UNIVERSITY OF OREGON

POLICY BRIEF:

SHARED MOBILITY, AUTONOMOUS VEHICLES, AND GHG EMISSIONS

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URBANISM NEXT CENTER

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INTRODUCTION

THE CHALLENGE

The transportation sector is the largest emitter of greenhouse gas (GHG) emissions in the United States, accounting for approximately 29% of all emissions in 2019 [1]. Cities, counties, states, and the federal government are increasingly taking action to understand how public agencies can reduce emissions from transportation while increasing access and improving mobility.

Even as our understanding of how transportation impacts GHG emissions is improving, the modes and ways people are moving are changing [2]. The increased processing power and connectivity allowed by the widespread use of computers and smart phones has allowed for the rise of shared mobility services on a wide-spread scale [3]. Shared mobility services including micromobility (bikeshare and e-scooter share); microtransit; carsharing; ride-hailing (also referred to as transportation network companies (TNCs)); and autonomous vehicles (AVs), many introduced in the last 10 to 20 years, are presenting new challenges and opportunities to reducing GHG emissions from transportation. Decision makers need to understand how shared services impact GHG emissions and what they can do to reduce emissions.

THE OPPORTUNITY

Local and state governments have learned a lot from the introduction of shared mobility services over the past 10 years. Many have adopted rules and regulations for the operation of these services in their communities, but not all. Other communities conducted pilot projects or have experience with the operation of these services and are now looking to create or update regulations to address challenges and opportunities. In addition, they want to ensure that shared mobility services address the transportation needs of all residents and do not continue to perpetuate existing inequities. Given these experiences, there are now best practices that can benefit state and local governments. These best practices include a range of mobility services, demographics, and geographies provide an opportunity to learn, refine, and introduce new policies. Now is the time to update the regulations for new mobility services, prepare for AVs, while reducing GHG emissions and increasing equitable mobility.

