

**SHARED  
ROADWAYS  
PLATFORMS  
& BENEFITS:  
INTEGRATING  
AUTONOMOUS  
TRAVEL CHOICES**

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## Introduction

After years of discussion and promises, autonomous vehicles (AVs) are now becoming a reality in U.S. cities in the form of robotaxis. Autonomous driving capabilities have the potential to be deployed in a variety of forms: in vehicles that are personally owned and/or in vehicles operated as fleets (e.g. robotaxis) available to riders and subscribers. These different AV deployment models are sometimes conflated but the effect of robotaxi deployment on mobility, congestion, and labor is likely to be quite different from the effect of personal AVs. Even within the robotaxi sphere alone, deployment options vary: robotaxis may be made available to riders on networks limited to robotaxis or on hybrid networks in which autonomous and human-driven vehicles operate together on the same platform, and this distinction too may have real implications for outcomes.

During this phase of early deployment, while companies experiment with new technologies, the existing vehicles and networks in use today will continue to be used and these roadways and networks will hybridize. But will this hybrid deployment be a short transitional phase or rather a long-term and sustainable new normal with different vehicle types continuing to serve different uses and market spheres?

Factors of costs, market demand, and consumer choices have and will continue to influence the shape of AV deployment, but choices made by policymakers, transportation officials, and technology companies will also matter. Officials seeking to achieve specific mobility and affordability goals for riders must consider how the shape of deployment will affect such outcomes.

Under current technological and economic conditions, robotaxis are expanding as geofenced services rather than as universally capable vehicles. Robotaxi companies face high fixed costs to procure or build vehicles and create the necessary digital infrastructure for AV operations. This paper argues that robotaxis, human-driven rideshare vehicles, and personally owned vehicles each face different cost structures and provide distinct mobility services and are therefore all likely to persist as complementary rather than fully substitutable modes.

Barring a significant change in these costs and technological capabilities, neither personal AVs nor robotaxis are likely to fully displace personally owned human driven vehicles or human driven taxis and rideshare for some time. Instead, it is likely that robotaxis, human driven taxis, and personally owned, human driven vehicles will share the roadways for the foreseeable future, each fulfilling distinct mobility needs of the market. This paper focuses primarily on the near- and medium-term implications of robotaxi deployment through hybrid networks, with Section Four addressing the longer-term implications of personally owned AVs as a distinct and later-arriving technology.

The persistence of shared roadways means that the overall impact of AVs on driving safety and travel patterns will be partial, and potentially uneven across geographic and demographic cohorts. It's also clear from early data and from modeling of AV deployment that the impacts of AVs on roadway safety, travel patterns, labor, and equity are not inherently positive or negative but depend instead on deployment market structures and policy decisions.

In light of this context, this paper argues that a hybrid network will enable transportation network companies to better manage supply of rides because human drivers provide dynamic supply alongside a fixed supply of robotaxis. The integration of human-driven and robotaxi fleets on a single network will allow riders to choose between autonomous and human-driven vehicles, maximizing cost competition and expanding rider benefits. Human drivers will also benefit from maintaining access to rider demand in hybrid networks and being able to compete for trips. As a result, such hybrid networks are not necessarily a transitional phase on the path toward full AV adoption and displacement of human drivers but rather may be a sustainable long-term model that maximizes benefits for riders, drivers, and cities alike – and one that policymakers and platforms should actively work to preserve.

## Terms and Organization

The following terms appear frequently in this paper.

- **Autonomous vehicles**, also referred to as AVs, are vehicles equipped with Automated Driving Systems (ADS) capable of performing all driving tasks without human intervention. Per the SAE J3016 standard, ADS encompasses Levels 3 through 5 of driving automation. For purposes of this paper, 'AV' refers specifically to Level 4 vehicles operating without a human driver present."
- **Personally owned AVs** are autonomous vehicles owned by individual households for personal use. Personally owned AVs are not currently commercially available. It is likely that personally owned AVs will require subscription services for remote assistance and digital mapping.
- **Fleet-owned AVs** are autonomous vehicles that are owned by corporations or governments for the purposes of commercial use.
  - This paper specifically focuses on fleet-owned AVs in the context of transportation-network companies utilizing autonomous vehicles for rideshare. The paper also explores the potential for individual vehicle owners to deploy vehicles on rideshare networks.
- **Shared Roadways** are roadways upon which both autonomous vehicles and human-driven vehicles are being operated.

- [Hybrid Networks](#) are transportation networks that offer both human-driven and autonomously driven vehicle ride options, operating in the same platform.
- [AV-only networks](#) in comparison, are a transportation networks that offer rides only in autonomous vehicles.

## Organization:

- [Section one](#) of this paper explores factors that affect technology adoption and dispersal and provides examples of historical analogues that may serve as a model for deployment of AVs.
- [Section two](#) describes and compares the current deployments of AVs as robotaxis in U.S. cities.
- [Section three](#) explores the implications of a hybrid network for critical societal outcomes including labor, safety, equity, and vehicle miles.
- [Section four](#) provides analysis of personal AV ownership, including expectations for the timeline of deployment and how the impact of personal AVs would differ from that of robotaxis.
- [Section five](#) offers policy recommendations in light of the analysis and findings.

## Section One: Technology Adoption Factors

Technological developments and breakthroughs occur because of research and scientific advancement, but the commercial deployment and adoption of that technology is also a social and economic function, derived from combined factors of technological reliability, functional value, consumer demand and preferences, and costs. For any given technology, there may be dynamics that promote adoption and others that limit it. New technology will offer a value proposition relative to prior tech when it reduces costs or improves performance or productivity enough to merit any additional cost. Yet even so commercial viability may hinge on whether the functionality is congruent with existing lifestyles, which ultimately affects consumer demand. Overall, new technologies will be deployed most quickly when they offer a compelling improvement in function or cost without requiring major changes in user behavior or business practice.

### Historical Analogues

As shown in the matrix below, automation has been introduced for other products, with varying results, which may serve as theoretical models for AV adoption. Both costs and functionality affect rates of technology adoption. Perception of technology function encompasses two dimensions: the extent to which it meets the existing need and fully replaces prior alternatives, and the reliability with which it performs that function.

### Value Proposition: Balance of Cost and Functional Value Informs Technology Adoption

		Functionality of Technology/Completeness of Replacement Value	
		INCOMPLETE	COMPLETE
Cost of Technology	HIGH	<b>Early ATMs and automated grocers</b> Technology adoption is limited due to costs and limited functionality	<b>Early Satellite Navigation System (ARPA's "Transit")</b> Technology adoption is limited to users willing to cover high costs
	LOW	<b>Modern ATMS and self checkout</b> Technology adoption is broad but does not fully replace prior used technology (e.g. bank tellers) creating a static hybridization	<b>Modern Satellite Navigation System (GPS)</b> Technology adoption is complete and has permanently changed navigation methods

Higher adoption →

More significant transformation →

Figure 1: Value Proposition: Balance of Cost and Functional Value Informs Technology Adoption

The history of global navigation satellite systems is an example in which the functionality dynamics were very positive for adoption, but high costs limited initial applications. When Transit, the first satellite navigation system launched in the 1960s, it offered an excellent improvement over the prior navigation technologies (e.g. celestial



*Figure 2: Transit System receivers received navigation signals transmitted by Transit satellites passing overhead and weighed as much as 250 pounds.  
Credit National Air and Space Museum, Smithsonian Institution*

navigation and radar) but the installation costs were so high that adoption was limited to government and industrial entities with a very high perception of the value and willingness to pay. Only after costs and sizes for modern GPS receivers dropped dramatically in the late 1990s did the technology achieve the widespread use seen today. The functionality and utility of the technology is such that GPS has fully replaced other navigation technologies (and significantly expanded the market beyond the prior users of radar navigation).

In other cases, automated technologies have been adopted while still not completely transforming the market. While the automated technology may be highly effective for certain uses, they fail to fully replace the functionality of the prior technology, fail to completely meet consumer needs, or require changes to business practices or lifestyles. These factors result in the technology being slower to deploy even when costs come down. Incomplete replacement can also lead to the emergence of a durable dual market in which the automated technology complements and/or competes with but does not replace the non-automated technology.

Deployment of automation in banking and groceries are examples of automated technologies that led to complementary dual markets. Early ATMs and automated grocery lines faced significant functionality challenges that undermined deployment in addition to their high installation costs. The automated services offered value particularly for a certain range of services and once costs became acceptably low, adoption became more widespread. However, their deployments have not fully replaced the labor of human clerks, who are needed to perform a wide range of functions and can better perform complex transactions. The human clerks and tellers also provide critical labor flexibility to enable businesses to meet peaks in consumer demand. The

complementary service alternatives provide multiple options for customers depending on their needs, improving efficiency. As a result, businesses routinely offer automated services as well as human tellers and clerks.

