Sustainable Mobility in the United States:

Challenges & Opportunities from New Technologies

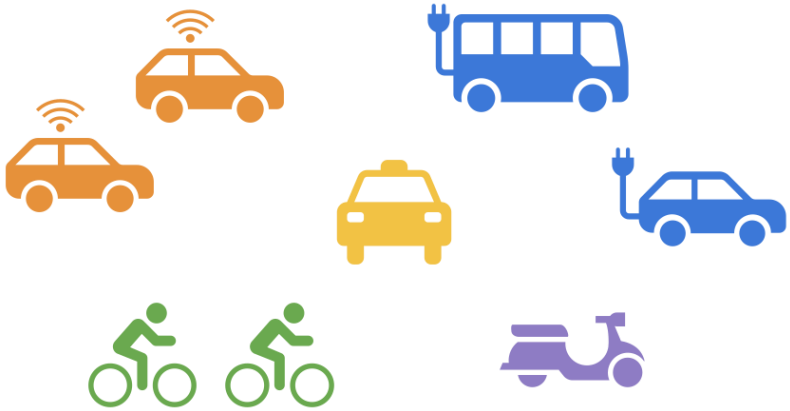

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Table of Contents

1 Executive Summary

In 2018, the transportation sector accounted for more than 24% of carbon dioxide (CO_2) emissions globally[1] and became the largest contributor of greenhouse gases (GHGs) in the United States, accounting for 29% of emissions.[2] While this sector is crucial for the development of any economy, it also has a large role to play in any meaningful efforts to transition to a low-carbon future. Therefore, it is necessary to view the transportation sector through the lens of sustainability, which encompasses economically viability, as well as human and environmental health.

In this report we define sustainable mobility as the application of technologies and management methods to promote better local and global environmental outcomes, while also remaining economically-viable and bridging socioeconomic gaps in the transportation network. Our main goal is to examine the current status of sustainable mobility in the United States and the policies that shape its adoption and impacts on the environment and society and develop strategic recommendations to ensure that the adoption of new mobility technologies truly benefit people and the planet. In doing so, we have focused on three key mobility technologies, which have a potential to transform the transportation sector: battery powered electric vehicles (EVs), shared mobility technologies (specifically ride-hailing and micromobility), and autonomous vehicles (AVs).

We examine policies and programs at the federal, state, and local levels that focus on promoting and regulating these three technologies. Specifically, we chose case studies focusing on two states, California and Michigan, and two cities, Washington, DC and Pittsburgh. We selected contrasting cases that represented differing policy approaches and stages of technology adoption. The state of California is at the forefront of technology innovation, as well as a leader in sustainability and climate efforts. Michigan, on the other hand, is the historic center of the US automotive industry, with a growing autonomous vehicle industry. As the capital of the United States, the city of Washington, DC boasts a robust and expanding transit network, along with a rapid growth in micromobility services. Pittsburgh, on the other hand, is a former industrial city that is becoming an emerging hub for AV technology and has taken a more collaborative approach to the integration of newer technologies.

The adoption of these technologies has an impact on multiple realms of society. We specifically examine their impacts on sustainability, equity, and data privacy outcomes. We find that sustainability impacts depend not only on tailpipe emissions, but the entire lifecycle of a technology, as well as where it is adopted, how it is adopted, and the sustainability of the modes of transportation it is replacing. Equity outcomes can also vary: the introduction of a new mobility technology does not mean that all groups benefit equally with enhanced mobility. As many of these new mobility technologies involve the collection of and use of large amounts of

[1] Wang and Ge, “Everything You Need to Know About the Fastest-Growing Source of Global Emissions.”
[2] U.S. Environmental Protection Agency, “Fast Facts on Transportation Greenhouse Gas Emissions.”

trip data, questions arise and precedents are set around data privacy and what data can and should be protected.

To ensure the best outcomes in the realms of sustainability, equity, and data privacy, we recommend frameworks that policymakers can use when making decisions about how to incorporate these new sustainable mobility trends into their transportation landscape. We also propose a framework that can be used to determine which policy approaches are best depending on how developed and widely used a mobility technology is. As a result, we hope that the American experience with sustainable mobility can serve as a learning experience going forward for policymakers everywhere.

2 Introduction

In this report, we will address the challenges and opportunities that the United States faces at the federal, state, and city level in promoting sustainable mobility. Before examining specific technologies and practices, it is first important to define “sustainable mobility” in this context. For the purposes of this report, we will refer to sustainable mobility as the application of technologies and management methods to promote better local and global environmental outcomes, while also remaining economically viable and bridging socioeconomic gaps in the transport network.

These objectives underpin the *Smart Cities* movement, which attempts to integrate technologies like remote monitoring and artificial intelligence to improve the performance of the city’s transportation and other systems. In Figure 1 we illustrate how various technologies integrate with and impact society, the economy, and the environment. While these tools offer great potential for improving efficiency, their rapid deployment has brought about concerns about the wider social implications, like digital privacy and the potential for algorithmic bias. Therefore, we will also be addressing the role and impact of data collection in developing transportation policies.

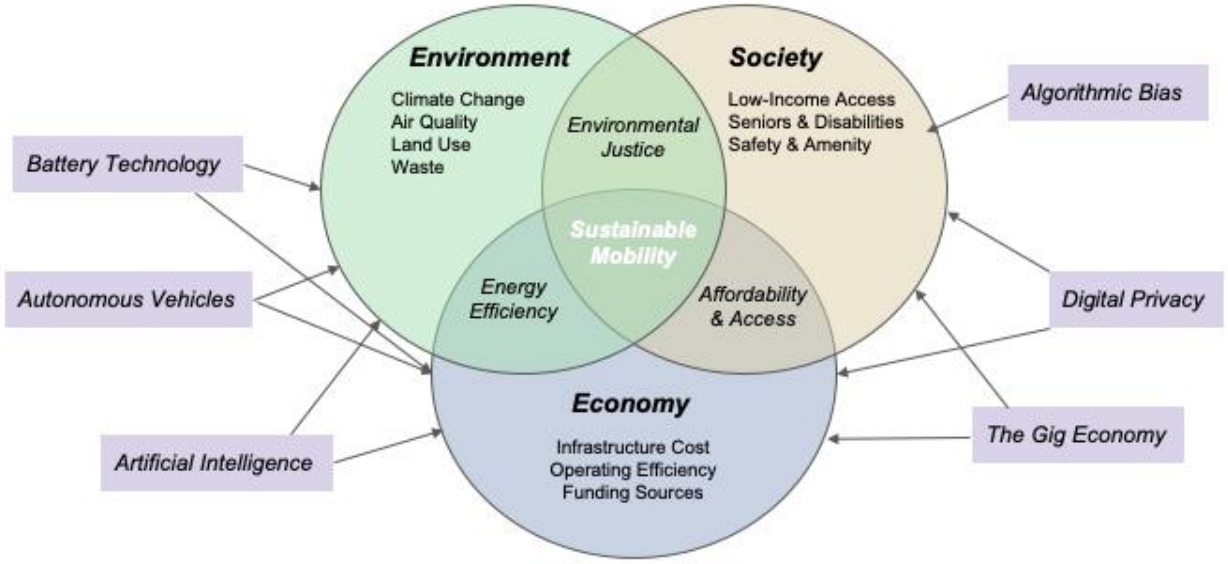

Figure 1: Sustainable Mobility and the Role of Technology

To evaluate impacts of new transportation technologies, we chose to examine the adoption of these technologies at three levels: federal, state, and municipal. For the more localized impacts we focused on specific metropolitan- and state-level case studies. The case studies selected for this report are California and Michigan at the state level; and Washington, DC and Pittsburgh at the metropolitan-level. The different geographic, economic, and demographic conditions in each of these cities and states correspond to different present and future transportation demand and constraints. Differences notwithstanding, these cases each feature public and/or private-sector innovation in the transport sector.

Within each case, we will examine not only the processes of technological diffusion and regulatory responses, but also their broader impacts on civil society. In particular, we will use existing evidence to identify threats and opportunities in the following areas:

- Environmental Sustainability: Do changes in the transportation system lead to a net reduction in greenhouse gas emission? What are the effects on local air quality? What changes in land use are expected? How are adverse environmental impacts distributed across space and social groups?
- Inclusion, Access, and Equity: Are new technologies widely affordable? Will implementation improve or worsen existing disparities in transportation services? Are groups with special needs (seniors, children, people with disabilities) adequately served?
- Data Management & Security: What kinds of data are being collected to support implementation of new transportation technologies? Are consumers aware of the information being collected? What measures are being taken to ensure consumer safety and privacy? How are data practices affecting different social groups? What are the tradeoffs involved in data collection/privacy?

As we will demonstrate in this report, those answers are rarely straightforward, and involve a complex set of choices by policymakers, manufacturers, and consumers. Especially in the case

of experimental or less-established technologies, the overall impact may be uncertain. We will aim to highlight some key controversies surrounding emerging topics in transportation systems, offering insights into the sources of uncertainty.

3 Methodology

We used a variety of information sources when compiling this report, including peer-reviewed literature, trade literature, and interviews with subject-matter experts. The first part of this report will focus broadly on new trends and technologies in urban transportation in the United States. This encompasses emergent technologies, evolving consumer trends, and changes in public-sector management of the transportation network. Throughout this report, we will frame these developments in the context of the *adoption curve*. The adoption curve refers to the relationship between a new technology's cost, relative to incumbent technologies, and its market penetration. In a 2018 paper, Meckling et al. examine how policy choices influence both the cost and deployment of new 'clean energy' technologies.[3] The authors identify three distinct phases of technological adoption, called *experience* in their formulation (Figure 2):

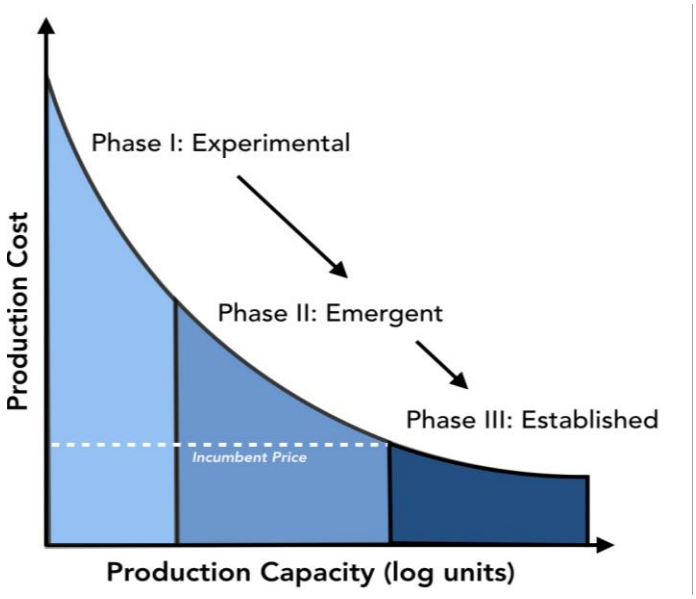

Figure 2: Adoption Curve[4]

At the top of the curve are *experimental* technologies. At this stage, technologies are generally too cost-prohibitive to implement beyond limited pilot or experimental applications. In the context of this report, autonomous vehicles remain in this phase of development.

The middle of the curve are *emergent* technologies. This stage is characterized by increasing cost-competitiveness, which may result from policy support, growing economies-of-scale, or improvements in manufacturing efficiency. Emergent technologies have not yet achieved cost-

[3] Meckling et al., "The Political Logics of Clean Energy Transitions."
[4] Adapted from Meckling et al.

parity with incumbents, but falling costs and technical improvements in this stage make these technologies viable for niche audiences. Though such technologies may have a niche commercial market, there remain barriers to widespread adoption. In most cases, cost is the principal barrier, though infrastructure constraints, ambiguous regulation, and consumer preferences can also present obstacles to implementation at-scale. Electric vehicles and shared mobility are currently at this phase of development.

At the bottom of the curve are *established* technologies. At this stage, newer technologies are deployable at-scale and cost-competitive with incumbents. Traditional manufacturers may have to reduce prices in order to compete with new competitors. Other companies will try to adapt to the changing situation by evolving to mimic their upstart competitors. For example, existing carmakers have invested in or acquired start-up firms in the AV sector.

The mobility technologies and practices evaluated in this report feature differing levels of adoption, resulting in different regulatory approaches. It is also important to note that adoption can vary by locality. Some places lack the infrastructure, resources, or technical capacity to support new transportation models and modes. In other places, there can be varying levels of social support or resistance toward changes in the transportation network.

4 Mobility Trends in the United States

4.1 Passenger Vehicles

The automobile and highways dominate perceptions of US transportation. Mobility in the United States has long been characterized by high private car use and ownership. There are about 766 cars for every 1000 people, whereas Europe has only 507 and China, 74.[5] A high share of the population, 70 % have drivers' licenses.[6] However, there is evidence that the prevalence of the private vehicle is slowly declining due to changes in demographics, technology, economics, and cultural preferences.

Americans have been using cars less to make their daily trips, as seen in the following trends:

- Vehicle miles traveled (VMT) growth has been stagnating since the Great Recession.[7]
- Americans drive on average 7.6% fewer miles than they did a decade ago.
- Demand for new cars has slightly decreased by 0.4%[8]
- The average number daily trips has decreased from 4.3 in 1995 to 3.4 in 2017.[9]
- The share of daily commutes in single-occupancy vehicles (SOV) has decreased slightly from 92.8% in 2001 to 91.4% in 2009.

[5] Bormans, "Statistical Pocketbook 2018."
[6] Keeney, "China's Booming Autonomous Car Opportunities."
[7] Martin et al., "Understanding Travel Behavior: Research Scan."
[8] ACEA, "Vehicles in Use - Europe 2018."
[9] Polzin, "Changing Travel Behavior."

In addition to making fewer trips and fewer trips by car, Americans are also increasingly less likely to own a car than in the past. There were 5-6% drops in the number of vehicles per person, vehicles per driver, and vehicles per household from 2006 - 2012, with the most pronounced declines in the millennial generation.[10] There has also been an increase in the percentage of households with zero to one car and a decrease in the share of households with two or more cars.[11] While the economic hardships that many faced in the wake of the financial crisis contributed to these drops, peak car ownership in the United States occurred before 2008, implying that the financial crisis only exacerbated a trend that was already happening.[12]

Urbanization and internet technology have contributed to this slow-down of car use and ownership. Those living in dense, urban areas are more likely to own fewer vehicles, and the U.S. population is urbanizing.[13] The rise of e-commerce has contributed to Americans taking fewer trips for shopping and errands.[14] Telecommuting and remote-work capabilities allow more people to work from home, but the lack of employer surveys makes it difficult to fully measure their impacts. These trends are fueled by changing demographics in the United States and different preferences amongst the generations.

4.2 Demographic Changes

The American population is aging. By 2030 one in five Americans will be 65 or older.[15] The millennial generation (born 1981-96) has surpassed the baby boomers (1946-64) as the largest adult generation in the United States.[16] Their travel behaviors will have the largest impact on American mobility moving into the future.

Car ownership rates have dropped the most for millennials as compared to any other generational cohort. The number of young people who are getting their driver's license is also at an all time low, making it unlikely that car ownership rates will rebound, since license rates are good indicators of future car ownership.[17] Millennials are also three times more likely to abandon their personal vehicle than any other generation.[18] To make up for reduced car use, millennials use other modes, such as carpool, public transit, and bicycling at rates higher than older generations. However, millennials are also travelling less than older generations were at the same age, according to the National Household Travel Survey.[19]

[10] Bouton et al., "Urban Mobility at a Tipping Point | McKinsey."
[11] Martin et al., "Understanding Travel Behavior: Research Scan."
[12] Berg, "U.S. Urban Population Is Up ... But What Does 'Urban' Really Mean? - CityLab."
[13] Berg, "U.S. Urban Population Is Up ... But What Does 'Urban' Really Mean? - CityLab."
[14] Polzin, "Changing Travel Behavior."
[15] Martin et al., "Understanding Travel Behavior: Research Scan."
[16] Fry, "Millennials Expected to Outnumber Boomers in 2019."
[17] Bliss, "Federal Highway Administration."
[18] Giffi et al., "The Changing Nature of Mobility."
[19] Martin et al., "Understanding Travel Behavior: Research Scan."

Some of this reduced car use can be explained by changing preferences amongst younger generations. Millennials and their younger cohort, Gen Z (1996-2012) do not see car ownership as important as older generations do. They are twice as likely to question whether they need to own a vehicle in the future and are less willing to buy a car than older generations.[20]

5 Electric Vehicles

Electric vehicles (EVs) have existed for more than a century; however, it is only in the past decade that there has been significant commercial interest in electric-powered cars. Since the first commercially available EV model entered the US market in 2010,[21] the industry has rapidly expanded. Newer models now have an increased range on a single charge and electric charging stations have become more plentiful. Today, there are several EV models available in the US market, and this number continues to increase. As an indication of the industry's shifting attitude toward EVs, there were four ads for EVs in the 2020 Super Bowl. In the next few years, the market will likely expand beyond early adopters.

5.1 Electric Vehicle Adoption in the United States

The United States is the third largest EV market in the world. EV sales in the United States increased by 81% in 2018, and the total number of EVs has surpassed 1.5 million. Despite the rapid growth of the EV sub-sector in recent years, they still comprise only 1.6% of private light vehicles in the United States making them an emergent technology on the adoption curve.

