3 REVOLUTIONS Sharing, Electrification and Automation

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Capturing the Climate Benefits of Autonomous Vehicles

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In November 2016, the Institute of Transportation Studies at the University of California, Davis (ITS-Davis) convened leading academic, government, private industry, and public interest stakeholders to explore science-based policies that could steer the three transportation revolutions- shared mobility, electrification, and autonomous vehicles, toward the public interest.

This policy brief reflects the opinions of the authors and not UC Davis. This brief is one in a series that presents a range of policy concepts, recommendations and research needs discussed at the Three Revolutions Conference.

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Summary

Autonomous vehicles could reverse years of progress in reducing greenhouse gas emissions or provide new opportunities for accelerating emission reductions. Policy options that pair autonomous technology with low-emission electric vehicles and shared-ride services can ensure climate benefits are realized from AV technology and potential emissions increases are minimized.

Introduction

This brief examines potential policy options outside of existing auto manufacturer vehicle emissions rules to ensure deployment of AVs results in positive climate outcomes. The policies include occupancy requirements, performance standards and fee-based approaches that would affect decisions about how AVs are used, complementing existing policies such as the zero emission vehicle program and greenhouse gas standards. To determine the appropriateness, effectiveness and timing of the policy concepts presented, further research is needed to understand the implications of AV and EV technology on the economics of ride-hailing and ride-sharing services, potential consumer responses to these services and

AV technology for personal use, and the emissions implications of various outcomes.

Background

Existing literature examining the potential climate impacts of AVs shows a wide range of possible futures, from more than a doubling of emissions to a reduction of emissions on the order of 90 percent (Greenblatt and Saxana 2015, Brown et al. 2014, Wadud et al. 2016). The high-emissions scenarios assume a large increase in vehicle miles traveled (VMT) resulting from low-cost AV technology coupled with internal combustion engine vehicles. For instance, in such a scenario, it could be commonplace for personally owned AVs to shuttle individual family members back and forth from school, work and other activities allowing otherwise unproductive time spent in vehicles to become more valuable and encouraging increases in the amount of travel or urban sprawl.

The low-emissions scenarios envision a future of shared, electric and highly efficient (i.e. reduced weight, right-sizing, reduced congestion, platooning, etc.) AVs allowing for rapid vehicle turnover and new technology dissemination in the vehicle fleet. Vehicle charging would be managed in order to cut carbon emissions, optimize renewables integration and provide ancillary electricity grid services. In this scenario, families could rely on electric-car ride-sharing services that provide predictable and on-demand transportation rather than owning a car themselves. Similarly, individual autonomous EV owners might rent their car out to such a service when they're not using it.

Regardless of the likelihood of these outcomes, which is uncertain, it is clear from global climate modeling that a low-emission outcome is required. Multiple possible policy levers exist to make a low-emission outcome more likely, including leveraging existing automaker-centric regulatory structures to ensure the vehicles themselves are low emissions. Additionally, we can consider new policies designed to directly impact the use of AVs to ensure they are used in a way that maximizes climate benefits. While a combination of policies is likely ultimately necessary, this policy brief primarily explores options for impacting the decisions about how AVs are used, rather than how they are manufactured.

Findings

Pairing the use of AVs with ride-sharing services (Uber Pool, Lyft Line) and electrification could increase mobility options while reducing emissions.

Changes in VMT resulting from existing ride-hailing fleets such as Uber or Lyft is a current area of research. On the one hand, ride-hailing services or transportation network companies (TNCs) like Uber and Lyft can provide last mile services to and from transit hubs, helping to make transit more accessible.[1] On the other hand, these services may also be displacing transit, walking or biking trips because of their convenience and modest cost.

Car ownership may also decrease with the availability of TNCs, car-sharing and other transportation options which historically resulted in lower individual VMT as a result of paying the price for every trip rather than having the sunk cost of vehicle ownership (e.g. purchase price and insurance). However, these mobility services are ultimately meant to increase mobility options, not reduce the number of trips people take, so it is unclear that a reduction in car ownership and the availability of greater mobility options will lead to a significant decrease in overall VMT.

However, ride-sharing provides an opportunity for reducing overall vehicle trips and lowering emissions per passenger mile while increasing passenger trips (i.e. improving mobility rather than reducing it). Pairing AV technology with EVs, particularly when powered with clean electricity, would further reduce per passenger

1 For example, Lyft reports that 24% of Lyft rides in San Francisco start or end near transit stations and 25% of surveyed riders say they use Lyft to connect to public transit. http://take.lyft.com/friendswithtransit/ Accessed 11/3/2016.

mile emissions (UCS 2015).

AVs may facilitate vehicle electrification and smart charging in ride-hailing and shared-ride fleets, though the speed at which this will occur is uncertain.

