Social Equity Considerations in the New Age of Transportation: Electric, Automated, and Shared Mobility

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Executive Summary: Access to employment, goods, services, and healthcare, is essential to quality of life and economic prosperity in the United States, and transportation is vital to providing that access (Blumenberg and Waller 2003). Access to current transportation systems is largely inequitable, leaving large percentages of the population without affordable access to public transportation or vehicles necessary for employment opportunities and access to essential goods and services. Low-income populations, which also are disproportionately people of color and people with disabilities, spend the most amount of time and money on transportation, which further burdens them financially. The same people also tend to live in areas that disproportionately suffer from health consequences and other negative externalities, like noise pollution and increased incidence of fatal traffic accidents associated with transportation congestion and emissions (Transportation Equity Network n.d.; Marcantonio et al. 2017).

Low-income populations rely on public transportation the most, yet currently they have less access than affluent communities (Center for Neighborhood Technology 2018; The Center for Neighborhood Technology 2017; National Equity Atlas 2016; Sutedjo-The and Lee 2018). Affordable housing is not supplied at high enough rates to remedy this, and planning usually does not take into consideration the cost of transportation and the cost of housing when determining location and eligibility (The Center for Neighborhood Technology 2017). Alternative modes of transportation, like bicycling and walking, are not prioritized in low-income communities and are often dangerous because of lack of infrastructure to support them (World Health Organiization and The World Bank 2004; S. Shaheen et al. 2017).

New mobility technologies, including shared mobility and automated vehicles have the potential to improve equity and access to transportation because they are not limited by transit infrastructure, but policymakers must implement policies to discourage current practices that favor people who already have access to transportation and leave out underserved communities. This includes ensuring that barriers to access for shared mobility, electric vehicles, and automated vehicles are reduced or eliminated. Policymakers also need to safeguard underserved and low-income populations from discrimination by service providers.

This deviates from the typical technology implementation protocol, in which policy is generally implemented following the slow diffusion of new technology. Instead, policymakers should act now before transportation technology is deployed to ensure maximum benefit to the entire population of the U.S.

To lessen the environmental burden on underserved and low-income populations, policymakers should implement policies that encourage behavior which promotes lower emissions, reduces congestion, and enhances mobility, while encouraging the adoption of low emission vehicles for private and public use. Policies include incentivizing the adoption of electric vehicles, increased public transit use, carpooling, and encouraging partnerships between mobility service providers so that they operate in partnership rather than in competition with each other. Policymakers should also prioritize equal access to new technologies and services like electric and automated vehicles, which have the potential to benefit low-income and underserved populations the most.

I. Introduction

Transportation is a fundamental necessity to everyday life in the United States. People living in urban, suburban, and rural areas require some form of transportation to meet their basic needs; getting to and from their job or school, buying groceries and other products, having those products delivered, going to medical appointments, and visiting family and friends are only some examples of everyday activities that require transportation. The transportation system in the United States has prioritized private on-road vehicles, with trillions of federal dollars spent on roadways, parking infrastructure requirements, and fuel subsidies. Over 99% of the vehicles currently on the road are powered by fossil fuels (International Energy Agency), making transportation the largest contributor to carbon dioxide emissions of any major sector (U.S. Energy Information Administration 2018).

The growth in the total number of vehicles on the road leads to increases in emissions and energy use. Part of the reason for this increase is a result of urban sprawl, which causes negative public health and environmental outcomes and an increasing economic burden (Logan E. Mitchell 2018). Low-income families, which are disproportionately people of color, people with disabilities, and rural populations, without access to reliable transportation face increased barriers to basic necessities to succeed in the US, propagating cycles of inequity. Without equal access to education, jobs, health care, and basic goods and services, these burdens are exacerbated. To make matters worse, low-income communities also suffer the most negative public health and environmental outcomes resulting from our over-reliance on vehicles, even though they receive the fewest benefits from urban planning and transportation policies (Karner 2017).

The global transportation system is currently undergoing several transformations, including the introduction of electric and alternative energy vehicles, shared mobility services, and automated vehicles. Rapidly evolving technologies will dramatically influence societies all over the world. They have the potential to address barriers to economic inequity by providing a reliable and affordable means of transportation to employment, education, health care, and basic goods and services. Automated vehicles could expand access to transportation for people with disabilities or other conditions preventing them from operating a vehicle. Shared and pooled vehicles offer an affordable and energy efficient means of transportation for people who live in areas not serviced by public transit. If vehicles transition to electric powertrains, we could lower emissions up to 57% by 2050 in the U.S. (Electric Power Research Institute 2018).

However, as these technologies are increasing in popularity, especially shared mobility services like Uber and Lyft, users continue to be more affluent, young, well-educated, and white than the general population (S. Shaheen et al. 2017), and there are documented cases of users experiencing racial discrimination and sexual harassment (Ge et al. 2016). Knowledge of electric vehicle technology follows a similar pattern; low-income, non-white, and less educated individuals are less aware of electric vehicle technologies, including charging

stations, and the benefits of electric vehicles (Singer 2016).

Ensuring that the development and deployment of the technologies and infrastructure needed for this transformation of mobility services to provide access to basic needs in an equitable way should be an urgent policy priority at the federal, state and local level. This report provides background into current inequities in transportation, outlines policies that have guided these efforts previously, and provides recommendations for moving forward.

II. Background: Inequity and Discrimination in Transportation

Transportation is fundamental to ensuring access to necessary opportunities to survive in the United States (Blumenberg and Waller 2003). Historically, access to transportation has not been enjoyed equally by the entire population in the US for a variety of reasons, including housing discrimination (Marcantonio et al. 2017). Low-income, rural, and underrepresented communities have less access to private and public transportation, and spend more of their income on transportation-related expenses. People in the bottom 20% income bracket spend 42% of their annual budget on vehicle ownership – over double the national average (Transportation Equity Network n.d.). Further, the quality of transportation disproportionately burdens these communities, both in its reliability and as a result of negative public health outcomes associated with those transportation modes.

Transportation planning and policy in the US has prioritized building a transportation infrastructure that has favored urban sprawl and use of personal vehicles. Historically, low fuel costs and low ownership costs have encouraged dependence on private vehicles. This has been aided by Federal transportation spending to build and improve interstate and intercity highways, starting with the Federal-Aid Highway Act of 1956 (Marcantonio et al. 2017), as well as government subsidies for driving (fuel, maintaining roads, and parking spots) provided by non-transportation related taxes like property and income taxes. Some European systems, in contrast, that have prioritized public transit systems and provided fewer incentives for private vehicle ownership, have as a result seen sustained ridership numbers and success, with fewer people dependent on cars (Jaffe 2015).

These policy decisions in the United States have resulted in barriers to transportation from underserved communities, which have in turn, perpetuated problems of inequity. This unequal access to transportation has resulted in more vehicles on the road, which in turn leads to increases in congestion, wasted time, and air pollution. The resulting negative health and economic consequences disproportionately affect low-income communities who tend to live near busy highways and have longer commutes. For example, people who suffer from asthma are disproportionately people of color, low-income, and underserved, and are more likely to be people who live near an area with heavy vehicular traffic (Transportation Equity Network n.d.).

Rapid transformation of the current transportation system provides an opportunity to remedy the inequities of the current system. Transportation Network Companies (TNCs), like Uber and Lyft, are changing the way people move around, by providing an on-demand vehicle that will take you to a specified place, all within a mobile app. Vehicles are moving towards more efficient technologies, like all-electric powertrains that have zero tailpipe emissions. Automated vehicle technology is making its way into the market, likely improving on-road safety, and public on-road fully automated vehicle testing is underway in some cities, a bulk of companies are operating in Arizona and California. This rapid transportation transformation has the potential to improve the quality of life of the entire U.S. population by improving safety and mobility. However, it also has the potential to further disadvantage people who are already underserved. Policy and public planning must analyze and address the implications of the new transportation world to ensure that access to mobility is equitable, affordable, and safe for the entire population

i. Current Inequities in Transportation

The most important and common transportation is to and from employment, because it occurs almost daily and provides people with their income. In the US, over three-quarters of people drive alone to work, and that number has increased every year in recent history (US Census Bureau 2017; Bureau of

Transportation Statistics 2016). Rising housing costs, especially in urban areas, are pushing low-income populations outside of urban centers, which increases commute distance and time. Many of these low-income neighborhoods do not have access to public transit necessary to commute to their jobs (Transportation Equity Network n.d.; Smedley and Tegeler 2016). Communities of color and low-income households tend to suffer the burden of this trend the most. In the U.S., only 9% of households in the total population are without a vehicle. That number is much higher for racial minorities – 20% of black households, 12% of Latino, and 14% of Native Americans (National Equity Atlas 2016).

