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Public Health and **Health Equity Considerations** of ***Autonomous Vehicles*** in California

By Ryan Snyder

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TABLE of **CONTENTS**

TABLE of **TABLES**

HEALTH IMPACTS

HEALTH AND EQUITY IMPACTS

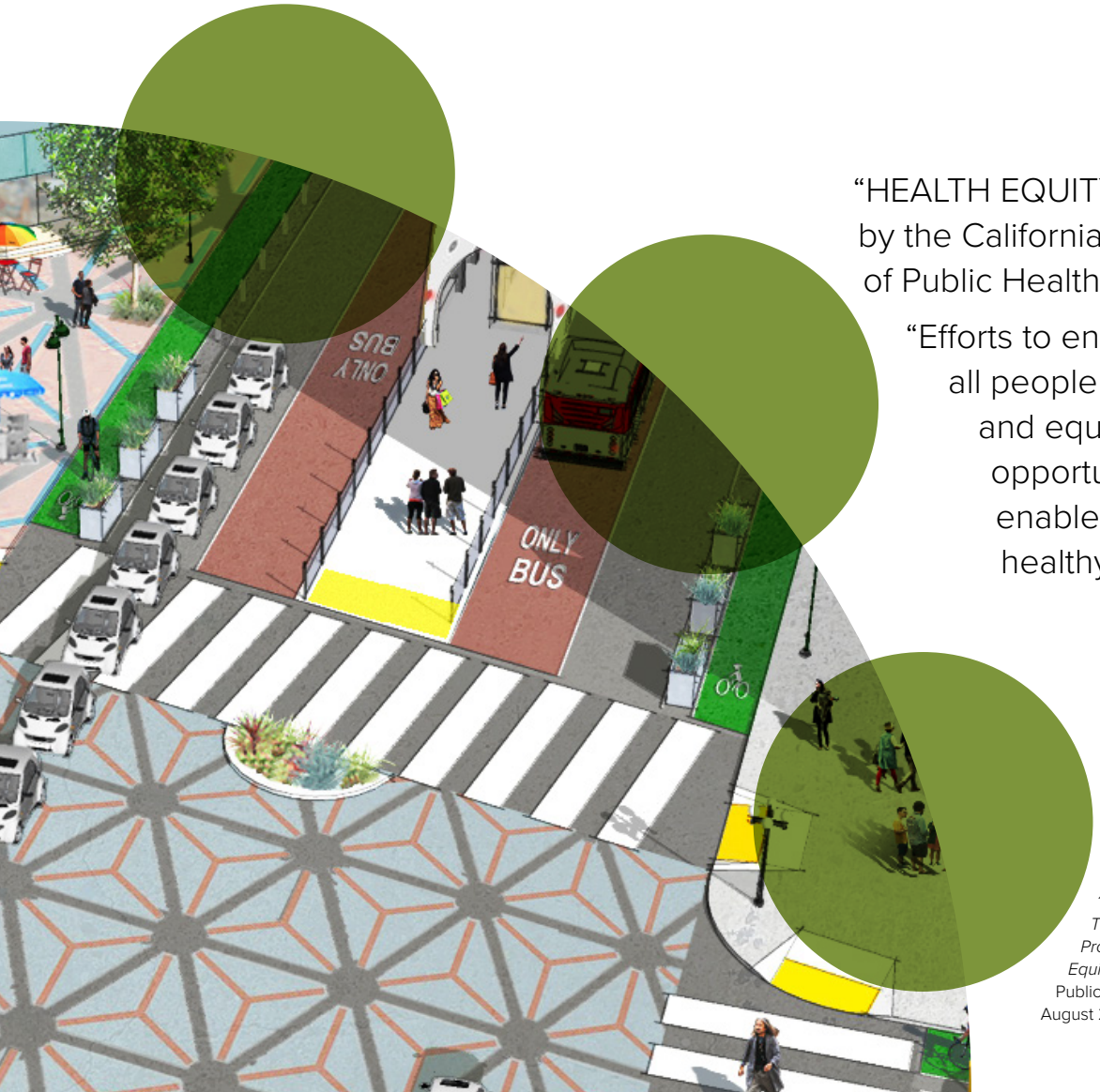
Public Health and **Health Equity Considerations** of ***Autonomous Vehicles*** in California

INTRODUCTION

Autonomous vehicles (AVs) are those that can operate without human drivers.

AVs will likely create substantial changes in Californians' lives, particularly in terms of mobility options and travel behaviors. There is debate as to when AVs will be in actual use, as opposed to in test phases, and when they will comprise a significant portion of the motor-driven vehicles on our streets and highways. The most accelerated estimates predict AVs' commercial arrival will be between 2018 and 2021, and that by 2030 most vehicles will be AVs. Experts at the other end of the spectrum argue that not until 2050 or later will AVs be widely used. Little debate exists that AVs are coming in the foreseeable future and that AVs will play a large role in our transportation system within most long-term planning horizons.

AVs are projected to be one of the most disruptive technological changes Californians will experience. AVs will likely significantly change the way we transport ourselves, our communities, and our daily lives. Their potential to significantly improve a wide array of health and health equity issues is enormous. At the same time, their potential to worsen these issues is also significant. Whether AVs improve our overall health and well-being or exacerbate social inequities will depend significantly on the public policies that are put in place.



"HEALTH EQUITY" as defined by the California Department of Public Health is:

"Efforts to ensure that all people have full and equal access to opportunities that enable them to lead healthy lives." [1]

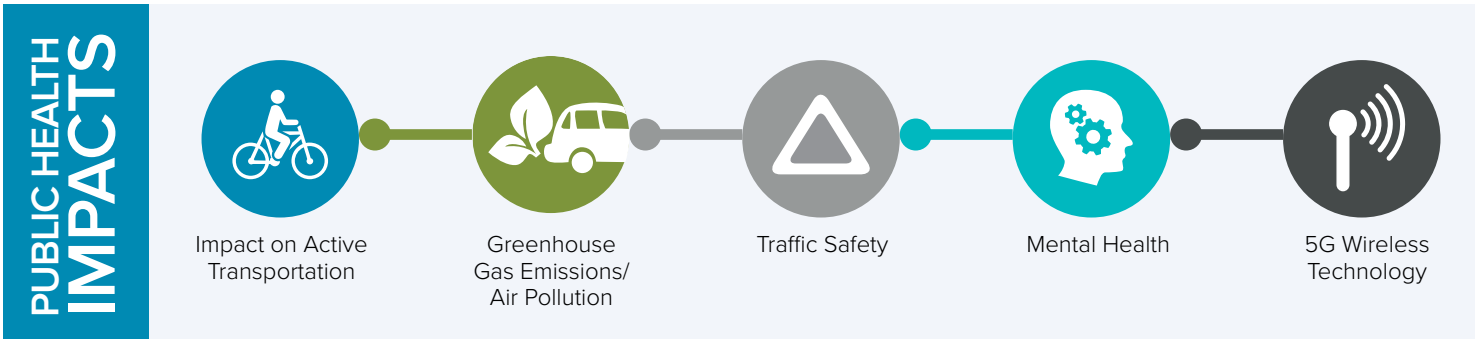
1. *Portrait of Promise: The California Statewide Plan to Promote Health and Mental Health Equity*, California Department of Public Health, Office of Health Equity, August 2015.

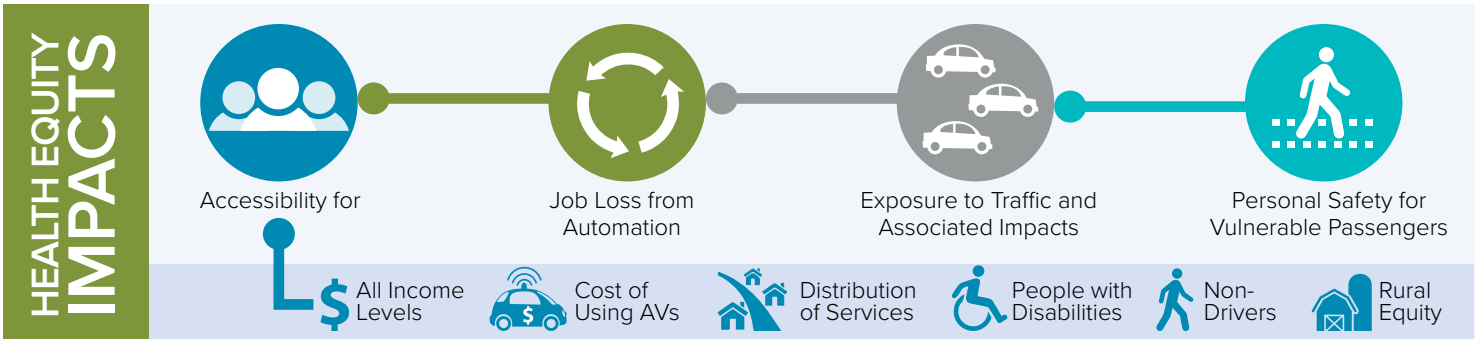
Since AVs are projected to greatly affect California, public policy will shape the way AVs are deployed, as well as the resulting impacts AVs have on California communities. AVs could help address health and equity issues in beneficial ways, or they could severely exacerbate health risks and disparities. Health and equity considerations must play a central role in formulating public policy to ensure AVs benefit California, including the state's low income and other vulnerable populations.

This paper examines the range of potential outcomes that AVs could bring to California's public health landscape and discusses the health equity considerations of AVs. It will analyze potential impacts of issues the authors believe are the most critical. As there will likely be many more--and many unforeseen—consequences, this report does not attempt to predict or assess them all.

The examination begins with a review of the literature on these topics, including both scholarly and journalistic sources. Next, the paper synthesizes the existing body of knowledge from these sources and speculates what the range of potential outcomes will be based on identified public policies. Finally, the paper makes a series of policy suggestions to help ensure AVs' potential to benefit our state is realized.

The following diagrams illustrate the topics that will be examined for their potential impacts from AVs.





LITERATURE REVIEW

AVs' health and health equity impacts span a range of topics, as AVs will likely affect many aspects of the environment and the health and well-being of Californians. This paper identifies central issues and summarizes key findings from existing literature.

As AVs are a new phenomenon and do not yet exist outside of testing, little solid data on their impacts exist. Many articles are primarily speculation, but some valuable research that applies to AVs has been written on related topics. The authors conducted a literature review by reading documents collected since 2012 and searching for additional research using keywords. The following sections document relevant findings by topic area. Each article has a separate bullet point with just one citation.

POTENTIAL HEALTH IMPACTS

Impact on Active Transportation

As communities become more conducive to walking and bicycling, people have more opportunities to integrate physical activity into their daily lives, thereby reducing the risks of inactivity-associated health problems. This paper examines the potential effects AVs will have on active transportation. Active transportation would especially benefit from AVs if they are safer than human-driven vehicles, thereby encouraging more people to walk and bicycle.

- An article titled "*Health Cobenefits and Transportation-Related Reductions in Greenhouse Gas Emissions in the San Francisco Bay Area*" found that the burden of cardiovascular disease and diabetes decreased by 14% with 4 to 22 minutes of median daily walking and bicycling. This health outcome of AVs will depend on whether they result in more or less walking and bicycling.[2]
- According to a study published in *The Lancet* (Effect of physical inactivity on major non-communicable diseases worldwide: an analysis of burden of disease and life expectancy) physical inactivity accounted for 9% of all deaths in the world in 2008.[3] This health outcome of AVs will depend on whether they increase physical activity (walking and bicycling) or not.

