

AUTONOMOUS VEHICLES

PERSPECTIVE PAPER



HORIZON

AUTONOMOUS VEHICLES

JUNE 2018

STUDY PARTNERS



ARUP

Front Cover: © User: Daniel Sessler/Unsplash

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An aerial photograph of San Francisco, California, taken during the "golden hour" of sunset. The sky is a mix of soft orange, pink, and light blue. In the foreground, the dense residential buildings of the city are visible, with various colors of roofs and walls. In the middle ground, several prominent buildings are visible, including the white, classical-style building of the San Francisco City Hall. In the background, the city's skyline is silhouetted against the bright sky, with the Transamerica Pyramid being a notable feature on the left. A semi-transparent blue rectangular overlay covers the upper portion of the image, containing the text "EXECUTIVE SUMMARY" in white, bold, sans-serif capital letters.

EXECUTIVE SUMMARY





EXECUTIVE SUMMARY

Autonomous vehicles (AVs) will dramatically shape the future of the Bay Area, presenting major opportunities and risks for region's goals and guiding principles. AVs will change how people travel, they will create new mobility choices, and they could transform public transit. AVs are an environmental wildcard; the technology has the potential to support or undermine climate and environmental protection efforts. AVs could disrupt the social fabric with major impacts on labor markets, equity, and access to opportunity. Fundamentally, AVs could also influence how we plan, design, build, and operate cities.

While the magnitude of AVs' impact is not unique to the Bay Area – all metropolitan areas will face foundational challenges and transformations – the Bay Area is uniquely situated to take advantage of the opportunities and mitigate against the risks AV present for three reasons. First, the Bay Area is home to much of the innovation driving this future paradigm shift. Second, since some of the region's governmental and non-governmental organizations already are planning for a world with AVs, the region has an opportunity to shape the future with thoughtful policies, programs, and pilots. Third, the diversity of the Bay Area can allow cities, suburbs, and towns to pilot and model policies that other communities can efficiently replicate.

This *Autonomous Vehicles Perspective Paper* presents a set of potential planning strategies for the Bay Area to seize the opportunities and meet the challenges that AVs are likely to introduce. This paper is the first in a series of Perspective Papers that will contribute to **Horizon**, a regional initiative exploring a range of external forces that have the potential to fundamentally alter the region's trajectory. The Horizon Guiding Principles – **Affordable, Connected, Diverse, Healthy, and Vibrant** – provide a framework for the implications and strategies. The report is appended with a comprehensive strategies menu from which the priority strategies were derived.

Over a two-week period in March 2017, Arup and MTC conducted an online Delphi survey. The survey participants represented government, industry, and academia and all had demonstrated expertise in an AV-related field.¹

TIMING 3 to 13 years until L5 AVs available for use

SAFETY +40% to +90% increase in safety

CAPACITY 0% to +45% increase in roadway capacity

DEMAND +5% to +40% increase in VMT

ENERGY/EMISSIONS -50% to + 100% change in GHGs

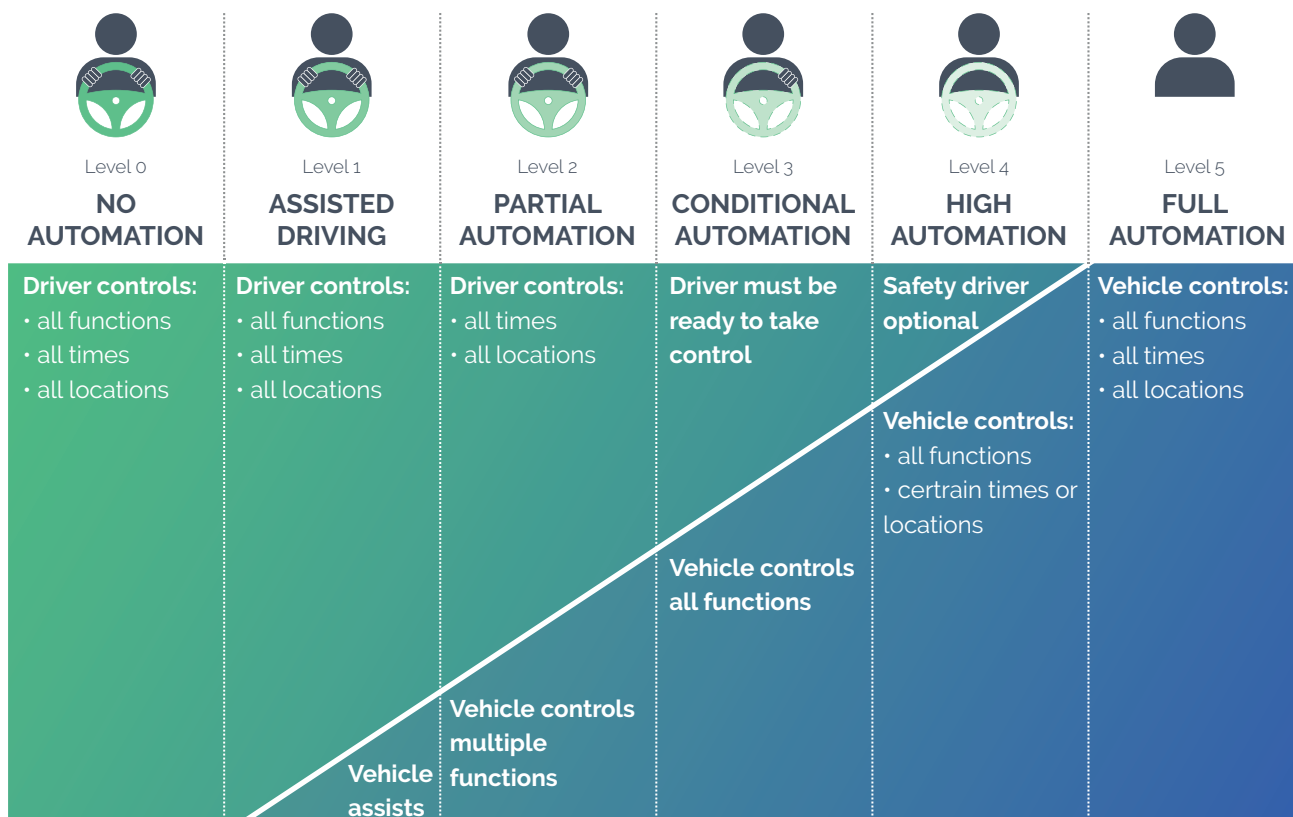
This survey demonstrates that expert opinion varies on when AVs will become available to travelers and how they will impact travel. In general, experts agree that AVs are likely to be available soon, they will be safer, they will increase roadway capacity but they will also induce demand. The environmental impacts are particularly uncertain, as vehicle autonomy could accelerate the shift to cleaner electric vehicles, but increased demand could increase energy use.



AN INTRODUCTION TO AUTONOMOUS VEHICLES

AVs use an array of sensors, powerful computers, and machine learning to navigate complex driving environments. With AV technologies, human operators and occupants will eventually be optional. This capability could have dramatic implications for personal mobility, public transportation, and the movement of goods. A standard framework created by the international Society of Automotive Engineers (SAE) defines basic steps in autonomous capabilities from no automation to full automation.

Levels of Automation

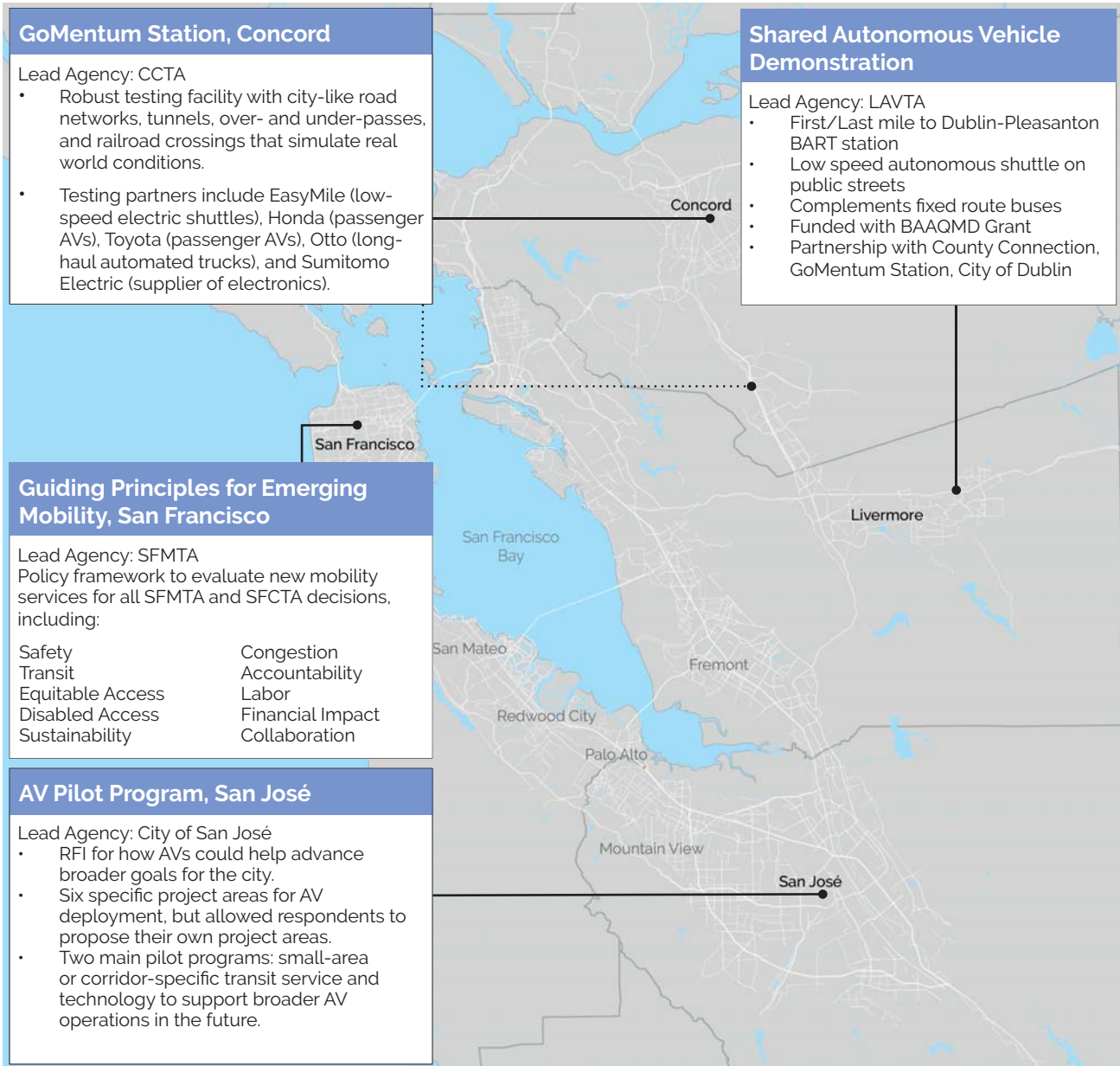


Source: SAE

AVs are likely to be applied to one of the four use cases below:

- **Private Mobility Services.** Private fleet services providing demand-responsive trips, akin to today's ridehailing services (e.g. Uber, Lyft), are anticipated to be early applications of AV technology.
- **Goods Movement.** Last-mile business and home delivery services may be early AV applications.
- **Public Transit.** Transit applications could include demand-responsive shuttles, autonomous bus rapid transit, and autonomous buses. With lower operating costs, AVs could also make nighttime transit services and services in low-density areas more feasible.
- **Privately Owned Vehicles.** Privately owned AVs will likely lag behind other applications because of the costs and technological challenges of achieving Level 5 autonomy.

San Francisco Bay Area AV Pilot Programs and Policies



A number of communities in the Bay Area are beginning to proactively explore applications of AV technology including: Contra Costa Transportation Authority (CCTA) and GoMentum Station, the San Francisco Municipal Transportation Agency (SFMTA) and the San Francisco County Transportation Authority (SFMTA), the City of San José, and Livermore Transit Authority (LAVTA).

Other communities will likely have increasing opportunities to explore AV pilot programs and policies. However, it is not necessarily clear what problem these pilot programs should be aiming to solve. Given the wide range of ways AV technology can be deployed, the shape and impact it will have on future travel is highly unpredictable. New autonomous modes of transportation with high uptake could have reverberating secondary and tertiary impacts on communities. The challenge for planners and policymakers, therefore, is to prepare for an exceedingly uncertain future.

Autonomous Vehicles Perspective Paper Strategies

Strategies presented in this paper aim to address this inherent challenge of advancing regional goals despite inherent uncertainty and a wide range of opportunities and risks. Organized by the Horizon Guiding Principles – **Affordable, Connected, Diverse, Healthy, and Vibrant** – this paper presents potential strategies to be evaluated as part of the regional planning process.

AFFORDABLE

Guiding Principle: All Bay Area residents and workers have sufficient housing options they can afford – households are economically secure.

AV OPPORTUNITIES AND RISKS

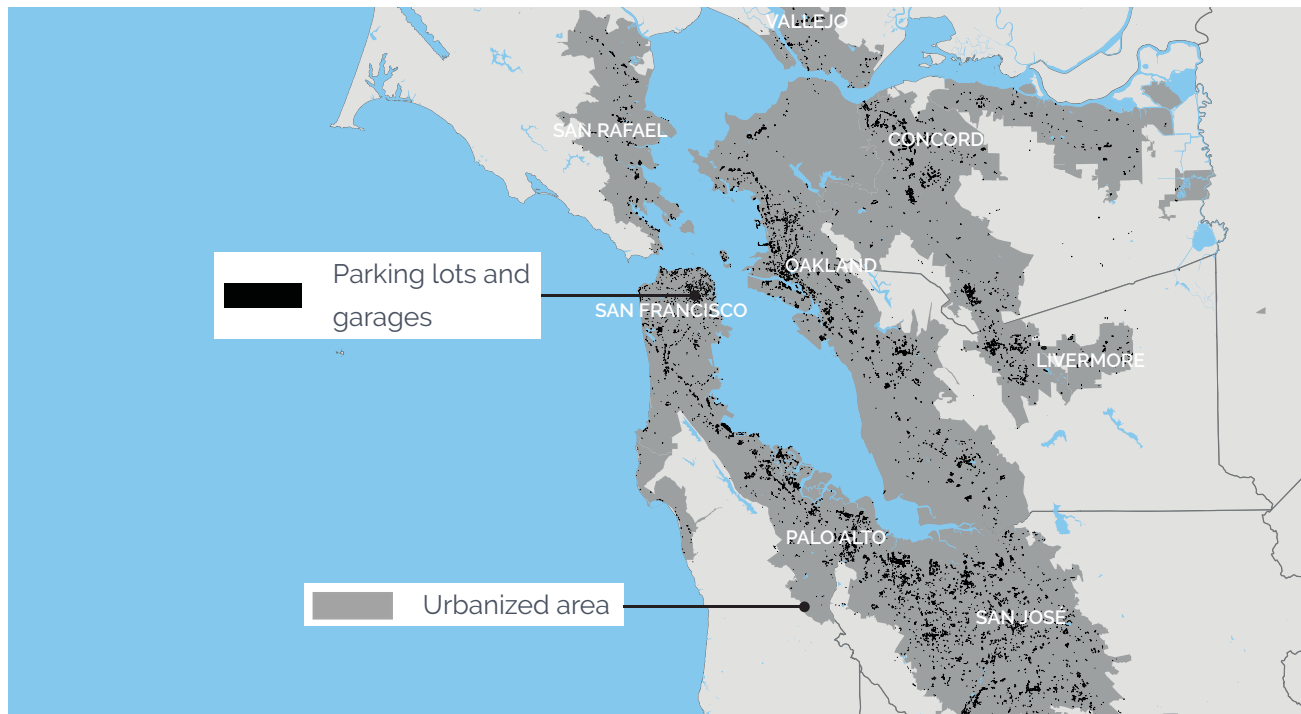
 Parking demand drops, new housing opportunity sites could emerge

 Facilitated sprawl, increasing travel costs as people live farther from jobs

PRIORITY STRATEGIES

- Repurpose off-street parking for infill development
- Institute parking maximums for both on- and off-street parking supply
- Retain or strengthen urban growth boundaries to control greenfield development

EXAMPLE APPLICATION: HOUSING OPPORTUNITY SITES



Housing Opportunity Sites in an Autonomous Future

The Bay Area has an imbalance of parking supply that could be repurposed to more productive uses, including housing, as parking demand decreases with AVs.

Desired outcome: Increase affordable housing supply

CONNECTED

Guiding Principle: An expanded, well-functioning transportation system connects the Bay Area – fast, frequent and efficient intercity trips are complemented by a suite of local transportation options, connecting communities and creating a cohesive region.