Access to public transportation is essential for low-income people who cannot afford personal vehicles to access jobs, goods, services, and vital healthcare. However, areas with little access to public transportation tend to be low-income and minority communities. Transit rail lines often move between affluent neighborhoods and urban job centers, leaving out areas with affordable housing. Only 71% of households without access to a car are within half a mile of a transit stop, making transportation expensive and difficult for those 29% of households without easy access to transit (Center for Neighborhood Technology 2018).

Figure 1 shows a data visualization of public transit stops overlaid onto a map with geographic lines drawn by median income, taken from a project from the Urban Data Challenge developed by Raymon Sutedjo-The and Sandra Lee to show transportation inequity (Sutedjo-The 2013). The upper map shows San Francisco, while the lower map shows Zurich. The map of Zurich shows that regions of low and median income have equal or greater access to public transit stops than higher income regions. San Francisco on the other hand, has large regions with dense low-income populations that have very little proximity to public transit stops, whereas many of the high-income neighborhoods have an abundance of public transit. Zurich transportation policies prioritize public transit in cities, while US public transit has resulted in dependence on personal vehicles for commuting. Also of note, is that public transit in Zurich appears to be more robust with fewer delays in all regions.

A study in New York City analyzed this backwards pattern further, neighborhoods ranking the highest in median household income,

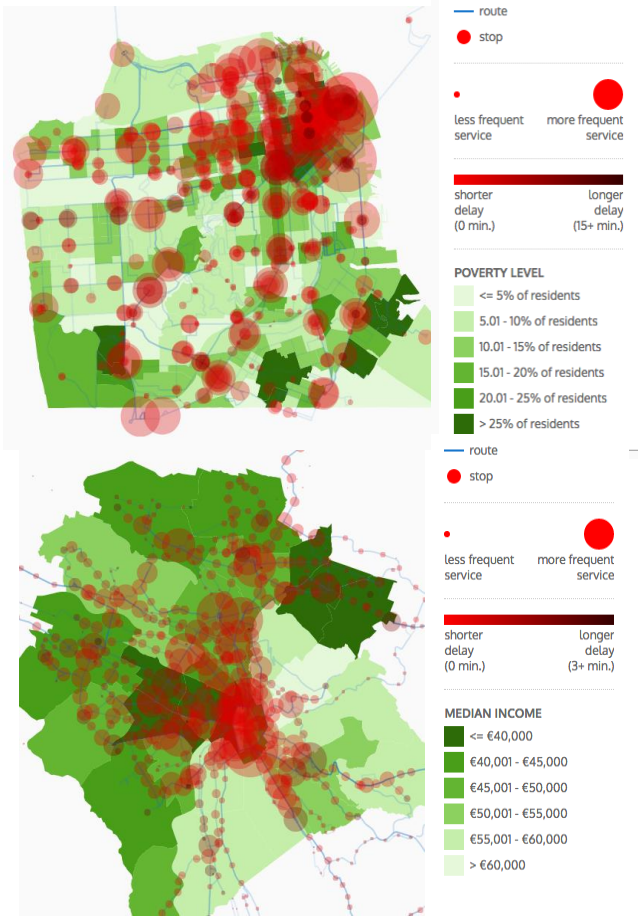

Figure 1. Map of transit and median income in San Francisco (top) and Zurich (bottom). Regions shaded in green signify median income brackets, with public transit stops signified by red dots. The size of the red dot signifies the frequency of service, and the shade signifies the delay in service. Visualization with permission and courtesy of (Sutedjo-The and Lee 2018)(Sutedjo-The and Lee 2018).

and lowest in unemployment, had the largest commute by transit on average, and only 10% commuted by car; the lowest income neighborhoods with higher unemployment rates reported 27-52% commuting by car (Kaufman 2015). The correlation between unemployment and insufficient access to public transit are related because transit is necessary for employment in a city like New York, where many low-income families live in the outer boroughs that are not served by the metro system (Bialik et al. 2015). In addition, low-income households that are forced to commute with a personal vehicle spend a larger percentage of their income and time on transportation (Kaufman et al. 2015), leaving less for

housing, groceries, health expenses, and other goods and services.

People who's only options are to walk or use a bicycle as their means of transportation in underserved areas tend to live in places with poor or outdated urban planning. These areas often attract heavy traffic through residential spaces, and have limited pedestrian crossing space, bicycle lanes, and public transit lanes (World Health Organization and The World Bank 2004). Low-income residents suffer the consequences of this poor planning, and are more vulnerable to traffic-related injury in addition to exposure to highly polluted air and increased noise. Low-income pedestrians and bicyclists are at a higher risk for injury than vehicle owners (World Health Organiization and UN-HABITAT 2010) (Bishai et al. 2006).

Urban sprawl has forced increased areas of low-income urban residence. High density housing contributes to high levels of air pollution from vehicles in those areas from localized emissions. Exposure to criteria pollutants from tailpipe emissions causes increased risk for heart disease and lung disease, causing disproportionate rates of asthma in children in low-income residential areas (National Equity Atlas 2016; World Health Organiization and UN-HABITAT 2010).

Research also shows that geographic location and mobility is a predictor of economic mobility (Chetty 2014). Residential segregation, income inequality, and school quality were each found to be major factors in a child's likeliness to reach a higher income bracket than his or her parents, and all three of those factors are dependent on access to transportation.
The Center for Neighborhood Technology has also developed the Housing + Transportation Affordability Index to highlight the relationship between housing costs and transportation costs (The Center for Neighborhood Technology 2017). Affordable housing planning usually only take the cost of housing into consideration when planning and assessing income eligibility, but the Housing + Transportation Affordability index reveals that both transportation and housing cost should be taken into consideration when planning location for affordable housing and determining eligibility. Increasing access to affordable housing and transportation is essential in moving towards equitable cities.

ii. Inequities in Shared Mobility

Ride sharing and carpooling have been utilized since cars became widely adopted (Teal 1987; S. A. Shaheen, Chan, and Gaynor 2016); however, information technology and smart phones have modernized their ease of use and now more people than ever are utilizing sharing and carpooling to save money and time. Shared mobility has enabled easy, on-demand access to transportation with payment connected through mobile apps. In this report, shared mobility refers to carsharing (ZipCar, car2go), Transportation Network Companies (TNCs) like Uber and Lyft, including both shared vehicle and carpooling services (like Scoop and Waymo carpool). Bikeshares and scooter-shares are also briefly discussed.

A recent UC-Davis study found that in major cities 21% of adults report having used ride-hailing services, and 90% reported having heard of or used the technology first or second-hand (Clewlow and Mishra 2017). However, the people who use ride-hailing tend to have higher incomes, be younger, and more educated than the rest of the population, suggesting there are social and economic barriers to overcome before new shared mobility technology is equitable (S. Shaheen et al. 2017). Further, the study found that users tend to reduce their use of public transit after using ride-hailing, suggesting that ride-hailing services are a substitution rather than a complement to public transit (Clewlow and Mishra 2017); at least among its current affluent users who choose convenience over cost.

New innovation in transportation, in concept, provides easier access to transportation in areas where taxis and public transit are limited, and where owning a vehicle is not economically viable (Committee for Review of Innovative Urban Mobility Services: Transportation Research Board 2016). Shared mobility technology has also had major impacts on the current transportation system, creating opportunities for employment, and lowering the cost and increasing access to transportation for some, including mid to low income households (Securing America's Future Energy 2018). However, users of shared mobility tend to be younger, higher income, more educated, and disproportionately white compared to the representative US population, meaning it is not

benefiting the people who need it most; it also may impact the availability and affordability of public transit options that many vulnerable populations rely on (Shaheen 2017).

Demographic and economic barriers to the adoption of mobility services are a result of several requirements to access them. Geographic inequality prevents people from using ride-sharing services for the same reason it prevents them from using public transit – it is not available where they live. Car-sharing services like Zip-Car, and bikeshare programs like Capital Bikeshare simply do not have many vehicle stations located in lower-income communities and communities of color (S. Shaheen et al. 2017).

