiple factors that affect vehicle distance traveled, two that are particularly relevant to this report are:
    - **SHARED MOBILITY:** A suite of shared-use mobility options, including carsharing, bikesharing, ridesharing, and ridesourcing/ridesplitting, are now available and are an important component of the discussion about vehicle distance traveled. AVs will likely have different impacts on the transportation system depending on if they are single occupancy vehicles (whether individually owned or provided by a service) or if they operate in shared-use fleets.
    - **MODE SPLIT:** Mode split, or mode share, refers to the distribution of person trips across transportation modes, most commonly walking, biking, scootering, taking transit, or using a motorized vehicle. The extent to which travelers rely on personal vehicles for traveling is another important component of vehicle distance traveled. Encouraging shifts in travel mode can be accomplished through a variety of transportation demand management strategies. The impacts that AVs will have on mode split will be influenced by the policies, programs, and pricing (such as taxes and fees) that are implemented that encourage and/or discourage certain travel behaviors.

- **SOURCE OF ENERGY:** The energy source used to power a vehicle is a key factor in GHG emissions. Battery-electric, plug-in electric, and hybrid vehicles are no- to low-carbon alternatives to conventional gasoline-powered vehicles, which emit far more carbon. If AVs are primarily electric, they would have positive impacts on GHG emissions as conventional gasoline-powered vehicles are replaced by electric AVs.

- **LAND USE/METROPOLITAN FOOTPRINT:** The compactness of the urban form is an important consideration in GHG emissions since the level of density and/or sprawl influences travel behavior. The extent to which AVs will impact residential location preference is an important consideration in the discussion of GHG emissions.

- **FREIGHT/GOODS MOVEMENT:** GHG emissions are not only related to the movement of people but also the movement of goods, and automated technology will extend to trucking and delivery. In addition, the rise of e-commerce and the increase in delivery of goods in recent years are impacting the transportation systems. According to Pitney Bowes, residents and companies in the United States spend more on goods delivery, $95.8 billion in 2016, than any other country in the world (Pitney Bowes, 2017). Parcel volume increased 8.2 percent year-over-year from 2015-2016. Worldwide, Pitney Bowes forecasts global parcel growth will continue to rise at a rate of 17-28 percent per year between 2017 and 2021.

LITERATURE REVIEW

VEHICLE DISTANCE TRAVELED

One of the most salient questions about AVs and other new mobility technologies is what impact they are likely to have on vehicle distance traveled as VMT/VKT is directly related to both GHG emissions and congestion; preliminary modeling results from the consulting firm Fehr & Peers suggest that AVs could lead to a 14-31% increase in vehicle distance traveled (Fehr & Peers). Travel behavior outcomes, including the choices that people make regarding frequency of travel (trip generation), and mode of travel (mode share), have direct impacts on VMT/VKT.[2] Research conducted by Greenblatt and Shaheen, Clewlow and Mishra, and others suggests that AVs could lead to an increase in the total of number of trips taken for a variety of reasons (Greenblatt & Shaheen, 2015; Clewlow & Mishra, 2017). AVs could increase the number of trips taken by those who are currently unable to drive, such as elderly persons or persons with disabilities (Greenblatt & Shaheen, 2015). This could have the effect of adding more vehicles to the transportation network compared to current scenarios. However, it is worth noting that an increase in trips by populations who may currently be experiencing latent demand issues could help achieve another important outcome of increasing mobility access.[3]

The adoption of AVs could contribute to induced demand encouraging users to take more vehicle trips than they would have otherwise. If we consider that AVs may operate similarly to how transportation network companies (TNCs) do today, with the difference being that there is no longer a human driver, preliminary research on TNCs supports the claim that AVs could induce additional vehicle trips. In a 2017 UC Davis study on ride-hailing, Clewlow and Mishra asked respondents to answer the question, "If Uber and Lyft were unavailable, which transportation alternatives would you use for the trips that you make using Uber and Lyft?" Twenty-two percent of respondents said they would have just made fewer trips if they hadn't used a TNC (Clewlow & Mishra, 2017). Since Uber and Lyft were an option, however, these respondents opted to take a vehicle trip that they would otherwise not have been made by any mode. This finding suggests that TNC users are increasing their overall VMT/VKT even though they are not driving personal vehicles for these trips. In terms of trip purpose, respondents cited their most common purposes for using a ridehailing service as going to bars and parties, going to restaurants and cafes, for family and community purposes, and for shops and services, in that order. Parking and the desire to avoid driving when drinking represented the top two reasons that respondents gave for opting to take a TNC in place of driving themselves (Clewlow & Mishra, 2017).

Several studies examining the impacts of TNCs on congestion have also concluded that TNCs are contributing to increased congestion, and as a result, additional VMT/VKT (Gehrke, Felix, & Reardon, 2018; Schaller, 2017; SFCTA, 2017). Researchers at the Metropolitan Area Planning Council in Boston found that 15% of ride-hailing trips are adding cars to regional roadways during morning and afternoon rush hours (Gehrke, Felix, & Reardon, 2018). In San Francisco, researchers concluded that on a typical weekday TNCs are averaging 570,000 VMT, which they consider to be a conservative estimate. In comparison, they estimate that taxis in San Francisco generate 66,000 VMT on a typical weekday (SFCTA, 2017). There are two important contributing factors: in-service VMT/VKT, or the distance traveled while transporting a passenger, and out-of-service VMT/VKT, or the distance traveled during circulation periods. With the current model of TNCs, those circulation periods represent single-occupancy trips but with fully automated vehicles, those same trips are likely to be zero-occupancy, or "zombie" trips with no people in the vehicle.

The amount of CO2 emitted while driving depends on a combination of factors including vehicle type, driving behavior, roadway type, and level of congestion. The speed at which a vehicle travels affects its fuel economy, which results in varying degrees of CO2 emissions throughout the course of

[2] *In order to maintain consistency with the research findings referenced in this literature review, the term vehicle-miles-traveled (VMT) is used alone if the researchers specifically measured impacts on VMT, and the term vehicle-kilometers-traveled (VKT) is used alone if the researchers measured impacts on VKT. The terms are used together when drawing general conclusions*

[3] *Latent demand refers to "the activities and travel that are desired but unrealized because of constraints" (Clifton & Moura, 2017).*

one vehicle trip. In general, emission rates per mile or kilometer are higher when a car travels at either very low average speeds, since that usually represents stop-and-go driving, or when it travels at much higher speeds as high speeds demand high engine loads, requiring more fuel (Barth & Boriboonsomsin, 2009). Increased congestion can result in cars accelerating, decelerating, and idling more frequently, which impacts CO2 emissions. Researchers at Texas A&M's Transportation Institute attempted to quantify the additional amount of emissions generated by urban congestion and found that "56 billion pounds of additional CO2 were produced at the lower speeds under congested conditions" (Eisele, et al., 2014, p. 73). The researchers calculated that 498 urban areas in the United States produced a combined total of 1.8 trillion pounds of CO2 emissions in 2011. These findings suggest that if TNCs are contributing to increased congestion and are spending more time idling while waiting for passengers, they are likely contributing to increases in CO2 emissions as well.

Of course, different vehicle types produce varying levels of CO2. Researchers have examined variations of fuel speed curves for vehicles with different powertrains to determine how they respond to congestion. They found that internal combustion engines lose fuel efficiency when traffic slows to approximately 30 miles per hour (mph), compared to hybrid gas-electric vehicles, which are less sensitive to speed changes and maintain fuel efficiency until 20 mph (Bigazzi & Clifton, 2015). The researchers found that fully electric vehicles actually increase fuel efficiency as the average speed drops down to about 20-30 mph, after which fuel efficiency begins to decrease. Additional information about the differences between different engine types and their environmental impacts is included in later sub-sections of this literature review, but it is worth noting here the role that congestion has in fuel efficiency.

SHARED MOBILITY

The impacts that AVs will have on climate pollution and congestion will also be governed by the extent to which they are shared. Will companies own fleets of AVs offering trips to users, i.e. mobility as a service (MaaS), or will individuals purchase AVs for personal use in the vein of traditional vehicle ownership? Historically, academic research on shared mobility has been focused primarily on the impacts of carsharing programs on travel behavior and vehicle ownership. More traditional carsharing models like Zipcar are station-based where vehicles have to be picked up and dropped off at the same location. Martin and Shaheen found that participation in a carsharing program did not reduce the absolute VMT for every household surveyed, but that the large reduction that some households made compensated for minimal increases in VMT by other households (Martin & Shaheen, 2011). Namazu and Dowlatabadi examined the impacts of carsharing on GHG emissions in Vancouver, BC. Instead of focusing on VKT, they focused on other travel behavior outcomes like trip aggregation, and they found that study participants were more likely to aggregate trips of shorter distances (<5km) when using carshare (Namazu & Dowlatabadi, 2015). This change in behavior reduced the overall number of trips taken since they eliminated some return trips and increased the likelihood that the vehicle's engine would remain at, or close to, its operating temperature, thereby increasing fuel efficiency in conventional gasoline-powered vehicles.

Newer carshare models, like Car2go, are "free-floating"; instead of going to a fixed location, users can pick up and drop off vehicles at different locations using GPS to locate the closest vehicle. Firnkorn and Müller studied the impacts of Car2go in Ulm, Germany after it was introduced in 2009. They concluded that the average Car2go user would likely emit less CO2 by using shared vehicles than they would otherwise. These researchers also discussed the potential benefits of carsharing in reducing "cold starts" through a reduction in cooling periods as a result of more frequent use (Firnkorn & Müller, 2011).

Free-floating carshare programs like Car2go more closely represent what we might expect an AV fleet model to look like, with the important distinction that the user would not have to travel to the nearest vehicle location. Instead, the vehicle could be summoned to the user similar to how ride-hailing apps currently function. Fagnant and Kockelman modeled the potential impacts of a fleet of AVs on GHG emissions. They designated a 10mi x 10mi service area with a gridded central business district and assumed a fleet of conventional gasoline-powered AVs would make individual trips to transport passengers (Fagnant & Kockelman, 2014). Their findings suggest that we might expect to see only minor reductions in GHG emissions to account for the increased driving required by a fleet of AVs that must travel to pick up passengers and, in their model, might also be occasionally relocated to more optimal areas based on demand. This finding is consistent with the more recent studies about TNC usage that suggest that TNCs contributed to increased congestion, partially due to the high number of out-of-service trips, resulting in negative climate pollution impacts. According to their model results, Fagnant and Kockelman conclude that a shared fleet would incur 11% more travel compared to non-shared vehicles, but they also suggest that a fleet of AVs could save participating users ten times the number of cars they would otherwise need, a potentially significant cost savings to individuals.

The question about whether users are willing to forego personal ownership of a vehicle in favor of programs like carsharing is one piece of the shared mobility puzzle. Another important question is if users are not only willing to share vehicles, but also share rides, similar to more traditional carpool and vanpool models. In 2014, both UberPOOL and Lyft Line were launched, allowing passengers to share rides for discounted rates. These services use algorithms to match passengers based on nearby pick-up and drop-off locations. While usage data on these services is still limited, there is some indication that adoption is growing. According to a recent report about the Future of Mobility, Susan Shaheen et al. noted that as of December 2017, "905 million UberPOOL and Lyft Line trips (combined) had been taken since the services launched. (Shaheen, Totte, & Stocker, 2018, p. 48). According to data shared by Lyft, "Line adds up to about a quarter of all trips on the Lyft platform" (Lekach, 2018). Lyft Line appears to be most popular in major cities like San Francisco, Los Angeles, Chicago, New York, and Miami, and it was used nearly 100 million times in 2017 (Lekach, 2018). Despite these promising figures, some questions remain about attitudes and willingness to share rides. Gehrke et al. found that only one-fifth of survey respondents took a shared ride like UberPOOL and that the majority of TNC travel in the Boston region involved a single passenger (Gehrke, Felix, & Reardon, 2018). Information about whether or not a shared ride was an option for respondents is not listed in the report, and it does not appear that respondents were asked to provide a reason for opting for a private ride over a shared ride when offered the option, so more research is need on this topic. However, preliminary findings do suggest that these services are most popular in dense, urban areas in major cities.

MODE SPLIT

The impact that AVs may have on mode share is another important consideration. Travel behavior theory suggests that the decision to use one mode over another is informed by a variety of factors including, but not limited to, socioeconomic status, age, the price of gas, urban form, and the availability of transportation options. In a recent white paper published by Circella et al., researchers analyzed the National Household Travel Survey (NHTS) and found that while the total number of person trips increased between 1995 and 2009, mode distribution shifted and the percentage of person trips made by car decreased (Circella, Tiedeman, Handy, Alemi, & Mokhtarian, 2016). Buehler and Hamre found that Americans became increasingly multimodal during that same time period (Buehler & Hamre, 2014). However, there have been a rash of more recent reports that have found that transit ridership is decreasing in most major U.S. cities, which may be attributed to a variety of factors including, but not limited to, a sustained period of economic growth following the Great Recession; the rise of transportation network companies[4]; higher rates of car ownership; and declining gas prices (Siddiqui, 2018; American Public Transportation Association, 2018). There are a few notable exceptions, including both Seattle, WA and Vancouver, B.C.; both cities have seen transit ridership grow in the last year (Lindblom, 2018; Kerr, 2018).

[4] Transportation network companies (TNCs) operate in Portland, OR and Seattle, WA, but they do not currently operate in Vancouver, B.C. due to Provincial legislation.

Unsurprisingly, the growth of TNCs in the last few years has impacted travel behavior and preliminary research suggests that TNCs are impacting transit ridership. In the Boston-area study conducted by the Metropolitan Area Planning Council (MAPC), researchers found weekly or monthly transit pass holders are substituting TNCs for transit more frequently, and that those "who ride transit more often are more likely to drop it for ride hailing, even while doing so at a huge cost differential, and even when they have already paid for the transit (Gehrke, Felix, & Reardon, 2018)." TNCs may also be replacing trips that otherwise would have been made by walking and biking. Using weighted data, Clewlow and Mishra found that only 39% of trips made using Uber and Lyft would otherwise have been made by car, i.e. drive alone, carpool, or taxi (Clewlow & Mishra, 2017). The majority of trips would otherwise not have been made at all, or would have been made by walking, biking, or transit. Transit services being too slow, not having enough stops or stations, and not having service at times needed where the primary reasons respondents cited for substituting ride-hailing for transit (Clewlow & Mishra, 2017). These findings are corroborated by MAPC in Boston. According to MAPC researchers, 42% of the people they surveyed indicated they would otherwise have taken public transit for their trip and an additional 12% said they would have walked or biked (Gehrke, Felix, & Reardon, 2018). If AVs follow the patterns we are beginning to see emerge with TNC usage, these trends could be worsened by AVs since a ride in a TNC-operated fully autonomous vehicle that does not include a driver will likely be cheaper than the cost of an average ride today. On the other hand, new mobility services like TNCs, and eventually AVs, could boost ridership if they help solve the first-mile/last-mile problem and serve as a complement to transit.