AV OPPORTUNITIES AND RISKS

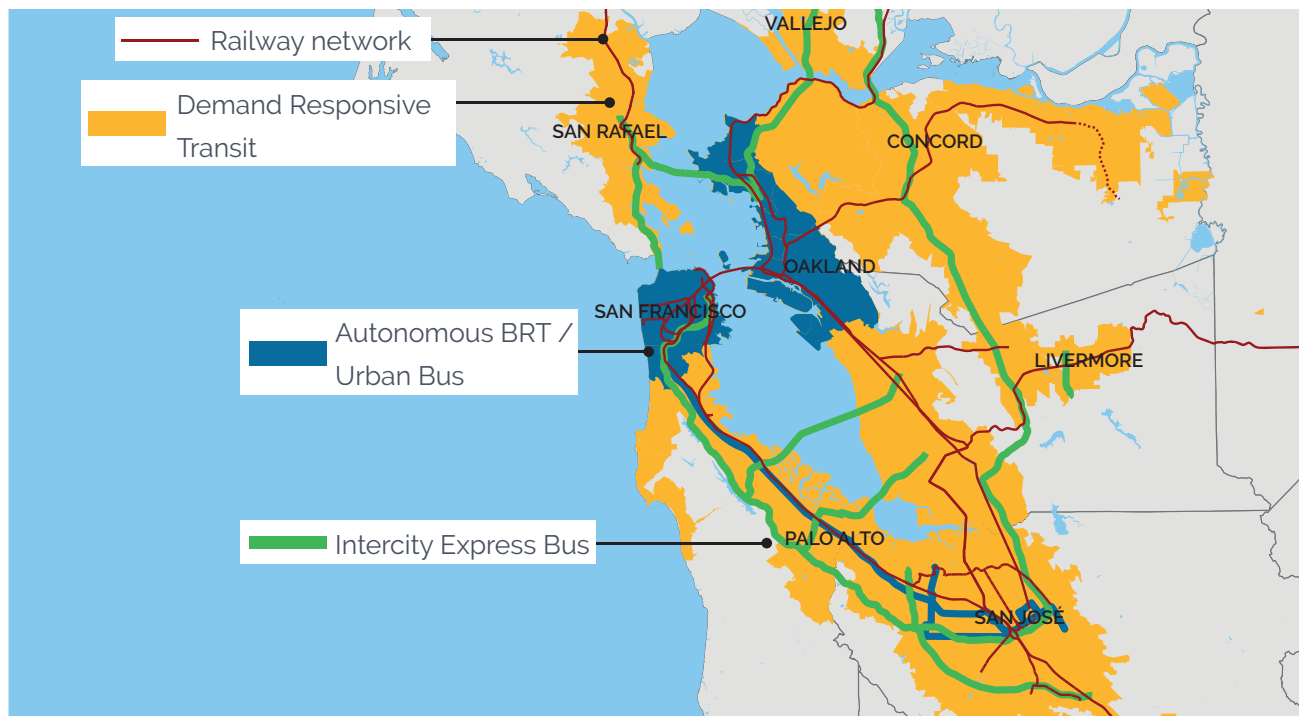
↑ Shared AV services could introduce a transit renaissance with improved on-demand services

↓ AVs could worsen congestion with more induced travel and empty vehicle circulation

PRIORITY STRATEGIES

- Double down on high-capacity bus and rail corridors
- Innovate suburban transit with autonomous, on-demand microtransit
- Develop a mobility-as-a-service platform to provide a unified, equitable gateway to services and information

EXAMPLE APPLICATION: DYNAMIC PRICING & AUTONOMOUS TRANSIT



Dynamic Pricing & Autonomous Transit

Significant reinvestment in transit with trunk link bus and rail improvements, microtransit services, a mobility-as-a-service platform, and new funding mechanisms to support investments.


Desired outcome: Expand access to high quality transportation

DIVERSE

Guiding Principle: The Bay Area is an inclusive region where people from all backgrounds, abilities, and ages can remain in place – with access to the region's assets and resources.

AV OPPORTUNITIES AND RISKS

 New business models can benefit people from all backgrounds, abilities and ages

 Widening of equity gap with declining public transit, service disparities, job loss, digital divide

PRIORITY STRATEGIES

- Mandate equitable provision of mobility services with transparent reporting
- Subsidize public transit innovations, replacing fixed route transit in some Communities of Concern
- Prioritize AV mobility services or programs for that serve Communities of Concern

EXAMPLE APPLICATION: EQUITABLE AV SERVICES



Photo: © User: Dianne Yee / Flickr

Equitable AV Services

Private mobility service operators should be required to monitor and improve their services to achieve equitable outcomes.

Desired outcome: Universal access to AV services

HEALTHY

Guiding Principle: The region's natural resources, open space, clean water, and clean air are conserved – the region actively reduces its environmental footprint and protects residents from environmental impacts.

AV OPPORTUNITIES AND RISKS

 Significant reduction in human driving error could save lives. EVs could improve air quality	 Hacking and cybersecurity could introduce new safety risks. Fossil fuel AVs worsen air quality
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PRIORITY STRATEGIES

- Cap speed limits in downtowns, neighborhoods
- Mandate that all AVs are EVs and invest in the necessary infrastructure
- Develop “bounty program” to reduce hacking vulnerability

EXAMPLE APPLICATION: VISION ZERO 2.0



Vision Zero 2.0


AVs allow for a new, expanded Vision Zero program to prevent a range of transportation-related health issues beyond traffic collisions, from air pollution to cybersecurity.

Desired outcome: Save lives and improve air quality

Guiding Principle: The Bay Area region is an innovation leader, creating quality job opportunities for all and ample fiscal resources for communities.

AV OPPORTUNITIES AND RISKS


 Reduction of transportation and logistics operating costs


 AVs could cause rapid job loss or a shift to other occupations

PRIORITY STRATEGIES

- Strengthen the capacity of training programs to expand opportunities for workers
- Target job clusters on industrially-zoned land for production, distribution, and repair
- Pilot innovative AV applications that could spur new job opportunities

EXAMPLE APPLICATION: “NEW DEAL” FOR MOBILITY



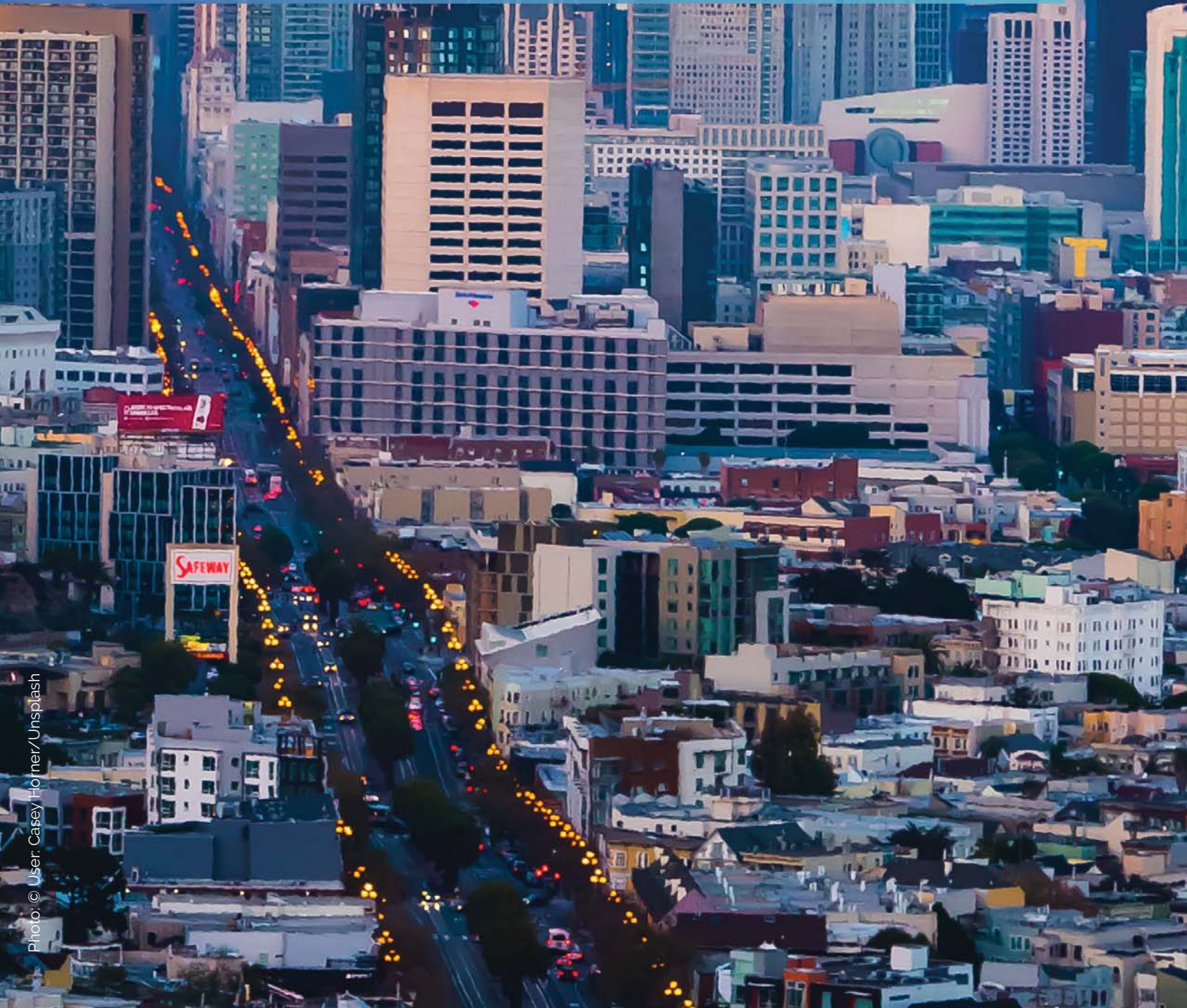
“New Deal” for Mobility

With the economic changes AVs likely will introduce, a comprehensive economic development program will maximize the local economic benefits of the technology revolution, including workforce development programs and manufacturing investments.

Desired outcome: Expand prosperity and access to jobs

NEXT STEPS

These priority strategies are only the beginning of the conversation about how the Bay Area should respond to AVs. Strategies described in this *Autonomous Vehicles Perspective Paper* will be put to the test as part of the "Futures" planning scenarios analyzed in the **Horizon** initiative. The Futures will have a range of assumptions for AV and EV market penetration, business models, and sharing preferences. Upon further analysis, promising strategies will be proposed for inclusion in Plan Bay Area 2050.



An aerial photograph of a two-lane asphalt road with yellow double lines, curving through a dense forest of green trees and shrubs. A semi-transparent blue rectangular box is overlaid on the upper portion of the image, containing white text.

CHAPTER 1 AUTONOMOUS VEHICLES IN THE BAY AREA

Autonomous vehicles have the potential to transform transportation and quality of life in the Bay Area over the coming decades.







1.1 INTRODUCTION

Autonomous vehicles (AVs) have the potential to catalyze transformative change in the Bay Area. Mobility in an autonomous world has the potential for wide-ranging implications – both positive and negative. These possible implications involve issues of critical significance: congestion, traffic safety, equitable access, jobs, air quality, and greenhouse gas emissions, to list only a few of the possible ways in which AVs could impact the Bay Area.

This paper is the first in a series of Perspective Papers that will contribute to **Horizon**, a regional initiative exploring a range of external forces that have the potential to fundamentally alter the region's trajectory. The topics of these papers include:

- Autonomous vehicles,
- Travel demand management and climate mitigation,
- Regional growth strategies,
- Bay crossings,
- Future of jobs,
- Regional governance, and
- Design and better buildings.

The *Autonomous Vehicles Perspective Paper* focuses on priority policy interventions and planning strategies for the Bay Area to seize opportunities and proactively address risks that AVs are likely to introduce. The intention of each Perspective Paper is to inform and develop inputs to the regional planning process that will be considered by partners and stakeholders and that will be put to the test. The strategies advanced in this paper will be applied and evaluated across a series of divergent "Futures," planning scenarios with a range of assumptions including AV and EV market penetration, business models, and sharing preferences. The results of the evaluation will inform a series of regional policy recommendations and investments for adoption in the next regional plan, Plan Bay Area 2050.



1.2 AV TECHNOLOGY

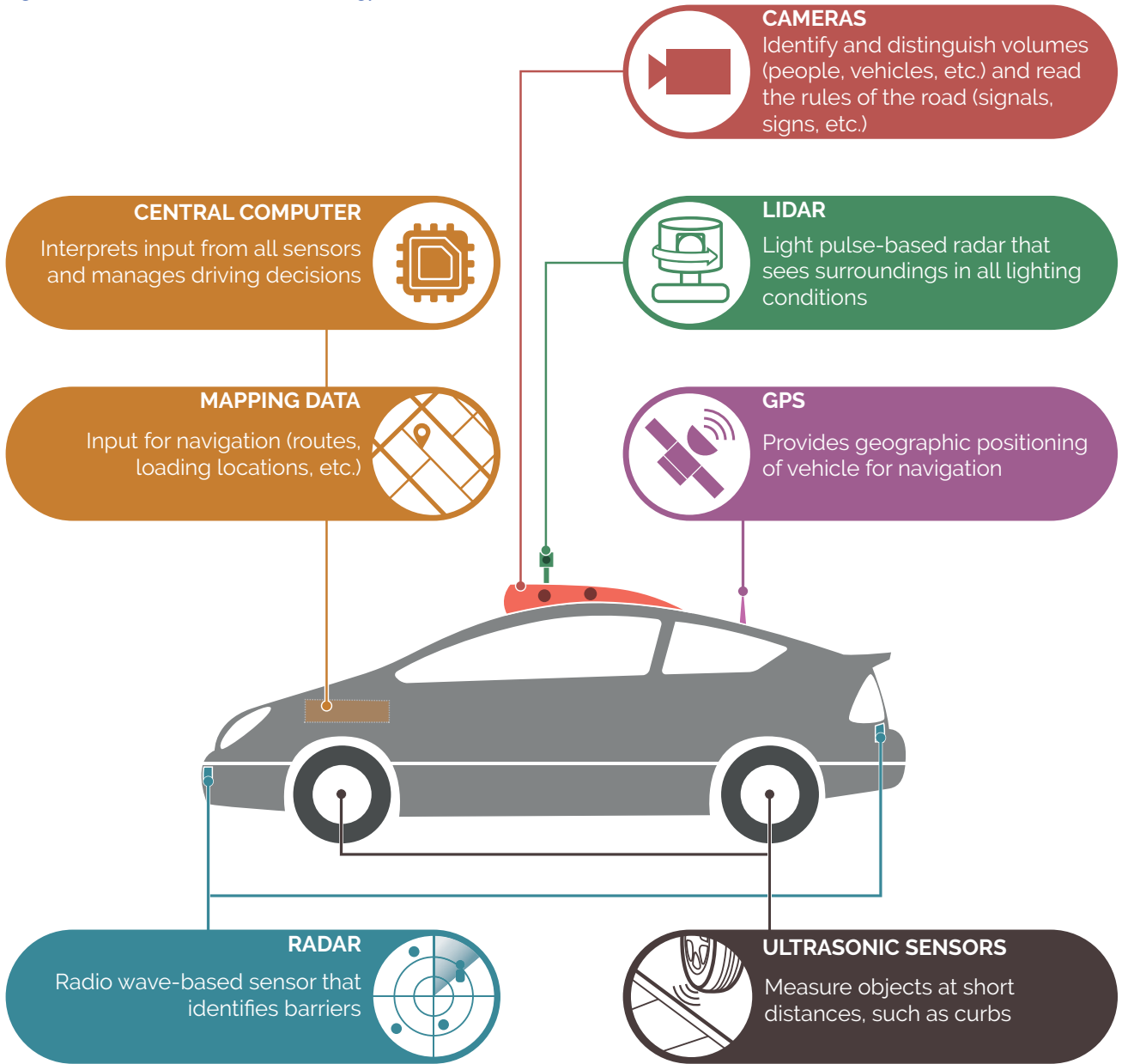
Automated or autonomous vehicles (AVs) may be the most significant change to transportation since the “horseless carriage” introduced the world to motor-powered mobility. AVs use an array of technological systems backed by powerful computers and machine learning to navigate complex driving environments. With AV technologies, vehicles will eventually be capable of driving themselves – human operators and occupants optional. This capability could have dramatic implications for personal mobility, public transportation, and the movement of goods.

While the many companies and organizations working on AV projects are in different phases of research or production, the fundamentals of AV technology are broadly standardized, and dependent on six key elements: LIDAR, cameras, RADAR, ultrasonic sensors, GPS, and on-board processors.

- Light detection and ranging (LIDAR) rapidly emits light pulses to provide a 360-degree moving 3D map of the surrounding landscape. LIDAR operates independent of ambient light, meaning it can see in the dark.
- Cameras document the surrounding environment, identifying and distinguishing volumes (e.g., people and vehicles) and reading the rules of the road (e.g., signals and signs).
- Radio detection and ranging (RADAR) is an older, less expensive, and more durable technology that operates similarly to LIDAR, but uses radio waves and detects objects at a lower resolution but from farther distances.
- Ultrasonic sensors provide short-range feedback to guide the vehicle in maneuvers such as backing up or parking.
- A large body of data, including maps and road rules, provides the foundation of an AV's ability, while GPS locates the vehicle in physical space to enable it to properly process that data.
- Finally, a powerful on-board processor enables the vehicle to analyze incoming data and respond appropriately (**Figure 1.1**).

Meanwhile, numerous other technologies being advanced in Silicon Valley will likely augment AVs including: general advances in artificial intelligence, 3D printing as it relates to vehicle prototyping and manufacturing, and virtual reality for numerous applications such as remote safety driving.