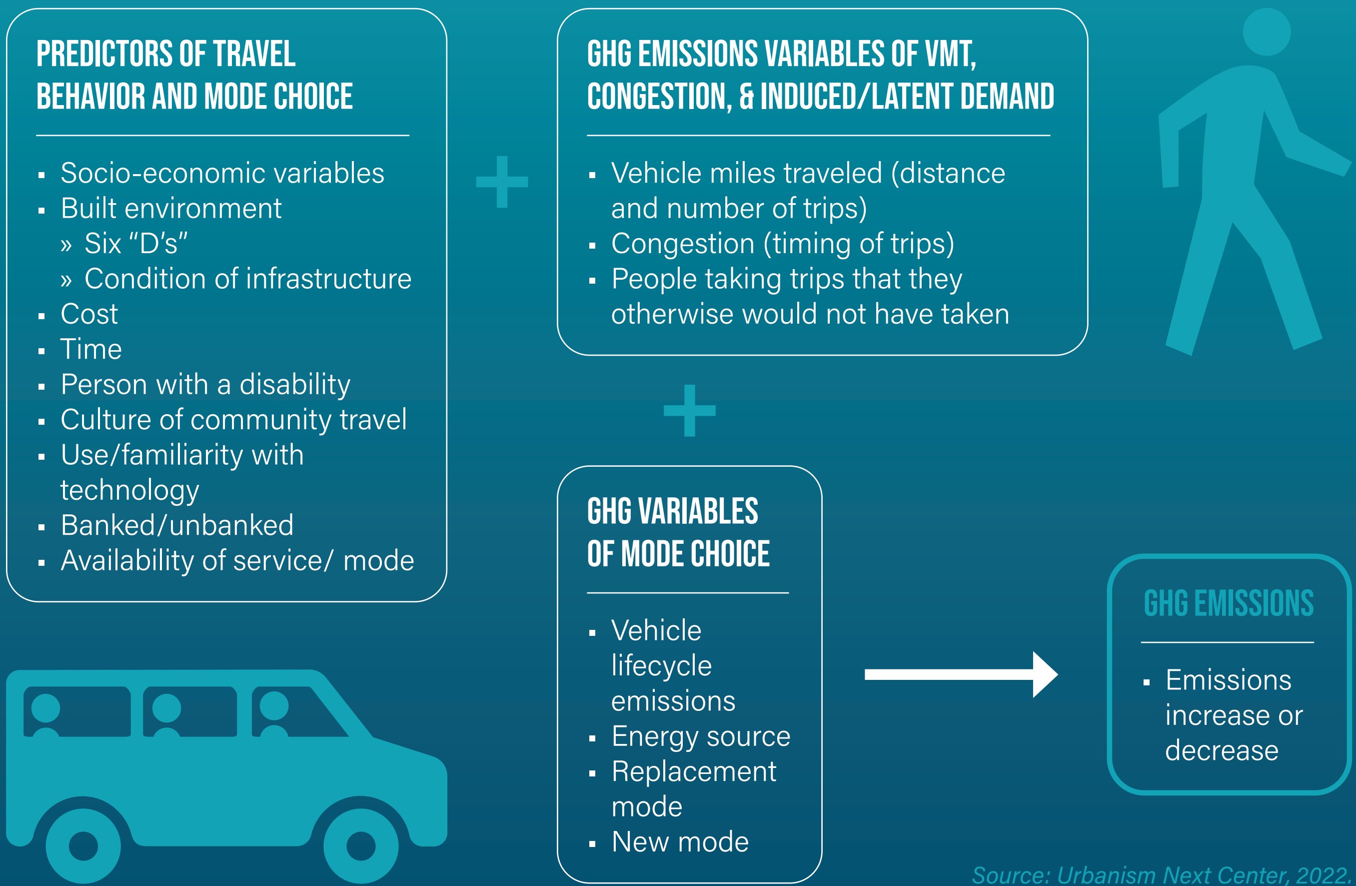
WHAT WE DID

The Urbanism Next Center conducted an extensive review of the academic (peer reviewed) and grey (professional) literature. We reviewed over 320 peer-reviewed academic articles and professional and technical reports to understand how shared mobility services are or could increase or decrease GHG emissions. This policy brief is based on that research. The full report will be published at www.urbanismnext.org when it is available.

What factors of new mobility shared services should we pay attention too?

Figure 1 shows a framework for thinking about the GHG emissions factors for shared mobility. We found that a combination of factors — predictors of travel behavior and mode choice, GHG impacts of mode choice, and GHG emissions variables of VMT, congestion, and induced and latent demand — influence GHG emissions for new mobility services. Most of the literature focuses on one or more of the factors listed in Figure 1, but not all of them.