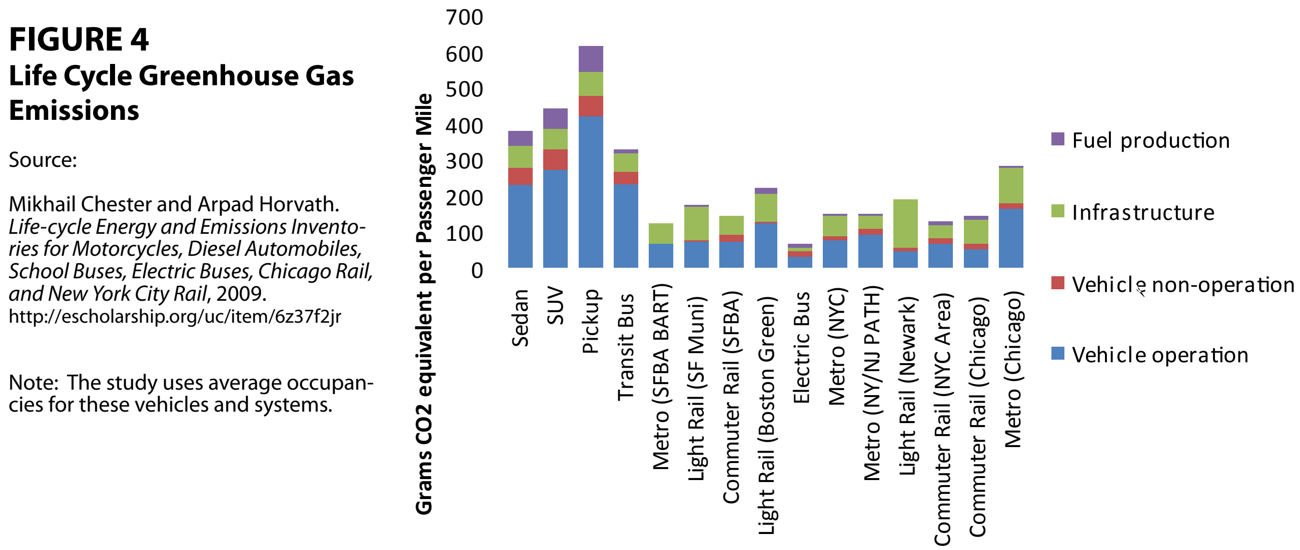
Because AVs could significantly cut into transit ridership if they are priced so competitively that they are cheaper than transit, or alternatively, could serve as a complement to transit, investing in transit upgrades and improvements that encourage mode shifts will likely be critical. Both Seattle and Minneapolis have seen ridership increase on bus lines that received significant improvements. In Minneapolis, for instance, buses along an enhanced bus route get priority at signals, riders can board at any door, stations are equipped with shelters, bicycle racks, and arrival information, and buses run every 10 minutes during peak periods; ridership has since increased by 30 percent (Schmitt, 2018).

In addition to improvements in active transportation infrastructure, a variety of pricing mechanisms can also be utilized to encourage mode shifts. Instituting congestion pricing has been shown to reduce single-occupancy mode share during peak travel times. Parking is also an important pricing mechanism that can be used to impact travel behavior. Free or low-cost parking encourages vehicle use, while higher parking costs, which can be dynamic based on demand, can help to encourage non-automobile modes. That said, in both the UC Davis and the MAPC studies on ride-hailing, respondents indicated availability and cost of parking as a primary reason for choosing to take a TNC. The cost of parking is influencing travel behavior, but since TNCs are an option, vehicle use is not necessarily decreasing. The demand for parking in an era of fully automated vehicles is likely to decrease further since AVs will be in a position to continue operating without anyone in the vehicle. If an AV is owned by an individual, that vehicle could potentially drop its owner off and then be sent to run other errands before returning for its passenger. A shared AV might be in even more continuous use since it would be picking up and dropping many riders, or perhaps performing other services like deliveries when not ferrying passengers. Given that parking costs may be less effective in influencing travel behavior in the future, congestion pricing and investments in infrastructure that encourage non-auto modes will likely be even more important.

From an environmental standpoint, the difference between emissions produced by private vehicles and the emissions produced by transit is a critical reason to invest in transit and encourage transit ridership. According to a 2009 report issued by the American Public Transportation Association (APTA) transit emissions can be measured by both 'debits' and 'credits.' Debits refer to the emissions that are produced by transit, such as tailpipe emissions from transit vehicles and electricity used, while credits refer to the emissions that are displaced by transit, such as car trips that are avoided and improved fuel efficiency resulting from decreased congestion (American Public Transportation Association, 2009). Based on a series of studies conducted between 2002 and 2008, APTA found that at the national level, transit benefits range from "16 to 37 million metric tons (MMT) of CO2-e per year offset by 12 MMT of emissions from transit, for a net benefit of between 4 and 25 MMT" (American Public Transportation Association, 2009, p. 2).

A report issued by the U.S. Department of Transportation Federal Transit Administration first released in 2009 and updated in 2010 also concludes that national averages "demonstrate that public transportation produces significantly lower greenhouse gas emissions per passenger mile than private vehicles" (Federal Transit Administration, 2010, p. 2). According to their analysis at the time, a private auto produced 0.96 pounds of CO2 per mile compared to the transit average of 0.45 pounds per mile. Emissions savings are also impacted by the number of riders; as ridership increases the net emissions benefits of transit also increase. While it is important to note that these findings are nearly ten years old and many vehicles now have improved fuel efficiency, the findings are nonetheless instructive. Transit emissions are lower than those of private vehicles even after accounting for emissions from construction, manufacturing, and maintenance (Fig. 2-1).

Figure 2-1. Life Cycle Greenhouse Gas Emissions, 2009



Source: Federal Transit Administration Report, 2010

SOURCE OF ENERGY AND ENERGY USE

The impacts of AVs on the environment will also depend on the types of vehicles that are automated. If AVs are largely conventional gasoline-powered vehicles and VMT/VKT is driven up as a result of some of the factors previously discussed, AVs would contribute to an overall increase in GHG emissions. However, electric autonomous vehicles (E-AVs) hold significant promise for reduced greenhouse gas emissions. In particular, Greenblatt and Saxena found that in 2030 battery-electric powered autonomous taxis could yield up to 87-94% reductions in GHG emissions compared to 2014 rates of internal combustion engine vehicles if combined with vehicle right-sizing (i.e., vehicle sizes to match total occupancy) (Greenblatt & Saxena, 2015).

It is worth considering the electric grid mix in the discussion of electric vehicles and GHG emissions, especially as there have been some conflicting reports about the extent to which electric vehicles provide environmental benefits if they are being powered by non-renewable sources. For example, a study completed in 2015 examined the differences in GHG emissions between electric and conventional gasoline vehicles, differentiating between fully electric vehicles, such as the Nissan Leaf, and hybrid electric vehicles like the Toyota Prius (Abdul-Manan, 2015). Abdul-Manan conducted a Life Cycle Assessment (LCA) and attempted to account for the possible variations that may affect the lifecycle GHG emissions of a vehicle. The author's findings suggest that GHG emission benefits from fully electric vehicles vary and are reliant on a few primary factors: the type of conventional vehicle being replaced, the type of electric vehicle replacing it, and the types of energy used to power the electric vehicle.

Another study completed by Yuksel and Michalek in 2016 concluded that gasoline and electric plug-in vehicles produce varying carbon footprints regionally (Yuksel, Tamayao, Hendrickson, Azevedo, & Michalek, 2016). In their study, the Chevrolet VOLT, a plug-in electric vehicle, was found to have higher life-cycle emissions than the Toyota Prius, a hybrid-electric vehicle, in all study counties due to a higher gasoline/mile use in charge sustaining mode. However, the Nissan Leaf, a battery-electric vehicle, had lower life-cycle emissions than the Toyota Prius in urban counties throughout much of the southwestern US, as well as Florida and Texas, while the Prius' emissions were lower than the Leaf's throughout most of the rest of the country.

However, new data released by the U.S. Environmental Protection Agency and analyzed by the Union of Concerned Scientists suggest that driving on electricity is cleaner than a 50 MPG vehicle for 75 percent of the U.S. (Reichmuth, 2018). In addition, according to their analysis, "99 percent of the country is in a region where electricity emissions would be lower than a 50 MPG gasoline vehicle" if you consider the more efficient EVs, including the Hyundai Ioniq BEV and the Prius Prime. Electric grids have been getting increasingly cleaner, contributing to the steadily increasing benefits of electric vehicles. They conclude that it is "vital that we accelerate the adoption of EVs, even if all power is not yet from renewable or low-carbon sources" (Reichmuth, 2018).

In terms of regional fuel mix, Vancouver, BC and Seattle, WA both rely heavily or exclusively on hydropower. According to Drive Clean Seattle, Seattle's electricity is carbon free, which means that "every gallon of gasoline or diesel which is replaced by electricity is a 100% reduction in carbon pollution" (Finn Coven, Bast, & Morgenstern, 2017, p. 4). The City of Vancouver is "serviced by a clean and reliable electrical system, which also powers much of the city's transit service" (City of Vancouver, 2016, p. 4). The City of Portland, however, draws power from a wider mix of sources. According to the City of Portland's 2015 Climate Action Plan, "despite substantial hydropower in the Pacific Northwest, two-thirds of the electricity that serves Multnomah County is generated from coal and natural gas" (City of Portland and Multnomah County, 2015, p. 59). While Portland's energy sources are not as clean as Seattle and Vancouver's, Portland nevertheless has an electric vehicle strategy in place, which acknowledges that: "The City seeks to further reduce upstream greenhouse gas emissions associated with EVs by strongly encouraging the deployment of both public and private charging stations powered by renewable electricity" (City of Portland, Undated).

For gasoline-powered vehicles and hybrid-electric vehicles (HEVs), the possibility that AVs hold of increased fuel efficiency is another important consideration. It is estimated that AVs could reduce energy use by up to

~80% from platooning, efficient traffic flow, and more efficient performance (Greenblatt & Shaheen, 2015). Wadud et al. also suggest that AVs could improve fuel efficiency via automated eco-driving, and potentially, a decreased emphasis on acceleration performance when a human is no longer behind the wheel (Wadud, MacKenzie, & Leiby, 2016). Iglinksi and Babiak also suggest that AVs will more strictly adhere to traffic laws based on their programming compared to human drivers, and they will be more likely to travel at posted speed limits, which are related to optimal fuel efficiency. (Iglinski & Babiak, 2017)

Of course, the production of light-duty, personal vehicles, regardless of fuel sources, also requires energy consumption. Life cycle assessments attempt to quantify the total GHG emissions associated with a vehicle from 'cradle-to-grave,' and reports on total amounts vary, though battery electric vehicles are considered altogether cleaner than gasoline-powered vehicles despite the higher emissions associated with manufacturing (Nealer, Reichmuth, & Anair, 2015). For this reason, it is worth circling back to the point about mode split and the benefits of prioritizing transit, especially electrified transit. Encouraging transit use is environmentally beneficial since emissions per mile or kilometer decrease as occupancy increases. In a battery-electric bus (BEB) emissions savings are even greater. Researchers at Carnegie Mellon University recently attempted to compare the life cycle emissions of BEBs compared to other bus types and in general, they found that BEBs are promising since they exhibit high fuel efficiency, have zero tailpipe emissions, and low external costs. They do note, however, that external funding is critical component in adopting BEBs since they have the higher purchase costs than conventional diesel vehicles (Tong, Hendrickson, Biehler, Jaramillo, & Seki, 2017). Increasingly transit agencies are moving towards electrified fleets. New York, for instance, announced in April 2018 that it will convert its bus system to an all-electric fleet by 2040 at the latest (Roberts, 2018). This announcement follows the publication of a report requested by New York City Transit comparing its current fleet of buses to an electric fleet. Greenhouse gas emissions were calculated for electric buses and compared to the annual GHGs for the existing fleet. According to the report, New York City could save "nearly 500,000 metric tons of CO2 per year by switching the fleet to all electric" (Aber, 2016, p. 12). This calculation accounts for the emissions associated with the regional power generation sources, which helps illustrate just how dramatic the savings would be. Thus, reducing reliance on personal vehicles in general is an important strategy in working towards the goal of carbon reduction.

LAND USE/METROPOLITAN FOOTPRINT

There has been much speculation about the impacts that fully automated vehicles will have on commute tolerance, which is an important consideration since there is a substantial body of research that links land use density to vehicle travel. If people are freed from the burden of being behind the wheel and can instead use that time for work or leisure, will they be willing to tolerate longer commutes? What kinds of pressures on dispersion and sprawl might AVs create and what are the potential impacts of changes in location preference on GHG emissions? As Barrington-Leigh and Millard-Ball note, "a large body of empirical evidence links sprawl with greater vehicle travel, energy consumption, and greenhouse gas emissions" (Barrington-Leigh & Millard-Ball, 2017, p. 1). In 2009, for instance, researchers Cervero and Murakami examined data from 370 urbanized areas in the U.S. and used structural equation modeling to determine that population density is strongly and positively associated with VMT per capita, meaning that as population density increases, VMT per capita decreases. However, they also found that positive effects of higher population densities are offset somewhat by the travel-inducing effects of dense roadway infrastructure, which they refer to as the "Los Angeles effect," where population density is high but where the intensity of the road network encourages driving over transit. Based on their findings, they assert "that the largest VMT reductions would come from creating compact communities which have below-average roadway provisions, more pedestrian/cycling infrastructure, and in-neighborhood retail activities which invite non-motorized travel" (Cervero & Murakami, 2010, p. 416).

Previous studies have shown that areas dominated by cul-de-sacs and three-way intersections, what Barrington-Leigh and Millard-Ball refer to as "street-network sprawl," more cars are needed and they are driven more, even after controlling for other aspects of the urban form. However, these researchers assert that previous studies do not capture the full impact of street-network sprawl on travel behavior and that the impacts are more than previously found. They write: “We find that reducing street-network sprawl can make a large contribution to greenhouse gas mitigation, particularly in the medium-to-long term. On current trends alone, we project vehicle travel and emissions to fall by ~3.2% over the 2015-2050 period, compared to a scenario where sprawl plateaus at its 1994 peak. Concerted policy efforts to increase street connectivity could nearly triple these reductions by to ~8.8% by 2050” (Barrington-Leigh & Millard-Ball, 2017, p. 12). One of the other important points they make is that when it comes to urban form, we have traditionally been much more likely to change buildings than roads; “residential roads tend to remain where they were first placed” (Barrington-Leigh & Millard-Ball, 2017, p. 2) These findings suggest that if the advent of AVs increases development pressures in suburban areas, the result could be an increase in GHG emissions as people locate in areas that encourage more auto travel.

A study conducted by researchers in Salt Lake City points to another reason why limiting sprawl is environmentally beneficial (Mitchell, et al., 2017). By tracking localized emissions in a variety of geographic areas in and around Salt Lake City over a ten-year span, these researchers were able to determine that there is a non-linear relationship between population growth and excess CO2 emissions. They found that “rapidly increasing daytime emission rates during the summer occurred in areas with initially low population density that underwent conversion of rural land to suburban developments while emissions were stable in the urban core despite population increases” (Mitchell, et al., 2017, p. 5). This suggests that having the right tools in place to encourage growth in previously urbanized areas could help reduce harmful environmental impacts related to sprawl.

Researchers in Vancouver, BC also found that compact development has important life-cycle GHG emissions benefits even if not co-located with high frequency transit. They compared four residential areas in Vancouver with different levels of residential densities and compared neighborhood-level GHG emissions by estimating the emissions from motorized transportation, quantifying the buildings’ operating energy, and quantifying the embodied energy related to construction and maintenance. Their results indicate that even with unchanged transportation consumption patterns, compact suburban developments (i.e. a mixture of large and small single-family homes, townhouses, and small apartment buildings) can realize emissions reductions of up to 22% (Senbel, Giratalla, Zhang, & Kissinger, 2014). The results of this study further support the notion that land use policies that discourage sprawling developments are an important component of efforts to reduce harmful GHG emissions.

FREIGHT AND PERSONAL GOODS DELIVERY

According to the Environmental Protection Agency, light-duty vehicles, which include passenger vehicles, trucks, and motorcycles, accounted for 60% of the transportation sector's GHG emissions in 2015, which is substantial (Environmental Protection Agency, 2017). However, medium- and heavy-duty trucking generated 23% of the transportation sector's GHG emissions in 2015, so it is also important to consider the movement of goods in addition to passengers as we consider an automated future (Environmental Protection Agency, 2017). A number of companies, including Daimler and Tesla are already working on developing autonomous heavy-duty freight technology, which, if implemented, could have important safety and efficiency implications. Given that the trucking volumes are expected to increase by 17% by 2026 according to the American Trucking Association, these improvements are even more anticipated (American Trucking Associations, 2015). The opportunity for platooning, which would enable two or more electronically connected trucks to travel in close proximity to each other, is just one way that autonomous trucking could reduce GHG emissions. Researchers from the University of Michigan cite several studies that estimate each vehicle in a platoon could experience fuels savings of up to 10% (Shoettle & Sivak, 2017). Cities should consider the ramifications that large autonomous vehicles may have on their transportation networks, such as enabling a platoon of vehicles to travel on arterials and major highways.