Shared-ride services coupled with electric drive AVs and low carbon electricity offer significant potential for positive climate outcomes (Brown et. al 2014). AVs in fleets could facilitate smart charging that cut costs while supporting the grid of the future. However there is little empirical evidence at this stage of the market to make any firm conclusions about the inevitability of a shared, electric, smart-charged, autonomous, ride-hailing future and perhaps more importantly, the speed at which it would occur absent policy drivers.

Lower operating costs for EVs resulting from savings on maintenance and low-cost electricity are cited as factors that will drive the industry toward electric AVs (Greenblatt and Saxena 2015). While these factors will likely influence long-term trends, it is unclear how quickly this transition might take place or how significant the existing barriers are to this outcome. Electric AVs for shared-ride fleets will need conveniently located charging infrastructure that facilitates smart charging.

It's not clear who should or will pay the significant up-front investment for this infrastructure: utilities that have access to capital and will benefit from smart charging; private charging infrastructure providers who see a potential return on investment; shared-ride fleets who may benefit from reduced operating costs (though the current model of driver ownership means TNCs do not directly pay operating expenses); automakers who may be compelled to sell more EVs; or public entities interested in the benefits of increased vehicle electrification.

The current business model of using personal vehicles for share-ride services is likely to evolve as AVs become available since a driver is no longer needed, adding further uncertainty for investment in charging infrastructure to support shared-ride electric AV fleets. Drivers could rent their AVs when not in use or TNCs may operate their own fleets of AVs. Home and public charging may be more important in one case, while dedicated charging stations may be more attractive in another.

Both gas-powered and electric-powered cars can be automated. In the near term, gasoline AVs requiring less upfront investment (i.e. lower initial vehicle cost and no new infrastructure needs) may prove more attractive to fleets despite the potential savings of electric AVs. For example, Uber is currently demonstrating gasoline-powered Volvo AV SUVs in Pittsburg (Vlasic 2016), and Ford has announced it will deploy an SAE level 4-capable vehicle by 2021 for ride-hailing service, but has made no mention of electrification and is currently using hybrid Fusions for AV testing (Ford 2016).

Some automakers are teaming up with ride-hailing services to encourage EV deployment in the current business model of using personally owned vehicles (Lyft/GM) through leasing arrangements with drivers. If these early deployments of EVs in ride-hailing services prove successful and cost-savings are realized, future electric AV deployment in these fleets may be more likely.

Current popularity of shared rides may be diminished with deployment of AVs in ride-hailing services.

The current pricing of shared rides provides an economic signal to consumers who may choose a shared ride for less cost in exchange for a longer ride and sharing space with strangers. AVs and EVs have the potential to significantly cut the cost of a ride by eliminating the labor cost of driving and lowering vehicle operating and maintenance costs. Depending on how this cost savings is translated to consumers, the economic signal to take a lower-carbon shared ride may be diminished as the introduction of AVs lowers overall trip costs.

Personally owned AVs for private use will increase VMT.

The ability to disengage from driving changes the value of time spent in a vehicle. This could lead to effects such as increased commute distances as housing choices change, more frequent long-distance car travel, or reduced transit use if parking and congestion are no longer a concern. And AVs could allow vehicle travel without any occupants (e.g. sending a vehicle on an errand, looking for parking, or circling the block while waiting for its owner), adding convenience for the owner but with the potential societal cost of increased congestion and emissions. On the other hand, a societal benefit of AVs would be to increase the mobility options for populations who are not currently able to get drivers' licenses due to disabilities, age, or other reasons. Any potential efficiency improvements resulting from personal use of AVs (e.g. platooning, efficient driving, etc.) could be overwhelmed by increases in VMT (Wadud et. al, 2016).

Policy Options for Positive Climate Outcomes of Self-driving Cars

To ensure positive climate outcomes from the deployment of AV technology, it is critical to look beyond existing policies targeted at how the vehicles are built and examine opportunities for influencing how AVs are used. AVs present numerous new opportunities for businesses and individuals to reimagine how they use the automobile. As such, fully-autonomous AVs (SAE level 4 or 5) capable of operating without driver intervention (SAE 2014) are unlikely to have an average use profile that looks similar to today's average new vehicle. And the largest climate risk of AVs is the increased VMT that could result from the use of the vehicles, an attribute of vehicle use that existing auto manufacturer standards do not address (for example, automakers are currently not held accountable for how the vehicle is used once it is sold, though durability and warranty requirements do offer protection against faulty emission controls).

TNCs, or ride-hailing fleets, are an early market driver for fully autonomous vehicles (Vlasic 2016) and could be an effective target of climate-focused policy making. While these companies do not currently own vehicles, as AVs come to fruition they are likely to be owned directly by TNCs or by others who are using the TNC platforms to operate their fleets.