FIGURE 1. TRANSPORTATION EMISSIONS FACTORS FOR SHARED NEW MOBILITY AND AV SERVICES



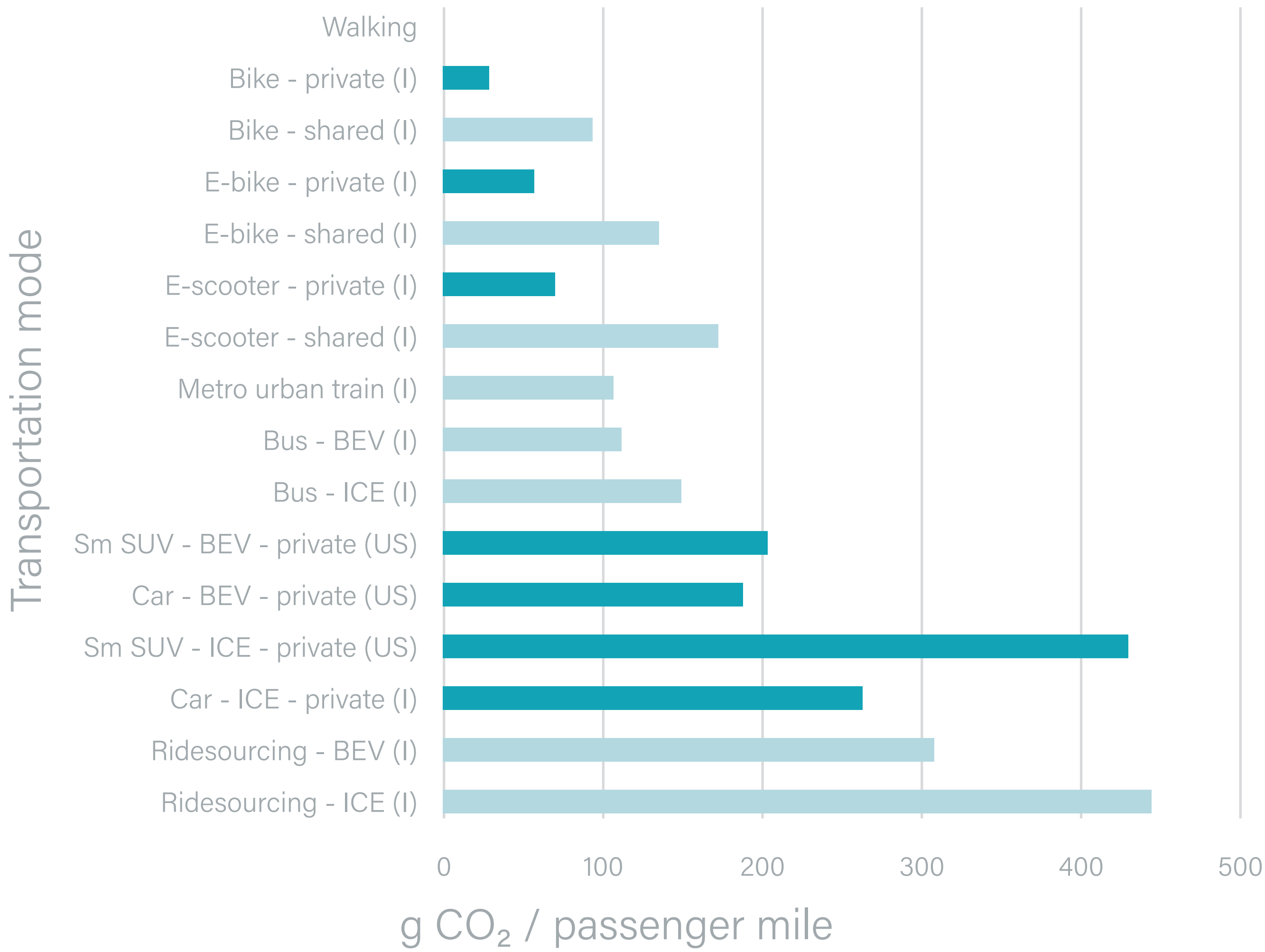
Source: Urbanism Next Center, 2022.

A wide range of variables influence how people decide to travel. For example, socio-economic variables such as age, gender, income, and education all influence travel decisions [4], along with development patterns in our cities (the six "D's": density, diversity, design, destination accessibility, distance to transit, and demand management (parking and cost) [5]), as well as trip travel time and cost are all important factors. People are also influenced by the culture of community travel – all your friends drive or because of the history of enforcement in your neighborhood. In addition, how difficult or easy it is to travel because of a disability [3], [6]–[8], use and familiarity with technology [9], [10], whether or not a person has access to traditional banking and credit cards [11], or whether or not the service is available are all important factors [11].

Once a decision has been made to travel, say by walking, taking transit, or taking a ride-hailing trip, then the lifecycle GHG emissions must be considered – from manufacturing of the vehicle, processing and consumption of the fuel, the building of the infrastructure, and operation of the service (see Figure 1 [12]. Given that new mobility services are relatively new, it is important to consider if the service is replacing a more or less intensive carbon trip. All travel that replaces walking trips increase carbon emissions, *except for the trip that otherwise would not have been taken.*

Finally, we have to consider the trip itself. How far (vehicle miles traveled or VMT) is the trip? Does the trip occur during the morning or evening commute when there is congestion and more vehicles delay everyone for longer periods of time? And, are people taking trips or driving more than they otherwise would if the new mobility service wasn't available? That concept is often referred to as induced or latent demand (see page 9 for more information).

FIGURE 2. INTERNATIONAL AND U.S. ESTIMATES OF LIFE-CYCLE GREENHOUSE GAS EMISSIONS OF URBAN TRANSPORT MODES PER PASSENGER MILE



Source: International (I) estimates converted from g CO2/km to g CO2/mile by Urbanism Next from Cazzola, Pierpaolo, and Philippe Crist. "Good to Go? Assessing the Environmental Performance of New Mobility." International Transport Forum Corporate Partnership Boar, 2020, p 23. US (US) estimates from Kelly, Jarod C., Amgad Elgowainy, Raphael Isaac, Jacob Ward, Ehsan Islam, Aymeric Rousseau, Ian Sutherland, et al. "Cradle-to-Grave Lifecycle Analysis of U.S. Light-Duty Vehicle-Fuel Pathways: A Greenhouse Gas Emissions and Economic Assessment of Current (2020) and Future (2030-2035) Technologies." Argonne National Laboratory, June 2022, pp 92 and 93, are for a small SUV and a mid-sized sedan and the battery electric vehicles have a 300 mi range.