In addition to large freight it is important to consider local delivery, or urban goods delivery, which has increased significantly with the growth of E-commerce and app-based ordering. More goods are being ordered online than ever before, and consumers are choosing shorter and shorter delivery windows as retailers offer those options. Amazon, for instance, offers a variety of shipping options ranging from same-day and one-day with Amazon Prime, to one- and two-hour delivery windows with Prime Now. While Amazon uses traditional package delivery companies like the United States Postal Service (USPS) for many of its shipments, it also offers independent contractors the opportunity to use their private vehicles to deliver items through their Amazon Flex program. Because companies like USPS are regulated carriers, data is collected about the number of trips they make. Individuals using their private vehicles for deliveries (i.e., Amazon Flex, UberEats, Instacart, Caviar, etc.) are not regulated as motor carriers and as a result, cities do not have data on the number of trips they are making, which means they are not accounted for in travel demand models (Rutter, Bierling, Lee, Morgan, & Warner, 2017). As researchers in the University of Washington's Urban Freight Lab note, "U.S. cities do not have much information about the urban goods delivery system" (Supply Chain Transportation & Logistics Center, 2018, p. 5). Beyond these express delivery services, most grocery stores now offer their own grocery delivery options enabling customers to shop online. The last several years have also witnessed the rise of meal kit delivery services, such as Hello Fresh and Blue Apron, in addition to personalized shopping services, like Stitch Fix, which enable customers to receive a shipment of new clothes without ever setting foot in a store.

While many of these services are replacing trips that customers would otherwise have made themselves in a personal vehicle, the rise of e-commerce and expedited delivery may also be contributing to a net increase in vehicle trips. For instance, a customer may drive to a store to try on clothes but order online later, precipitating an additional vehicle trip than otherwise would have been generated if they had purchased the item in-store. Today, Uber drivers can toggle between passenger and food delivery, and it is certainly possible that fully automated AVs will operate similarly, especially if they operate as shared fleets. The continuation of these trends means that even more delivery vehicles may be on the road vying for limited curb and loading zone access, contributing to congestion, and increasingly cities are recognizing the need to reexamine curb space and loading zones to accommodate both TNCs and delivery services. While public agencies have data on city streets, goods delivery utilizes not just private vehicles, as acknowledged above, but also private loading facilities. In recognition of the need for more information about urban goods delivery, the Seattle Department of Transportation partnered with the University of Washington's Urban Freight Lab, and the Urban Freight Lab assessed "privately-owned and operated elements of the Final 50 Feet of goods delivery supply chains" (Supply Chain Transportation & Logistics Center, 2018, p. 5). While this assessment provides useful data about the daily usage rate of privately-owned loading facilities, more information is needed to understand the total number of deliveries generated by these facilities since some personal goods deliveries are made using private vehicles that do not access the loading facilities. Since limited information exists about this topic, this is an area where future research is needed.

The next section of this report will explore plans and policies that relate to the themes identified in this literature review.

3

POLICY AND PLAN REVIEW RELATED TO GREENHOUSE GAS EMISSIONS AND AUTONOMOUS VEHICLES

ABOUT

This section begins with a broad overview of plans by the Cities of Portland, Seattle, and Vancouver to reduce greenhouse gas emissions, followed by an overview of the policy and programmatic approaches and strategies being developed for new mobility by each city in the context of adopted climate action plan goals. Then, this section goes into detail about specific land use and transportation topics and how other North American cities are regulating AVs and new mobility technologies, especially related to mitigating potential negative impacts related to GHG emissions. A distinction is drawn between policies and plans that have been adopted and documents that have been developed, primarily by city staff or consultants, to inform AV and new mobility policies that have yet to be adopted.

PORTLAND, SEATTLE AND VANCOUVER CLIMATE ACTION PLANS

The Cities of Portland, Seattle, and Vancouver have adopted plans to reduce GHG emissions. These plans inventory carbon emissions from all sources in their respective cities, identify goals to reduce GHG emissions, and then describe strategies and actions to reduce emissions. The introduction of autonomous vehicles presents the greatest risks and opportunities to GHG emission goals for land use and transportation strategies and actions. This section provides a brief overview of the Cities of Portland and Seattle's Climate Action Plans, and Vancouver's Greenest City Action Plan and identifies the land use and transportation strategies that will be most relevant when crafting new mobility strategies. This section also identifies how each of the three cities have incorporated equity considerations into their climate planning processes. Table 3-1 shows an overview of GHG emission reduction goals for each city.

Table 3-1. Overview of Climate Action Plans for Portland, Seattle, and Vancouver

	Plan Name	Adoption Date	GHG Reduction Goals	VMT/VKT Reduction Goals
City of Portland	City of Portland and Multnomah County Climate Action Plan	2015	2030: 40% reduction from 1990 levels 2050: 80% reduction from 1990 levels	2030: 30% reduction in daily per capita VMT from 2008 levels
City of Seattle	Seattle Climate Action Plan	2013	2030: 58% reduction from 2008 levels 2050: 100% carbon neutral	2030: 20% reduction in VMT from 2008 levels
City of Vancouver	Greenest City 2020 Action Plan	2015	2050: 80% reduction from 2007 levels	2020: 20% reduction per resident from 2007 levels

CITY OF PORTLAND

The City of Portland adopted its first plan to reduce GHG emissions in 1993 with the Carbon Dioxide Reduction Strategy. Since then, it has created two updated strategies, the most recent being the 2015 City of Portland and Multnomah County Climate Action Plan (CAP) (City of Portland and Multnomah County, 2015). The 2015 document is summarized in this section.

The City and County have a goal of reducing local carbon emissions by 80% by 2050 from 1990 levels, with an interim goal of 40% by 2030. The CAP estimates that about 24% of the reductions will need to come from land use and transportation. To accomplish those goals, the CAP identifies that residents and employers will need to drive less and use less electricity, among other things. It designates a goal of reducing per person emissions from 15 metric tons (1990) to 2 metric tons (2050). It also sets the goals of daily passenger miles per person from 17 (1990) to 6 (2050) and electricity from 13,000 (kWh) per person (1990) to 6 (2050).

The Portland and Multnomah CAP identifies 20 objectives and over 100 actions that will help it achieve these goals. The most relevant objectives for the creation of AV and new mobility polices are those that influence urban form and transportation. The four objectives related to urban form and transportation are:

- Objective 4: Create vibrant neighborhoods where 80 percent of residents can easily walk or bicycle to meet all basic daily, non-work needs and have safe pedestrian or bicycle access to transit. Reduce daily per capita vehicle miles traveled by 30 percent from 2008 levels.
- Objective 5: Improve the efficiency of freight movement within and through the Portland metropolitan area.
- Objective 6: Increase the fuel efficiency of passenger vehicles to 40 miles per gallon and manage the road system to minimize emissions.
- Objective 7: Reduce lifecycle carbon emission of transportation fuels by 20 percent.

The Portland and Multnomah CAP illustrates how compact urban form reduces carbon. It notes that more people walk and bike when there is a certain density of destinations within ¼ mile and 3 miles, respectively. In addition, new multifamily buildings are more carbon efficient than single-family homes. Given that the City anticipates that 80 percent of new residential development will be multi-family, this gives the City an opportunity to increase residential densities in Centers and Corridors where close proximity of housing and destinations encourages walking and biking.

Many of the actions for the four objectives listed above identify the need for funding to ensure a multi-modal system that covers the construction for capital projects as well as operations and maintenance.

- Objective 19: Reduce carbon emissions from City and County operations by 53% from fiscal year 06-07 levels as well as Objective 20: Build City and County staff and community capacity to ensure effective implementation and equitable outcomes of climate action efforts are both important objectives (and associated actions) to track and build upon to make sure that policies related to AVs are equitable and that the City and County are doing all they can to reduce GHG emissions.

In order to better integrate equity considerations into the planning process, the City of Portland formed a Climate Action Plan Equity Work Group to advise the City on equity implications for the 2015 Climate Action Plan. The City ultimately conducted an equity assessment of every action proposed in the draft Climate Action Plan and updated actions to reduce negative and increase positive impacts for disadvantaged populations. The primary equity considerations they identified include (Williams-Rajee & Evans, Climate Action Through Equity, 2016, p. 12):

1. Disproportionate impacts. Does the proposed action generate burdens (including costs), either directly or indirectly, to communities of color or low-income populations? If yes, are there opportunities to mitigate these impacts?

2. Shared benefits. Can the benefits of the proposed action be targeted in progressive ways to reduce historical or current disparities?

3. Accessibility. Are the benefits of the proposed action broadly accessible to households and businesses throughout the community – particularly communities of color, low-income populations, and minority, women, and emerging small businesses?

4. Engagement. Does the proposed action engage and empower communities of color and low-income populations in a meaningful, authentic and culturally appropriate manner?

5. Capacity building. Does the proposed action help build community capacity through funding, an expanded knowledge base or other resources?

6. Alignment and partnership. Does the proposed action align with and support existing communities of color and low-income population priorities, creating an opportunity to leverage resources and build collaborative partnerships?

7. Relationship building. Does the proposed action help foster the building of effective, long-term relationships and trust between diverse communities and local government?

8. Economic opportunity and staff diversity. Does the proposed action support communities of color and low-income populations through workforce development, contracting opportunities or the increased diversity of city and county staff?

9. Accountability. Does the proposed action have appropriate accountability mechanisms to ensure that communities of color, low-income populations, or other vulnerable communities will equitably benefit and not be disproportionately harmed?

CITY OF SEATTLE

The City of Seattle adopted the most recent Seattle Climate Action Plan (Seattle CAP) in June 2013 (City of Seattle, 2013). This plan built upon the efforts in the early 2000s for green building and Seattle City Light going 100% carbon neutral. In an effort to meet the Kyoto Protocols, the City of Seattle adopted its first Climate Action Plan in 2006. The 2013 Seattle CAP provides a coordinated strategy that lists actions related to road transportation, building energy, non-road transportation, and industry that the City can take to reduce GHG emissions.

The Seattle CAP established the following goals for 2030:

- Reduce emissions from passenger vehicles by 82%
- Reduce vehicle miles traveled by 20%
- Reduce emissions per mile traveled by 75%

The Seattle CAP identified 32 actions to implement by 2013, which can roughly be categorized as:

- Acquire transportation funding (such as renewing the Extend the Gap Levy and securing authority of transit agencies to levy a motor vehicle tax) that prioritizes active transportation projects;
- Develop transit, freight, transportation, and land use plans that implement Seattle CAP goals;
- Invest in pedestrian and bicycle facilities and programs in target areas across the city; and
- Invest in and encourage the increased adoption of electric vehicles for individuals, municipal fleets, and for-hire vehicles.

The Seattle CAP also notes that the City estimated that road pricing and parking management actions could reduce GHG emissions by about 25%

by 2030. The CAP states, "Additionally, road pricing is an essential strategy over the long term, because the actions not only reduce emissions, but also represent the single largest potential source of local or regional funding to implement transportation choices." (City of Seattle, 2013, p. 19). Besides highlighting the need for funding and road pricing, the plan also outlines actions related to transportation infrastructure and services, transportation demand management, vehicle fuels and technology, complete communities, and parking management.

In April, 2018, the City of Seattle published Seattle Climate Action in response to President Trump's decision to withdraw the U.S. from the Paris Climate Agreement (City of Seattle, 2018). The City Council directed the Office of Sustainability & Environment (through Resolution 31757) to detail actions the City will take to limit warming to 1.5 degrees Celsius (City of Seattle, 2017). Among the actions that this report includes are:

- Expanding transit, bicycling, and pedestrian infrastructure and services;
- Expanding charging infrastructure to foster increased adoption of electric vehicles;
- Guiding growth to walkable and transit-accessible neighborhoods; and
- Providing price signals that reflect the true cost of driving and incentivizes shared and electric transportation choices.

Importantly, this document declared the intention of the city to address congestion and transportation emissions through pricing.

The Seattle CAP identifies a number of implementation actions that are designed to address equity. For example, the CAP states that the City will design actions to:

1. Meet the needs of families, immigrant communities, an aging population, people with disabilities, and lower income residents.

2. Assist existing residents and businesses to remain and thrive in walkable, transit-oriented communities.

3. Expand low-cost transportation options to mitigate the impacts of economic signals that increase the cost of transportation, especially for lower income residents.

The city also identified the need to include "health, safety, and equity outcomes in transportation and land use planning building on the Healthy Living Assessment project" and "Research the benefits of pricing policies on climate protection, transportation and community goals (e.g. reduced congestion, improved air quality, revenue generation) and their potential social equity impacts and solutions by examining the experience of other communities" (City of Seattle, 2013, p. 10).

CITY OF VANCOUVER, BC

City of Vancouver policy direction is founded in four key plans: The Greenest City Action Plan (2011), Transportation 2040 (2012), The Healthy City Strategy (2014), and the Renewable City Strategy (2015). All of these plans contain policy to varying degrees that address carbon reduction, green transportation and compact communities. The Greenest City Action Plan is a high-level aspirational document with goals and targets towards making Vancouver the greenest city by 2020. Transportation 2040 is the principle plan that guides transportation planning for the City. The Healthy City Strategy contains a section on 'getting around' that references policies in Transportation 2040. The Renewable City Strategy focuses on reducing emissions from transportation, buildings, and waste.

The Greenest City Action Plan (GCAP) sets out aspirational goals and targets towards making Vancouver the greenest city in the world by 2020, outlining ten goal areas and 15 targets. By 2015, 80% of the actions were complete. An updated plan completed that same year focused on three goal areas: zero carbon, zero waste, and healthy ecosystems, with new target and actions including:

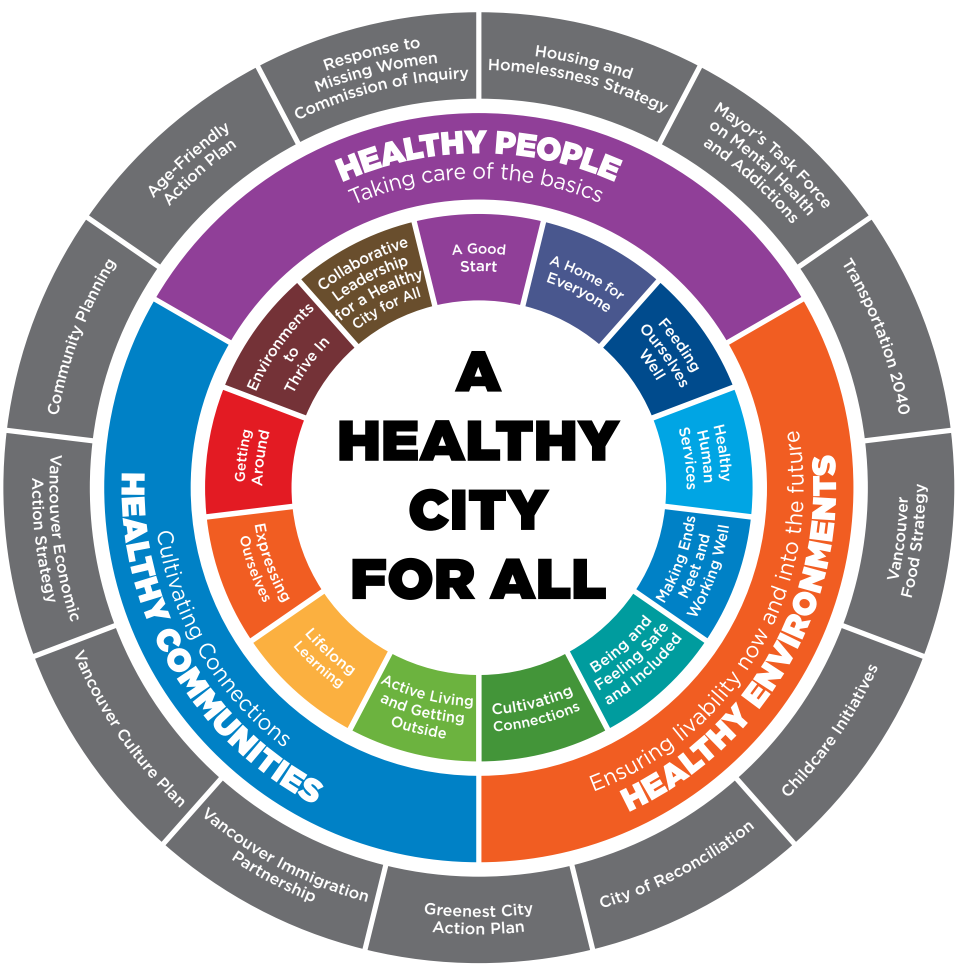
- Reduce community-based GHG emissions from 2.85 tCO_2e (2007) to 1.92 tCO_2e
- Make 100% of Vancouver's energy from renewable sources by 2050 (City of Vancouver, 2015, p. 5).