2. Neil Mailzlish, James Woodcock, Sean Co, Bart Ostro, Amir Fanal, David Fairley, "Health Cobenefits and Transportation-Related Reductions in Greenhouse Gas Emissions in the San Francisco Bay Area, *American Journal of Public Health*, March 8, 2013.

3. Lee, I. M., Shiroma, E. J., Lobelo, F., Puska, P., Blair, S. N., Katzmarzyk, P. T., & Lancet Physical Activity Series Working Group. "Effect of physical inactivity on major non-communicable diseases worldwide: an analysis of burden of disease and life expectancy", *The Lancet*, 2012.

- The California Vital Statistics Query showed that 248,118 deaths were recorded in California in 2013.[4] Extrapolating the statistic above to California assuming that 9% of all deaths here are due to physical inactivity, that would be 22,331 in our state. This health outcome of AVs will depend on whether they increase physical activity (walking and bicycling) or not.
- In 2013 (the latest year California Statewide Integrated Traffic Records System data is available), 752 pedestrians were killed in traffic crashes in California, and 12,331 were injured. In that same year, 164 people on bicycles were killed in traffic crashes, and 13,283 were injured in California.[5] This health outcome will depend on whether AVs are safer than human-driven vehicles or not.

Greenhouse Gas Emissions and Air Pollution

Combustion engine vehicles emit carbon dioxide, methane, and nitrous oxides. These gases are called greenhouse gases (GHGs) because they become trapped in the earth's atmosphere and cause a greenhouse effect, heating the planet. The emission of GHGs is leading to global climate change, and some of the key human health impacts associated with climate change include:

- Rising sea levels
- Droughts
- Floods
- Crop failures
- Vector-borne diseases
- Wildfires

Vehicle emissions of common pollutants like carbon monoxide, nitrous oxides, and fine particulates, and the ozone formed when reactive organic gases react with sunlight (i.e., smog), harm health throughout most of California. These emissions aggravate respiratory disease, increase cancer risk, contribute to heart disease, and reduce lung function, among other health harms.

This paper examines AVs' potential to increase or decrease vehicle-related emissions, and the potential concentration of those emissions. The following documents reveal some relevant findings.

- According to a research paper by the Rand Corporation, the U.S. Environmental Protection Agency (EPA) states the use of light-duty passenger vehicles in the United States accounts for almost 20% of national GHG emissions and approximately 60% of petroleum use. The article notes that whether AVs will improve or worsen energy use depends on three factors:
  - The fuel efficiency of AVs
  - The carbon-intensity and life cycle emissions profile of the fuel used to power AVs
  - The total change in vehicle miles travelled (VMT) resulting from use of AVs[6]
- Jeffrey Gleenblatt and Samveg Saxena in a *Nature Climate Change* article conclude that AVs could reduce GHG emissions by 87% to 94% below 2014 conventional vehicles, and 63% to 82% below expected 2030 hybrid vehicles. This reduction could occur through:
  - Decreases in GHG electricity emissions through clean energy sources
  - Smaller vehicles used for autonomous taxis
  - Higher annual VMT increasing electric vehicle technology[7]

4.California Vital Statistics Query (CA-VSQ), Center for Health Statistics and Informatics. California Department of Public Health, 2015.

5. 2013 California Statewide Integrated Traffic Records System (SWITRS), California Highway Patrol.

6. James, M. Anderson, Nidhi Kalra, Karlyn D. Stanley, Paul Sorensen, Constantine Samaras, Oluwatobi A. Oluwatola, *Autonomous Vehicle Technology: A Guide for Policymakers*, Rand Corporation, 2016.

7. Jeffrey Gleenblatt and Samveg Saxena, "Autonomous Taxis Could Greatly Reduce Greenhouse-Gas Emissions of U.S. Light-Duty Vehicles," *Nature Climate Change*, July 6, 2015

- "Research has repeatedly shown that driving in formation significantly improves fuel economy and reduces severity of accidents for big trucks — currently one of the most dangerous, fuel-hogging transportation segments". AV technology allows for trucks to communicate with each other and to virtually "hook up" into platoons. National Renewable Energy Laboratory (NREL) trials show that "trucks leading a platoon pack saw 2.2% to 5.3% in fuel savings, with trailing vehicles saving 2.8% to 9.7%, or roughly 6.4 % per team". The trucking industry can greatly benefit from AV technology and platooning. In 2014, combination trucks drove 169.8 billion miles and consumed more than 29 billion gallons of fuel. According to NREL Senior Fleet Test and Evaluation Engineer, Michael Lammert, more than 65% of that distance could be driven in a platoon formation. Lammert "calculated that widespread adoption could reduce total truck energy use by 4.2%, assuming a minimum platooning duration of 15 minutes at 50 miles per hour at least. That's 1.5 billion gallons of petroleum-based fuels and 15.3 million metric tons of carbon dioxide saved annually."[8]

8. Tiffany Hsu, "Trucking Experts Say Platooning is Near, Mull Cross-Carrier Partnerships, Data Sharing," Trucks.com, May 4, 2017.

- The University of California (UC) Davis Institute of Transportation Studies convened the Three Revolutions conference to discuss AVs, electrification of transportation, and ride sharing. Breakout groups focused on various sub-topics. One group (whose work is summarized in the policy brief *Keeping Vehicle Use and Greenhouse Gas Emissions in Check in a Driverless Vehicle World*) looked at GHGs and AVs. The group determined that to support VMT and GHG containment climate goals, the following would be necessary:
  - AVs being deployed as shared-use vehicles only rather than privately owned
  - Widespread carpooling
  - Deployment of AVs with zero tailpipe emissions and energy-efficient design
  - Effective pricing strategies
  - Increased transit use alongside AVs rather than replacing transit
  - Programming of AV behaviors to improve streets' overall livability, comfort, and safety

It is also estimated that if driverless vehicles, deployed through shared ownership and shared rides only, are coordinated with transit, VMT could be reduced by a quarter, GHGs by a third, and travel costs by more than half. However, this idealized model of shared ownership and shared rides is not likely to happen unless a strong policy framework is in place.[9]

- *A Transportation Research Part* A report's findings show that privately-owned AVs for personal use would increase VMT. While AVs offer potential societal benefits, such as increasing mobility options for populations without licenses or people with disabilities, societal costs, including congestion and

9. Giovanni Circella, Chris Ganson, Caroline Rodier, *Keeping Vehicle Use and Greenhouse Gas Emissions in Check in a Driverless Vehicle World*, Three Revolutions Policy Brief, April 2017.

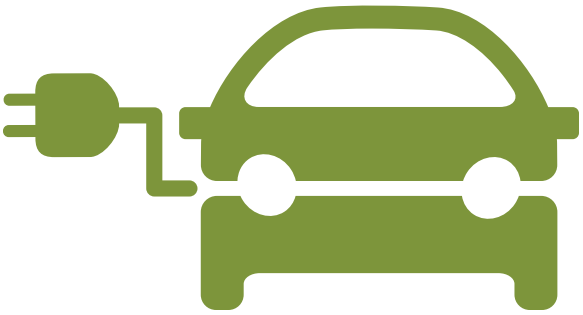
GHG emissions, could result from personal AV ownership. This could lead to "increased commute distances as housing choices change, more frequent long-distance car travel, [...] reduced transit use," or allowing vehicle travel without any occupants.[10]

- Another policy brief from the Three Revolutions conference (*Capturing the Climate Benefits of Autonomous Vehicles: Policy Recommendations*) provides a policy framework that could help ensure AV technology provides climate change benefits, such as low-emissions standards and ride sharing. These policies include:
  - **AV electric vehicle requirements:** Require all AVs to have electric drive and be powered by clean electricity. The safety, convenience, and cost-saving benefits of this requirement should be realized to encourage further deployment of electric AVs.
  - **Electric passenger mile standards:** Require increasing electric passenger miles travelled, which is VMT multiplied by the number of passengers in the vehicle. This policy is more relevant for AV fleet operations than privately-owned AVs, and would encourage more electric AV fleets and ride sharing in electric AVs.
  - **A carbon intensity performance standard:** Require declines in emission intensity per passenger mile (e.g., grams CO2 equivalent/passenger mile). This would discourage zero-occupancy vehicle travel and influence electricity choices or other fuel options for electric vehicle (EV) charging. To guarantee that overall emissions reductions are aligned, carbon intensity requirements could be adjusted regularly based on VMT impact assessments of AV deployment.
  - **A carbon fee:** Require a fee charged to fleet operations based on their carbon intensity per passenger. This fee-based structure could provide a cost differentiation that encourages the deployment of more electric AV fleets and incentivizes consumers to choose rides with the lowest climate impact. This fee could also incorporate a congestion fee.
  - **Zero-Passenger Miles Requirements**: Potential requirements could include implementing a temporary moratorium on the personal use of AVs until testing allows for more controlled fleet operations, or imposing local or state government fees on AV owners and operators for zero-occupancy passenger miles. This policy could help limit AVs operating for personal use with no passengers, such as "circling the block while running an errand or eating dinner or sending a vehicle home to park and return to pick you up."[11]
- A recent article in the *Annals of the American Thoracic Society* concluded that air pollution in California causes approximately 3,632 deaths per year.[12] The number of deaths caused by air pollution will depend on whether AVs increase or reduce air pollution.

10. Zia Wadud, Don Mackenzie, Paul Leiby, "Help or Hindrance? The Travel, Energy and Carbon Impacts of Highly Automated Vehicles," *Transportation Research Part A*, December 2015.

11. Don Anair, Patty Monahan, Levi Tilleman, Matthew Barth, *Capturing the Climate Benefits of Autonomous Vehicles*, Three Revolutions Policy Brief, February 2017.

12. Cromar, K. R., Gladson, L. A., Perlmutt, L. D., Ghazipura, M., & Ewart, G. W., "American Thoracic Society and Marron Institute Report. Estimated Excess Morbidity and Mortality Caused by Air Pollution", American Thoracic Society–Recommended Standards, 2011–2013, *Annals of the American Thoracic Society*, 2016.



Traffic Safety

The California Office of Traffic Safety reports 3,176 traffic fatalities in 2015, and 10,995 serious injuries in 2014.[13] Nationally, 94% of all crashes are caused by human error.[14] On average, just under 9 people in the California die each day in traffic.[5] This paper examines how AVs could increase or reduce those numbers. Once AVs are safer than human-driven vehicles, many of the crashes caused by human error should be reduced.

- Public health researcher Janet Fleetwood's article, *Public Health, Ethics, and Autonomous Vehicles*, finds that AVs could reduce traffic fatalities up to 90%. This would save more than 277 lives per year in California based on 2014 data.[15]

Mental Health

As AVs change transportation systems and mobility options for communities, they could potentially impact mental health in several ways.

Stress

Certain causes of stress associated with driving (i.e., traffic congestion, loss of time, fear of collisions/accidents, etc.) could be reduced by AVs, which could help improve mental health and well-being.

Traffic safety

AVs could help reduce injuries and loss of life, which would help promote a sense of security and safety, that would result in improved overall mental health and well-being.