These fleets will make decisions on the types of vehicles they employ and the pricing of the services they offer (single occupancy vs. shared, right-sized vehicles, electric vs. gasoline, etc.). These fleets are also likely to represent the vast share of early fully autonomous vehicle miles traveled both because of the economic advantage of reduced labor costs and the large investment these companies (Uber, Lyft, and many automakers) are already making in the technology.

Policy centered on fleet owners and their operations could effectively accelerate the adoption of electric AVs as well as increase the use of shared rides – two important outcomes needed for low-carbon deployment of AVs. Policies could also be directed at the personal use of AVs to ensure that the convenience of AV technology doesn't automatically lead to increased emissions and congestion.

With vehicles like the Chevy Bolt (238-mile EPA electric range) coming to market today, EV range is rapidly expanding. Fuel cell electric vehicles are also coming to market providing additional electric drivetrains options. Electric drivetrains on AVs would not necessarily limit their market introduction or utility, though charging and fueling infrastructure would need to be addressed. The following are policy options that could be explored to help ensure that AV technology is paired with low-emissions vehicle technology (electrification) and high-occupancy use (shared-ride services) to ensure that climate benefits are realized from AV technology or potential emissions increases are minimized.

- **AV Electric Vehicle Requirements**: Require that all AVs deployed are electric drive and powered by clean electricity. This requirement could be implemented immediately, phased in over some time period, or triggered after some level of initial deployment is reached. If AV technology proves highly desirable for convenience and safety reasons, such a policy would have the effect of increasing EV sales, improving economies of scale and lowering costs of the technology. On the other hand, this approach should avoid slowing the realization of the safety benefits of AVs.

- **Electric Passenger Mile Standards:** Set a requirement for an increasing share of passenger miles traveled (PMT) to be electric. Passenger miles traveled is the number of miles a vehicle travels (VMT) multiplied by the number of passengers in the vehicle. This type of policy would be more conducive to fleets operating AVs rather than personal vehicles. AV fleets could comply by increasing the number of electric AVs in their fleets, and would encourage ride-sharing in the electric AVs (i.e. a shared-ride in an electric AV would provide twice the electric PMT).

- **Carbon Intensity Performance Standard:** Set a requirement for a declining emissions intensity per passenger mile (e.g. grams CO2eq/passenger mile). This approach could allow for greater flexibility and allow incorporation of emissions from zero-occupancy vehicle travel and electricity choices for EV charging or other fuel choices, but be a less direct signal for electrification depending on the stringency of the standard. An intensity standard is also no guarantee that overall emissions from vehicles will decline, especially if VMT increases rapidly as a result of AVs. To provide a greater guarantee that overall emissions reductions stay on course, carbon intensity requirements could be adjusted regularly based on assessed VMT impacts of AV deployment. Alternatively, an emissions cap could also be considered.

- **Carbon fee:** A complementary policy to regulatory requirements could be a fee-based structure to provide a direct price signal related to the climate emissions of the use of AVs. A fee charged to the fleet operators based on the carbon intensity per passenger of the rides they deliver could provide a larger price differential or economic incentive to a consumer to choose the service having the lowest climate impact (i.e. shared ride) and also influence the technology deployment decisions of fleet operators (i.e. electric AVs). This approach could also incorporate a congestion fee as well.

- **Encourage smart charging of AVs in shared fleets:** To the extent that policies and market forces move self-driving vehicles toward electrification, complimentary policies that encourage smart charging of vehicles could further accelerate carbon emission reductions. For example, implementing price signals that effectively drive vehicle charging to occur when there is surplus power could facilitate greater integration of renewable energy sources on the utility grid.

- **Discourage zero-passenger miles:** One risk, as noted earlier, is that the convenience of owning an AV leads to increased vehicle trips with no occupant in the vehicle. These zero-occupancy miles are inevitable for fleets operating like taxis, where there are times between passengers. However, occupancy requirements could be useful in preventing some increases in VMT for personal-use AVs. For example, requiring a human passenger to be in the vehicle at all times could limit the risk of vehicles operating with no passengers solely for personal convenience, like circling the block while running an errand or eating dinner or sending a vehicle home to park and return to pick you up. This type of policy could help limit an increase in VMT from unoccupied vehicles, but would not mitigate the other potential VMT increases from personal-use of AV technology (increased sprawl, etc.). Others have suggested a temporary moratorium on personal-use AVs in order to allow time for testing and data gathering in more controlled fleet applications. Additionally, local or state governments could impose fees on AV owners and operators for zero-passenger miles to discourage congestion and pollution.