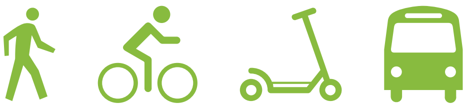
Note: (I) = International estimate; (US) = United States estimate; BEV = battery electric vehicle; ICE = internal combustion engine.

The International Transport Forum (ITF) published a study in 2020 that included life-cycle assessment of a comprehensive list of transport vehicles including those used in new mobility, as shown in Figure 2 [12]. Figure 2 also includes some additional information for mid-sized sedans (car) and small SUV's for the US [13]. The operations component accounts for the additional VMT from deadheading for ride-hailing (referred to as ride-sourcing), taxis, public transit, and shared micromobility.

WHO USES SHARED MOBILITY SERVICES?

First adopters appear to be: younger, more affluent, more educated, live in dense urban environments, and are more likely to be male than female [14]–[19]. As familiarity, low-income programs [20], pooled services [21], and outreach increases, new mobility users still tend to skew younger, but otherwise it is more representative of the surrounding population [22].

WHAT WE FOUND



The modes with the lowest GHG emissions are walking, personal and shared biking and e-scooters, and public transit.

Transportation managers should ensure that these modes are among the best options by investing in access, infrastructure, and supporting programs to ensure it is the fastest, cheapest, safest, and most comfortable way for everyone to travel.

Microtransit and carsharing can support car-free or car-light households and likely don't increase GHG emissions significantly, especially if station-based instead of free floating, and are designed to support transit.

Personally owned and ride-hail vehicles emit the most GHG emissions from transportation today. Electric vehicles emit fewer GHG emissions than an internal combustion vehicle.

Ride-hailing results in increased congestion, VMT, and GHG emissions. AVs likely will as well (and could be even worse). Electric ride-hailing and AVs could help, but increased VMT and congestion may cancel out the benefits.

The focus should always be to get people out of their personally owned vehicles and into services with lower emissions (generally, walking, personally owned and shared bike and e-scooters, and transit). But keep in mind, the local context is important. Not all shared services will be appropriate in all locations.

Strategies to reduce GHG emissions should be coupled with efforts to ensure that all residents, especially the most vulnerable, have access to low-cost, time efficient, high-quality transportation when and where they need it. Whether that is by ensuring that people with less access to technology such as smart phones (and the data plans necessary to access mobility apps) have a way to access shared services, who don't have access to a credit card and need a cash option, or that need apps in multiple languages. It also means building more housing in places that people want to live at prices they can afford and ensure there are jobs, shopping, and schools close by. Finally, communities have a responsibility for understanding and addressing systemic inequities that result in disproportional enforcement against BIPOC users [23] or historical lack of investment in sidewalks, protected bicycle lanes, and other infrastructure that makes it unsafe or uncomfortable to walk, bike, e-scooter, or take transit.

Personally owned vehicles, ride-hailing, and autonomous vehicles emit more GHG emissions than other transportation options [24]. While electrification of vehicles will reduce the emissions impact, the conversion to electric will take time and still won't deliver the emission reductions we need [25]. Making high carbon options more expensive is one way to nudge people towards a lower carbon option, current pricing is way too low [26]. In addition, policy makers should consider the competing goals of improving quality of life by increasing travel options even if those options result in higher carbon emissions.

The rest of this report presents the key findings from the literature review for micromobility (bikeshare and e-scooter share), carshare, microtransit, ride-hailing, and AVs.