Figure 1.1 Autonomous Vehicle Technology

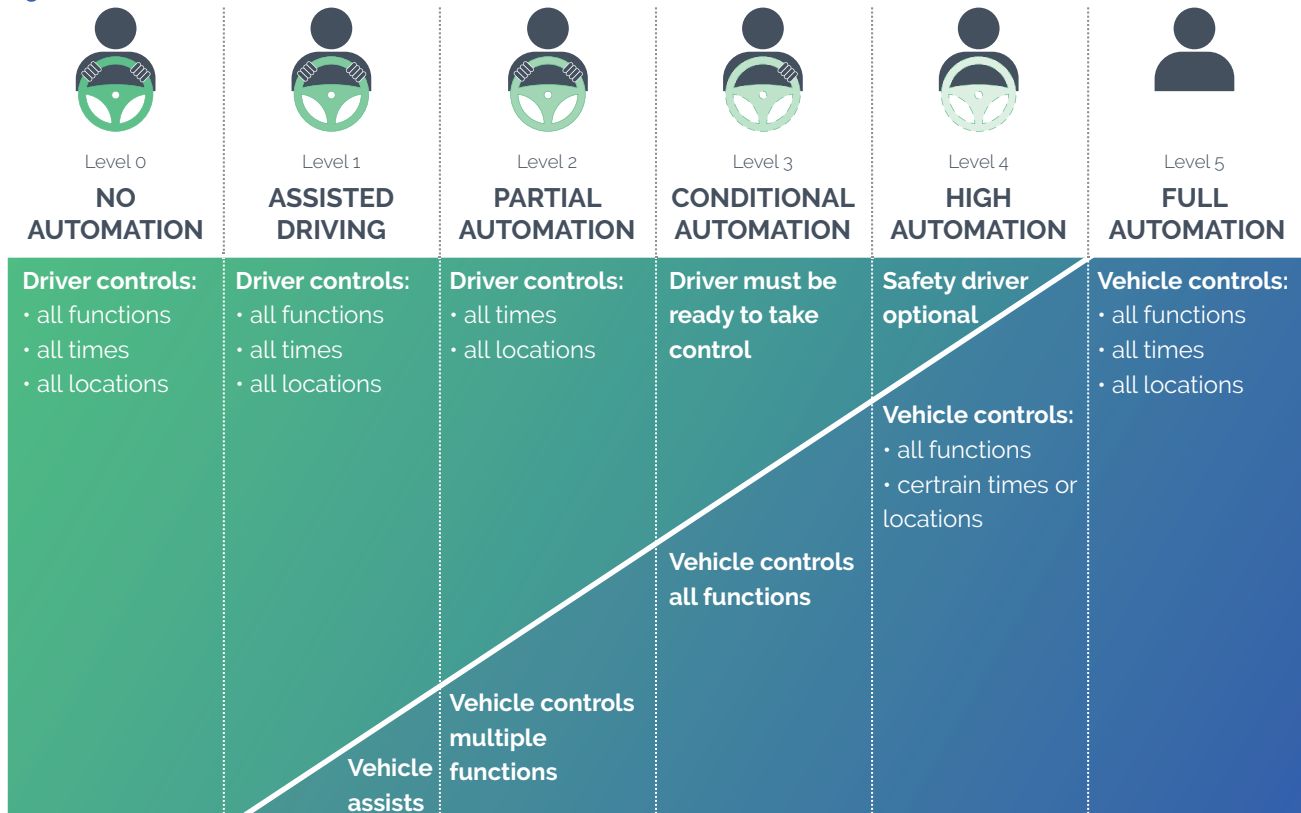


Source: Arup

1.2.1 LEVELS OF AUTOMATION

A standard framework created by the international Society of Automotive Engineers (SAE) defines basic steps in autonomous capabilities. The SAE's levels of automation increase incrementally from no automation at Level 0 to full automation at Level 5 and Levels 1-3 all require significant human management at all times (**Figure 1.2**). Human drivers of Level 1 and Level 2 vehicles are needed to actively operate the vehicle, as Level 1 includes drive assist features and Level 2 involves partial automation that operates multiple functions simultaneously (e.g. steering and throttle). The vehicle controls all driving functions in Level 3 – conditional automation – but requires a driver to be ready to take immediate control of the vehicle when needed. Level 4 allows for autonomous driving in specific conditions, such as in geofenced geographies or under certain weather conditions. Level 5 describes a vehicle that is fully autonomous in any setting. Currently, most AV testing operations are Level 3 or Level 4.

Figure 1.2 Levels of Automation



Source: SAE

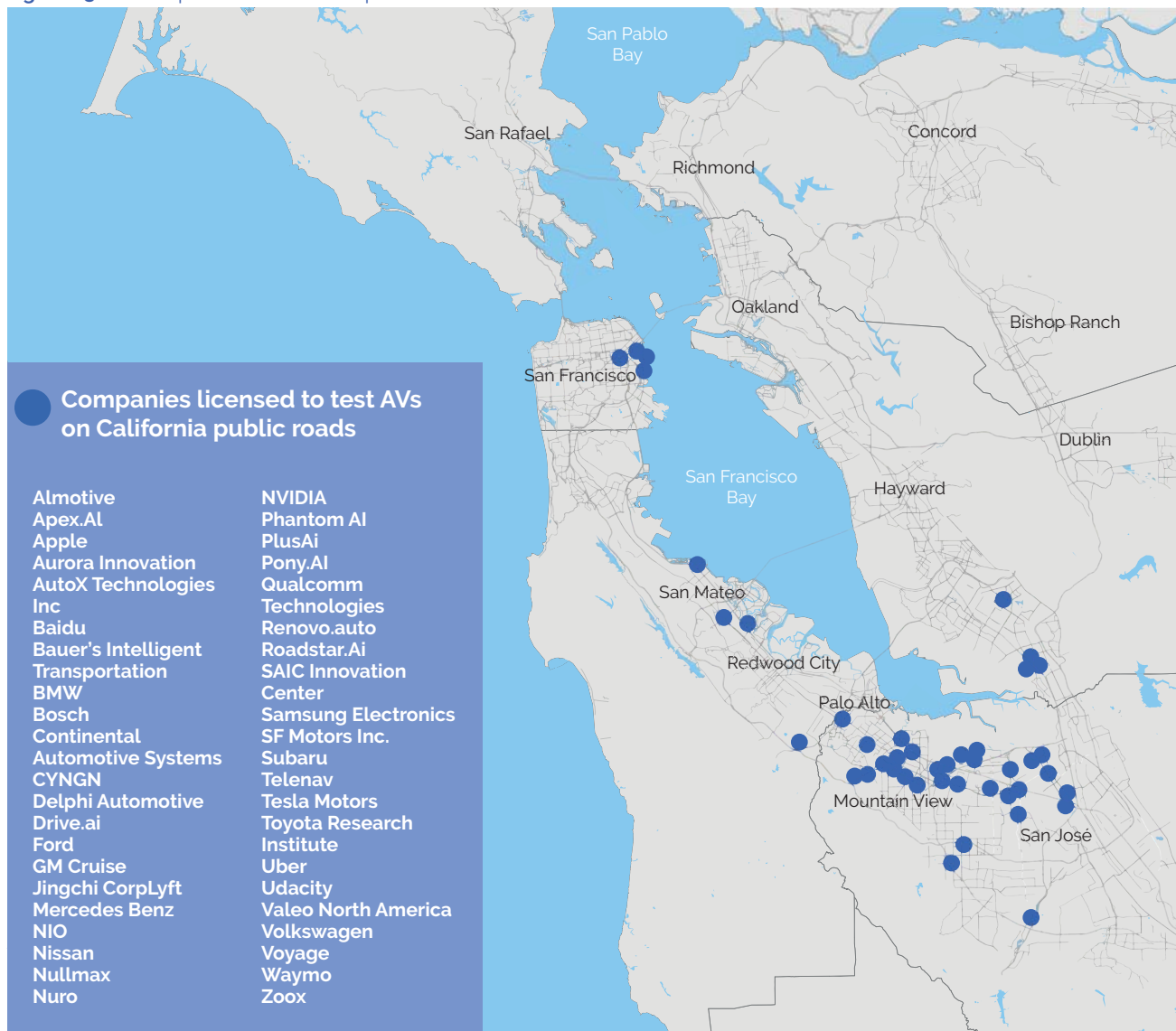
Terminology note: Media often refer to this technology as driverless or self-driving; in scholarly literature and policy documents, the terms autonomous or automated vehicles are more common. Generally, all these terms refer to Level 4 or 5 autonomy in which a vehicle can operate independent of human operators. The term connected and autonomous vehicles (CAVs) is also frequently used, particularly outside the United States. The specific amount and type of connectivity is unclear. "Connected" and "autonomous" can actually be interpreted as antonyms, and AV companies are generally developing their technology to operate independently of ubiquitous vehicle-to-infrastructure (V2I) or vehicle-to-vehicle

(V2V) connectivity. However, some forms of “connectivity”, such as Global Position Systems (GPS), are inevitable, and additional communications between vehicles, infrastructure, and other systems would complement and enhance the performance of AVs. This paper generally uses the term AV. Unless specified, connectivity is not implied.

1.3 AV DEVELOPMENT

The last decade has seen a virtually exponential increase in the amount of activity on the development and testing of AV technology. In California alone, the Department of Motor Vehicles has licensed over 50 companies to test AVs on public roads (**Figure 1.3**). Most of these operations are conditional and require a human safety driver in the vehicle at all times. The DMV also allows for two more advanced AV licenses:

Figure 1.3 AV Companies Licensed to Operate on Public Roads in California



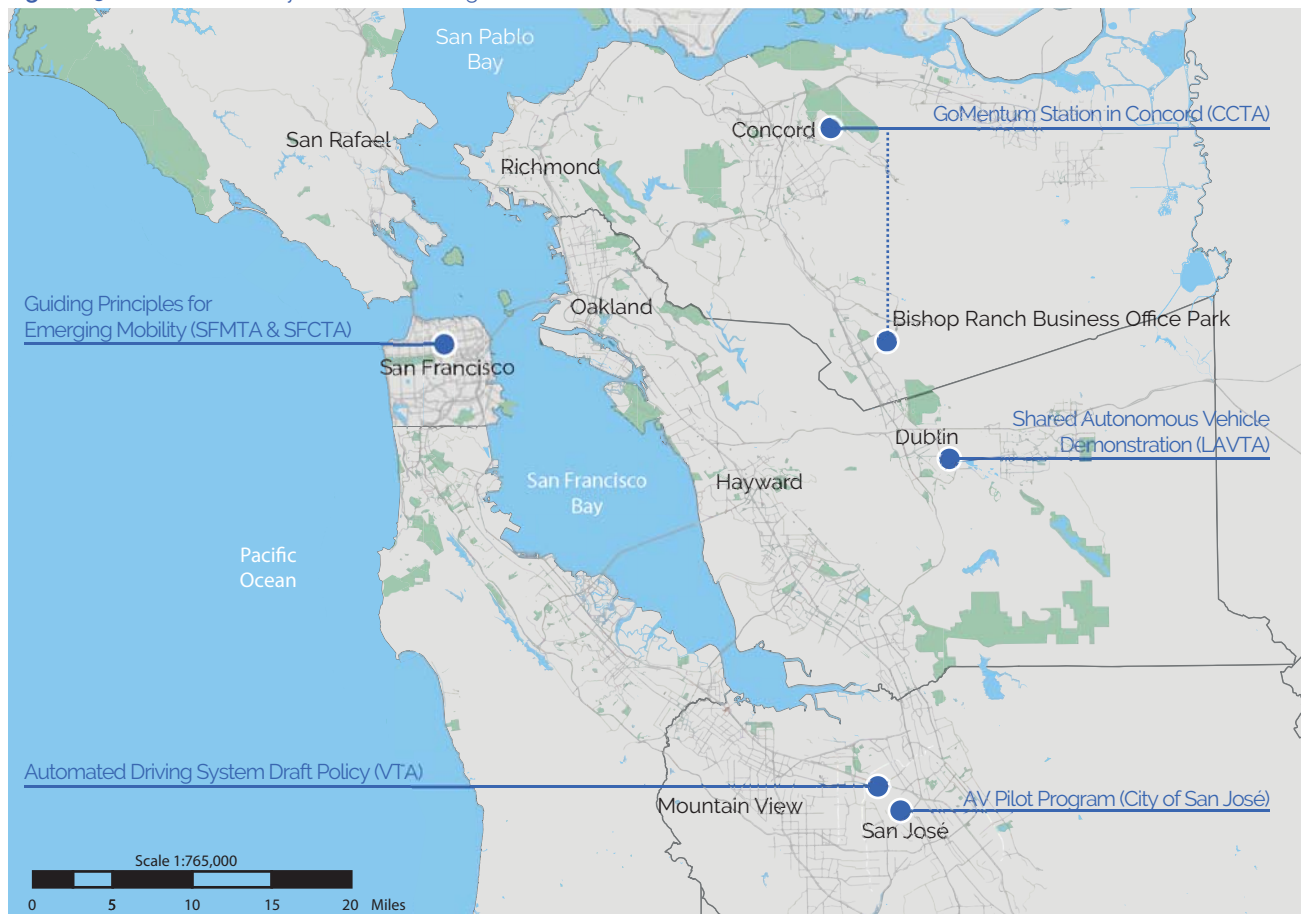
Source: California Department of Motor Vehicles


GM employees can ride in GM-owned Cruise Automation vehicles. Uber was offering rides to the public in Phoenix and Pittsburgh, Pennsylvania until they suspended all AV operations following an Uber AV involved pedestrian fatality in March 2018.³ Meanwhile, some automation is increasing in the vehicle market at large with many auto manufacturers including Level 1 driver assist functions and some automakers adding Level 2 partial automation on current models.

1.3.2 BAY AREA PILOT PROGRAMS AND POLICIES

A number of communities in the Bay Area are beginning to proactively explore applications of AV technology (**Figure 1.5**). For instance, the City of San José has advanced a series of pilot programs to develop communications infrastructure, implement spatial data collection, and provide service with Level 4 (high automation) fleets. GoMentum Station (Concord) is a robust AV testing facility with city-like road networks, tunnels, over- and under-passes, and railroad crossings that simulate real-world conditions. Bishop Ranch Office Park (San Ramon) is piloting AV shuttles to transport workers around the office park. The pilot will move into its final phase this year, operating outside of the office park to connect with local transit.

Figure 1.5 San Francisco Bay Area AV Pilot Programs





In addition to the explicit AV pilot programs, many other entities are exploring future-facing policies, programs, and regulations. The San Francisco Municipal Transportation Agency (SFMTA) and the San Francisco County Transportation Authority (SFCTA) recently developed Guiding Principles for Emerging Mobility, a policy framework to evaluate new mobility services for all SFMTA and SFCTA decisions. The Santa Clara Valley Transportation Authority (VTA) is developing an Automated Driving System Draft Policy, an effort to address the issues and opportunities AVs present and explore pathways to incrementally introduce automation into VTA's business model and practices. Finally, the California Public Utilities Commission (CPUC) has moved forward on releasing a proposed framework for regulating two AV pilot programs, one with drivers in the vehicle, and one without drivers in the vehicle.

1.4 AV DEPLOYMENT

For the past few years, researchers have sought to quantify the implications of AVs and prepare policy and infrastructure needs for the technology. The ways in which consumers will access AV technology once they reach the market are wide-ranging. Vehicle ownership as the predominant method of accessing cars is likely to change. Potential business models for personal mobility include: autonomous taxis; subscription-based access to a fleet of vehicles; sharing the use of one vehicle, akin to a real estate time-share; rental of others' private cars by the day or hour; and the continuation of full private ownership.

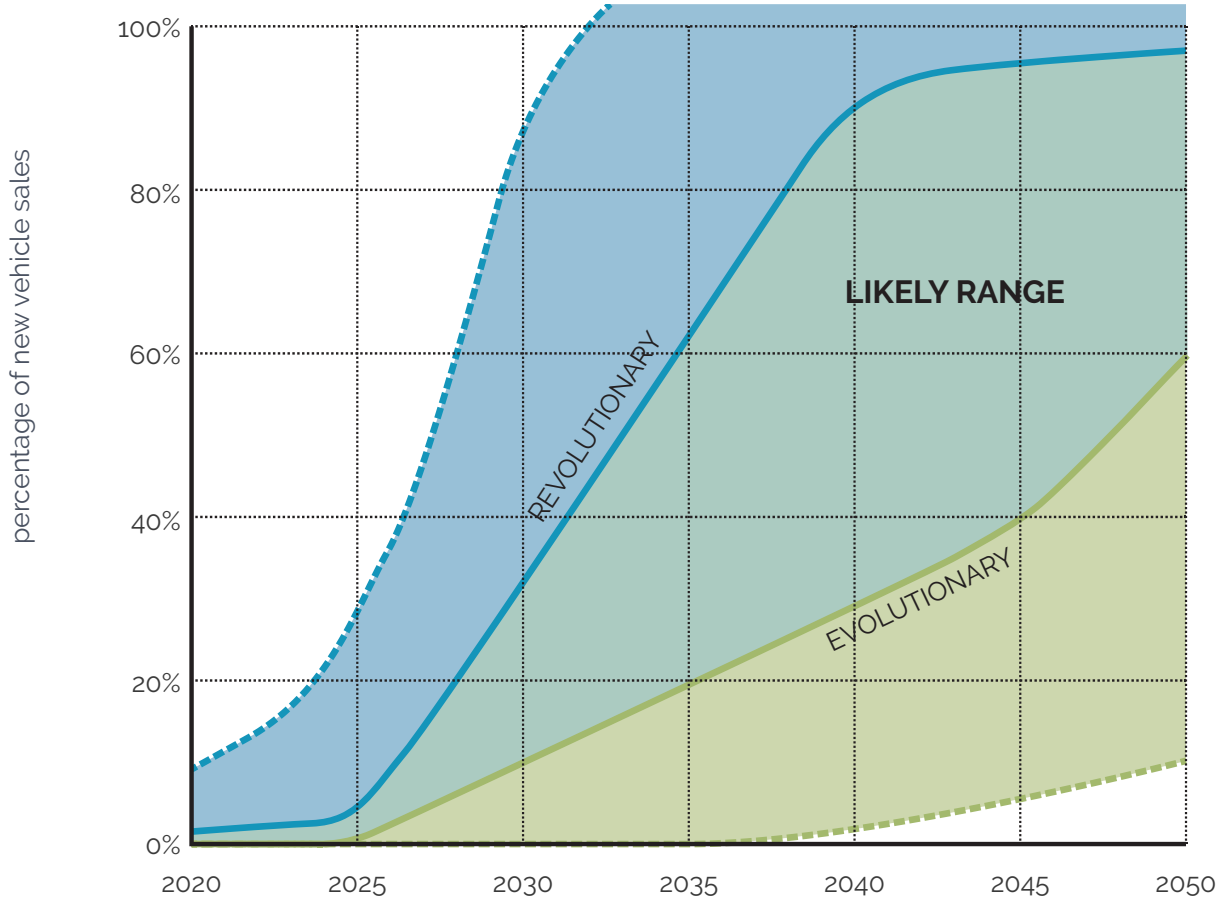
Four key use cases of AV technology are below:

- **Private Services.** Private fleet services providing demand-responsive trips, akin to today's ridehailing services (e.g. Uber, Lyft), are anticipated to be early applications of AV technology. Ridehailing companies have demonstrated that a large market exists for the service, and this popularity will be amplified if the user cost is reduced. The high utilization of vehicles in fleet applications will provide a higher return on the investment in technology than private ownership. These services will become common in moderate and high-density areas first where shorter trip lengths, diverse land uses, and higher concentrations of activity can be most efficiently served.
- **Goods Movement.** Last-mile business and home delivery services may be early AV applications. Increasing demand for rapid response deliveries creates an attractive application of AVs. However, intercity trucking will likely face more significant regulatory challenges and trucking applications of Levels 1-3 technology may be feasible far before Levels 4 and 5.
- **Transit.** Although there is some early piloting of low-speed autonomous shuttles, public transit will likely be slow to adopt AV technology because of long-term investment cycles, concerns regarding job loss, and a need to remain risk averse. However, there will be early opportunities for first/last-mile services and demand-responsive services in low-density areas. These services could be delivered as a partnership between public agencies and private operators. Additional applications could also include autonomous buses and autonomous bus rapid transit. AVs could also make nighttime transit services with lower operating costs more feasible, adding critical service for passengers traveling outside of typical operating hours.