New technologies also change lifestyles and business processes, but the change must be perceived as an improvement relative to the prior norm. GPS is an example in which the technology has dramatically changed not only navigation and travel patterns but also telecommunications, agricultural practices, financial transactions, and dozens of other elements of the modern economy.

Shared use technologies have the potential to reduce or replace personal ownership of an asset, and as a result, the sharing economy has had significant impacts on certain markets. However, the impact of shared use technologies is more complete when the technology requires less change to lifestyle or business practices. For instance, personally owned CDs, DVDs, and digital libraries have largely been replaced by streaming services. Streaming services not only replaced the media assets one may have previously owned but also benefited subscribers by providing much broader access to music and video content. Streaming apps also integrated easily into existing systems for listening to or watching digital media, requiring minimal change to lifestyles. Streaming services do face certain downsides in the form of subscription costs and the risk of licensing changes or media being removed from the platform. For most people though, the ease and value of access to streamed content exceeds the benefit of owning and storing digital content.



*Figure 3: Shared bikeshare systems provide access to bicycling and have not replaced personal bike usage*

Bikeshare systems also have achieved widespread adoption and have expanded access to bicycles however the impact has not been the complete replacement of privately owned bicycles. Rather the bicycle market has evolved into a dual market in which shared and personally owned bicycles solve different user needs, with some riders using and preferring one form or the other, and with many individuals maintaining both a personal bike and a bikeshare subscription.

Bikeshare networks provide riders with an economical mode of transport with low upfront purchase costs and no maintenance costs; they are widely

available to commuters or tourists in multiple locations across the shared network, and are convenient especially for one-way trips, transit connections, and for riders away from home. On the other hand, bikes and docks may not be available during peak demand periods, costs per trip can be high, and the weight and maneuverability of the bikes are less versatile, making them better for some ride locations and durations than others. In contrast, personal bikes can be customized for an individual's size, comfort and riding style, but with higher upfront and maintenance costs; they're always available for the owner's use but must be accessed from their last parked location. The differences in these technologies' ideal uses and benefits/weaknesses result in their being complementary goods rather than either option entirely dominating the market for bikes.

## Technology Factor Implications for AV Deployment

Just as with these other technology examples, a variety of factors will impact the timeline and nature of AV deployment, including questions of technological reliability, infrastructure readiness, costs and market demand. Each factor will influence where, how, and at what speed companies bring the technology to market. Adoption depends not only on whether the technology works, but also on which mobility uses it can reliably substitute at acceptable prices, and where companies will be able to recoup investments into the product. This helps explain why AV deployment will be uneven and—for the foreseeable future—hybrid. AVs are likely to expand in specific use cases where they provide a clear value proposition and where commercial markets make deployment viable. Because AV deployment cannot fully replace all mobility use cases in the near or medium term, AVs will coexist with incumbent modes (both personally owned non autonomous cars and human-driven rideshare options, and transit and non-vehicle travel) that remain better suited to flexibility, geographic coverage, or individualized convenience.

**Costs and Market Factors:** The AV cost conditions relative to the economics of transportation network companies vary in important ways that increase the likelihood that a dual market for autonomous and non-autonomous taxi or rideshare to emerge. Human-driven rideshare companies face minimal upfront costs since assets are typically owned by drivers employed as independent contractors. Instead TNCs face high operating expenses to pay driver wages and provide incentives to ensure adequate supply of drivers. In contrast, robotaxi companies must make significant upfront capital investments to build vehicles with autonomous driving technology, as well as investments in digital infrastructure, such as mapping locations for deployment. Robotaxis will still face ongoing operating costs including labor costs, as companies must still conduct fleet maintenance and provide back-office work support to maintain vehicle software and provide remote assistance as needed. Nonetheless, the marginal cost per mile or trip is much lower than for human-driven rideshare, and many robotaxi

costs will be fixed to large degree such that the average costs will decline the more trips that are taken.<sup>1</sup>

Robotaxi companies' current business model is to make significant investments of capital to own a fleet of AVs; this has two primary implications for their operations. First, this means they will have a fixed fleet size with minimal ability to respond quickly to changes in rider market demand. Second, companies will seek to ensure that these high capital assets are fully utilized to reduce average costs and amortize their investments. Profitability for robotaxi companies will likely depend on their generating sufficient trip volume per vehicle, running the vehicle as close to 24-7 as possible. But of course, ride demand does not stay flat throughout the 24-7 period; instead demand is characterized by peak and off-peak levels of ridership. Demand for rideshare fluctuates

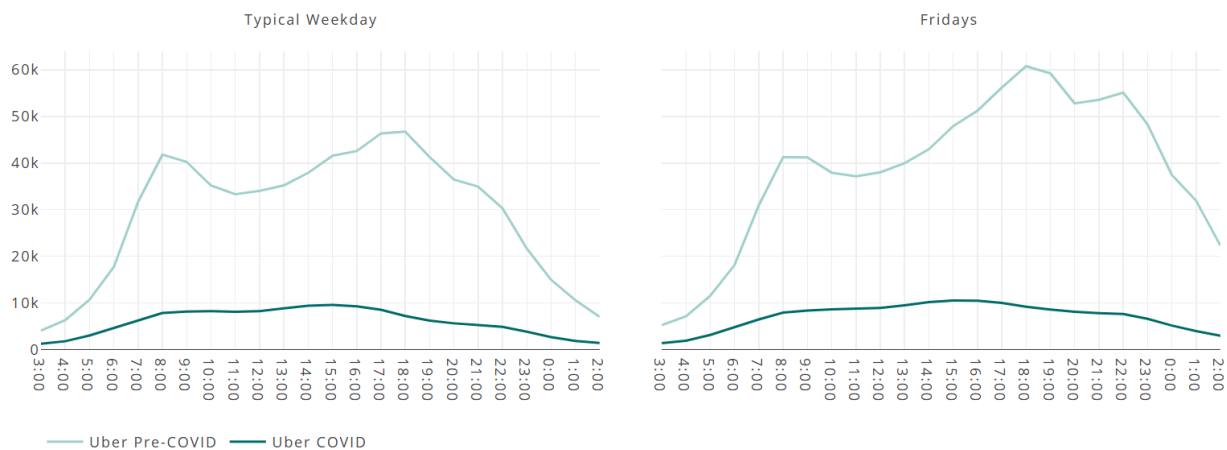


Figure 4: Uber Trips by Time of Day on an Average Typical Weekday and Friday, September 2019 to August 2020  
Credit: "TNCs 2020: A Profile of Ride Hailing in California" SFCTA

throughout the day and week, with demand spiking not only during commute hours but also on weekend nights and during bad weather and special events. If AV companies want to achieve maximum utilization for their full fleet, they cannot invest in the number of AVs that would be in use at peak demand, as that would guarantee that some number of those vehicles would be parked and unprofitable in off-peak periods.

In contrast, human-driven rideshare platforms benefit from tremendous flexibility in their labor and vehicle pool. The large pool of independent contractors choose when to enter their vehicle and service into the rideshare network based on price incentives. As demand for rides increases, so do wages available to drivers; this allows the network to maintain adequate supply to balance demand. Absent conducive prices, human drivers can choose not to participate in the market and instead use their time and vehicle for other purposes. In other words, the business model for human-driven TNCs produces market forces that result in a dynamic supply that responds to changing rider demand levels.<sup>2</sup>

Modeling of the TNC and robotaxi market suggest that “AVs will, in most plausible cases, not fully replace [human driven vehicles] even if AVs have a lower total cost (i.e., the sum of the fixed cost and the variable cost). The reason is the lower flexibility of AVs. AVs are capital-intensive assets that must be pre-committed to a market and incur fixed costs, regardless of whether they are operating or not. This means that AVs are cost competitive only if their utilization is sufficiently high.”<sup>3</sup> Rather than a one-to-one replacement of human-driven vehicles, autonomous rideshare may be deployed more profitably on a hybrid network by providing the “baseload” supply of rides demanded, while meeting peak demand by supplementing with human driven vehicles drawn to the market through the same price signals used today.



Figure 5: LiDAR-equipped AVs. Credit: iStock

In general, AVs are more capital intensive than human driven vehicles due to the necessity of adding LiDAR, cameras, and computing power. Estimates today suggest that autonomous driving capability will add several thousand dollars to the cost of new vehicle purchase prices and also require subscription services for infrastructure mapping or vehicle support.<sup>4</sup> Given the slow turnover of the personal

vehicle fleet and the substantial cost premium of AV technology, near-term deployment will be limited to robotaxi fleets rather than personally owned vehicles.

