Avoiding “potholes” in a self-driving future

Autonomous vehicles are not a panacea to issues plaguing transportation systems. Smart policies that are flexible enough for emerging technologies can help cities and states realize the benefits of these vehicles.

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There are as many predictions of when households may finally buy an autonomous vehicle (AV) as there are papers expecting this technology to solve transportation problems[1]. Most expect AVs will decrease crashes, and some expect emission, supply chain labor shortage, and (de)congestion benefits too[2]. If AVs are to transform passenger and freight mobility, there must be a paradigm shift. Else, cities will likely see a repeat of the issues that affect transportation systems today (e.g., congestion, emissions, air quality, funding insolvency, and crashes).

As people migrate to urban areas for jobs, congestion will continue increasing. Already, US drivers sit in traffic an average of 99 hours a year[3], which may portend similar outcomes for developing countries with increased car dependency and lack of choices. An expected increase in total vehicle-miles traveled (VMT) per year will also increase energy consumption for a sector dependent on petroleum products, worsening the climate crisis[4,5]. Fortunately, several developing countries have adopted European and US emission standards for new vehicles. The introduction of more ambitious standards should improve air quality in urban regions, especially where diesel vehicles are the majority[6]. Even with regulations to reduce vehicle emissions, improving air quality is inextricably linked with transitioning transportation away from carbon-powered vehicles[7].

Though electric vehicles (EVs) are better for the environment considering production to end-of-life, a criticism of the transition to EVs is their effect on gas tax revenues. However, not mentioned in this argument are the longstanding contributors to the decline in revenue, namely vehicle efficiency gains and legislators’ unwillingness to raise taxes (or indexing the tax to inflation in the US)[8]. Replacement of the gas tax with a distance-based fee (“VMT fees”) can address revenue shortfalls and counteracts the rise of EV-specific registration fees meant to recoup lost gas tax revenues, which may slow the adoption of EVs[9]. The public may accept a VMT fee, and the transition to AVs will help ensure compliance in payment.

Still, it may be decades before there is large-scale adoption of AVs given a complex set of technological challenges, costs, regulatory standards, including safety, liability, insurance, as well as public perceptions and market trends. Since many tout AVs as removing human error—a factor in 9 out of 10 serious crashes[10]—then the goal of zero vehicle fatalities (“Vision Zero”) requires mitigating present-day risks leading up to the crash event (like speeding and roadway design). There are 38,000 American traffic fatalities each year, and some groups like pedestrians and cyclists have seen fatality rates increase since 2010[11,12]. Action to reduce the number and severity of traffic crashes is necessary since AVs are not expected to reach large-scale adoption soon. Traffic crashes also contribute to about 25% of US roadway delays (likely similar elsewhere), and 7% of motor vehicle crash costs are recovered from public revenues and not insurance or crash participants[13].

The true costs of driving must capture environmental and societal externalities, or the car-centric system will continue with AVs. If vehicles continue to receive subsidies in the form of minimum parking requirements, lane expansions, and suburban development patterns that create the environment that requires a car, then the policy question of "how do we get people out of their cars?" remains unanswered. Designing cities to give people efficient, reliable, safe, and affordable alternatives like transit, cycling, or walking is as critical to the future of transportation is as relying on new technologies. Policy solutions that shift the responsibility of driving costs may address these existing issues and provide the environment for new technologies to mature and avoid the "potholes" in the future.

Two Self-Driving Futures

The early adopters of AV technology are likely fleets offering passenger service, though freight is not far behind. Shared autonomous electric vehicle (SAEV) service has begun operating in pilots and limited use cases around the world[14]. After securing regulatory approval, SAEVs will provide door-to-door private passenger service and offer reduced fares for passengers willing to share the ride with strangers. SAEVs may complement traditional public transit services, such as rail through first-mile/last-mile transfers or partially replace the often less-utilized, fixed-route local bus. Over time, households may choose to buy a personal autonomous vehicle (PAV) or rely on a mix of competitive mobility providers, from line-haul transit to on-demand SAEVs[15–17]. Absent policy changes to address transportation revenue shortfalls, on-road emissions, and congestion, the transition to a world with AV technology may lead to either one of two self-driving futures: car-dependent sprawl or shared multi-modal compact cities.

In the business-as-usual scenario, suburban and exurban towns continue to attract low-density, car-dependent development through loose land use policies. Households buy PAVs to make better use of their in-vehicle travel time, like reading or working, and to reduce driving stress or fatigue[18]. A combination of sprawl, better use of travel time, and increased demand from previously under-served populations (like seniors, persons with disabilities, and those without a driver's license) lead to increased per-capita VMT[19]. Lane expansions, the time-tested action of alleviating congestion, lead to the same, if not more, congestion through induced demand[20]. PAVs significantly change long-distance travel behavior by substituting for air travel[21]. Electric PAVs are adopted due to lower costs and electric powertrain benefits for the onboard computer systems, but longer trips partially offset energy consumption improvements[22]. In this scenario, cities and states trade gains in property tax revenues for long-term infrastructure maintenance and congestion costs.