Public perception of EV technology has been tepid.[22] This has slowed EV growth in the United States since consumer awareness and understanding are critical precursors to EV market growth.[23] In addition, mismatched policies from states have sent mixed signals to auto manufacturers, which has delayed the scaling up of EV manufacturing as well as the development of lower cost and more sophisticated vehicles.[24] As a result, EVs are still significantly more expensive than gasoline-powered vehicles, and early adoption has been limited to the rich and those committed to environmental causes.[25]

EV owners in the United States typically fall into certain socioeconomic categories. Those who are male, middle-aged, highly educated, or make over 100,000 USD make up the largest shares of EV owners.[26] Another important factor that encourages EV adoption is the availability of charging infrastructure. A widespread charging infrastructure network that includes home,

[20] Vitale et al., “2019 Global Automotive Consumer Study.”
[21] Canis, Clark, and Sherlock, “Vehicle Electrification: Federal and State Issues Affecting Deployment.”
[22] Fitzgerald and Li, “Driving a Shared, Electric, Autonomous Mobility Future: What China, India, and the United States Can Learn from Each Other.”
[23] Slowik, “The Continued Transition to Electric Vehicles in U.S. Cities.”
[24] Fitzgerald and Li, “Driving a Shared, Electric, Autonomous Mobility Future: What China, India, and the United States Can Learn from Each Other.”
[25] Fitzgerald and Li.
[26] Nickkar, “Electric Vehicle Ownership Factors and Commuting Behavior in the United States.”

workplace, and public locations not only increases driver confidence in the vehicle's range, but also increases visibility and public awareness of EV technology. Consumer research shows that the decision to buy an EV is directly related to the availability of fast-charging stations.[27] Markets with high EV uptake have at least 300 public charging points per million people. In the United States, by contrast, half of the population lives in a market with charging infrastructure at least 70% below this benchmark.[28]

5.2 EVs and the Electricity Grid

Another barrier to EV diffusion at scale is insufficient infrastructure, particularly in relation to residential charging. In a scenario with mass EV adoption, the demands on existing electricity distribution networks would likely exceed local capacity. Introducing electric vehicles will increase total electricity consumption (shifting from liquid fuel to electricity), but more importantly it has the potential to dramatically increase demand at peak hours. If every household in a neighborhood charges their vehicle in the evening, the amount of electricity needed to support this activity will in many cases exceed local distribution capacity. If demand exceeds available capacity, wholesale prices spike dramatically, and blackouts or frequency losses (which can disrupt electronics) are possible. Customers do not directly observe price spikes due to time-averaged pricing, but if they occur with regularity it would likely result in higher household rates potentially dampening demand for electric vehicles.

If mass EV replacement of conventional vehicles is to occur, there will need to be corresponding shifts in policy. The "hardware" solution is to increase local distribution capacity, including infrastructure like high-voltage DC lines to support commercial charging. This can be paired with distributed generation (e.g. rooftop solar) and battery storage to increase local power availability. The "software" solution is to implement demand-responsive pricing to shift charging times to less constrained times of day. This requires real-time electricity pricing, and demand responsiveness will vary. Some activities cannot be shifted to another time, and some people will be willing to pay more, or unaware of the increased electricity cost. There is also a behavioral aspect. Charging during daytime hours while at work, for example, could reduce peak-hour demands on the grid. Similarly, shorter and/or fewer trips can reduce the energy consumption of EVs.

[27] Bonges and Lusk, "Addressing Electric Vehicle (EV) Sales and Range Anxiety through Parking Layout, Policy and Regulation."
[28] Slowik, "The Continued Transition to Electric Vehicles in U.S. Cities."

5.3 Sustainability Implications

With no tailpipe emissions EVs will reduce local air pollution. They also have the potential to decrease greenhouse gas (GHG) emissions depending on the power supply of the grid. In areas where the majority of electricity is generated by renewables, the use of EVs will decrease GHG emissions. However, plug-in EVs might not prove to be as sustainable in regions where the electricity generation mix is mostly fossil fuels, such as in Florida, where only 2% of electricity generated is from renewables.[29]

As EVs have become more established in the marketplace, there has been increased scrutiny over their broader social and environmental impact, especially as it relates to materials, manufacturing, and waste management. The lithium-ion batteries used in EVs today are crucial in determining cost, performance, and range; however, the manufacturing of these batteries requires intensive inputs of resources like lithium and cobalt, while also encountering sustainability concerns. In a high EV-adoption scenario, the demand for these minerals will increase significantly, leading to a rise in demand for lithium and cobalt. This will have numerous negative implications. For example, with 70% of the world's cobalt resources located in the Democratic Republic of Congo (DRC), the country has been known for artisanal mining and child labour, which have been major concerns of the consumers in the automotive sector. Moreover, the instability of the country, exacerbated by its mineral wealth has given rise to internal conflicts which often lead to supply disruptions and price volatilities.[30]

A recent study also highlighted that while an electric car can reduce emissions, making their EV batteries could emit more carbon dioxide than manufacturing conventional cars. To power an electric vehicle, batteries must be significantly larger than those used in consumer electronics. The battery packs used in Tesla models contain between 7,100-8,300 'cells,' while a smartphone can be powered by a single cell.[31] Larger batteries would produce more CO_2 gases, especially if the electricity required for battery manufacturing utilizes fossil fuels. An example for this would be the use of energy derived from coal plants in Germany to manufacture a battery, leading to an overall increase in CO_2 emissions.[32]

The battery is not the only design consideration that impacts the life-cycle sustainability of EVs. Lighter-weight vehicles offer improvements in battery performance. With less energy required on a per-mile basis, weight reduction reduces electricity consumption, improves vehicle range, and reduces cost for consumers. Though these all appear to be positive effects for sustainability and adoption, the assessment becomes more complicated when accounting for materials used in manufacturing. The primary way to reduce vehicle weight is to use lighter-weight materials in the vehicle frame. Aluminum is substantially lighter than steel, however the manufacturing process is significantly more energy-intensive, resulting in a 7 times higher carbon footprint per

[29] Bellan, "The State of Electric Vehicle Adoption in the U.S."
[30] Azevedo et al., "Lithium and Cobalt - a Tale of Two Commodities."
[31] Kerns, "When Electric Vehicles Take Over."
[32] Autovista Group, "Conflicting Reports on the Carbon Footprint of EVs."

unit.[33] While EVs have great potential to decrease the GHG emissions of the transportation sector, these life-cycle impacts should be taken into account when considering EVs' overall sustainability.

5.4 Equity Implications

It is necessary to consider the equity implications of increasing the number of electric vehicles on the roads. While EVs will definitely have a positive impact on the environment due to decreased tailpipe emissions, equity driven policies and programs will be needed to ensure EV adoption is not confined to the wealthy or environmentally conscious. While EVs are approaching cost parity, especially due to negligible fuel and maintenance costs, there are still hurdles that need to be overcome, such as their high upfront cost and a varied availability of charging infrastructure in cities.

Another potential hurdle is the likely increase in electricity prices due to rising peak demand as the number of electric vehicles connected to the grid rise. The higher rates would impact both households that have EVs and those that do not, and would disproportionately affect low-income households. A recent report from the American Council for an Energy Efficient Economy (ACEEE) highlighted the fact that low income households on an average spend 7.2% of their household income on utilities, more than thrice as much as a higher income household in 48 of the largest cities in the United States.[34] Thus, there is a need for government intervention through policies and programs that would specifically promote equity while simultaneously increasing adoption levels of electric vehicles.

5.5 Federal Policy and EVs

The US government uses a suite of policy tools that directly and indirectly encourage the adoption of EVs, including financial incentives, emissions standards, and informational tools. Overall, there has been less action on the part of the federal government to encourage EV adoption than there has been at the state or local level.

The most impactful federal policies encouraging EV adoption have been financial incentives. Examples include:

- **The plug-in electric tax credit** allows purchasers of electric vehicles to take a tax credit up to 7,500 USD for each vehicle that can be recharged by plugging into the grid. Multiple studies have shown that this incentive has had a positive impact on EV adoption.[35] This tax credit phases out after a manufacturer has sold 200,000 vehicles. So far only Tesla and General Motors have met that threshold. These companies along with Nissan, the Alliance for Automobile Manufacturers, the Edison Electric Institute, and several environmental and public health groups have been lobbying the Trump

[33] Kerns, "When Electric Vehicles Take Over."
[34] Drehobl and Ross, "Lifting the High Energy Burden in America's Largest Cities: How Energy Efficiency Can Improve Low Income and Underserved Communities."
[35] Zhou, Levin, and Plotkin, "Plug-in Electric Vehicle Policy Effectiveness: Literature Review."

Administration to extend the cap. Working against them are oil and gas interests who are lobbying to end the credit.

- In April 2019, Senators Debbie Stabenow (D-MI), Lamar Alexander (R-TN), Gary Peter (D-MI) and Susan Collins (R-ME) and Congressman Dan Kildee (D-MI) introduced the **Driving America Forward Act** in both chambers of Congress. The act calls for increasing the plug-in electric tax credit vehicle cap to 600,000 qualifying sales for each automaker. So far this act has only been introduced in Congress not approved as law.[36]
- There was also a **tax credit for the installation of alternative fuel vehicle refueling property**, which included EV charging stations, and expired in 2017. For residential installations it allowed a tax credit of 1,000 and up to 30,000 USD for business installations.

Indirectly, EV adoption has been encouraged by the **Corporate Average Fuel Economy (CAFE) Standards**. These standards aim to improve the fuel economy of cars manufactured for sale in the United States. While the Trump Administration proposed rolling back the standards to lower miles-per-gallon levels, car manufacturers have stated that this has not deterred them from continuing to produce and sell EVs.[37] **Investment in transportation electrification research and development**[38] has been another way that the federal government has supported the development and adoption of electric vehicles.

Other initiatives at the federal level that have promoted EV adoption include:

- **Electrify America** - Volkswagen settlement: While not a government policy, the 2016 Volkswagen settlement has a large impact on the adoption of EV technology nationwide. Volkswagen has agreed to pay the government 14.7 billion USD to settle allegations of cheating on emissions standards. Volkswagen is also required to invest 2 billion USD to increase public awareness about EVs and support public charging infrastructure.39
- **Clean Cities Coalitions** - The Clean Cities Coalitions Network is a Department of Energy (DOE) program. Under this federal umbrella there are almost one hundred coalitions in the United States made up of local stakeholders. The local coalitions undertake transportation projects, such as implementing alternative fuels like electric batteries, fuel-saving technologies and practices, and new mobility choices in their communities. At the federal level the DOE provides information and resources to help stakeholders achieve their alternative fuel goals, in the form of federal grants and data-driven online tools such as the Alternative Fuels Data Center. Clean Cities Coalitions help with building EV infrastructure and encourage EV fleets.[40]

[36] Stabenow, “S.1094 - 116th Congress (2019-2020).”
[37] Merchant, “Can the Electric Vehicle Push Defy a CAFE Standards Rollback?”
[38] Canis, Clark, and Sherlock, “Vehicle Electrification: Federal and State Issues Affecting Deployment.”
[39] Bellan, “The State of Electric Vehicle Adoption in the United States”
[40] U.S. Department of Energy, “Clean Cities Coalition Network.”

6 Shared Mobility

Shared mobility refers to transportation services and resources that are shared among users, either concurrently or one after another.[41] This includes public transit; taxis and limos; carsharing; carpooling and vanpooling; ride-hailing; micromobility (bikesharing and scooter-sharing); shuttle services and "microtransit"; and more. This report will address the newest and most disruptive of these services to the American transportation system—ride-hailing and micromobility.

6.1 Shared Mobility Adoption in the United States

Use of certain forms of shared mobility, such as ride-hailing and micromobilty, has been growing in the United States, especially among younger city residents. However, shared mobility usage in the United States is still much lower than in Europe or China, since driving a personal vehicle is often the cheapest (due to low gas prices) or most available mode of transport. The most common form of shared mobility in the United States is ride-hailing,[42] but it is still mostly concentrated in urban centers. Similar to EVs, the users of shared mobility are predominantly younger, urban, middle-upper income, highly-educated, and male. Young people in particular are more likely to try shared mobility: 42% of millennials are willing to try ride-hailing and other modes of shared mobility, whereas in older generations only 28% are willing to try.[43]

6.1.1 Ride-hailing with Transportation Network Companies (TNCs)

Ride-hailing is an arrangement where a passenger travels in a private vehicle driven by its owner for a fare. Booking of and paying for rides is done through a smartphone app with a transportation network company (TNC) such as Uber or Lyft. In ride-hailing, there is only one passenger or group riding in the vehicle. Ride-sharing is another option offered by TNCs and is similar to ride-hailing with the exception that the driver may pick up additional passengers along the route requiring passengers to share their ride with strangers. Ride-sharing fares per passenger tend to be lower to account for the reduced convenience and comfort.

Ride-hailing is the most well-known and widely used form of shared mobility in the United States. Since 2015, the share of the US population that has used ride-hailing services has more than doubled.[44] Despite its relative popularity with respect to other modes of shared mobility, 42% of respondents in a Deloitte study reported that they had never used a ride-hailing service. However, in 2017, that number was greater, with 55% never having used ride-hailing.[45] We find ride-hailing is still an emergent technology as so many people still have not used it.

[41] "What Is Shared Mobility?"
[42] Santos, "Sustainability and Shared Mobility Models."
[43] Giffi et al., "The Changing Nature of Mobility."
[44] Jiang, "More Americans Are Using Ride-Hailing Apps."
[45] Vitale et al., "2019 Global Automotive Consumer Study."

6.1.2 Micromobility

Micromobility includes shared bicycles, electric pedal assisted bicycles, and electric scooters. It is usually used to travel short distances, often the first or last mile of a journey or connections to public transit. Shared bicycles can be stationed-based, meaning they have to be returned to a designated station at the end of the ride or free-floating, where they can be left anywhere streetside within a certain geographical area. Electric scooter programs are usually free-floating.

Micromobility use in the United States has been increasing. From 2017 to 2018, the number of trips that Americans took by shared micromobility more than doubled, totalling 84 million trips in 2018.[46] The micromobility market in the US is predicted to be worth 200-300 billion USD by 2030.[47] While stationed bikeshare has the longest history in the US, in 2018 electric scooter use emerged as extremely popular and surpassed station-based bikeshare in number of rides taken (see Figure 3).

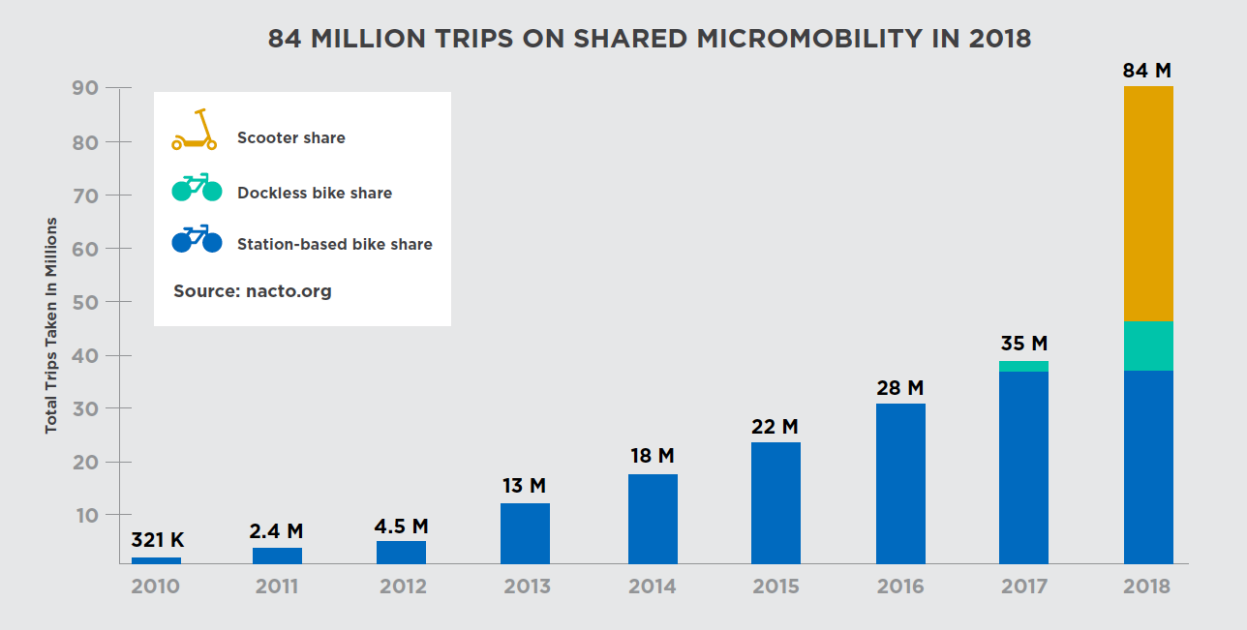

Figure 3: Shared Micromobility Trips Per Year[48]

The adoption of micromobility in the United States will be somewhat slowed by the fact that the use of micromobility is concentrated in urban areas, where distances between points of interest are closer. The six cities with the most station-based bikeshare usership account for 84% of all station-based bike trips in the country. Similarly for e-scooters, three metropolitan areas account for 40% of all trips nationwide.[49] Since the adoption of micromobility has exploded in some

[46] NACTO, “Shared Micromobility in the U.S.”
[47] Heineke et al., “Micromobility’s 15,000-Mile Checkup.”
[48] Taken from DuPuis and Griess, “Micromobility in Cities: A History and Policy Overview.”
[49] NACTO, “Shared Micromobility in the U.S.”.

places but has not actually reached that many cities, we classify micromobility as on the cusp between an experimental and emergent technology.