Robotaxi service is likely to provide a complementary use case to personally owned human-driven vehicles, just as TNCs do already, offering a different mobility service with unique costs and benefits. The net costs of paying per ride in a robotaxi or TNC versus paying the full cost of owning and operating a personal vehicle varies based on an individual’s lifestyle.<sup>5</sup> Paying per-ride and avoiding the fixed costs of car ownership tends to be cost effective for households that drive or ride less than 6,000 miles per year, whereas for those above that level cost ownership tends to be lower cost.<sup>6</sup>

Households in urbanized areas are less likely to own a car relative to the nationwide average, which has made such areas more lucrative locations for deploying robotaxis. Estimates of TNC impact on household vehicle ownership suggest that there is

measurable impact on rates of car ownership, but the change has been marginal and not anything approaching a full replacement.<sup>7</sup> To the extent that robotaxis offer a lower cost per trip than human driven rideshare, they could make it more cost effective for more households to choose robotaxis over personal vehicle ownership. But as noted above, other factors also affect the adoption of new technologies.

<p><b>Human Driven Rideshare Companies</b></p>	<p>Minimal upfront capital costs          High variable costs          Can use pricing signals to easily increase supply of drivers and rides          Geographic distribution constrained by ridership density and policy structures</p>
<p><b>Autonomous Robotaxi Companies</b></p>	<p>High upfront capital costs          Low variable costs          Supply of rides is fixed and unable to increase in short-term to meet demand surges          Geographic distribution constrained by ridership density, policy structures, digital mapping, and operational support</p>

**Functionality and reliability factors:** In addition to high costs, AVs require an ecosystem of support, including an initial investment into “unlocking” the location e.g. mapping a geographic area to facilitate the autonomous driving function within that geofenced service area, as well as provision of remote support. The delivery of autonomous rideshare will likely exist as an ecosystem between the autonomous software provider, OEMs, fleet management, rider support, and demand aggregators. Software providers have already begun to experiment with these partnership structures, such as working as the fleet manager in some cities while outsourcing to rideshare companies to serve as demand aggregators and fleet managers.

These factors are more conducive to fleet management rather than personal ownership. While support services could be provided on a subscription basis, geofencing vehicle driving ranges would not be compatible with current use of personal vehicles and therefore has significant implications for functionality. Unlike TNC and taxi services, whose geographic limits are defined by supply and demand rather than technical capability, a robotaxi cannot operate outside its mapped ODD regardless of rider demand. Both types of service have geographic constraints, but where human-driven services can follow demand wherever it emerges, robotaxi expansion requires upfront investment in digital infrastructure first. Both differ significantly from a personal vehicle, which faces neither constraint.



Figure 6: Autonomous driving is supported by digital maps of the ODD.

Credit: iStock

AVs are constrained to the geographic limitations of their ODD in part because this enables the vehicles to avoid situations and roadways where the autonomous driving function cannot determine the appropriate way to navigate and the vehicle stops functioning. Although functionality of AVs has broadly improved as AVs have accumulated more miles and experience, AVs continue to encounter “edge cases” that confuse the autonomous technology. This functionality challenge has been described as a “jagged technological frontier” that can be slow to resolve. While AVs are able to easily accomplish some operations, others of apparently similar levels of difficulty can cause the technology to stop functioning. This results in a development process that involves trial and error to find and resolve edge cases, which will potentially have a “long tail”.<sup>8</sup> On the other hand, within the ODD, the AVs can achieve a high rate of functionality, particularly as they accumulate miles within that geographic area. This may contribute to a scenario of rapid increase in both the numbers of vehicles deployed and level of functionality of those vehicles in the locations that have been unlocked, while other geographic locations still face slow timelines for deployment.

**Lifestyle integration factors:** Other factors will affect uptake of robotaxis versus human-driven TNC rides. Consumers vary in their eagerness to adopt new technology

and may have preferences and needs that make a vehicle with autonomous driving technology more or less attractive. Some riders may prefer the presence and assistance of a human driver, to share suggestions on tourist destinations or to help with luggage; others may appreciate the privacy offered by an AV.

For consumers, outside of these preferences and needs, the mobility service offered by a robotaxi will largely be the same as that offered by a human TNC driver and require minimal if any lifestyle change. In contrast, the full substitution of robotaxis for trips in a personally owned vehicle would involve more lifestyle changes. Personally owned vehicles offer certain conveniences to households, enabling owners to keep equipment and car seats in their car, and have the vehicle available to them when the household requires it. Rideshare trips also offer conveniences, different from those of personal vehicles, including avoiding parking at the destination or driving under the influence, and the ability to take a one-way trip. An individual's preference between using a personally owned vehicle versus riding in a TNC or robotaxi vehicle may vary by the trip, depending on these and a multitude of other factors.

## Hybrid Networks

The technology adoption factors discussed in this section will influence the deployment of robotaxis and the conditions under which those deployments can succeed. Robotaxis will not satisfy all travel demand under foreseeable technological and economic conditions, and they will enter a market already served by human-driven TNCs, personal vehicles, transit, and other modes. The question is not whether these modes will coexist, but how this coexistence is structured.

Hybrid networks offer an efficient answer to this question. Providing access to robotaxis on hybrid networks that include human-driven vehicles will maximize benefits for riders through expanded choice and the ability to easily compare prices and wait times. Rideshare companies can serve as demand aggregators, balancing the fixed supply of robotaxi fleets against the elastic supply of human drivers to ensure service coverage across the demand curve rather than only at the baseload. A hybrid network structure also lowers the barrier to entry for new market entrants, allowing them to access an established rider base rather than building network effects from scratch. This can be a significant advantage as multiple autonomous options enter the market simultaneously. A hybrid structure expands competition on the supply side and improves price transparency and choice on the demand side – providing benefits to riders, operators, and cities that may not be accessed through fragmented AV-only networks.

## Section Two: The Existing Shared Roadways

Early deployments of fleet-operated autonomous rideshare by Cruise (before GM's suspension of its service), Waymo, and Tesla provide the first real-world examples of autonomous and human-driven vehicles sharing urban roadways, along with the opportunities and challenges that co-existence presents. The variation in how these vehicle networks have been structured, and the outcomes that follow, also illustrate why deploying AV fleets through a hybrid network produces better results for riders, drivers, and cities.

Austin and Atlanta provide examples of hybrid networks in which both autonomous and human-driven rideshare options are available through a single shared platform (currently Uber). By contrast, in San Francisco, Los Angeles, and Phoenix, AV and human-driven rideshare operate on separate platforms.

Cities with active deployments vary in the pace of their AV network growth, but share common patterns: slightly higher costs for autonomous rideshare, longer wait times for AVs relative to human-driven rideshare at peak hours, and continued utilization of human-driven rideshare, whether on a hybrid or separate network. Another consistent theme is the need for collaboration between city officials and AV operators to work through the challenges of integrating autonomous vehicles into existing roadway systems.

### Market Share and Mileage

Autonomous vehicles were first deployed in San Francisco in 2022; in that year AVs drove a total of 0.2% (7 million miles) of the city's total vehicle miles traveled (VMT).<sup>9</sup> In the following year, with San Francisco still being the only city in which AVs were deployed in California, 9.1 million autonomous miles were driven in the state.<sup>10</sup> As autonomous VMT increased, so did the number of trips taken in AV, growing from 3,576 to 400,731 from 2022 to 2024.<sup>11</sup> AV deployment expanded to Los Angeles in November, 2024. As of August 2025, Waymo had around 800 vehicles operating in San Francisco and 500 in Los Angeles (which collectively was 65 percent of Waymo robotaxis operating nationwide.)<sup>12</sup> By June 2025, Waymo robotaxis were competing robustly with other TNCs and providing 14,448 rides per day, e.g. approximately 20.5% of the rideshare rides in San Francisco (within Waymo's SF ODD). By that same date in Los Angeles, Waymo made up 2.4% of the rideshare market within Waymo's LA ODD, providing 8,395 rides per day.<sup>13</sup>

Autonomous rideshare deployments in Austin launched in 2025, with Waymo partnering with Uber to provide robotaxi rides directly through the Uber app. As of June 2025, Waymo made up 4% of the rideshare market, providing 3,631 rides/day.<sup>14</sup> According to Uber's CEO, the approximately 100 Waymo vehicles in the city typically

complete more trips per day than human drivers on the app.<sup>15</sup> A similar approach and outcome occurred in Phoenix, when Uber and Waymo partnered to create a temporary hybrid network in 2025, leading to rapid expansion of market share for robotaxis. In Phoenix, the 400 Waymo robotaxis provided 9,240 rides/day or 6% of the TNC market share as of June 2025.<sup>16,17</sup>

The following graph highlights vehicle utilization in comparison to rides per day across deployment locations. The graph compares rides per day per number of vehicle and market penetration. While San Francisco has the greatest market share and number of vehicles, its number of daily rides per vehicle is comparable to Los Angeles and less than both Austin and Phoenix. Austin, the only representative of a hybrid network, displays the highest number of rides per day per vehicle.