Transportation 2040 (T2040) identifies policies, actions and targets to support overarching sustainability goals (a thriving economy, healthy citizens, and enhanced natural environment). Policies and actions fall under seven direction areas: Land Use, Walking, Cycling, Transit, Motor Vehicles, Goods/Services and Emergency Vehicles, and Education/Encouragement/Enforcement. As of 2018, 80% of the plan is complete. Two key targets are identified in the plan (City of Vancouver, 2012):

- By 2040, at least two-thirds of all trips will be made on foot, bike or transit.
- Move toward zero related fatalities.

The Healthy City Strategy aligns with both the GCAP and T2040 and creates a vision where the city is "creating and continually improving the conditions that enable all of us to enjoy the highest level of health and well-being possible" (City of Vancouver, 2015, p. 6) Figure 3-1 shows the healthy people, communities, and environments framework and the plans it informs. The Healthy City for All identifies the target from the Greenest City Action Plan and Transportation 2040 goal of the majority (over 50%) of trips are on foot, bike, and transit. The indicators the city is tracking to determine if it has achieved the goal are: (1) sustainable transportation mode share (%), (2) number of active transportation trips, and (3) traffic-related fatalities.

Figure 3-1. City of Vancouver's A Healthy City for All Framework



Source: City of Vancouver, A Healthy City for All, 2015

The Renewable City Strategy is a continuation of the Greenest City Action Plan and sets the direction for Vancouver to be powered entirely by renewable energy by 2050 (City of Vancouver, 2015). The strategy initially focused on reducing emissions from transportation and buildings, but added waste with the updated plan in 2017. Transportation actions are aligned with T2040 including supporting compact communities, zero emission vehicles, car sharing and mobility pricing, and increase freight efficiency and transitioning commercial vehicles to sustainable fuels. Key goals include:

- 55% renewable energy by 2030, with a carbon reduction of 50% below 2007 levels
- 100% renewable energy by 2050, with a carbon reduction of 80% below 2007 levels

Major achievements in Vancouver over the past five years include:

- Greenhouse gas emissions (GHGs) have been reduced by 7% across the city, an 18% reduction per capita since 2007.
- By 2015, 50% of all trips were made by walking, cycling and transit, 5 years ahead of the 2020 goal.
- By 2018, there are 321 kilometers (km) of cycling infrastructure, with 81km of all ages and abilities (AAA) routes. Mobi bikeshare was established in 2016 with a fleet of 1,250 bikes and has seen huge public uptake. It is now being expanded with new stations and an additional 500 bikes this year.
- Transit, operated by TransLink, the regional transportation authority, is experiencing record ridership growth across the system. In 2017, total boardings were 407 million; by May 2018 ridership was up 9% over the same time the previous year.
- Four car-share services are operating in Vancouver and, as of 2017, 31% of Vancouver adults were car share members.

FEDERAL AND STATE/PROVINCE POLICY FRAMEWORK FOR AUTONOMOUS VEHICLES

Different levels of government have different roles when it comes to the regulation of motor vehicles and motor vehicle equipment. In Canada and the United States, the federal governments generally set safety standards and enforce compliance, including the management of safety recalls. The federal governments also conduct a number of public safety programs. The states and provinces regulate the human drivers and other aspects of operating the vehicle, such as issuing drivers licenses, registering vehicles, creating and enforcing traffic laws, conducting safety and environmental inspections, and regulating insurance and liability. Finally, local jurisdictions build and regulate the environment that vehicles operate in, such as through the creation, regulation and management of the local transportation system.

FEDERAL AUTONOMOUS VEHICLE POLICY

UNITED STATES

The United States has not adopted federal autonomous vehicle legislation, though the American Vision for a Safer Transportation Through Advancement of Revolutionary Technology (AV START) Act was introduced in September 2017. That same month, the National Highway and Transportation Safety Administration (NHTSA) released federal guidelines, A Vision for Safety 2.0, on Automated Driving Systems (ADS) (National Highway Traffic Safety Administration, Undated). This document provides voluntary guidance for the automotive industry and key stakeholders and includes 12 safety design elements including vehicle cybersecurity, human machine interface, crashworthiness, consumer education and training, and post-crash ADS behavior. It also includes guidance to states that encourage states to focus on enabling legislation and leave safety regulations to the federal government.

CANADA

Like the United States, the Canadian government has yet to adopt comprehensive autonomous vehicle legislation. Regulation of motor vehicles in Canada parallels the U.S. structure where the federal government focuses on safety and environmental regulations. The Policy and Planning Support Committee (PPSC) Working Group on Connected and Automated Vehicles published The Future of Automated Vehicles in Canada in January 2018 (Policy and Planning Support Committee (PPSC) Working Group on Connected and Automated Vehicles, 2018). While it is fairly high-level, it does identify 10 guiding principles/key issues that governments at all levels should consider when developing AV policies:

1. Road safety remains paramount
2. Standards and regulations cannot be developed in isolation
3. Innovation must be supported

4. There are significant privacy issues
5. Education and awareness is key
6. Technology expertise is urgently needed
7. Traffic laws must be updated
8. There are gaps in liability and insurance
9. Transitioning could be the primary challenge
10. Physical infrastructure modifications can wait

STATE AND PROVINCE AUTONOMOUS VEHICLE POLICY

OREGON

The State of Oregon passed HB 4063 in the 2018 Legislature establishing the Task Force on Autonomous Vehicles (representatives from the University of Oregon and the City of Portland in association with the League of Oregon Cities are members of the Task Force) to establish statewide enabling legislation (Oregon State Legislature, 2018). A legislative report with policy recommendations related to licensing and registration, law enforcement and crash reporting, insurance and liability, and cybersecurity and long-term issues is due in September 2018.

WASHINGTON

Washington State's Governor, Jay Inslee, issued an executive order in June 2017 that established a work group on autonomous vehicles and provided regulations for pilot projects (Inslee, 2017). The executive order work group is organized around five key areas: economic development and education, infrastructure, licensing and pilot programs, safety and law enforcement, and liability and insurance. On March 3, 2018 the Washington legislature also passed HB 2970 requiring the transportation commission to establish an executive and legislative work group tasked with developing policy recommendations (Washington State Legislature, 2018).

BRITISH COLUMBIA

The only province that has adopted AV regulations is Ontario, which created Canada's first regulations to allow AV pilots and testing in January 2016. The Province of British Columbia is unlikely to address AVs until after the Canadian government addresses federal issues and provides guidance to the provinces.

AUTONOMOUS VEHICLE AND NEW MOBILITY POLICIES FOR PORTLAND, SEATTLE, AND VANCOUVER

This section provides a broad overview of what the three cities have done related to AVs as of July 2018.

Table 3-2. New Mobility Reports and Resolutions Issued by Portland, Seattle, and Vancouver

	Name	Date	Agency	Description
City of Portland	Resolution 37296	June 2017	City of Portland	Guidance for AV policy, rules and implementation initiatives
City of Seattle	New Mobility Playbook, Version 1.0	Sept 2017	Seattle Dept. of Transportation	New mobility policy and strategy recommendations
City of Vancouver	Future of Driving	August 2016	TransLink	New mobility policy and strategy recommendations

THE CITY OF PORTLAND

The Portland City Council adopted Resolution 37296 on June 14, 2017 to support smart autonomous vehicle initiative implementation (City of Portland, 2017). The resolution directed the Portland Bureau of Transportation (PBOT) to include an autonomous vehicle policy in the Transportation System Plan (TSP 3) update, to "regulate and permit the use of Autonomous Vehicles through administrative rules," to gather information to launch autonomous vehicle pilot projects, and to implement an outreach strategy.

On June 15, 2018, the Portland City Council adopted an updated Transportation System Plan which includes automated vehicle goals and policies. The AV policies prioritize fleet automated vehicles that are electric and shared (known by the acronym FAVES). The TSP AV policy also includes:

Ensure that all levels of automated vehicles advance Vision Zero;

- Improve travel time reliability and system efficiency by maintaining or reducing vehicle trips and reducing low occupancy vehicles trips during peak congestion and include pricing based on congestion levels, VMT, vehicle occupancy, and vehicle energy efficiency;

- Cut vehicle carbon pollution by reducing vehicles with zero or one passengers. Also prioritize electric and zero emission vehicles; and

- Ensure benefits of AVs are equitable and that traditionally disadvantaged communities are not disproportionately hurt by AVs.

TSP Policy 9.69 reinforces the need for AVs and private data communications devices installed in the City right-of-way help to implement the goals in the City's Comprehensive Plan and Transportation System Plan. This section includes policy language for the City to identify and develop data sharing requirements for the management of the transportation system while protecting personal data. The City will also design and manage the mobility zone, curb zone, and traffic control devices to increase safety and manage the overall system. In addition, the City will create user-pays funding mechanisms that ensure that AVs and smart infrastructure, and private data communications operating in the City right-of way-help to pay for infrastructure investments and service, as well as support system reliability and efficiency.

CITY OF SEATTLE

Of the three cities, the City of Seattle's Department of Transportation (SDOT) has conducted the most in-depth analysis of new mobility and what it means for the city. In September 2017, SDOT published the New Mobility Playbook, Version 1.0, which is a "set of plays, policies, and strategies that will position Seattle to foster new mobility options while prioritizing safety, equity, affordability, and sustainability in our transportation system." (City of Seattle Department of Transportation, 2017, pp. 6-7) While not adopted policy, the Playbook and technical appendices outline specific strategies that the City will initiate over the next five years. The five plays are:

1. Ensure new mobility delivers a fair and just transportation system for all.
2. Enable safer, more active, and people-first uses of the public right of way.
3. Reorganize and retool SDOT to manage innovation and data.
4. Build new information and data infrastructure so new services can "plug-and-play."
5. Anticipate, adapt to, and leverage innovative transportation technologies.

Each of these "plays" include specific strategies; SDOT prioritized strategies focused on policy adoption, program initiation, conducting research, and prototyping or piloting projects.

The Playbook incorporates a wide range of social equity components. For example, the vision and values it identifies include a goal to "eliminate serious and fatal crashes in Seattle", "to provide an easy-to-use, reliable transportation system", and to provide "all people high-quality and low-cost transportation options." It acknowledges that historically disadvantaged groups continue to experience systemic discrimination and exclusion, and that the Playbook is designed to advance transportation options that work for everyone. One of the five principles is to advance race and social justice:

Mobility, whether shared, public, private, or automated, is a fundamental human need. Everyone needs a barrier-free transportation system and affordable transportation options that are understandable and accessible to all who want to use them. New mobility models should also promote clean transportation and roll back systemic racial and social injustices borne by the transportation system (City of Seattle Department of Transportation, 2017, p. 32).

CITY OF VANCOUVER

The City of Vancouver, in coordination with TransLink, the region's transportation authority, began planning for new mobility in 2015. The Future of Driving report, completed in August 2016, identified three primary policy recommendations (TransLink, 2016):

1. Update transportation policies and regulations to promote shared automated vehicles in support of regional objectives;

2. Proactively position TransLink to navigate rapid change while maintaining the resiliency of transportation operations and improving the customer experience; and

3. Create opportunities for government, industry and experts to explore and test innovative ideas to harness the positive benefits of automated vehicles and new mobility services.

The City of Vancouver developed a Future Mobility Workplan with City Council direction in 2018 (Bracewell, 2018). The City is now creating a strategic roadmap for new mobility and working with regional partners at TransLink and Metro Vancouver municipalities on new mobility policy options that will ultimately be incorporated into long range transportation plans. The strategic roadmap includes language that references the need to work together and coordinate policy; test innovative ideas that support mobility and safety goals; futureproof parking and other infrastructure; plan for a resilient economy that can respond to a changing job market; and encourage a shared approach that supports city and regional goals.

COMPARISON OF AUTONOMOUS VEHICLE AND NEW MOBILITY POLICIES FOR NORTH AMERICAN JURISDICTIONS

In order to contextualize the actions taken by the Cities of Portland, Seattle, and Vancouver, University of Oregon staff also reviewed plans, policies, and reports produced by other North American jurisdictions related to AVs specifically and new mobility services more broadly. A scan of these documents helps to better illustrate what actions the three case study cities have taken compared to other North American jurisdictions and what steps and/or policies they might considering pursuing. Table 3-3 outlines the additional documents reviewed and Figure 3-1 presents a flowchart to represent where these jurisdictions are in the planning process.

Table 3-3. Reports, Plans, and Policies Issued by Other North American Jurisdictions

Jurisdiction	Name	Date	Agency/Group	Description
Atlanta, GA	Regional Transportation Technology Policy Document	Dec 2016	Atlanta Regional Commission	Policy and strategy recommendations
Austin, TX	Smart Mobility Roadmap	Oct 2017	City of Austin and Capital Metro	Policy and strategy recommendations
Chandler, AZ	Ridesharing and Autonomous Vehicles Zoning Code Amendments	May 2018	City of Chandler	Adopted parking to passenger loading ratio zoning code updates
Los Angeles, CA	Urban Mobility in a Digital Age	2016	LA Dept. of Transportation	Policy and strategy recommendations
	Mobility Plan 2035	Sept 2016	Dept. of City Planning	Adopted as part of the General Plan in 2016
NY/NJ/CT Region	New Mobility: AVs and the Region (Component of Fourth Regional Plan)	Oct 2017	Regional Plan Association	Policy and strategy recommendations included in the Fourth Regional Plan (Nov 2017)
St. Louis, MO Region	Emerging Transportation Technology Strategic Plan	June 2017	East-West Gateway Council of Governments	Policy and strategy recommendations
Toronto, ON	Preparing the City of Toronto for AVs	Jan 2018	Transportation Services	Report on steps taken and proposed next steps

Fig. 3-2. New Mobility Policy Flowchart

Source: Urbanism Next, 2018.

Using the topics covered in the literature review as a guiding framework, this section outlines the policies and/or strategies that the Cities of Portland, Seattle, and Vancouver have identified or adopted pertaining to AVs and other new mobility technologies. This section is organized so that a summary of the case studies appears first followed by references to strategies and policies from other North American jurisdictions, as relevant. (Note that every document from jurisdictions other than the three case study cities is not referenced in every section.)

VEHICLE DISTANCE TRAVELED (VMT/VKT)

One of the most important ways to decrease transportation-related GHG emissions is to reduce the total vehicle distance traveled for both passengers and goods. All three case study cities focus on increasing active transportation mode split, in part by decreasing the vehicle distance traveled. As identified in the literature review, there is a significant risk of vehicle distance traveled increasing with the advent of autonomous vehicles and other new mobility technologies. Taken together, the package of policies, programs, and pricing strategies the Cities of Portland, Seattle, and Vancouver are developing are aimed at reducing the total distance traveled by passenger vehicles. Strategies related to reducing total distance traveled center around two efforts:

1. Reduce the distance between land uses, such as homes and work, shopping, school, and recreation; and

2. Change the mode of travel from vehicles to active transportation such as walking, biking, and transit. This section highlights specific language in policies or programs with the stated goal of reducing distance traveled of passenger vehicles.

CASE STUDY CITIES

CITY OF PORTLAND

Portland's new mobility policy in the Transportation System Plan (TSP) prioritizes FAVES: fleet automated vehicles that are electric and shared. The TSP policy supports actions that reduce the number of vehicle trips during peak congestion, reduce low occupancy vehicles, and ensure that these users of trips pay for the use of and impact on Portland's transportation system, taking into account congestions levels, vehicle miles traveled, vehicle occupancy, and vehicle energy efficiency. The TSP also includes a policy to reduce carbon pollution by reducing low occupancy "empty miles" by vehicles with zero or one passenger.