- **Privately Owned Vehicles.** Privately owned AVs will likely lag behind other applications because of the technological challenges of achieving Level 5 autonomy. Additionally, AV sensors and software are still too expensive for owned AVs to be feasible for most consumers.

Timing is one of the most critical questions. When will AVs be accessible to the public? When will they be common? When will they be so prevalent that they are ubiquitous, making legacy (human driven) vehicles effectively outmoded? Several studies have estimated AVs will reach significant market penetration in the 2040s. A fully autonomous world in which people rarely, if ever, drive vehicles is decades away, with estimates converging on the 2050s. **Figure 1.6** represents a broad range of possible uptake scenarios with AVs at 0%-15% of the total vehicle fleet in 2020 and up to 10%-100% of the vehicle fleet by 2050. In all scenarios, there will be an extended period of time with a mixed autonomous-legacy fleet.

Figure 1.6 Autonomous Vehicles Estimated Uptake



Note: Fully Autonomous Vehicle (L4/5) uptake predictions based on high disruption scenarios, indicates possible percentage of new car sales 2016 to 2050.

REVOLUTIONARY
<ul style="list-style-type: none"> • Technology breakthroughs • Regulatory resolutions • Shared model, at much lower cost than ownership • Rapid adoption

EVOLUTIONARY
<ul style="list-style-type: none"> • Slower technology development and rollout • Owned AV model with cost premium • Slower adoption

Clearly, the future timing and uptake of these vehicles is highly uncertain, making it challenging for planners and policymakers to know how and when to respond.

An aerial photograph showing a wide river with multiple channels and islands, surrounded by a dense residential neighborhood with many houses and trees. The image is used as a background for the report cover.

CHAPTER 2 PREPARING FOR AUTONOMOUS VEHICLES

Five key strategies will facilitate a more affordable, connected, healthy, vibrant, and diverse Bay Area with autonomous vehicles.





Photo: © User: Peter Thoeny/Flickr



2.1 CHAPTER ORGANIZATION

To kick off the **Horizon** initiative, MTC and ABAG have established a set of Guiding Principles, concluding four months of public and stakeholder engagement engaging Bay Area residents with over 10,000 public comments. The Guiding Principles are intended to reflect the aspirations of the region through 2050 and be applicable across all long-range planning work. Prioritized strategies and investments should likewise be aligned with these core values.

Ultimately, five principles were selected for use in Horizon: **Affordable, Connected, Diverse, Healthy, and Vibrant**. These principles were used to organize and prioritize an extensive set of strategies for the region to consider in an uncertain AV future.

Organized by Guiding Principle, this chapter presents a set of priority strategies, and possible applications considered most promising for shaping a better region with AVs and reducing the potential risks they hold. Following a brief highlight of the state of the Guiding Principle in the Bay Area, each section is organized as follows:

- 1. AV Implications.** Major opportunities and risks with AVs
- 2. Priority Strategies.** Strategies related to the Guiding Principle that are likely to either maximize the opportunity or minimize the risk of AVs
- 3. Example Application.** Example applications of the priority strategies (generally one example application per Guiding Principle) that will be inputs to the regional planning process

The development of the priority strategies was informed through an extensive research effort. The appendices include the longer list of strategies that were considered (organized by Guiding Principle), a selection of case studies, and references to all the research material. Additional details on potential future applications will be developed as part of the Horizon process.

2.2 AFFORDABLE

Horizon Guiding Principle: *All Bay Area residents and workers have sufficient housing options they can afford – households are economically secure.*

Affordability in the Bay Area. The Bay Area is the most expensive housing market in the country. Many residents are burdened by housing costs: 40% of renters and 23% of homeowners in the Bay Area spent over 35% of their annual income on housing in 2015.⁴ Plan Bay Area 2040 estimates that housing and transportation costs could increase to 67% of lower income household budgets by 2040.

Affordability and AVs. AVs could impact housing preferences and the cost and location of new construction. As parking demand drops, new housing opportunity sites could emerge. However, AVs also could facilitate sprawl, increasing travel costs as people live farther from jobs. Additional major implications of affordability and AVs are explored in Section 2.2.1.



2.2.1 AV IMPLICATIONS

This table highlights the major implications of AVs associated with affordability in the Bay Area. Each implication is derived from the literature provided in Appendix C: Further Reading.

Opportunities	Risks
<ul style="list-style-type: none"> • Transportation Costs. Mobility services operating costs, and ultimately consumer costs, will come down significantly if drivers are no longer needed, making it cheaper to get around. • Parking. With any AV business model paradigm, particularly a shared fleet business model, the need for proximate parking will decrease. AVs will be able to drop off passengers at their destination and either drive to the next passengers, find parking in a more consolidated location, or return to a home base. When all vehicles are fully autonomous, parking demand could drop by as much as 90%.⁵ This net decrease in demand would open both on- and off -street parking for other uses, including housing development. • Housing Development. Reduced parking needs could help reduce the cost of housing as less new parking will need to be constructed. • Housing Accessibility. Lower cost AV mobility options could increase housing choices and access to employment. 	<ul style="list-style-type: none"> • Transportation Costs. The additional cost of autonomous features may be prohibitive for most people to purchase AVs, potentially limiting access to the technology. Further, while low-cost AV services may proliferate in urban and suburban areas, shared fleets are less likely to be economically and logistically feasible in rural contexts. • Sprawl. AVs could make longer commutes more productive and more tolerable as a result, and people may choose to live farther from their employment. Longer trips could increase travel costs.





2.2.2 PRIORITY STRATEGIES

Priority strategies related to the *Affordable* Guiding Principle focus on leveraging reduced parking demand to increase housing supply and lower housing costs while continuing to prevent sprawl.

1. Repurpose off-street parking for **infill development**

AVs are highly likely to reduce car ownership and parking demand, particularly where demand-responsive mobility services proliferate. This reduced demand could free up space currently used for parking lots, structures, and garages for other uses, particularly housing development. Ideally, this housing would be located near services, employment, and high capacity public transit.

2. Institute **parking maximums** for both on- and off-street parking supply

Parking supply maximums for new developments are already being used in several Bay Area communities to help reduce traffic and use land more efficiently. These policies could be accelerated and expanded to additional locations in anticipation of reduced parking demand with shared AVs.

3. Retain or strengthen urban growth boundaries to **control greenfield development**

AVs could induce sprawl, since travel time could be productive, making longer commutes more tolerable. Urban growth boundaries, urban limit lines, community separators, and greenbelt separators are all policies intended to help prevent sprawl, preserving open space and agricultural lands. Combined with strategic infill development, travel distances can be moderated. This, in turn, would make a wider range of mobility options available and would reduce travel costs.



2.2.3 EXAMPLE APPLICATION

HOUSING OPPORTUNITY SITES IN AN AUTONOMOUS FUTURE

Amid the Bay Area's affordability crisis and growing population, it is essential to increase the supply of housing, particularly housing affordable to a larger portion of the population. The proliferation of AVs will likely reduce demand for parking, producing opportunities for infill development. **Figure 2.1** shows clustering of off-street parking lots and garages in the urbanized Bay Area. If these areas were redeveloped into housing, hundreds of thousands of new housing units would be added. Additionally, household garages could be redeveloped into accessory dwelling units and on-street parking could be redesigned with bike lanes, parklets, and landscaping to improve access and quality of life.

Housing Opportunity Sites in an Autonomous Future

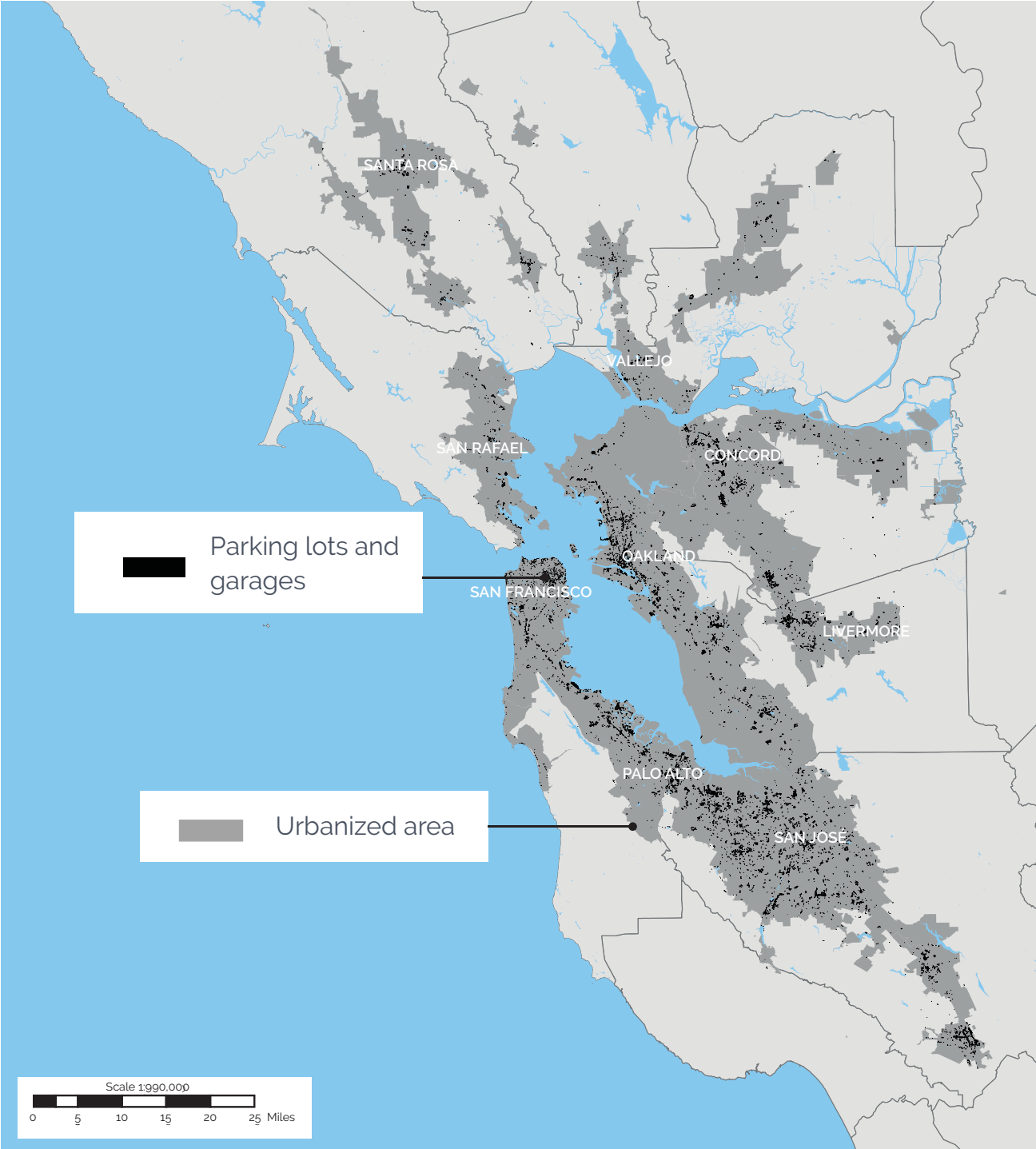


Figure 2.1 Housing Opportunity Sites in an Autonomous Future

The map displays the abundance of parking lots and garages across the Bay Area. In a future with a high penetration of autonomous vehicles, some communities may repurpose some of these locations for other uses as parking demand decreases.

2.3 CONNECTED

Horizon Guiding Principle: *An expanded, well-functioning transportation system connects the Bay Area – fast, frequent and efficient intercity trips are complemented by a suite of local transportation options, connecting communities and creating a cohesive region.*

Connectivity in the Bay Area. Congestion in the Bay Area has worsened 64% since 2000, putting Bay Area traffic behind only Los Angeles as worst in the nation. Each year for four consecutive years, the region's traffic has hit record highs. Economic and housing conditions are such that the number of mega-commuters – those who commute more than one hour one way – are at an all-time high, totaling 15% of all commuters.⁶ While congestion impacts travelers across all modes, transit riders log an average commute time nearly twice as long as drivers: 51 minutes on transit, compared to 29 minutes in the car.





Connectivity and AVs. AVs will likely have a profound impact on transportation in the Bay Area. Shared AV services could introduce a transit renaissance with improved demand-responsive services. However, AVs also could worsen congestion with more induced travel and empty vehicle circulation. Additional major implications of connectivity and AVs are explored in Section 2.3.1.

2.3.1 AV IMPLICATIONS

This table highlights the major implications of AVs associated with connectivity in the Bay Area. Each implication is derived from the literature provided in Appendix C: Further Reading.

Opportunities	Risks
<ul style="list-style-type: none"> • Roadway Capacity. AVs could increase the capacity of roadways to ease congestion by reducing traffic incidents such as those caused by driver error, inclement weather, and emergencies. Roadways may also operate more efficiently with high AV market penetration resulting from less lost time at signals, smoother traffic flow on highways, and shorter distances between vehicles. • Enhanced Public Transit. Lower operating costs could enable transit agencies to replace low frequency fixed routes with more frequent demand-responsive transit in low density areas. • Active Mobility. AVs could make biking and walking more appealing by making streets safer, particularly as legacy vehicles become less common. • Street Redesign. As demand for concentrated passenger loading zones replaces demand for on-street parking, streets can be redesigned to extend sidewalks and proliferate biking facilities, green infrastructure, and parklets. • Network Optimization. Large fleets of AVs create the opportunity for increased control over operations and route choice. More active network-scale management and optimization could result in better performance on average. 	<ul style="list-style-type: none"> • Increased Demand. AVs are highly likely to increase the amount of vehicle miles traveled (VMT). Non-driving populations will likely have increased access to independent car travel. Empty vehicles will likely travel the streets. Lower per-mile costs with demand-responsive mobility services and lower value of travel time (i.e., driving time can be productive) will likely induce demand. Goods movement trends are indicating more, faster deliveries. • Roadway Capacity. Roadway capacity induces demand in congested areas. Any capacity increases resulting from AVs will likely result in additional demand for vehicle travel. • Mobility Service Competition. Demand-responsive AVs may have lower operating costs compared to existing driver-dependent ridehailing services. As a result, different service providers could create additional traffic as they compete to provide the lowest waiting time. • Transit Ridership. If mobility services are effective, they may compete with transit, potentially causing ridership to fall, exacerbating the already lower viability of off-peak services and routes in low-density geographies. • Curb Demand. The demand for curb space will almost certainly increase as passengers expect front door service, leaving their vehicles to find parking after drop-off or continue roving if shared. Demand for curbside passenger loading will compete with on-street parking, transit loading, goods loading, and bicycle facilities.



2.3.2 PRIORITY STRATEGIES: TRANSIT

This first set of priority strategies related to the *Connected* Guiding Principle are focused on maximizing the efficiency of the transportation network and establishing a stronger public system.

1. Double down on **high-capacity bus and rail corridors**

Even with the efficiency advantages AVs are expected to bring, freeways will continue to have capacity constraints. Rail and high-capacity bus services will remain the most efficient way to move people through these corridors to high-demand activity centers.

AVs could attract people away from high-capacity transit, adding more vehicles to roadways while they could also augment the region's transportation system by providing valuable first/last-mile services. Affirming the role of high-capacity bus and rail – including BART, Caltrain, Muni Metro, and others – for accessing high-demand areas is more important than ever. Therefore, even with the rise of AVs, these high-capacity bus and rail corridors will remain high priorities and require additional investment given their ability to provide person throughput in the region's most congested corridors. Positioning AVs to access high-capacity transit through demand-responsive services while avoiding the need to park on-site may help create a more accessible Bay Area.

2. Innovate suburban transit with autonomous, **demand-responsive transit**

Transit in suburban and rural communities is often expensive to provide and inconvenient to use. As these transit vehicles meet their useful life cycle, they should be replaced with new autonomous, demand-responsive services. Such services operated in vehicles right-sized for ridership demand could greatly improve mobility and accessibility for residents in these areas.

3. Develop a **mobility-as-a-service (MaaS)** platform to provide a unified and equitable gateway to services and information

More than 20 different transit operators serve the nine-county Bay Area, with its own funding, fare structures, policies, governing boards, and service areas. While Clipper has made substantial progress in improving the transit user experience in the region, better integration is still needed. A unified platform could be created to bundle multiple modes and operators (public and private) to make the user experience more seamless and provide more equitable pricing mechanisms.