In an optimistic future, cities encourage compact, transit-oriented developments with safe routes for non-motorized travel for all levels of comfort[23]. Households living near dense urban centers have multiple travel modes available for most destinations and give up car ownership to save money. Investments in separated pedestrian and bicycle infrastructure, shared electric bikeshare programs, and converting temporary COVID-19 street reallocation pilots to permanent fixtures of urban life increases daily active transportation and improve physical wellbeing. A mix of AV services complements light-rail transit and commuter rail[24]. For example, demand-response autonomous minibuses lower wait times and are sized to meet temporal changes in demand[25]. SAEVs offer private door-to-door rides and pooled rides for travelers willing to take a slight detour for a reduced fare. Right-sizing vehicles to match occupancy levels and sharing rides saves money overall, takes solo cars off the road, and reduces transportation's energy demand. Fewer privately-owned vehicles lower the demand for urban parking, which may increase opportunities for green redevelopment, reduce the urban heat island effect and stormwater runoff, and create more cohesive communities. Plentiful travel choices (Figure 1) increase the frequency of trips, but both sharing vehicles and rides paired with more active travel may negate the expected rise in travel from AVs.

Even with great uncertainty around AV benefits on travel times, traffic flow rates, and overall VMT, many predictions are too good to be true. The myth of AVs reducing congestion and travel times is not new (Figure 2). Relying on technology in the future to solve today's challenges is not realistic and ignores how policies today can shape the development of AVs tomorrow. Cities must first acknowledge the current problems and address them while preparing for a world with AVs. Solutions to address congestion, crashes, and emissions must maximize benefits for as many people as possible. Regressive policies are to be avoided, and travel improvements should seek access to education, health care, and jobs for all[1,26].

Figure 1: Traveler plans a trip from their smartphone (EXAMPLE: We'd like to see the screen report total monthly VMT, travel credits remaining, #rides shared, avg CO2 lbs reduced).

Figure 2: A 1974 illustration titled "Self-driving cars on superhighway" by Günther Radtke

Can Pricing Alone Fix It?

The pandemic has shown how shifting activities' locations, start times, and durations can lessen congestion by spreading out peak demand. To manage urban growth and use scarce roadway capacity judiciously, shifting travel to off-peak periods may be part of the solution. Although tolling previously "free" roads is a politically heated decision, cities have already or are beginning to develop (de)congestion pricing schemes (e.g., London, Singapore, and New York

City)[27,28]. Congestion pricing often uses dynamic tolls that rise and fall due to demand so that vehicles can travel closer to the designed speed, which might lock in the post-pandemic redistribution of traffic levels, lower total VMT, and emissions[29].

Revenue-neutral, *credit-based* congestion pricing (CBCP) can address equity concerns that low-income, under-served households, who live further from jobs and may not have reliable and convenient public transit, are most financially burdened[30,31]. All adults receive a transportation credit (allocated from the tolling budget) to spend on local travel. Below-average motorists who take short and infrequent trips, ride public transit, or travel during non-peak times can receive credits as compensation, while above-average, peak-period drivers pay out-of-pocket after depleting the credit. Credits may be redistributed to low-income households having higher mobility needs due to the housing affordability crisis. However, changes in land use policy, like upzoning, are also necessary to create affordable, multi-modal communities that offer travelers viable alternatives under CBCP. This new policy rewards travelers that make small changes to reduce network congestion and has co-benefits of reducing emissions and crashes from stop-and-go traffic[32].

While CBCP emphasizes reducing congestion, replacing the gas tax may help transportation financing issues. Gas taxes will become irrelevant as households purchase EVs, and implementing a separate EV charging tax is unnecessary if GPS-based onboard devices can tally (de)congestion tolls and VMT fees. Changes in vehicle efficiency previously impacted the volumetric-based gas tax, while the distance-based fee can finally shift responsibility for transportation funding to those driving the most. The fee structure, if designed as a flat rate, will hurt rural and low-income residents whose mobility needs are higher[33]. Tailoring VMT fees to the external cost of driving requires assigning costs based on driving location (urban versus rural), vehicle weight, and vehicle carbon intensity. For example, larger vehicles wear out roads faster, increase crash severity, and require more energy. EVs, which are generally heavier than combustion engine vehicles due to battery packs, may not pay higher fees because the carbon intensity of electricity in the US is lower than gasoline. Urban regions will likely benefit the most because they have higher external costs of driving (e.g., noise and air pollution, crashes, and congestion). Rural regions will have lower per-mile fees to adjust for naturally higher per-capita VMT.