CITY OF SEATTLE

Play 5, Strategy 5.2, which is outlined in the New Mobility Playbook, is to "establish a comprehensive set of people-first policy parameters to introduce and manage fully shared, electric, connected and automated vehicles." In addition, many of the strategies it is initiating to promote active transportation are intended to shift mode share and result in a reduction of total vehicle distance traveled. For example, the current funding investments in transit are paying off with increased transit service and per capita reductions of single-occupancy vehicles in the city center. In addition, recently enacted changes in parking policies, including unbundling the cost of parking from rent for developments of a certain size and clarifying the definition of "frequent transit service" in a way that will expand project areas that do not require parking, may also help shift more people from single-occupancy vehicles to other modes (Lloyd, 2018).

CITY OF VANCOUVER

The City of Vancouver has been directed by Council to explore an ACES approach to autonomous vehicles: automated, connected, electric, and shared. Policy options the City is considering to futureproof infrastructure include road space reallocation for car-lite streets, expanding transit priority lanes, and promoting district parking through policy and development requirements. The City will be bringing policy direction to Council in early 2019. In addition, the City is embarking on a public outreach campaign over the upcoming year to build capacity, including with fire and police services, and learn together as the City prepares for technological changes in transportation.

Transportation network companies are currently not allowed to operate in the Province of British Columbia, but the Province is exploring options that would enable them to expand their services within the next year. The Province of British Columbia is currently reviewing a legislative framework, and the City of Vancouver has submitted recommendations to the Province for consideration.

OTHER JURISDICTIONS

STATE OF CALIFORNIA

The State of California has adopted two important pieces of legislation that bear mentioning. Relating to AVs in particular, California's Office of Administrative Law approved a set of comprehensive driverless testing regulations in February 2018 and as of April, the Department of Motor Vehicles is now able to approve permit applications.

In 2013, the State of California enacted Senate Bill 743 to start the process of changing the way transportation impacts are measured from the traditional level-of-service (LOS) to VMT in order to "promote the reduction of greenhouse gas emissions, the development of multimodal transportation networks, and a diversity of land uses" (Los Angeles Department of City Planning, 2016).

LOS ANGELES, CA

The City of Los Angeles explicitly addresses vehicle miles traveled in the Mobility Plan 2035 and has established a goal to decrease its VMT per capita by 5% every five years, to 20% by 2035. The shift in how California will evaluate transportation impacts is an important tool that will help Los Angeles move towards this goal, but many other tools are needed. A few of the City's strategies include:

- Create a GHG Emission Tracking Program: Quantify total reduction in GHG from vehicle miles traveled reductions. Include data in the Citywide Climate Action Plan and the Climate Action Registry. Maintain a database of completed infrastructure projects; track and apply offset credits (resulting from GHG and VMT reductions) towards the city's compliance with SB 375, AB 32 and the region's Sustainable Community Strategy (p. 151).

- Support ways to reduce vehicle miles traveled (VMT) per capita. Greenhouse gas (GHG) emissions are closely correlated with Vehicle

Miles Traveled (VMT). Reducing VMT is therefore an important component of the overall strategy to reduce GHG emissions. Efficient fuels and alternative vehicle technologies, which produce fewer GHG emissions per mile traveled, are another component. Reducing VMT requires a combination of sustainable approaches working together:

» Land use policies aimed at shortening the distance between housing, jobs, and services that reduce the need to travel long distances on a daily basis.

» Increasing the availability of affordable housing options with proximity to transit stations and major bus stops.

» Offering more attractive nonvehicle alternatives, including transit, walking, and bicycling

» Transportation Demand Management (TDM) programs that encourage ride-sharing

» Pricing mechanisms that encourage commuters to consider alternatives to driving alone, including:

  - Congestion or cordon pricing, which would charge vehicles entering into a congested area (such as downtown during rush hour) (p. 126).

In terms of prioritizing shared mobility, the City of Los Angeles has not explicitly adopted a FAVES/ACES program. However, in the Mobility Plan 2035, they establish the following shared mobility goals:

- Provide a shared use vehicle within a half-mile of 75% of households by 2035.

- Provide access to bicycle sharing within a quarter mile of 50% of households by 2035.

In addition, the City of Los Angeles is piloting 10 mobility hubs that “will provide first-last mile connectivity and on-demand services such as bikeshare, carshare, bike repair and storage, fare payment, etc.” (Hand, 2016, p. xiii).

AUSTIN, TX

Austin’s Smart Mobility Roadmap is centered on the opportunities offered by the convergence of shared, electric, and autonomous vehicles: “The convergence of shared, electric and autonomous vehicle services can offer a lower cost, more efficient and accessible, less polluting and less congested transportation system. Therefore, this plan will seek to address the synergy to incorporate all three platforms – shared, electric and autonomous – into a comprehensive strategy” (City of Austin and Capital Metro, 2017, p. 6).

Although the Roadmap does not explicitly set a VMT reduction goal, it does advocate for shared-use mobility: “Promoting shared-use practices now will have immediate benefits of taking drivers off the road and reducing the congestion, greenhouse gas emissions and household transportation costs, even without the benefit of electric and autonomous vehicles, offering a more immediate way to shape the future with affordable, accessible and equitable multimodal options. Cultivating shared mobility practices now is important to start the behavioral shift towards a shared, electric autonomous vehicle future” (City of Austin and Capital Metro, 2017, p. 8).

ATLANTA, GA

The Atlanta Regional Council’s Transportation Technology Policy document does not explicitly set a reduction in vehicle distance traveled, but it does acknowledge that there is a potential for increased vehicle travel even with shared new mobility alternatives. It suggests policies that can be implemented to reduce vehicle travel, including pricing incentives, toll or parking credits for using higher occupancy vehicles, and regulatory travel demand management strategies (Atlanta Regional Commission, 2016, p. 41). The document also identifies the following potential policy action: “Encourage use of technology innovations to support demand management and system management, including dynamic use of financial incentives and gamification to encourage use of higher occupancy modes of travel, off-peak travel, and utilization of less congested routes, including during special events and other disruptions" (Atlanta Regional Commission, 2016, p. 46).

NEW YORK/NEW JERSEY/CONNECTICUT

The New Mobility component of the Regional Plan Association's Fourth Regional Plan recommends implementing VMT fees or instituting higher tolls in order to "deter congestion" (Regional Plan Association, 2017). Furthermore, it suggests the number of overall AVs allowed in an urban center be capped at certain times of day and that geofencing be used to implement these caps. It does not, however, identify an explicit VMT reduction goal.

ST. LOUIS REGION

The St. Louis Region Emerging Transportation Technology Strategic Plan identifies VMT as a key area of uncertainty (ICF, 2017). It does not explicitly call out a specific VMT reduction goal, but it acknowledges that increased VMT could work against some of the plan's guiding principles, including "Support a diverse economy with a reliable system" and "Protect air quality and environmental assets." It notes the following:

Overall, the extent to which new technologies induce VMT will be subject to local policy decisions that will incentivize some travel modes (e.g., transit) and/or technologies/services (e.g., telecommuting) over others. Efforts to implement road pricing or time-adjusted subsidies or fees on certain modes could also provide incentives to curtail VMT (ICF, 2017, p. 34).

MODE SPLIT

Cities that want to decrease the number of vehicles clogging city roads must create communities that are safe, comfortable, and convenient for walking, biking, and taking transit. All three case study cities have strong land use, transportation, and climate action plans that support active transportation. However, all three cities struggle to find the funding necessary to expand and improve active transportation infrastructure and transit services, though the City of Seattle has had a string of successes with the passage of several ballot initiatives increasing funding.

CASE STUDY CITIES

CITY OF PORTLAND

Portland's adopted people moving policy prioritizes modes as follows:

1. Walking
2. Cycling
3. Transit
4. Fleet Automated Vehicles that are Electric and Shared (FAVES)
5. Other shared vehicles
6. Low or no occupancy vehicles, fossil-fueled non-transit vehicles

CITY OF SEATTLE

The City of Seattle's New Mobility Playbook's Play 1: Strategy 1.5 directs the city to "ensure new mobility complements and enhances the public transit system." The City identified the short-term action to "partner with King County Metro and Sound Transit to develop a microtransit policy framework and pilot its ability to serve first-/last-mile connections, emerging transit markets, and capacity relief needs" (City of Seattle Department of Transportation, 2017, p. 43).

CITY OF VANCOUVER

The City of Vancouver has achieved one of the most aggressive goals in both its Greenest City Action Plan and Transportation 2040 Plan of having 50% of trips be active transportation trips. The GCAP notes that limited capacity and facilities will be the biggest challenge to achieving its goal of having 2/3rd of trips be active transportation trips in 2040. The TransLink report, the Future of Driving, made several recommendations and identified the following potential actions:

- Recommendation 1: "Strengthen the role of active transportation by rapidly increasing investment in safe, attractive and direct walkways and bikeways and pedestrian and bicycle priority areas." (TransLink, 2016, p. 8).

- Recommendation 3: "Collaborate with partners to set up and fund a social innovation lab that would explore concepts for mobility-as-a-service systems including public transit service delivery models including flexible last-mile services." (TransLink, 2016, p. 8).

OTHER JURISDICTIONS

ATLANTA, GA

The Regional Transportation Technology Policy identifies three themes of the Region's plan, and one of those themes is: "Ensure the region is comprised of healthy, livable communities" (p. v). It goes on to identify a need to develop "walkable, vibrant centers that support people of all ages and abilities." Unlike other some of the other documents reviewed, however, it does not establish a clear people-first priority.

AUSTIN, TX

According to information cited in the Smart Mobility Roadmap, Austin set a goal of increasing commuter bicycling to 15% and reducing single-occupancy vehicle trips by 10% by 2020. The document notes that high-capacity transit will continue to be the fastest, most efficient form of transportation for moving people in high-density areas. To that end, the Smart Mobility Roadmap notes that the City of Austin will work with Capital Metro to pursue first- and last-mile projects pilots. It goes on:

> First-and last-mile public infrastructure can also help neighborhoods retain residents and increase mobility. Cities and suburbs have found that walkable, mixed-use developments attract and retain residents and businesses. Infrastructure for walking and cycling offers people more mobility options thereby reducing emissions and the use of single-occupancy vehicles (City of Austin and Capital Metro, 2017, p. 15).

LOS ANGELES, CA

In the Mobility Plan 2035, the City of Los Angeles outlines the following goals related to mode split (p. 81):

- Ensure that 90% of all households have access within one-half mile to high quality bicycling facilities (protected bicycle lanes, paths, and neighborhood enhanced streets) by 2035.
- Increase the percentage of 0/1 car ownership (car-light) households from 50% currently to 75% by 2035.
- Reduce the average share of household income spent on transportation costs to 10% by 2035 through the provision of more transportation options.
- Increase the combined mode split of persons who travel by walking, bicycling or transit to 50% by 2035.

Some of the strategies they intend use to achieve these goals include:

- 2.3 Pedestrian Infrastructure: Recognize walking as a component of every trip, and ensure high quality pedestrian access in all site planning and public right-of-way modifications to provide a safe and comfortable walking environment (p. 61).

- 2.5 Transit Network: Improve the performance and reliability of existing and future bus service. Working in collaboration with the transit operators, combined with street improvements of city managed enhancements, the Transit-Enhanced streets outlined in the Plan strive to: provide reliable and frequent transit service that is convenient and safe; increase transit mode share; reduce single-occupancy vehicle trips; and integrate transit infrastructure investments with the identity of the surrounding street. These corridors were selected based on a data-driven analysis of factors such as ridership, destinations, employment, and population. Transit enhanced streets may receive a number of enhancements to improve line performance and/or the overall user experience for people who walk and take transit. Enhancements may range from streetscape improvements to make walking safer and easier, to transit shelters, or bus lanes (p. 63).

- 4.8 Transportation Demand Management Strategies: Encourage greater utilization of Transportation Demand Management (TDM) strategies to reduce dependence on single-occupancy vehicles (p. 109).

Though not adopted as policy like the Mobility Plan 2035, Urban Mobility in a Digital Age outlines some additional strategies and recommendations of note:

- The City of Los Angeles has partnered with Xerox to launch Go LA, which compares mode options by speed, price, and sustainability. One suggestion that is included in the Urban Mobility Strategy is to include an estimate on the time it will take to find parking in the total travel time using parking inventory data as a way of encouraging the use of other modes. (Hand, 2016, p. xii)

NEW YORK/NEW JERSEY/CONNECTICUT

According to the Fourth Regional Plan, issued by the Regional Plan Association, New York City intends to have dedicated 80% of all urban street space to walking, biking, and transit by 2040. The Fourth Regional Plan also lays out the same prioritization of modes that Portland has adopted.

ST. LOUIS REGION

Under “Potential actions to support transit and urban vitality” the St. Louis Regional Strategy identifies “Encourage multi-modal lifestyles” as a topic area. Potential actions include (p. 43):

- Establish clear and fair rules for operating mobility services such as ridesharing, carsharing, and micro-transit systems, so as to reduce the burden of operating those services in the region.

- Designate “mobility hubs” where several modes, such as biking, walking, ridesharing, and public transit can all intersect.

TORONTO, ON

In its short report, “Preparing the City of Toronto for AVs,” the General Manager of Transportation Services notes: “The City of Toronto will take a transit-centric approach to vehicle automation. The City will encourage the adoption of advanced driver assistance systems for public and mass transit vehicles, with the purpose of improving reliability, efficiency, safety, and seamlessness of transit. The City will also encourage the development of advanced driver assistance systems that facilitate increased transit priority” (City of Toronto General Manager, Transportation Services, 2018, p. 16).

PRICING

Pricing policies and regulations are one of the most direct way to impact travel behavior to ensure that AVs support efforts to reduce GHG emissions. Many governmental entities are considering pricing AVs and other new mobility technologies for two primary reasons. One, if AVs are primarily hybrid or electric vehicles, then fuel tax revenue will decrease. Given that the fuel tax is a significant source of transportation infrastructure funding, replacing the fuel tax may be necessary for continued investments in the nation's transportation infrastructure. Two, emerging technologies may make it possible, for the first time, to develop pricing systems that can help manage the transportation in real time or very close to it. A suite of programmatic and pricing incentives falls under the category of "transportation demand management" (TDM), which are intended to reduce vehicle travel and encourage active transportation and carpooling. While many cities outside of North America have a congestion tax or charge (London, UK and Stockholm, Sweden are two examples), no city in North America has implemented a wide range of pricing options that include a combination of vehicle distance traveled, time of day, congestion levels, number of people or volume of goods, GHG emissions, or other factors that impact the efficient use or environmental impact of the transportation system.

While all three case study cities are studying congestion pricing, none of the studies currently include curb pricing, though staff at all three cities indicate they are considering that option as well.

CASE STUDY CITIES

CITY OF PORTLAND

The City of Portland's TSP Policy 9.69.d. calls for the city to develop "sustainable user-pays funding mechanisms to support connected and automated vehicle infrastructure and service investments, transportation system maintenance, and efficient system management." (Portland Bureau of Transportation, 2018, p. 36). Policy 9.69.e. identifies the need for AVs to help pay for infrastructure and service investments and requires the City to "develop a tiered pricing structure that reflects vehicle impacts on the transportation system, including factors such as congestion level, vehicle miles traveled, vehicle occupancy, and vehicle energy efficiency." (Portland Bureau of Transportation, 2018, p. 36).

The City of Portland has already established new mobility user-pay mechanisms in the form of ride fees for TNCs and shared electric scooters. TNCs users in Portland pay a flat $0.50 fee per ride according to the Transportation Fee Schedule, which is collected by the TNCs and remitted to the City (City of Portland). The City of Portland also recently launched an electric scooter pilot project and as part of their permitting process they established a requirement that each scooter share company pay a $0.25 fee per ride (City of Portland Bureau of Transportation, 2018). While neither of these fees are tiered, or priced based on total distance traveled, they do help to establish a precedent of user-pay mechanisms.