6.2 Sustainability Implications

Shared mobility offers the promise of reducing emissions and congestion by getting people to stop driving alone and share a ride or use a bike or scooter. Whether or not shared mobility actually does that depends on the mode. Ride-hailing, the most common form of shared mobility in the United States, has been shown to increase congestion in certain cities, as drivers often drive around passenger-less between customers.[50] Ride-hailing has also had the effect of taking some passengers off of public and active transportation and into cars.[51] According to a recent study by the Union of Concerned Scientists, trips on ride-hailing services produced nearly 70% more emissions than the modes of transportation they replace.[52] Ride-hailing trips are shared only around 15% of the time, but pooling more trips could help reduce both emissions and congestion impacts.[53] Pooled trips in EVs could significantly reduce the climate impacts of ride-hailing by cutting emissions up to 68% compared to a private car trip.[54]

All micromobility options are more environmentally friendly than a private vehicle trip. However, electric scooters are less environmentally friendly than many of the modes of transport they replace: walking, bicycling, and some modes of public transportation. While tailpipe emissions are non-existent for e-scooters, it is their entire life cycle, which includes the production of lithium-ion batteries and aluminum parts; manufacturing; shipping (often from China); and the collecting, charging, and redistributing of scooters, that makes up their environmental impact.[55] Similarly, bikeshare bikes need to be redistributed, though unless they are electric assist they do not need to be recharged.

6.3 Equity Implications

As mentioned above, users of shared mobility are more likely to be younger, male, and well educated compared to the general population. This is despite the fact that shared mobility could enhance the mobility of disadvantaged communities through improved job access and by making mobility cheaper, more available, and faster. Access to credit and debit cards for low-income commuters is a challenge for micromobility and ride-hailing use as the associated smartphone apps and stationed bikesharing kiosks require a credit or debit account.

Disability access is also a challenge for shared mobility where very few ride-hail vehicles are equipped to take on a passenger in a wheelchair and micromobility options are almost

[50] Hawkins, “Uber and Lyft Finally Admit They’re Making Traffic Congestion Worse in Cities.”
[51] Fitzgerald and Li, “Driving a Shared, Electric, Autonomous Mobility Future: What China, India, and the United States Can Learn from Each Other.”
[52] Union of Concerned Scientists, “Ride-Hailing Is a Problem for the Climate.”
[53] Urbanism Next, “Estimated Percent of Total Driving by Lyft and Uber.”
[54] Union of Concerned Scientists, “Ride-Hailing Is a Problem for the Climate.”
[55] Hollingsworth, Copeland, and Johnson, “Are E-Scooters Polluters?”

exclusively designed for able-bodied users. The dockless versions of micromobility, when not properly placed or ridden off the path of the sidewalk can become harmful obstacles for disabled pedestrians. As a result there have been two lawsuit filed against micromobilty companies for violating the Americans with Disabilities Act.[56]

Ride-hailing and sharing use in the United States is largely concentrated in urban centers. Only 19% of Americans living in rural areas use ride-hailing apps, whereas in urban and suburban areas, those numbers are 45% and 40% respectively.[57] Rural areas are much less lucrative money-making opportunities for potential drivers and the ride-hailing companies themselves, since there are fewer and typically longer rides. Indeed, ride-hailing is most economical for all where the distance is short and the parking is expensive, which is not usually the case in rural areas.[58]

6.4 Federal Policy and Shared Mobility

The federal government has played a very limited role in regulating shared mobility. State and especially local governments tend to play a larger role due to their involvement in transportation planning, parking policies, and public transportation.[59] TNCs like Uber and Lyft classify themselves as technology companies, so they have largely avoided being regulated like traditional transportation companies. This has drawn criticism, especially as the companies avoid transportation and labor regulations.[60] However, it has been states like California, New Jersey, and New York, rather than the federal government, that have proposed laws to regulate these companies.[61]

For micromobility, scooters are regulated the same as bicycles at the federal level. An electric bicycle (or scooter) is considered legal to go on the roads if it does not go above 20 mph and has a maximum motor power of 705W. Within this range the scooter or bicycle does not require a license or registration in most states. Like bicycles, electric scooters should go in the bike lane, where available, and are permitted in the street with cars, where not.[62]

[56] Kerr, “Disability Rights Group Sues Scooter Companies over Clogged Sidewalks.”
[57] Jiang, “More Americans Are Using Ride-Hailing Apps.”
[58] Shrikant, “Transportation Experts See Uber and Lyft as the Future. But Rural Communities Still Don’t Use Them.”
[59] Shaheen, Cohen, and Zohdy, “Shared Mobility Current Practices and Guiding Principles.”
[60] Beene, “Uber, Lyft May Face More Federal Oversight, Lawmaker Warns.”
[61] Sherman, “‘Catastrophically Huge’: New Labor Laws Aimed at Independent Contractors Could Be a Huge Drag on Uber and Lyft Stock.”
[62] EnvyRide, “Laws and Legislation on Electric Scooters.”

7 Autonomous Vehicles

Autonomous vehicles (AVs) have drummed up a lot of hype in recent years. A fully autonomous vehicle is one that can guide itself without human direction, or even a human present in the car. There are five levels of autonomous driving, but we will primarily deal with the highest levels (4 and 5) or high and full automation, since they will be the most disruptive and do not require a human driver in most conditions (Figure 4). Levels 1-3 range from driver assistance to conditional automation, and there are many such systems on the market today, but all require a driver to be in the car.[63] Both automakers and software companies are testing fully autonomous models, but none yet are available on commercial markets.

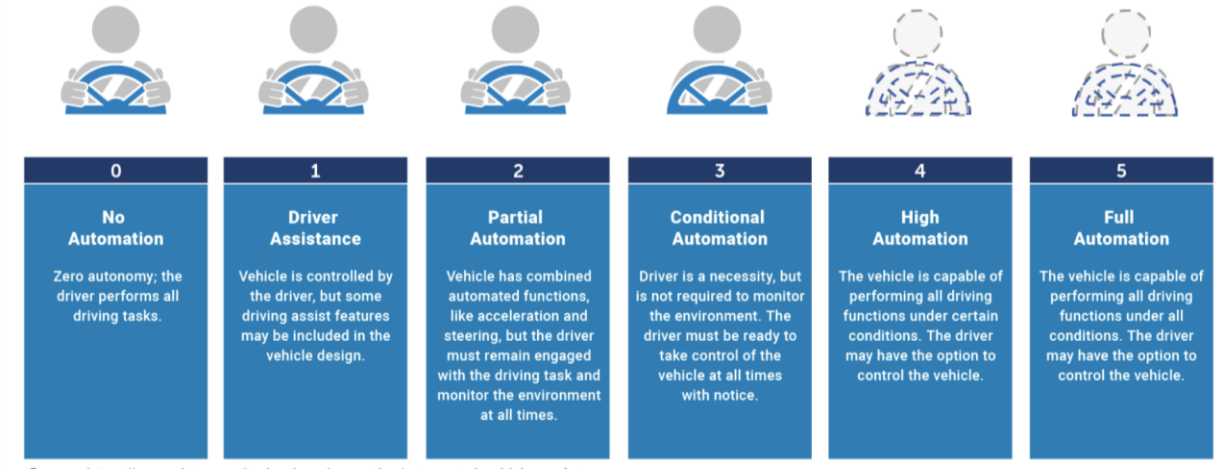

Figure 4: Automation Levels[64]

7.1 Autonomous Vehicle Adoption in the US

While some have promised that AVs will hit the market soon, the theory that there will be a massive adoption of AVs in the near future is flawed. To launch AVs somewhere, there needs to be rich and textured maps for the vehicle to use that include not just street maps and GPS information, but also visual imagery of the streets. The process of mapping with this level of detail is very time and resource intensive, which is why there are only a small number of pilot programs in select cities. For this reason, AVs are clearly still in the experimental phase of the adoption curve.

Currently, Uber is testing in Pittsburgh, Pennsylvania, and the Dallas-Ft. Worth area in Texas; Ford is running a pilot in Austin, Texas; and Waymo is testing in Phoenix, Arizona. Almost all of these cities are in the Sunbelt where the weather is clear and sunny most of the time, the cities are less dense with larger metropolitan areas, and there are not strong public transportation

[63] National Highway Traffic Safety Administration, “Automated Vehicles for Safety.”
[64] Taken from National Highway Traffic Safety Administration.

networks.[65] Rain, snow, and stormy weather still pose a significant technical challenge to AV development as the computers need to learn how to interpret the precipitation correctly, "see" around it, and modify driving accordingly.

AVs that operate more as slow-moving shuttles along a set route are likely to be adopted much faster than a personal-vehicle model. Ideal for campuses and shopping areas with limited traffic, these shuttles are already being piloted in a wide range of locations across the country, such as Florida, Texas, Colorado, Maryland, and Massachusetts.

7.1.1 Consumer Perceptions

According to a BCG survey, 52% of respondents said they were likely or very likely to take a ride in an AV. When considering the possibility of one day riding in an AV, many consumers are drawn to convenience. The ability to drop someone off, find a parking spot, and park without a driver were some of the top reasons that people would want an AV. Another selling-point is the ability to multitask while the car drives.[66]

Young and technologically savvy people are more likely to say that they intend to use AVs.[67] Knowing this, AV companies are targeting the younger generations who tend to be more urban, more connected, and less interested in car ownership and more interested in potential AV subscription-based service models.[68] Desire for automation is strongest for lower level features, such as driver assistance to prevent skidding. Millennials prefer these features in cars; however, they are not necessarily willing to pay more for vehicles with them.[69]

One roadblock to eventual AV adoption is trust—or lack thereof—that people have for a computer to drive a car. Reports of accidents during self-driving tests, such as a pedestrian killed in Arizona in 2018,[70] reduce the trust people have in AVs. Media reports of accidents have caused over 50% of consumers to state that they are more cautious of AV technology.[71] Consumer perception on whether AVs will be safe dropped everywhere from 2017 to 2018 and did not improve much in 2019.[72] In this way, the race to develop the first commercially-available AV is just as much of a "trust race" as it is a "technology race" for the industry.[73] One way that trust in AVs could be rebuilt and boosted is through the promotion of lower levels of automated driving that are already popular, such as Advanced Driver Assistance Systems (ADAS). People with ADAS features in their vehicles are more willing to use AVs.[74] Also, the more the public

[65] Rubin, interview.
[66] BCG, "Self-Driving Vehicles & Car Sharing."
[67] HERE Technologies, "Consumer Acceptance of Autonomous Vehicles."
[68] Rubin, interview.
[69] Giffi et al., "The Changing Nature of Mobility."
[70] Hawkins, "Uber Halts Self-Driving Tests after Pedestrian Killed in Arizona."
[71] Vitale et al., "2019 Global Automotive Consumer Study."
[72] Vitale et al.
[73] Rubin, interview.
[74] HERE Technologies, "Consumer Acceptance of Autonomous Vehicles."

interacts with AVs, such as the slow-moving shuttles, the more likely their views of the technology will be positive.[75]

7.2 Sustainability Implications

The sustainability of AVs on American roads will depend on which model of ownership is dominant. An AV can be a product—an item purchased and used by a consumer, like a traditional automobile—or AVs can be used as a service. AVs as a service would involve fleets of AVs owned by a company and dispatched to customers to bring them or their goods to a destination for a fee or as part of a subscription plan. In a study by HERE Technologies, about 57% of respondents found the AV ownership model appealing and only slightly less, 52%, found the service model appealing.[76]

The more that AVs are shared, the more cars will be taken off the road and the more likely the overall impact of AVs will be environmentally friendly. Shared AVs may save up to ten times the number of cars needed for self-owned AVs, as they can perform trips for many other people while a self-owned AV might not be in use.[77] However, AVs will capture not just current car use, but also rides from all different modes of transport. There is a real risk that AV adoption will increase congestion as people move to AVs from public transport, walking, biking, and not travelling at all.[78]

AVs would not necessarily need to be parked on city streets or always near the user, which could change the urban landscape and narrow streets[79] as cities get rid of parking spaces. However, AVs driving to homes or parking lots outside of city centers would require them to drive further using more energy, causing more congestion, and possibly creating more urban sprawl. To avoid these negative consequences of AV adoption there needs to be electrification of AV fleets, the widespread adoption of ridesharing of AVs, along with the continued maintenance and development of high capacity public transit. Depending on the predominant ownership mode, the net effects of AVs on energy use could range from more than 90% fuel savings with a predominant shared service model to 150% increase in energy use with personal AV ownership dominating.[80]

Fortunately, from a sustainability perspective, it is likely that an AV shared service model will dominate once AVs hit the market.[81] The mapping process that needs to be undertaken in each new locality where AVs are to be released is extremely resource and time intensive. Not only do street maps and GPS data have to be put together, but all of the roads that the AV would drive

[75] Penmetsa et al., “Perceptions and Expectations of Autonomous Vehicles – A Snapshot of Vulnerable Road User Opinion.”
[76] HERE Technologies, “Consumer Acceptance of Autonomous Vehicles.”
[77] Fagnant and Kockelman, “The Travel and Environmental Implications of Shared Autonomous Vehicles, Using Agent-Based Model Scenarios.”
[78] HERE Technologies, “Consumer Acceptance of Autonomous Vehicles.”
[79] Goulding and Butler, “Rethinking Urban Mobility.”
[80] Konings, “Mobility as a Service Concept.”
[81] Rubin, interview.

on have to be mapped visually, with every tree, sign, and building uploaded into the system. This is an expensive process as it is so intensive, and the cost of it passed down to consumers of individual vehicles would be prohibitive to all but the richest. By launching subscription-based models for AVs as a service, where instead of owning a vehicle customers pay for a monthly mobility subscription, companies can help spread this development cost to many users, making the subscription price tag more affordable and allowing for increased adoption.[82]

Similarly for cost reasons, AVs are likely to be electric. With the development and mapping costs still so high, AV companies are striving to bring down other costs as much as they can. EVs make sense because after the initial cost of the battery, fuel cost are significantly lower than purchasing gasoline and maintenance costs are also much lower for EVs as there are fewer moving parts that could break. For this reason most companies developing AVs are making them electric.[83]

7.3 Equity Implications

While still very much in the future AVs are poised to have large effects on socioeconomic equity. By not requiring a driver, AVs will bring access to mobility to those who cannot travel on their own because they cannot drive a car, walk, or cycle somewhere. Seniors, children, and those with disabilities will have a greater ability to travel where they like when they like with the adoption of AVs.

Whether AVs are introduced as vehicles to be owned by households or as a service to subscribe to would greatly impact the amount and distribution of access to AVs. For the foreseeable future under an ownership model, it is likely that only the upper classes would be able to afford to purchase an AV, until the cost of development goes down. This would exclude lower income groups from the enhanced mobility that AVs can offer—the ability to pick up deliveries with a driver, mobility for non-driving family members, and the increased time to perform other tasks while travelling rather than driving. Since the ownership model is more likely to increase congestion on streets, those who do not own an AV will suffer from its negative externalities, like increased traffic, while reaping none of the benefits.[84]

If AVs are introduced as a service, then access to mobility may become more affordable to households than current car ownership is today. Pricing of rides and subscriptions could be offered with varying levels of trips per time period enabling consumers to pay only for the mobility they need when they need it, thus avoiding large car-loan payments, maintenance expenses, and parking fees associated with owning a vehicle.

The most discussed equity impact of AVs is that their widespread adoption would make obsolete the jobs of drivers who work for taxi companies, delivery and shipping companies, and TNCs. Currently there are 3.3 million of people in the United States whose jobs would be

[82] Rubin.
[83] Rubin.
[84] Sperling, *Three Revolutions: Steering Automated, Shared, and Electric Vehicles to a Better Future*.

replaced by AVs.[85] As governments at all levels consider policies related to the adoption of AVs, they will also need to consider their impacts to employment and think of ways to ensure well-being of displaced drivers.

7.4 Federal Policy and AVs

Federal policy on AVs to date has primarily focused on the safety of the emerging technology. In 2016, the federal government issued the Federal Automated Vehicles Policy. It sets forth the Vehicle Performance Guidance for Automated Vehicles, which requires all manufacturers to perform a safety assessment before they are allowed to test or deploy AVs on public roads. In addition to ensuring adequate safety measures are in place, the safety assessment also requires that the manufacturer addresses potential issues related to data recording and sharing, privacy, and vehicle cybersecurity.[86]

At the 2020 CES tech conference, US Transportation Secretary Elaine Chao announced updated principles for AVs, which unify efforts across 38 US departments and agencies. These new principles are not regulatory rules, but are more flexible with the aim to allow for more innovation. Critics say that these voluntary guidelines are unenforceable and will not result in adequate performance standards.[87]

If the federal government were to develop more enforceable standards, those developing and manufacturing AVs would welcome national-level regulation.[88] This would preempt the need for individual state and municipal laws and avoid the extra costs of needing to deal with multiple different standards.

[85] Mudge et al., “America’s Workforce and the Self-Driving Future.”
[86] U.S. Department of Transportation, “Federal Automated Vehicles Policy - September 2016.”
[87] Shepardson, “U.S. Outlines Strong Support for Self-Driving Cars at CES.”
[88] Rubin, interview.