Mobility operators and transit agencies providing SAEV and minibus service will face the same VMT fees as individual motorists driving or riding in a PAV. SAEV operators competing for market share will weigh repositioning of vehicles to meet demand with paying VMT fees for their empty travel. Cities should impose caps on %empty VMT for mobility operators while banning PAVs from traveling unoccupied on public roads. PAVs may provide mobility benefits for families with young children and the elderly who cannot drive, but not at the expense of others. For example, cities can avoid hundreds of PAVs picking up curbside orders or driving around the city to find free parking.

With new pricing mechanisms (CBCP and VMT) and zero-occupancy caps/bans, the arrival of AVs may look like the second self-driving future. Distance-based fees disincentive sprawl and long-distance leisure trips that come with cheaper, easier travel with AV technology. Credit-based (de)congestion pricing will incentive high vehicle occupancies through the pooling of travelers with similar trips and may nudge people to abandon personal car ownership in favor of shared vehicles. Travel credits from CBCP could carry over towards any travel mode, including public transit or shared micromobility like electric bicycles. By addressing transportation challenges upfront via pricing, the advent of AVs may avoid the "potholes" of congestion, lane expansion, and environmental harms.

New transportation financing for maintenance and investment is needed and can be performed in conjunction with (de)congestion schemes to optimize the use of existing assets. Implementing progressive transportation financing now is necessary to define the market environment for emerging technologies, like EVs and AVs, that are anticipated to deliver numerous benefits for society. However, pricing is just a part of the solution. Policymakers must combine transportation pricing reforms with land-use changes to provide access to opportunities for all and truly offer convenient, affordable, and reliable travel choices.

Self-driving Future is Shaped by Policies Today

Smart regulations that address existing problems while anticipating emerging technologies can help our cities and states realize the benefits of AVs, namely: fewer crashes, greater mobility for the transport-disadvantaged, ability to safely multitask en route, and all-electric drivetrains. Otherwise, we risk compounding crash costs, congestion, emissions, sprawl, and non-active travel/ unhealthy lifestyles.

References

1. Litman, T. *Autonomous Vehicle Implementation Predictions: Implications for Transport Planning*. 48 https://www.vtpi.org/avip.pdf (2021).
2. Fagnant, D. J. & Kockelman, K. Preparing a nation for autonomous vehicles: opportunities, barriers and policy recommendations. *Transportation Research Part A: Policy and Practice* 77, 167–181 (2015).
3. INRIX. INRIX: Congestion Costs Each American Nearly 100 hours, $1,400 A Year. *Press Releases* https://inrix.com/press-releases/2019-traffic-scorecard-us/ (2020).
4. Federal Highway Administration. *FHWA Forecasts of Vehicle Miles Traveled (VMT): Spring 2021*. 9 https://www.fhwa.dot.gov/policyinformation/tables/vmt/2021_vmt_forecast_sum.pdf (2021).
5. EIA. Energy use for transportation. *Use of energy explained* https://www.eia.gov/energyexplained/use-of-energy/transportation.php (2021).
6. Mulholland, E., Miller, J., Braun, C., Jin, L. & Rodriguez, F. *Quantifying the long-term air quality and health benefits from Euro 7/VII standards in Europe*. 13 https://theicct.org/sites/default/files/publications/eu-euro7-standards-health-benefits-jun21.pdf (2021).
7. Peng, W., Yang, J., Lu, X. & Mauzerall, D. L. Potential co-benefits of electrification for air quality, health, and CO2 mitigation in 2030 China. *Applied Energy* 218, 511–519 (2018).
8. Dutta, U. & Patel, N. *The Impact of Energy Efficient Vehicles on Gas Tax (Highway Trust Fund) and Alternative Funding for Infrastructure Construction, Upgrade, and Maintenance*. 55 (2012).
9. Federal Highway Administration. Vehicle-miles Traveled (VMT) Fees. *Tolling and Pricing* https://www.fhwa.dot.gov/ipd/tolling_and_pricing/defined/vmt.aspx.
10. National Highway Traffic Safety Administration (NHTSA). *Automated Driving Systems 2.0: A Vision for Safety*. 36 https://www.nhtsa.gov/sites/nhtsa.gov/files/documents/13069a-ads2.0_090617_v9a_tag.pdf (2017).