Physical activity

If AVs are deployed in a way that promotes active transportation, then the increase in transport-related physical activity could improve mental health. However, if AVs are deployed in a way where they are replacing active transportation (i.e., people riding AVs instead of walking or bicycling), then that could have detrimental impacts to mental health (and physical health, and overall well-being).

Social contact

Social contacts improve mental health.[16] AVs impact on social contacts could go different ways for different reasons. If little sharing of rides occurs, social isolation may increase. On the other hand, if most rides are shared there would be an increase in social contact. Daily rides could include encounters with new acquaintances. With more people bicycling and walking, and with more street space reallocated to social space, social contact would increase. With affordable robot deliveries, e-commerce (electronic shopping) will likely grow, reducing the need to personally shop in stores which would reduce opportunities for social contact with other people.

The following literature links potential mental health impacts with AVs.

- A 2010 article from *The Telegraph* cites research that concludes driving is more stressful than taking a bus. Heart rates of drivers were compared with those of people riding on buses and found that, on average, stress of those on buses was 33% lower than those driving.[17] As people will not need to drive AVs, their stress level should decrease.

13. California Office of Traffic Safety 2016 Annual Report.

14. National Highway Traffic Safety Administration, Traffic Safety Facts, *Critical Reasons for Crashes Investigated in the National Motor Vehicle Crash Causation Survey*, U.S. Department of Transportation, 2015.

15. Janet Fleetwood, "Public Health, Ethics, and Autonomous Vehicles," *American Journal of Public Health*, April 2017.

16. Patrick W. Cacioppo, "Loneliness: Human Nature and the Need for Social Connection," *W.W. Norton & Company*, 2008.

17. Andrew Alderson, "Driving a Car is More Stressful than Going by Bus, Says New Research," *The Telegraph*, September 19, 2010.

- An article in the *American Psychological Association* links exercise to mental health. The author, Jennifer Carter, wrote "... as evidence piles up, the exercise-mental health connection is becoming impossible to ignore." She goes on to say, "Usually within five minutes after moderate exercise you get a mood-enhancement effect." The article cites research that also links exercise and alleviation of long-term depression.[18] If AVs increase opportunities for people to engage in active transportation, as discussed earlier, those who do will benefit accordingly.
- A book published by Patrick W. Cacioppo, *Loneliness: Human Nature and the Need for Social Connection*, links social connection to mental health. He found research showing that social isolation increases the stress hormone cortisol, altered gene expression in immune cell and higher blood pressure.[16] If AVs increase opportunities for social interaction, this should improve mental health. On the other hand, if social isolation increases, then negative mental health impacts could be worsened.

Possible Impacts from 5G Wireless Technology

Presently, communication central to AV capabilities is conducted over Direct Short-Range Communication (DSRC) technology. Experts anticipate that AV communications may switch to 5G wireless technology once it is available, perhaps sometime between 2020 and 2025.

5G wireless technology is projected to revolutionize data collection and all of the things that data is used for. Like AVs, it brings great potential to change many things. Much more than an upgrade from 3G to 4G networks, 5G will bring unprecedented abilities. It will transmit much greater amounts of data much faster than present networks. Because of this, 5G will require many more transmitters to carry this data over a high-frequency spectrum that will be close to where we live, work, and carry out our daily activities. The switch to 5G network raises health concerns over radiofrequency radiation. Nothing has been proven, but research is underway and more is needed.

The following article discusses the health concerns.

- The *Los Angeles Times* reported that the National Toxicology Program, (a division of the National Institute of Environmental Health Sciences) released preliminary data showing small increases in tumors in male rats that were exposed to cellphone radiation. This raises concerns over the higher degree and proximity of radio frequency radiation that 5G would bring. While nothing has been proven, there is cause to be cautious. Keven Mottus, the outreach director for the California Brain Tumor Association, said, "There is big concern with the previous technology and it's just being made worse with 5G." Mottus followed with, "These are microwave transmitters and the closer you are to them, the more problems."[19]

18. Jennifer Carter, "The Exercise Effect," *American Psychological Association*, December 2011.

19. Jim Puzzanghera, "Is 5G Technology Dangerous? Early Data Shows a Slight Increase of Tumors in Male Rats to Cellphone Radiation," *Los Angeles Times*, June 18, 2017.

HEALTH EQUITY CONSIDERATIONS

Accessibility

Access is defined broadly as the ability to get to jobs, services, transit, and other destinations for daily needs, as well as the time, convenience, and cost of reaching destinations. This paper examines AVs' potential to increase or decrease transportation access. Accessibility is analyzed as it relates to access for people of all income levels, the cost of using AVs, how well transportation services are distributed, accessibility and mobility for people with disabilities, access and mobility for those who don't drive, and rural equity issues.

Access to Transportation for All Income Levels

Affordable transportation is a critical factor in enabling people to access jobs, services, and other destinations for daily needs. This is particularly true for those with limited budgets.

- A recent report titled *Driverless Future* recommends that cities provide services such as transit ride subsidies, pay-as-you-go alternatives, and dial-a-ride services to address access to transportation for people without smart phones or those in economically underserved areas.[20] This issue will become particularly significant if AV transportation services will be ordered by smart phone and paid for by credit card.
- The *Journal of the American Planning Association* published a study on transportation's role in connecting subsidized housing recipients to employment in the federally sponsored *Moving to Opportunity for Fair Housing* (MTO) program. The research findings suggest individuals having access to a car are two times more likely to find a job, and four times more likely to retain employment by maintaining access to a car. Proximity to transit services is also essential to participants' mobility, as results show a strong relationship between relocating to transit-richer neighborhoods and retaining employment. Among unemployed participants, however, moving to transit-richer neighborhoods does not appear to increase the likelihood of gaining employment.[21] If AV services become available at affordable rates, this would likely increase access for lower-income people.
- According to one of the UC Davis Three Revolutions policy briefs, *Can We Advance Social Equity with Shared, Autonomous and Electric Vehicles?,* "very low-income families spend, on average, over 30% of their income on transportation." These families face barriers such as limited access to jobs, education, health care, and other opportunities.[22] If AV services become available at affordable rates, then this could help reduce what families have to spend for transportation.
- Recent research for the National Bureau of Economic Research found that due to driver discrimination, African Americans wait 29% to 35% longer for an UberX ride than white passengers.[23] Without drivers in AVs, this type of discrimination could be eliminated.

20. Peter Glus, Eric Rothman, Joe Iacobucci, *Driverless Future: A Policy Roadmap for City Leaders*, Acadis, HR&A Advisors, Sam Schwartz Consulting, 2017.

21. Evelyn Blumenberg, Gregory Piece, "A Driving Factor in Mobility? Transportation's Role in Connecting Subsidized Housing and Employment Outcomes in the Moving to Opportunity (MTO) Program," *Journal of American Planning Association*, August 13, 2014.

22. Stuart Cohen, Sahar Shirazi, Terra Curtis, *Can We Advance Social Equity with Shared, Autonomous and Electric Vehicles?,* Three Revolutions Policy Brief, February 2017.

23. Yanbo Ge, Christopher R. Knittel, Don MacKenzie, Stephanie Zoepf, "Racial and Gender Discrimination in Transportation Network Companies," *National Bureau of Economic Research*, October 2016.

Cost of Using AVs

The cost of travel is a component of accessibility. This paper looks at the likely cost of travel by AVs and how affordable it might be for people of various income levels. The following articles discuss the cost of AVs.

- A *Recode* article explains that Uber pays drivers 65% to 80% of each fare, and Uber takes 20 to 35 cents for every dollar of revenue.[24] This shows that, once there is no driver, the cost to provide ride services should come down. Market competition should then bring the cost to users down even further.
- The Victoria Transport Policy Institute released a study explaining how AVs will be a cheaper alternative to owning a vehicle driven fewer than 6,000 annual miles. The study shows owning a personal automobile typically costs about $4,000 annually in fixed expenses, plus $0.20 per mile in operating costs. This is more expensive than conventional taxis ($2–$3 per mile) for vehicles driven fewer than 2,500 annual miles, and car sharing services ($0.60–$1 per mile) for vehicles driven fewer than 6,000 annual miles. The study suggests that AV taxis will be cheaper than owning a car for people who travel 2,500 to 6,000 miles per year.[25]
- The UC Davis Three Revolutions conference policy brief *Capturing the Climate Benefits of Autonomous Vehicles: Policy Recommendations*, claims that AV ride-hailing (flagging down a ride at the point of the vehicle) services may diminish the popularity of shared rides (for example, current human-driven carpool services that utilize GPS navigation devices, smartphones, and social networks to arrange one-time shared rides on short notice). Current rider behavior shows that consumers may choose a shared ride for less cost over a longer ride that requires sharing space with strangers. With the deployment of AVs, trip costs could be significantly lower for consumers and inherently encourage more AV rail-hailing. It is possible that some ride-hailing trips could be shared, which could reduce costs even further.

Distribution of Transportation Services

No literature was found that has direct applicability to this sub-topic. However, this paper provides a speculative analysis of how well AV transportation services could reach different neighborhoods and communities.

Accessibility and Mobility for People with Disabilities

This paper examines potential access to AV transportation services for people who have ambulatory, sight, or hearing disabilities. Transportation for people with disabilities requires that vehicles are accessible for them to enter and disembark. Without such vehicles, it would be difficult or impossible for these people to get around without other options. With such vehicles, they would have more options with AVs than they do today. Some people with disabilities need assistance getting in and out of cars. Without special provisions, these people may have fewer options than they do today if all vehicles become autonomous. The literature below provides some insight as to how people with disabilities may fare in California with AVs.

- The Ruderman Family Foundation's white paper titled *Self-Driving Cars: The Impact on People with Disabilities* finds that, in the United States alone, approximately

24. Johana Bhuiyan, "As Uber's Robot Cars Hit the Streets in Pittsburgh, the Fear of Its Human Drivers Have Become a Reality," *Recode*, September 14, 2016.

25. Todd Litman, *Autonomous Vehicle Implementation Predictions: Implications for Transport Planning*, Victoria Transport Policy Institute, February 27, 2017.

one in every five people has a disability. This adds up to more than 57 million people. People born with disabilities, as well as people who acquired disabilities throughout their lives, including the 3.8 million veterans with a service-connected disability, comprise this total. The paper identifies a recent government transport survey indicating approximately six million individuals with a disability have difficulty getting the transportation they need. The paper further states that approximately 3.5 million individuals, including 1.9 million with disabilities, never leave their homes. These individuals tend to be older, have more severe disabilities, or have already expressed mobility difficulties.[26] AVs may offer another option to get around for these people. Without special services, they would provide the most help to those who do not need assistance getting in and out of vehicles.

- A research analysis completed by the Shared-Use Mobility Center shows potential mobility benefits for people with disabilities. The center's article, *Shared Mobility and the Transformation of Public Transit*, cites a recent Federal Transit Administration study that found between 1999 and 2012, "the annual number of ADA [Americans with Disabilities Act] paratransit trips increased from 68 million to 106 million, while the average cost increased from $14 to $33 per trip (a cost increase of 138%, compared with an increase in the unit cost of fixed-route bus service of 82% over that same period)." While ADA paratransit trips clearly have an increased cost, operating ADA paratransit via AVs could reduce this cost, as was the case with transportation network companies (TNCs).[27] Since AV services can operate without a driver they will likely offer less expensive travel options than with human-driven vehicles.