2.3.3 EXAMPLE APPLICATION: TRANSIT

REGIONAL AUTONOMOUS DEMAND-RESPONSIVE TRANSIT

Transit agencies will have the opportunity to leverage AV technology and digital platforms to provide more cost effective, demand-responsive service. Transit is likely to evolve on two different pathways depending on the built environment (i.e., urban, suburban, or rural): high-capacity, high-frequency regional trunk lines and demand-responsive local service. Trunk lines – such as rail lines and bus rapid transit – reliably and frequently connect activity centers. Fixed-route bus service in low-density areas could be replaced by demand-responsive, door-to-door, and first-/last-mile services provided by AVs. **Figure 2.2** shows a generalized example of how such investments could transform transit in the region. Additionally, MaaS models and public-private partnerships should be considered to optimize user experience, improve regional transit governance, and deliver more efficiency across all services.

Regional Autonomous Demand-Responsive Transit

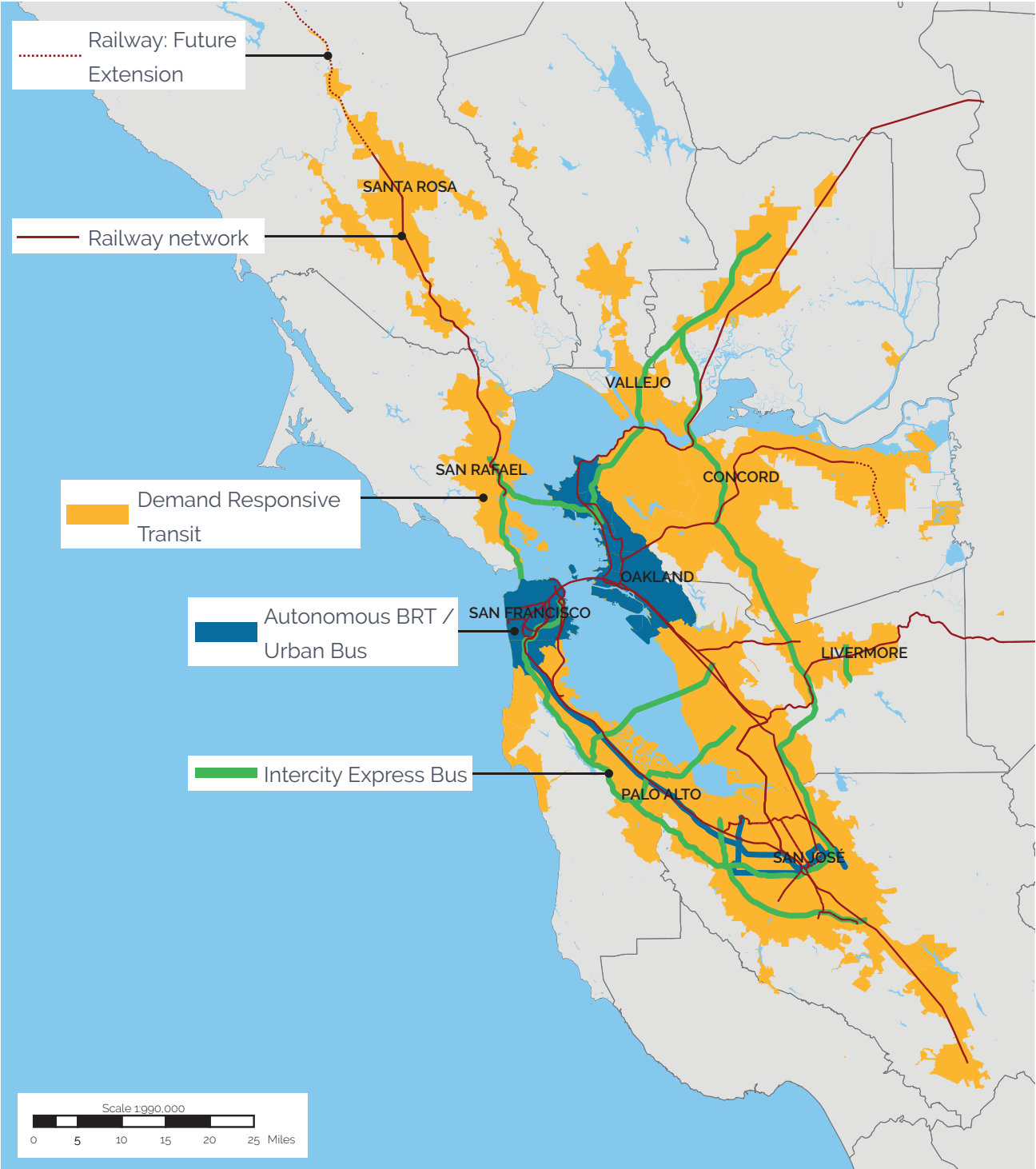


Figure 2.2 Regional Autonomous Demand-Responsive Transit
Investment in the region's core transit lines, including key rail and bus lines, along with autonomous, demand-responsive connecting services throughout urban, suburban, and rural areas could improve connectivity and access throughout the Bay Area.



2.3.4 PRIORITY STRATEGIES: PRICING

This second set of priority strategies related to the *Connected* Guiding Principle are focused on managing the available infrastructure efficiently through pricing strategies, management, design, and data sharing strategies.

1. Price mobility fairly through **dynamic road pricing**

AV proliferation is likely to bring a multitude of new mobility services and demand to the road network. Vehicle trips should be subject to dynamic road pricing schemes like variable pricing in high demand areas (e.g., congested corridors and urban downtowns), and enhanced and increased express lanes. Not only will this price mobility fairly, it will have cascading effects such as encouraging more shared trips. Importantly, dynamic pricing requires real-time connectivity between vehicle or service operators and network operators. To establish secure, efficient connectivity for these purposes, data sharing standards and protocols will need to be collaboratively created.



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2. Design **smart streets** with dynamic allocation of street and curb space

With the rise of transportation network companies (TNCs) such as Lyft and Uber, the demand for curbside passenger loading has grown substantially more pronounced, particularly in downtowns and other high-demand activity centers. This demand is exacerbating curbside conflict among bicyclists, delivery vehicles, transit vehicles, and parked cars.

Since demand for curbside service will continue to increase with AV passenger loading, curb management strategies (and therefore street management) needs to be updated. Ideally, the curb would be assigned in real time to reflect changing demand during the day. For example, a segment of curb could serve high-capacity transit in the morning, parking and passenger loading midday, high-capacity transit again in the afternoon, passenger loading in the late evening, and goods movement when needed and where appropriate. Such a dynamic street would require data standards, updated regulations, and active enforcement to be effective.



3. Develop industry-wide **data sharing protocols** to provide real-time information to connected AVs

A standardized data sharing system would benefit both AV developers and regulators. To safely and efficiently function, connected AVs need data on infrastructure (such as curb and traffic signal inventories), and street operations (such as construction rerouting). They also gather 3D maps generated from LIDAR, radar, and cameras. Meanwhile, cities would benefit from better data on traffic operations, safety concerns, origins and destinations, occupancy rates, and other service and safety information. Data standards would help establish baseline protocols to facilitate data sharing and to prepare for more advanced network optimization.



2.3.5 EXAMPLE APPLICATION: PRICING

DYNAMIC PRICING OPPORTUNITIES IN AN AV FUTURE

Regional, coordinated, and dynamic road pricing will improve efficiency and quality of the entire transportation network by leveling the playing field for all modes and providing a more nimble and effective means to nudge travel choices. Similarly, street and curb pricing for downtown cores will ensure that cities are adequately prepared to meet the complexities of a growing demand for curb space that will only increase moving forward. Additionally, curb pricing could help offset parking revenues lost. Pricing both road and curb use fairly will help mitigate congestion and safeguard the important role of public transit within the larger transportation network.

Figure 2.3 shows how such a pricing network could alleviate congestion in the Bay Area. The green lines show a possible network of dynamically priced corridors and the blue dots highlight the downtown of the region's major cities that may benefit from cordon pricing.

Dynamic Pricing Opportunities in an AV Future

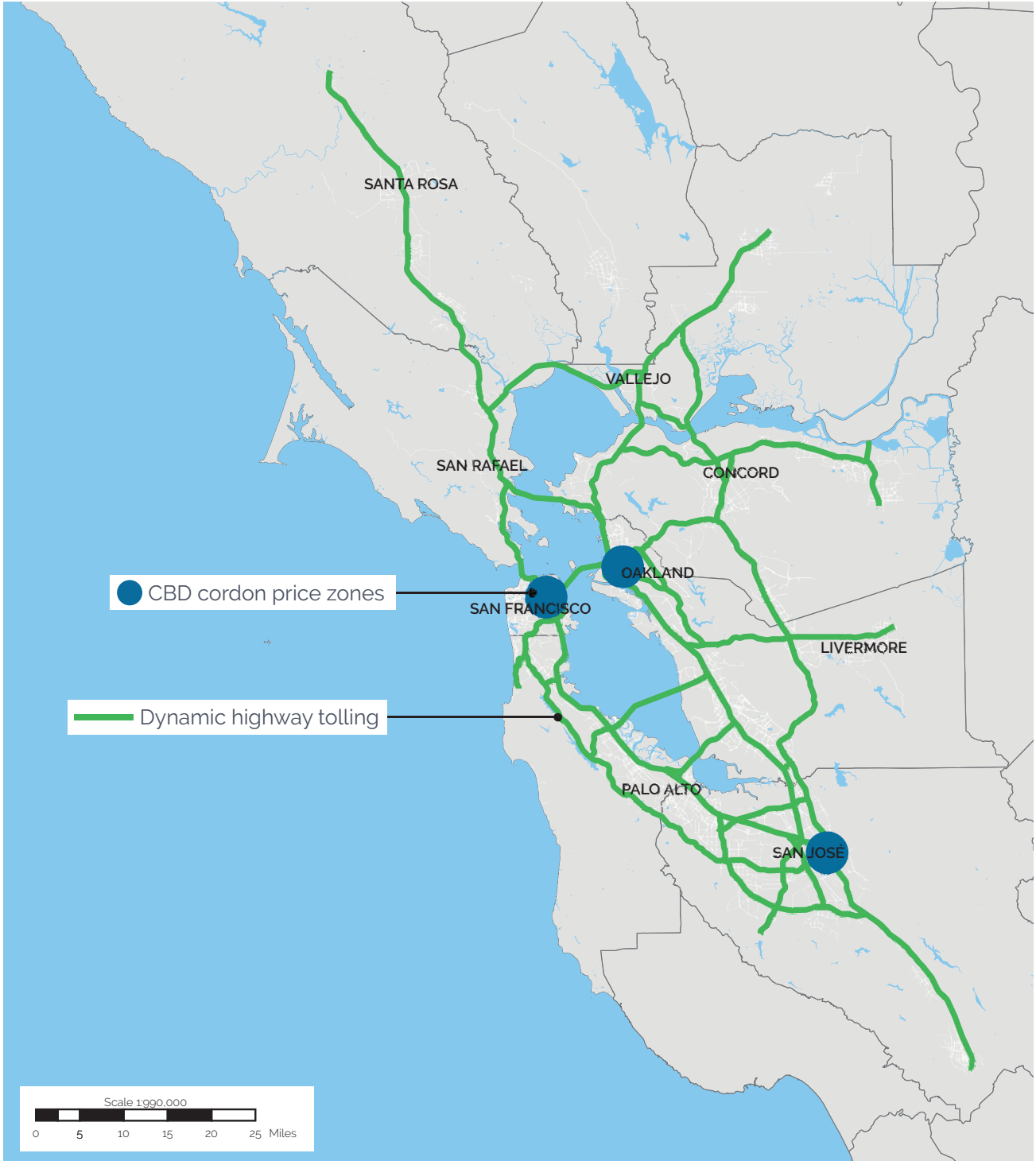


Figure 2.3 Dynamic Pricing Opportunities in an AV Future

A dynamic pricing system throughout the Bay Area's major corridors and in the three major cities would improve congestion and provide funding to transit and active mobility.

2.4 DIVERSE

Horizon Guiding Principle: *The Bay Area is an inclusive region where people from all backgrounds, abilities, and ages can remain in place – with access to the region's assets and resources.*

Diversity in the Bay Area. The Bay Area has long been considered a cultural hub, welcoming people from myriad backgrounds. Currently the fourth largest metro area in the US, it is also one of the most diverse ranking second among all metropolitan areas.⁷ In the Bay Area, no racial group is the majority; though non-Hispanic whites comprised just over 40% of the population in 2013, compared to nearly 25% for both Hispanic and Asian populations. The region has continued its legacy of international diversity with over 30% of the population foreign-born in 2013.⁸

Diversity and AVs. Mobility options could proliferate with new AV business models, benefitting people from all backgrounds, abilities, and ages. However, AVs could widen the equity gap with declining public transit, service disparities, job loss, and digital divide. Additional major implications of diversity and AVs are explored in Section 2.4.1.



2.4.1 AV IMPLICATIONS

This table highlights the major implications of AVs associated with diversity in the Bay Area. Each implication is derived from the literature provided in Appendix C: Further Reading.

Opportunities	Risks
<ul style="list-style-type: none"> • Universal Accessibility. The mobility benefits AVs could introduce to current non-driving populations, such as the elderly and disabled, is profound, improving independence and quality of life. • Environmental Justice. Automotive land uses with high noise and air pollution tend to be located in Communities of Concern. Such land uses may become less necessary with AVs, opening redevelopment opportunities for housing, jobs, and public amenities such as parks. • Access to Opportunity. The demand-responsive and flexible nature of AVs could improve residents' ability to access jobs and other activity centers, thereby widening their access to opportunity. 	<ul style="list-style-type: none"> • Limited Accessibility. Universal accessibility will only be achieved with intentional design, which is likely to require regulatory pressure. Private services are unlikely to provide universal access unless mandated to do so. • Reduced Transit Ridership. AV services could draw choice riders away from transit, straining transit operators with lower funds. This could result in more constrained services to transit-dependent communities. • Environmental Justice. Since proximate parking demand is likely to decrease, consolidated parking, charging, and maintenance facilities may become more common. Where these facilities locate will likely be an environmental justice concern. • Digital Divide. Just as TNCs are accessible only to smartphone owners,⁹ AVs could require a more exclusive digital accessibility and literacy. Further, it is unlikely AV mobility services will cater to the unbanked. • Inequitable Service. Without regulatory pressure, AV operators may be less likely to provide service to Communities of Concern because of assumed lower profits. Instead, AV service providers may be biased in favoring wealthier, denser, and/or commercial districts.



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2.4.2 PRIORITY STRATEGIES

Priority strategies related to the *Diverse* Guiding Principle are focused on ensuring and improving access to new mobility services.

1. Mandate **equitable provision** of mobility services with transparent reporting

Without regulation, there is a real potential for AV service providers to cluster near busy, high-income zones, such as business or shopping districts, leaving Communities of Concern with longer wait times and dropped rides. Mobility operators should be required to provide data to demonstrate equitable service.

2. Subsidize public **transit innovations**, replacing fixed route transit in some Communities of Concern

Without the need for a driver, autonomous transit could bring longer service hours, demand-responsive scheduling and routing, and greater community investment through improved access. In particular, autonomous transit innovation may provide the greatest value to Communities of Concern that may currently be underserved by transit. Subsidizing transit innovations in Communities of Concern may help channel AV technology to deliver better transit options to those who stand to benefit most.

3. Prioritize **AV mobility services or programs** for that serve Communities of Concern

As evidenced by the large response to the City of San José's request for information regarding possible AV programs in July 2017, it is reasonable to assume that the Bay Area's many AV startups would vie for involvement in government-sponsored pilot programs. Capitalizing on this interest, government entities in the region could create competitions to challenge and incentivize companies to prioritize Communities of Concern in their business models and shared mobility platforms.



2.4.3 EXAMPLE APPLICATION

EQUITABLE AV SERVICES

AV technology presents a tremendous opportunity to drastically improve service in Communities of Concern and correct transportation justice issues of the past. Today, Communities of Concern face numerous challenges related to accessibility including long waits and travel times and unreliable service for transit. Historically, these communities have faced inequitable service and discrimination across all modes, most recently with TNCs such as Uber and Lyft.¹⁰ Without specific government mandates and oversight of mobility service providers, there is a real risk that Communities of Concern will be disproportionately negatively affected with the rise of AVs. With the right policies and transparency, AV services could be an important value add, especially in the autonomous transit realm.

As a region, the Bay Area is positioned to lead in the transportation equity space and require accountability for all mobility service providers – public and private. This leadership will involve developing clear targets, forming realistic but ambitious equity metrics, monitoring progress actively, and requiring continual improvement. This improvement should be directed to specific equitable outcomes.



2.5 HEALTHY

Horizon Guiding Principle: *The region's natural resources, open space, clean water, and clean air are conserved – the region actively reduces its environmental footprint and protects residents from environmental impacts.*

Health in the Bay Area. While bringing convenience and enhanced mobility to the public, cars have introduced myriad health risks. Over the last 15 years, more than 6,500 people have died on Bay Area roads with an average of 6 in 100,000 residents losing their lives in traffic incidents.¹¹ In 2016 alone over 33,000 major traffic collisions were reported in the Bay Area.¹² Additionally, Bay Area residents generate greenhouse gas emissions at a rate substantially higher than the global average.¹³ These greenhouse gasses pose threats to public health and climate change goals. As the region's population grows, more cars on the road will increase the potential for vehicle collisions, pollution-related illness, and environmental degradation.

Health and AVs. AVs could save lives by reducing human driving error. However, hacking and cybersecurity could introduce new safety risks. Additionally, AVs could worsen air quality if they are not electric. Additional major implications of health and AVs are explored in Section 2.5.1.



2.5.1 AV IMPLICATIONS

This table highlights the major implications of AVs associated with health in the Bay Area. Each implication is derived from the literature provided in Appendix C: Further Reading.