8 Data Privacy

With the proliferation of application-based mobility options such as ride-hailing and micromobility services, data privacy is becoming an increasing area of concern. Within the mobility space, opinions vary around the collection and sharing of trip data. One approach being adopted by an increasing number of cities is the Mobility Data Specification (MDS), a standard for exchanging data between mobility operators and cities or other regulators through a set of application programming interfaces (APIs).[89] MDS requires mobility providers to share real-time data on the number of vehicles in operation at any given time, their location, and their condition. It also requires the sharing of information related to the parking of vehicles, operating costs, vehicle utilization, and start and end trip data.[90] Twenty-seven cities across the country and the globe have adopted the MDS model and established the Open Mobility Foundation, a coalition focused on building open-source technology tools for the management of micromobility services.[91] As of November 2019, the Open Mobility Foundation owns and manages the MDS repository[92]

While the use of approaches such as MDS could aid regulators in enforcing policies around the equitable and safe use of micromobility and TNC services, critics of MDS have pointed to potential data privacy issues related to the sharing of real-time trip data. Research has shown that even if personally identifiable information (PII) is excluded from the data, it is possible to re-identify it given certain data points. For example, a 2013 paper showed that it is possible to identify 95% of individuals given four Global Positioning System (GPS) timestamp points, and 50% with only two.[93]

Additional concerns arise around the ease of access to raw trip data once it is shared with a public entity such as a city government, for example through a Freedom of Information Act (FOIA) request or an open data platform. Consumers may also not be aware of how their information is being shared and with whom. Some cities may attempt to minimize data privacy concerns by fuzzing the timestamp and points of trip data, for example by rounding the points to the nearest 150 meters and the timestamp to the nearest 15 minutes; however, this has little to no impact on the ability to re-identify the data. Potential solutions include aggregating trip data by location and time or restricting the types of information shared to only the data that is necessary.[94]

[89] "Mobility Data Specification: A Data Standard to Enable Communication between Mobility Companies and Local Governments."
[90] Los Angeles Department of Transportation, "Mobility Data Specification: Information Briefing."
[91] "Open Mobility Foundation."
[92] "Mobility Data Specification: A Data Standard to Enable Communication between Mobility Companies and Local Governments."
[93] Montjoye et al., "Unique in the Crowd: The Privacy Bounds of Human Mobility."
[94] Castellanos, interview; Herlocker, interview.

9 Case Studies

This report examines four case studies, two each at the state and city level, to compare policy approaches across locations and levels of government and their implications for sustainability, equity and data privacy. As shown in Figure 5, the cases selected represent a variety in both the stages of adoption and approaches to adoption of new mobility technologies.

Figure 5: Summary of Case Studies Selected

The state of California is at the forefront of technology innovation, as well as a leader in sustainability and climate efforts. Michigan, on the other hand, is the historic center of the US automotive industry, with a growing autonomous vehicle industry. As the capital of the United States, the city of Washington, DC boasts a robust and expanding transit network, along with a rapid growth in micromobility services. Pittsburgh, on the other hand, is a former industrial city that is becoming an emerging hub for AV technology and has taken a more collaborative approach to the integration of newer technologies.

9.1 California

California is a state on the west coast of the United States with a land area of about 156 thousand square miles.[95] California's economy is the largest in the United States, with a gross state product of 3.155 trillion USD as of the third quarter of 2019.[96] If California were a country, its economy would rank fifth in the world, surpassing that of the United Kingdom.[97] The state

[95] "US Census Bureau QuickFacts."
[96] U.S. Department of Commerce, Bureau of Economic Analysis, "Gross Domestic Product by State, Third Quarter 2019."
[97] Segarra, "California's Economy Is 5th Biggest in the World, Ahead of the UK | Fortune."

makes up 12% of the US population, with an estimated 39.5 million people as of July 1, 2019.[98] The population is projected to reach 51.1 million by 2060, with the Central Valley, San Francisco Bay Area, Inland Empire, and greater Sacramento area expected to grow faster than the state average. At 9.4 million, the millennial generation was the largest generation in California in 2016 (24% of the population). The population size of Generation X is expected to exceed that of the baby boomer generation in 2019, when both generations become about 20% of California's population. Between 2016 and 2036, the percentage of the population 65 years of age and older is expected to increase from 14 to 23%.[99]

9.1.1 Climate Policies

A leader on environmental stewardship, California has a decades-long history of enacting policies to reduce pollution, address climate change and create a clean energy economy. The state's landmark Global Warming Solutions Act of 2006 (Assembly Bill 32) sets a target to reduce California's greenhouse gas emissions to equal 1990 levels by 2020. California met its goal four years early in 2016 and proceeded to pass additional legislation in the form of Senate Bill 32 and Senate Bill 100, which extended the emissions reduction targets to 40% below 1990 levels by 2030 and required public utilities to provide 100% renewable electricity by 2045. However, meeting these steeper targets will require the state to reduce emissions from harder-to-reach sectors—primarily transportation. The transportation sector represents 41% of California's greenhouse gas emissions, with on-road passenger vehicles alone accounting for 28%. Transportation emissions have continued to increase from year to year, although the rate of increase has slowed.[100]

9.1.2 Electric Vehicles

To help tackle the state's transportation emissions, California has put forth ambitious goals to reach 1.5 million zero-emission vehicles (ZEVs) on California roads by 2025, and 5 million ZEVs by 2030.[101] With 49% of all EVs in the United States registered in California, the state already has the highest EV market share in the country.[102] As of August 2019, the state has reached nearly 600,000 EVs sold, with EVs representing about 8% the total automotive sales volume.[103] To continue on this upward trend and meet its targets, the state has implemented a number of policies, consumer incentive programs, and charging infrastructure initiatives, as described below.

[98] "U.S. Census Bureau QuickFacts"; Kuczynski and Sharygin, "California Tops 39.9 Million Residents at New Year per New State Demographic Report."
[99] Shaheen, Totte, and Stocker, "Future of Mobility White Paper."
[100] Next 10, "2019 California Green Innovation Index."
[101] Governor's Interagency Working Group on Zero-Emission Vehicles, "2018 ZEV Action Plan Priorities Update."
[102] Alternative Fuels Data Center, "Electric Vehicle Registration Counts by State."
[103] Kane, "California's Progress On 5 Million ZEV By 2030."

EV Policies in California

- **Executive Order B-16-12**, issued by California Governor Jerry Brown in 2012, called for 1.5 million zero-emission vehicles (ZEVs) to be on the road by 2025.
- **Executive Order B-48-18**, issued in January 2018, expanded the target to 5 million ZEVs by 2030 and included infrastructure targets for plugin electric vehicle chargers and hydrogen fueling stations to support this growth in EVs.
- The **Clean Energy and Pollution Reduction Act of 2015** (Senate Bill 350) established that electrification of the transportation sector is necessary for achieving the state's climate goals.
- **Assembly Bill 1236** requires all cities and counties to develop a streamlined permitting process for EV charging stations.
- **ZEV Action Plans** by the Administration in 2013 and 2016 and a 2018 Priorities Update identify actions that the government will take to achieve the targets set out in the executive orders, as described below.

9.1.2.1 Consumer Incentives

The state administers a couple consumer incentive programs to promote the purchase of electric vehicles and make electric vehicles available at varying income levels:

- **Rebates** - the State of California provides rebates on the purchase or long-term lease of electric vehicles, including 5,000 USD for hydrogen fuel cell electric vehicles, 2,500 USD for pure battery electric vehicles, and 1,500 USD for plug-in hybrid electric vehicles. In 2016, the rebate program also introduced an income cap that prohibits rebates for high-income individuals, as well as providing an additional 1,500 USD rebate for low- and moderate-income individuals.[104]
- **High Occupancy Vehicle Lane Access** – drivers of electric vehicles can apply to the Clean Air Vehicle (CAV) decal program to use carpool lanes that are otherwise reserved for high-occupancy vehicles (HOV) only. Originally, there were an unlimited number of decals available for zero emission vehicles (battery electric vehicles and hydrogen fuel cell electric vehicles), while only a limited amount was available for plug-in hybrid electric vehicles. These decals expired as of January 2019, and only vehicles that meet California's super ultra-low emission vehicle standard can apply for new decals.[105]

9.1.2.2 Charging Infrastructure

The state has implemented a number of initiatives to expand the charging networks for plug-in electric vehicles, including:

- **Utility Programs** – the California Public Utilities Commission has authorized a few pilot projects with utilities, including Southern California Edison, San Diego Gas & Electric, and Pacific Gas & Electric, to install EV chargers at condominiums, apartment buildings and workplaces.

[104] Governor's Interagency Working Group on Zero-Emission Vehicles, "2018 ZEV Action Plan Priorities Update."
[105] State of California Department of Motor Vehicles, "Clean Air Vehicle Decals - High Occupancy Vehicle Lane Usage."

- **Building Standards** – changes in the California Green Building Standards Code now require all new parking lots and homes to have the electrical capacity in place to be able to install EV chargers.
- **Accessibility** – California adopted the first accessibility requirements in the United States in 2016, requiring that all charging stations be accessible to EV users with disabilities.
- **Corridor Charging** – the California Energy Commission has provided funding for the installation of DC fast chargers along important interstate highway corridors.[106]

Nine other states have adopted California's ZEV regulations, including Connecticut, Maine, Maryland, Massachusetts, New York, New Jersey, Oregon, Rhode Island and Vermont. Combined, these nine states and California represent almost 30% of new car sales in the United States.[107]

9.1.3 Shared Mobility

As a technology innovation hub, California is home to many TNC and micromobility companies: Uber, Lyft, Lime, Spin, Scoot and Skip have headquarters in San Francisco, while Bird is headquartered in Santa Monica. As such, California has been a testing ground for the deployment and regulation of these technologies.

9.1.3.1 Ride-hailing with TNCs

With over 600,000 ride-hailing vehicles in California, TNCs contribute significantly to the state's transportation emissions.[108] In fact, a December 2019 report by the California Air Resources Board (CARB) estimated that emissions from TNCs were about 50% higher than the vehicle fleet average across the state. The report was produced in response to Senate Bill 1014, enacted in 2018, which directs CARB and the California Public Utilities Commission (CPUC) to develop and implement measures to reduce emissions from TNCs. The modeling tools used in this report will be used to feed into target scenarios for a Clean Miles Standard Regulation expected in December 2020.[109]

The employment status of TNC drivers has additionally recently come into question in California. While TNCs maintain that their drivers are independent contractors who use their platform, class action lawsuits have asserted that the drivers are employees of the TNCs and should receive employment benefits. California Assembly Bill 5, which came into effect as of January 1, 2020, sets new standards for hiring independent contractors, requiring many to be reclassified as employees covered by minimum wage, overtime, workers' compensation, unemployment, and disability insurance. To qualify as an independent contractor, a worker must

[106] Governor's Interagency Working Group on Zero-Emission Vehicles, "2018 ZEV Action Plan Priorities Update."
[107] California Air Resources Board, "Zero-Emission Vehicle Program."
[108] Tony Barboza, "California Says Ride-Hailing Pollutes More than Regular Trip."
[109] California Air Resources Board, "SB 1014 Clean Miles Standard - 2018 Base-Year Emissions Inventory Report."

now pass all three parts of the "ABC test," modeled after laws in Massachusetts and other states: workers must (A) work independently, (B) do work that is different from what the business does, and (C) offer their work to other businesses or the public.[110] To comply with this new law, Uber is reportedly making changes to the Uber app for drivers in California, giving them more flexibility in choosing which rides to accept and allowing riders to select favorite drivers so they can schedule rides with those drivers in the future. In this way, Uber is attempting to maintain the "independent contractor" status of its drivers.[111] However, these potential changes could raise equity concerns around refusing rides based on the geographical location of riders as well as differentiated economic opportunities for drivers.

TNC Regulation in California

- **California Public Utilities Commission (CPUC)** regulations stipulate that TNCs may only provide pre-arranged trips requested through their app and may not pick up curbside passengers as taxis do. TNCs may also operate anywhere within the state, with the exception of airports, where they may only operate under the authorization of the airport. Taxi services, on the other hand, are regulated under city and county regulations. TNCs must report to the CPUC on the provision of accessible vehicles, service provided by zip code, problems reported about drivers, hours logged by drivers, miles logged by drivers, and drivers completing a driver training course.
- **The California Vehicle Code** requires that all drivers transporting passengers for compensation may not drive for more than 10 consecutive hours or more than 10 hours within 15 consecutive hours. However, it is unclear how the CPUC can enforce these drive time restrictions across multiple platforms, for example for drivers who drive for both Uber and Lyft.
- **California Department of Motor Vehicles (DMV)** regulations surrounding driver's licenses, vehicle registration, and the use of cell phones while driving also apply to TNC drivers.[112]

9.1.3.2 Micromobility

Approaches to managing and regulating micromobility services vary on a city-by-city basis in California. A home to many startup technology companies, San Francisco has been at the forefront of micromobility services since their inception. In 2013, the city partnered with other public agencies throughout the Bay Area to introduce a Bay Area Bike Share pilot. The program saw a major expansion in 2017 that is planned to culminate in 320 stations and 4,500 bikes, ultimately covering about half the city.[113] The system has since been rebranded as Bay Wheels, with operation through Lyft. To address equity concerns, the program requires at least 20% of stations to be located in areas designated by the Bay Area's Metropolitan Transportation Commission (MTC) as "communities of concern."[114] A subsidized membership program, Bikeshare for All, additionally allows low-income individuals to sign-up for a one-year 5 USD

[110] Roosevelt, "California's AB 5 Is Changing How Businesses Treat Workers."
[111] Siddiqui, "Project Luigi: Uber's Secret Plan to Circumvent AB5, California's Gig-Worker Law."
[112] San Francisco County Transportation Authority, "The TNC Regulatory Landscape."
[113] San Francisco Municipal Transportation Agency, "Bikeshare."
[114] Lyft, Inc., "Bay Wheels System Expansion."

membership, which includes rides up to one hour. After the first year, the membership fee is 5 USD per month. Payment options include credit card, cash, or prepaid cards.[115]

The introduction of dockless electric scooters in San Francisco caused initial tensions between operators, residents, and city officials. In early 2018, Lime, Bird and Spin deployed hundreds of scooters throughout the city in a matter of weeks. While the scooters experienced great usage, residents also perceived them as hazardous and irritating. After receiving about 2,000 public complaints, the San Francisco Municipal Transportation Agency (SFMTA) banned scooters in May 2018 and set up a pilot permitting process.[116] In December 2019, the city additionally approved the creation of an Office of Emerging Technology, housed under the Department of Public Works, to manage the deployment of new technologies on city streets and sidewalks. The new office would evaluate applications for deployment based on whether the technologies would "ultimately result in a net common good" and would impose fines on companies that fail to request permission before deploying technologies that could block the public right of way.[117]

Critics of San Francisco's approach towards scooter deployment have argued against its initial ban on scooters and its choice in pilot project awardees, pointing to their inability to reach the city's equity goals. According to SFMTA data, over 60% of scooter riders during the pilot project were white and earned over 100,000 USD per year. At the same time, less than 200 low-income residents signed up for the companies' discount programs, out of tens of thousands of riders. Community organizers also noted that the pilot project awardees did not reach out to underserved neighborhoods on the westside of the city and concentrated their operations in the downtown area. Groups from these areas lobbied in support of Lime's permit application, as Lime had been the only company to reach out to the neighborhood groups before launching. City officials in neighboring Oakland have therefore opted for a less punitive approach.[118] With the addition of the three new permittees, there is hope that the city will be able to better reach its equity goals.

9.1.3.3 Data Privacy

California has been a recent testing ground for the handling of micromobility data, with differing approaches proposed at the state and city levels. At the state-level, a collection of current and proposed regulations and policies promote data protection and privacy (see list below). For example, the California Consumer Privacy Act (CCPA) and California Electronic Communications Privacy Act (CalECPA) combined function similarly to the European Union's General Data Protection Regulation (GDPR).[119]

At the city-level, however, some governments have promoted a more active management approach towards the collection and handling of micromobility data. As part of a one-year dockless vehicle pilot program in 2018, the City of Los Angeles developed the Mobility Data

[115] Lyft, Inc., "Bay Wheels Bike Share for All."
[116] DuPuis and Griess, "Micromobility in Cities: A History and Policy Overview."
[117] Wray, "San Francisco's Office of Emerging Technology Gets the Green Light."
[118] Aguilar-Canabal, "Mobility and Equity."
[119] Herlocker, interview.

Specification (MDS), which requires that transportation companies provide real-time geolocation data for scooters at the starting and ending points of the trip, as well as provide the full ride route within 24 hours.[120] Uber has filed a federal lawsuit against the city, arguing that the requirement violates CalECPA, and that real-time data is not required for planning and permitting purposes, but would rather be used by the city for surveillance.[121]

With this level of real-time data, there is also the potential for the city to implement real-time interventions to remotely slow down speeding vehicles, such as AVs. However, geofencing using GPS is not very accurate, especially in dense urban areas where the "urban canyon" effect causes the GPS signal to bounce off of buildings. Therefore, it would be dangerous to rely on this type of data to control the speed of a moving vehicle with passengers inside.[122]

Assembly Bill 1112, "Shared mobility devices: local regulation," is currently being considered by the California Legislature and would preempt cities from collecting MDS data.[123] While the bill could prevent the collection of sensitive information, some have argued that it would infringe upon cities' authority to manage micromobility deployment and ensure micromobility access in underprivileged communities. Technology companies Uber, Lyft, and Bird are additionally the primary advocates of the bill, raising questions about its motivation.[124] While the bill is currently tabled, it could come up again in the next few years. As a leader in policy formation, the California Legislature's decision on the bill could set the stage for wider national policy making on micromobility and data privacy.