26. Henry Claypool, Amitai Bin-Nun, Jeffrey Gerlach, *Self-Driving Cars: The Impact on People with Disabilities*, Ruderman Family Foundation, January 2017.

Accessibility and Mobility for Non-Drivers

No literature was found that has direct applicability to this sub-topic. However, this paper provides a speculative analysis of how transportation with AVs may increase or decrease options for people who do not drive. This includes older adults who are no longer able to drive, children who are too young to drive, those who are not able to afford to drive, and those who choose not to drive.

Rural Equity Issues

No literature was found that has direct applicability to this sub-topic. However, this paper provides a speculative analysis of the potential for AVs to provide transportation access for people in rural areas.

27. Colin Murphy, Sharon Feigon, "Shared Mobility and the Transformation of Public Transit," *TCRP J-11/Task 21*, Shared-Use Mobility Center, for the American Public Transit Association, March 2016.

Job Losses from Automation

This paper identifies what types jobs may be lost or created from AV technology, along with income and education levels associated with those jobs. The citations below provide related information.

- The aforementioned *Driverless Future* report describes how professional drivers will need to remain competitive in the new economy as AV adoption occurs over time. Partnering with transportation companies to provide new training and certifications to operate and maintain AVs may allow these professions to participate in the newly created industries.[20]
- According to research conducted by the Center for Global Policy Solutions, nearly 3% (2.86% exactly) of all U.S. workers are employed in driving professions, whether as bus drivers, delivery and heavy truck drivers, or taxi drivers and chauffeurs. The study estimates that more than four million jobs will be lost with a rapid transition to car automation. In California alone, more than 430,000 individuals would be unemployed at the onset of rapid AV integration. While whites, who hold 62% of the more than four million total jobs, would be the most-affected group, members of minority groups who earn "driving premiums" would also be affected. These drivers, primarily Latinos and African Americans, earn more as drivers than they would in non-driving professions. Latinos who work as drivers earn approximately $5,800 more in real wages than Latinos in non-driving occupations. African Americans earn about $2,500 more as drivers than in non-driving occupations. The study also points out that the majority of all drivers have low levels of educational attainment. According to the nationwide study, 93.17% of drivers have less than a college degree, compared with 66.91% of workers in other fields.[28]

28. Cherrie Bucknor, Kevin Cashman, Maya Rodkeymore, *Stick Shift: Autonomous Vehicles, Driving Jobs, and the Future of Work*, Center for Global Policy Solutions, March 2017.

Exposure to Traffic and Associated Impacts

This paper examines who will potentially be most affected by traffic and its externalities, such as noise, emissions, and congestion. The following articles provide insight to this issue.

- A *Los Angeles Times* article describes frustration over how Southern California continues to build homes within 500 feet of freeways despite over a decade of warnings from state air quality officials. Today, more than 1.2 million people live in high-pollution zones within 500 feet of a Southern California freeway, with more moving in every day. The *Times* obtained pollution readings near freeways and found that the concentrations of pollution particles in the air from vehicle exhaust in these areas were three to four times higher than in neighborhoods at a distance. Carcinogens in vehicle exhaust pose nearly three times the cancer risk previously thought, according to state environmental officials.[29] To the degree that AVs operate on electricity, as many policymakers are hoping, this impact should diminish.
- The UC Davis Three Revolutions policy brief, *Can We Advance Social Equity with Shared, Autonomous and Electric Vehicles?,* discussed earlier in this paper, notes that "disadvantaged communities often suffer the worst impacts of our current transportation system, from higher levels of air pollution to greater numbers of injuries and deaths from car crashes."[22] To the degree that AVs operate on electricity, as many policymakers are hoping, this impact should diminish. Traffic injuries and deaths are expected to be reduced with the deployment of AVs as well (see *Traffic Safety* section above).

29. Tony Barboza, Jon Shleus, "LA Keeps Building Near Freeways, Even Though Living There Makes People Sick," *Los Angeles Times*, March 2, 2017.

- A recent *Governing* article documents that people in low-income neighborhoods are more likely to be hit by vehicles while walking than in other neighborhoods. Further, a correlation exists between a neighborhood's poverty and the number of pedestrian deaths. U.S. Census tracts with a poverty rate of less than a 5% averaged 3.8 pedestrian deaths per 100,000 between 2008 and 2012, while those with a poverty rate of over 30% experienced 12.6 pedestrian deaths over the same period.[30] If AVs are safer than human-driven vehicles, this disparity should diminish.

In-Vehicle Personal Safety for Passengers

No literature was found that has direct applicability to this sub-topic. However, potential impacts on passenger safety and comfort when sharing rides with strangers in vehicles without drivers is discussed. Without a driver, some passengers may feel more vulnerable riding with strangers, and could experience real or perceived safety threats. Others may feel unsafe on a public transit AV (i.e., autonomous bus) without a driver present to intervene if something were to happen. This issue could also impact the ability to maximize the number of people in shared ride vehicles, which could have implications for many of the issues discussed above (i.e., transportation costs; as well as efficiencies and benefits from sharing rides such as energy/fuel savings, GHG emissions reduction, reductions in VMT, and more).

30. Mike Maciag, "Pedestrians Dying at Disproportionate Rates in America's Poorer Neighborhoods," *Governing*, August 5, 2014.

PRIMARY DETERMINANTS

The health and equity impacts of AVs will depend largely on:

1. The degree to which transportation is shared
2. The degree to which transportation is electrified, and the sources of electrical generation
3. Other public policies

THE DEGREE TO WHICH TRANSPORTATION IS SHARED

AVs have strong potential to induce single- and lower-occupancy travel for three reasons:

1. They will reduce the time cost of travel
2. They may reduce travel time
3. They may shift some trips from transit to lower-occupancy vehicles

Time Cost of Travel

AVs are expected to enable travelers to engage in activities other than driving. Without the need to focus people's concentration and time on driving, AVs could help make travel less onerous and burdensome by allowing people to engage in other activities during transit time (i.e., work, sleep, read, watch videos or movies, catch up on emails, and so forth). This could encourage "ex"-drivers to travel more and to travel longer distances. With AVs, single-occupancy travel would likely become less stressful and therefore more appealing. Additionally, increasing the ease of vehicular travel could encourage more suburban sprawl type development patterns and increase VMT.

Travel Time

UC Berkeley researcher Steven Shladover wrote that highway capacities will increase with AVs. Adaptive cruise control coupled with autonomous collision avoidance (or fully automatic braking) could provide safer and more efficient conditions for motorists. Compared with today's freeway conditions, these technologies could potentially increase highway capacity by 100% (from 2,000 vehicles per hour per lane to 4,000 vehicles per hour per lane) and increase travel speeds by greater than 20 miles per hour while reducing safe spacing requirements by about 50%. These factors could reduce, and in many cases, eliminate congestion and thereby decrease travel time.[31]

Once AV technology is safer than humans driving, it is projected that we will have fewer crashes. The Federal Highway Administration reports that 60% of congestion is caused by crashes and mishaps.[32] By reducing congestion, travel times would decrease and become more predictable. This could likely increase single-occupancy vehicular trips and induce more VMT, as well as encourage suburban sprawl.

31. Steven Shladover, Xiao-Yun Lu, *Impacts of Cooperative Adaptive Cruise Control on Freeway Traffic Flow*, Conference Paper in Transportation Record Journal of the Transportation Research Board, January 2012.

32. Federal Highway Administration (FHWA). Traffic Incident Management. Overview of Program Areas. Office of Operations. Accessible: https://ops.fhwa.dot.gov/aboutus/one_pagers/tim.htm (June 27, 2017).

Shift Trips to Lower-Occupancy Vehicles

A study of app-based transportation network companies (TNCs) like Lyft and Uber in New York City indicates that their rapid growth in ridership has come at the expense of public transit, walking, and bicycling, as well as traditional taxis. This has resulted in a 7% increase in VMT in three years.[33] The point-to-point service that TNCs provide, along with their availability, speed, and comfort, make them an attractive travel option. Additionally, since travelling via TNCs is generally less expensive than taxis, this makes them even more attractive. As noted above, without the costs needed to pay drivers, the overall cost of TNC services could be reduced as much as 65% to 80%.[24] The affordability of TNC-provided AV services could potentially shift a significant number of transit trips to lower-occupancy vehicles, thereby increasing VMT.

Sharing Travel

While the previous discussion demonstrates the potential to induce single- or lower-occupancy travel with AVs, conversely, AVs offer a high potential for people to travel together. Today Californians travel to work with an average of 1.28 persons per vehicle.[34] Increasing that to just two persons per vehicle per trip would significantly reduce GHGs and other emissions, and congestion. The potential to share rides with AVs is much greater than with today's vehicles. The economics of transportation will change significantly without paid drivers for services offered by TNCs, taxis, buses, and other transportation options (the downside of job loss is presented later in this paper). For many people, this economic change may cause them to opt out of owning their own car in favor of paying for transportation as a service on demand. Without the sunken costs of vehicle purchase, insurance, maintenance, parking, and other costs associated with vehicle ownership, ordering a ride will likely be more affordable as a transportation option for many people. Without car ownership, people may be more likely to use alternative modes of transportation, including walking, bicycling, taking transit, and sharing rides with others. As more people enter the pool for shared ride services such as Lyft Line or Uber Pool, the chances could significantly increase in being matched with people travelling the same direction at the same time, making these services more convenient. If public policy offers incentives to share rides in cars, vans, or buses with multiple passengers, then that could encourage even more people to share rides, which could reduce GHGs, air pollution emissions, and overall VMT.

THE DEGREE TO WHICH TRANSPORTATION IS ELECTRIFIED, AND THE SOURCES OF ELECTRICAL GENERATION

Electrifying vehicles can significantly reduce both GHGs and air pollution emissions. But the degree of change depends largely on the source of electricity. A study by the Electric Power Research Institute and the Natural Resources Defense Council found that GHGs could be reduced between 45% and 77% by 2050 relative to 2015 levels if 53% of personal VMT are made via electric vehicles.[35]

As a greater portion of VMT is done in electric AVs, and as a greater portion of electricity is generated by non-polluting renewable energy sources, GHGs and other emissions should be reduced further.

These strategies could help address the impacts to health from GHG-induced climate change and air pollution emissions, and to address health equity by reducing air pollutants and other traffic exposures for communities located in close proximity to areas of high traffic.

33. Bruce Shaller, *The Growth of App-Based Ride Services and Traffic, Travel and the Future of New York City*, 2017.

34. 2010 U.S. Census.

35. *Electrifying Transportation Reduces Greenhouse Gases and Improves Air Quality*, Electric Power Research Institute and the Natural Resources Defense Council, September 16, 2015.