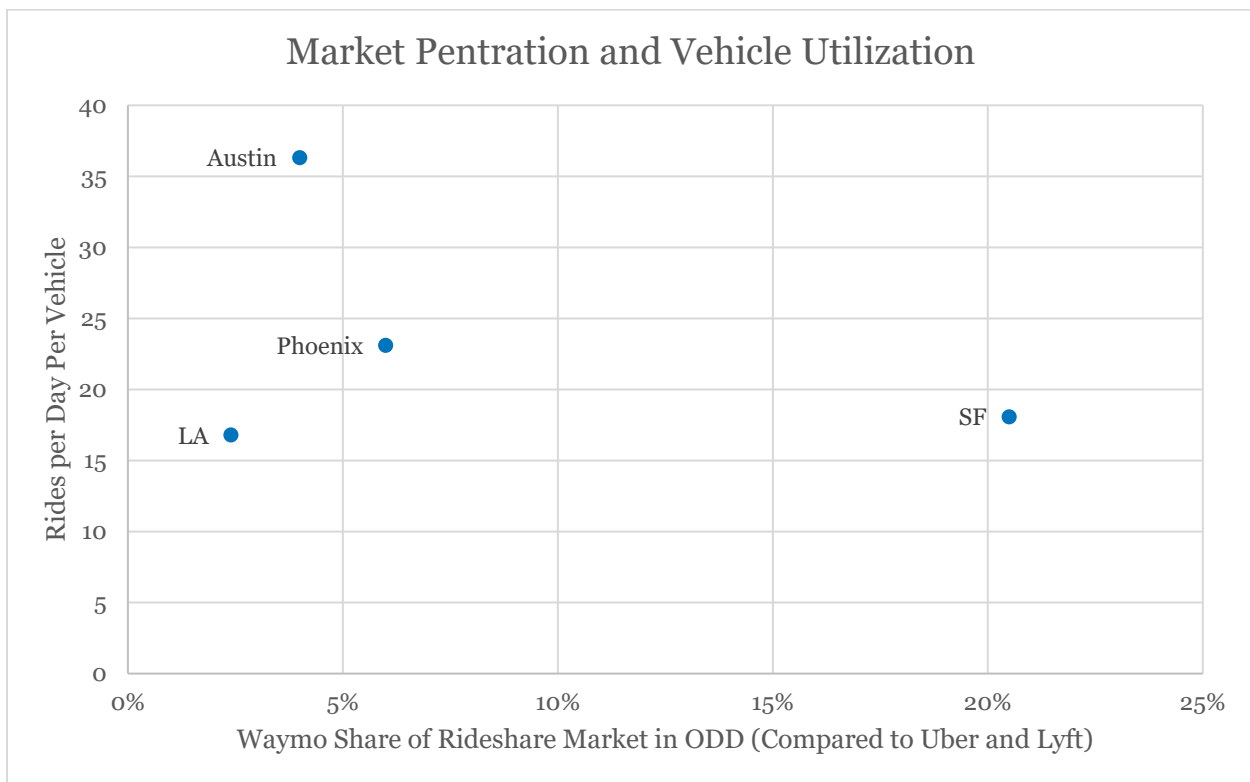


Figure 7: Market Penetration and Vehicle Utilization

In comparison, data from the California Public Utility Commission from the September 2019-August 2020 period indicates that Uber drivers on average provided 15 trips per day and Lyft drivers provided 17 trips per day, working an average of 4-5 hours per day.<sup>18</sup>

### Costs

In San Francisco, autonomous rideshare is slightly more expensive than human-driven rideshare. Waymo rideshare costs have decreased over the past year, but still remain

higher on average than Uber and Lyft costs. (Tesla’s autonomous rideshare in the city, which still has a driver behind the wheel, is notably cheaper than prices for Waymo or other TNCs. The comparison to Tesla may be less useful however, in part because the company may be subsidizing costs as it assesses viability.) Waymo has a higher price per kilometer than human-driven vehicles but costs begin to converge for longer trips.

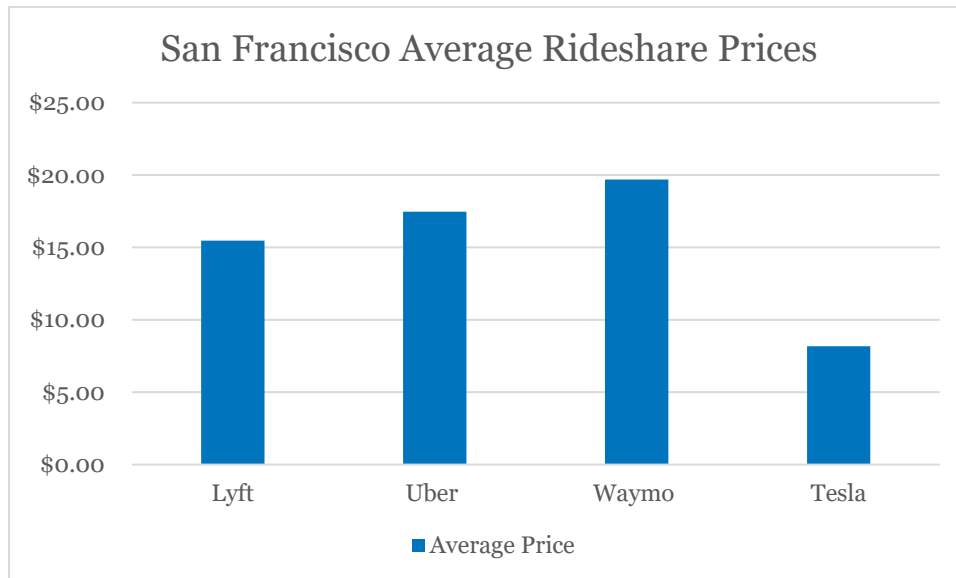


Figure 8: San Francisco Average Rideshare Prices

In San Francisco, the premiums on autonomous trips are more pronounced during peak hours (7AM-9AM and 4PM-6PM). Ride costs are higher at rush hour across the board, but Waymo rides see a greater price jump than Uber or Lyft. Uber and Lyft typically implement surge pricing as an incentive to increase driver supply so that it matches the higher levels of ride demand. For autonomous vehicle fleets, supply of rides remains fixed throughout the day, so price increases are not a mechanism to induce supply on an AV only platform. Instead, increases in prices on an AV-only network are likely better understood as profit-maximizing behavior by the AV operator, to help offset losses incurred when the vehicles experienced lower utilization at other times of the day. Waymo vehicles operating in San Francisco on the AV-only network are cheaper than human-driven vehicles early in the morning hours (especially on Fridays and Sundays) and consistently more expensive during the day during weekends (and into the night on Saturdays).

A hybrid network provides the benefit of flexible supply through human driven vehicles as demand shifts throughout the day and week; it also enhances cost transparency and competition for riders. Recent data from Austin (a hybrid network) shows Waymo rides have similar or slightly higher prices than Uber while Tesla offered significant discounts. Data from Austin also reveals that autonomous vehicles in the hybrid network currently have longer wait times and trip times than human-driven rideshare. In February 2026,

Waymo riders in Austin had around 30% longer wait times and 45% longer trip times in comparison to Uber’s human drivers and Tesla has around 120% longer wait times and 65% longer trip times in comparison to Uber.<sup>19</sup> Presenting both AV and non-AV option on the same network enables a rider to choose the price, timing, and experience they prefer.

Research from the Yale School of Management found that having a network of both autonomous- and human-driven vehicles could best serve the demand of riders and also facilitate successful deployment for AVs. “The existence of this flexible, elastic market for [human driven vehicles or] HVs is a critical determinant of market outcomes for AV services.”<sup>20</sup> If human driven and autonomously driven vehicles operate on separate demand aggregating platforms, demand will be pulled away from the human-driven platform, resulting in a loss of drivers and subsequent increase in prices. According to the modeling, the only scenario that ensures lower prices is a competitive marketplace with both human-driven and autonomously driven vehicles operating on a shared platform.<sup>21</sup> In other words, the hybrid network option is most likely to provide the best options for both human-drivers, riders, and robotaxis operators. These findings point to the conclusion that rather than conceiving of hybrid networks as a transitional phase, instead it may be considered an ideal long term market structure.

## Existing Policy Frameworks

In the United States, vehicle safety regulations for all vehicles are issued by the National Highway and Traffic Safety Administration (NHTSA) at the federal level in the form of Federal Motor Vehicle Safety Standards (FMVSS). NHTSA is working to advance FMVSS updates for autonomous vehicles specifically. At the state level, permits may be required to provide autonomous and/or commercial vehicle services and state regulators set standards for AV commercial operations within their state. These may include requirements to obtain and sustain permits, testing protocols and data sharing requirements, and law enforcement interaction plans. Each of the states with current AV deployments first passed enabling legislation prior to the initial deployments. State standards vary in their restrictiveness, with California considered more stringent in comparison to Arizona. However, state policy has not addressed the deployment of vehicles on hybrid or AV-only networks—decisions about the market structure in the cities have been made by operators and platform owners.