Further, access to the required technology is a barrier to low-income households. Almost all of the shared mobility platforms require both access to a mobile app (with data plan) or at least the internet, and online banking. Lack of internet or mobile data access provides a significant barrier to use of shared mobility technology, which mainly limits use by people over the age of 65 and low-income people(S. Shaheen et al. 2017). Restricted use of or access to online banking or credit cards also prevents use of shared mobility. Unbanked households are more likely among less educated, lower income, and disabled households. According to the Federal Deposit Insurance Corporation (FDIC), in 2015 only 7% of the overall population was unbanked, however the rate is 25% for households making less than $15,000/year, 18% for black households, 16% for Hispanic households, 23% for people without a high school education, and 18% for disabled people (Burhouse et al. 2016). Other barriers to shared mobility technology access include language barriers for immigrant populations, and resistance to technology for older people and people from diverse cultures.

Discrimination compounds the economic and social barriers stemming from systemic inequities. A recent study found that in Boston and Seattle, African-American riders were more likely to have their rides canceled than white riders, twice as much in Boston. The discrimination was based both on the picture of the rider, or the name sounding "distinctively black." They also found that in Boston, rides for women tended to be longer and more expensive than for male counterparts (Ge et al. 2016).

If shared mobility barriers are lowered and technology is widely adopted, without policy guidelines and regulations, the public health and environmental consequences could further propagate inequity among low-income and under-served communities. An increase in vehicle miles traveled (VMT), especially if vehicles do not transition to electric (addressed in a later section), will increase localized pollution and displace public transit (Clewlow and Mishra 2017). These negative consequences have disproportionate public health consequences on low-income and underserved communities.

However, if policies and regulations are implemented to address lowering barriers to access shared mobility while also increasing access to utilization of public transit, there are potential benefits to underserved and low-income communities. Without discrimination and with accessible options for users, ride-hailing and carsharing can help provide transportation to people who do not have personal vehicles or access to public transit. Shared mobility can provide access to transportation for people who cannot operate a vehicle or take public transit because of disability, age, language barriers, or other reasons. Ideally, shared mobility could be used to supplement public transit for people who do not live in an accessible region or are limited by the time of day they work.
If carpooling is widely used instead of taking a private ride, congestion and negative environmental consequences of increased access to transportation would be minimized or even reduced depending on the vehicle technologies being used.

iii. Barriers to Access for Advanced Vehicle Technologies

iii.i Electric Vehicles

Electric vehicles (EVs) present a potential solution to environmental and public health issues caused by tailpipe emissions, and will perform better and better in well to wheel comparisons as our national grid continues to move to clean sources of electricity (Nealer, Reichmuth, and Anair 2015). EVs have continued to see record sales in the US, which have grown exponentially since 2013 (Wood et al. 2017).

More than half of those purchased were manufactured in the US, creating new technology job opportunities and adding to GDP (Department of Energy 2018). EVs also have the potential to boost local and regional economies through creating jobs and spending on local energy sources, compared to gasoline-powered cars.

Unfortunately, EV adoption has not been as fast as is necessary to meet climate goals previously set by the Paris agreement (Unfccc n.d.). Underserved and low-income communities are necessary consumers to accelerate the adoption of EVs, and they have the most to gain from a shift to electric transportation (Greenlining 2018). People of color support climate action policies overwhelmingly, and are the fastest growing consumer segment in California (Green for All 2014), but EVs are not typically marketed to them. A Greenlining report showed that in California, only 42% of the population are white, however 69% of hybrid and alternative fuel vehicle owners are white, even though California residents of color are more concerned about air pollution. This suggests that they are not a targeted market and have higher barriers to access. For example, infrastructure for sales of hybrid and electric vehicles like public charging stations (Song 2011). Moving large numbers of EVs into the market is an important first step in consumer awareness, realization of operating cost benefits, and consumer acceptance (Soltani-Sobh et al. 2017).

The initial cost of purchasing an EV is currently too expensive for low-income communities to buy, despite existing tax incentives. Long-term affordability strategies like tax incentives and subsidies aim to lower the operating costs, but do not reduce the burden of the upfront cost of an EV, even in California. Current ownership and predictions show that those willing to own EVs tend to be younger, live in urban cities, and have more education than the general population (Soltani-Sobh et al. 2017). This trend also holds true to consumers who are aware of EVs and EV charging stations (Singer 2016). Consumers who do not know someone who owns an EV or know where an EV charger is located are much less likely to be aware of or have a favorable opinion of EVs.

Publicly available fast chargers are essential in improving market penetration of EVs (Neaimeh et al. 2017). Many low-income and underserved families do not have access to an outlet where they park their vehicle. Most multi-unit dwellings do not have the infrastructure to support an EV charger in the designated parking area, or do not have a parking area at all. In low-income and underserved areas there are less publicly available charging stations in existing gas stations and retail locations. However, recent research shows that to increase EV adoption, chargers need to be available and targeted intervention for underserved areas is necessary (Silvia and Krause 2016).

The same barriers to use are also observable in rural areas, where there is less awareness of EVs and EV infrastructure, and as a result, a lower percentage of people own EVs. Another problem in rural areas is range anxiety; people are required to drive further and are afraid of running out of charge before they reach their destination (Bonges Iii and Lusk 2016). Rural residents tend to have lower incomes and spend more of their money on transportation than urban and suburban residents, so they stand to benefit from lower operating costs of EVs if the proper infrastructure was installed.

iii.ii Automated Vehicles

Automated vehicle (AV) technology is already available in new cars, with systems that incorporate automatic braking, parking assistance, adaptive cruise control, and lane change alerts. Fully automated vehicles (also referred to as autonomous and self-driving vehicles) are currently being tested on roads in Arizona and California, and expanding to others. These technologies have the potential to greatly improve safety by eliminating common human errors caused by distracted and impaired driving (Kalra and Groves 2017; Kockelman et al. 2016). Moreover, AVs theoretically could improve equity of transportation. By providing mobility to people who are unable to drive or own a vehicle because of disability, age, and income, and through operating in areas where public transit is unavailable, AVs have the potential to help underserved communities. However, they also have the potential to exacerbate inequality if these communities do not have equal access to the technology, and if AVs cause worse urbanization burdens through increased overall vehicle travel.

Currently, AV awareness shows similar patterns to EV awareness. People with a high level of education, who are young, high income, and white are more aware of AV technologies and the benefits of that technology than low-income communities and people of color (Clewlow and Mishra 2017; AAA n.d.). This shows a low probability of AV technology reaching the communities they stand to benefit the most, unless marketing and communication of the technology improves as it is developed. It is essential that a planning process occurs for AV deployment and that these important stakeholders are engaged and encouraged to give input.

If AVs are deployed without urban planning and policy to incentivize decreased tailpipe emissions and access for underserved communities, there is potential to worsen urban sprawl and gentrification. Affluent people who can afford AV technology and high-priced housing could move outside of expensive urban areas where there is no public transit access. This in turn would drive up the cost of living in those areas, further marginalizing communities who currently live there. Further, if AVs are privately owned and conventional engines (rather than EVs), congestion and emissions are likely to increase if people commute further and own more vehicles, increasing energy consumption up to 200% (Stephens et al. 2016).

On the other hand, if AV deployment and planning are implemented with equity and climate justice as policy priorities, equity in mobility and public health could improve. Accidents and congestion are among leading causes of tailpipe emissions from idling and inefficient driving behavior (Stephens et al. 2016). Incorporating connected vehicle technology into smart cities could increase energy efficiency with technologies like ride smoothing and traffic control signals, which would minimize braking and accelerating.

If carsharing and carpooling are utilized with AVs, and AVs are mainly electric, the cost per mile of transportation would be dramatically reduced to less than $0.20 per mile (Bösch et al. 2018) and energy use could be reduced by up to 60% (Stephens et al. 2016). A lower cost per mile means public transit could be made readily available and more flexible based on demand with connected infrastructure like connected traffic signals, route optimization, and ride smoothing. If the cost of delivery is reduced because of automated technologies eliminating the cost of a driver and operation costs of a vehicle, goods would be more accessible to underserved communities as well.

If AV carsharing and routing data is shared while they are deployed, there is also a potential improvement in planning for infrastructure, optimized traffic routing, and even eliminating insurance discrimination. Even early stage automated vehicles, data from AV systems could improve insurance models to help determine liability without human bias. This would ensure more equitable insurance pricing, and help incentivize safe driving practices (Dhar 2016). However, policy would need to safeguard data so it isn't used to further discriminate against already marginalized groups.