OTHER PUBLIC POLICIES

Although a detailed discussion is beyond the scope of this report, it is worth noting that other health and equity issues may be addressed with various public policies. These include policies related to ensuring:

- Safe operation of AVs
- Access to convenient and affordable transportation for all income levels
- Access to convenient and affordable transportation for people of all abilities
- Access to convenient and affordable transportation for people in rural areas
- Access to job training and new jobs to replace those lost to automation
- Safe use of 5G or other wireless transmission technology
- Measures to improve personal safety for people on shared ride vehicles and buses

RANGE OF POTENTIAL OUTCOMES

Predicting outcomes now is largely speculative, as the widespread deployment and use of AVs is not yet a reality, and most likely there will be many unforeseen consequences and impacts. We can, however, build upon the body of research highlighted in this paper, and the existing literature on transportation behavior.

The three scenarios presented following portray a range of potential outcomes in a future with AVs, taking into account the body of knowledge thus far. These scenarios depict futures that assume all or nearly all vehicles are AVs. This would likely be any time between 20 and 40 years from now.

Given the level of speculation inherent in these scenarios, they come with plenty of room for legitimate debate.

The **FIRST SCENARIO** represents outcomes in California where there are no purposeful public policies enacted to specifically address the potential public health and health equity impacts of widespread deployment and use of AVs.

The **SECOND SCENARIO** presents a middle ground where a modest number of public policies are enacted to address public health and health equity issues related to the widespread deployment and use of AVs. This scenario could result if policies such as those below were enacted:

- Modest incentives for electric vehicles
- Modest subsidies for transit-related services and services for people with disabilities
- Safety regulations
- Provisions for access to transportation services for people without credit cards or smart phones
- Dedicated lanes for shared AVs on some freeways
- Requirements to make boarding and disembarking easier for people with disabilities who typically need assistance
- Measures enacted to improve personal safety for vulnerable passengers

The **THIRD SCENARIO** paints a picture of California's future where we have enacted deliberate public policies to ensure optimal public health and health equity benefits. Policies that could lead to this type of future scenario would likely include policies that prioritize the following:

- Pricing, time, and location incentives for sharing rides
- Regulations requiring electric vehicles
- Subsidies for transit-related services and services for people with disabilities
- Regulations requiring an adequate number of vehicles providing service to the public are accessible
- Aggressive vehicle safety regulations
- Provisions for access to transportation services for people without credit cards or smart phones
- Adequate job training and adequate efforts to ensure that people who lose jobs to automation have other employment options available
- Land use planning promoting compact development, and significantly reducing parking
- Regulations prevent the widespread use of 5G wireless technology, or other transmission technology, until research shows that it can be used safely
- Measures enacted to improve personal safety for vulnerable passengers

SCENARIO 1: NO POLICIES ADDRESSING PUBLIC HEALTH & HEALTH EQUITY IMPACTS OF AVS ARE ENACTED

Health Impacts

Impact on active transportation

- If AVs turn out to be safer than human-driven vehicles, bicycling and walking will become safer and as a result, more attractive and more people will engage.
- Without measures to ensure maximum vehicle safety, the increase in bicycling and walking will be limited by the degree of the safety gains.
- If induced travel puts significantly more vehicles on our streets, it will further degrade the experience of bicycling and walking, thereby limiting their increase.

GHGs and air pollution

- The reduction in the time cost and travel times will induce travel significantly.
- People will have incentives to live further away for less expensive housing, causing more suburban sprawl.
- More people will live in neighborhoods with the conventional suburban form of low densities and super block street networks, which are not conducive to public transit, walking, and bicycling.
- Zero-occupant vehicles will circulate to distant parking or to wait for the next passenger to pick up.
- Public transit will further lose ridership to personal vehicles and to app-based ride services due to the door-to-door capabilities of affordable transportation.
- With lower costs of app-based ride services, more people may opt to share rides with others living near them and working near them for commutes.

Traffic safety

- AVs may significantly reduce the number of crashes caused by human error.
- AVs may increase the number of crashes if they operate before the technology has sufficiently prepared for the full range of situations that they will encounter on streets and highways.
- As pedestrian/bicycle-to-vehicle communication becomes commonplace, walking and bicycling will become safer.

Mental health

- If AVs make environments safer for pedestrians and bicyclists, and thus encouraging more active transportation, then as more people walk and bicycle, their mental health could improve due to increased levels of physical activity.
- As safety risks associated with driving decrease, stress should decrease and mental health will improve as a result of increased feelings of safety and security.
- As the stress of driving decreases, drivers' mental health will improve.
- As induced travel results in more vehicles on the streets, stress will increase and mental health will decrease due to higher levels of traffic and traffic related exposures (noise, pollution, etc.)
- If more people travel alone, social isolation will increase. If more people share rides, social isolation will decrease.
- Affordable driver-less "robot" deliveries of purchases will reduce social contact as people stay at home to shop instead of going to stores.

Possible impacts from 5G Wireless Technology

- Along with mobile phones and other uses of 5G, AV use of 5G may or may not cause cancer.

Health Equity Impacts

Access to transportation for all income levels

- Reductions in the cost of app-based ride services will provide a wider range of transportation choices, some significantly more convenient than public transit offers for those without personal cars.
- Racial discrimination in taxi and app-based ride services will be largely eliminated without a driver to discriminate.
- Reductions in congestion will enable people from disadvantaged neighborhoods to access more jobs and other regional destinations.
- Induced travel will offset some of the reduction in congestion and may even exacerbate congestion.
- As bicycling and walking become safer and more attractive, they will provide low-cost transportation options for short trips. They will also provide better access to public transit.
- Profit-based app-based ride services will gravitate to areas where demand is greatest, leaving some communities or neighborhoods underserved. This may happen in disadvantaged communities and in low-density suburban and rural neighborhoods.
- As public transit loses passengers to app-based ride services, its quality will decline, making it less convenient. The constituency to support greater subsides for public transit will erode, and may lead to reductions in transit subsidies and thereby services. This may be partially offset by the cost of transit significantly decreasing without the need to pay drivers.
- Without special access card services, app-based ride services will be limited to those who have credit cards and smart phones.
- Language barriers will prevent some people from using app-based services.

Cost of using AVs

- The cost of personally-owned vehicles will increase with the cost of AV technology. Current estimates for the additional cost of AV technology are $5,000 to $10,000 per vehicle in the next decade. If AVs are electric, this will add another $10,000 to the cost of a vehicle in the earlier years. By 2050 the total cost of the AV technology and electrification should come down to $10,000.[36]
- People with relatively higher incomes will have access to convenient transportation with the time cost advantages of not having to drive.
- Reductions in the cost of app-based ride services will enable some who currently spend a large portion of their take-home income on auto ownership to opt out of ownership.

Distribution of transportation services

- Reductions in the cost of app-based ride services will provide a wider range of transportation choices to people in many neighborhoods and communities. This will improve access to jobs, services, and shopping choices.
- Public transit services will decline, especially in lower-density neighborhoods.
- Profit-based app-based ride services will gravitate to areas where demand is greatest, leaving some communities or neighborhoods underserved.

36. Lew Fulton, Jacob Mason, Dominique Meroux, *Three Revolutions in Urban Transportation*, UC Davis Sustainable Transportation Energy Pathways, 2017.

Mobility for people with disabilities

- The cost to provide accessible vehicle services will decrease. People with disabilities who can afford it will have more transportation services available where providing accessible vehicles is profitable.
- Neighborhoods and communities where providing accessible services is less profitable will have few additional options for people with disabilities.
- Low-income people with disabilities may not be able to afford some accessible services.
- People who need assistance boarding and disembarking (with walkers, wheelchairs, etc.) won't be able to use these vehicles.
- Language barriers will prevent some people from using app-based ride services.

Mobility for older adults and children too young to drive

- Older adults who do not drive and children too young to drive will have newly available transportation services.
- Older adults will regain some of the independence they lost (i.e., due to losing their ability to drive).
- Access to new transportation options for these people will be limited to those who can afford them.

Rural equity issues

- Rural areas will have fewer options for shared transportation than urban areas due to the lack of critical mass to share rides. Therefore, personally-owned vehicles will remain more prevalent in rural areas.
- The additional cost of AVs will postpone the widespread adoption of personal ownership. Human-driven vehicles will remain longer in rural areas.
- As a higher proportion of people in rural areas will have personally-owned vehicles, they will be less able to take advantage of app-based ride services' lower cost.
- Cost reductions of app-based ride services will provide some people with transportation options they do not currently have. This will be most useful to older adults who do not drive, children too young to drive, and people with disabilities that prevent them from driving.

Job losses from automation

- A high percentage of TNC drivers, taxi drivers, bus drivers, and other delivery drivers will lose their jobs and be left to search for jobs in a market that may not match their skills. Some may maintain jobs with parcel delivery as people may be needed to load and unload the goods.

Exposure to traffic and associated impacts

- Induced travel will increase exposure to emissions, congestion, crashes and noise for everyone.
- People in urban areas and those living closest to freeways and other areas of high traffic will have the greatest exposure to emissions and noise.

In-vehicle personal safety for passengers

- Without special safety measures, some passengers will become victims of crime while riding in shared ride vehicles.
- Without special safety measures, some passengers will feel vulnerable to crime while riding in shared ride vehicles.
- Without special safety measures, some passengers will not enter into ride sharing situations where they do not feel safe, and they will have to pay a higher price to use more expensive transportation.

SCENARIO 2: MODEST POLICIES ADDRESSING PUBLIC HEALTH & HEALTH EQUITY IMPACTS OF AVS ARE ENACTED

Health Impacts

Impact on active transportation

- With safety measures in place, people on bicycles and those walking will be safer and feel safer.
- As bicycling and walking become safer and more attractive, more people will engage.
- If induced travel puts significantly more vehicles on our streets, the experience of bicycling and walking will degrade, thereby limiting their increase.
- Transit support will offset some induced travel, and thereby offset some of the degradation to the walking and bicycling experience.

GHGs and air pollution

- The reduction in the time cost and travel times will induce travel significantly.
- People will have an incentive to live further away for less expensive housing, causing more suburban sprawl.
- More people will live in neighborhoods with the conventional suburban form of low densities and super block street networks, which are not conducive to public transit, walking, and bicycling.
- Zero-occupant vehicles will circulate to distant parking or to wait for the next passenger to pick up.
- Public transit will further lose ridership to personal vehicles and to app-based ride services due to the door-to-door capabilities of affordable transportation.
- Transit support will offset some of the loss in public transit ridership.
- With lower costs of app-based ride services, more people may opt to share rides with others living near them and working near them for commutes.
- Support for EVs will increase their numbers, thereby reducing GHGs and air pollution. The degree of the support given will determine the amount of these reductions. They may completely offset emissions created from induced travel, partially offset emissions from induced travel, or not offset more emissions than those emitted from induced travel.
- Dedicated shared AV lanes increase usage and decrease single-occupancy travel.

Traffic safety

- AVs will significantly reduce the number of crashes presently caused by human error.
- As pedestrian/bicycle-to-vehicle communication becomes commonplace, walking and bicycling will become safer.
- As pedestrian-to-vehicle communication becomes commonplace it will allow for safer pedestrian crossing of streets.
- Dedicated shared AV lanes on freeways will further encourage greater use and will reduce crashes.

Mental health

- If AVs make environments safer for pedestrians and bicyclists, and thus encouraging more active transportation, then as more people walk and bicycle, their mental health could improve due to increased levels of physical activity.
- As safety risks associated with driving decrease, stress should decrease and mental health will improve as a result of increased feelings of safety and security.
- As the stress of driving decreases, drivers' mental health will improve.