Opportunities	Risks
<ul style="list-style-type: none"> • Safety. Since human error is responsible for an estimated 90% of traffic fatalities, improving safety is a fundamental reason for the development of AVs. It is reasonable to assume roadway safety will improve significantly when AVs achieve regulatory approval, public acceptance, and widespread adoption. • Emissions. If AVs accelerate EV proliferation then localized emissions (and likely life-cycle emissions) would decrease. EV proliferation would also reduce air pollution. • Active Mobility. AVs could make biking and walking more appealing by making streets safer, particularly as legacy vehicles become less common. • Environmental Justice. Automotive land uses with high noise and air pollution tend to be in Communities of Concern. Reduced congestion and shift to EVs could improve local air quality and reduce noise issues. • Urban Greenery. More redevelopment of parking lots and garages means more opportunities for easily accessible community open space and urban agriculture. 	<ul style="list-style-type: none"> • Safety. New forms of safety and security risk may be introduced with hacking and cybersecurity vulnerabilities of automated and connected transportation systems. • Emissions. Given the induced demand AVs are likely to introduce, AVs using fossil fuels could deteriorate air quality and increase emissions. This trend would be of particular importance for historically disadvantaged communities, for which higher exposure to particulates is more common. If AVs are EVs, electricity source will be a consideration, as the use of nonrenewable sources of electricity could present other risks. • Active Mobility. AVs could make biking and walking less prevalent by making it easier, and possibly more affordable, to travel by vehicle. In some contexts, AVs could further low-density development, making walking and biking still more difficult. • Air Quality. If AVs operate on fossil fuels, air pollution could worsen as induced demand increases VMT. • Environmental Justice. Since proximate parking demand is likely to decrease, consolidated parking, charging, and maintenance facilities may become more common. Where these facilities locate will likely be an environmental justice concern. • Manufacturing. With higher utilization of vehicles likely with a shared AV fleet, more manufacturing could mean more waste and manufacturing-related emissions. As new mobility options proliferate, recycling old vehicles may become a challenge. • Sprawl. In some contexts, continued outward expansion of development into vulnerable ecosystems and agricultural lands will be made more attractive with AVs. This has the potential to work against California's ambitious climate goals and impact the many benefits that nature provides people like clean water, clean air, fresh and healthy food, and recreation.



Photo. © User: Baron Reznik/Flickr/CC BY-NC-SA 2.0

2.5.2 PRIORITY STRATEGIES

Priority strategies related to the *Healthy* Guiding Principle are focused on improving public health, mitigating emissions, and ensuring community security.

1. Cap **speed limits** in downtowns and neighborhoods

A multitude of studies suggest that reducing speed limits reduces injury and death on roadways. One benefit of AV technology is the AV's capability for automatic self-enforcement of laws and regulations. In anticipation of AVs, cities and municipalities should reduce speed limits to increase safety for all road users, but particularly for bicyclists, pedestrians, and other active transportation users.

2. Mandate that all **AVs are EVs** and invest in the necessary infrastructure

Given the potential AVs have to add more cars to the transportation network, it is important that AVs are predominately electric. So far, many AV developers are beginning with EVs or hybrid electric-gasoline vehicles because fleet operators could optimize recharging cycles; maintenance costs are lower; and on-board computation requires significant energy. A mandate at the state level would ensure all AV developers continue this shift. Undoubtedly, an influx of electric AVs to the fleet will require new infrastructure for charging. Municipalities, local utilities, and mobility service providers should collaborate to ensure adequate charging. As part of that, electricity sources should be carefully considered in the provision of new infrastructure with preference given to renewable sources.

3. Develop "bounty program" to reduce **hacking vulnerability**

Connected AVs could be networked via hacking-vulnerable channels. Some AV developers may opt to not connect their vehicles in real time to protect against hacking, but since real-time connectivity will offer many safety, service, and congestion benefits, secure connectivity is in the interest of all road users.

To address hacking exploits and vulnerabilities, transportation departments and other infrastructure authorities can establish so-called bounty programs. Through these programs, individuals are compensated for accurately reporting vulnerabilities. Authorities can then use the discovered information to resolve issues before vulnerabilities can be exploited. Public and private entities have established bounty programs including Google, Microsoft, Facebook, and the United States Department of Defense.



2.5.3 EXAMPLE APPLICATION

VISION ZERO 2.0

AVs have the potential to introduce a paradigm shift in transportation-related public health issues. AVs are likely to greatly reduce driving error and resulting death and injury because they have much broader vision; do not get tired, impaired, or distracted; follow the rules of the road; automatically react with caution to unpredictability; and learn exponentially from a vehicles network. Additionally, AVs hold the promise of improving other public health outcomes – not just avoided death and injury from collisions – but also reduced rates of pollution-related illness like asthma, heart disease, and cancer from improved air quality with a shift to EVs. Other health benefits may include increased street safety, increased active mobility, and lower obesity rates.

AVs are likely to greatly assist cities in the Bay Area in meeting their Vision Zero goals for zero traffic-related deaths by 2024. A regional Vision Zero 2.0 strategy would elevate the goal of eliminating traffic fatalities to the regional level while targeting other transportation-related health issues, including eliminating traffic-related deaths, nullifying cybersecurity vulnerabilities, and improving air quality.



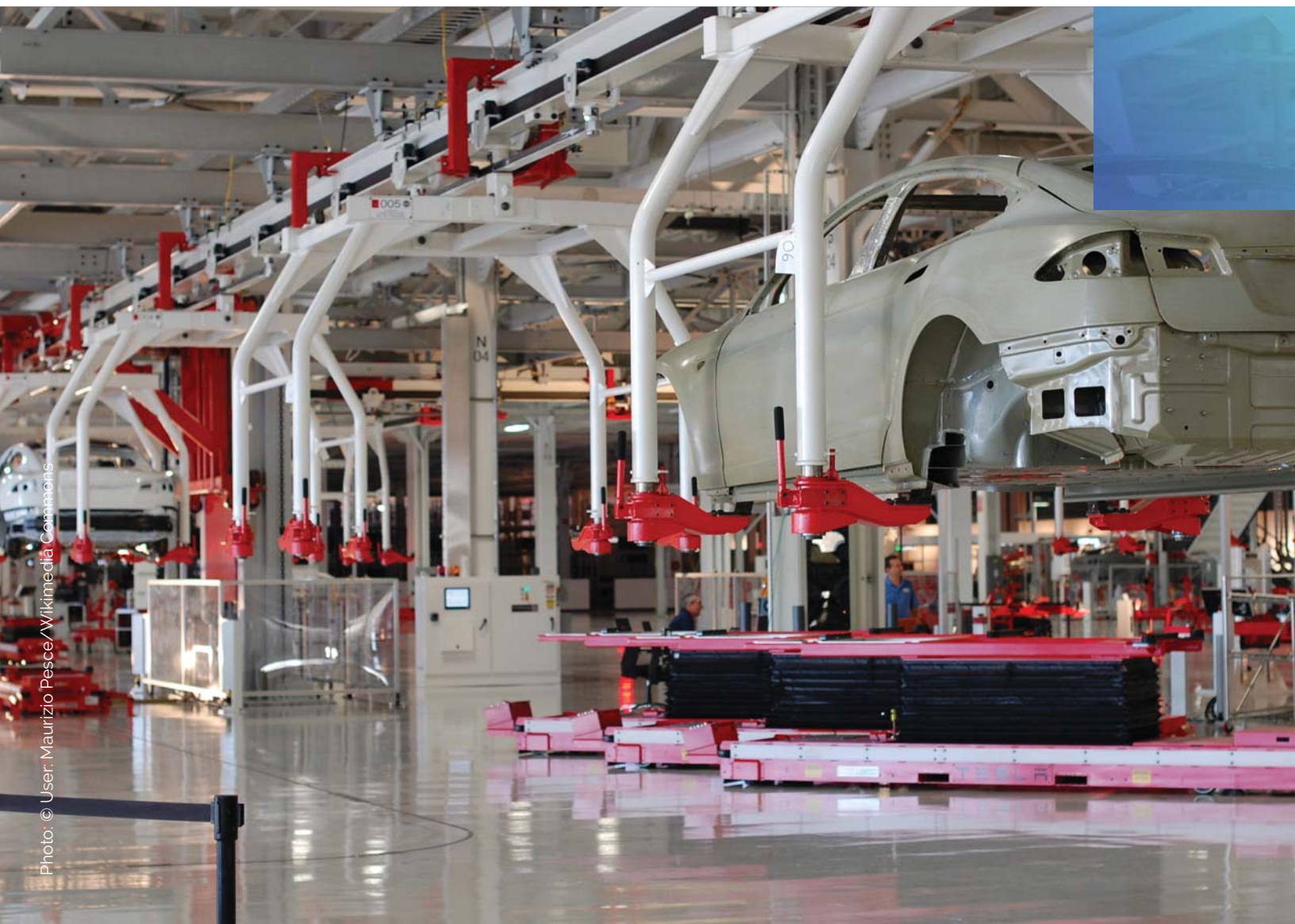
Photo: © User: Eric Gilliland/Flickr/CC BY 2.0

2.6 VIBRANT

Horizon Guiding Principle: *The Bay Area region is an innovation leader, creating quality job opportunities for all and ample fiscal resources for communities.*

Vibrancy in the Bay Area. Over \$700 billion strong, the Bay Area economy is one of the most robust in the world.¹⁵ Economic output has risen 28% per capita since 2001, 42% overall, putting the Bay Area's growth first in the nation.¹⁶ While unemployment has fallen to a low 4.3%,¹⁷ median income has remained relatively constant, creating income disparity.¹⁸ Between 2001 and 2015 the region's poorest households saw a median income increase of 15%, compared to a 42% income growth rate for the wealthiest households.¹⁹ Though bringing prosperity to the region, these economic conditions present a paradox for the Bay Area.

Vibrancy and AVs. AVs have the potential to reduce transportation and logistics operating costs, adding to economic prosperity. However, AVs could cause rapid job loss for workers currently employed in trade, transportation, and utilities industries. Additional major implications of vibrancy and AVs are explored in Section 2.6.1.



2.6.1 AV IMPLICATIONS

This table highlights the major implications of AVs associated with vibrancy in the Bay Area. Each implication is derived from the literature provided in Appendix C: Further Reading.

Opportunities	Risks
<ul style="list-style-type: none"> • Job Creation. AVs have already created some new jobs, such as developers and safety drivers in test AVs, and a range of new careers are possible as AVs burgeon. • Economic Shifts. Much as smartphones introduced a wide range of previously inconceivable business models and disrupted decades-old industries, from cameras to calculators, AVs could introduce unforeseeable consumer products and services with a wide range of implications for the retail, service, and information industries. This economic shift could give birth to new industries with new opportunities. • Business Models. Today, two transportation business models are most common. In most cases, travelers either purchase a vehicle – a product – that they are free to use whenever and for however long, or they pay a mobility operator on a per-trip basis. It is unknown which model will proliferate for passenger travel with AVs or if other forms of procuring mobility will dominate. • Accessibility. AVs are likely to increase access to opportunity for current non-driving populations – the disabled, the elderly, children, and others. • Manufacturing. Today, personal vehicles are used less than 4% of the day to make an average 2-3 trips per day. With a shared AV fleet, utilization could go up significantly, with vehicles in use more than 75% of the day. Higher vehicle utilization means higher fleet turnover and greater AV servicing and manufacturing needs. • Productivity. According to the AAA American Driving Survey, Americans drive more than 45 minutes a day on average.²⁰ That time can be reclaimed with AVs, no matter the business models that emerge. 	<ul style="list-style-type: none"> • Jobs Lost. Today, the automotive industry employs an estimated 5 million workers nationwide. Many of these jobs have low education requirements and provide secure incomes. Most of these same jobs are at risk with vehicle automation, including bus drivers, long-haul truck drivers, taxi drivers, and drivers of services such as Uber and Lyft. • Economic Shifts. As a disruptive technology, it is inherently difficult to predict how AVs will be applied. However, it is highly likely that whole industries, and the jobs they support, will become outmoded. • Government Revenues. Several sources of government revenue could diminish with AVs. As parking demand drops with the rise of shared AV services and the shift of parking outside of high-demand areas, parking fees will likewise decrease. Ticketing will also decrease as fewer vehicles disobey the law. Transit fares could also drop if ridership drops. Further, if EV conversion accelerates, gas tax revenue will fall, depleting a major source of revenue for services and infrastructure investment.



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2.6.2 PRIORITY STRATEGIES

Priority strategies related to the *Vibrant* Guiding Principle are focused on minimizing worker displacement while investing in grassroots innovation.

1. Strengthen the capacity of **training programs** to expand opportunities for workers in the AV industry

As demand for drivers drops, thousands of workers could no longer be needed. In the interim, significant driver shortages are possible as workers retire, recruitment stagnates, and mobility demand continues to rise. Enhanced training programs could build skills in related growing fields such as customer service, data analytics, and specialized mechanics.

2. Target job clusters on **industrially-zoned land** for production, distribution, and repair

Dozens of AV companies already exist in the Bay Area. Once mainstreamed, the technology is likely to have an agglomeration effect, spurring other supportive industries like AV production, distribution, and repair, all requiring physical space and resources. Cities should work to ensure these trends benefit the whole community in part by zoning for manufacturing, distribution, and other industrial uses.

3. Pilot **innovative AV applications** that could spur new job opportunities

Even though much AV innovation is focused on the passenger economy, opportunities in goods movement are significant. Government agencies should launch competitions and support pilot programs in AV logistics, including sidewalk robots, drone delivery, modular urban logistics systems, and truck platooning.



2.6.3 EXAMPLE APPLICATION

“NEW DEAL” FOR MOBILITY

Economists project the AV passenger economy will be a trillion-dollar industry.²¹ Thus far, the AV industry has largely benefitted high-income earners in the information and technology space, with risk of threatening low- and middle-income jobs such as bus drivers or long-haul truckers. Moving forward, both industry and government agencies alike must consider the need for the economic prosperity spurred by AVs to inclusively and equitably benefit the Bay Area and its residents.

By prioritizing grassroots pilots and innovation within the AV industry and developing a comprehensive program to maximize economic benefits of AVs, the region's workers may have expanded opportunities because of this new technology. Jobs creation and prevention of job loss for low- and middle-income workers should take precedence for both agencies and industry alike through commitment to workforce development, manufacturing innovation, and goods and transit pilot programs.



Photo. © User: Scott Szarapka/Unsplash

CHAPTER 3 NEXT STEPS









This paper is the first in a series of Perspective Papers that will contribute to **Horizon**, a regional initiative exploring a range of external forces that have the potential to fundamentally alter the region's trajectory. The *Autonomous Vehicles Perspective Paper* focuses on priority policy interventions and planning strategies for the Bay Area to seize opportunities and proactively address challenges that AVs are likely to introduce.

The priority strategies should be considered only the beginning of the regional conversation about how the region should respond to AVs. In upcoming months, these strategies will be put to the test as part of the Horizon process.

Following the release of this and other Perspective Papers, MTC and ABAG staff will engage stakeholders to identify which of the priority strategies can overcome the various challenges facing the region across a series of divergent "Futures," planning scenarios with varying assumptions on the economy, technology, and the environment.

Following the Futures analysis and the stakeholder engagement, a short list of strategies that are most effective in overcoming regional challenges will be recommended for inclusion into Plan Bay Area 2050. The Plan's expected release in 2021 will include an implementation plan to identify essential near-term actions that MTC, ABAG, and partners can take to begin strategy implementation.



ENDNOTES

¹ The survey consisted of eight broad questions, two of which were split into sub-questions specifying a particular year or type of roadway facility. Eighteen participants completed the first round, and 22 completed the second. Participants in the second round were shown results from the first round. In completing the Delphi survey, respondents were instructed to provide holistic and high-level responses, without particular concern (unless otherwise specified) for details concerning the political and regulatory environment, roadway type, surrounding land use, available infrastructure, or proportion of shared vehicles. Except for the first three questions about timing, all survey questions and responses referred to a year and location when Level 5 AVs represent 90% of traffic.

² Waymo and one other unnamed company have applied for a second level license, but as of June 15, 2018 the DMV had not awarded this license to any entity.

³ On the evening of March 18, 2018 in Tempe, Arizona outside Phoenix an Uber Self-Driving Car struck and killed a pedestrian while in autonomous driving mode. This incident marked the first traffic fatality involving a Level 4 or 5 AV. While the National Transportation Safety Board (NTSB) conduct investigations into the incident, Uber has suspended all public AV testing operations. The NTSB has published a preliminary report: <https://www.nts.gov/investigations/AccidentReports/Pages/HWY18MH010-prelim.aspx>.

⁴ Metropolitan Transportation Commission. 2017. Vital Signs, Transit Cost-Effectiveness. Retrieved from: <http://www.vitalsigns.mtc.ca.gov/transit-cost-effectiveness>

⁵ Zhang, W., Guhathakurta, S., Fang, J., and Zhang, G. 2015. "Exploring the Impact of Shared Autonomous Vehicles on Urban Parking Demand: An Agent-based Simulation Approach." *Sustainable Cities and Society* Volume 19 (December): 34-45. Retrieved from: <http://www.sciencedirect.com/science/article/pii/S221067071530010X>.

⁶ Metropolitan Transportation Commission. 2017. Vital Signs, Commute Time. Retrieved from: <http://www.vitalsigns.mtc.ca.gov/commute-time>

⁷ San Francisco Foundation. 2017. An Equity Profile of the Nine-County San Francisco Bay Area. Retrieved from: http://nationalequityatlas.org/sites/default/files/Final_9_County_BayAreaProfile.pdf

⁸ Association of Bay Area Governments. 2015. State of the Region Report. Retrieved from: <http://reports.abag.ca.gov/sotr/2015/section3-changing-population.php>

⁹ While there are some services that connect people to Lyft and Uber without a smartphone, such as GoGo Grandparent, there is still some awareness and digital literacy required for these services. However, such services may become more common, narrowing the digital divide.

