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A Policy Framework for the Future of Automated Mobility: The Need for Local Government Policy

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Abstract

Rapidly evolving urban mobility ecosystems and recent innovations in autonomous vehicle (AV) and electric vehicle (EV) technologies suggest we are on the brink of fundamental shifts in the urban transportation landscape. Many of these advanced technologies—in particular, autonomous vehicles which are both electric and shared—promise to reduce reliance on the personally-owned gasoline-powered car and have the potential to make our cities safer, cleaner, more inclusive, and more sustainable.

But as these technologies advance in real-time, cities have been hard-pressed to address the many expected shifts in transportation patterns, let alone new policy challenges around data, privacy, cybersecurity, and micromobility. Meanwhile, city, state, and federal governments are increasingly navigating overlapping and cross-jurisdictional policy landscapes as these technologies challenge historically clear areas of responsibility. Globally, the rate of technological change is now largely outpacing new legislation and regulation related to autonomous vehicle technology and other recent innovations in transportation that will shape the cities of our future.

Yet in spite of these challenges, local policymakers across the world are uniquely positioned to harness these technological innovations and deliver a brighter urban future. Cities are currently some of the earliest adopters of autonomous vehicle technologies and are beginning to consider how changes made to today's built environment can accelerate the deployment of these technologies in the future—considerations such as curb use and demand management, parking redesign, asset maintenance, right of way standardization, and cyclist and pedestrian-friendly projects. These new technologies can help cities meet emerging transportation demand more efficiently and completely, while still supporting critical societal values such as sustainability, social justice, and service equity.

1. Autonomous Vehicles and the Transportation Policy Landscape

Overview of the State of AV Policies: Delivering on the promise of autonomous vehicle travel will require coordination among all levels of government. Given the unique nature of this technological shift, policymakers at all levels—local, regional, state, federal, or international—are turning to existing precedent to inform their approaches to AVs. It is against this backdrop that we are already witnessing varied approaches to AV regulation—and often in an overlapping fashion.

In the United States in particular, delayed federal AV legislation has created regulatory and legislative ambiguity. A number of states have advanced a policy framework governing AVs through executive orders, legislation, and regulations. These state AV policy frameworks contemplate everything from

testing and deployment to road safety and cybersecurity. As states emerge to fill this policy vacuum left by the federal government, cities are also exploring what role they are to play in an autonomous future. Given the current federal landscape, local and state-level policy efforts are thus exploring what, if any, role they have to play, with few policymakers focused on considering how the built environment may change in a shared, autonomous, and electric future.

Overview of U.S. Policy Landscape: While progress is being made, there is still no federal AV legislation in the United States, which has created a regulatory and legal vacuum for states and cities. Legislation like the **AV START Act** and **SELF DRIVE Act** would create a national framework for the testing and deployment of automated vehicles that would mirror the existing regulatory precedent for human-driven vehicles. These efforts would clearly delineate the authority of the federal government from that of states and localities, namely over the design, construction, and performance of highly automated vehicles and driving systems. However, these efforts have been critiqued for both substantive and political reasons on the grounds that the proposed frameworks would provide only limited oversight over the development of AVs while preempting states and local governments from regulating the safety of their streets in the face of this innovative technology.

Similarly, the U.S. Department of Transportation (USDOT) has advanced its own guidance, most recently through the December 2019 "Ensuring American Leadership in Automated Vehicle Technologies" report, referred to as **Automated Vehicles 4.0**.[1] This report works to deliver parallel guidelines to support AV industry maturation, focusing on three high-level principles—protecting users and communities, promoting efficient markets, and facilitating coordinated efforts. Yet it has been similarly critiqued for its focus on voluntary safety consensus, particularly in the wake of high-profile crashes around AV testing.[2] The recommendations are closely tied to the National Highway Traffic Safety Administration (NHTSA) Automated Vehicles 2.0 guidelines which outlined a pathway for safe vehicle operations and provided high-level regulatory guidelines.[3]

The Department of Transportation has taken several other noteworthy steps, including publishing a Request for Comment in 2018 over regulatory barriers to AV testing, a 2019 Advanced Notice of Proposed Rulemaking (ANPRM) on crash protection standards, and a 2020 Notice of Proposed Rulemaking (NPRM) to modernize occupant protection standards for AVs with traditional seating configurations.

The State of AV Regulation Today—U.S. Cities and States

As a result of the current lack of federal guidance, cities and states have stepped in to backfill, advancing their own AV policies, each with unique direction and guidance and subsequent frameworks. This process has created uncertainty and a regulatory patchwork that is unable to keep pace with the rate of technological change.

Meanwhile, of the cities and states that have advanced policies, the absence of federal guidance has led to some policy overlap on issues historically handled at the federal level, such as vehicle safety performance standards. Furthermore, while some non-profit advocacy groups such as the American Planning Association, which outline design and planning principles for AVs in PAS 592,[4] have provided AV-specific design and land use suggestions, there are few policy frameworks specifically for local government.