Automated technologies could also disproportionately replace low-wage labor jobs (technological unemployment) that are held mostly by people of color (Union of Concerned Scientists 2017). Many taxi drivers and bus drivers would suffer negative consequences of automated driving, and have already suffered job-loss as a result of TNCs. It is essential for policymakers and planners to ensure they develop retraining programs to make sure that low-wage workers are not displaced in favor of high-wage tech workers. Displacement of heavy-duty truck and delivery drivers is also of consideration, however truck drivers are experiencing a shortage, because they are aging out of the profession with a majority of drivers being over the age of 35. Therefore, the impact of technological unemployment on truck drivers will not have a large economic impact (Madrigral 2018).
Automated vehicles are a young technology with huge widespread implications, therefore ensuring that equity and environmental justice are considered in their implementation will require policy intervention before they are widely deployed.

III. Policy Recommendations and Current Case Studies

To ensure success in transportation equity and a path towards environmental justice, policymakers must first ensure that the transportation system is designed so that public transit, vehicles, and other modes of transportation are not competing, but instead are complementing each other. The system

should be designed to move people instead of cars, and to ensure that emissions are minimized.

In the past, policymakers have waited until technology is fully developed and available to implement policies to guide its use. This has resulted in disadvantaged populations benefiting last from new technology (Martin and Robinson 2007). For example, the internet was not available to low income students until many years after it benefited upper and middle class school districts (Du et al. n.d.). In the case of transportation, implementing a policy framework before the technology is widely utilized will prevent this type of inequity, while providing benefit to the public by ensuring efficient mobility, and preventing the use of public money on an outdated system that will not work efficiently.

Policymakers should incentivize use of public transportation and encourage people to walk and bike to work when possible. Encouraging people to utilize carpooling and ride sharing instead of owning private vehicles is essential for reducing congestion and emissions. Policymakers should work to make ride sharing, automated vehicles, and electric vehicles accessible to communities who are underserved by implementing incentive programs to build the necessary infrastructure, enticing private companies to serve those communities, and reducing barriers to these technologies that underserved communities tend to face.

i. Encouraging Travel via Public Transportation and Alternative Transportation Modes

As discussed in Section II, cities in the United States are plagued with traffic congestion, poor air quality, and lack of public transportation as a result of public policy and funding priorities that have historically favored personal vehicles as means of transportation, People have become dependent on owning a vehicle to have access to employment, goods, and services, and these policies have made travel more expensive (Litman 2017). To make transportation more equitable, affordable, and safe, policies should be centered on discouraging personal vehicle use for commuting and incentivizing other modes of transportation, especially walking, biking, and public transit, in an equitable way.

A case of a successful policy to address equity issues in public transportation can be found in 2015, when SeaTac, WA began a project to ticket passengers on Sound Transit based on their income using a program called ORCA LIFT (King County Metro). The program gives discounts to people with a household income up to 200% of the federal poverty level. SeaTac is a suburb of Seattle, where many people who cannot afford to live in the city reside but who need to commute there for their job. Seattle has one of the largest income gaps in the country. After one year, more than 25,000 residents signed up for the program, and 3.7 million trips were taken using the program on buses and light rail, increasing access to low-income riders (Constantine 2016).

Depending on the city and needs there are many policy solutions to increasing access to public transit to underserved and low-income communities. First, ensuring that public transit is affordable is crucial to making it accessible. In some cities the cost to ride public transit to work is more expensive than driving a personal vehicle. This encourages car ownership and burdens low-income households. Policymakers should consider subsidizing the public transit agencies further, and subsidizing the cost of public transit to riders by offering reduced fares to riders who qualify based on income.

However, in some areas, there is no option to use public transportation in low-income areas because it does not serve locations with affordable housing. To improve public transit access, cities and localities should analyze the affordability of the area using the Housing + Transportation affordability index (The Center for Neighborhood Technology 2017), or another quantitative metric to account for housing and transportation cost relative to income. Based on the results of the assessment, the city should implement programs to ensure transportation is accessible to low-income and underserved communities. There should not be a populated area where residents must own a car to have access to employment or healthcare.

This equity begins with current public transit affordability and routing. Policymakers and city planners should ensure that public transit lines are serving low-income communities. An example of an already available resource is from the Center for Neighborhood Technology, which developed a tool called "AllTransit™ Gap Finder" to assess geospatial locations that public transit is not serving, and where they would have the most impact for underserved

communities (The Center for Neighborhood Technology 2018). The tool also assigns metrics for equity in public transit, accessibility to jobs and frequency of service. This is an invaluable tool for policymakers and city planners to assess where improvement is needed, and where current systems are working.

In addition to prioritizing public transit instead of personal vehicles in urban planning, policymakers and planners should prioritize and incentivize people to walk and bike commute when they have the means. People walking and biking remove cars from the road, improves public health, and journeys are free for commuters. Encouraging people to commute this way begins with infrastructure – improving sidewalk width, increasing crosswalks, building protected bike lanes, and developing commercial and residential buildings in an efficient layout for traffic flow. A recent study of 90 cities found that cities with more bike lanes and bike paths have significantly higher rates of bike commuters (Buehler and Pucher 2012). Policymakers should also provide cities incentive to adopt bikeshare and scooter shares, with both dockless bikeshares and docked bikeshares. Docked bikeshare companies should be required to install bike stations in underserved neighborhoods so they have guaranteed and reliable access to bicycles.

Another incentive to shift from vehicle ownership to alternative transportation modes is removing the minimum parking requirement from many city codes. By reducing the availability of parking this could discourage people from driving to their location, and encourage them to take an alternative form of transportation instead (Weinberger 2012). Austin, TX changed their land development code (Section 25-6-478.E.3) to reduce the amount of parking spaces in exchange for a designated carshare space. It has incentivized carsharing while also reducing incentives for vehicle ownership (NRDC and Nutter Consulting 2018). This policy would need to work in concert with ensuring equal access to public transportation and alternative modes of transportation, to ensure that low-income workers are not penalized for owning a vehicle because they do not have access to public transit.

ii. Increasing Equity, Access, and Efficiency in Shared Mobility

Shared mobility presents an important part of ensuring access to mobility for people who cannot afford to own a personal vehicle and for people who do not have access to public transportation. Because the population who currently tend to use shared mobility is already well-served by other modes of transportation, shared mobility has been shown to displace public transit instead of supplementing it, further perpetuating inequity in transportation access and increasing vehicle emissions and congestion (S. Shaheen and Sperling 2018; Weinberger 2012). To ensure equity and environmental sustainability in shared mobility, policymakers should encourage TNCs, carshare providers, and taxis to service underserved areas while also encouraging use of public transit to supplement it.

Parking maximums have shown to disincentivize driving in New York City. This policy imposes a maximum number of parking spots for residential development, as opposed to a minimum number. The results of the policy were an increased number of people who used alternative modes of transportation to get to their destination when it was available (Weinberger 2012).

In collaboration with U.S. Department of Transportation Federal Highway Administration, Susan Shaheen outlines policy recommendations to ensure that shared mobility is accessible, addressing ways to overcome barriers to use in a framework called STEPS, which includes Spatial, Temporal, Economic, Physiological, and Social barriers (S. Shaheen et al. 2017). Her policy recommendations should be considered at the federal and local level to ensure equal access to this disruptive new transportation mode that has the potential to greatly improve mobility access for those who need it most. To improve the inequities discussed in the section above, Shaheen's STEPS policy framework should be implemented as discussed in the text box (S. Shaheen et al. 2017).

To reduce negative consequences of the potential increase in vehicles on the road, policymakers should ensure that shared mobility is used as a complement to public transit, not in competition with it. Shared mobility drivers and companies that use EVs should

be given a credit, and the automakers that sell fleets to them should be given tax incentives. Carpooling services should also be rewarded with subsidies or credits to the companies providing the service, and riders who choose to carpool over riding alone (S. Shaheen and Sperling 2018).

To relieve congestion and encourage carpooling, local policymakers and planners should designate stopping areas for drop-off and pickup so that vehicles are not blocking car lanes, bike lanes, or driving where pedestrians have the right of way. For example, DC is testing a program that would restrict parking during busy night life hours to allow for

STEPS Framework Policy Recommendations, summarized and adopted from Shaheen, et al., 2017. This framework could also be adopted for Shared Automated Vehicle services.