Image: stock.adobe.com, Mirko Vitali

MICROMOBILITY

	POTENTIAL FACTORS DECREASING GHG EMISSIONS	POTENTIAL FACTORS INCREASING GHG EMISSIONS
MICROMOBILITY	▪ Shift from personally owned vehicles, carshare, ridehailing, autonomous vehicles ▪ Longer lasting shared bikes and e-scooters ▪ Swappable batteries ▪ Redistribution with electric vehicles ▪ Reduced VMT ▪ First/last mile for transit	▪ Shift from walking, personally owned biking and personally owned e-scooters

Note: The tables at the beginning of each of the shared mobility sections is adapted from M. Massar, I. Reza, S. M. Rahman, S. M. H. Abdullah, A. Jamal, and F. S. Al-Ismail, "Impacts of Autonomous Vehicles on Greenhouse Gas Emissions - Positive or Negative?," International Journal of Environmental Research and Public Health, vol. 18, May 2021, doi: https://doi.org/10.3390/ijerph18115567.

Bikeshare and e-scooter share has the potential to lower GHG emissions than personally owned vehicles in the U.S. where there is a large proportion of SUVs and vehicle miles traveled (VMT) is generally higher [27]. Walking, and personally owned bikes and e-scooters could reduce emissions even more. While first generation shared e-scooters had relatively short lifespans and were collected each night for recharging and then redistributed each morning resulting in GHG emissions comparable to an internal combustion engine vehicle (sedan) [27], newer e-scooters are much hardier and companies are using e-scooters with swappable batteries, cutting down on GHG emissions from collection, charging, and distribution.

The research suggests that bikeshare and e-scooter share services can lead to a reduction in GHG emissions when coordinated and located near to transit [28]-[31]. **Station-based bikeshare and scooter share programs emit fewer emissions than dockless services** [27]. The reason being is that dockless services more often replace more efficient walking and public transit trips compared to station-based bike sharing which replace more car trips. The presence of protected bike lanes contributes to higher ridership, as does proximity of bikeshare stations to denser populations.

Most notably, **bikeshare and e-scooter share can expand transportation options to communities that are traditionally underserved by public transit**. Lower income communities experience real and lasting benefits in terms of transportation cost reductions by not having to rely on cars for most trips when bikeshare and scooter share are available [32].

CARSHARING AND MICROTRANSIT

	POTENTIAL FACTORS DECREASING GHG EMISSIONS	POTENTIAL FACTORS INCREASING GHG EMISSIONS
MICROTRANSIT	▪ Supports car-free & car-lite households ▪ Reduced personally owned vehicle use ▪ First/last mile for transit ▪ Electric vehicle	▪ Shift from walking, shared and personally owned bike and e-scooters, transit ▪ Internal combustion engine vehicle
CARSHARE	▪ Supports car-free & car-lite multi-modal households ▪ Electric vehicle ▪ Station-based services	▪ Shift from walking, shared and personally owned bike and e-scooters, transit ▪ Free-floating services ▪ Internal combustion engine vehicle

Research shows that **station based carshare is more effective than dockless car share in terms of reducing VMT and GHG emissions** as dockless carshare trips are more likely to replace walking trips, while station-based car share trips are more likely to replace private vehicle trips [17]. More people are more likely to participate in carshare if stations are placed in high density areas.

EV carshare can result in reductions in GHG emissions and people who use EVs while carsharing are more likely to purchase an EV at a later date when buying a vehicle [33], [34].

More research is needed to understand the impacts of microtransit's contribution to GHG emissions. Some research, particularly that conducted by microtransit companies, shows reductions in VMT and increases in connections to mass public transit, while other research shows that microtransit can increase VMT because of its inefficient point-to-point service.

MANAGING THE PUBLIC RIGHT-OF-WAY: PREEMPTION, PILOTS, AND PERMITTING

Local governments are responsible for building and maintaining roads (often with funding and guidance from the state and federal government) and managing how those roads are operated. State governments sometimes limit what local governments can do. For example, almost all **states have preempted local jurisdictions** *from regulating ride-hailing companies, often restricting or prohibiting local governments from collecting information about how many ride-hailing vehicles are on city streets, where they are causing the most congestion, or charging fees [35].*

Local jurisdictions took the lessons learned from the introduction of ride-hailing companies and applied them to other transportation services, including e-scooters [36]. **Many cities conducted pilot projects** *of new transportation services to learn about both the challenges and opportunities before creating new regulations and* **permits** *that allow full-scale deployment on city streets [37]. The period between introduction of a new service and the expectation of companies for the policy and regulatory framework to be in place can be quite short. Local governments that have done their homework will be better prepared to protect the public good when new transportation services come to town.*