CITY OF SEATTLE

The City of Seattle's New Mobility Playbook Play 3, Strategy 3.6 is broader than Portland's as it states the City will "(e)stablish new transportation funding mechanisms in response to the changing financing landscape." In April, 2018, Seattle's Mayor, Jenny Durkan, announced that the City will toll city roadways as a way to manage congestion and reduce GHG emissions (City of Seattle, 2018). The Seattle Department of Transportation is studying congestion pricing options now and will deliver recommendations to the City Council when they are developed.

CITY OF VANCOUVER

The Future of Driving report identifies two potential actions to incorporate pricing into the City of Vancouver's new mobility strategies. Recommendation 1 is to "(i)ntroduce region-wide road usage charging to manage demand for increased vehicle usage resulting from automated vehicles" and Recommendation 2 is "plan for reductions from parking and fuel sales taxes" (TransLink, 2016). In 2017, the Mobility Pricing Independent Commission (MPIC), a group of 14 representatives from around the Vancouver Metro region, began work on decongestion charging recommendations for the Mayors' Council on Regional Transportation and the TransLink Board of Directors. The MPIC issued their report, the Phase I Project Update Full Report, in January, 2018. The report focuses on pricing strategies and implementation measures that would reduce traffic congestion, promote fairness, and support transportation investments for all users. The MPIC is now studying implementation, specifically different approaches to where, when, and how policy tools could be used. The policy tools it is studying include congestion point charges, cordon charges, and distance-based charges varying by time and location. In addition, the Commission is studying the implementation of a private paid parking tax as a complementary tool.

OTHER JURISDICTIONS

ATLANTA, GA

The Regional Council's document does identify pricing mechanism as potential policy actions, such as tolls and parking credits for higher occupancy vehicles. Unlike other jurisdictions, however, there is no discussion of a vehicle distance traveled fee.

AUSTIN, TX

The Smart Mobility Roadmap references pricing in its sections about the integration of public mass transit and private sector services and parking. It notes that dynamic pricing can be used as a tool to incentivize trips using transit/vanpooling and disincentivize trips competing with transit:

- Trip pricing may fluctuate depending on a combination of variables and pilot findings, including: origin and destination; number of passengers; level of congestion; environmental impact; and household income (p. 17).

Beyond that, it does not explicitly recommend vehicle distance traveled fees or other specific fees.

LOS ANGELES, CA

The City of Los Angeles takes a slightly different approach to the "user pays" concept and instead is focusing on how much of the public infrastructure is being used to determine pricing. One of the three primary goals in Urban Mobility in a Digital Age is to establish infrastructure as a service:

- Infrastructure as a Service proposes that the use of public infrastructure should be subject to pay-as-you-go user fees that more closely align the costs associated with providing the infrastructure itself to how the infrastructure is being used. As this is a fundamental rethinking of how we pay for and access our public right-of-way, Infrastructure as a Service requires a phased approach, which is already being introduced: the State of California has launched a nine month pilot this summer to test the concept of charging drivers for vehicle miles traveled as an alternative to the gas tax; and tolling high occupancy vehicle (HOV) lanes on the 110 and 10 Interstates is currently in place (Hand, 2016, p. iii).

NEW YORK/NEW JERSEY/CONNECTICUT

As noted in the section about vehicle distance traveled, the New Mobility component of the Fourth Regional Plan does explicitly call out implementing VMT fees as a strategy for urban centers.

ST. LOUIS REGION

Under the section "Potential actions to improve mobility and reliability," the St. Louis regional strategy identifies the following as an action pertaining to demand management:

- Consider policies to reduce vehicle travel leveraging technology, such as road pricing, or toll or parking credits for using higher occupancy vehicles, or shared ride services [These policies can be integrated into a broader strategy for transportation infrastructure funding] (p. 46).

SOURCE OF ENERGY

All of the case study cities' Climate Action Plans identify the need to reduce GHG emissions by ensuring that residents, businesses, and governments run vehicles that are more efficient and use cleaner fuel sources. All of the case study cities are doing this, in large part, by encouraging the electrification of vehicles. Current efforts focus on both encouraging residents to purchase and buy electric vehicles as well as changing city policies to require electric charging infrastructure in new buildings and structures as well as the electrification of fleets (especially city-owned vehicles and transit fleets). However, the energy sources used to power electric vehicles must also be considered.

CASE STUDY CITIES

CITY OF PORTLAND

Portland's FAVES approach to AVs directly ties new mobility strategies to the City's efforts to reduce carbon pollution through support for walking, bicycling, and shared rides (including transit) and the electrification of vehicles. The FAVES strategy also builds on Electric Vehicles: The Portland Way. The City's EV strategy outlines a variety of policies and strategies to facilitate the transition to electric vehicles, including use of the right-of-way for EV charging (City of Portland, Undated). Current efforts focus on personally owned vehicles and public fleets; the emphasis on new mobility fleet-owned vehicles suggest a need to adapt these polices in the future. For example, vehicle charging in the future may need to be concentrated at fast-charging stations, with less demand in dispersed charging infrastructure.

The City of Portland's fuel mix includes coal and natural gas, so some of the benefits of electric vehicles may be offset by the additional consumption of these fuel types. However, the City of Portland's EV Strategy does note that "The City seeks to further reduce upstream greenhouse gas emissions associated with EVs by strongly encouraging the deployment of both public and private charging stations powered by renewable electricity" (City of Portland, Undated, p. 3).

CITY OF SEATTLE

Strategy 5.3 in the City of Seattle's Mobility Playbook establishes that the City should "promote the shift toward electric shared mobility services" and it outlines the following policy need related to that goal:

- Adopt a policy framework and permit program that enables electric vehicle charging in the public right of way.

Because the City of Seattle relies primarily on hydropower, electric vehicles can be charged using clean energy. The promotion of electric AVs is supported by the Drive Clean Seattle electrification initiative.

CITY OF VANCOUVER

Similar to the City of Portland, the City of Vancouver has established an ACES approach to AVs and the effort to promote electric AVs is supported by the City's EV Ecosystem Strategy, adopted in 2016. The document outlines a series of actions to be undertaken between 2016-2021 to expand EV infrastructure.

OTHER JURISDICTIONS

AUSTIN, TX

Although the City of Austin is not fueled entirely by clean energy sources, it has made a concerted effort to ensure that electric vehicles that are powered by wind energy. According to the Smart Mobility Roadmap:

- In 2011, Austin Energy installed the first EV charging infrastructure in the region. Today, Austin Energy has over 600 EV charging ports at 172 locations, including retail, workplace, multifamily and fleet locations throughout the city.36 Austin Energy is adding 8-10 DC Fast Chargers to the network beginning in 2018. The fast chargers will recharge a vehicle within 15 minutes and are slated to be positioned along major transportation corridors. Additionally, the Plug-In EVerywhere network is powered by clean, renewable wind energy via Austin Energy's

GreenChoice Program and the cost to Plug-In Everywhere customers is only $4.17 per month for unlimited electric 'fill-ups'" (City of Austin and Capital Metro, 2017, p. 23).

ATLANTA, GA

The Regional Council document suggests advancing the adoption of electric vehicles and "green" logistics, though it does not have a mandate that autonomous vehicles be electric (Atlanta Regional Commission, 2016, p. 41).

LOS ANGELES, CA

In the Mobility Plan 2035, the City has outlined the following goals related to energy consumption (p. 124):

- Convert 100% of City General Services Division vehicle fleet to alternative fuels and/or zero emission vehicles by 2035.
- Convert 100% of City refuse collection trucks and street sweepers to alternative fuels by 2020.
- Reduce transportation-related energy use by 95% and reduce maintenance requirements of City vehicle fleet. Install more than 1,000 new publicly available EV charging stations throughout the City.

In addition, Urban Mobility in a Digital Age identifies the following needs related to electric vehicles:

- Currently, there is considerable range anxiety in the Los Angeles region which impacts electric vehicle purchasing behavior - without the charging infrastructure, consumers are hesitant to buy pure electric and are more likely to buy hybrid vehicles. It would help drivers know the location of available of power; charger specifications; any associated costs or rules of access; and real-time status of the availability of chargers. LADOT should encourage the adoption of this standard regionally and advocate for this information to be included in tools such as GoLA and Google Waze (Hand, 2016, p. 21).

NEW YORK/NEW JERSEY/CONNECTICUT

The New Mobility document outlines that AVs must be safe and low-carbon. It states, "All AVs should have the lowest possible carbon footprint, with cities making investments to encourage the adoption of hybrid and fully electric vehicles." (Regional Plan Association, 2017, p. 4). The document does not discuss regional fuel mix.

ST. LOUIS REGION

The St. Louis strategy notes that "there is reason to believe that market forces may steer AVs to be electric." (ICF, 2017, pp. 52-53). Irrespective of that, the strategy suggests that policies focused on the deployment of electric vehicles for personal use should be advanced. It also notes that "EV market growth needs to be accompanied with a strategy to reduce emissions from the generation of electricity" (ICF, 2017, p. 53) and includes several potential actions to advance the goal of ensuring environmental quality. Two of those actions are "Deploy Green Infrastructure" and "'Green' Logistics" (p. 53-54):

- Evaluate the potential of deploying smart and sustainable infrastructure, such as solar highways, and a grid-integrated network of charging stations to effectively support EV adoption and use. Since autonomous electric vehicles will likely be served by wireless inductive charging, consider a strategy to integrate wireless charging into plans to deploy charging infrastructure.

- Implement policies to support and promote the use of low emission freight vehicles and strategies, such as green supply chain. Policies include incentives for efficient shipments, for platooning and/or fuel-efficient vehicles, or for use of alternative fuels. Examples include allowing higher weight limits in freight vehicles using alternative fuels and/or automated logistics.

LAND USE / METROPOLITAN FOOTPRINT

Autonomous vehicles and new mobility technology is anticipated to have two opposing effects on land use. On the one hand, the anticipated reduced demand for parking is expected to increase the available supply of land throughout cities. This presents an opportunity to redevelop the land for housing, employment, or parks and open space. On the other hand, the ability to use time spent in a vehicle for work or leisure activities instead of having to drive may allow those people who want to live in suburban or rural communities, but work in a city, possible. It is also possible that there will be increased pressures on sprawl with the introduction of AVs. While none of the case study cities specifically address land use in their preliminary new mobility strategies the impacts of new mobility strategies, that could be, in part, because all three cities have adopted policies that limit sprawl.

CASE STUDY CITIES

PORTLAND REGION AND CITY OF PORTLAND

The Portland region has an adopted urban growth boundary. The 2040 Growth Concept designates that new growth in the region will be primarily in Centers and Corridors. The City of Portland has an objective to "create vibrant neighborhoods where 80 percent of Portland and Multnomah County residents can easily walk or bicycle to meet all basic daily, non-work needs and have safe pedestrian or bicycle access to transit. Reduce daily per capita vehicle miles traveled to 30 percent from 2008 levels" (City of Portland and Multnomah County, 2015, p. 26).

CITY OF SEATTLE

The Seattle Climate Action Plan also explicitly identifies land use policies as a component of the efforts to reduce GHG emissions. The City of Seattle is a member of the Growth Management Planning Council, which adopts and manages the Urban Growth Area (UGA) within King County. The City of Seattle's Climate Action Plan has a target goal of 45% of households in Urban Centers and Villages, along with 85% of jobs (City of Seattle, 2013).

CITY OF VANCOUVER

The City of Vancouver is constrained by the Regional Growth Strategy (2011) which is part of Metro Vancouver's Sustainability Framework. It designates an Urban Containment Boundary (UCB), which contains sprawl, and focuses growth in Urban Centres and Frequent Transit Development Areas.

OTHER JURISDICTIONS

AUSTIN, TX

The Smart Mobility Roadmap identifies land use and infrastructure as one of the five key areas of focus. It notes: "The City of Austin will need the bold land use policies prescribed in the City's Imagine Austin comprehensive plan to be adopted into the CodeNEXT regulatory document that will encourage densification and discourage single-occupancy commuting options." (City of Austin and Capital Metro, 2017, p. 10). It lists nine recommended actions under land use and infrastructure, several of which pertain to parking. It also includes enhancing compact and connected use along key transit/travel corridors using E-AVs (electric AVs).

CHANDLER, AZ

The City of Chandler has not yet created a new mobility document, but it recently became the first U.S. city to adopt a ridesharing and autonomous vehicles zoning code amendment. There are two primary objectives of the zoning code amendments (City of Chandler Development Services, 2018):

- Provide the City with more flexibility to reduce minimum parking requirements as parking demand changes
- Encourage developments to install passenger loading zones.

The amendments would enable the City of Chandler to "administratively reduce minimum parking requirements by 10% for each passenger loading zone that is provided in ratio with the building square footage identified in the proposal up to a maximum of 40%." This amendment recognizes that the need for parking is already decreasing in some areas as a result of TNCs and is likely to continue to decrease with the advent of fully autonomous vehicles.

LOS ANGELES, CA

The City of Los Angeles recognizes the need for dense, mixed-use areas that encourage non-vehicle modes. Some of the policies they have adopted in the Mobility Plan 2035 include:

- 3.3 Land Use Access and Mix: Promote equitable land use decisions that result in fewer vehicle trips by providing greater proximity and access to jobs, destinations, and other neighborhood services (p. 85).

- 3.10 Cul-de-sacs: Discourage the use of cul-de-sacs that do not provide access for active transportation options. A daylighted cul-de-sac is an alternative to the conventional closed-off design. Daylighting refers to the modification of a dead-end street to allow for pedestrian and bicycle through access. In addition, there are a number of design tools available in the Complete Streets Design Guide to reduce and calm through traffic within neighborhoods (p. 93).

In the Urban Mobility in a Digital Age, the recommendations include eliminating parking minimums and rethinking parking garages.

NEW YORK/NEW JERSEY/CONNECTICUT

The New Mobility component of the 4th Regional Plan explicitly states, "We should shape how AVs are used in suburbs." This means increasing the attractiveness of ridesharing and promoting compact development, especially near rail stations. It notes, "If we don't take appropriate action, private ownership of AVs will encourage more sprawl and increase congestion on our roadways and in our cities." (Regional Plan Association, 2017, p. 3).

ST. LOUIS REGION

The St. Louis strategy includes several actions related to land use, zoning and urban design with intention of promoting more compact development (p. 42):

- Encourage local governments to consider new zoning requirement for development that reflect reduced needs for parking for privately owned vehicles, more use of shared vehicles, and other technology-enabled options.
- Advance regional and local land use policies to encourage development of downtown areas and regional activity centers linked through public transportation (i.e., dense transit-oriented development), recognizing in particular the potential for transportation technologies to encourage decentralization.
- Support incentives and policies to encourage density in transit-oriented locations, tied to use of technology to enhance transit, such as reducing parking requirements for residential and commercial buildings in downtown areas.

FREIGHT/GOODS MOVEMENT

The Cities of Portland, Seattle, and Vancouver regularly work with state, province, and federal partners to plan for the efficient movement of heavy freight to, and through, their respective metropolitan regions. The rise of e-commerce and use of smart phones to order goods and services is creating explosive growth in local goods delivery. According to a report by Pitney Bowes, worldwide parcel volumes increased by 50% between 2014 and 2016 (Pitney Bowes, 2017).

CASE STUDY CITIES

CITY OF SEATTLE

The City of Seattle addresses local goods delivery in its new mobility strategy to support the development of efficient urban goods delivery and new freight technology solutions (Play 2: Strategy 2.3). One of the prioritized action items is to work with the University of Washington's Urban Freight Lab to better understand the impacts of e-commerce and urban goods delivery in Seattle.

CITIES OF PORTLAND AND VANCOUVER

The Cities of Portland and Vancouver have not identified goods delivery in new mobility policies or reports to date. While many of the policies recommended by the City of Portland for adoption will likely apply to goods delivery, none call out goods delivery specifically. The City of Vancouver may be working on goods delivery issues, but it too is not identified specifically in its new mobility work plan.