Current and Proposed Data Protection and Privacy Policies in California

- **Assembly Bill 1112** – the California Legislature is currently considering this bill, which would preempt cities from collecting MDS data.[125]
- **California Consumer Privacy Act (CCPA)** – enacted in 2018, this act requires private entities to give users the right to delete the data they are sharing with third parties.[126]
- **California Electronic Communications Privacy Act (CalECPA)** – passed in 2015, this act requires that all public agencies collecting personally identifiable information (PII) from a private entity must receive consent from the user to collect it. If the user does not consent, agencies must have a warrant to collect the data.[127]

[120] "Mobility Data Specification: A Data Standard to Enable Communication between Mobility Companies and Local Governments"; PYMNTS, "Uber Files Federal Suit Against LA Over Data."
[121] PYMNTS, "Uber Files Federal Suit Against LA Over Data."
[122] Herlocker, interview.
[123] "AB-1112 Shared Mobility Devices: Local Regulation."
[124] Zipper, "The California Legislature Is Getting Played by Micromobility Companies."
[125] "AB-1112 Shared Mobility Devices: Local Regulation."
[126] "California Consumer Privacy Act (CCPA)."
[127] "SB-178 Privacy: Electronic Communications: Search Warrant."

9.1.4 Autonomous Vehicles

State-level policies regarding autonomous vehicles primarily center around the testing of AVs on California roadways. There are two testing permits that a manufacturer can apply for: testing with a driver and testing without a driver.[128] For both permits, manufacturers are required to provide the Department of Motor Vehicles with a report of any traffic collisions involving an autonomous vehicle within ten business days of the incident. Manufacturers are also required to submit an annual disengagement report summarizing all the instances in which the manufacturer disengaged the technology during testing. As of November 21, 2019, there are 64 autonomous vehicle testing permit holders, including many major car manufacturers such as Volkswagen, Mercedes Benz, Tesla Motors, Nissan, BMW, Honda and Ford.[129] As of October 30, 2018, there is one driverless testing permit holder (Waymo LLC).[130] On April 2, 2018, regulations governing the post-testing deployment of autonomous vehicles became effective.[131]

9.2 Michigan

Michigan is located in the midwestern region of the United States. Known as the “Great Lakes State,” it is formed by two peninsulas known as the upper and the lower peninsula, which are bounded by four of the five great lakes in addition to Lake Saint Clair. It is the tenth most populous state with a population of 10 million. The majority of its population lives in the industrialized center of the lower peninsula and is mainly urban. Though the upper peninsula is large, it has a population of fewer than 333,000 inhabitants due to it being heavily forested and mountainous. As a result of its geographic isolation, citizens of the upper peninsula travel vast distances between the two ends of the state.

The economy of Michigan has had ups and downs. During the ‘lost decade’ from 2000 - 2009, Detroit's economy fell by 15% while the national GDP grew by the same amount.[132] However, the state has significantly improved its position and currently represents 2.63% of the US GDP, making it the thirteenth largest state economy as of 2016. The manufacturing sector accounts for the largest share in Michigan’s GDP—19.3% in 2018. Known as the nation's automotive capital, the state has a rich history with the “Big Three” automakers: General Motors Corp., Chrysler LLC, and Ford Motor Co. Michigan is home to 17% of total US vehicle production and 76% of North American automotive research and development with 10 billion USD being spent on R&D each year. Moreover, the state is also a frontrunner in advanced manufacturing with two world-class autonomous vehicle testing sites, and one of the leading states in testing and development of next-generation transportation technology.

[128] State of California Department of Motor Vehicles, “Autonomous Vehicles in California.”
[129] State of California Department of Motor Vehicles, “Testing of Autonomous Vehicles with a Driver.”
[130] State of California Department of Motor Vehicles, “Driverless Testing of Autonomous Vehicles.”
[131] State of California Department of Motor Vehicles, “Deployment of Autonomous Vehicles for Public Operation.”
[132] Wilkinson, “Michigan’s Economy Is Bigger than Ever. Now Is the Time to Diversify.”

9.2.1 Electric Vehicles

EVs currently represent only a small percentage of the automotive fleet in Michigan, but the state is trying to change that as quickly as possible. The state has had year-on-year growth of 30.23% in the sales of EVs, with 3,571 vehicles sold in 2018, up from 2,742 cars in 2017. Moreover, according to the Energy Department's Alternative Fuels Data Center, Michigan currently has 1,119 public and 253 private charging outlets at 607 charging stations, and the majority of those are concentrated in populated areas such as Detroit.[133] Thus, the state is increasing its fleet and improving adoption rates as well as supporting the growth of necessary infrastructure.

9.2.1.1 Private Sector Initiatives

The private sector has been a big propeller for the above increases in EV use, especially the "Big Three" companies. They have all announced increases in their investment in EVs in the state.

- **Fiat Chrysler** announced its plans to invest 4.5 billion USD by building an assembly plant in Detroit. The investment plan includes setting up 3 plants to manufacture hybrid and fully electric Jeep models. Moreover, the investment will create 6,500 jobs in the state.
- **General Motors** also announced its 300 million USD plant to build its new Chevrolet Bolt EV while also investing 2.2 billion USD investment in its Detroit-Hamtramck assembly plant to manufacture an array of all electric SUVs and trucks and create 2,200 jobs for the state.[134]
- **Ford** is also making a significant investment of 850 million USD in an assembly plant in the state and to build the company's next-generation Mustang. This is part of the 11 billion USD investment that Ford promised as a commitment to EVs. Ford has also invested 500 million USD in an electric vehicle start-up called Rivian. This partnership was formed to develop an all-new EV, which is built on the start-up's battery-electric skateboard platform.

Thus, private sector investments in the automotive sector of Michigan will help boost the economy. According to Michigan's Automotive Industry's Economic Contribution study, the industry contributes 225 billion USD to Michigan's economy. Moreover, in December 2019, the unemployment rate of the state was at 3.9%,[135] in comparison to a high unemployment rate of 14.6% witnessed by the state in June 2009. A boost in the economy provided by these private investments as well as introduction of newer EV batteries and hybrid models in the market can induce an increase in the adoption rate of electric vehicles in the state.

[133] Lawrence, "Michigan Bills Aim to Open State Parks to Electric Vehicles."
[134] General Motors, "Detroit-Hamtramck to Be GM's First Assembly Plant 100 Percent Devoted to Electric Vehicles."
[135] Department of Numbers, "Michigan State Unemployment Rate and Total Unemployed."

9.2.1.2 State Initiatives

The state of Michigan has undertaken numerous initiatives to propel the adoption of electric vehicles.

- **Alternative Fuel Vehicle Emissions Inspection Exemption** - Vehicles powered by alternative fuels as defined by the Michigan Department of Transportation are excused from the state's emission inspection requirements. Alternative fuels include electricity, propane, and compressed natural gas, or another source deemed by the department.[136]
- Seven school districts in the states are to receive electric school buses as a part of the **Fuel Transformation Program** to promote cleaner energy and air quality. In September 2019, the Michigan Department of Environment, Great Lakes, and Energy stated that they would provide 4.2 million USD towards the project. The funding for these buses has also been provided by the Volkswagen Clean Air Act Civil Settlement[137] as well as the Lansing Clean Cities Coalition.[138] Michigan received 64.8 million USD from the 3 billion USD settlement. The school buses are equipped with technology enabling bi-directional vehicle-to-grid power exchange, allowing the grid to draw power from the batteries during peak demand periods.[139]

- The greater Lansing area is part of the **Clean Cities Coalition**, a program under the US Department of Energy's (DOE) Vehicle Technologies Office, which has also been a part of funding the school bus replacement project mentioned above.

- From the 64.6 million USD settlement received by Michigan from Volkswagen, 9.7 million USD is earmarked for building EV charging stations, with construction to begin in 2020. The focus of the state is to construct charging infrastructure along interstate highways, to aid in improving the feasibility of travel that exceeds a typical day's work commute and relieve range anxiety for drivers.[140]

- The state commissioned studies to find optimal locations for fast charging stations to meet the forecasted demand by 2030.[141] The report by the Michigan Agency for Energy highlighted an optimal charging network spanning the entire state. Additionally, researchers considered two scenarios, low tech and high tech scenarios. The low tech scenario considers a conservative projection of technology and hence, would have a higher number of electric charging stations throughout the state, Furthermore it would be more expensive to implement that high tech scenario, as the latter would require a less robust charging system.[142]

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[136] U.S. Department of Energy, "Alternative Fuels Data Center: Michigan Laws and Incentives."
[137] U.S. Environmental Protection Agency, "Volkswagen (VW) Settlement."
[138] U.S. Department of Energy, "Clean Cities Coalition Network: About Clean Cities."
[139] Nichols, "Volkswagen Clean Air Settlement Money Powers First-Ever Electric School Buses in Michigan."
[140] Galbraith, "What's next for Michigan's Electric Vehicle Charging Infrastructure?"
[141] Balaskovitz, "Electric Vehicle Drivers in Michigan See Increased Investment in Fast Charging."
[142] Michigan State University, "Electric Vehicle Charger Placement Optimization in Michigan: Phase I - Highways."

However, Michigan does lack a state level policy to support electric vehicle adoption. Moreover, there is an evident disparity between the taxes and fees charged to electric vehicles in comparison to gasoline powered vehicles. An EV driver pays an additional surcharge on registration fees to cover the unpaid cost of gas taxes by the car, which leads to EVs paying 135 USD above the value based fee (ad valorem) tax of the state. The electric vehicles ultimately end up paying more in annual transport related taxes than their gasoline counterparts.[143] The high charges are acting as a deterrent to buy electric vehicles, especially since these cars also face a higher up-front cost.[144] Thus, the state requires a consolidated law to advance the adoption of electric vehicles, beginning with an incentive to buy EV's rather than penalising them by increasing upfront costs, especially if it wants to keep its title as a hub of the automotive industry.

9.2.1.3 Utility Initiatives

Utility-backed EV charging is playing an important role to encourage EV adoption. Utilities in Michigan, such as Consumer Energy, Indiana Michigan Power and DTE Energy, are offering several rebate and reimbursement opportunities to customers installing charging infrastructure as well as providing time-of-use rate options for plug-in electric vehicle (PEV) owners. Consumer Energy and Indiana Michigan Power are providing a rebate to commercial and residential customers installing level two or direct current fast charging electric vehicle supply equipment. In addition, Consumer Energy's *PowerMiDrive* initiative, approved by the Michigan Public Service Commission, is a 10 million USD, three-year plan to incentivize the deployment of EV chargers at homes, apartments, schools, workplaces, and other public charging sites. It also includes fast chargers along highways.[145] The program will utilize rebates and consumer education to encourage program participation and support "off-peak" charging through the incorporation of time-of-use rates. The utility issued 127 rebates at-home and public vehicle charging stations in the first two months of launching the program, portraying a strong start. The increase in EV charging stations will hopefully increase the adoption rates of EV's in the future. DTE also launched the 'Charging Forward program in June 2019. The utility planned to spend 13 million USD to create programs which incentivise customer education and outreach as well as charging infrastructure growth.[146]

[143] VanSteel and Griffith, "Paying Their Fair Share: The Problem with Michigan's EV Road Funding Fees and Potential Solutions."
[144] VanSteel and Griffith.
[145] Fox 47 News, "Michigan Approves First Electric Vehicle Charging Infrastructure Program."
[146] Walton, "Michigan Utilities Propose More than $20M in EV Charging Programs."

9.2.1.4 Future policies in Michigan

State senator Mallory McMorrow proposed a four-bill package in 2019 which is co-sponsored by two Republicans and two Democrats that would aim to make Michigan "the first fully-networked state in the country." The aims of the bill are:

- Create an Electric Vehicle Council to assess the statewide infrastructure and identify locations for public charging stations. The council would work together with stakeholders, utility companies and researchers.
- Permit state parks to lease space for public charging stations and the revenue earned will go back into the state parks system.
- Incentivize “small businesses and multi-family dwellings” through installation of electric vehicle chargers.[147]

9.2.2 Shared Mobility

Innovation in mobility services has begun reshaping existing transportation modes. The increasing adoption of innovative mobility services such as ride-hailing, micro-transit, and bike sharing is starting to alter travel behavior and change habits of individuals while also affecting public transit and private vehicles. As mobility is redefined and adoption rates increase, states will have to upgrade their laws and existing infrastructure to match this rising demand.

9.2.2.1 State Initiatives

- **MichiVan** is a ridesharing service sponsored by the Michigan Department of Transportation (MDOT) and operated by Enterprise Rideshare, in a public-private partnership. The company supplies fully insured passenger vans to commuter groups and pays for the maintenance, insurance, titling, and licensing. Around 5 to 15 commuters can share a van along an established route while paying a monthly fee as low as 55 USD per month. MDOT through MichiVan also provides services to employers looking to coordinate ridesharing for their employees. The MichiVan operator, currently Enterprise Rideshare, provides the vehicle and pays for the maintenance/repairs, insurance, titling, and licensing).[148]
- **The Ann Arbor Area Transportation Authority (AAATA),** branded as **The Ride,** is a public transit system for the greater Ann Arbor-Ypsilanti area enabling the residents to reach their destinations at a reasonable cost while offering the region an efficient and environmentally sound transportation alternative. The uniqueness of this transportation authority is its provision of a paratransit system which has helped immensely in integrating the public transport of Ann Arbor with the shared mobility service provided by AAATA. The AAATA offers a combination of vans, taxicabs and small buses to help

[147] Michigan Radio, “Bills Aim to Make Michigan First ‘Fully Networked’ State for Electric Vehicles.”
[148] Jeffrey Cunningham, “‘Wheels to Work’ Program Getting Employees to Work -- and on Time - Mlive.Com.”

senior citizens and people with disabilities which prevent them from utilizing the fixed route service.[149]

- The **$8 Million Michigan Mobility Challenge** aims to fund numerous pilot transportation projects of varying sizes to solve mobility issues encountered by seniors, persons with disabilities, and veterans in urban, rural, and suburban communities throughout the state. MDOT is partnering with various other government agencies for the program. Out of all the 47 applications, thirteen projects were approved and provided funding in 2018.[150] Hence, the program focuses on improving accessibility and equity by providing innovative solutions to problems that limit the capability of certain people to avail these services.

9.2.2.2 Ride-hailing with TNCs

Effective March 21 2017, transportation network companies (TNC) such as Uber and Lyft are regulated by the state of Michigan, under the Limousine, Taxi Cab and Transportation Network Company Act. The Act helps to ensure the safety of the citizens of Michigan as it requires TNC companies to conduct background checks of drivers and obtain their driving records. In addition to a zero-tolerance policy for drivers who use drugs and alcohol while driving, if a driver has four moving violations or one major violation in a three year period before the date of their application, is registered in the National Sex Offender Registry database or has certain felony convictions, he/she will be prevented from registering. The law also promotes equity by preventing TNCs and drivers from discriminating against passengers and accommodating people with disabilities and special needs at no additional cost.[151] Furthermore, TNC driver or TNC on behalf of the driver needs to maintain an automobile insurance recognizing the TNC driver, with the covering him when he is logged on to the digital network of the TNC as well as during a prearranged ride.

The single regulatory framework provided by the Act is beneficial for TNCs, as they do not have to follow an array of local laws /and can operate legally in Michigan. The law provides them with a standard set of regulations which increases their ease of conducting business in the state.[152]

9.2.2.3 Micromobility

Ford-owned scooter company Spin and the University of Michigan announced their plan to introduce a new fleet of 200 scooters in the city of Ann Arbor and the University of Michigan. The city was chosen due to its commitment to constructing designated bike lanes. The scooters were launched in May 2019 and cost 1 USD to unlock via the Spin app and 15 cents per minute to ride. The scooters can accelerate up to the speed of fifteen miles per hour and can be operated on streets with speed limits of less than forty five miles per hour, as well as on sidewalks—though some parts of the city and the university will be geo-fenced as no-go zones.

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[149] Ann Arbor Area Transportation Authority, “TheRide - New Mobility.”
[150] Michigan Department of Transportation, “$8 Million Michigan Mobility Challenge.”
[151] Government of Michigan, “Uber and Lyft Now Regulated Under New State Law.”
[152] Michigan House Republicans, “Michigan House Approves Measures to Allow Uber, Lyft to Operate in State.”

In 2018, Detroit partnered with the National Association of City Transportation Officials and SharedStreets (a neutral anonymized clearing house for data collected by transportation providers, private companies and government agencies) to find a solution for cities with e-scooters and dockless bike share providers for sustainable transportation, reducing accidents and providing equitable transportation access. This would be done by analyzing trip data by Lime and Bird while still maintaining the privacy standards.[153]

9.2.3 Autonomous Vehicles

Michigan is home to the world's most dense automotive industry cluster and is well-positioned to drive the industry's transformation and growth. It is also the state with the most massive deployment of V-2-I (vehicle-to-infrastructure technology) in the United States with more than 350 infrastructure miles compatible with V-2-I. In 2013, Michigan became the fourth US state to regulate the testing of AVs. The Public Acts 231 and 251 of 2013 aided in updating Michigan's legal code to facilitate manufacturers, suppliers, and upgraders of AV technology to test prototype autonomous driving systems on public roads when registered with a special license plate.

9.2.3.1 Private Sector Initiatives

- **Google Waymo** – Google's former self-driving car project announced on April 23, 2019 that it had picked an existing facility in Detroit to produce its self-driving fleet. Google is planning to spend 13.6 million USD in addition to a grant from the state of Michigan worth up to 8 million USD. Moreover, the company is testing its autonomous Chrysler Pacifica minivans on Michigan’s roads in late 2017.
- **Ford** – Southeast Michigan workers will also make Ford's first autonomous vehicles starting in 2021. In addition, the company is investing in an Autonomous Vehicle center where employees will install the vehicles' unique self-driving technology and unique interiors.
- MDOT is partnering with the **Suburban Mobility Authority for Regional Transportation (SMART)** and Macomb County to provide transit signal priority to SMART buses using AV technology units along critical routes within the county, to provide improved travel time reliability and reduce travel delays.[154]

[153] NACTO, “The City of Detroit, SharedStreets, and NACTO to Pilot New Data Standard for Dockless Mobility.”
[154] Michigan Department of Transportation, “Connected and Automated Vehicle Program Strategic Plan.”