RIDE-HAILING

RIDE-HAILING (RH)	POTENTIAL FACTORS DECREASING GHG EMISSIONS	POTENTIAL FACTORS INCREASING GHG EMISSIONS
	▪ Supports car-free & car-lite multi-modal households ▪ Shift from single-occupancy ride-hail to ooled/shared rides ▪ Electric vehicle	▪ Shift from walking, personally owned biking and personally owned e-scooters, personally owned vehicles ▪ Internal combustion engine vehicle ▪ Increased deadhead vehicle miles traveled ▪ Increased travel by underserved

Ride-hailing has a high likelihood of shifting people away from low emissions modes (walk, bike, transit). This can lead to significant increases in VMT, congestion, and GHG emissions [38]–[41].

Ride-hailing can help people live a car-lite or car-free lifestyle, but emissions increase if they are replacing personally owned vehicles with occasional or regular ride-hailing services.

Much of the policy focuses on electrification as a primary way to reduce emissions from ride-hailing. California is taking a strong lead here, along with Uber and Lyft. Interesting that TNC's represent just .5% of all electric vehicles in California, but use 30% of electricity from fast charging stations. Even if every vehicle is electric, Californians would still need to reduce VMT by 20% to achieve their emissions reduction goals [25].

Shared rides are pulling low-income riders from transit. It is often the most vulnerable, price sensitive riders that use pooled or shared rides [21]. A study in Chicago found that pooled trips are more likely to start or end in disadvantaged Census tracts and could be converted to walking trips if there were sidewalks and people felt comfortable and safe [42].

Existing pricing to nudge behavior (such as to encourage pooling of ride-hail) is far too low to result in behavior change. More research is needed to determine how much public agencies/private companies would have to charge to impact travel behavior. "Many travelers seem to need a strong nudge – more like a shove – to choose a pooled ride hail journey now or a shared AV trip in the future. Government officials could provide one, either by making shared travel a lot faster (by offering dedicated street space) or a lot cheaper (by imposing fees on private trips that make them relatively more expensive)" [43].

Congestion matters. Congestion is due both to additional vehicles on the road, as well as pickup and dropoff activities. "The estimated models show that TNC vehicles stopping at the curb to pick-up or drop off passengers have a notable disruptive effect on traffic flow, especially on major arterials" [39, p. 10]. The impact on congestion from pickup and dropoff may be even larger with the AVs. Public agencies in San Francisco have noted that AVs are stopping in the traffic lane and not pulling over for pickup and

POOLED RIDES COMPETING WITH SINGLE-OCCUPANCY RIDES? OR TRANSIT?

Incentives designed to lure single-occupancy ride-hailing users to pool or share rides may result in pulling price sensitive riders off of transit instead. For example, one study found that "...the most captive and price sensitive TNC users are often the most vulnerable.. females, travelers aged 18 to 30 years old, travelers with an annual income less than $35,000, car owners/leasers, and public transit users are among the most likely to share an on-demand ride" [44, pp. 200–201]. Single-occupancy ride-hailing trips may need to be much more expensive to incentivize pooled rides.

dropoff, which is a moving violation, increases congestion, and is a safety hazard for users [45].

Image: pexels.com, @hazardos.prod

Data matters. Multiple studies emphasized the need to require data-sharing for better management of shared services [3], [22]. "Limited data in the public sector perpetuates less-informed decision-making, which in turn results in transportation systems that do not meet the public's needs." [19, p. 30]. "To provide consumers with information about real-time service availability across all modes, cities and states should change their shared mode enabling regulations to require access to such information. With these data in hand, agencies and jurisdictions should collaborate to create publicly available platforms that integrate and share information from all sources about modal options and their cost, duration, and emissions." [3, p. 2]

Density and design matters. For example, shared mobility modes were over four-times higher in SF than in the other eight counties, according to a survey in the SF Bay area [46]. Ride-hailing is often between highly accessible neighborhoods that could be accessed by other modes [47]. "...the built environment is significantly correlated with shifts from traditional modes to ride-hailing. Especially, higher accessibility to bus services can significantly reduce the likelihood of the substitution of ride-hailing for sustainable modes. Therefore, optimizing the access to bus services may be particularly effective to alleviate transportation challenges caused by ride-hailing." [38, p. 11].