Policy Recommendations and Opportunities for Future Research

The policies described above are concepts that could be employed to make AV outcomes more positive for climate emissions and would complement existing auto manufacturer requirements, clean vehicle incentives, and other policies designed to deploy low-emission technologies.

Policy measures, like a vehicle occupancy requirement, could prevent undesirable outcomes of AV use such as a proliferation of unoccupied personal vehicle travel and could be implemented as a reasonable precaution. This type of policy, with appropriate provisions for fleet operated vehicles or other special use cases, would not restrict the deployment of AV technology but would provide assurances that initial deployment of AVs does not lead to a proliferation of zero-occupant vehicle travel and avoid challenges associated with interactions of unoccupied vehicles with other road users. This type of policy could also be adjusted over time as experience with the technology increases.

Other policies, including performance-based requirements or fees, require additional research and analysis as well as data acquisition as AV technologies come to market. The following are recommendations for developing a better understanding of the impact of AVs and to inform future policy making to ensure climate benefits result from the deployment of AVs.

1. **Research: Increase our understanding of the current impact of ride-hailing fleets on VMT, vehicle ownership, and transit use impacts.** Increasing mobility options through ride-hailing and ride-sharing fleets may reduce car ownership. And paying for transportation by trip rather than the sunk cost of vehicle-ownership could encourage reduced VMT or increased walking and biking. However, research on the impact of current ride-hailing and lower-cost ride-sharing services is limited. To understand how AVs might affect transportation decisions and emissions, a better understanding of how current mobility options are affecting emissions and VMT is required.

2. **Utilize pilot projects to better understand the potential for, and barriers to, ride-hailing services to integrate EVs, charging infrastructure, smart charging, and future AV use**. Pilot projects with cities, ride-hailing fleets, utilities, and EV manufacturers can help consumers, policymakers and businesses explore potential challenges to the deployment of EVs and charging infrastructure in shared-ride fleets. Such projects also provide an opportunity to gather and analyze data about vehicle use, inform future business cases and policy opportunities, and promote strategies for smart charging of ride-hailing vehicles to provide grid benefits. Results from these efforts could provide greater certainty around the likelihood of EV adoption in the absence of further policies.

3. **Research: Evaluate how the travel cost impacts of AVs are likely to affect the popularity of shared-ride services.** Eliminating the driver labor costs for ride-hailing services could dramatically lower the cost of a trip. This may encourage increased vehicle trips as well as discourage shared trips if the cost savings are diminished. More research is needed to determine what policies and appropriate level of stringency or cost differential are needed to encourage shared-rides under lower costs enabled by AVs.

4. **Research public perceptions of fairness and tradeoffs with AVs: AVs could be a particularly disruptive technology,** affecting not only the way we drive, but also the cost and level of access to mobility services and the potential to eliminate entire job categories from the economy. Further, increased vehicle safety may outweigh all other considerations related to this technology. The complex tradeoffs for AV adoption and increased personal convenience for those who can afford it may not be in line with goals for improving air quality and reducing emissions. It's therefore important to

understand how people's perception of fairness and tradeoffs related to AV adoption integrate their concerns about environmental benefits and costs associated with the technology.

5. **Ensure policies encourage the lowest carbon solution, equitable access to transportation and avoid unintended consequences.** Ride-hailing and ride-sharing fleets are a small percentage of overall VMT today but could increase substantially in the coming years. AVs could accelerate the share of VMT that is traveled by fleets of vehicles providing transportation services. Policies aimed at these fleets to promote shared rides and EV adoption will need to consider impact on overall transportation decisions. For example, if ride-hailing services prove to reduce vehicle ownership and reduce personal VMT even under future AV scenarios, climate-based pricing mechanism or policies aimed at fleets should be designed to avoid discouraging their use over current private vehicle ownership. Policies aimed at reducing climate emissions from AVs should also ensure that they increase equitable access to transportation rather than exacerbate current inequities.

6. **Access to Data: Evaluating the effectiveness of various policies and their impacts on different demographic groups and communities will require access to information about early AV use and existing ride-hailing and ride-sharing services.** Many of the policy concepts and future research described here will require information about how AVs are used including the miles they travel, their energy use or carbon emissions, their occupancy, and the communities and customers they serve. Without this information, it is difficult to assess current impacts of ride-hailing and ride-sharing fleets or design effective policy for the introduction of AVs. Establishing guidelines, best practices, or requirements for the sharing of AV data with the appropriate protections for data privacy and business competitiveness concerns is needed.

Conclusion

Policies that drive AV technology use toward low-emission outcomes are only one important consideration for AV deployment, but are critical to address prior to widespread availability of the technology. The next few years are a critical time for further research, data gathering, and pilot projects to develop expertise and understanding of how this technology might reshape the transportation landscape and how best to guide its deployment toward positive outcomes, not just for climate, but for communities as a whole.

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