While city authority varies by state, in general cities have less authority to set standards for autonomous operations as permitting and licensing of vehicles and commercial services typically occurs at the state level. At the same time, cities are the primary enforcers of traffic safety laws and are on the frontlines to respond to challenges posed by AVs losing functionality and blocking travel lanes, disrupting an emergency response, and other such edge cases. Without direct regulatory authority over AV operators, cities

have had to rely on good relationships with AV operators to quickly address operational issues as they emerge. Recent examples of such issues have included interactions with law enforcement and blackouts in San Francisco, and autonomous vehicles passing school buses in Austin. As AV deployment locations have expanded to more cities, local officials have collaborated with each other to share lessons learned in working with autonomous vehicle operators.

The lessons learned have been significant, as demonstrated by the fact that in each of the early deployment locations, the state followed the passage of their initial enabling legislation with regulatory updates, reflective of their deployment experience as well as technology updates. California is currently undergoing a regulatory update of its AV permitting regulations including changes related to data sharing, first responder plans, and testing hours.<sup>1</sup> Texas also updated its state level regulations to enable the revocation of permits from operators (to be implemented in late May 2026).<sup>22</sup> Beyond states already in update cycles, many jurisdictions still drafting initial AV legislation have designed those frameworks around vertically integrated, first-party platforms, in which one company owns the vehicles, operates the fleet, and controls the rider application. As hybrid networks, in which AV operators partner with existing TNC platforms, become increasingly common, these frameworks may require modernization to account for a market structure their drafters did not anticipate.

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<sup>1</sup> The California updates are likely to reflect some of these concerns raised at the city level, including through SFCTA's 2023 Conceptual Safety-Focused AV Permitting Framework. In 2023 San Francisco also sued the California Public Utilities Commission for issuing autonomous vehicle permits following a fatal Cruise crash.

## Section Three: The Hybrid Network Marketplace Going Forward

As robotaxi deployments continue, the outcomes for riders and drivers will not be predetermined, but rather they will be shaped by decisions made by policymakers and platforms. This section examines four key outcomes in the context of shared roadways and hybrid networks: labor, safety, equity, and VMT.

### Labor

Autonomous vehicles are poised to compete for trips with human drivers and will likely be able to outcompete human-driven vehicles at certain hours, particularly in off-peak hours. However, given the fluctuations in demand for rideshare across the day and week along with rider needs and preferences, it is unlikely that AVs will fully replace human-driven rideshare drivers. For drivers who continue in the TNC workforce, the impact of AVs may include both positive and negative effects, but the ability to compete transparently with AVs on a hybrid network will help to mitigate many potential negative impacts and facilitate positive ones.

For operators of hybrid networks, human drivers will be an essential component of the rideshare network's ability to dynamically respond to meet ride demand. This function will fill in continuing supply gaps for robotaxis; operator needs for human-driven rideshare on hybrid networks are therefore unlikely to disappear. Maintaining rider access to a human driven rideshare and driver access to rider networks should therefore continue to be a priority for policymakers and rideshare platforms even as AV supply expands and competes for a greater share of off-peak ride demand.

Early data from existing deployments, where AVs exist at low penetration rates, already indicate that autonomous robotaxis are placing downward pressure on wages and trips for TNC drivers. Gridwise Analytics examined TNC driver outcomes and found that while nationwide pay per trip increased by 3.5 percent between July 2024 and July 2025, in the four cities with active AV deployment pay per trip actually declined in three of the four cities and increased by a meager 0.4 percent in Los Angeles.<sup>23</sup>

The impact on drivers' hours and occupancy rates is mixed but still consistent with the finding that hybrid networks produce better outcomes for drivers. The same report shows that driver trips per hour fell sharply in the non-hybrid network cities of Los Angeles and San Francisco—at rates higher than the nationwide average decline—whereas driver trips on the hybrid networks in Austin and Phoenix increased over the same period.<sup>24</sup> (Other factors may also contribute to these results, including the fact that the Waymo deployment in Austin is more recent. The AV market penetration rates in Austin and Phoenix are also much lower than in San Francisco, although similar to Los

Angeles.) The following chart shows the changes to pay per trip (in blue) and trips per hour (in orange) from 2024 to 2025 across deployment locations in comparison to the national average (shown in the left-most column).

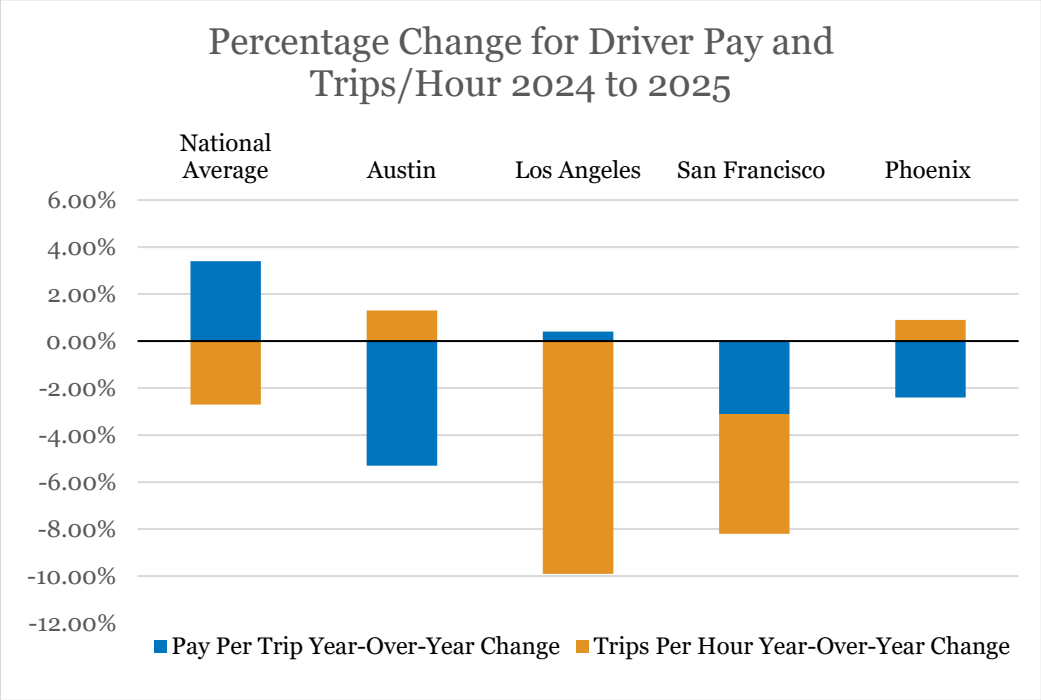


Figure 9: Percentage Change for Driver Pay and Trips/Hour 2024 to 2025

This data on its own still leaves numerous gaps in understanding the impact on drivers. For instance, the Gridwise Analytics report does not indicate how many, if any, drivers have left or will choose to leave their TNC earnings opportunities due to increased competition with AVs or new alternative earnings opportunities. The Bureau of Labor Statistics produces 10-year estimates for employment changes in industry, and projected that taxis drivers, including rideshare drivers, would increase in employment numbers by more than 13 percent between 2023 and 2033, an increase of nearly 25 thousand drivers.<sup>25</sup> Regardless, there are sufficient early indications of pressure on human drivers that platforms seeking to maintain the reliability of a hybrid network have reason to act now to maintain support and incentives for human driver participation in the workforce.

TNC drivers are independent contractors and set the timing and duration of their own hours. Many drivers have full- or part-time employment outside of their TNC driving, and place a premium on the flexibility to set their own hours.<sup>26</sup> According to survey data from 2015, 52 percent of Uber drivers worked full-time at another job, 14 percent of drivers had a separate part-time job, and only a third of drivers worked for Uber as their sole job.<sup>27</sup> The majority of drivers also do not work full-time hours: 83 percent of those surveyed worked as Uber drivers under 35 hours per week, and more than half of all drivers surveyed worked under 15 hours per week. The survey also found considerable

week-to-week variation in hours spent on the platform. In addition to this flexibility on work schedule, TNC platforms also typically enable drivers to set other preferences, including limiting the geographical boundaries in which they'll provide rides.

Assuming robotaxis are introduced at levels that meet only the baseload of trip demand and not the peak periods of demand, the impact of robotaxi competition will be greatest on that minority of drivers working full time as TNC drivers. For the majority of drivers, who primarily work only during peak periods, the competition posed by robotaxi services could be more limited. The presence of robotaxis may also enable human drivers to be more selective about the trips they opt to take, allowing robotaxis to cover shorter, low-complexity trips while human drivers select longer or higher pay trips.

Outside of the driver workforce impacts, autonomous rideshare will have broader labor implications including job creation in supporting functions needed to ensure AV functionality. AVs require remote operators to be available to assist or take over driving functions when the autonomous driving technology is unable to navigate an unfamiliar driving task. Unlike in TNCs, where vehicles are owned and maintained by independent contractor drivers, robotaxi fleets will need fleet managers and maintenance workers to oversee cleaning, servicing, mechanical maintenance, and parking during any off hours. As companies have deployed robotaxis, the breadth of job functions outside of driving that AVs cannot perform has become clearer, including seemingly mundane activities like waking a sleeping passenger or shutting the door that a passenger leaves open.