OTHER JURISDICTIONS

ATLANTA, GA

One of the policy needs identified in the Regional Transportation Technology Policy Document is the need to "develop policies that address changing needs in relation to use of public right-of-way, zoning, and urban form due to technology trends to support livable communities." (Atlanta Regional Commission, 2016, p. 47). A potential policy action is recommended:

- Provide tools to address increasing local freight deliveries. Require use of tools as a condition of new developments to assess regional impact.

AUSTIN, TX

The Smart Mobility Roadmap does not spend much time on freight or goods delivery explicitly but like many of the documents reviewed, it does discuss the need for better curb management. It notes the following pertaining to both passenger and freight transportation:

- In support of fleets of autonomous vehicles, whether for passenger or freight transportation, Austin is reviewing the possibilities and technologies related to curb access, electric recharging at on-street parking spaces, multi-modal transportation hubs and creating designated areas for AVs between uses to reduce unnecessary circling (p. 33).

In addition, it appears to be the only document that includes a recommendation action about E-AV delivery robots. One of the 13 recommendations under its autonomous vehicles section is to "increase public awareness of last mile E-AV delivery robots." (City of Austin and Capital Metro, 2017, p. 12).

LOS ANGELES, CA

A policy outlined in the Mobility Plan 2035 related to freight is:

- Truck movement should be limited to the arterial street network as much as possible since these streets have the lanes and wider turning radii to accommodate these heavy large vehicles. Land uses along heavily used truck routes should also coincide with goods movement priorities and limit interaction with residential uses (p. 87).

Strategies to improve local goods delivery include the following:

- Identify and Implement incentives to encourage off-peak hour delivery operations (p. 157).

- In non-industrial areas, require off-street dock and/or loading facilities for all new non-residential buildings and for existing non-residential buildings and undergoing extensive renovations and/or expansion, whenever practical (p. 159).

- Encourage the designation of on-street loading areas, through removal of curb parking, in established industrial areas where off-street loading facilities are lacking. Update the Commercial Loading Zone Ordinance (p. 159).

NEW YORK/NEW JERSEY/CONNECTICUT

The New Mobility document identifies a similar set of priorities as Portland and Seattle. It notes that street space should be prioritized for public transit, pedestrians, bikes and freight. In urban areas, sufficient curb space should be allocated for efficient delivery use without impeding the flow of traffic. This document also includes a graphic that envisions four phases of AV deployment (Regional Plan Association, 2017, p. 16). Phase 2 (2022-2027) includes the designation of new loading zones to accommodate freight.

ST. LOUIS REGION

One of potential actions noted in the St. Louis strategy pertaining to freight is the incentivization of off-peak deliveries. It recommends considering policies, including financial incentives, to encourage large-scale freight and package deliveries during off-peak times. It also includes freight and logistics as a separate, standalone section tied to two goals: Support Quality Job Development and Strengthen Intermodal Connections. This section includes the following potential actions (p. 49-50):

- Prioritize freight corridors when outfitting roads with necessary CV/AV technologies.

- Improve curb space management via sensors, dynamic reservations, and other technologies.

- Facilitate the centralization of data for freight shipment across modes (air, road, rail, and marine) to optimize decision-making across stakeholders. This entails the inclusion of freight agencies (public and private) in Integrated Corridor Management strategies and the development of freight-specific portals of communication.

- Provide truckers with real-time information on parking availability and truck routes.

- Cooperate in tests of autonomous and connected vehicle technology for freight systems by having a clear process for permitting pilot programs and tests.

4

POLICY AND PROGRAMMATIC OPPORTUNITIES TO REDUCE GHG EMISSIONS THROUGH AV-RELATED IMPLEMENTATION STRATEGIES

ABOUT

It has been said before, but it bears repeating: autonomous vehicles may prove to be as disruptive as the introduction of the automobile over a century ago. The automobile has shaped decades of land use patterns and certainly not always for the best. The movement of people and goods drives social and economic interactions, but the inefficient movement of people and goods has led to inequitable and environmentally detrimental outcomes. Autonomous vehicles and other new mobility services could help mitigate these negative impacts, or they could exacerbate them. What has become clear is that as communities consider new mobility policies, programs, and pricing options, city leaders and municipal staff should consider a wide range of community goals to ensure cities address the greenhouse gas risks emerging technologies may present while at the same time working to achieve co-benefits. Informed by the findings from the literature and policy reviews, this section presents a series of objectives, strategies, and actions that could be undertaken to proactively address the potentially negative impacts that emerging technologies and in particular, autonomous vehicles, could have on greenhouse gas emissions

EQUITY CONSIDERATIONS

Though we have included implementation actions that we consider promising in this section, ***none of these actions should be taken without a comprehensive, community-specific analysis of the equity considerations.*** As noted in the City of Portland and Multnomah County's Climate Action Through Equity, "carbon reduction strategies can exacerbate existing disparities unless there is an explicit equity focus" (Williams-Rajee & Evans, Climate Action Through Equity, 2016, p. 4). If the market will not ensure equitable outcomes without regulatory intervention, as is generally the case, then cities and agencies need to create regulations that focus specifically on equity when crafting policies. For example, the City of Portland recently drafted a permit application in anticipation of the launch of a four-month Shared Electric Scooter Pilot. The application, which companies were required to complete in full by July 12, 2018 if they were interested in participating in the pilot, includes several equity-informed components. In addition to providing information about safety records and complaint histories, the companies were required to submit the following (City of Portland Bureau of Transportation, 2018, p. 5):

- User Equity Plan
    - » What strategies will you use to increase access and utilization of Shared Scooters among low-income and historically underserved communities?
    - » What will your discounted pricing be for people living on low-incomes?
    - » Describe any plans to offer a cash payment option.
    - » What languages are your services provided in?
    - » Are your apps and websites accessible and screen reader compatible?
- Economic Opportunity Plan
    - » How will you create jobs for people living on low-income and traditionally underserved, including people of color, low-income

people, immigrants and refugees, veterans, people with disabilities, women, and formerly incarcerated people?

» How will you contribute to enhancing the economic and civic vitality of Portland?

In addition, companies whose permit applications were granted are required to deploy a minimum of 100 shared scooters or 20% of their fleet, whichever is less, in historically underserved East Portland neighborhood as identified in the 2035 Comprehensive Plan. Without this explicitly stated requirement, companies may not have ensured comprehensive coverage in these areas. This is a prime example of how cities can prioritize equity when crafting regulations for emerging technologies.

Agencies in Portland and Seattle have developed community-informed equity toolkits and checklists that provide guidance and contain a comprehensive list of questions to consider before implementing any actions. (See the City of Portland and Multnomah County's Climate Action Through Equity; King County Equity Impact Review Toolkit; and Seattle Race and Social Justice Initiative's Equity Toolkit. Section 3 of this report also includes the full list of questions identified in some of these documents.) The questions that are included under the User Equity Plan and the Economic Opportunity Plan in the Shared Electric Scooter Pilot application, listed above, seem to be informed by the checklist listed in Portland's Climate Action Through Equity. Ultimately, the question all jurisdictions should continually be asking is ***how new technologies can be deployed in ways that reduce greenhouse gas emissions while minimizing displacement and benefiting communities of color, low-income populations, people with disabilities, aging populations, LGBTQ populations, immigrant and refugee communities and other historically disadvantaged populations.***

After reviewing the various new mobility documents identified in Section 3 of this report, the Urbanism Next researchers compiled a list of policies and programmatic opportunities that cities could consider to reduce GHG emissions. Using the minimization of greenhouse gas emissions as an overarching goal we developed an outline based on the logic flow presented below (Fig. 1). We compiled a variety of implementation actions

DEVELOPMENT OF GUIDING OUTLINE

from our literature review, existing new mobility documents, conversations with stakeholders, and conversations with partners in the public, private, and academic sectors.

In much of the literature that we reviewed, goals, objectives, strategies, and implementation actions were often conflated and listed equally. This confusion in the literature is sometimes mirrored by a confusion in the field where specific actions such as pricing are discussed as equal to overarching goals such as increasing access. Our approach here has been to create an explicit organization that starts with an agreed upon goal—minimize greenhouse gas emissions—then moves to policy objectives, strategies, and finally implementation actions. The items and organization we have included represent what we consider to be a checklist that can be used as a starting point for developing new mobility policies while keeping climate objectives front and center (see Outline below).

Under the goal of 'Minimizing Greenhouse Gas Emissions', we have separated the objectives into two categories: policy objectives and governance/operational objectives. The policy objectives represent what we see as the primary ways that governmental agencies can approach thinking about transportation and land use so as to minimize greenhouse gas emissions. These Policy Objectives include:

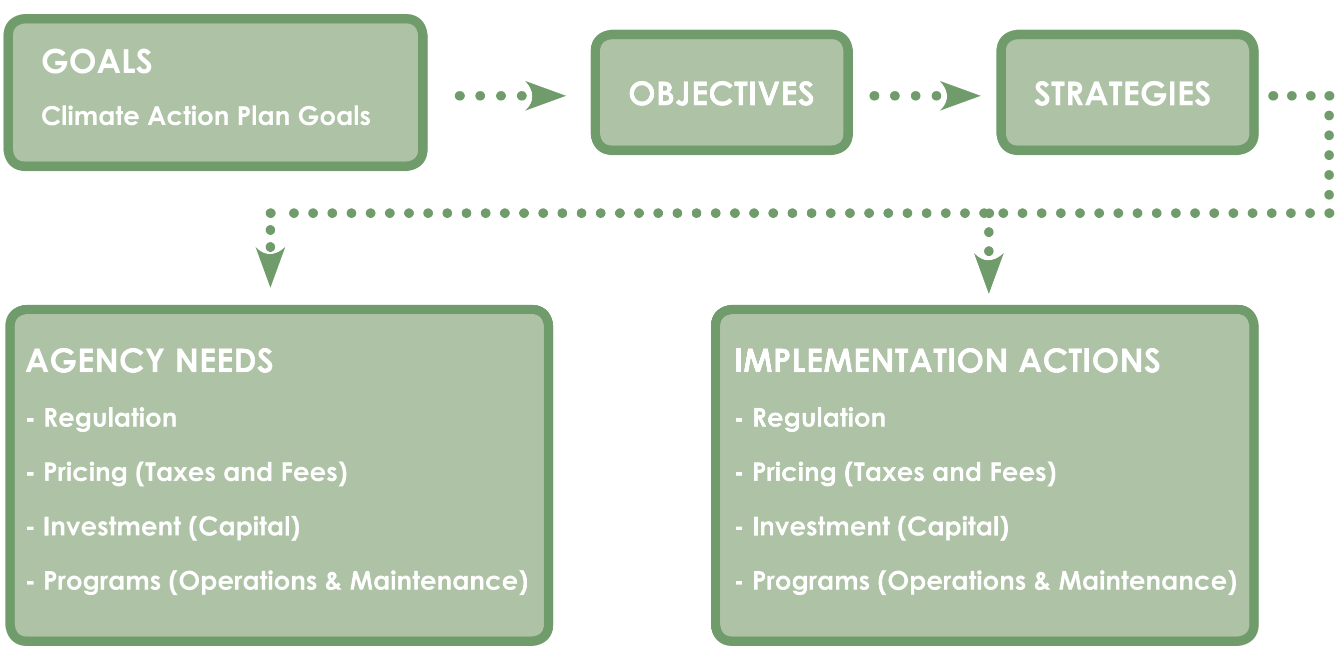
1. **Maximize System Efficiency and Passenger Accessibility While Reducing Energy Use**
2. **Enable Efficient Freight and Goods Movement**
3. **Prioritize Clean Energy Sources**
4. **Limit Metropolitan Footprint Expansion**
5. **Adapt to Land Use Changes Over Time**

Given the speed at which technology is advancing, governmental agencies need to be able to implement pilot projects and act with more flexibility. Thus, the governance/operational objectives pertain to necessary changes that have been identified by a variety of governmental agencies in order to streamline decision-making and enable a more flexible approach. These Government and Operational Objectives include:

1. **Update Organizational Structures and Facilitate Communication**
2. **Promote Culture of Innovation and Flexibility**

It is important to note that while we think this outline can serve as a starting point for thinking about the impacts of AVs on climate goals and how best to mitigate the potentially negative ones, we know that this will be an ongoing, iterative process and other objectives, strategies, and actions will be identified by individual jurisdictions. This point especially pertains to the implementation actions that we have identified in Tables 4-1 through 4-7. While robust, we acknowledge that this is a preliminary list and, as such, we are sure there are other actions not listed here that could be taken and can be added to future lists of this type.

Fig. 4-1. Logic Flow



OUTLINE

GOAL: MINIMIZE GREENHOUSE GAS EMISSIONS

POLICY OBJECTIVES

1 Maximize System Efficiency and Passenger Accessibility While Reducing Energy Use

1.1 Minimize Motorized Transportation Demand

1.1.1. Promote Compact Development

1.1.2. Prioritize Land Use Mix

1.2 Maximize Transportation Network Efficiency

1.2.1 Prioritize Shared-Use Modes and Shared Rides

1.2.2 Reduce Vehicle Distance Traveled

1.2.3 Prioritize Curb Zone Management

1.2.4 Reduce Demand for Parking

1.2.5 Update Street Design Standards

1.2.6 Facilitate Information Sharing

2 Enable Efficient Freight and Goods Movement

2.1 Enable Efficient Line-Haul Movement (Movement of Freight by Any Transport Mode)

2.2 Promote Efficient Goods Delivery

2.2.1 Prioritize Curbside Access

2.2.2 Integrate and Optimize ‘Less Than Truckload’ Shipping

2.2.3 Facilitate Freight and Goods Movement Information Sharing

2.2.4 Enable Mixing of Passenger and Goods Delivery

3 Prioritize Clean Energy Sources

3.1 Promote Adoption of Zero Emission Vehicles

3.1.1 Incentivize Deployment of Zero Emission Vehicles

3.1.2 Support Clean Energy Sources

4 Limit Metropolitan Footprint Expansion

4.1 Limit Sprawl and Land Consumption

5 Adapt to Land Use Changes Over Time

5.1 Prepare for Changes to Existing Land Uses

5.1.1 Parking Land Reuse

5.1.2 Respond to Changes to Land Valuation

5.2 Prepare for New Land Uses

5.2.1 Enable New Uses

GOVERNANCE AND OPERATIONAL OBJECTIVES

1 Update Organizational Structures and Facilitate Communication

1.1 Streamline Organizational Structures and Increase Capacity

1.2 Identify/Establish Funding Structures for New Mobility Projects

1.3 Promote Cross-Agency Communication / Public Communication

1.4 Create New Regional, State/Province Coordinated Revenue System for Funding Transportation Infrastructure and Management

1.5 Create and Execute Equity Assessments of Proposed Policies

2 Promote Culture of Innovation and Flexibility

2.1 Establish Organizational Structure that Supports Innovation

2.2 Facilitate Pilot Projects

2.3 Promote Culture of Calculated Risk-Taking

POLICY AND GOVERNANCE/OPERATIONAL OBJECTIVES TABLES

Tables 4-1 through 4-7 expand on the outline presented above by identifying potential implementation actions for each strategy and referencing documents that have explicitly addressed these ideas, where applicable. We have also included some actions that we identified internally as being potentially beneficial, but they are not explicitly identified in the any of the documents we reviewed. In addition, there are columns included in each table that indicate whether or not the action has either been undertaken or identified as an action to consider by the Cities of Portland, Seattle, and Vancouver, **to the best of our current knowledge and understanding**. If the action has been undertaken we note that has been *adopted* or is *underway*; otherwise we simply note that the action has been *identified.*

Table 4-1. Policy Objective 1. Maximize System Efficiency and Passenger Accessibility While Reducing Energy Use[5]

Strategy	Implementation Action	Type	P	S	V	Examples/References
1.1 Minimize Motorized Transportations Needs						
1.1.1. Promote Compact Development	Ensure that comprehensive plan and zoning code allow for compact development	Regulation	✔	✔	✔	Adopted in Cities of Portland, Seattle, Vancouver, and others
1.1.2. Prioritize Mixed Land Use	Ensure that comprehensive plan and zoning code allow for mixed-use development	Regulation	✔	✔	✔	Adopted in Cities of Portland, Seattle, Vancouver, and others
1.2 Maximize Transportation Network Efficiency						
1.2.1. Prioritize Shared-Use Modes and Shared Rides	Prioritize streets and street network for pedestrians, bikes, public transit, and freight above private vehicles	Regulation	✔	✔	✔	Hierarchy of modes adopted by Portland; Identified in NY/NJ/CT Regional Plan Association New Mobility (p. 3); Seattle New Mobility Playbook (Appendix C, p. 5)
	Prioritize autonomous vehicle fleets offering shared rides	Regulation	✔	✔	✔	Identified in Seattle's FAVES, Portland's SAVI, and Vancouver's ACES
	Prioritize shared rides and micro-transit for first- and last-mile connections	Regulation		✔		Pilot projects underway in Austin, TX; Sacramento, CA; Centennial, CO, and others; Identified in Seattle New Mobility Playbook (p. 43)
	Implement an 'empty seat tax' or dynamic pricing model in order to incentivize shared rides	Pricing	✔	✔		Identified in NY/NJ/CT Regional Plan Association New Mobility (p. 4), Seattle New Mobility Playbook (Appendix C, p. 9)
	Invest in transit upgrades that increase ridership	Investment (Capital) / Program	✔	✔	✔	Already underway in Cities of Seattle, Portland, Minneapolis, Vancouver
	Create mobility hubs with transit shelters with real-time transit arrival information, bike share, scooter share, car share, etc.	Investment (Capital) / Program	✔	✔		Pilot projects in Los Angeles, CA; Austin Smart Mobility Roadmap (p. 12); and Seattle New Mobility Playbook (p. 44)
	Incentivize and properly regulate shared bike/scooter/etc. personal mobility options		✔			Shared Electric Scooter Pilot in Portland
	Develop Mobility as a Service (MaaS) platform with integrated access and payment across all modes	Investment (Capital) / Program	✔	✔		Whim App has been adopted in Helsinki, Finland and West Midlands, UK; Identified in Seattle New Mobility Playbook (p. 44); TriMet in the Portland Metro areas is developing a Mobility on Demand app.