- As induced travel results in more vehicles on the streets, stress will increase and mental health will decrease due to higher levels of traffic and traffic related exposures (noise, pollution, etc.).
- If more people travel alone, social isolation will increase. If more people share rides, social isolation will decrease.
- Affordable driver-less "robot" deliveries of purchases will reduce social contact as people stay at home to shop instead of going to stores.

Possible impacts from 5G Wireless Technology

- Along with mobile phones and other uses of 5G, AV use of 5G may or may not cause cancer.

Health Equity Impacts

Access to transportation for all income levels

- Reductions in the cost of app-based ride services will provide a wider range of transportation choices, some significantly more convenient than public transit offers, for those without personal cars.
- Racial discrimination in taxi and app-based ride services will be largely eliminated without a driver to discriminate.
- Reductions in congestion will enable people from disadvantaged neighborhoods to access more jobs and other regional destinations.
- Induced travel will offset some of the benefits of reductions in congestion and may exacerbate congestion.
- As bicycling and walking become safer and more attractive, they will provide low-cost transportation options for short trips. They will also provide better access to public transit.
- Profit-based app-based ride services will gravitate to areas where demand is greatest, leaving some communities or neighborhoods underserved. This may happen in disadvantaged communities and in low-density suburban and rural neighborhoods.
- As public transit loses passengers to app-based ride services, the quality will decline, making public transit less convenient. This may be partially offset by the cost of transit significantly decreasing without the need to pay drivers.
- Increases in subsidies for public transit will offset some or all of the loss of convenience, service and thereby ridership. Without drivers to pay, subsidies for public transit will go much further and may lead to an overall increase in transit service.
- Special access card services will enable people without credit cards or smart phones full access to app-based ride services.

Cost of using AVs

- The cost of personally-owned vehicles will increase with the cost of AV technology. Current estimates for the additional cost of AV technology are $5,000 to $10,000 per vehicle in the next decade. If AVs are electric, this will add another $10,000 to the cost of a vehicle in the earlier years. By 2050 the total cost of the AV technology and electrification should come down to $10,000.[36]
- People with relatively higher incomes will have access to transportation that is convenient with the time cost advantages of not having to drive.
- Reductions in the cost of app-based ride services will enable some who currently spend a large portion of their take-home income on auto ownership, to opt out of ownership.

Distribution of transportation services

- Reductions in the cost of app-based ride services will provide a wider range of transportation choices to people in many neighborhoods and communities. This will improve access to jobs, services, and shopping choices.
- More urban areas may have some additional public transit.
- Profit-based app-based ride services will gravitate to areas where demand is greatest, leaving some communities or neighborhoods underserved.

Accessibility and Mobility for people with disabilities

- The cost to provide accessible vehicle services will decrease. People with disabilities who can afford it will have more transportation services available where it is profitable to provide accessible vehicles.
- Neighborhoods and communities where it is less profitable to provide accessible services will have few additional options for people with disabilities.
- Low-income people with disabilities may not be able to afford some accessible services.
- Special accessibility provisions for people who typically need assistance boarding and disembarking increase the number of people who can use them.
- Language barriers will prevent some people from using app-based ride services.

Accessibility and Mobility for older adults and children too young to drive

- Older adults who do not drive and children too young to drive will have new transportation services available to them.
- Older adults will regain some of the independence they lost (i.e., due to losing their ability to drive).
- Access to new transportation options for these people will be limited to those who can afford them.

Rural equity issues

- Rural areas will have fewer options for shared transportation than urban areas due to the lack of critical mass to share rides. Therefore, personally-owned vehicles will remain more prevalent in rural areas.
- The additional cost of AVs will postpone widespread adoption of personal AV ownership. Human-driven vehicles will remain longer in rural areas.
- As a higher proportion of people in rural areas will have personally-owned vehicles, they will be less able to take advantage of the lower cost of app-based ride services.
- Cost reductions of app-based ride services will provide some people with transportation options they do not currently have. This will be most useful to older adults who do not drive, children too young to drive, and people with disabilities that prevent them from driving.

Job losses from automation

- A high percentage of TNC drivers, taxi drivers, bus drivers, and other delivery drivers will lose their jobs and be left to search for jobs in a market that may not match their skills. Some may maintain jobs with parcel delivery as people may be needed to load and unload the goods.

Exposure to traffic and associated impacts

- Induced travel will increase exposure to emissions, congestion, crashes and noise for everyone.
- People in urban areas and those living closest to freeways and other areas of high traffic will have the greatest exposure to emissions and noise.

In-vehicle personal safety for passengers

- With special safety measures, a smaller number of passengers (compared to Scenario 1) will become victims of crime while riding in shared ride vehicles.
- With special safety measures, a smaller number of passengers (compared to Scenario 1) will feel vulnerable to crime while riding in shared ride vehicles.
- With special safety measures, a smaller number of passengers (compared to Scenario 1) will not enter into ride sharing situations where they do not feel safe. Those that do will have to pay a higher price to use more expensive transportation, but they will have more transportation options than without AVs.

SCENARIO 3: ASSERTIVE POLICIES ENACTED TO ACHIEVE HEALTH AND EQUITY BENEFITS OF AVS

Health Impacts

Impact on active transportation

- Bicycling and walking will become safer and more attractive, and many more people will engage.
- As incentives reduce VMT, streets will become safer and more attractive to bicycle or walk along.
- As incentives reduce VMT, and as AVs require less space on the streets, communities will be able to implement road diets (reduce the number of travel lanes) on many streets. This space may provide for better bicycle facilities and wider sidewalks, thereby making bicycling and walking safer and more attractive.
- As ridesharing increases, fewer people will own vehicles, and the demand for parking will significantly decrease. This will allow for even more street space to be used by people on bicycles or walking.
- As space on streets is repurposed to people, streets will become livelier and increasingly attractive to walk and bicycle along. More streets will become social spaces.
- As pedestrian/bicycle-to-vehicle communication becomes commonplace, walking and bicycling will become safer. This will increase the number of people walking and bicycling.
- As pedestrian-to-vehicle communication becomes commonplace, it will allow for safer and more convenient pedestrian crossing of streets, thereby increasing the number of people walking.
- As land use planning promotes more compact development, more destinations will come within walking and bicycling distance.

GHGs and air pollution

- As all vehicles become electric, and most or all electricity is generated by clean sources, GHGs and air pollution will significantly decrease. This will be both on an ambient level, and on the local level.
- VMT will significantly decrease as:
  - Pricing, time, and locational incentives encourage maximum ridesharing
  - More people walk and bicycle
  - Land use planning encourages more compact development

Traffic Safety

- AVs will significantly reduce the number of crashes that are presently caused by human error.
- As pedestrian/bicycle-to-vehicle communication becomes commonplace, walking and bicycling will become safer.
- As pedestrian-to-vehicle communication becomes commonplace, it will allow for safer pedestrian crossing of streets.
- Lane clearance technology will provide faster access for emergency vehicles.

Mental health

- If AVs make environments safer for pedestrians and bicyclists, and thus encouraging more active transportation, then as more people walk and bicycle, their mental health could improve due to increased levels of physical activity.
- As safety risks associated with driving decrease, stress should decrease and mental health will improve as a result of increased feelings of safety and security.

- As the stress of driving decreases, drivers' mental health will improve.
- As induced travel results in more vehicles on the streets, stress will increase and mental health will decrease due to higher levels of traffic and traffic related exposures (noise, pollution, etc.).
- If more people travel alone, social isolation will increase. If more people share rides, social isolation will decrease.
- Affordable driver-less "robot" deliveries of purchases will reduce social contact as people stay at home to shop instead of going to stores.
- As cities reclaim street space for walking, bicycling and social space, social contacts will increase.

Possible impacts from 5G Wireless Technology

- As policy ensures that 5G, or other transmission technology, cannot be widely used until it is known to be safe, there will be no increases in cancer from it.

Health Equity Impacts

Access to transportation for all income levels

- Reductions in the cost of app-based ride services will provide a wider range of transportation choices, some significantly more convenient than public transit offers for those without personal cars.
- Racial discrimination in taxi and app-based ride services will be largely eliminated with no driver to discriminate.
- Reductions in congestion will enable people from disadvantaged neighborhoods to access more jobs and other regional destinations.
- As many more ridesharing and transit services become available, people from disadvantaged neighborhoods will have greater access to jobs and other regional destinations.
- As bicycling and walking become safer and more attractive, they will provide low-cost transportation options for short trips. They will also provide better access to public transit.
- As pricing, time, and location incentives are provided for ridesharing, new convenient and inexpensive transportation options will become available.
- As land use planning promotes compact development, and little to no parking is needed in new development, the cost to build housing will come down.
- As the cost to build housing comes down, more people will be able to afford to live in neighborhoods previously too expensive for them.
- As more people live in compact neighborhoods, walking and bicycling will become more convenient.
- As little parking will be needed, existing parking structures and lots can be converted to other uses such as housing or parks.
- Special access card services will enable people without credit cards or smart phones full access to app-based ride services.

Cost of using AVs

- The cost of personally-owned vehicles will increase with the cost of AV technology. Current estimates for the additional cost of AV technology are $5,000 to $10,000 per vehicle in the next decade. If AVs are electric, this will add another $10,000 to the cost of a vehicle in the earlier years. By 2050 the total cost of the AV technology and electrification should come down to $10,000.[36]
- People with relatively higher incomes will have access to transportation that is convenient with the time cost advantages of not having to drive.

- Reductions in the cost of app-based ride services will enable some who currently spend a large portion of their take-home income on auto ownership to opt out of ownership.
- As pricing, time, and location incentives enable a much greater array of transportation options, fewer and fewer people will need to have their own vehicles. Vehicle ownership will become unnecessary for most people, especially in more urbanized areas.

Distribution of transportation services

- Reductions in the cost of app-based ride services will provide a wider range of transportation choices to people in many neighborhoods and communities. This will improve access to jobs, services, and shopping choices.
- As pricing, time, and location incentives create more transportation options, these will spread throughout urban areas, and to suburban and rural areas.

Accessibility and mobility for people with disabilities

- The cost to provide accessible vehicle services will decrease.
- Requirements for an adequate number of vehicles to become accessible will increase convenience for people with disabilities.
- As pricing, time, and location incentives create more transportation options, people with disabilities will have more options and more affordable options.
- Special accessibility provisions for people who typically need assistance boarding and disembarking increase the number of people who can use them.
- Special language provisions on public transit and ride services will reduce barriers to people who speak languages other than English.

Accessibility and mobility for older adults and children too young to drive

- Older adults who do not drive and children too young to drive will have many new transportation services available to them.
- Older adults will regain some of the independence they lost (i.e., due to losing their ability to drive).
- As the array and cost of transportation options expands, more older adults and children will be able to afford them.

Rural equity issues

- Rural areas will have fewer options for shared transportation than urban areas due to the lack of critical mass to share rides. Therefore, personally-owned vehicles will remain more prevalent in rural areas.
- The additional cost of AVs will postpone widespread adoption of personal ownership of AVs. Human-driven vehicles will remain longer in rural areas.
- As the array and cost of transportation options expands, more people in rural areas will have access to them.
- Cost reductions of app-based ride services will provide some people with transportation options they do not currently have. This will be most useful to older adults who do not drive, children too young to drive, and people with disabilities that prevent them from driving.
- Subsidies will provide more transit services to rural areas. As the cost of operating driverless buses will be low, the subsidies needed should be relatively modest. These will likely be microbuses sized appropriately for the critical masses present in rural areas.