## Safety

Early safety data from AV deployment experience indicate positive outcomes from robotaxis but also highlight areas where human drivers and support remain necessary. Waymo data released in September 2025 suggests significant safety benefits of AV deployment. In 127 million miles traveled without drivers, the Waymo vehicles experienced 90% fewer crashes (serious injuries or worse), 82% fewer airbag deployments in crashes, and 81% fewer injury-causing crashes compared to an average human driver over comparable mileage.<sup>28</sup> The data also shows that impacts on vulnerable road users declined, including 92% fewer pedestrian crashes with injuries, 83% fewer cyclist crashes with injuries, and 80% fewer motorcycle crashes with injuries.

Several simulation-based and analytical studies have modeled how safety outcomes change at different AV penetration levels. One study suggests that safety improvements will be limited at low penetration rates, with much more significant benefits appearing as AVs become a larger proportion of the vehicle fleet—typically in the 10 percent and higher range.<sup>29</sup> Another paper assessed safety across the full spectrum of connected and AV penetration (zero to 100 percent), concluding that optimal safety benefits were

observed near 70 percent penetration, but smaller incremental improvements emerge as AVs first appear on the road.<sup>30</sup>

Studies also indicate that safety benefits may vary based on external factors such as road types and geometry, driving behavior, and the extent of interaction with human drivers, and that as AV share increases, the number of minor and major collisions on shared roadways starts to decrease noticeably, but these effects are not linear.<sup>31</sup> Some papers highlight context-specific factors, like merging areas or complex intersections, where the safety gains from higher AV penetration are more pronounced. Research on scenarios with lower implementation rates and therefore a higher level of interaction between AVs and more variable human and infrastructure elements emphasize that AVs will experience some challenges in early implementation.<sup>32</sup>

While early data on AV performance is promising, more data is needed to fully understand the impacts of autonomous vehicles on shared roadways. Waymo's Director of Safety Research and Best Practices notes that there is not enough mileage yet to draw conclusions from subsets of the data. 127 million miles represents a small fraction of the 3.3 trillion VMT nationwide and the locations and speeds of the Waymo miles traveled are not necessarily representative of the nationwide VMT, as they are driven primarily on select lower-speed urban roadways. There is agreement in the literature and among interviewees that more research based on mileage is needed to fully understand safety impacts of deployments.<sup>33</sup> Other concerns have also been raised with the Waymo data, including the combination of fatalities and serious injuries, which according to some researchers makes the data less reliable, the lack of differentiation between useful mileage and deadheading, and the challenge of drawing conclusions in the face of changes resulting from software updates.<sup>34</sup>

AVs avoid risk factors that affect humans, such as tiredness or impairment, however there are also areas where human drivers are currently better equipped than autonomous vehicles. Human drivers are better able to adapt to unexpected scenarios. For example, during a mass power outage event in San Francisco, human drivers were able to treat traffic light outages as four way stops. Autonomous vehicles first needed to validate that the lights were out, which due to the scale of the outage overwhelmed remote assistance for the vehicles. In emergency situations, there is still a gap between human knowledge and autonomous vehicle programming. For instance, in Austin, a Waymo drove through a shooting event. These various experiences point to a level of situational judgement that human drivers have navigating different operating environments. While these competencies can be programmed to a certain extent, AVs will also have to learn through a trial-and-error phase and will require ongoing safety evaluations.

As data on AV deployment expands, so will questions about the performance standards to which autonomous vehicles should be held and compared. Compared to the general population, rideshare drivers tend to have more experience and safer traffic records. Data from the 2025 Lyft safety report indicates that the fatality rate per 100 million miles traveled ranged from 0.68 to 1.02 for Lyft drivers, compared to the nationwide average of 1.33 to 1.38 for the same time period.<sup>35</sup> Uber reports similar traffic fatality rates of about half the national average.<sup>36</sup> To the extent that AVs are deployed as robotaxi services and displacing miles driven by human rideshare drivers, the appropriate safety comparison arguably should be to non-impaired rideshare drivers rather than a comparison to general human drivers.

On shared roadways, the safety outcomes of AVs will also be affected by the driving behavior of human drivers on the roadways; anecdotal experience of individuals in early deployment locations suggests that humans have a range of responses to AVs. In some cases, the careful following of traffic laws by AVs may produce new driving norms that create a stronger safety culture, positively influencing the driving behavior for human driving. On the other hand, overly cautious driving can lead human drivers to drive aggressively to pass AVs, creating new risks. Waymo has begun to program its autonomous driver to operate more aggressively to accommodate urban driving. Rather than changing the safety culture by strict rule following, autonomous vehicles may instead conform to a more human dictated driving culture.

Policymakers should also consider the public's expectations of higher safety performance from autonomous vehicles. Survey data from Obi, a rideshare aggregation and price comparison tool, found that only 20 percent of riders said they would choose autonomous vehicles on the basis of safety.<sup>37</sup> At the same time more than half of respondents said they anticipated autonomous rideshare to be safer than human-driven rideshare over the next five years.

AV technology hardware and software programming also affect their safety performance, as they determine how AVs perceive roadways and road users and how they respond to different roadway conditions. In terms of software, AV companies are constantly updating their driving software based upon real-life learning experiences they see in the field, and updates may be programmed and installed remotely to affect the entire fleet. Companies are also developing new hardware systems and learning from early deployment experiences to improve hardware functionality. For instance, LiDAR provides more accuracy compared to other sensing technology such as radar or camera-based systems, which may struggle in poor visibility scenarios.

Physical infrastructure design also affects safety, including clear machine-readable roadway markings and digital infrastructure for V2X technologies. AV companies have emphasized that they are building their vehicles to be able to navigate a variety of

scenarios. Policymakers seeking to update roads to accommodate AVs would need to know in advance and take into consideration the AV hardware systems, sensor types and redundancy, and the software systems, all of which may be subject to change. Stakeholders interviewed for this project did not believe that cities should specifically make changes to their roadway designs and infrastructure to better accommodate AVs although infrastructure improvements like clear signage that benefit AVs can also benefit human users.

## Equity and Social Benefits

While autonomous mobility has the potential to expand transportation access, existing barriers may result in uneven distribution of those benefits. The extent to which AVs increase accessibility may vary across populations and may depend on the social, spatial, and regulatory context in which the AVs operate. In this section, social equity encompasses varying user preferences, cost considerations, and the extent to which software and vehicles provide access to all riders across all geographies. Robotaxis are not yet available in most locations and transportation access across geographic areas will likely require continued access to human-driven vehicles and other modes of transportation.

Rideshare users may have a variety of needs and preferences, and some rideshare companies are seeking to lean in to accommodating such preferences, allowing riders to select a preference for female-driven vehicles or electric vehicles. In this context, a hybrid network further expands rideshare user choices. Numerous interviewees noted that riders' preferences appear to vary significantly with regard to drivers versus driverless cars. While some riders, such as women, may prefer to be alone when traveling to their destination, others may prefer the company of a driver. For example, survey data from rideshare company Obi indicates that male respondents are more trusting of autonomous vehicle rides to transport children and elderly relatives or in emergency situations.<sup>38</sup> Making such options available can help expand potential equity benefits and accommodate user preferences of marginalized or vulnerable populations.

Robotaxis present the opportunity to expand mobility options across age demographics, especially for the elderly and young riders, as well as for members of the disability community, but achieving this will require intentional design and policy choices. Uber and Lyft offer accounts specifically designed for teenage users, while Waymo is currently restricted to users aged 18 and up in most of its deployments with the exception of Phoenix. In this case, a hybrid network would expand options for riders of different ages to identify the options available to them. Elderly populations also have unique user needs, such as more limited smartphone access. Preferences among riders over 60 may also tend away from driverless vehicles, according to survey data from Obi, which highlights low confidence levels in AVs among older respondents and a preference for

access to human-driven rideshare.<sup>39</sup> User-centric design is also a key aspect of unlocking expanded access for the disability community. Wheelchair accessible vehicles are limited and there is currently no way for wheelchair users to self-secure within vehicles, posing a challenge for such riders in AVs. Hybrid networks that provide a range of options, including AVs, human-driven vehicles, and vehicles equipped to accommodate wheelchairs, enable riders to select the vehicle type that best meets their needs.

The benefits of AVs will be limited to those with access to rides, specifically those within their deployment geographies, which are currently limited to high-density areas. Such areas already have existing rideshare and transit options. To expand to new geographies autonomous vehicle companies must first geofence and map the area and collect testing data with human drivers. These upfront investments to expand autonomous services are not insignificant and must be recouped in ride fares but lower density locations are more likely to provide lower profits because the lower density of people and destinations results in higher levels of deadheading and unproductive time traveling without a customer.