INDUCED AND LATENT DEMAND

There are many people that would like to travel, but for a variety of reasons they don't or can't. ***Induced demand*** *is the concept that people consume more of something, in this case they travel more, because traveling became easier, less expensive, or more comfortable [48]. For example, researchers have found that Tesla cars with Autopilot result in driving the vehicles 4,880 additional miles per year [49], in part because of the ease of traveling with Autopilot.*

Latent demand *reflects the demand for trips that aren't taken because of actual or perceived ability or access, including:*

- *It costs too much – Purchasing a car or taking a ride-hailing trip is too expensive*
- *It's inconvenient – Transit runs infrequently and not at convenient times*
- *It's unsafe – There aren't sidewalks or bike lanes, traffic is fast and loud*
- *Can't drive – Too young, older adult, person with a disability*
- *The trip is too long*
- *The trip is at night*

The "chauffeur experiment" conducted by researchers at UC Davis illustrates both the promise and the peril of induced and latent demand. Researchers gave 43 households a chauffeur to drive their car on-demand to simulate what it might be like to have an autonomous vehicle. They found that the total vehicle miles driven increased by 60% during the experiment [50]. One household with an older adult and one with a disability that had no access to a car (they were transit dependent) experienced a dramatic 700% increase in VMT. AV services allowed them to cut their commuting time and mileage and double the miles they traveled for social activities by freeing them from transit schedules. They noted, "...that an AV will change their lives by allowing them to 'go more places and go at different times" [50, p. 501].

AUTONOMOUS VEHICLES

	POTENTIAL FACTORS DECREASING GHG EMISSIONS	POTENTIAL FACTORS INCREASING GHG EMISSIONS
AVS	▪ Easy parking ▪ Eco-traffic ▪ Vehicle right-sizing ▪ Carpooling ▪ Eco-driving ▪ Platooning ▪ Collision avoidance ▪ Law adherence ▪ Congestion mitigation and efficient routing	▪ Easier travel ▪ Increased travel by underserved ▪ Increased deadhead vehicle miles traveled ▪ Faster travel ▪ Modal shift from other modes ▪ Land-use changes

Source: M. Massar, I. Reza, S. M. Rahman, S. M. H. Abdullah, A. Jamal, and F. S. Al-Ismail, "Impacts of Autonomous Vehicles on Greenhouse Gas Emissions - Positive or Negative?," International Journal of Environmental Research and Public Health, vol. 18, May 2021, doi: https://doi.org/10.3390/ijerph18115567. *Figure 1, p 4.*

No one knows if or how AV services will rollout or how it will impact GHG emissions. Unlike the other new mobility transportation services described in this brief, autonomous vehicle services are not widespread. In fact, commercial passenger services are available only in a handful of communities – including Las Vegas, San Francisco, and in the Phoenix area. It remains to be seen if most people will purchase vehicles that have autonomous capabilities or if autonomous ride-hailing services will be more common. Expensive personal vehicles may favor AV ride-hailing services, in which case many of the factors that result in GHG emissions for ride-hailing services may carry over for AV.

There are GHG emissions reductions that are only possible with AVs, but they might not be enough. For example, AVs can be programmed to drive in ways that minimize GHG emissions, such as eco-driving including driving at speeds with the least GHG emissions, smooth driving that minimize hard braking and acceleration, and platooning to avoid air resistance [51]–[54]. Several studies have modeled how AVs could be optimized to reduce the total number of vehicles on city streets, reduce VMT, and reduce emissions through shared rides and connected vehicles [55], [56]. These studies provide an optimistic picture of how on-demand AV services could operate. Real life is often much messier. Studies of individuals that own vehicles with automated driving elements (such as automatic braking, parking assist, adaptive cruise control and other features that are becoming common on current model vehicles) find that they induce demand and drive more because automation makes driving easier [48], [57].