9.2.3.2 State Initiatives

At the end of 2016, Michigan Governor Rick Snyder signed four bills into law that created one of the first comprehensive nationwide self-driving regulations in the United States. Introduced to the state Senate in May 2016, the bills amended existing Michigan Motor Vehicles requirements as well as another law that barred autonomous driving in the state.

- **Senate Bill 995** authorized operation of "an automated motor vehicle . . . on a street or highway in this state". It eliminated the prior need for an AV to have a human driver behind the wheel to take control. The manufacturers have to follow all safety requirements for AV testing.[155]
- **Senate Bill 996** permits the creation of conditions for the "safe autonomous vehicle" or "SAVE" projects. These are private initiatives in which eligible motor vehicle manufacturers create automated vehicle fleets providing on-demand transportation to the public within a defined geographical boundary. Automated vehicle manufacturers are allowed to structure their service according to their preferences but have to share data regarding accident information and insurance requirements.
- **Senate Bill 997** eliminates the requirements of road signage for mobility research centers.
- **Senate Bill 998** eliminates the liability of auto mechanics and repair facilities from product liability for repairs on autonomous vehicles as long as the repairs were conducted according to the specifications of the manufacturer.[156]
- Additionally, the creation of the **Michigan Council of Future Mobility** within the Department of Transportation to provide recommendations to the governor and the legislature regarding changes to state policy to ensure Michigan position as a world leader in automated, driverless, and connected vehicle technology. This innovative initiative has been the first of its kind in the country, and provides recommendations annually to the Governor and the Legislature of Michigan.[157]

9.2.3.3 Data Privacy

While Michigan is propelling itself to be at the forefront of the next automobile evolution, it needs to consider the implications of adopting new technology on society. With a transformation of the mobility sector, lawmakers must reshape existing rules and regulations to accommodate the change better. As we know, increasing the level of automation requires a higher amount of data to be collected. Navigating without incident, speed enforcement, and traffic management, all these activities necessary for an AV to function require collecting and analyzing data.
Though Michigan did pass a law to promote the development of autonomous vehicles, the law did not pay much attention to privacy implications. The people of Michigan are entitled to protect their privacy. Compromising private data of individuals could also lead to security threats. A cybersecurity bill proposed by Michigan lawmakers aimed to punish car hackers with a sentence

[155] Tasker, “Michigan Continues to Take the Lead in Autonomous Vehicle Legislation.”
[156] Orr, Goetz, and Berliner, “Michigan Enacts New Autonomous Vehicle Legislation.”
[157] Michigan Department of Transportation, “Michigan Council on Future Mobility.”

of life in prison.[158] Though extreme, at the very least, it does portray the determination of the politicians to make changes in the law. However, another crucial issue that requires attention is detering manufacturing companies from monetizing all the private data collected from the enhanced systems for private gain. This law would also extend to shared and micromobility as they are also privy to sensitive data of their users.

9.3 Washington, DC

The Washington, DC metropolitan area is home to 6,251,240 residents, and is among the nation's fastest-growing and highest-earning metropolitan areas. Home to the US federal government, the public sector directly accounts for 21.25% of employment in the area,[159] and also supports associated knowledge-intensive industries, notably legal services, consulting, and aerospace/defense. With the high concentration of monuments, museums, government buildings, and event spaces, Washington attracts a large number of tourists and business travellers each year–a total of 23.8 million in 2018.[160] As part of the Northeast Corridor, the Washington area features extensive regional and national linkages, with its three airports and Union Station serving as a gateway to and from the region. These transportation hubs are significant in shaping local transportation demand.

9.3.1 Administrative Structure

The Washington, DC metropolitan area spans two states, Maryland and Virginia, as well as the District of Columbia, which has a unique administrative status. The District of Columbia, as the seat of the US capital, is legally under the direct authority of the US federal government. In practice, however, the District shares many characteristics with states. Under the District of Columbia Home Rule Act of 1973, the District received standing authorization to establish a popularly-elected District Council and Mayoral office, in effect granting it many of the same executive functions as a state. Still, all legislation passed at the District level must be approved by Congress, including the annual budget. This allows a majority in Congress to effectively block legislation that was approved at the District level, limiting the District's capacity to implement local policies that are unpopular among national policymakers. This unique constitutional arrangement means that the US federal government has significant direct and indirect influence over transportation planning and policy in the Washington, DC area.

Beyond the limitations on DC's sovereignty, the multi-state character of the DC metro area complicates planning, funding, and implementation of transportation projects. For example, the two commuter rail systems serving the DC area (MARC and VRE) each serve a specific state, though plans were recently announced to expand MARC service into Virginia for the first time. To resolve challenges in coordinating across state boundaries, there are cross-functional bodies designed to facilitate collaboration among the different governments in the area such as **WMATA** (Washington Metropolitan Area Transportation Authority). WMATA is the primary

[158] Michigan Legislature, "Senate Bill 0927 (2016)."
[159] U.S. Bureau of Labor Statistics, "Washington Area Employment – October 2019."
[160] U.S. Bureau of Labor Statistics.

public transit operator serving the District of Columbia and its inner-ring suburbs. The Authority offers rail (MetroRail) and bus (MetroBus) service. WMATA is administered by a Board of Directors, which consists of 2 representatives from each jurisdiction: DC, Maryland, Virginia, and the US Federal Government. Funding is shared between the jurisdictions.

9.3.2 Transit Initiatives

The Washington, DC area already features a well-developed public transportation network; however, there remain several opportunities to improve access, equity, and sustainability. In 2018, WMATA launched its Energy Action Plan, which will implement 65 million USD in capital investments to improve the network's energy efficiency. The plan includes implementing regenerative braking technology, meeting LEED building efficiency standards in new construction and major renovations, and replacing station lighting with energy-efficient LEDs. The plan also calls for improvements in bus service–cashless payment, all-door boarding, and right-of-way enhancements (dedicated lanes and traffic signal priority) are all expected to improve travel time, reduce idling, and expand ridership. The plan also calls for an electric bus pilot, which will be addressed in greater detail in the following subsection.Together, WMATA anticipates 16 million USD in annual energy cost savings and 160,000 metric tons of avoided CO_2 per year–the equivalent of removing 35,000 cars from the road.[161]

In addition to improvements to the existing network, there are also ongoing and proposed service extensions. The Silver Line, which first opened in 2015 and serves the Northwest suburbs in Fairfax County, Virginia, will reach Dulles International Airport when Phase III is complete (scheduled for July 2020, following delays). Construction of the Purple Line has also started. The Purple Line is a 16-mile light rail project intended to link existing MetroRail Red, Green/Yellow, and Orange lines in the Maryland suburbs. Construction and operation of the Purple Line is funded by Maryland Department of Transportation through a public-private partnership (30-year operations and maintenance contract, with the state maintaining ownership), and the first phase is anticipated to open in 2022.

Finally, WMATA's Joint Development Program is an initiative[162] designed to promote transit-oriented development through land value capture. Land value capture seeks to maximize the benefit from transportation investments by improving the land adjacent to stations, and can include residential/commercial developments, improvements in public space, or safety/accessibility enhancements. Through the joint development project, WMATA offers land sales or leases for qualifying projects around its stations. WMATA is currently soliciting proposals for the following projects:[163]

- Solar energy installations around 4 of its MetroRail stations
- Consolidation of existing parking/bus infrastructure and new commercial property development on WMATA-owned land surrounding the Huntington station in Virginia

[161] Washington Metropolitan Area Transit Authority, "2025 Energy Action Plan."
[162] Washington Metropolitan Area Transit Authority, "Why Metro Matters."
[163] Washington Metropolitan Area Transit Authority, "Current Offerings and Solicitations."

These projects increase transit demand around stations, promote community development, and generate ongoing revenues for the agency.

9.3.3 Electric Vehicles

Electric vehicles currently account for a small share of vehicles in the DC metro area, but the region is preparing to accomodate a much higher number as consumer demand grows in the next decade. Moreover, transportation electrification is slated to play a major role in the city's plan to reduce Washington, DC's carbon footprint 50% by 2032. The Clean Vehicle Transition Plan specifically calls for:

- Target of 25% of private vehicles registered in DC to be zero-emission by 2030
    - Additionally, half of all vehicles used by privately-operated taxi and limousine services are to be zero-emission by 2030.
- Replace 100% of public and school buses with zero-emission models when they reach end-of-life, beginning in 2021

To promote private EV ownership, the District has implemented policies relating to vehicle registration and private development of charging infrastructure. The vehicle registration policy links registration cost to the vehicle's emission levels, disincentivizing dirtier vehicles. It is worth noting that this approach may adversely impact low-income residents, who have fewer affordable vehicle choices and are therefore more likely to drive older, less efficient vehicles. In regard to charging infrastructure, the District offers tax incentives for property developers to install chargers, up to 1,000 USD per residential charger and as much as 10 thousand USD for public-access charging. Additionally, there are proposed changes to the building code that would require new office buildings and multi-family housing developments to be EV-ready.[164] Another method the District is employing to direct its shift toward electric vehicles has been in its fleet management policies. The DC Department of Transportation's *Circulator* bus service introduced 14 battery electric buses in 2018, and the District also plans to shift procurement across other agencies toward EVs.

Despite the District's regulatory commitment and promising initial steps, there remain considerable obstacles to implementation across the region. First, electric fleets require a much higher initial investment than those using diesel or CNG fuel. DC's contract with manufacturer Proterra for the circulator vehicles cost 1.1 million USD per bus.[165] This compares to an average of about 300,000 USD per diesel bus, and 400,000 USD for models that run on CNG (compressed natural gas).[166] Despite the increased initial costs, the District expects to save more than 6 million USD on maintenance and fuel costs over the life of the buses.[167] Still, the high initial costs are likely to be a critical barrier for other transit authorities, which may lack the

[164] Eric Campbell, interview.
[165] Council of the District of Columbia, "CA22-0144 - Proposed Task Order Cooperative Agreement with Proterra, Inc."
[166] Eric Campbell, interview.
[167] District Department of Transportation, "Mayor Bowser Celebrates Arrival of New Electric Circulator Buses."

resources and environmental commitment of the DC Department of Transportation. Moreover, the District is just one stakeholder in WMATA, which runs the majority of bus lines in the area. This means that it lacks the legal capacity to unilaterally impose vehicle restrictions on the agency.[168] Without WMATA participation, the District cannot meet the bus component of its electrification strategy. Even when procurement is handled by a District-level agency, like the *Circulator* electric buses, the process still may require coordination between different agencies and administrations, and it can take up to 2 years to finalize a contract.[169]

Additionally, there remain technical barriers to EV implementation. At the neighborhood level, the anticipated electricity consumption peaks resulting from mass EV adoption would surpass the current system capacity, requiring expensive upgrades to local transformer capacity.[170] On a similar note, fleet managers with longer routes must carefully consider the logistical implications of converting to a battery-limited range. To support these uses, there will need to be additional development of fast-charging infrastructure for commercial and industrial vehicles. Finally, there are social and legal obstacles at the neighborhood-level that make adoption challenging. For one, it is illegal in the District to run charging cables from a residence to the curb (assuming that one can parallel park within reach in the first place). This rule is designed to protect the pedestrian right-of-way, but is a significant obstacle for those without driveways or designated off-street parking. Additionally, any plan that reduces parking availability (such as designated spaces for EV charging) is likely to face community opposition from conventional vehicle owners. This has happened in response to related initiatives in Philadelphia, Pennsylvania and Berkeley, California.

9.3.4 Shared Mobility

9.3.4.1 Ride-hailing with TNCs

Shared mobility has become a significant part of the Washington area transportation network. Ride-hailing apps like Uber and Lyft have rapidly overtaken traditional taxi services. Taxi fare revenues during the peak month of March fell by 35% between 2017 and 2019, representing a loss of more than 6.5 million.[171] There remain 3,240 licensed taxi-drivers in Washington, DC; for most, driving is their main source of income. Uber, on the other hand, employs part-time 'contract' labor. A Georgetown University report released in 2019 showed that 1 in 3 Uber drivers in the DC area reported taking on personal debt as part of their job, and all 40 drivers in the survey reported a lack of transparency surrounding compensation.[172] 85% of them reported having another job in addition to driving for Uber.

In addition to disrupting local taxi operators, the arrival of TNCs to the area has had wide-reaching impacts for mobility across the region. On the positive side, TNCs may help to address

[168] Eric Campbell, interview.
[169] Eric Campbell.
[170] Eric Campbell.
[171] Department of For-Hire Vehicles, "DFHV Dashboard and Statistical Data Sets."
[172] Kalmanovitz Initiative for the Working Poor at Georgetown University, "The Uber Workplace in D.C."

temporal and geographic service gaps in public transportation. For shift workers that have late night or early morning commutes (such as those in restaurants, hotels, and entertainment venues), TNCs have improved access at times when transit is not operating, though at a higher cost. Similarly, TNCs can improve access for those living in less-connected parts of the metropolitan area.

Ride-hailing also exhibits different demand characteristics than other modes in the DC area. While single-occupancy driving, public transportation, and taxis are most active on weekdays, TNCs are busiest on the weekends (Figure 6).[173] This can provide some complementarity to existing networks, which provide less frequent weekend service.

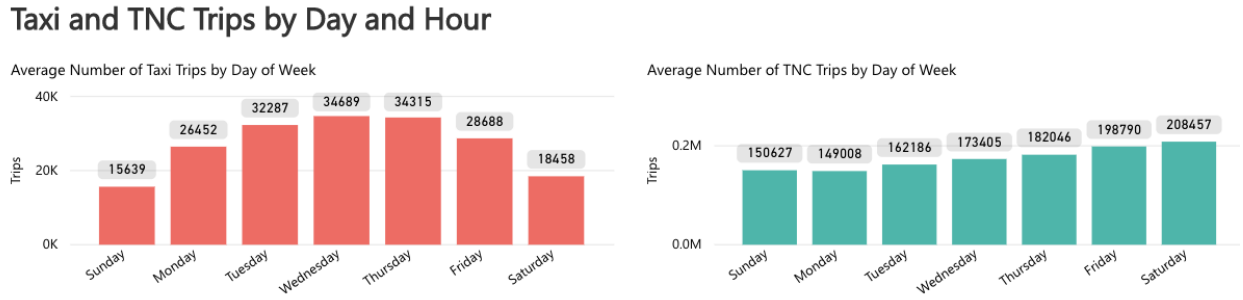

Figure 6: Taxi vs TNC Trips by Day of Week, Washington, DC[174]

Though the proliferation of flexible, on-demand transit has closed some service gaps, it may also be pulling ridership from public transportation. In the period since Uber entered the DC market in 2011, MetroRail average weekday ridership has fallen by 15%, reflecting a net loss of more than 110,000 trips per day.[175] This decline in ridership is even more concerning given that the Washington, DC metro area grew by 8.4% in the same period, and Metro opened 5 new stations on the new Silver Line in 2014. MetroRail service disruptions during this period likely played a role in the ridership decline, however the introduction of on-demand ride-hailing in suburbs (where metro service is less frequent) probably also contributed to the passenger loss. Another possible explanation is the radial configuration of the MetroRail system, which makes it inconvenient to travel between suburban destinations. In 2019, Northern Virginia accounted for 71% of new jobs in the greater Washington, DC-MD-VA labor market, up from 52% in the prior year[176]. With the increasing growth of jobs in the suburbs, trips between different suburban areas are growing. These commutes are not well served by the existing network, which converges in downtown Washington.

[173] Department of For-Hire Vehicles, “DFHV Dashboard and Statistical Data Sets.”
[174] Department of For-Hire Vehicles.
[175] Washington Metropolitan Area Transit Authority, “Ridership Data Portal.”
[176] McCartney and politicsEmailEmailBioBioFollowFollow, “Northern Virginia’s Economic Growth Risks Leaving Maryland Suburbs behind.”

In response to the surge in demand for TNC services, the District of Columbia has developed new regulatory approaches. The 2014 Vehicle for Hire Innovation Amendment Act restructured the city's Taxi Commission as the Department of For-Hire Vehicles, in the process expanding its mandate to accommodate TNCs. This legislation also introduced vehicle standards, insurance requirements, and background checks for drivers. The 2014 act includes measures to limit the potential for discrimination in customer ratings by ensuring that riders have access to view their ratings, and by hiding customer ratings for drivers until after a ride has been accepted. In 2018, the Private Vehicle for Hire Data-Sharing Amendment Act expanded on minimal data-sharing requirements that were included in the earlier act. TNCs are now required to share quarterly data on the number of active drivers, average fares and driving distance, and the time and location of pick-up/drop-offs. An important provision in the 2018 data-sharing bill is its explicit exemption from public information requests through the Freedom of Information Act.

9.3.4.2 Micromobility

Micromobility is also expanding in the DC area. *Capital Bikeshare* was launched in 2008, making it North America's first bikeshare system. Today it operates 4,300 bikes and 500 stations[177] across the Washington metro area. Dockless vehicles have arrived more recently, and rapidly emerged as a popular component of the transportation mix in the area. As in many cities, the introduction of dockless mobility in the District was characterized initially by a large number of operators and ambiguous regulations. In 2019, the District announced that it was revising its dockless vehicle policies. Most notably, the plan reduced the number of scooter operators, from the 8 that had been operating in the District to just 4 (Jump, Lyft, Skip, and Spin). Each company can permit a maximum of 2,500 vehicles, capping the total at 10,000 scooters. Additionally, Jump and Helbiz were selected to provide dockless bicycles–2,500 and 770 respectively, with no more than 2,020 deployed publicly at any time in the District between the two providers.[178]

The finalists were selected according to a 198-point scoring system, though the process drew scrutiny for its selections.[179] Among those excluded was Lime, despite having been one of the first operators in the District and the one that received the highest company rating in regard to its prior track record in the District. Some of the permit recipients were also controversial, especially Spin, which received widespread local publicity after one of its scooter batteries caught on fire in summer 2019.