Areas with relatively high density but low or uneven levels of transit access may be better disposed to benefit from expansions in the autonomous network that are still commercially viable. Policy interventions can help to establish access goals. For instance, a bill proposed by the Washington DC Council will require equal coverage and wait times across the city along with discounts for rides connecting to transit.<sup>40</sup>

Those in rural areas who cannot drive or do not have access to a personal car or to transit systems uniquely stand to benefit from expanded rideshare networks. Unfortunately, the high costs of service and low levels of demand will mean that the rollout of AV robotaxi service is likely to be slowest in such locations, short of policy interventions.

Transportation cost is an additional area in which realization of potential social benefits across both social and geographic populations may require policy intervention. Data from existing deployments indicates that robotaxi prices are higher, especially during peak hours, compared to the TNCs and public transportation systems also operating in their networks.<sup>41</sup> In other words, riders choosing robotaxis are in a socioeconomic group willing and able to pay a cost premium for the service.

## Vehicles Miles Traveled

Robotaxis will provide largely the same service that TNC rides provide today and are operating in areas already covered by TNCs so substitution is the most likely near-term outcome for robotaxi VMT impacts. To the extent that robotaxis substitute for some

portion of rideshare trips without changing trip costs, the impact of robotaxis on nationwide VMT may not be significant.

Empirical analyses and household-level modeling show low expectations for the number of people that will give up household vehicles as a result of gaining access to shared AV fleets. In this regard, TNC impacts on vehicle ownership are likely a good estimate for how robotaxis will influence vehicle ownership choices. Access to TNC options has been found to slightly reduce per-capita vehicle ownership (3.1% on average after a TNC entered a city) and lower rates of vehicle ownership are associated with lower average VMT for an area.<sup>42</sup> Nonetheless, TNCs typically increase overall VMT in an area due to “empty” trips, substitution of vehicle travel for transit, and expanding access to vehicle travel for those without personal vehicles. In comparison, estimates of TNC VMT suggest that 20 to more than 40 percent of total TNC miles result from deadheading—this is still lower than estimates for taxi services.<sup>43,44</sup> TNCs also provide an alternative to transit and other non-vehicle modes of travel, which can increase total VMT.

Recent analyses of early deployment of AVs in California show that approximately 54 percent of all miles traveled by Waymo vehicles between August 2023 and December 2025 were driven with a passenger aboard, and the other 46 percent was deadheading trips. The study also found that this share of empty miles traveled decreased over the study period as the number riders increased and as the robotaxi fleet and its geographic dispersion increased.<sup>45</sup> AV companies also drive their vehicles for hundreds of thousands of miles in an urban area prior to their commercial deployment in order to build the digital maps that enable the autonomous driving function.

A hybrid TNC network may improve efficiency and reduce deadheading miles through scheduling and routing practices and reducing deadheading would be consistent with goals to maximize AV utilization rates. Enabling AVs to take low-priority trips, without regard to a drivers’ location preferences or trip types may enhance routing efficiency. Ultimately minimizing deadheading relies on deploying larger numbers of robotaxi vehicles so that the vehicles are distributed evenly across the service area, but increasing the number of vehicles on streets may contribute to higher VMT levels if they expand overall car usage.

Human-driven TNC	Hybrid Network (Best Outcomes)	AV-only Network
<p>Elastic supply responds to demand peaks</p> <p>Geographic flexibility – no mapping needed</p>	<p>Resilient platform – Human drivers maintain service when AVs encounter edge cases, outages, or system disruptions</p>	<p>Low marginal cost per trip, especially off-peak</p> <p>Consistent 24/7 availability</p>

<p>Surge pricing induces more driver supply</p> <p>Situational judgment in edge cases</p> <p>Human assistance for riders</p> <p>Flexible local employment</p> <p>Zero upfront infrastructure investment</p>	<p><b>Lower prices for riders –</b> Price competition on a shared platform drives costs below what either model achieves alone</p> <p><b>Preserves driver earning opportunities –</b> Driver trips per hour increase in hybrid markets – human drivers remain essential, not residual</p> <p><b>Most efficient vehicle utilization –</b> AVs serve consistent baseload demand; human drivers absorb peaks – eliminating stranded fleet capacity and unmet demand</p> <p><b>Reduces excess VMT –</b> Coordinated supply across human and AV vehicles limits deadheading through shared routing and demand matching</p> <p><b>Equitable access platform –</b> Riders choose between human and autonomous options based on their preferences, age, disability, or safety needs</p>	<p>No driver fatigue or impairment risk</p> <p>Fixed, predictable supply and pricing</p> <p>Privacy – no human driver present</p> <p>Technology-driven safety improvements</p> <p>Lower operating cost per mile at scale</p>
<p>Human-driven and autonomous vehicles are structurally complementary, not substitutes. A hybrid platform delivers outcomes - lower prices, driver earnings, service resilience, reduced VMT, and equitable access - that neither model achieves on its own.</p>		

## Section Four: Expectations and Implications for Personal AV Ownership

This paper has explored the implications of AVs in the near and medium term, which will almost certainly be limited to robotaxi fleets in that period. However, in the longer term, personally owned AVs will also become a component of shared roadways. Robotaxis and personally owned AVs need to be understood and evaluated as functionally different technologies that will be used and impact mobility in different ways, just as personal vehicles and human-driven taxis vary today.

The share of personal vehicle usage in the U.S. exceeds the combined rideshare and taxi usage by a factor of approximately 40 to one, so while disruptions and changes caused by robotaxi competition in the rideshare market may be significant, the impact of personal AVs replacing human-driven cars would be a vastly more significant impact on mobility, congestion, and usage of vehicles.<sup>46</sup>

### Timeline Expectations for Personal AVs

Personal AVs must be able to operate autonomously in any location in order to replace the use of human-driven personal vehicles. Under current technological and economic conditions, robotaxis operating as fleets in specific geofenced areas will achieve widespread deployment before that level of functionality is achieved for personal AVs. Some researchers and industry watchers anticipate that even in the long-term, while autonomous functions will expand in personally owned vehicles, fully autonomous vehicles will not fully displace human-driven personal vehicles as a result of technology and infrastructure challenges as well as personal preference.

Estimates for widespread AV have shifted backward even as technology development has progressed. Ten years ago, a 2016 AV industry report from McKinsey stated, “A progressive scenario could see ~50 percent of passenger vehicles sold in 2030 being highly autonomous and ~15 percent being fully autonomous.”<sup>47</sup> In contrast, in the most recent McKinsey industry survey, industry respondents expect the global rollout of robotaxis at large scale in 2030, with private passenger vehicles with level 4 autonomy becoming available several years thereafter.<sup>48</sup>

The current S&P Global Mobility snapshot indicates similar expectations: “For the next decade, autonomous tech will be limited to two specific areas: geofenced robotaxis operated by fleets in specific areas, and hands-off systems with various safeguards in personal vehicles that will still require some form of driver engagement.” Level 5 AVs may be technically feasible as early as the late 2020s, however, technical feasibility is not equivalent to deployment. The S&P Global Mobility analysis indicates that Level 5 autonomy will not be publicly available before 2035, “and probably for some time after that.”

From the initial point of availability of personal autonomous vehicles, there will also be a lengthy period between widespread adoption due to the slow rate of fleet turnover for cars. The average lifespan of a vehicle has been trending upward and reached 12.8 years in 2025.<sup>49</sup> The additional cost of AVs compared to human-driven vehicles due to technology add-ons will also tighten the potential consumer base for personally owned autonomous vehicles. Technology improvements and cost reductions—e.g. if the costs of integrating radar and LiDAR systems decline dramatically—would help to drive down AV costs and expand the pool of potential buyers. Alternatively, if safety data and increased public support emerges for camera-based autonomous driving functions (e.g. the Tesla model) AVs could become more affordable and widespread more quickly.

In contrast to the limited operations of robotaxis within defined ranges, personal AVs will be expected to operate on any public roadways (and even non-public roadways). Such driving conditions will lead vehicles to encounter more edge cases that could cause vehicles to lose functionality. In addition, to the extent that vehicle driving will require access to digital maps of the roadways, there will be high costs for companies to provide map that much broader geographic domain. Personally owned AVs will likely require subscription-based systems to pay for these mapping costs and to provide remote and on-site assistance when vehicles freeze or encounter traffic situations they cannot navigate.

One potential consumer model that could speed deployment of AVs would be if personal AVs were adopted as the secondary car, in addition to the human-driven household car. Since more than half of the households in the U.S. own more than one vehicle, once AVs become available for personal consumption, the differences between AV and non-AV features, costs, and capabilities may lead households to diversify their vehicle assets and purchase both types of vehicles and use them on trips and roadways where best suited.

## **Implications of Personal AVs for Rideshare and Robotaxis**

Setting aside the timeline for deployment of personal AVs and the possibility that widespread deployment may be several or even many years away, personal AVs do have the potential to cause additional disruptions in the rideshare market.