- *Spatial* - To improve mobility of populations who live in areas without access to transit or personal vehicles, policymakers should mandate that TNCs and other operators provide service in areas identified as a gap in transit. Partnerships between these companies and transit providers should be formed to subsidize and incentivize drivers to provide service to areas with less potential for profit.

- *Temporal* – Service time, hours of service, and travel time should all be optimized and made available for riders who work hours without public transit, and those live in areas with limited transit access. Service providers should be required to operate 24 hours per day. Policymakers should facilitate partnerships between employers who require off-peak workers and service providers. Finally, transit and other shared vehicles with more than one rider should be given access to designated high occupancy lanes to improve reliability of service and reduce travel time.

- *Economic* – To reduce the barrier to access for people who do not have access to a smart phone, bank, or internet, policymakers should prioritize making it easier to hail a ride using alternative technologies like kiosks, smartcards, or other modes like telephone or texting ride hailing. Allowing customers to use the same smart card for public transit and shared services, without linking it to a bank account would dramatically lower the barrier to access for low-income people. Low-income and underserved populations should also be given a subsidized rates for shared mobility especially carpooling.

- *Physiological* – To ensure shared mobility is fulfilling the opportunity to increase transportation access for people with physical disabilities, policymakers should help assess training and technology needs for service providers to invest in. Accessible vehicles should be incentivized, and providers should be required to train at least a fraction of drivers to assist users who need help at the beginning or end of a trip.

- *Social* – Increasing awareness about using shared mobility as a means of transportation should be made a marketing priority by service providers. Policymakers should organize community-based engagement concerning shared mobility companies and policies. They should also utilize technology to improve communication and ease of use for riders who have limited English proficiency or other social barriers to required technology and interaction with ride-hailing services.

easier loading and unloading of TNCs and taxis in those spaces that would be occupied by a parked vehicle (Transportation 2017). Another way to help planners is for policymakers to require that TNCs and other service providers share the geographic and route data they collect on trip information (not passenger information) and to make it available to the public. This would give planners access to information to help design traffic flow and analyze areas for improvement in a rapidly growing mobility method (S. Shaheen et al. 2017). This information would be completely anonymize the riders, to help ensure rider privacy. Data made public could be analyzed data or metadata so it completely separated from user information. However, privacy concerns need to be addressed and data collection regulated in order to address these concerns.

Policymakers and shared mobility providers should also be required to share demographic information and make an effort to thwart discrimination for passengers of color. This could include anonymizing passengers (not providing pictures or names) to drivers when a ride is requested, and incentivizing drivers to serve less profitable neighborhoods.

iii. Encouraging Electric Vehicle Access and Affordability

Despite rapid growth in EV purchases in the last year, only half of consumers could name a specific plug-in electric vehicle model. In a survey (Singer 2016), 47% of consumers said that in order to consider purchasing an EV it would need a 300 mile range. Policies should focus on increasing the market penetration of EVs, including making them affordable and accessible to low-income communities. At the federal level, fuel efficiency standards and emissions regulations, tax incentives, gasoline prices, and Zero Emissions Vehicles (ZEV) mandates are critical to getting EVs onto the market. Policymakers must implement stringent regulations and a tax structure that encourages auto manufacturers and consumers to purchase and utilize EVs. The effectiveness of tax incentives is apparent in the case of the state of Georgia, where EV adoption rate was among the highest in the country when consumers were given a $5,000 tax credit. In 2015, the tax break expired and Georgia became the only state in the US with declining EV sales, and they declined by 80% (Walton 2017).

Many critics point out that current EV incentives disproportionately reward high-income people who can afford to purchase EVs despite their high upfront cost. The money rewarded to people who do not need an incentive is being taken from public funds that could benefit low-income people. In fact, studies have shown that a majority of the tax incentives are rewarded to individuals making over $75,000 in annual income, who have received 60% of the over $18 billion credit dollars awarded in the U.S (Borenstein et al. 2016). To remedy this inequity, policymakers should institute an income cap on rebates, and provide an incentive scale based on income. California recently instituted a similar policy, instituting an income cap for the annual EV rebate program for individuals making over $250,000 annually, and $500,000 for joint income, while giving an extra rebate to incomes less than 300% of the federal poverty level (King 2016). It should also be noted that the environmental benefits of increasing EVs on the road benefits low-income individuals as much or more than wealthy people, especially those living near highways and in polluted city centers (C2ES 2016). So although the tax benefit currently disproportionately benefits the wealthy, the offset of the negative externality from the adoption of EVs benefits those affected by air pollution the most.

Policymakers can also encourage adoption through consumer awareness. One of the easiest ways for policymakers to increase consumer awareness is to hold community outreach. These efforts should be made in coordination with local community-based organizations. Effort should also be targeted at low-income communities so that planners and policymakers can better understand their needs. Hiring practices should also be targeted at local workers to fill positions that will help manage plans for installing infrastructure and increasing awareness of EVs (Greenlining 2018).

If consumers interact with EVs, they are more likely to want to purchase one (Cahill, Davies-Shawhyde, and Turrentine 2014). Policymakers should require that government fleets are entirely made up of EVs, and private corporate rental car fleets are incentivized to purchase EVs. Consumers who rent EVs will be more aware of them and the experience of driving an EV, and will be less hesitant to shift to a personally owned EV (Schaller Consulting 2018).

This could also be implemented through partnerships between EV companies and shared mobility companies including carsharing platforms, like car2go, and TNCs. Dealerships should also be incentivized to provide education efforts to increase knowledge of EV technology, benefits of EVs, and how to take advantage of financial incentives.

To ensure affordability of EVs for low income communities, policymakers should address the initial cost barrier of EVs by offering low-income buyers a purchase voucher or rebate to lower the initial cost of the EV (Greenlining 2018). California offers a program like this if the purchaser also agrees to scrap a vehicle with high emissions. California Public Utilities Commission and NRG Energy also filed a settlement to make EVs more accessible to underserved communities. The settlement included increased infrastructure support, support for low-income carsharing programs (Prosper 2012).

Importantly, public infrastructure should be made an immediate priority for city planners and policymakers should ensure that infrastructure development is implemented as quickly as possible. Not only will this ensure the availability of chargers for EVs on the road, but it will increase awareness of EVs and the charging support network currently in place to consumers. Retail establishments, residential buildings, and employers should be given subsidies and tax breaks for providing charging stations. Home chargers and installation should be subsidized to encourage people to properly utilize the system they already have. The installation of this infrastructure should be equitable, and policymakers should require charging station providers to install chargers in underserved areas at the same level as more affluent areas.

iv. Ensuring the Future of Automated Vehicles is Equitable

Fully automated vehicles are not readily available to the market yet, but to ensure equal access to them in the future, policymakers should start laying a framework today. Much is unknown about how AV technology will be developed, at what rate, and how it will be used; it is therefore important for policymakers to steer AV development in a direction that will benefit both the economy and the environment. The National Highway Transportation Safety Administration (NHTSA) and Congress have passed rulemaking for cybersecurity and passenger safety, but efforts now need to be focused on transportation planning and infrastructure. The goal should be to provide low-cost transportation and reduce congestion and emissions. This would be done by incentivizing car manufacturers producing AVs and transportation service providers using AVs to build them on electric powertrains and to incentivize shared use of the vehicles through carpooling or public transit.

AV manufacturers should be required to utilize the technology for public transit purposes in addition to vehicles. Policymakers can encourage the development of zero-emissions AV technology by adopting ZEV mandates and increasing fuel economy standards. Extra tax credits should be rewarded to transportation providers who use fully automated vehicles, which are defined as fully operational without a driver in designated situations (level 4), and all situations (level 5) (SAE International 2016) for carpooling purposes (Sperling, van der Meer, and Pike 2018). To further reduce congestion and the negative environmental consequences of congestion, shared AVs should be integrated with public transit by providing first and last mile services to public transit stops for underserved communities with transit gaps, similar to the way TNCs could complement public transit (Litman 2017; Union of Concerned Scientists 2017).

Many of the policies to ensure shared mobility equity can be adopted and immediately implemented for AVs. Most importantly, policymakers and planners should implement community engagement to understand the needs and wants of low-income and underserved communities. AVs have similar potential benefits to underserved populations as shared mobility, including 24 hour service, increased service area, and mobility service for people with disabilities. However, they also share the same potential barriers if not implemented carefully. The STEPS policy framework developed by Shaheen, et al. for shared mobility can easily be implemented for AVs, especially if they are used as TNC fleet cars initially as opposed to privately owned vehicles. Moreover, similar policies to increasing the adoption of EVs to low-income and underserved neighborhoods should be used to increase adoption of AV use for the same populations.