[5] *Portland, Seattle, and Vancouver are represented by the letters P, S, and V in the following tables.*

1.2 Maximize Transportation Network Efficiency (cont'd.)

Strategy	Implementation Action	Type	P	S	V	Examples/References
1.2.2. Reduce Vehicle Distance Traveled	Cap overall number of vehicles during certain times of day (similar to air traffic control)	Regulation				Identified in NY/NJ/CT Regional Plan Association New Mobility (p. 3)
	Use geo-fencing as a way of charging vehicles and/or restricting vehicles in certain areas	Regulation		✔		Identified in NY/NJ/CT Regional Plan Association New Mobility (p. 3); Seattle New Mobility Playbook (Appendix C, p. 6)
	Institute road usage charges via tolls, VMT/VKT fees, etc.	Pricing	✔	✔		Pilot projects in OR, WA, CA; Identified in NY/NJ/CT Regional Plan Association New Mobility (p. 3); Seattle New Mobility Playbook (Appendix C, p. 9)
1.2.3. Prioritize Curb Zone Management	Restrict curbside access to certain types of vehicles	Regulation				Identified in NY/NJ/CT Regional Plan Association New Mobility (p. 3)
	Restrict curbside access by time of day and/or occupancy	Regulation				Identified in NY/NJ/CT Regional Plan Association New Mobility (p. 3)
	Amend zoning codes to establish passenger loading zones	Regulation				City of Chandler, AZ has adopted zoning code amendments
	Establish curbside access in relation to land use, street type, urban form and parcel vs. district	Regulation				City of Chandler, AZ has adopted zoning code amendments that get at this
	Map and inventory curb space	Program				Washington, D.C. Commercial Loading Zone Management Program
1.2.4. Reduce Demand for Parking	Phase out parking off-street minimums	Regulation	✔	✔		Identified in Seattle New Mobility Playbook (Appendix C, p. 10); NY/NJ/CT Regional Plan Association New Mobility (p. 4)
	Establish demand-based meter pricing	Pricing	✔			SFPark project; Identified in LA Mobility Plan 2035 (p. 159); Portland adopted Performance Based Parking Management Manual;
	Establish loading zone to parking spot exchange ratios	Regulation				City of Chandler, AZ has adopted zoning code amendments that get at this
	Allow for shared parking between businesses/time of day	Regulation	✔			Identified in LA Mobility Plan 2035 (p. 159), Austin Smart Mobility Roadmap (p. 12)
	Develop bicycle parking corrals in on-street parking spaces	Investment (Capital)	✔			Identified in LA Mobility Plan 2035 (p. 163)

1.2 Maximize Transportation Network Efficiency (cont'd.)

Strategy	Implementation Action	Type	P	S	V	Examples/References
1.2.5. Update Street Design Standards	Change design standards to enable new more efficient transport modes (e-scooters, terrestrial drones, etc.)	Regulation				None identified
	Keep lane widths to a minimum	Regulation				NACTO Blueprint for Autonomous Urbanism (p. 24)
	Require fewer curb cuts to prepare for fewer parking lots	Regulation				None identified
	Prioritize improvements to pedestrian and bicycle infrastructure	Investment (Capital)	✔	✔		Identified in Seattle New Mobility Playbook (Appendix C, p. 8)
1.2.6. Facilitate Information Sharing	Develop clear and uniform set of data standards	Regulation	✔			Identified in NY/NJ/CT Regional Plan Association New Mobility (p. 4). Los Angeles Mobility Data Standards, Portland Shared Scooter Data Sharing Agreement requirements.

Table 4-2. Policy Objective 2. Enable Efficient Freight and Goods Movement

Strategy	Implementation Action	Type	P	S	V	Examples/References
2.1 Promote Efficient Line-Haul Movement						
2.1.1. Enable Efficient Line-Haul Movement	Establish dedicated lanes of travel	Regulation				None identified
	Promote platooning to help mitigate fuel inefficiency	Program				Identified in NY/NJ/CT Regional Plan Association New Mobility (p. 18)
	Prioritize freight corridors when making technological upgrades	Investment (Capital) / Program				St. Louis Region Emerging Transportation Technology Strategic Plan (p. 49)
	Identify new regulatory needs for freight strategies	Investment (Capital) / Program				None identified
	Make freight priority signal improvements	Investment (Capital) / Program	✔			Portland Transportation System Plan Freight Priority Program
2.2 Promote Efficient Goods Delivery						
2.2.1. Prioritize Curbside Access	Incentivize off-peak deliveries, pedestrian deliveries, and deliveries made by non-motorized vehicles	Regulation				Identified in LA Mobility Plan 2035 (p. 157)
	Require off-street dock and/or loading facilities for many new buildings	Regulation				Identified in LA Mobility Plan 2035 (p. 159)
	Charge for curbside access based on use, street type, and time of day	Pricing				Washington, D.C. Commercial Loading Zone Management Program
	Convert curb parking to on-street loading	Program				Identified in LA Mobility Plan 2035 (p. 159)
	Provide delivery personnel with real-time information on parking availability	Program				St. Louis Region Emerging Transportation Technology Strategic Plan (p. 49)
2.2.2. Integrate and Optimize 'Less Than Truckload' Shipping	Work with shippers to determine needs related to load optimization (full truckloads vs. less than truckloads) to enable 'hub and spoke' operations	Program		✔		Seattle New Mobility Playbook (Appendix C, p. 8)

Table 4-2. Policy Objective 2. Enable Efficient Freight and Goods Movement

2.2.3.	Facilitate Freight and Goods Movement Information Sharing	Establish information sharing requirements for delivery services that hire local staff as independent contractors	Regulation				None identified
		Facilitate centralization of information for freight shipment across modes	Program				St. Louis Region Emerging Transportation Technology Strategic Plan (p. 49)
2.2.4.	Enable Mixing of Passenger and Goods Delivery	Optimize vehicle trips and reduce overall number of vehicle trips by enabling seamless delivery of passengers/goods	Program				None identified

Table 4-3. Policy Objective 3. Prioritize Clean Energy Sources

3.1 Promote Adoption of Zero Emission Vehicles						
Strategy	Implementation Action	Type	P	S	V	Examples/References
3.1.1. Incentivize Zero Emission Vehicle Deployment	Require charging infrastructure in new developments	Regulation	✔	✔		Seattle New Mobility Playbook (Appendix C, p. 10)
	Prioritize autonomous vehicle fleets that are electric	Regulation	✔	✔		Seattle New Mobility Playbook (Appendix C, p. 6)
	Establish home charging rebate programs	Pricing				Austin Smart Mobility Roadmap (p. 24)
	Deploy shared-electric mobility options and infrastructure in affordable housing developments	Program				Austin Smart Mobility Roadmap (p. 12); Blue LA pilot project
3.1.2. Support Clean Energy Sources	Allow higher weight limits in freight vehicles using alternative fuels or automated logistics	Regulation				St. Louis Region Emerging Transportation Technology Strategic Plan (p. 54)
	Support charging infrastructure powered by clean energy	Investment (Capital) / Program	✔	✔	✔	Austin Smart Mobility Roadmap Plug-In EVerywhere (p. 23)

Table 4-4. Policy Objective 4. Limit Metropolitan Footprint Expansion

4.1 Limit Sprawl and Land Consumption						
Strategy	**Implementation Action**	**Type**	**P**	**S**	**V**	**Examples/References**
4.1.1. Encourage Density and Limit Sprawl	Advance land use policies that encourage development of downtown areas, regional activity centers and corridors linked through transit	Regulation	✔	✔	✔	Adopted in Portland, Seattle, Vancouver; Identified in St. Louis Region Emerging Transportation Technology Strategic Plan (p. 42)
	Support incentives and policies to encourage density in transit-served locations	Regulation	✔	✔	✔	Adopted in Portland, Seattle, Vancouver; Identified in St. Louis Region Emerging Transportation Technology Strategic Plan (p. 42)
	Limit urban expansion through smart growth policies	Regulation	✔	✔	✔	Adopted in Portland, Seattle, Vancouver
	Implement VMT/VKT charges to disincentivize longer commutes	Pricing				None identified to specifically disincentivize longer commutes. Oregon and Washington both have VMT pilot projects underway.
	Allocate/prioritize road space that opens up as a result of automation to bicycling, walking, high-capacity transit, etc.	Investment (Capital) / Program				None identified

Table 4-5. Policy Objective 5. Adapt to Land Use Changes Over Time

Strategy	Implementation Action	Type	P	S	V	Examples/References
5.1 Prepare for Changes to Existing Land Uses						
5.1.1. Enable Redevelopment of Parking	Rezone and repurpose parking lots for affordable housing	Regulation				Identified in NY/NJ/CT Regional Plan Association New Mobility (p. 5)
	Encourage adaptable parking garages that can easily be repurposed	Regulation				Austin Smart Mobility Roadmap (p. 12), City of Rochester Design Guidelines (C.11, C.12)
5.1.2. Reassess Developable Lands Inventory	Rezone and repurpose auto oriented uses like gas stations, car lots, etc. for new housing/employment/parks uses	Regulation				Update how housing and employment needs analysis are conducted to reflect changes in the market and local conditions (No examples identified.)
5.1.3. Respond to Changes to Land Valuation	Rezone to respond to market changes and mitigate fiscal impacts	Regulation				None identified
	Identify alternative income streams for municipal budgets to mitigate property tax revenue changes.	Program				None identified
5.2 Prepare for New Land Uses						
5.2.1. Enable New Uses	Rezone areas for fleet storage, charging spaces, and maintenance of fleets	Regulation				None identified

Table 4-6. Governance and Operational Objective 1. Update Organizational Structures and Facilitate Communication

Strategy	Suggested Actions	P	S	V	Examples/References
1.1 Streamline Organizational Structures and Increase Capacity	Create centralized, regional data management to increase analysis capacity	✔	✔		City of Austin's 'Data Rodeo' collaboration between City of Austin and University of Texas (p. 41 in Austin Smart Mobility Roadmap); Identified in Seattle New Mobility Playbook (p. 44)
	Establish 'New Mobility' teams prioritizing communications, financial and resource management, risk management, grant writing, quality control and testing, etc.	✔	✔		Identified in Austin Smart Mobility Roadmap (p. 68)
	Build staff capacity in data analytics and technology experience	✔	✔		Identified in Seattle New Mobility Playbook (p. 44); St. Louis Regional Plan (p. 55)
1.2 Identify/Establish Funding Structures for New Mobility Projects	Adjust Transportation Improvement Program (TIP) criteria to support technology deployment				Identified in St. Louis Regional Plan (p. 66); Cape Cod Joint Transportation Committee includes use of modern technology as a project scoring criterion
1.3 Promote Cross-Agency Communication and Public Communication	Coordinate city/regional planning activities	✔			Ex. Develop policy statement on the role of technology in next Regional Transportation Plan update as identified in St. Louis Regional Plan (p. 59)
	Establish robust and continuous public communication strategies about new mobility		✔		Identified in Seattle New Mobility Playbook (p. 44)
1.4 Create New Regional, State/Province Coordinated Revenue System for Funding Transportation Infrastructure and Management	Coordinate with regional jurisdictions and state/ provincial agencies to create a revenue system that incentives walking, biking, transit, then shared vehicles, then low to no occupancy vehicles; Consider rates for freight				Portland, Seattle, Vancouver and others
1.5 Create and Execute Equity Assessment of Proposed Policies	Follow adopted procedures for equity or use a highly-rated toolkit to address existing inequities, if possible, and ensure the policies do not create new ones	✔	✔		Examples include Portland's Shared Electric Scooter Permit application

Table 4-7. Governance and Operational Objective 2. Promote Culture of Innovation and Flexibility

Strategy	Suggested Actions	P	S	V	Examples/References
2.1 Establish Organizational Structure that Supports Innovation	Create new staff positions to promote innovative transportation services	✔	✔		Austin Smart Mobility Roadmap suggests creation of Chief Officer of EV/AV transportation services (p. 68)
2.2 Facilitate Pilot Projects	Enable a process by which unsolicited proposals may be accepted to provide streamlined processes				Ex. LA Metro Office of Extraordinary Innovation
	Promote public-private partnerships that advance city goals and objectives		✔		Ex. Austin CityUP, a smart city consortium of companies, organizations, individuals; Identified in Seattle New Mobility Playbook (Appendix C, p. 8)
2.3 Promote Culture of Calculated Risk-Taking	Encourage innovation by considering changes to organizational structures, staff skills, and procurement rules to advance city goals and objectives		✔		Identified in Seattle New Mobility Playbook (p. 40)
	Create and implement a communication plan to promote new culture with constituents and stakeholders			✔	City of Vancouver is working on a 'Learn Together' strategy

CONCLUSIONS

According to the U.S. Environmental Protection Agency, the transportation sector accounts for the largest portion of greenhouse gas emissions compared to all other sectors (28% in 2016) (United States Environmental Protection Agency, 2018). In Canada, the transportation sector, along with the oil and gas sector, accounts for nearly 50% of total GHG emissions (Government of Canada, 2018). The Cities of Portland, Seattle, and Vancouver have adopted ambitious climate goals that involve a significant reduction in greenhouse gas emissions by 2050. Given that the transportation sector accounts for a significant percentage of total greenhouse gas emissions, transportation is a critical focus area for the three cities. However, the Cities' ability to reach their climate goals may be threatened by the deployment of autonomous vehicles and other emerging technologies. Preliminary research suggests that AVs will operate much like TNCs do today, and worryingly, TNCs appear to be contributing to increases in vehicle distance traveled and congestion, as well as decreases in transit ridership and other non-vehicular modes. In addition, the rise of e-commerce and app-based ordering has contributed to an increase in urban freight and local delivery trips. These trends could cause detrimental environmental impacts, as well as detrimental impacts on equity if current disparities are exacerbated rather than mitigated. What is clear is that the Cities will need to enact equity-informed programs and policies that help to mitigate these impacts in order to achieve greenhouse gas emission goals. While there may be challenges, there are also many opportunities to make positive changes, though that will require a culture of flexibility, innovation, and transparency.

APPENDIX

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