As part of their operating conditions, these TNCs are required to submit monthly reports to the District. The information from the real-time data feed is used to evaluate system performance, track safety metrics, and ensure compliance with vehicle limits and parking requirements. Though APIs are made public, the information is filtered to remove possible identifiers. According to the District Department of Transportation (DDOT) website, "given the sensitivity of

[177] "About Company & History."
[178] "Dockless Vehicles in the District | Ddot."
[179] "Bird, Lime, Bolt, And Razor Scooters To Leave D.C. After Unsuccessful Appeals."

the data, DDOT is not publicly posting origin-destination data but is seeking other avenues for public access to more information about the performance of the program."[180]

[180] DC Department of Transportation, "Dockless Data and Application Programming Interface (API)."

9.3.5 Autonomous Vehicles

Autonomous vehicles have yet to considerably shape the transportation system in the Washington, DC metropolitan area; however, the Union of Concerned Scientists has released a detailed report analyzing various AV adoption scenarios and their impacts on local environment and marginalized communities.

In all scenarios, AVs are projected to result in a significant increase in VMTs–though the specific mode of adoption greatly influences the extent of the demand increase. In a private ownership model, akin to the current norms around car ownership, the projected increase in VMTs in the Washington, DC area is 66%.[181] If AVs are deployed in a pooled ride model, and accompanied by increased investment in public transportation, then this drops to 46%, which is still significant. The increase in transport demand can be attributed to the added convenience from AVs, which is likely to divert ridership away from public transportation.

In terms of AV policies, the District passed the Autonomous Vehicles Study Amendment Act of 2018, which authorized funding for a public study on the projected impacts of autonomous vehicle adoption. The Act specifies inquiry into the following: regional economy and employment; impact on the District government's transportation revenue; infrastructure, congestion, and public space; environment and public health; public safety (including pedestrians and cyclists); impact on disabled persons; impact on other transportation modes; and projected data collection and sharing needs. The District also joined the Bloomberg Aspen Initiative on Cities and Autonomous Vehicles (a peer-to-peer network sharing best practices) in 2017, and a task force on autonomous vehicles was set up in 2018.[182] In January 2020, Uber announced plans to expand its self-driving program to the DC area, though it will remain in the data collection phase (with human drivers) in the near future.[183]

9.4 Pittsburgh

Pittsburgh is a medium-large city in Western Pennsylvania that has been striving to shed its Rust Belt image and establish itself as a leader in high-tech economic sectors. The population within city limits was 301,048 in 2018, down 64.7% from a peak of 676,806 in 1950[184]. This dramatic (55%) decline in population followed the collapse of the steel industry, especially in the 1970s and early 1980s. This population figure misrepresents the city's true size, however. Allegheny County, which includes Pittsburgh and 129 other self-governing municipalities, has a population of 1.223 million. If the city and county were to consolidate, it would be the 10th-largest city in the United States.

[181] Union of Concerned Scientists, "Where Are Self-Driving Cars Taking Us? Pivotal Choices That Will Shape DC's Transportation Future."
[182] Office of the Deputy Mayor for Planning and Economic Development, "Autonomous Vehicles Working Group."
[183] Hawkins, "Uber Is Bringing Its Self-Driving Cars to Washington, DC."
[184] Sauter, "These 5 Cities Have Lost Half or More of Their Populations since 1950."

Pittsburgh's geography and history have had a major influence on the city's development, generating a path dependence that continues to shape the city's transportation network. The city's landscape is dissected by wide rivers, deep ravines, and steep slopes. This reduces the amount of land available for development, and adds to construction and maintenance costs for infrastructure like bridges, tunnels, and retaining walls. The difficult terrain can also increase trip length, as routes snake around topographical barriers.

The city's history has also created lasting implications for transportation in the area. Many of Pittsburgh's suburbs were not developed as residential communities serving Pittsburgh's labor market, but as standalone industrial towns based around factories. This is especially true of communities extending outward along the city's three rivers, which were built at medium-density and featured mixed residential, commercial, and industrial areas. Three significant trends dramatically reshaped the city's spatial organization in the middle- and late-20th century: mass automobile adoption, the collapse of the steel industry, and migration to the Sun Belt. The collapse of the steel industry contributed to unemployment, poverty, and crime. The legacy of environmental pollution, poor economic prospects, and unappealing weather (Pittsburgh is among the US cities with the fewest annual sunlight hours) enticed many residents to seek better opportunities elsewhere. Of those who remained rooted in the region, many left the urban core for new development on the suburban periphery, contributing further to the decline of their communities. Therefore, while the population declined in the latter half of the 20th century, the urban area actually expanded in size during the same period.

Despite these challenges, the city appears to be reversing its fortune through a growing emphasis on technological innovation. The city hosts Carnegie Mellon University, a world-class engineering institution, as well as the University of Pittsburgh, a large and well-ranked public university. The proximity to major research institutions and low cost-of-living made Pittsburgh an appealing choice for tech companies looking to locate outside of expensive coastal tech hubs like Boston or Silicon Valley. This status has helped the city become one of the emerging hubs for autonomous vehicle technology. Uber has been a high-profile arrival, as we will discuss later this section.

The new technology jobs, however, have not improved outcomes for most of the city's working-class residents. The relatively-low share of college graduates in the local workforce means that most positions are filled by newcomers, and gentrification is advancing (though Pittsburgh remains one of the most affordable major cities in the United States). The newly-arrived technology workforce has made the city's demographics younger and whiter, as displaced workers are pushed to suburban areas. Low-income households in the suburbs face greater barriers to job access, and those without cars must contend with infrequent service and transfers, adding significantly to door-to-door travel times.

Public transportation in Allegheny County is provided by the Port Authority, and includes bus and light rail service (*The T*, which operates underground downtown and at ground level along most other segments). In addition to conventional bus lines that operate in mixed traffic, the Port Authority also operates two busways, which are closed to private automobiles and provide

frequent, limited-stop service between Downtown and multiple residential and commercial districts in the city's East and West Ends. Given that Allegheny County consists of 130 different municipal governments (many of which are too small to offer transit services), there is a strong need to coordinate at the county level. Considering its relatively dispersed population, public transportation ridership is proportionally-higher than in many larger and denser metropolitan areas (Figure 7).

Figure 7: Transit Commute Share and Selected Characteristics, Pittsburgh and Comparisons[185]

Metro Area	Metro Area Pop.	Area	Density	Transit Share
Chicago	9,497,790	28,120 km2 10,856 mi2	338 per km2 875 per mi2	12.1%
Cleveland	2,057,009	10,307 km2 3,979 mi2	200 per km2 517 per mi2	2.7%
Detroit	4,326,442	5,568 km2 2,150 mi2	777 per km2 2,012 per mi2	1.3%
Los Angeles	13,291,486	87,490 km2 33,954 mi2	152 per km2 391 per mi2	4.8%
Philadelphia	6,096,372	13,256 km2 5,118 mi2	460 per km2 1,191 per mi2	9.8%
Pittsburgh	2,324,743	13,840 km2 5,343 mi2	168 per km2 435 per mi2	5.6%
Washington, DC	6,251,240	14,412 km2 5,565 mi2	434 per km2 1,123 per mi2	13.0%

The Port Authority also operates paratransit service in coordination with private operator ACCESS Transportation Systems. The demand for paratransit is high in the Pittsburgh area– 14.7% of area residents have a disability (the national rate is 12.6%), and the service provides 5,000 average weekday trips, amounting to 1.5 million trips per year.[186] According to the Port Authority, this makes it one of the highest-volume paratransit services in the United States.

9.4.1 Transit Initiatives

The primary transit initiative in Allegheny County is the proposed Bus Rapid Transit (BRT) project that would link Downtown, Oakland (where the universities are located), and the East End. There are already multiple bus lines that run along the proposed route, but the project is expected to considerably reduce transit times and increase line capacities. The proposal includes raised platforms and pre-ticketing to reduce dwell time at stops. By improving travel times through this busy corridor, the project intends to improve access to the high concentrations of both professional and service jobs in Downtown and Oakland. The Port

[185] "Census - Means of Transportation to Work by Selected Characteristics."
[186] Port Authority, "Accessibility."

Authority estimates that 66% of all employment in the region will be accessible from the BRT plan.[187] The project is also appealing for its associated upgrades to stormwater and utility infrastructure. The city is seeking almost 128 million USD in federal funds to help pay for the project (see Figures 8 & 9 below).[188] The grant proposal, though not final, received a rating of 'high' for the Federal Small Start Grant Program, which would account for 97.75 million USD (around half of the entire project). The project cannot be funded as designed without this grant. It is worth noting that the estimated cost has increased to 225 million since the original proposal, an increase of 14%.

Figure 8: Pittsburgh BRT Project by Funding Source (2017 Proposal)

Funding Source	**Amount (figures in USD)**	**% Total**
Federal	127.92 million USD	64.85%
State (Pennsylvania)	32.5 million USD	16.48%
County (Allegheny)	19.07 million USD	9.67%
City (Pittsburgh)	17.76 million USD	9.00%
TOTAL	197.25 million USD	*100%*

Figure 9: Pittsburgh BRT Project by Funding Type (2017 Proposal)

Funding Source	**Amount (figures in USD**	**% Total**
Federal Grants	127.92 million USD	64.85%
General Funds (State & Local)	15.55 million USD	7.88%
Bonds (State & Local)	11.25 million USD	5.70%
Sales Taxes (State & Local)	1.60 million USD	0.81%

In addition to new lines, the Port Authority has also focused on incorporating new digital tools to improve its service. Pittsburgh offers a real-time transit feed specification, along with an API and open-access to its geographic data. By offering this level of data access, the city enables third-party developers to offer smartphone applications and other tools. An example of this approach working in practice are integrated, privately-developed platforms like MoovIt and Transit, mobile applications that aggregate different modes and offer real-time information on travel times and delays throughout the Port Authority network.

[187] Bauder, "Bus Rapid Transit System Is Top Priority for Local Officials."
[188] U.S. Department of Transportation, "Downtown-Uptown-Oakland-East End Bus Rapid Transit."

It is important to note that this service depends on publicly-available data, making it subject to some of the same data privacy concerns mentioned in the California case.

9.4.2 Electric Vehicles

The city of Pittsburgh wants to "commit to fossil fuel free fleet by 2030, tackling the transportation sector, a major contributor to poor air quality and carbon emissions, to improve the health of its residents and employees," according to Mayor Bill Peduto. The city itself owns 19 "fully electric" sedans, including nine vehicles purchased in June using state grant funds. Additionally, the Port Authority has purchased two electric buses to test for the aforementioned BRT project. The buses cost 2.27 million USD, around the same price per bus as the Washington, DC contract. To support fleet electrification, Port Authority invested 400,000 USD to install two fast-charging stations at its East Liberty garage.[189] It is interesting to note that charging stations in Pittsburgh have concentrated primarily in gentrifying neighborhoods like East Liberty, raising concerns about equity impacts.

9.4.3 Shared Mobility

9.4.3.1 Micromobility

Pittsburgh has adopted a unique approach to micromobility implementation with the Pittsburgh Mobility Collective. The Collective is a self-organized forum that includes different mobility service providers, which are tasked with submitting proposals for meeting the city's transportation service gaps through community-defined pilot projects. Collective members meet directly with city residents with transportation needs that are not well-supported by the existing network of services, including single mothers, people with disabilities, construction workers with shifting job sites, and those who cannot drive due to criminal convictions. Current members of the collective include developer Skinny Labs, the Transit app, Zipcar, Ford Mobility, Waze, and Swiftmile. The collective combines the capabilities of these mobility service providers, each of which serves a slightly different niche, while blocking outside companies from competing for bids during the pilot phase.

The Mobility Collective represents a radical shift from the dockless vehicle implementation observed patterns in other cities over the same time, which has been characterized by a rapid expansion of services as competing providers jostle for market share. This has led to concerns about platforms building 'walled gardens' which separate their mobility services from competing options (including, in some cases, public transportation). In one example, Lyft blocked the Transit app from providing information on its CitiBike service in New York City. Beyond the lack of integration, chaotic market entry in other cities has led to uncontrolled influxes of dockless vehicles, leading to unresolved questions about vehicle parking, roadway safety, and pedestrian access.

[189] Blazina, "Port Authority Getting First Electric Buses, Considering Fleet for Downtown-Oakland Rapid Transit."

Pittsburgh is instead intending for a slower, more deliberate introduction of dockless vehicles to its transportation mix. As an additional benefit, this approach is designed to reduce the administrative burden for the local government, asking the companies instead to define guidelines according to community consultation. Last year, members of the collective were tasked with developing a single application that could be used to access multiple non-car modes. Spin advanced the winning proposal, which involves establishing 'mobility hubs' around bus transfer points and other nodes in the existing network. These hubs would feature some combination of dockless vehicles, the city's HealthyRide bike share platform, Zipcar access, and Waze designated pickup points.[190] Both the collaborative approach and the solution it designed remain in the experimental phase; however, if successful it could become a model for other cities to better manage their dockless vehicle adoption and promote integration between mobility provider offerings.

9.4.4 Autonomous Vehicles

Carnegie Mellon University (CMU), located in Pittsburgh, has been on the forefront of developing AV technology for more than thirty years. CMU developed one the first autonomous vehicles with onboard computing. Argo AI, one of the leading technology companies, is founded by CMU alumni. In March 2019, Carnegie Mellon and Argo AI announced a 5 year research collaboration where ARGO AI will fund research into advanced perception and next-generation decision-making algorithms for autonomous vehicles.[191] In late 2016, Uber's fleet of autonomous vehicles arrived on the streets of Pittsburgh as a pilot program, further positioning the city on the forefront of autonomous evolution. The city's difficult terrain and weather along with ageing infrastructure increased the difficulty of testing AVs, thus making it one of the best test sites. Aptiv, Argo AI, Aurora and CMU are also testing AVs in Pittsburgh, with the majority of testing being done in Strip District and Lawrenceville.

In 2018, when Uber's self-driving car killed a woman in Tempe, Arizona, the company stopped testing its vehicles in Pittsburgh. The accident led to a huge setback for the entire industry, highlighting the issue of the technology still being at a nascent stage and not ready for commercial adaptation. In 2019, Mayor William Peduto of Pittsburgh issued his executive order on testing and operation of self-driving vehicles in the city.[192] The executive order, called the 'Pittsburgh Principles' showcased the focus of the city to once again lead the development of technology, while providing inclusive and safe transportation to its residents. The order identified the Department of Mobility and Infrastructure (DOMI) as the leading department which would provide guidelines to companies testing AVs in the public streets of the city. The department will also guide and collaborate with numerous stakeholders such as public agency partners, private sector industry and general stakeholders to develop sound policy for the technology. Furthermore, the guidelines released by DOMI required companies to submit material to the

[190] Bliss, "A Micromobility Experiment in Pittsburgh Aims to Get People Out of Their Cars."
[191] Carnegie Mellon University, "Carnegie Mellon, Argo AI Form Center for Autonomous Vehicle Research with $15M Multiyear Grant."
[192] City of Pittsburgh, "Executive Order, Self Driving Vehicle Testing and Operations in the City of Pittsburgh."

department ten days before the proposed testing of vehicles while also providing existing testers thirty day to provide a retroactive submission. The guidelines take the safety of the citizens of Pittsburgh seriously and have stressed that two trained operators who have undergone training and background checks are required to be in the car.[193]

Argo AI, a leading tech company from Pittsburgh, received a 1 billion USD investment from Ford,[194] and Amazon invested 530 million USD in Aurora.[195] In April 2019, Uber also received a 1 billion USD investment from SoftBank, Toyota and Denso towards Uber's self-driving unit. The increasing investments provide major competitors in this industry the confidence and resources to innovate and improve their technologies and progress towards a future of automation.

10 Conclusions

Comparing policy approaches across the various case studies revealed a number of lessons learned and best practices related to the sustainability, equity, and data privacy implications of new mobility technologies. In this section, we present our key findings and propose a framework for policy making in each of these three areas. Lastly, we examine various policy approaches and how they can be used to speed or slow mobility technology adoption, and provide recommendations for situations in which policymakers may wish to choose one approach over another.

10.1 Sustainability

New mobility technologies such as EVs, shared mobility, and AVs carry the promise of a more sustainable transportation sector, but as we have seen from their adoption in the United States the actual impacts of these technologies can depend on a multitude of factors. Sustainability impacts are determined by a technology's entire lifecycle, where it is adopted, how it is adopted, and the sustainability of the modes it is replacing. To help ensure the adoption of these technologies is sustainable, we recommend the following framework (Figure 10).

[193] Department of Mobility and Infrastructure, "Self-Driving Vehicle Testing in Pittsburgh - Summary of Findings."
[194] Reuters, "Ford to Invest $1 Billion in Autonomous Vehicle Tech Firm Argo AI."
[195] Demaitre, "Aurora Raises $530M Series B as Amazon Joins Self-Driving Car Race."