AV services should be operated in low-income areas and available 24 hours per day. Low-income residents should be targeted in marketing and education programs so that they are made aware of AV technologies and are more likely to use the technology. AVs services should be accessible by telephone or kiosk so that people without smart phones or bank accounts have access to the service. Some AVs should be retrofitted for people with disabilities, including human assistance for those who need it at the beginning and end of trips (S. Shaheen et al. 2017). Companies providing AV services should be required to share data to help planners and policymakers ensure efficient and clean transportation systems (Union of Concerned Scientists 2017), and improve the equity of insurance (Dhar 2016). In a world with connected and automated vehicles, AV manufacturers, policymakers, and service providers should take extra caution in cybersecurity to ensure that driving systems cannot be hacked, and that the vehicles are driven efficiently and safely. Caution should also be taken so that personal data collected from AV systems is safe from hackers and privacy is ensured. Policymakers should consider the integration of AVs into roadways with human driven cars, and assess whether they should be utilized in special lanes, or integrated with regular vehicles depending on automation level. Planners and policymakers should also begin consideration of connected infrastructure both for AVs and for smart traffic control that will optimize the efficiency of traffic flow, decreasing congestion. Planners should start considering how parking infrastructure in cities will change if owners no longer need to park cars at their destination, while carefully implementing guidelines that will encourage shared use of AVs over personal ownership. They should also take AV infrastructure into consideration when installing EV infrastructure so that they are complementary and efficient. AV infrastructure should also be prioritized in underserved communities.

To ensure that AVs do not displace already underserved communities by encouraging middle and high-income households to move further outside of city centers where there is more land, affordable housing policy should be made a priority. Policymakers and city planners should prioritize affordable housing in neighborhoods around urban cities, and in areas where low-income residents are currently living so that they are not forced to move in the event that AV technology encourages urban sprawl and gentrification. Housing and Transportation Affordability metrics should be updated to take into consideration the impact of AVs in this event, and affordable housing requirements and locations should be adjusted accordingly. Job displacement should also be considered, which would have disproportionate impacts on marginalized and underserved communities. AV companies should prioritize retraining programs and target individuals whose jobs are being displaced for potential hires. Cities should also remove barriers for taxi drivers that TNCs do not face so that they have equal opportunity in the transportation market.

AVs have the potential to improve vehicle safety for passengers and also for pedestrians and cyclists (Kockelman et al. 2016). Policymakers must continue updating and improving policy required to ensure the safety of AVs for passengers, pedestrians, and cyclists. Standards should be regularly updated as technology progresses, and automakers should be incentivized through reward programs to continue developing safeguards (Sperling, van der Meer, and Pike 2018).

IV. Conclusion

The world is in the midst of a dramatic transformation of our transportation system. Access to transportation is essential for people to succeed in our society, as it provides access to employment, healthcare, and goods and services. The current and historic transportation system has oftentimes been inequitable, especially for low-income and underserved populations. The many modes of transportation should be optimized and utilized so that it is accessible to the maximum amount of people in the most efficient way possible. This requires a deep understanding of the roots of systemic inequity in transportation and urban planning, and policies ahead of the evolving infrastructure required for advanced transportation technologies that ensure equitable access. Policymakers must not wait for the diffusion of this technology to implement policy, or it will leave the already underserved behind the same way other revolutionary technologies have in the past.

To ensure transportation systems in the new age of transportation technologies are equitable and efficient, policymakers first need to identify areas for improvement and actions that can be taken to improve the current system. Policymakers should identify geographical gaps in public transportation access and implement proven policies to expand and encourage use of public transit to help relieve congestion and environmental burdens that fall disproportionately on populations without access to the current system. Policies that incentivize alternative modes of transportation should also be implemented, and policies that incentivize personal vehicle ownership and use should be discontinued (see i. Encouraging Travel via Public Transportation and Alternative Transportation Modes).

Policymakers should then start identifying policy opportunities in deployed new transportation technologies that will both reduce congestion and emissions, while also expanding services to underserved areas. Shared mobility services should be encouraged with incentives to serve low-income areas using the STEPS program (S. Shaheen et al. 2017). They should also be encouraged to maximize the number of carpooled miles driven and to partner with local public transit agencies so that they are complementary rather than competing services. Both of these policy priorities will reduce overall congestion while increasing mobility.

Finally, incentives should be implemented to electrify vehicles used for shared mobility fleets to reduce tailpipe emissions that burden residents who live near high-traffic roadways (see **ii. Increasing Equity, Access, and Efficiency in Shared Mobility**). Incentives to reduce fossil fuel emissions should be implemented and strengthened, and incentives should be given to ensure electric vehicles are affordable upfront to low-income populations. To increase adoption of EVs, policymakers and city planners should increase awareness through community engagement and campaigns which teach low income and rural communities about the technology and its benefits. This includes encouraging EV adoption for fleet managers, carshare companies, public transit, and TNCs. Additionally, city planners should be required to install EV infrastructure in low-income and rural areas where market adoption rates are currently low. Awareness of EV charging infrastructure increases acceptance and adoption of EVs. These policies will encourage adoption and utilization of EVs (see Encouraging Electric Vehicle Access and Affordability).

Ensuring that future transportation technology is equitable and efficient requires policymakers and city planners to implement policies before the technology is widely deployed. Automated vehicle technology is rapidly developing, and policymakers and planners should prioritize policies that will ensure the widespread deployment of AVs increases mobility and reduces congestion and emissions of vehicles. First, automakers should be incentivized to ensure AVs are safe, efficient, electrified, and affordable through financial incentives and regulations. Automakers should also be required to share data to help city planners make evidence-based decisions that will optimize the use of AVs. Automakers should partner with companies that provide shared mobility, including public transportation and ride sharing companies, so that AV technology is complementary. The use of AVs for carpooling should also be highly incentivized so that vehicle miles traveled are not dramatically increased, worsening pollution and congestion. City planners should also prioritize infrastructure that encourages AV utilization to be shared and electrified, and should plan for the gradual deployment of AV technology.

To ensure equal access to AVs, policymakers and city planners should provide incentives to automakers and AV service providers to serve rural and low-income areas. This includes sharing demographic data on ridership, community engagement to increase awareness, and incentives to utilize AVs supplementary to public transportation and for carpooling. The STEPS framework (S. Shaheen et al. 2017) can also be implemented in the case of AVs to ensure that they are being used to increase equity in transportation (see Ensuring the Future of Automated Vehicles is Equitable).

Transportation is in the midst of a rapid transformation. We have a chance to improve mobility for those who have traditionally been left out and systemically discriminated against. Adopting policies to ensure the new age of transportation is equitable and environmentally sustainable would improve the economy, improve social welfare, and overall quality of life.

References

AAA. n.d. "Americans Feel Unsafe Sharing the Road with Fully Self-Driving Cars | AAA NewsRoom." AAA Newsroom. Accessed June 8, 2018. https://newsroom.aaa.com/2017/03/americans-feel-unsafe-sharing-road-fully-self-driving-cars/.

Bialik, Carl, Andrew Flowers, Reuben Fischer-Baum, and Drumil Mehta. 2015. "Uber Is Serving New York's Outer Boroughs More Than Taxis Are | FiveThirtyEight." FiveThirtyEight. 2015. https://fivethirtyeight.com/features/uber-is-serving-new-yorks-outer-boroughs-more-than-taxis-are/.

Bishai, David, Asma Quresh, Prashant James, and Abdul Ghaffar. 2006. "National Road Casualties and Economic Development." *Health Economics* 15 (1): 65–81. https://doi.org/10.1002/hec.1020.

Blumenberg, Evelyn, and Margy Waller. 2003. "The Long Journey to Work: A Federal Transportation Policy for Working Families The Brookings Institution Series on Transportation Reform." https://www.brookings.edu/wp-content/uploads/2016/06/20030801_Waller.pdf.

Bonges Iii, Henry A, and Anne C Lusk. 2016. "Addressing Electric Vehicle (EV) Sales and Range Anxiety through Parking Layout, Policy and Regulation." https://doi.org/10.1016/j.tra.2015.09.011.