¹⁰ Ge, Y., Knittel, C., MacKenzie, D., and Zoepf, S. 2016. Racial and Gender Discrimination in Transportation Network Companies. National Bureau of Economic Research. DOI: 10.3386/w22776. Retrieved from: https://faculty.washington.edu/dwhm/wp-content/uploads/2016/10/TNC_Main_NBER.pdf

¹¹ Metropolitan Transportation Commission. 2017. Vital Signs, Fatalities from Crashes. Retrieved from: <http://www.vitalsigns.mtc.ca.gov/fatalities-crashes>

¹² Metropolitan Transportation Commission. 2017. Vital Signs, Fatalities from Crashes. Retrieved from: <http://www.vitalsigns.mtc.ca.gov/fatalities-crashes>

¹³ Metropolitan Transportation Commission. 2017. Vital Signs, Greenhouse Gas Emissions. <http://www.vitalsigns.mtc.ca.gov/greenhouse-gas-emissions>

¹⁴ In 2014, San Francisco developed an ambitious goal to reduce all traffic-related fatalities within a decade.

¹⁵ Metropolitan Transportation Commission. 2017. Vital Signs, Economic Output. Retrieved from: <http://www.vitalsigns.mtc.ca.gov/economic-output>

¹⁶ Metropolitan Transportation Commission. 2017. Vital Signs, Economic Output. Retrieved from: <http://www.vitalsigns.mtc.ca.gov/economic-output>

¹⁷ Metropolitan Transportation Commission. 2017. Vital Signs, Unemployment. Retrieved from: <http://www.vitalsigns.mtc.ca.gov/unemployment>

¹⁸ Metropolitan Transportation Commission. 2017. Vital Signs, Income. Retrieved from: <http://www.vitalsigns.mtc.ca.gov/income>

¹⁹ Metropolitan Transportation Commission. 2017. Vital Signs, Income. Retrieved from: <http://www.vitalsigns.mtc.ca.gov/income>

²⁰ AAA. 2016. American Driving Survey: 2014-2015. Retrieved from: <https://aaaafoundation.org/american-driving-survey-2014-2015/>

²¹ Seba, T. and Arbib, J. 2017. Rethinking Transportation 2020-2030. Rethinx. Retrieved from: <https://tonyseba.com/portfolio-item/rethinking-transportation-2020-2030/>; and Lanchot, R. 2017. Accelerating the Future: The Economic Impact of the Emerging Passenger Economy. Strategy Analytics. Retrieved from: <https://newsroom.intel.com/newsroom/wp-content/uploads/sites/11/2017/05/passenger-economy.pdf>

²² Gehrke, S., et al. 2018. Fare Choices: A Survey of Ride-Hailing Passengers in Metro Boston. Metropolitan Planning Area Council. Retrieved from: www.mapc.org/wp-content/uploads/2018/02/Fare-Choices-MAPC.pdf

APPENDIX







APPENDIX A STRATEGIES MENU

Guided by current literature and the Horizon Guiding Principles, an extensive list of strategies that show promise of being relatively feasible and effective towards seizing the opportunities and overcoming the risks with AVs. A selection of strategies is outlined in the paper as priority strategies. These priority strategies were selected from the longer list because they can:

1. Be reevaluated over time and can be adjusted given ongoing changes in technology, business models, and public preferences; and
2. Advance regional goals no matter the future conditions of and responses to AVs.

What follows is the full list of strategies developed, organized by Guiding Principle. Included for each is an estimation of the strategies effectiveness and a feasibility timeframe which help guide long-term regional interventions.

A.1 AFFORDABLE STRATEGIES MENU

Strategy	Effectiveness	Feasibility Time Frame
Local jurisdictions institute reduced parking minimum requirements and parking maximums for both on- and off-street parking supply.	●○○	Short-term
Reallocate on-street parking to create complete streets (e.g. HOV lanes, protected bike lanes, loading zones, landscaping etc.).	●●●	Mid-term
Include strategies to repurpose parking facilities in local land use plans.	●●○	Short-term
Local authorities adopt reduced parking minimums as well as parking maximums for new development in anticipation of lower parking demand with AVs.	●●○	Short-term
Develop parking reuse plans anticipating lower parking demand with AVs.	●●○	Short-term
Streamline local processes to convert residential garages to accessory dwelling units, in order to leverage reduced car ownership to increase housing supply.	●●○	Short-term
Develop local and regional funding strategies for the conversion of parking to other uses with public benefits, such as parks or affordable housing.	●●○	Mid-term

A.2 CONNECTED STRATEGIES MENU

Strategy	Effectiveness	Feasibility Time Frame
Transit operators launch pilots of AV-enabled transit service models (e.g. autonomous microtransit, first-/last-mile, demand-responsive transit) to complement or replace fixed routes with low productivity.	●●●	Mid-term
Incrementally apply AV technology to transit fleets, such as collision avoidance, to improve safety and passenger experience.	●○○	Mid-term
Make regional investments in upgrading high capacity, high frequency rail and bus trunk lines connecting activity centers, combined with automated first and last mile connections.	●●●	Mid-term
Cities partner with waste collection contractors to pilot automated waste collection vehicles and routes to assess feasibility and understand potential traffic implications.	●○○	Mid-term
Major cities explore below-grade autonomous freight delivery and waste collection in urban environments (i.e., goods pipelines or subterranean delivery networks) to minimize vehicle traffic in dense areas.	●●●	Long-term
Mandate off-peak AV freight delivery with suitable receiving points in congested areas.	●●○	Mid-term
Support the development of industry-wide data sharing protocols, defining data needs with appropriate privacy principles to provide real-time infrastructure, congestion, and pricing data to connected vehicles.	●●●	Short-term
Cities develop digital, open, and standardized transportation infrastructure inventories (e.g. including curbs, parking regulations, traffic signals, etc.) to streamline regulation and operation of AVs.	●●●	Mid-term
Establish a city- or regional-scale data sharing pilot program in collaboration with private industry partners.	●●●	Short-term
Support statewide implementation of VMT-based road user charge for all vehicles (including AVs) as a replacement to the gas tax.	●●●	Short-term
Cities implement pilot programs for curb access fees in dense areas.	●●○	Short-term
City- and regional-level dynamic pricing for road user charges, e.g. congestion pricing on high-demand corridors or zones.	●●●	Mid-term
Implement ubiquitous dynamic, real-time micro-tolling of all vehicles based on level of congestion and potentially other criteria (e.g. emissions, vehicle occupancy).	●●●	Long-term
Mandate top-down trip routing and scheduling to optimize network performance (e.g. route choices for AVs are assigned by a central control system).	●●●	Long-term
Consolidate and integrate transit agencies to manage the evolution of Bay Area transport, reduce overhead costs, increase consistency, simplify the passenger experience, increase leverage, and coordinate service across jurisdictional boundaries.	●●●	Mid-term
Develop curb allocation, management, and enforcement best practices that can be consistently applied across multiple jurisdictions.	●●○	Short-term
Digitize and price the curb with dynamic assignments based on policy and demand.	●●○	Mid-term

A.3 DIVERSITY STRATEGIES MENU

Strategy	Effectiveness	Feasibility Time Frame
Mandate data transparency on all vehicles with appropriate privacy protections, potentially via a third-party aggregator.	●●●	Long-term
Incorporate incentives for AV owners to carpool in public and private sector Travel Demand Management (TMD) programs such as preferential drop-off locations and real-time carpool apps.	●○○	Mid-term
Transit operators replace low demand transit services with subsidies for private sector AV mobility services, while ensuring safety, value, and equity.	●●○	Long-term
Subsidize private autonomous shared mobility services for Communities of Concern, and/or as a replacement for fixed-route transit.	●●○	Mid-term
City or state-level mandates for equitable provision of mobility services (such as providing disabled accessibility, serving the unbanked, or ensuring service in Communities of Concern).	●●●	Mid-term

A.4 HEALTHY STRATEGIES MENU

Strategy	Effectiveness	Feasibility Time Frame
In the case that AVs are not EVs, work with the state to require eco-driving by AVs, such as efficient acceleration and braking, maximum highway speeds.	●○○	Short-term
Create low emissions vehicle zones in areas with poor air quality in which high emissions vehicles are banned or charged higher usage fees.	●●●	Long-term
The region (i.e., BAAQMD) coordinates with utility providers to create a regional EV charging blueprint and investment roadmap for passenger, transit, and goods movement fleet charging.	●●●	Short-term
Continue state and local incentives for investment in renewable energy infrastructure such as solar and wind as power requirements for electric AVs increase.	●●●	Short-term
State and local environmental protection agencies require sustainable AV manufacturing methods.	●○○	Mid-term
State and local environmental protection agencies develop programs to repurpose or recycle vehicles.	●○○	Long-term
Require measurement of people throughput rather than vehicle throughput when determining capacity needs.	●●○	Mid-term
Coordinate with state to ensure safety standards for local testing and deployment operations are observed as part of the licensing process.	●○○	Short-term
Collaborate with state and industry to develop an enforcement and first responder training program.	●●●	Short-term
Collaborate with the state and industry to implement prevention, response and reporting protocols for shared AV riders to protect against harassment, property theft, and violent crimes.	●●○	Mid-term
Require that relevant vehicle operating data (such as observed road hazards) is provided to cities to supplement safety programs (e.g. Vision Zero).	●○○	Short-term
Establish maximum speed limits in urban areas based on minimizing injuries and fatalities for vulnerable road users, rather than on prevailing speeds.	●●●	Mid-term
Cities implement dedicated low-speed AV zones to increase safety in heavy pedestrian areas.	●●○	Mid-term

A.5 VIBRANCY STRATEGIES MENU

Strategy	Effectiveness	Feasibility Time Frame
Launch collaborative working groups for city officials to share knowledge and experience.	●●○	Short-term
Establish innovation hubs to facilitate public-private collaboration and investment with the mandate to apply technology consistent with regional priorities.	●●○	Short-term
Local governments perform risk assessments to public revenue streams with AVs.	●○○	Mid-term
Conduct a regional-scale study of the potential impacts of vehicle automation on the Bay Area labor market.	●○○	Mid-term
Launch workforce advancement programs for interested commercial drivers to transition to other roles such as on-board attendants, data analytics, vehicle maintenance and cleaning, etc.	●●○	Long-term
Build public roaming delivery and distribution centers serviced by drones and AVs.	●○○	Long-term
Regularly study the impacts of logistics and e-commerce trends.	●●○	Short-term
Pilot truck platooning on Bay Area freeways.	●●○	Short-term
Cities partner with private companies on pilot programs for autonomous goods movement (e.g. sidewalk robots, drone deliveries, modular urban logistics systems, etc.) to evaluate impacts such as congestion, curb utilization, vulnerable road users.	●○○	Short-term
Support emerging technology pilots for urban logistics and regional supply chain distribution (e.g. sidewalk robots, drone deliveries, modular urban logistics systems, etc.) to evaluate congestion and other impacts.	●○○	Mid-term



APPENDIX A CASE STUDIES

AVs are one component of rapid innovation that is changing the transportation landscape. Appendix B examines early indicators of mobility transformation and, importantly, it reviews the ways in which policymakers have responded. This analysis is presented in three parts. First, transportation network companies (TNCs) could provide insight into market interest and regulatory response to AV services. Several TNC regulatory stories serve as valuable case studies. Second, a limited number of AV pilot programs in the Bay Area and elsewhere are demonstrating the increasing viability of the technology, despite significant struggle. Finally, other metropolitan organizations as well as non-profit organizations and think tanks are beginning to explore policies and pilot programs to take advantage of opportunities and mitigate against risks with AVs.

A.1 TRANSPORTATION NETWORK COMPANIES

TNCs, also known as ridehailing services, entered the United States mobility market in 2010. TNCs are associated with a variety of companies, most notably Lyft and Uber. TNCs enable users to conveniently access demand-responsive transportation services with a smartphone application connecting riders and drivers, and offers riders real-time updates of trip price, pick-up and drop-off times, and mobile payment. In the nearly 10 years since they first entered the mobility landscape, the popularity of TNCs has grown rapidly, with more than 250 million users globally in 2017. The impacts on urban mobility and airport access have been significant.

A.1.1 TNCs AND CITIES

Ridehailing services permeated the urban landscape so quickly because they are convenient and easy for all users involved, but their meteoric rise poses a number of risks to cities concerning the diversion of transit riders, traffic generation, equity and the privatization of mobility, lack of data sharing, safety, and concerns about shifting labor markets. A 2018 study conducted in metropolitan Boston indicated that over 42% of TNC riders would have taken transit if the TNC service had been unavailable, underscoring a pervasive concern that ridehailing may be pulling the bulk of its passengers from transit or active modes of transportation, instead of automobiles.²² Recent research from New York City found that TNCs generated an additional 600 million vehicle miles traveled over between 2013 and 2016, suggesting that ridehailing services may be worsening, not relieving, congestion in cities.

Over the past decade, various levels of government have sought to regulate TNCs, a challenge complicated by the initial difficulty in classifying the service. Overlapping regulations from both state and city agencies have created a complex regulatory landscape that directly affects the local characteristics of TNC operations.

SAN FRANCISCO, CALIFORNIA

In California, TNCs are regulated primarily by the California Public Utilities Commission (CPUC). The California Constitution and the Charter-party Carriers Act designate regulation jurisdiction to the CPUC for passenger transportation in which drivers are directly compensated. Presently, CPUC regulations chiefly concern safety, accessibility, and liability for TNCs, requiring them to prove compliance with background checks, commercial insurance, a zero-tolerance drug and alcohol policy for drivers, driver training programs, the monitoring of requests for wheelchair-compliant vehicles, initial and annual company registration fees, and select quarterly reporting requirements.

While the California Constitution enables municipalities to enact their own legislation, such ordinances must not conflict with state law. In San Francisco, the regulation of TNCs is managed by the San Francisco Municipal Transportation Agency (SFMTA). Presently, SFMTA indirectly regulates TNCs through regulations that generally apply to all vehicles, such as the enforcement of curb and parking regulations (e.g., metered parking, loading or restricted parking zones) and general traffic engineering (e.g., traffic control devices, intersection, or street design). Building on a study from the San Francisco County Transportation Authority (SFCTA) on TNCs, a new pilot program currently being developed in San Francisco proposes adjustments to curb use and regulation to better manage demand for TNC services, including the conversion of parking spaces to passenger loading zones, and the in-app restriction of TNC loading to specific areas. This "geo-fencing" of TNCs would represent an important move to shift some critical regulation of TNC behavior from the state to the local level.

Lessons learned:

- Specific local jurisdiction (e.g., over curb use) may enable municipalities to enact regulation in addition to state laws.
- The "disruptive" and novel nature of new mobility services can defy clear classification, and result in their regulation by multiple diverse government agencies.

Further reading:

- San Francisco County Transportation Authority. "The TNC Regulatory Landscape: An Overview of Current TNC Regulation in California and Across the Country." December 2017. www.sfcta.org/sites/default/files/content/Planning/TNCs/TNC_regulatory_020218.pdf
- Fitzgerald Rodriguez, Joe. San Francisco Examiner. "Mayor Lee to tackle Uber, Lyft traffic congestion through pilot program." May 15, 2017. www.sfexaminer.com/mayor-lee-tackle-uber-lyft-traffic-congestion-pilot-program/

AUSTIN, TEXAS

In December 2015, Austin's City Council passed an ordinance that increased the regulation of TNCs by requiring fingerprint-based background checks for all drivers. Supporters of Uber and Lyft, the primary TNCs in the city, quickly launched a bid to repeal this ordinance as Proposition 1. Proposition 1 was defeated in Spring 2016 with 56% of the vote in opposition, despite Uber and Lyft spending a combined \$8 million in support of the proposition (while the opposition spent close to \$200,000). In the face of such determination by the voting residents of Austin, both Uber and Lyft ceased operations in the city, citing onerous expenses required to comply with the new ordinance. In their absence, new ridehailing services came to Austin, including Fare, Fasten, and the non-profit Ride Austin.

However, in 2017, Representative Chris Paddie (R-District 9) introduced a bill to the state legislature creating statewide regulations for TNCs that would supersede any standing local regulations. Governor Greg Abbott signed HB100 into law in 2017, thereby immediately overruling Austin's stricter TNC background check regulations. Uber and Lyft immediately resumed operations in Austin. Within a few months, Fare exited the Austin market, and Fasten and Ride Austin saw their ridership bases decline, though both are still in operation in the city. This legislative effort from the state of Texas indicates the possibility for regulation to begin with a strong local presence that may later be overruled by increased jurisdiction claimed by the state.

Lessons learned:

- The strength of local decision-making can be tempered by state legislation.
- State power can directly impact the local mobility landscape.

Further reading:

- Austin, Texas, City Code §13-2-509 ("Transportation Network Company Service") www.austintexas.gov/edims/document.cfm%3Fid=245769
- Mekelburg, Madlin. The Texas Tribune. "Austin's Proposition 1 Defeated." May 7, 2016. www.texastribune.org/2016/05/07/early-voting-austin-proposition-against

PINELLAS COUNTY, FLORIDA

Just west of Tampa, the Pinellas Suncoast Transit Authority (PSTA) has partnered with multiple private services to provide a series of new mobility solutions. In 2016, PSTA announced its Direct Connect program: subsidized Uber or United Taxi rides for trips made to or from bus stops within designated zones. PSTA pays the first five dollars of each qualifying trip, a subsidy designed to address the "first mile/last mile" accessibility challenge in the county. Taking both the demand-responsive trip subsidies and the savings from cancelled low-ridership feeder bus routes into account, PSTA estimated a savings of \$100,000/year through Direct Connect.