Job losses from automation

- A high percentage of TNC drivers, taxi drivers, bus drivers, and other delivery drivers will lose their jobs and be left to search for jobs in a market that may not match their skills. Some may maintain jobs with parcel delivery as people may be needed to load and unload the goods.
- As the number of vehicles travelling will significantly decrease, fewer jobs will be available to people who manufacture and service vehicles, such as assembly line workers, mechanics, and car washers.
- Job training programs will prepare people for jobs related to AVs, and other fields appropriate for their education.
- Industrial policy will be specifically designed to create jobs for people who lose jobs to automation.

Exposure to traffic and associated impacts

- Electrification of vehicles will nearly eliminate noise and emissions to those exposed to vehicle travel.
- As VMT decreases, exposure to noise, crashes, congestion and emissions will decrease.
- People in urban areas and those living closest to freeways and other areas of high traffic will benefit the most.

In-vehicle personal safety for passengers

- With special safety measures, a smaller number of passengers (compared to Scenario 1) will become victims of crime while riding in shared ride vehicles.
- With special safety measures, a smaller number of passengers (compared to Scenario 1) will feel vulnerable to crime while riding in shared ride vehicles.
- With special safety measures, a smaller number of passengers (compared to Scenario 1) will not enter into ride sharing situations where they do not feel safe. Those that do will have to pay a higher price to use more expensive transportation, but they will have more transportation options than without AVs.

The following tables summarize the outcomes of these three scenarios. To reiterate, these tables are based on speculation and their contents are highly debatable.

POSITIVE IMPACT	NEGATIVE IMPACT	NEUTRAL/ NOT CLEAR/ NOT APPLICABLE

Table 1: Health Impacts

Impact on Active Transportation

	SCENARIO 1	SCENARIO 2	SCENARIO 3
Safer to walk/bike			
Increase in walking/biking related to safety gain			
Impact from volume of vehicles			
Transit support reduces vehicles			
Incentives reduce VMT and increase safety			
Road diets allocate more space to walk/bike			
Streets become livelier			
Safer due to vehicle-to-pedestrian/ bicycle communication			
Vehicle-to-pedestrian communication makes streets safer to cross			
Land use planning reduces walking/bicycling distance			

Table 2: Health Impacts

Greenhouse Gases and Air Pollution

	SCENARIO 1	SCENARIO 2	SCENARIO 3
VMT increases			
Suburban sprawl further increases VMT			
Suburban form reduces walking/biking/transit			
Zero-occupant vehicles increase VMT			
Transit ridership decreases			
People share rides more for commuting			
Transit support offsets some ridership loss			
More electric vehicles			
All electric vehicles			
Incentives for ridesharing reduce VMT			
Increase in walk/bike reduce VMT			
Land use planning reduces VMT			

Table 3: Health Impacts

Traffic Safety

	SCENARIO 1	SCENARIO 2	SCENARIO 3
Reduce crashes caused by human error			
Increase crashes if technology not ready			
Pedestrian/bicycle-to-vehicle communication increases safety			
Pedestrian-to-vehicle communication improves street crossings			
Lane clearance technology provides faster emergency access			

POSITIVE IMPACT | NEGATIVE IMPACT | NEUTRAL/ NOT CLEAR/ NOT APPLICABLE

Table 4: Health Impacts

Mental Health

	SCENARIO 1	SCENARIO 2	SCENARIO 3
Greater use of active transportation			
Safety risks decrease causing a decrease in stress			
Less driving reduces stress			
Induced travel causes stress			
Social contact increases from more ride sharing			
Social contact decreases from more solo travelling			
Robot deliveries reduce social contact in stores			
Reclaiming street space for social space increases social contact			

Table 5: Health Impacts

Potential Impact from 5G Wireless Tech

	SCENARIO 1	SCENARIO 2	SCENARIO 3
Cancer caused by 5G			
Cancer not caused by 5G			

POSITIVE IMPACT | NEGATIVE IMPACT | NEUTRAL/ NOT CLEAR/ NOT APPLICABLE

Table 6: Health Equity Impacts

Access to Transportation for All Income Levels

	SCENARIO 1	SCENARIO 2	SCENARIO 3
Reductions in app-based rides improve access			
Racial discrimination from drivers eliminated			
Reductions in congestion improve access			
Induced travel offsets congestion benefits			
Bicycling and walking improve low-cost options			
Profit-based services leave some areas underserved			
Public transit ridership and service decline			
Services unavailable to those without credit cards/smart phones			
Transit subsidies increase service			
Access card services to those without credit cards/smart phones			
More ride sharing services available improve access			
Bicycling and walking become safer and provide low-cost option			
Pricing, time, & location incentives provide affordable options			
Land use planning brings cost of building housing down			
Lower building costs enable people to live in more neighborhoods			
Parking lots and structures converted to housing or parks			

Table 7: Health Equity Impacts

Cost of Using Autonomous Vehicles

	SCENARIO 1	SCENARIO 2	SCENARIO 3
Cost to personally-owned vehicles increases			
People with higher incomes have better options			
Reduction in cost of ride services provides more low-cost options			
Pricing, time, and location incentives provide adequate options			

Table 8: Health Equity Impacts

Distribution of Transportation Services

	SCENARIO 1	SCENARIO 2	SCENARIO 3
Reductions in app-based rides improve access			
Declines in transit (some in urban, more in other areas)			
Pricing, time & location incentives increase transportation options			
Profit-based ride services leave low-demand areas underserved			

POSITIVE IMPACT | NEGATIVE IMPACT | NEUTRAL/ NOT CLEAR/ NOT APPLICABLE

Table 9: Health Equity Impacts

Accessibility/Mobility for People with Disabilities

	SCENARIO 1	SCENARIO 2	SCENARIO 3
Cost of accessible service decreases			
Accessible services more available in profitable areas			
Services may be too expensive for some low-income people			
Language barriers prevent some people from using ride services			
Requirements ensure adequate number of accessible vehicles			
Pricing, time, and location incentives create more options			
With special provisions for people who need assistance, more can ride			
Special language provisions eliminate language barriers			

Table 10: Health Equity Impacts

Accessibility/Mobility for Older Adults and Children

	SCENARIO 1	SCENARIO 2	SCENARIO 3
Older adults/children have new transportation options			
Older adults regain independence			
Access limited to those who can afford services			
Transportation options expand and become more affordable			

POSITIVE IMPACT | NEGATIVE IMPACT | NEUTRAL/ NOT CLEAR/ NOT APPLICABLE

Table 11: Health Equity Impacts

Rural Equity Issues

	SCENARIO 1	SCENARIO 2	SCENARIO 3
Rural areas have fewer options than urban areas			
Cost of AVs will postpone their use and advantages in rural areas			
More people own vehicles means less access to lower-cost options			
Low cost of ride services will provide people with new options			
As transportation services expand people will have more options			
With subsidies, more transit service will become available			

Table 12: Health Equity Impacts

Job Losses from Automation

	SCENARIO 1	SCENARIO 2	SCENARIO 3
A high % of TNC, taxi, bus, delivery drivers will lose their jobs			
People who manufacture and service cars will lose jobs			
Job training prepares people for other jobs			
Industrial policy creates jobs for those lost to automation			

POSITIVE IMPACT | NEGATIVE IMPACT | NEUTRAL/ NOT CLEAR/ NOT APPLICABLE

Table 13: Health Equity Impacts

Exposure to Traffic and Associated Impacts

	SCENARIO 1	SCENARIO 2	SCENARIO 3
Induced travel increases emissions, noise, congestion and crashes			
People in urban areas and near freeways will have most exposure			
Electrification will nearly eliminate noise and emissions			
As VMT decreases, exposure to noise, congestion and emissions will decrease			
People in urban areas and near freeways will benefit most			

Table 14: Health Equity Impacts

Personal Safety for Vulnerable Passengers

	SCENARIO 1	SCENARIO 2	SCENARIO 3
Vulnerable passengers experience crime on shared ride vehicles			
Vulnerable passengers feel unsafe on shared ride vehicles			
Vulnerable passengers won't share some rides; pay for more expensive transportation			
Safety measures in place; ridesharing is safer than without these measures			
Safety measures in place; ridesharing feels safer than without these measures			
Safety measures in place; some vulnerable users ride share			

POSITIVE IMPACT | NEGATIVE IMPACT | NEUTRAL/ NOT CLEAR/ NOT APPLICABLE

PUBLIC POLICIES TO ADDRESS HEALTH AND HEALTH EQUITY OUTCOMES

The aforementioned scenarios vary dramatically in their projected outcomes. The outcomes will be determined, to a large degree, on public policies that guide how AVs are integrated within our existing transportation systems.

As such, it is important for California to determine the outcomes we want and develop the corresponding public policies to ensure the highest likelihood of achieving these outcomes. In fact, each level of government, including the federal, state, metropolitan planning organization, county, and city level, will likely play a separate and key role in developing sound public policies regarding AVs. The following are public policy considerations that could play a central role in advancing public health and equity:

POLICIES TO ENCOURAGE SHARING OF RIDES

The more transportation is shared with people riding in multi-passenger cars, vans, buses and trains, the more we can:

- Encourage active transportation by having more space available in our streets and reducing exposure to traffic
- Reduce GHGs and air pollution
- Improve safety with fewer vehicles
- Reduce congestion and thereby improve access for people of all income levels
- Reduce the cost of transportation by having more options available
- Better distribute transportation services by having more options available
- Provide mobility for people with disabilities, older adults, and children by having more options available
- Provide more options and lower cost options to rural communities
- Reduce exposure to noise, emissions, congestion and crashes

The following three strategies can encourage ride sharing.

Pricing

People respond to pricing strategies. They will gravitate to lower cost options, but only if the price advantage/disadvantage is strong enough, and if they have attractive lower cost alternatives. The following principles should guide pricing:

- **Charge by the occupancy of the vehicle and the distance travelled.** As AV technology will essentially be computerized transportation, pricing can be scaled according to the number of passengers. People travelling alone should pay a steep price per mile. People on public transit would pay the least. The cost per person of public transit would be so low, making it free may make sense. The administrative costs of collecting and processing the revenue coupled with the time it takes for people to pay a fare while boarding a bus may outweigh the benefit of charging a fare. Free fare transit that one can easily hop on and get off would provide a strong incentive to ride.