Borenstein, Severin, Lucas Davis, Lucas W Davis, Hunt Allcott, Josh Blonz, Judd Boomhower, Jim Bushnell, et al. 2016. "The Distributional Effects of U.S. Clean Energy Tax Credits" 30 (1): 191–234. http://ei.haas.berkeley.edu.

Bösch, Patrick M., Felix Becker, Henrik Becker, and Kay W. Axhausen. 2018. "Cost-Based Analysis of Autonomous Mobility Services." *Transport Policy* 64 (May): 76–91. https://doi.org/10.1016/J.TRANPOL.2017.09.005.

Buehler, Ralph, and John Pucher. 2012. "Cycling to Work in 90 Large American Cities: New Evidence on the Role of Bike Paths and Lanes." *Transportation* 39 (2): 409–32. https://doi.org/10.1007/s11116-011-9355-8.

Bureau of Transportation Statistics. 2016. "Net Change in Commuters by Mode | Bureau of Transportation Statistics." United States Department of Transportation. 2016. https://www.bts.gov/content/net-change-commuters-mode.

Burhouse, Susan, Karyen Chu, Keith Ernst, Ryan Goodstein, Alicia Lloro, Gregory Lyons, Joyce Northwood, et al. 2016. "2015 FDIC National Survey of Unbanked and Underbanked Households." https://www.economicinclusion.gov/surveys/2015household/documents/2015_FDIC_Unbanked_HH_Survey_Report.pdf.

C2ES. 2016. "Using Data to Evaluate the Equity of EV Policies — Center for Climate and Energy Solutions." 2016. https://www.c2es.org/2016/05/using-data-to-evaluatethe-equity-of-ev-policies/.

Cahill, Eric, Jamie Davies-Shawhyde, and Thomas S. Turrentine. 2014. "The Future of Electric Vehicles Part 1: Car Dealers Hold the Key - ITS." https://its.ucdavis.edu/blog-post/the-future-of-electric-vehicles-part-1-car-dealers-hold-the-key/.

Center for Neighborhood Technology. 2018. "AllTransit." 2018. https://alltransit.cnt.org/.

Clewlow, Regina R., and Gouri Shankar Mishra. 2017. "Disruptive Transportation: The Adoption, Utilization, and Impacts of Ride-Hailing in the United States." *Ucd-Its-Rr-17-07*, no. October. https://itspubs.ucdavis.edu/wp-content/themes/ucdavis/pubs/download_pdf.php?id=2752.

"Climate Change & Communities of Color Key Poll Findings and Top Lines." 2014. https://d3n8a8pro7vhmx.cloudfront.net/greenforall/pages/1746/attachments/original/1431391119/ExecutiveReportGFA.pdf?1431391119.

Committee for Review of Innovative Urban Mobility Services: Transportation Research Board. 2016. "Between Public and Private Mobility: Examining the Rise of Technology-Enabled Transportation Services." In . Washington, D.C.: Transportation Research Board. https://doi.org/10.17226/21875.

Department of Energy. 2018. "FOTW #1026, April 23, 2018: Nearly Two-Thirds of U.S. Plug-In Vehicles Were Assembled in the United States | Department of Energy." 2018. https://www.energy.gov/eere/vehicles/articles/fotw-1026-april-23-2018-nearly-two-thirds-us-plug-vehicles-were-assembled.

Dhar, Vasant. 2016. "Equity, Safety, and Privacy in the Autonomous Vehicle Era." https://www.computer.org/csdl/mags/co/2016/11/mco2016110080.pdf.

Du, Janxia, Byron Havard, William Sansing, and Chien Yu. n.d. "The Impact of Technology Use on Low-Income and Minority Students' Academic Achievements : Educational Longitudinal Study of 2002." Accessed August 13, 2018. https://pdfs.semanticscholar.org/c628/7502607153d29d306001f784d6339f461f97.pdf.

Electric Power Research Institute. 2018. "U.S. National Electrification Assessment." https://www.epri.com/#/pages/product/000000003002013582/?lang=en.

Ge, Yanbo, Christopher R. Knittel, Don MacKenzie, and Stephen Zoepf. 2016. "Racial and Gender Discrimination in Transportation Network Companies." *Nber*.

https://economics.stanford.edu/sites/default/files/zoepf.pdf.

Greenlining. 2018. "Electric Vehicles for All: An Equity Toolkit." 2018. http://greenlining.org/publications-resources/electric-vehicles-for-all/.

International Energy Agency, Iea. n.d. "Global EV Outlook 2017 Two Million and Counting." Accessed August 11, 2018. www.iea.org/t&c/.

Jaffe, Eric. 2015. *The Future of Transportation*. CityLab.

Kalra, Nidhi, and David G Groves. 2017. "RAND Model of Automated Vehicle Safety (MAVS): Model Documentation." https://www.rand.org/content/dam/rand/pubs/research_reports/RR1900/RR1902/RAND_RR1902.pdf.

Kaufman, Sarah M, Mitchell L Moss, Jorge Hernandez, and Justin Tyndall. 2015. "Mobility, Economic Opportunity and New York City Neighborhoods," no. November: 39.

King, Alanis. 2016. "Rebates On Electric Vehicles In California Will Soon Have An Income Cap." Jalopnik. 2016. https://jalopnik.com/rebates-on-electric-vehicles-in-california-will-soon-ha-1766041090.

Kockelman, Kara, Paul Avery, Prateek Bansal, Stephen D Boyles, Pavle Bujanovic, Tejas Choudhary, Lewis Clements, et al. 2016. "Implications of Connected and Automated Vehicles on the Safety and Operations of Roadway Networks: A Final Report (FHWA 0-6849-1)." https://library.ctr.utexas.edu/ctr-publications/0-6849-1.pdf.

Litman, Todd. 2017. "Transportation Affordability Evaluation and Improvement Strategies." http://www.vtpi.org/affordability.pdf.

Madrigral, Alexis C. 2018. "How Automation Could Worsen Racial Inequality." *The Atlantic*, January 2018. https://www.theatlantic.com/technology/archive/2018/01/black-workers-and-the-driverless-bus/550535/.

Marcantonio, Richard A, Aaron Golub, Alex Karner, and Louise Nelson. 2017. "Confronting Inequality in Metropolitan Regions: Realizing the Promise of Civil Rights and Environmental Justice in Metropolitan Transportation Planning." *Fordham Urban Law Journal* 1017. https://ir.lawnet.fordham.edu/ulj/vol44/iss4/4.

Martin, Steven P., and John P. Robinson. 2007. "The Income Digital Divide: Trends and Predictions for Levels of Internet Use." *Social Problems* 54 (1): 1–22. https://doi.org/10.1525/sp.2007.54.1.1.

National Equity Atlas. 2016. "Indicators: Car Access." 2016. http://nationalequityatlas.org/indicators/Car_access.

Neaimeh, Myriam, Shawn D. Salisbury, Graeme A. Hill, Philip T. Blythe, Don R. Scoffield, and James E. Francfort. 2017. "Analysing the Usage and Evidencing the Importance of Fast Chargers for the Adoption of Battery Electric Vehicles." *Energy Policy* 108 (September): 474–86. https://doi.org/10.1016/j.enpol.2017.06.033.

Nealer, Rachael, David Reichmuth, and Don Anair. 2015. "Cleaner Cars from Cradle to Grave How Electric Cars Beat Gasoline Cars on Lifetime Global Warming Emissions." https://www.ucsusa.org/sites/default/files/attach/2015/11/Cleaner-Cars-from-Cradle-to-Grave-full-report.pdf.

NRDC, and Nutter Consulting. 2018. "Los Angeles Shared-Mobility Climate and Equity Plan." *APRIL*. https://assets.nrdc.org/sites/default/files/los-angeles-shared-mobility-climate-equity-report.pdf?_ga=2.126941321.587469252.1528337949-969569565.1527797147.

Prosper, Terri. 2012. CPUC Files Settlement That Will Bring Electric Vehicle Charging Infrastructure to California's Diverse Communities California Public Utilities Commission.

Puentes, Robert, and Elizabeth Roberto. 2008. "Commuting to Opportunity: The Working Poor and Commuting in the United States." Brookings Institute. 2008. https://www.brookings.edu/research/commuting-to-opportunity-the-working-poor-and-commuting-in-the-united-states/.

SAE International. 2016. "J3016A: Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles - SAE International." 2016. https://www.sae.org/standards/content/j3016_201609/.

Schaller Consulting. 2018. "The New Automobility: Lyft, Uber and the Future of American Cities." www.schallerconsult.com.