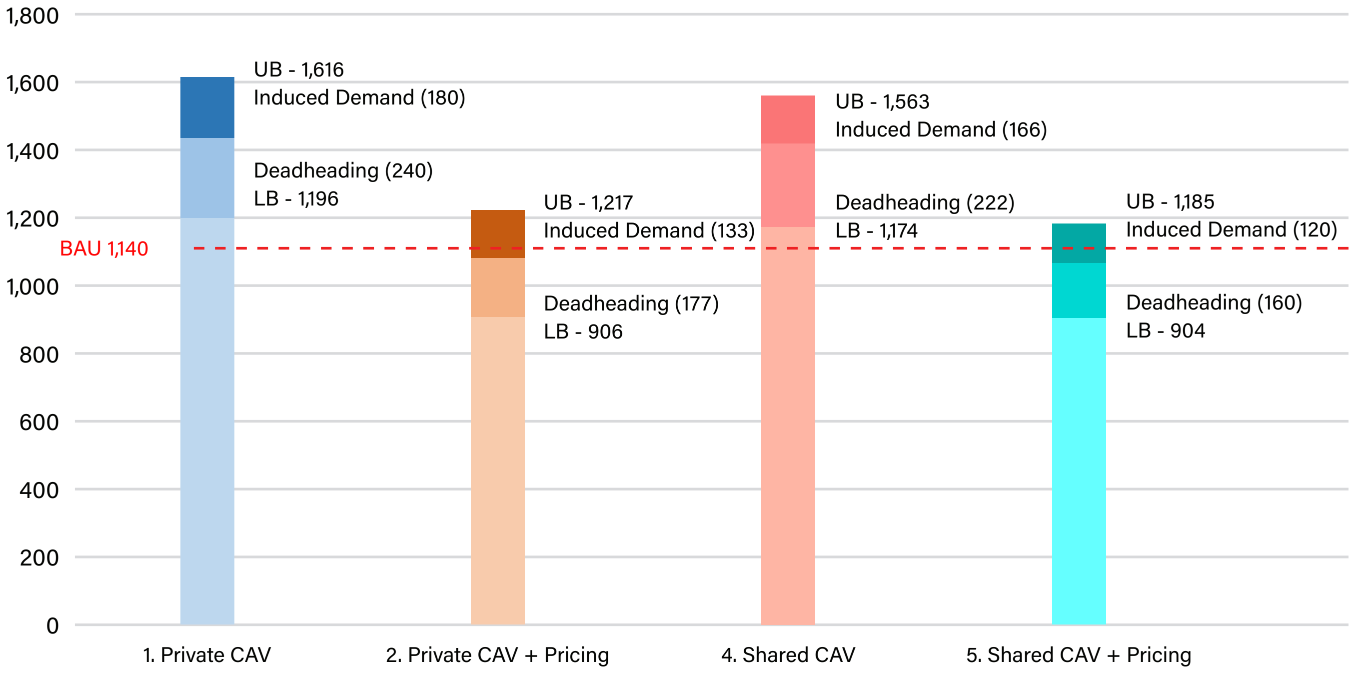
Research suggests that the GHG emissions impacts may be even bigger for AVs than for ride-hailing services. A more recent study by researchers at UC Davis modeled the emissions impact of CAV deployment in California in 2050 using the California Statewide Travel Demand Model (CSTDM) [58]. This study modeled VMT for connected and automated vehicles (CAVs) and found all scenarios increased VMT (see Figure 3), in part due to deadheading and induced demand, compared to the business-as-usual baseline scenario.

These studies provide a cautionary lesson that replacing personally owned vehicles with personally owned or shared AVs will likely result in even worse congestion, VMT, and potentially GHG emissions than if AVs were never introduced.

Researchers should continue to study the GHG emissions implications of shared transportation services as the technology evolves. Many transportation and technology companies are working to reduce their emissions. Public agencies should encourage these efforts through policy requirements and voluntary collaborations. Data-informed decision making will make these efforts more effective and help communities achieve their GHG emissions reduction goals.

Image: stock.adobe.com, Metamorworks

FIGURE 3. RANGE OF VMT FOR MODEL SCENARIOS (MODELED FOR CA 2050)



Source: G. Circella, M. Jall, R. Sun, X. Qian, and F. Alemi, "Emissions Impact of Connected and Automated Vehicle Deployment in California," National Center for Sustainable Tranportation and the UC Davis Institute of Transportation Studies, UC Davis, Academic NCST-UCD-RR-21-10, 2021. Accessed: Jun. 22, 2022. [Online]. Available: https://escholarship.org/uc/item/0qf4k22c, p xii.

Note: BAU = Business as Usual.

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