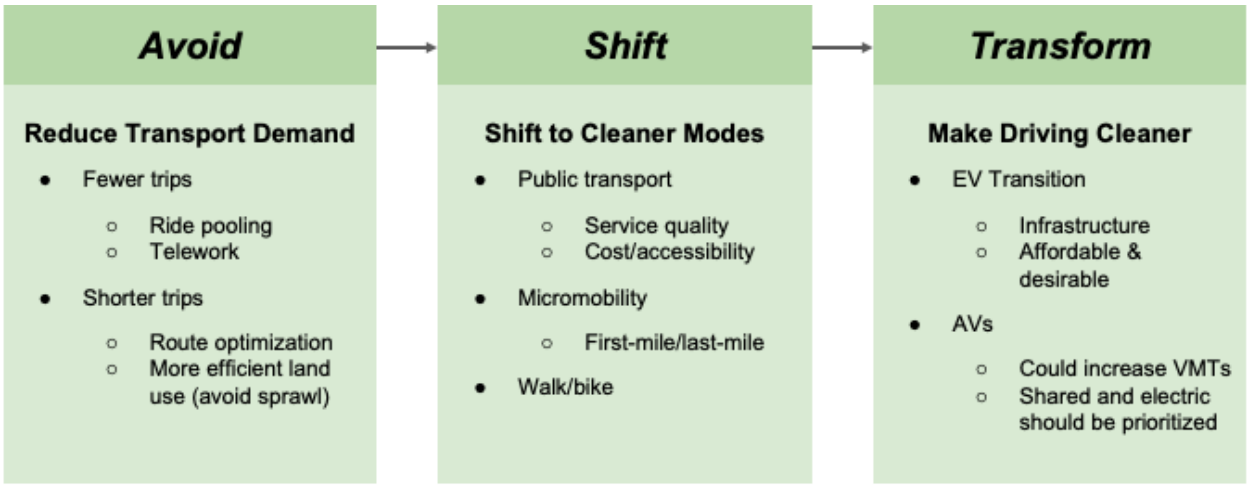

Figure 10: A Sustainability Framework

To promote environmental sustainability, we endorse and build upon the Avoid-Shift-Improve (A-S-I) framework promoted by the Sustainable Urban Transport Project and others.[196] The first objective, **Avoid**, refers to reductions in transportation demand. We identified two pathways to achieving demand reductions: generating fewer trips, and promoting shorter distances for the trips that occur. Reducing the number of trips depends on shifts in consumer behavior, including limiting the number of commuting days (such as remote working or the 4-day workweek) or by pooling rides. Reducing trip length can be achieved to some extent through route optimization, though more substantial distance reductions depend on land use planning.

In practice, however, we acknowledge that many trips cannot be easily avoided. For these, we recommend the second-best scenario, **Shift**. Shift refers to the modes of transportation used, with the objective being to replace single-occupancy vehicle travel with more sustainable modes. Even in metropolitan areas with good public transportation options, single-occupancy vehicles remain the predominant mode of travel throughout the United States. Washington, DC has the second-highest annual ridership of any metro system in the United States, though more than two-thirds of area commuters continue to rely on single-occupancy vehicles.[197] To promote shifts to cleaner modes, they must be made accessible, reliable, and comfortable.

As an alternate approach, policymakers could also promote mode shifts by increasing the cost of driving. These approaches include gas taxes and roadway tolls (marginal cost) or by increasing the cost of vehicle ownership through registration fees or residential parking permits (fixed cost). It is worth noting that the majority of American voters are car owners and regular drivers, making such policies politically-unpopular.

Finally, we acknowledge that there are some trips that cannot feasibly be *avoided* or *shifted*, and that are likely to remain reliant on single-occupancy travel. In low-density suburban areas, for example, the demand for transit may be insufficient to justify the cost of effective service

[196] Sustainable Urban Transport Project, “INUA #9.”
[197] “Public Transportation Ridership Report.”

provision. In these situations, we are left with the need to **transform** existing driving habits to foster greater sustainability. At present, the leading approach for such transformation is the electrification of the transportation sector. To facilitate EV adoption, there must be sufficient provision of charging infrastructure. Moreover, the actual environmental impact of EVs depends on the generation mix in the electricity grid. As our findings show, an EV leads to a significantly-higher emission reduction in California than in Michigan, due to differences in the generation sources providing electricity in each state. For this reason, transformations in the mobility sector must be accompanied by transformations in the electricity sector to achieve meaningful improvements in sustainability.

10.2 Equity

Without proper planning, the adoption of new, disruptive mobility technologies may contribute towards a widening of socioeconomic inequality in society. There is a need, therefore, for deliberate planning to ensure that the integration of these technologies promotes equity through access, affordability and inclusion across all sections of society, as presented in Figure 11. With this proposed framework, we see a need to simultaneously ensure progress across all three recommendations, as each supports the other two.

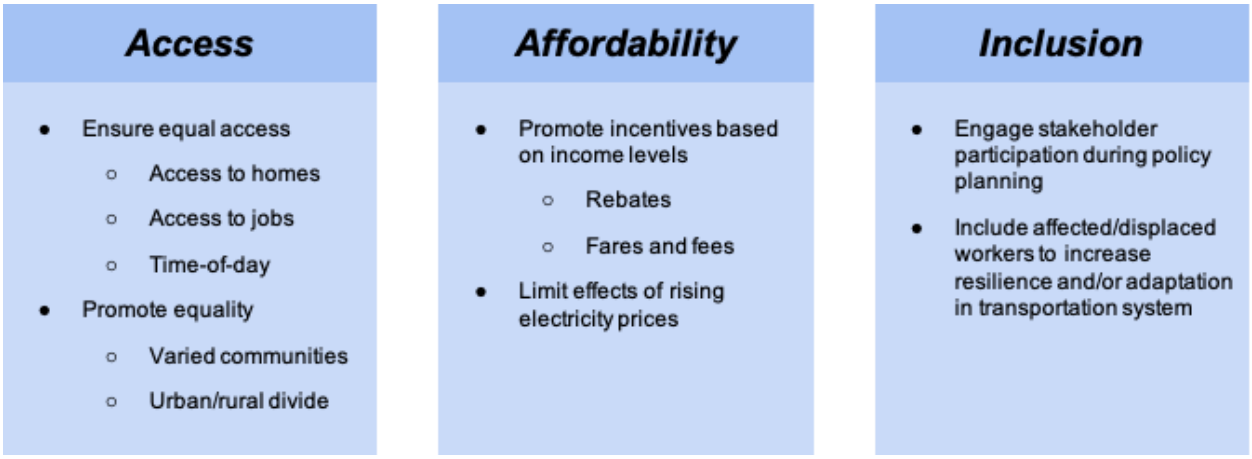

Figure 11: An Equity Framework

Access to sustainable mobility services such as bikes and scooters, as well as to critical infrastructure such as charging stations is a crucial element to ensuring equity in transportation. Access to transportation and its supporting infrastructure can improve access to opportunities, especially in cases where mobility is a limiting factor. Accessibility involves being located reasonably close to a route, charging station, or micromobility options as well as being able to use that service most hours of the day and not only during regular business hours.

Access to transportation, especially new forms of mobility, tends to be concentrated in more well-off areas. For example, charging stations for EVs are mostly located in upper-middle class neighborhoods. Thus, in order to promote the use of these technologies, it is crucial to identify existing gaps and ensure programs and policies that explicitly promote the provision of

infrastructure in low income areas. Geographic inequities must also be addressed. For example, rural areas often are typically not included in new shared mobility programs, despite there often being a need for more transportation options.

Ensuring **affordability** is another important element to providing mobility to all parts of society. Electric vehicle rebates are a great example of increasing affordability, especially when they are given based on household income levels. Other examples include reducing registration fees and taxes often applied to EVs. It is also crucial to provide discounts and lower prices to shared mobility services, such as bikes, scooters, and shared rides.

We also recommend limiting the potential rise in electricity prices, due to increased demand from EVs, by upgrading power grids. As seen previously, there could be an increase in electricity prices due to higher tendencies of the system to reach peak demand with an increasing number of EVs connected to the system. This could drive up the prices of electricity and disproportionately harm low income households, who have a higher electricity bill to income ratio.

Inclusion involves engaging every stakeholder in the planning stage of policies that could have an effect on them. This is especially important for groups that will be negatively impacted by the introduction of a new technology. For example, as the transformation of this sector continues, there will be many more displaced drivers, especially with the increased adoption of AVs. Ensuring displaced workers adapt and find alternate work is essential, especially to limit the impact on their lives and livelihoods. The inclusion of all stakeholders in transportation planning processes can help make transportation systems more resilient and adaptive, as a diversity of perspectives can lead to creative solutions, as well as make sure that no one gets left behind.

10.3 Data Privacy

Access to mobility data can be valuable to city governments for planning and permitting purposes. However, the sharing of trip data can also create privacy concerns, especially if those data are shared more widely, for example via an open source platform or an information request. Multiple approaches to the handling of data, especially micromobility data, are currently being tested out at the city and state level. Some of these approaches, such as the active management approach promoted by the city of Los Angeles, raise multiple privacy and safety concerns, including their compliance with privacy laws, as well as the potential for real-time interventions to remotely slow down speeding vehicles. As the data standards put in place now will be expanded to other technologies such as AVs in the future, it is important to ensure that these standards prioritize the safety and privacy of citizens' personal data. To that end, we propose a three-pronged approach presented in Figure 12 for the handling of mobility data.

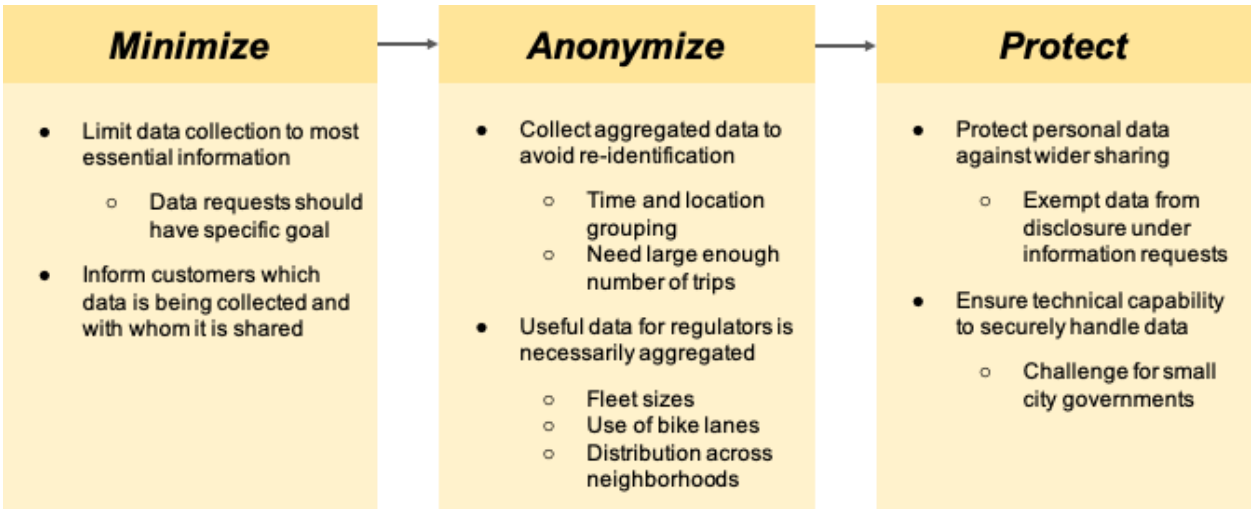

Figure 12: A Data Management Framework

We recommend first of all to **minimize** the data that is collected by city governments and limit data requests to only the most important information, with a specific goal for the data requested. Additionally, customers should be clearly informed about what data is collected and with whom it is being shared.

As a second step, we recommend **anonymizing** any data that is collected to avoid the potential for re-identification. To do so, we recommend that city governments collect data in an aggregated format with grouping by both time and location. In general, the data that regulators require for planning and permitting purposes is by definition aggregated, such as fleet sizes, use of certain routes, and the distribution of vehicles across neighborhoods. Therefore, collecting data in an aggregated format should be sufficient for the city government's needs. However, anonymizing data in this way requires that there is a large enough number of trips to properly aggregate them. Therefore, this approach may be best suited to larger cities with higher numbers of users.

Lastly, for any data that cannot be anonymized, we recommend **protecting** it against wider sharing. This can be achieved, for example, by classifying it as confidential and exempting it from disclosure under information requests, as Washington, DC has done in its Private Vehicle for Hire Data-Sharing Amendment Act. City governments additionally need to ensure that they have the technical capability to securely handle the data. This can be a challenge for small city governments, who may not have designated information technology (IT) or other technical staff.

10.4 Policy Approaches

From examining the adoption of EVs, shared mobility, and AVs in our case studies, we have observed that public policy approaches to transportation innovation can range from those that encourage faster technology adoption to those that slow technology adoption as well as those that involve more or less public-private collaboration (Figure 13). Within those two spectrums we have identified four categories that describe the types of public policies and practices that may be used at any level of government to impact the adoption of sustainable mobility technologies.

	Faster Adoption	***Slower Adoption***

Less Collaboration
Public-Private Sector
	I. Laissez-Faire Approach
	- Private sector largely unregulated
	- Adoption follows market logic
	  - Least cost; consumer satisfaction
	- Assumes sufficient underlying demand
	- Examples:
	  - Scooters in DC; Ride-hailing (early days)
		II. Status Quo Approach
		- Policies resist or exclude new technologies
		- Protect the role of incumbents
		- May be appropriate where trust is lacking
		- Examples:
		  - San Francisco Scooter Ban

More Collaboration
Public-Private Sector
	III. Policy Promotion Approach
	- Facilitates wider adoption than free market
	  - Decrease costs/increase uptake
	- Favors innovators over incumbents
	- Policymakers can guide development principles
	  - May build trust
	- Examples:
	  - R&D Subsidies; Vehicle tax rebates
		IV. Guideline Setting Approach
		- Greater opportunity for stakeholder engagement
		  - May build trust
		- Attempt to balance public/private sector goals
		- Consensus-building can be slow, difficult
		- Examples:
		  - Scooters in Pittsburgh

Figure 13: Policy Approaches to Transportation Innovation Framework

I. The **Laissez-Faire Approach** is characterized by the government allowing private sector companies to operate largely unregulated. The adoption of the mobility technology is therefore determined by the market logic of prices and consumer preferences. For the Laissez-Faire Approach to be effective at speeding up adoption, there must be underlying demand for the technology. Some examples of this approach include the introduction of scooters in Washington, DC as well as in San Francisco, where operators were initially allowed to (or at least not restricted from) introducing their scooters as they willed. The introduction of ride-hailing in the United States also initially followed this approach.

II. In the **Status Quo Approach,** the government passes policies to resist or exclude new technologies. This approach can be used to protect the status of incumbent technologies and may be appropriate in instances where there is a lack of trust in a new technology. After the laissez-faire introduction of dockless scooters in San Francisco, the city received thousands of complaints that they were hazardous and irritating, indicating a loss of trust. The city then temporarily banned the operation of dockless scooters. As another example, many cities do not yet trust the safety of AVs and therefore are not permitting their testing on public roads.

III. The **Policy Promotion Approach** involves more collaboration between the public and private sectors. In this approach the government actively promotes a technology. Through policies and incentives the government facilitates wider and faster adoption of a new technology than would normally occur in a free market, often by decreasing costs to the consumer. Using this approach, policymakers can more actively guide the development of a technology in their jurisdiction, which may help build trust in the technology. R&D subsidies are an example of the Policy Promotion Approach, as well as the national electric vehicle tax rebates, which have helped accelerate the adoption of EVs.

IV. The **Guideline Setting Approach** is also characterized by high levels of cooperation between the public and private sectors, but results in a slower rate of technology adoption than the Policy Promotion Approach. In this approach the government works with private sector actors to establish guidelines for the use of a technology, attempting to find balance between public and private sector goals. This approach allows for more opportunities to involve various stakeholders, which may help to build trust, however, consensus-building can be slow and difficult. An example of this approach is the Mobility Collective in Pittsburgh, which is a consortium of mobility service providers who work with the city government and engages with residents to help determine services that can be introduced to meet unaddressed transport needs.

Determining the best policy approach to address new mobility technology depends on where the technology lies on the adoption curve as well as the goals and capacity of the government considering a policy. The Laissez-Faire Approach can work well for experimental technologies where the government would like to see fast adoption but might not have the will or capacity to closely oversee its development, as in early scooter and ride-hailing adoption. Laissez-Faire can similarly work well for established technologies where the public sector trusts the private sector and market dynamics to determine further adoption. In this case, minimal involvement is more efficient than more active promotion on the part public sector.

The Status Quo Approach is best used in cases where the government wants to slow, pause, or prohibit the adoption of a new technology. Governments may prefer this option if they want to protect incumbent technologies or lack trust in the new technology. We may see the use of the Status Quo Approach as we see more AV adoption and governments have safety concerns or want to protect the jobs of those who work as drivers.

The Policy Promotion Approach is best for experimental and emergent technologies where the government hopes to speed up adoption. As Policy Promotion often involves government spending in the forms of incentives, tax credits, or R&D investment, using this approach for established technologies that are already at cost-parity with incumbent technologies is an inefficient use of government funds and not recommended.

As technologies move along the adoption curve and become more established, policies tend to shift to the Guideline Setting Approach. Governments develop a better understanding of the

technology so they can be actively involved in setting policy with the private sector, but they do not want or need to promote the technology as actively as when it was in a more experimental phase of development.

As sustainable mobility technologies continue to develop in the United States, making smart transportation policy will be no simple feat. All levels of government will have to consider their own capacity and transportation goals as well as understand technologies' adoption level, sustainability impacts, equity effects, and data privacy implications.

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