Securing America's Future Energy. 2018. "Transportation Network Companies: Broadening Access and Improving the Efficiency of Travel." http://www.schallerconsult.com/rideservices/automobility.pdf.Accessed.

Shaheen, Susan A., Nelson D. Chan, and Teresa Gaynor. 2016. "Casual Carpooling in the San Francisco Bay Area: Understanding User Characteristics, Behaviors, and Motivations." *Transport Policy* 51 (October): 165–73. https://doi.org/10.1016/J.TRANPOL.2016.01.003.

Shaheen, Susan, Corwin Bell, Adam Cohen, and Balaji Yelchuru. 2017. "Travel Behaviour. Shared Mobility and Transportation Equity," 66.

Shaheen, Susan, and Daniel Sperling. 2018. "Shared Mobility: The Potential of Ridehailing and Pooling." In *Three Revolutions: Steering Automated, Shared, and Electric Vehicles to a Better Future*, 55–76.

Silvia, Chris, and Rachel M. Krause. 2016. "Assessing the

Impact of Policy Interventions on the Adoption of Plug-in Electric Vehicles: An Agent-Based Model." *Energy Policy* 96 (September): 105–18. https://doi.org/10.1016/J.ENPOL.2016.05.039.

Singer, Mark. 2016. "The Barriers to Acceptance of Plug-in Electric Vehicles: 2017 Update." https://www.nrel.gov/docs/fy18osti/70371.pdf.

Smedley, Brian D., and Philip Tegeler. 2016. ""Affirmatively Furthering Fair Housing:" A Platform for Public Health Advocates." AJPH. https://prrac.org/pdf/place_based_interventions.pdf.

Soltani-Sobh, Ali, Kevin Heaslip, Aleksandar Stevanovic, Ryan Bosworth, and Danilo Radivojevic. 2017. "Analysis of the Electric Vehicles Adoption over the United States." *Transportation Research Procedia* 22 (January): 203–12. https://doi.org/10.1016/J.TRPRO.2017.03.027.

Song, C.C. 2011. "Electric Vehicles: Who's Left Stranded?" Berkeley, CA. http://greenlining.org/wp-content/uploads/2013/02/ElectricVehiclesReport.pdf.

Sperling, Daniel, Ellen van der Meer, and Susan Pike. 2018. "Vehicle Automation: Our Best Shot at a Transportation Do-Over?" In *Three Revolutions: Steering Automated, Shared, and Electric Vehicles to a Better Future*, 77–108.

Stephens, T S, J Gonder, Y Chen, Z Lin, C Liu, and D Gohlke. 2016. "Estimated Bounds and Important Factors for Fuel Use and Consumer Costs of Connected and Automated Vehicles." https://www.nrel.gov/docs/fy17osti/67216.pdf.

Sutedjo-The, Raymon, and Sandra Lee. 2018. "Urban Data Challenge | Transit Quality & Equity." 2018. http://ray-mon.com/urbandatachallenge/.

Teal, Roger F. 1987. "Carpooling: Who, How and Why." *Transportation Research Part A: General* 21 (3): 203–14. https://doi.org/10.1016/0191-2607(87)90014-8.

The Center for Neighborhood Technology. 2017. "The H+T Affordability Index." 2017. https://htaindex.cnt.org/.

———. 2018. "Gap Finder | AllTransit." 2018. https://alltransit.cnt.org/gap-finder/.

Transportation, District Department of. 2017. "Streamlining the District's Nightlife Curbside Access Managing High-Demand Curbside Passenger Loading Zones." Washington, D.C. https://nacto.org/wp-content/uploads/2017/12/NACTOTNCWebinarPresentation-1.pdf.

Transportation Equity Network. n.d. "Transportation + Social Equity: Opportunity Follows Mobility." Accessed May 31, 2018. https://www.aarp.org/content/dam/aarp/livable-communities/learn/transportation/policy-webinar-transportation-and-social-equity-opportunity-follows-mobility-aarp.pdf.

Unfccc. n.d. "ADOPTION OF THE PARIS AGREEMENT - Paris Agreement Text English." Accessed August 12, 2018. https://unfccc.int/sites/default/files/english_paris_agreement.pdf.

Union of Concerned Scientists. 2017. "Maximizing the Benefits of Self-Driving Vehicls." https://www.ucsusa.org/sites/default/files/attach/2017/02/Maximizing-Benefits-Self-Driving-Vehicles.pdf.

US Census Bureau. 2017. "American Community Survey (ACS)." 2017. https://www.census.gov/programs-surveys/acs/.

Walton, Robert. 2017. "Georgia Electric Vehicle Sales Shrink 80% in Wake of Tax Credit Repeal | Utility Dive." Utility Dive. 2017. https://www.utilitydive.com/news/georgia-electric-vehicle-sales-shrink-80-in-wake-of-tax-credit-repeal/434092/.

Weinberger, Rachel. 2012. "Death by a Thousand Curb-Cuts: Evidence on the Effect of Minimum Parking Requirements on the Choice to Drive." *Transport Policy* 20 (March): 93–102. https://doi.org/10.1016/J.TRANPOL.2011.08.002.

Wood, Eric, Clément Rames, Matteo Muratori, Sesha Raghavan, and Marc Melaina. 2017. "National Plug-In Electric Vehicle Infrastructure Analysis." https://www.nrel.gov/docs/fy17osti/69031.pdf.

World Health Organiization, and The World Bank. 2004. "World Report on Road Traffic Injury Prevention." http://apps.who.int/iris/bitstream/handle/10665/42871/9241562609.pdf;jsessionid=1B06CB088A0A279A9E2508B840E46B74?sequence=1.

World Health Organiization, and UN-HABITAT. 2010. "Hidden Cities: Unmasking and Overcoming Health Inequities in Urban Settings." http://www.who.int/kobe_centre/publications/hiddencities_media/who_un_habitat_hidden_cities_web.pdf?ua=1%0Ahttp://www.who.int/kobe_centre/publications/hiddencities_media/who_un_habitat_hidden_cities_web.pdf?ua=1%0Ahttp://www.who.int/kobe_centre/publicatio.

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V. Appendix

Table 1: List of Terminology

Automated Vehicle	A vehicle with technology that automates any part of driving in place of a human driver. Society of Automated Engineers Levels 1-5 are referenced. (Society for Automobile Engineers International 2014). Level 5 automated vehicle is sometimes used synonymously with Autonomous and Self-driving. This report uses automated mainly referring to Levels 4 and 5 automation.
Electric Vehicle	Includes Hybrid Electric Vehicle, Plug-in Electric Vehicle, Plug-in Hybrid Electric Vehicle, and Fuel Cell Electric Vehicle Plug-in Hybrid Electric Vehicles (PHEVs) Run on both electricity and gasoline. Can be plugged in and charged, but use gasoline once the battery is empty Hybrid Electric Vehicle (HEVs)Gasoline powered vehicle that contains an electric motor that is charged during braking and coasting from regular driving. The electric motor powers the wheels at low speeds and features like stereo and air conditioning. Plug-in Electric Vehicles (PEVs)/Battery Electric Vehicles (BEVs) Run only on electricity, powered through an electrical outlet either in home or through a publicly-available charging station. These have zero tailpipe emissions and are considered Zero Emissions Vehicles (ZEV) Fuel Cell Electric Vehicles (FCEV) Run on hydrogen fuel to power an electric motor. Zero tailpipe emissions. These are not widely available currently and are beyond the scope of this report.
Public Transportation/Public Transit	Transportation services open to the public and are regular and in perpetuity. Includes public buses, public rail services, and services offered for disabled riders. Does not include intercity rail, private charter buses, school buses, or recreational services.
Shared Mobility	Transportation services that are shared by multiple users. Includes public transportation, privately owned shared vehicles such as taxis, limousines, transportation network companies' shared personal vehicles (such as Uber and Lyft), bikeshare programs, rental car services, carsharing, private shuttle services, scootershare programs, ridesharing (carpool services such as UberPool, Scoop, and Waze carpool).
Equity	The fairness with which opportunities, goods, and services are distributed. Equal distribution of burdens and benefits.
Transportation Network Company (TNC)/ Mobility Service Provider (MSP)	Organizations that use mobile apps to pair passengers with a destination in mind to a driver who can provide the service.

Underserved	Communities of people who have less access to public services and goods. Sometimes used interchangeably with disabled individuals, communities of color and low-income communities and individuals