In an expansion to this public-private partnership, PSTA also ran a one-year pilot program offering up to 23 free Uber rides per month between the hours of 9PM and 6AM. Pinellas County has a large population of service industry employees, and the TD Late Shift pilot aimed to improve mobility for transit-dependent workers who require late-night transportation services. The program proved popular and received a second round of state funding in 2017 (with a 10% match from PSTA).

Lessons learned:

- Coordination between state and local actors can lead to valuable funding support.
- Integration of multiple private partners into a single program can offer mobility services that are not dependent on one solitary company.

Further reading:

- PSTA. "Public Private Partnership Increases Transportation Access in Pinellas Park and East Lake." www.psta.net/about-psta/press-releases/2016/public-private-partnership-increases-transportation-access-in-pinellas-park-and-east-lake
- PSTA. "PSTA, Uber offer free, late-night rides for low-income residents." www.psta.net/about-psta/press-releases/2016/psta-uber-offer-free-late-night-rides-for-low-income-residents
- PSTA. Direct Connect. www.psta.net/riding-psta/direct-connect
- PSTA. Transportation Disadvantaged Program. www.psta.net/programs/td-transportation-disadvantaged

CHICAGO, ILLINOIS

Chicago has used a complex and unique suite of solutions to price its mobility infrastructure and services. Specifically, the City has leased its curbside parking meters to a private entity in exchange for an upfront payment and it has leveraged a per-ride fee on TNCs to help fund transit.

Curb Management

In response to budgeting shortfalls in 2008, Chicago's City Council under then-mayor Richard M. Daley voted to award the 75-year lease of the city's parking meter system (36,000 meters) to a fund managed by Morgan Stanley in exchange for a \$1.2 billion upfront payment. Among other restrictions, the concession agreement includes adverse action clauses that specifically prevent the city from reducing the market value of parking meter revenues, which may occur through the temporary removal of meters (e.g., during a street festival), or through their permanent removal (e.g., for bike lanes, dedicated transit lanes). This lost revenue must be compensated for through either a direct financial penalty reflecting the maximum possible revenue for the meter, or the installation of a new meter in a location that would generate the same amount of revenue.

The overall implication of the meter lease has been to restrict the city's control over curbside space. The

contract's inclusion of financial penalties ("true-ups") for lost revenue means that the city's temporary or permanent removal of parking meters results in payments to the leaseholder for lost parking revenue, or the installation of a new meter elsewhere that would earn a comparable amount. While Mayor Rahm Emanuel negotiated lower true-up penalties in 2014, the large cost associated with swapping parking meters for new curbside uses – like bus rapid transit routes and stops, reducing blind spots around bicycle lanes, or bulbouts – can deter implementation of such projects. This deterrence acts in two ways: by increasing the cost of projects that propose to remove parking meters, and by providing an incentive not to install such projects in areas that may offer locations of "comparable" parking meters for future meter relocation.

TNC Fee

In 2015, Chicago introduced a 30-cent per-ride fee for ride-hailing services, which supports the city's general fund. After rising to 52 cents per ride in 2016, Mayor Rahm Emanuel's 2018 budget for the city increased the fees to 67 cents per ride, with an additional 5-cent increase in 2019. All revenue from the new 15-cent fee supports the Chicago Transit Authority (CTA), and is estimated to provide an additional \$16 million for transit in 2018. In gathering support for his proposal, the mayor cited recent research indicating that TNC use contributes to congestion and draws most of its users from transit, walking, or biking. The CTA will use the new revenue for the financing of a new bond measure.

Lessons learned:

- The privatization of discrete parts of a city's transportation infrastructure can have widespread effects.
- Expectations of parking revenue may be closely tied to allocation of curb space.
- Demand for curb access is high and involves a wide array of constituents.
- By earmarking income from TNCs for transit, the city can capitalize on new modal habits to bolster transportation options that may be more accessible to everyone.

Further reading:

- The Chicago Reader. "Wait, we sold that off too?" <https://www.chicagoreader.com/Bleader/archives/2009/06/23/wait-we-sold-that-off-too>
- Active Transportation Alliance. "Unrealized Assets: A Critique of the Chicago Parking Meter Deal." <https://www.scribd.com/document/203514167/Unrealized-Assets-a-critique-of-the-Chicago-parking-meter-deal>
- City of Chicago. "City of Chicago Response to the ATA Report." https://www.cityofchicago.org/dam/city/depts/rev/supp_info/ParkingMeter/CityResponsetoATAREport.pdf
- Stephanie Farmer. "Cities as Risk Managers: The Impact of Chicago's Parking Meter P3 on Municipal Governance and Transportation Planning." *Environment and Planning A: Economy and Space*. <http://journals.sagepub.com/doi/abs/10.1068/a130048p>

CONCLUSION

Throughout the myriad regulations developed around TNCs, a common thread emerges as critical to regulatory success: coordination between different governing bodies, and the clear communication of needs and priorities for involved agencies. As illustrated in San Francisco, a city may have recourse to regulate TNCs more closely than the broader state agency does; conversely, Austin outlines the capacity for one governmental body to override another, and the importance of cooperation in regulation. Florida's Pinellas County illustrates the capacity to include multiple private operators in one state-funded but locally-managed program, integrating state, local, and private interests. Chicago's efforts to balance curb restrictions with TNC fees has helped the city fund transit.

In general, the rapid uptake of TNCs in cities likely portends the urban response to AVs, particularly shared AV services, once they are available. Through this rapid uptake, TNCs have demonstrated latent demand for a more user-friendly form of transportation than existing forms, including driving and riding transit. While offering an appealing service to individuals, TNCs have had a significant impact on cities, inducing more traffic, increasing the demand for curb space, and offering uncertain implications for public transit. Meanwhile, regulatory conflicts have resulted in mixed outcomes for cities. Heeding the lessons of TNCs will be critical for cities and metropolitan areas with the advent of AVs.

A.1.2 TNCs AND AIRPORTS

Data is beginning to show that the popularity of TNCs is fundamentally shifting landside airport operations. The strong, positive user experience features of smartphone-enabled ridehailing – convenient ride requests and payment, curb-to-curb service, and up-front pricing – are particularly attractive to travelers embarking on one of multiple legs of a journey. For example, at San Francisco International Airport, TNC trips jumped from 2.9 million to 7 million from 2016 to 2017 alone, according to the airport's 2017 TNC report. TNCs may be replacing traditional taxi cab services and other modes as well, with the potential to significantly impact airport parking revenues.

Airports represent a microcosm of the TNC regulatory field. Many airports collect concessions or other access fees from taxi cab and livery services, and in the process of adapting this system to the arrival of TNCs, a variety of tactics have been tested and modified. Since ending an outright ban on TNCs in early 2017, Boston Logan International Airport charges per-ride fees and enforces designated passenger loading zones. Likewise, Detroit Metropolitan Airport adopted a fee-per-ride and passenger loading zone policy in early 2017. Unlike in Boston, however, where the new regulations reduced the number of citations to TNCs for illegal activity, Detroit's tools have engendered a sharp uptick in citations and even banning of individual TNC drivers as a result of increased operation outside designated passenger loading zones. In other words, while new regulations reduced illegal activity in Boston, regulations markedly increased illegal activity in Detroit. Airports around the country have adopted regulations of varying complexity; a review of the case in San Francisco offers an illustration of the way in which TNC adoption may impact passenger travel behavior.

Further reading:

- Zipkin, Amy. "Airports Are Losing Money as Ride-Hailing Services Grow." The New York Times. December 11, 2017.
- Vaccaro, Adam. "Uber gets permission to operate at Logan." The Boston Globe. January 31, 2017.
- Colthorp, Jason. "Some Uber, Lyft drivers banned from Detroit Metro Airport." Click on Detroit (Local 4). November 21, 2017.

SAN FRANCISCO INTERNATIONAL AIRPORT

San Francisco International Airport (SFO) boasts one of the most sophisticated programs for TNC regulation in the country. In 2012, SFO's first acknowledgment of regular airport TNC service consisted of cease-and-desist letters citing the illegality of non-permitted commercial ground transportation services. However, some drivers (classified as "independent contractors" by TNCs) may not have been aware of the pertinent regulations, and the continued operation of their services led to the issuance of a stream of warnings and citations. In response, SFO and CPUC developed an operating permit for TNCs and real-time tracking for vehicles making TNC-enabled trips.

The SFO program includes three primary components: a per-trip fee (\$3.80 as of February 2018), designated passenger loading zones, and a real-time vehicle tracking system. As of July 2017, fees assessed on TNC trips have generated over \$52 million in net revenue since the start of permitted operations in October 2014. While the revenues from TNC activity have grown, the increase in TNC use at SFO has likely led to a proportional decrease in parking revenue for the airport. Although parking revenue increased 3% between 2016 and 2017, due to increased rates intended to reduce demand in the face of construction-related parking shortages, parking use declined 8% in the same time period, rental car contracts decreased nearly 6%, perhaps also reflecting a shift towards TNC use.

Among more standard ground transportation requirements like fee payment and insurance coverage, SFO's TNC permits require real-time vehicle tracking. Since TNC drivers do not drive full-time commercial vehicles, the standard regulations of full-time trade dress (including decals) and transponders are infeasible to require. To track vehicle information – including vehicle entrance, exit, and passenger pick-ups or drop-offs – SFO developed a real-time tracking system. The tracking data is used to audit trip-number reports from TNCs, and consequently to assess any additional trip fees. From October 2017 through August 2017, SFO issued over 21,000 administrative fines (totaling \$2.4 million) for violations of the permit operating requirements. In 2015, SFO licensed its tracking application for its use by other national airports, in light of continued interest in its efficacy.

As the popularity of TNCs for traversing the City of San Francisco continues to grow, so does its use for dedicated airport travel. By July 2017, TNCs comprised 71% of all paid commercial ground transportation trips at SFO – an almost four-fold increase from October 2014. The swift rise of this new technology

highlights users' willingness to adopt new tools to improve their mobility experience. As a dynamic and uncertain new mobility future approaches, embracing engagement with new systems to design sophisticated, effective regulation will be paramount.

Lessons learned:

- Many airports have seen significant change in landside access patterns as a result of TNCs.
- TNC operations at airports present a possible example for cities to price and manage the curb.

Further reading:

- San Francisco International Airport. "Transportation Network Companies at San Francisco International Airport." September 2017.

A.2 AV PILOT PROGRAMS

A limited number of AV testing operations have opened their doors to the public, allowing riders access to the backseat of an AV. MIT startup nuTonomy launched the first publicly accessible AV pilot in the summer of 2016 within a business district in Singapore. Since then, public pilots have launched throughout the world and across the U.S. This section highlights the major pilots in the U.S., followed by a focus on the Bay Area.

A.2.1 WAYMO IN PHOENIX

Waymo, the AV division of Alphabet (the parent company of Google), launched an "early rider" program in 2017 in the Phoenix, Arizona metropolitan area. This program offers free rides to volunteers in a fleet of fully autonomous Fiat Chrysler Pacifica minivans. The pilot program was successful enough that the company won approval from the Arizona Department of Transportation in February 2018 to launch a ride-hailing service using an exclusively AV fleet with no human drivers present.

A.2.2 UBER IN PITTSBURGH

In 2015, Uber launched its Advanced Technologies Center in Pittsburgh, in part to test vehicles on the city's diversity of roads and driving conditions. Despite some friction with the local authorities around expectations of data sharing, employment practices, and community benefits, Uber expanded its presence in the city with a pilot program beginning in 2016 that utilized AVs in its ridehailing service. Eventually, the company expanded testing operations in multiple North American cities, including San Francisco, Toronto, and Phoenix.

Then, on the evening of March 18, 2018 in Tempe, Arizona, outside Phoenix, an Uber self-driving car struck and killed a pedestrian while in autonomous driving mode. This incident marked the first traffic fatality involving a Level 4 or 5 autonomous vehicle. While the National Highway Traffic Safety Administration and

the National Transportation Safety Board conduct investigations into the incident, Uber has suspended all public AV testing operations.

A.2.3 LYFT/NUTONOMY IN BOSTON

Lyft is the second largest TNC in the United States, and in June 2017 the company partnered with nuTonomy, a software company from MIT that focuses on developing AV technology. In December 2017 Lyft and nuTonomy launched a pilot program in the Seaport district of Boston that pairs Lyft users with AVs. The app offers users the option to accept an AV (with backup driver) to complete their trip or to request a human driver.

A.2.4 POLICY EXPLORATIONS

In the last few years, several major policy reports have been published throughout the world. In the United States, numerous professional associations, non-profit organizations, academic institutes, and metropolitan authorities have explored the ways in which AVs could impact cities and communities. Generally, the purpose of these reports is to describe potential change with AVs and recommend proactive measures to shape a better world.

Not all recommendations directly addressed AVs; most were concerned with improving the systems and communities into which AVs will operate. For example, better regional coordination was commonly cited as a requisite need for improving flexibility and adaptability to new mobility services generally. Policies common to most reports include:

- 1. Parking.** There is consensus that parking demand will decrease. Public agencies should plan for this decrease in demand by reducing or eliminating off-street parking minimums and converting on-street parking to space for biking, walking, and transit, goods, and passenger loading.
- 2. Pricing.** AVs will shift the mobility market, and therefore the method for financing transportation operations and infrastructure. New pricing mechanisms – VMT and/or vehicle occupancy fee, cordon or other congestion pricing, and curb pricing among the most common – was frequently cited as a critical need.
- 3. Multimodality.** Transit, biking, and walking are already minority modes compared to driving in most U.S. communities. AVs could exacerbate this mono-modal system. Policies prioritizing and enhancing multimodal networks, options, and experiences are consistently recommended throughout all reports.
- 4. Data.** Digital infrastructure, and supportive data standards, create the foundation upon which mobility innovation is made possible. Without clear data policies, innovation – at least innovation in support of communities – stalls. All reports make at least baseline mention of the need to support digital infrastructure.

5. Equity. To varying degrees, most reports recognize the importance of equity. Common equity-based policies include workforce preparedness, public engagement, and neighborhood coverage or geographic access programs and planning efforts.

Beyond the common policies, the reports include a range of more unique recommendations, including topics as wide ranging as digitizing the curb and creating user experience working groups. In general, the reports consistently recommend that the public sector develop flexible future-facing policies grounded in core community values.

APPENDIX A FURTHER READING

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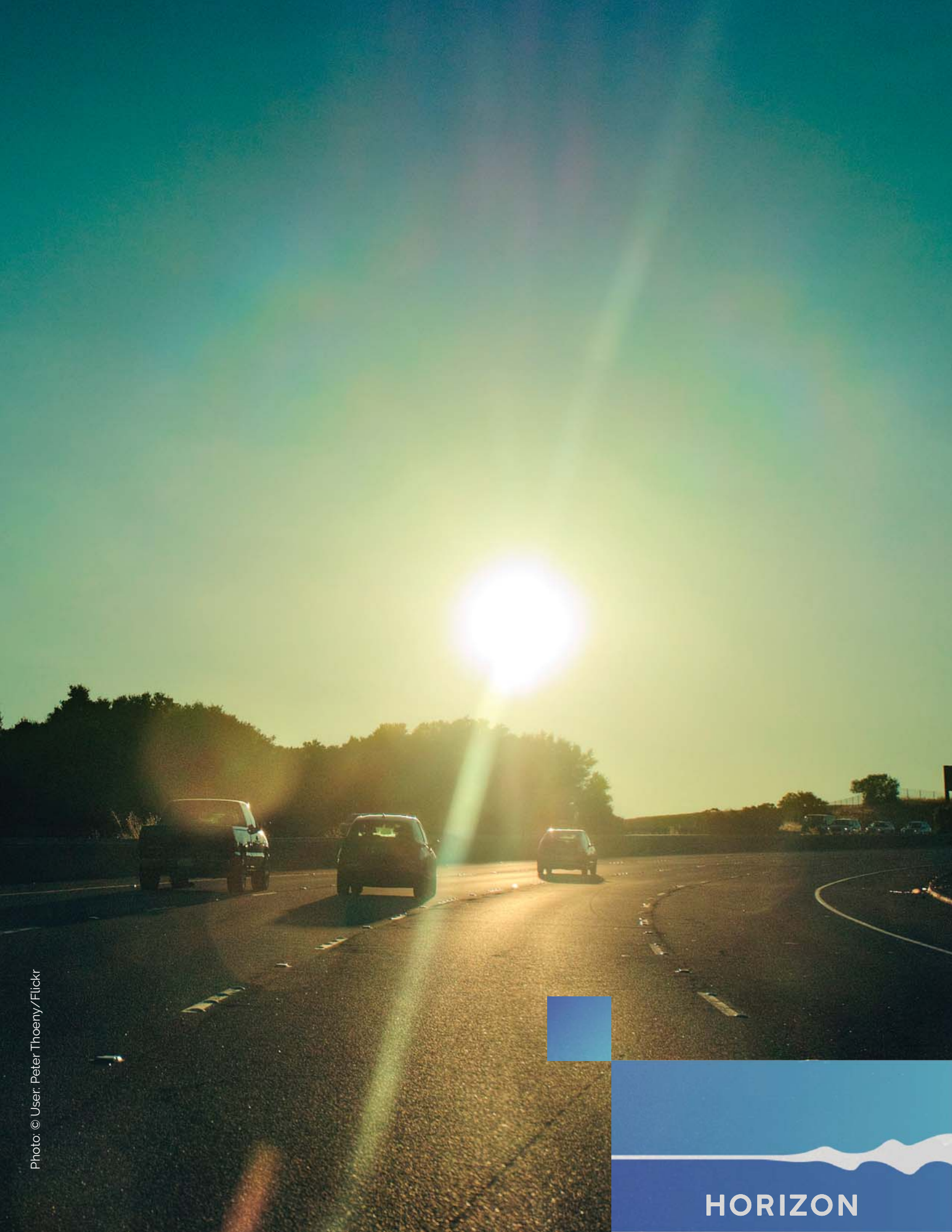


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