- **Aim to capture trips on ridesharing and micro-transit.** Many trips lend themselves to three-person, six-person or 12-passenger vehicles better than fixed-route transit. Fixed-route transit often doesn't serve the scattered nature of our daily trips that take place on numerous streets and roads. These trips are served by the same pricing principle that pays by the distance, and by the number of people in the vehicle.
- **Include a charge based on the amount of GHGs and air emissions created by the vehicle.** This would incentivize using electric vehicles and cause people to right-size the vehicle they use so that they choose one no heavier than necessary. Heavier vehicles use more energy and thereby emit more GHGs and other air pollution.
- **Price empty seats and empty cargo space**. This will encourage ride services to fill seats with passengers and reduce zero-occupant VMT.
- **Price to pay for the cost to society for streets and roads.** Recent years have seen a growing reliance on sales taxes and other revenue to pay for streets, roads, and transportation services, and less reliance on the traditional user fees: gasoline taxes. As we electrify transportation, we will generate even less revenue from gasoline sales taxes to pay for our transportation. We will need to replace these taxes with another source. The pricing strategies listed here can fill that role. Further, if we collect enough revenue, we can replace regressive taxes, such as sales taxes, with more equitable user fees. We may also want to use revenue to subsidize transit, walking, and bicycling, as well as services to people with disadvantages.
- Pricing will be attached to each vehicle, not to the passenger. The public will be more accepting of a mechanism that preserves privacy than one that they perceive is too intrusive.
- Hypothetically, pricing policies could be enacted now with human-driven vehicles and could address some of the same issues. But they are politically unpopular. As people opt for transportation as a service instead of personal ownership, they will likely pay for these costs as part of their fares and political opposition will likely diminish. Paying for what we use and the burdens we place on our transportation system, and on our health and environment through GHG emissions and air pollution, is arguably the fairest way to price systems. Doing so will also enable us to provide convenient low-cost options for low-income people.

Providing time advantages

We currently provide time advantages using dedicated lanes and signal priority treatments. High-occupancy vehicle lanes on freeways provide time advantages to people in carpools, vanpools, and buses. They allow these people to go faster, as they won't get stuck in as much congestion as they would in the other lanes. Bus lanes on surface streets allow buses to move faster and more predictably. We allow buses to avoid more delay with signal priority treatments that give them faster and longer green signal time.

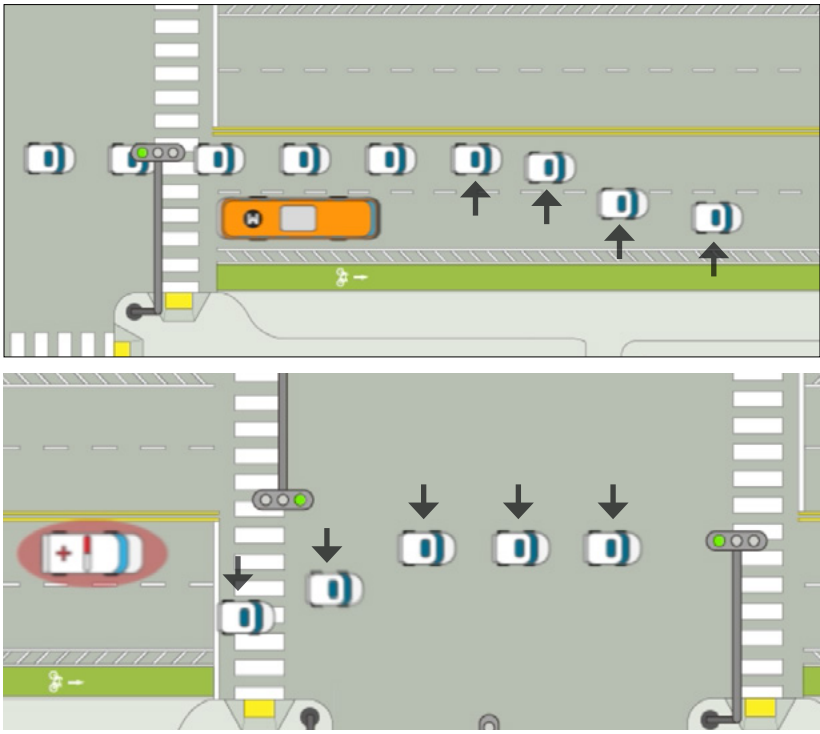
With AV technology, we can continue these time advantages with dedicated lanes. However, this technology opens up another powerful strategy: *lane clearance technology*. Without full-time dedicated lanes, we can use vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication to give preference to selected vehicles, such as buses. As buses are coming, the other vehicles can automatically clear the lane for the bus and return to the lane after the bus has passed. This is virtual infrastructure and requires no expensive, time consuming construction of physical infrastructure. In very little time, each of our bus routes that run on multi-lane streets could

become transit-priority routes that allow buses to travel faster than other vehicles. This would become possible after all vehicles are AVs, or at a time when only AVs could use this lane.

Moreover, we could define the priority vehicle eligible for lane clearance as a 40-passenger bus, but also an 18-passenger shuttle or a 12-passenger microbus, depending on the amount of space available in the lane. AV technology brings full computer programmable capabilities. We could even scale time advantages according to the number of people in the vehicle. The 40-passenger bus could have priority over the 18-passenger shuttle, which has priority over the 12-passenger microbus, which has priority over the six-passenger van, which has priority over the three-passenger carpool, which has priority over the solo-passenger car. The higher-occupancy the vehicle you travel in, the greater the time advantage you get.

Further, we could set speeds according to vehicle priority. For example, priority vehicles can travel 35 miles per hour on primary streets, while low-occupancy vehicles travel at 25 mph.

Once lane clearance technology has proven to be reliable virtual infrastructure, we could also apply it to freeways and allow public buses to travel at high speeds, perhaps 100 mph, 120 mph, or even 150 mph. Our regional freeway networks in the San Francisco Bay Area, the Los Angeles region, San Diego County, and Sacramento could become high-speed transit networks with transfer stations at interchanges and stations along the way that connect to local bus service, ride services, bike sharing, and the like. Inter-regional high-speed buses could link our regions. In a short time, with little infrastructure cost, we could have high-speed transit connecting from San Diego to the Bay Area and Sacramento. Once a passenger travels from one region to another, they would be met with regional high-speed service that drops them off at a local station close to their destination where they board local transportation.



Lane clearance technology could be used to clear lanes automatically when a bus or emergency vehicle is approaching.

With such time advantages, many trips will be made faster by higher-occupancy vehicles, or at least in a competitive time with low-occupancy options.

With lane clearance technology, we can also provide priority to emergency vehicles, allowing them to provide ambulatory services and fire services within a safer time frame.

Providing locational incentives

We could provide locational incentives by allowing only preferred vehicles access to pre-determined areas. For example, we could restrict access to downtown areas to vehicles of 12-passengers or more. We may designate which areas have such restrictions, and the number of passengers. We could also vary this by time of day, or day of the week. Again, using the computer technology on the AVs, this could be done, or changed with a central computer that communicates with each vehicle. Little new infrastructure would be needed.

As more people use AV transportation services, curb space will become more valuable in urban settings. Those travelling in shared vehicles could be given the most convenient curb space for pick-up and drop-off. The curb space can also be priced.

Some have advocated the idea that only shared AVs be permitted to operate on streets and highways.[9] This is another policy for consideration that falls under the umbrella of providing locational incentives.

POLICIES TO ELECTRIFY TRANSPORTATION WITH CLEAN ENERGY SOURCES

Electrifying transportation will be crucial to reducing GHGs and air pollution. It will also address equity issues related exposure to air pollution and noise.

California can speed electrification of vehicles by providing subsidies or tax credits to purchase EVs as we now do. This could be accelerated by increasing the subsidies.

We can also simply mandate that after a certain date all vehicles must run on electricity either by battery power or hydrogen fuel cells.

An all-electric California will need plenty of widely-distributed charging stations. These stations will also need to be fast charging to enable EVs to become practical for a wide variety of trips. Alternatively, it may become possible to recharge vehicles with wireless technology.

The amount of GHGs and air emissions attributable to EVs will depend on the source of electrical energy that charges them. To reap the highest reductions in GHGs and air pollution, we will need to switch to clean energy sources. So, California's clean energy policies link closely with EV and AV strategies.

MISCELLANEOUS POLICIES

A variety of other policies can address other health and equity issues. They include:

- Policies to ensure safe operation of AVs
  - Testing of AVs should gradually prove their safety, and care should be taken before AVs are permitted to operate throughout our transportation network. We should allow AVs to operate in a carefully crafted and graduated set of situations, streets, and highways.
  - Safety equipment should be required as needed.
  - AVs should be required to have "black boxes" that record crashes so that we can learn from them and correct deficiencies in the technology.
- Policies to ensure access to convenient and affordable transportation for all income levels
  - Research should be conducted to ensure that disadvantaged neighborhoods receive the transportation services they need.
  - Transportation access cards should be provided that enable people without credit cards or smart phones to use any transportation service.
  - Subsidies may be needed for students, retirees, and low-income people to ensure that they have good access transportation services. These may be less necessary with good pricing strategies.
  - Subsidies may be needed for public transportation to ensure that it provides services where needed.
- Access to convenient and affordable transportation for people with disabilities
  - Ride services should be required to provide an adequate portion of their fleets to ensure that vehicles are accessible to people with mobility impairments. These should include special provisions for people who typically need assistance

boarding and disembarking. These may be vehicle equipment requirements, and/or requirements for a certain number of vehicles to have a person there to help.

- Ride services should be required to provide an adequate portion of their fleets to be accessible to people with hearing and sight impairments. Travel information should be provided in both audible and visual forms.
- Language options should be provided throughout our transportation system that provide information about services.

O Access to convenient and affordable transportation for people in rural areas

- Subsidies will likely be needed to provide transit services in rural areas. Due to the low cost of AVs, these subsidies may be modest.

O Access to job training and new jobs to replace those lost to automation

- California should thoroughly research the issue of job replacement for drivers and others who will lose their jobs to AVs. This research should recommend the jobs that will most logically replace lost jobs based on education level, location, and other relevant factors, along with the job training that will be needed.
- Once we understand what jobs will be needed, we should adopt industrial policies to create those jobs.
- Once we understand what jobs will be needed, we should make the needed job training available and affordable.

O Land use policies that reduce the need for travel, and make development conducive to walking, bicycling, and transit

- Local governments should enact land use policies that mold new development into compact, mixed land uses.
- Local governments should enact land use policies that encourage development of affordable housing.

New land-use policies will make streets more conducive to walking and cycling.

- Local governments should reduce or eliminate parking requirements in new developments and allow any new parking to be convertible to other land uses as it becomes obsolete.

O 5G wireless technology should be permitted for widespread adoption only after research demonstrates that it is safe.

O Efforts should be made to improve personal safety for people sharing rides. Some preliminary measures might be:

- Requiring police call buttons that can be indiscreetly pushed on all vehicles that pick up multiple passengers.
- Requiring cameras on all vehicles that pick up multiple passengers.
- Requiring data sharing with the police to identify who summoned a ride when a crime has taken place.
- When a police call button has been pushed redirecting the vehicle route to meet a police car.
- Ensure that options are available for people to choose who they share rides with. For example, someone could order a shared ride only with women.

CONCLUSION

AVs will introduce extremely disruptive technology to California.

On one hand, they will bring potential to significantly alleviate transportation, health, and equity problems. On the other hand, they will also bring significant potential to exacerbate transportation, health, and equity problems. Public policies can help to ensure that the widespread deployment of this new technology can help to advance public health and social equity.

As a state, we need to determine the goals that we want this technology to achieve for us and enact public policies to guide the outcomes to meet those goals. There are many unknowns, and we are just at the beginning of determining the policy direction we should take. Over time, our needed public policies will become clearer. Given what is known now, this paper presents policy options that appear to steer us in the desired direction to meet our health and equity goals.