Personal AVs –assuming they have the ability and legal authority to travel empty—would not have to be parked at the rider’s destination and would be available for one-way trips, from which they could return home empty. These factors could help to change the relative costs and benefits of using a rideshare or robotaxi vehicle versus using one’s own personal vehicle. On the whole, these factors would likely reduce demand for rideshare or robotaxi in favor of one-way trips in a personally owned AV.

Personal AV owners could also potentially make their vehicles available on a robotaxi network similar to the way that rideshare drivers participate in TNCs. The economic incentives for personal AV rideshare participant would be different from those of the AV fleet owners. Unlike fleet owners, with the incentive to maximize utilization of the AVs, personal AV owners would only make vehicles available on the rideshare marketplace when they weren't in need of the vehicle themselves and/or when the price incentive became sufficiently high. As a result, personally owned AVs could provide the same dynamic response to increases in rider demand during peak periods that human drivers provide today. With the lower operating costs of the AVs, personally owned AVs on a rideshare network could displace a greater amount of human drivers.

Industry analysts interviewed for this paper provided a range of views and considerations regarding the likelihood of this potential type of AV deployment. On the one hand, the vehicle owner will face high costs for AVs due to the addition of technology and subscription costs, and households may look to the TNC market as a means to defray the costs of the vehicle. AVs could even be purchased as an investment to generate rideshare revenues. On the other hand, some individuals expressed skepticism that households would purchase premium vehicles and make them available for rideshare use without any human present to ensure the vehicle was not vandalized or damaged.

## Section Five: Policy Recommendations

The shape and outcome of AV deployments are neither predetermined nor inherently positive or negative. Instead, outcomes will be influenced by decisions made by platform owners and policymakers. In light of the technological and economic conditions that will remain present for the near and medium term, AV robotaxis fleets will not replace human-driven vehicles in the near and medium term. Operating and providing access to AVs through a hybrid network alongside human-driven vehicles will maximize benefits of AV fleets for both riders and human drivers. As Congress considers potential federal regulation of autonomous vehicles and as states continue to shape their deployment policies and regulations of both AVs and commercial vehicle services, policymakers and rideshare platforms should prioritize policy actions that maximize the benefits of a hybrid network and access to autonomous vehicles across geographies and socioeconomic classes.

Chief among these priorities are the needs of cities and drivers as those on the front lines of the implementation of autonomous vehicles. While robotaxis do not fully replace the function of human driven rideshare, human drivers are already feeling downward pressure on wages and hours in the locations where AVs have been deployed. Platforms must ensure that as they integrate AVs into their services, human drivers are not a cost to be phased out but rather remain a key component of rideshare networks. Human-driven rideshare also provides important opportunities in local economies for flexible work. In addition to providing incentives and support for human drivers, the following policies should be considered by states and federal policymakers as robotaxis expand across U.S. cities.

### City-Company Relationships

Maintaining trust between cities and companies is important but, when possible, these communication channels should be formalized. In Texas, the state created a Connected and Autonomous Vehicles Committee years before deployments began to ensure communication channels; that committee provides a good example of a formalized relationship between companies and city officials. When issues occur, such as during blackouts, companies must be immediately responsive to city officials.

An important component of this relationship is data sharing that ensures cities are aware of the safety impacts of a hybrid network. There are several important considerations for data reporting requirements -- they should be specific and goal oriented and limited to what cities have the capacity to process or what can be utilized to work towards actionable safety goals. Data reports must also protect the privacy of individual user information. While crash reporting to NHTSA provides federal regulators with an overview of AVs safety, cities are faced with day-by-day operational

challenges. As federal regulations are updated, data frameworks must also ensure clear channels of communication across levels of government.

A potential policy intervention to improve the relationship and responsibilities between AV companies and cities that some cities and States have considered is to establish an agreed upon compensation structure through which fleet operators to defray the cost of emergency services that are used to help AVs navigate in non-emergency situations. This could be achieved through fees on AV operators that are used to defray first responder costs. It is appropriate for emergency services to provide support for autonomous vehicles as they would human driven vehicles, but early deployment locations have experienced some increase in service needs that would not be experienced with human drivers. Time and resource constrained local services should not become a backstop for AV companies' customer support.

### **Driving Standards and Roadway Stewardship**

Clear communication on expectations for driving behavior can also improve deployment outcomes. AV driving performance should at least meet that of human drivers. An effective hybrid network is reliant on shared expectations between vehicle types. For example, when completing drop offs, autonomous rideshare vehicles should fully pull up to the curb as would be expected of a human driver. Another important component of being a good roadway steward for AVs is roadway usage when they are not directly serving a customer. AV companies should also limit VMT and road usage when not serving or traveling to and from customers and should ensure that vehicles are good stewards when using other infrastructure such as parking and EV charging.

### **Transportation Access and Equity**

In addition to being good roadway stewards, AV companies must also consider their role within a hybrid network and the existing transportation network gaps. If they are marketing their potential to expand transportation options, this should include efforts to fill transportation gaps, serve more suburban and rural areas, provide first and last mile access to transit hubs, and to design for accessibility, especially as NHTSA continues FMVSS updates to enable more purpose-built vehicles. The current market incentives for AV companies have led to a development pattern of deployments in locations with existing high density and access to multiple transportation options. Both private and public investment may be needed to utilize autonomous driving to fill in transit gaps. Some cities have already piloted autonomous mobility for transit services.

Transit is also an important component of an effective hybrid network. AVs can complement existing transit systems rather than making them redundant. In New York state, there has been a push to keep autonomous robotaxis out of New York City while allowing AVs to operate in the rest of the state where transit is less abundant.

Autonomous vehicles companies are unlikely to favor such geographic limitations. However, cities can also use tools like congestion pricing to manage overutilized roadways in areas where there are transit options. AV companies should also expand incentive programs that discount rides connecting to transit, and design for first and last mile access for riders with disabilities. Where public incentives are deployed, rigorous analysis should ensure the most effective use of public dollars across all mobility options. The shared platform model of hybrid networks is itself a mechanism for expanding customer choice – companies that aggregate both human-driven and autonomous options reach a broader range of users while enabling meaningful price and service comparison.

### Case Study: Washington D.C.

A bill currently proposed in the District of Columbia's City Council, the Autonomous Vehicle Deployment Authorization Amendment Act of 2026,<sup>50</sup> provides an example of policymaking seeking to maximize benefits of the integration of robotaxis into a transportation system. The bill would enable permitting of robotaxis in DC (a city where they cannot currently operate without a safety driver) while requiring prioritization of equity and city needs but could go further to protect the continued role of human drivers as well as local rider needs.

The legislation seeks to have a mutually beneficial relationship between the city and autonomous vehicle operators. For example, the proposed legislation includes having operators share data collected on areas with needed infrastructure improvements. The legislation also requires quarterly reporting, including on VMT and the number of times vehicles are disabled. Additional data sharing is required if crashes occur. The legislation also requires a comprehensive plan from operators which includes strategies to minimize deadheading, provide equitable access throughout the city, and incentivize transit usage. Operators must also ensure that their user interface enables those with disabilities to request services.

The DC bill allocates funding through permit fees, a vehicle miles tax, and other fines and fees to be directed to a fund to support implementation of the policy and to support workers displaced by the onset of autonomous vehicles. While the legislation's focus on labor displacement is important, it should also more explicitly consider the continued role of human drivers. The legislation could go further by providing specific support for drivers that continue to operate or incentives for shared networks between human and autonomously driven vehicles.

## Conclusion

The arrival of autonomous vehicles will not result in an immediate replacement of human driving. In the near-term, autonomous vehicles will be available as robotaxis and will not fully replace human ride share drivers in that period. The economic and technological conditions of fleet owned autonomous vehicles along with the fluctuating demand for rideshare throughout the day and week, provide human drivers with a continued, essential and durable role in rideshare networks even as robotaxi deployments expand.

Rather than view human drivers as an element of rideshare networks to be phased out, they should be understood as a key element of effective networks – and platforms and policymakers must act to protect their continued participation. Empirical research from the Yale School of Management demonstrates that hybrid networks with access to both autonomous and human-driven vehicles will maximize benefits for both riders and drivers. Hybrid networks also expand equity benefits through broader customer choice and access. Evidence from existing deployment locations indicates that there are not set outcomes from the introduction of autonomous vehicles but rather differing outcomes depending on market structure and policy decisions. Accordingly, policymakers and platforms must ensure that equity and expanded transportation access are the explicit goals – not byproducts – of AV network design.

As federal, state, and city level officials shape regulations and responses to autonomous vehicles, they must recognize that the shape and benefits of AV deployment are not inevitable; they are the product of choices that governments and platforms make now. Decisions about network structures and incentives will determine whether the benefits of autonomous technology are spread across socioeconomic and geographic groups and help to fill in gaps in the existing transportation network. These decisions will also determine whether human drivers are treated as a structural component of networks that serve riders best, or as a cost to be gradually displaced. That outcome is not a technological inevitability but rather a policy choice, and the time to make it deliberately is now.

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