11. National Highway Traffic Safety Administration (NHTSA). 2020 Fatality Data Show Increased Traffic Fatalities During Pandemic. *News* https://www.nhtsa.gov/press-releases/2020-fatality-data-show-increased-traffic-fatalities-during-pandemic (2021).
12. Buehler, R. & Pucher, J. The growing gap in pedestrian and cyclist fatality rates between the United States and the United Kingdom, Germany, Denmark, and the Netherlands, 1990–2018. *Transport Reviews* 41, 48–72 (2021).
13. Blincoe, L., Miller, T. R., Zaloshnja, E. & Lawrence, B. A. *The Economic and Societal Impact of Motor Vehicle Crashes, 2010 (Revised)*. 194–196 https://linkinghub.elsevier.com/retrieve/pii/S0196064415005119 (2015).
14. Shared-Use Mobility Center. Learning Module: Shared Autonomous Vehicles. *MOD Learning Center* https://learn.sharedusemobilitycenter.org/learning_module/shared-autonomous-vehicles/ (2021).
15. Bansal, P. & Kockelman, K. M. Forecasting Americans' long-term adoption of connected and autonomous vehicle technologies. *Transportation Research Part A: Policy and Practice* 95, 49–63 (2017).
16. Lavieri, P. S. *et al.* Modeling Individual Preferences for Ownership and Sharing of Autonomous Vehicle Technologies. *Transportation Research Record* 2665, 1–10 (2017).
17. Menon, N., Barbour, N., Zhang, Y., Pinjari, A. R. & Mannering, F. Shared autonomous vehicles and their potential impacts on household vehicle ownership: An exploratory empirical assessment. *International Journal of Sustainable Transportation* 13, 111–122 (2019).
18. Simoni, M. D. & Kockelman, K. M. Vehicles that Drive Themselves: What to Expect with Autonomous Vehicles. in *International Encyclopedia of Transportation* 4569 (Elsevier, 2021).
19. Wellik, T. & Kockelman, K. Anticipating land-use impacts of self-driving vehicles in the Austin, Texas, region. *JTLU* 13, 185–205 (2020).
20. Institute for Transportation & Development Policy. The Next Pandemic Surge: Traffic. *Transport Matters* https://www.itdp.org/2021/03/22/the-next-pandemic-surge-traffic/ (2021).
21. Perrine, K. A., Kockelman, K. M. & Huang, Y. Anticipating long-distance travel shifts due to self-driving vehicles. *Journal of Transport Geography* 82, 102547 (2020).
22. Lee, J. & Kockelman, K. M. Energy and Emissions Implications of Self-Driving Vehicles. in (2019).
23. Zipper, D. The Dangerous Promise of the Self-Driving Car. *Bloomberg CityLab* https://www.bloomberg.com/news/articles/2021-10-12/the-dangerous-promise-of-the-self-driving-car (2021).
24. Huang, Y., Kockelman, K. M., Garikapati, V., Zhu, L. & Young, S. Use of Shared Automated Vehicles for First-Mile Last-Mile Service: Micro-Simulation of Rail-Transit Connections in Austin, Texas. *Transportation Research Record* 2675, 135–149 (2021).
25. Huang, Y., Kockelman, K. M. & Truong, L. T. SAV Operations on a Bus Line Corridor: Travel Demand, Service Frequency, and Vehicle Size. *Journal of Advanced Transportation* 2021, e5577500 (2021).
26. Fleming, K. L. Social Equity Considerations in the New Age of Transportation: Electric, Automated, and Shared Mobility. 13, 20 (2018).
27. Gu, Z., Liu, Z., Cheng, Q. & Saberi, M. Congestion pricing practices and public acceptance: A review of evidence. *Case Studies on Transport Policy* 6, 94–101 (2018).

28. Southern California Association of Governments (SCAG). Decongestion Fee System. *Local Resources: 100 Hours* https://scag.ca.gov/decongestion-fee-system (2018).
29. Parks, H. Investigating the Impact of Congestion Pricing Around the World. *Climate-XChange* https://climate-xchange.org/2019/05/29/investigating-the-impact-of-congestion-pricing-around-the-world/ (2019).
30. Kalmanje, S. & Kockelman, K. M. Credit-Based Congestion Pricing: Travel, Land Value, and Welfare Impacts. *Transportation Research Record* 1864, 45–53 (2004).
31. (Vivian) Li, W., Kockelman, K. M. & Huang, Y. Traffic and Welfare Impacts of Credit-Based Congestion Pricing Applications: An Austin Case Study. *Transportation Research Record* 2675, 10–24 (2021).
32. Litman, T. *Pricing for Traffic Safety: How Efficient Transport Pricing Can Reduce Roadway Crash Risks*. 16–22 https://www.vtpi.org/price_safe.pdf (2021).
33. Larsen, L., Burris, M., Pearson, D. & Ellis, P. Equity Evaluation of Fees for Vehicle Miles Traveled in Texas. *Transportation Research Record* 2297, 11–20 (2012).