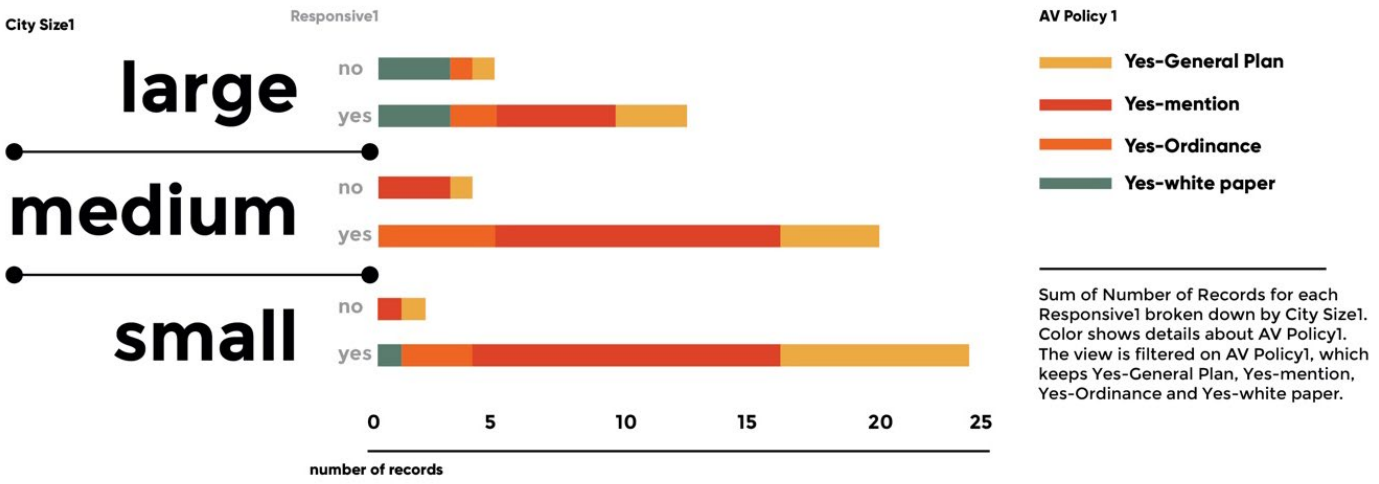

Figure 1. Number of Cities with AV Policy with a Responsive Website by City Size

As shown in Figure 1, at the local level there is patchwork of policy emerging with many smaller cities leading with at least acknowledging or mentioning AVs and establishing language in local comprehensive or general plans. At the same time, medium and larger cities have been active in enacting local ordinances and publishing white papers. The variation across geography aligns with how many cities are working to keep up with the pace of technological change but have little window into how it is evolving in the private sector.

Research indicates that generally regional transportation planning agencies are struggling to keep up with the technology.[5] In 2018, of the top 600 cities in the U.S., 75 (12%) had any dialogue in planning documents on AVs and their impact on urban space.[6] Of these 75, just 29 had a law in the form of an ordinance or general planning principle. The remainder were either white papers or mentions in planning documents. Examples in the U.S. include:

- *Boston, Massachusetts:*[7] Before testing on streets, companies must meet important performance standards, including ease of manual takeover from autonomous mode, emergency braking and emergency stop functionality, and basic driving capabilities such as staying with a lane. Initial testing can only occur during optimal weather conditions and daylight hours in geolimited areas. Once a company reaches predetermined milestones, some limitations are lifted and testing can be done in other areas of Boston, at night-time, and during inclement weather. Testing in Boston includes the use of a safety driver focused on roadway activity, as well as an engineer monitoring the vehicle's software. Companies must provide a history of their testing practices, documentation of extensive off-street and previous on-street testing, compliance with federal safety guidelines for AVs, and detailed safety driver training procedures.

- *Portland, Oregon:*[8] Portland has established policies to ensure that all levels of AV operate safely for users, requiring adequate insurance coverage for operators, customers, and the public at-large by providers of AVs. The policies also consider system reliability and efficiency by working to: (1) maintain or reduce the number of vehicle trips during

peak congestions; (2) reduce low occupancy vehicles; (3) pay for use of and impact on transportation systems including factors such as congestion and vehicle miles traveled, vehicle occupancy, and vehicle energy efficiency; and (4) support and encourage the use of public transportation. Their goal is to lower carbon pollution by reducing low occupancy vehicles while making the benefit of automated mobility available on an equitable basis to all segments of the community.

- *San Antonio, Texas:*[9] San Antonio plans to pursue testing on roadways based on guidelines from the NHTSA tied to its' SmartSA program. Recommendations are limited to: ensuring the transition from self-driving mode to driver control is safe; having capability to detect, record, and inform the driver; ensuring the installation and operation of AVs does not disable any federally required safety feature or systems; and ensuring AVs record information about the status of the automated control technologies in the event of a crash or loss of vehicle control.

- *Seattle, Washington:*[10] The city of Seattle's policy framework covers AV testing and development. This preliminary framework aims to (1) continue prioritizing the needs of people walking, biking, and taking transit to leverage the growth of the city's robust transit network; (2) support the development and testing of automated mobility technology by learning from pilots and partnerships with local and national technology and operating equipment manufacturers; and (3) establish clear policy parameters that ensure AVs help achieve the Mayor's five core values and the City's shared and emerging mobility principles. Fundamental to this framework is a "people and transit first" approach to AVs, recommending mixed fleet operations of human-driven and fully automated vehicles within Seattle to eliminate the risks of partial automation. The policy also recommends encoding operating parameters such as speed limits within connected and automated vehicles. The framework also underscores collaboration with federal and state policymakers to ensure that the Seattle Department of Transportation retains local control and enforcement powers on AV regulations such as time-based access restrictions or pricing for geofenced congestion management. Mandatory transfer of sensor data from vehicles as well as anonymization of personally identifiable data from connected and automated vehicles are also emphasized. Lastly, the framework includes parameters for equity and accessibility of service, pilots and partnerships, infrastructure and street design, mobility economics, and land use and building design.

Given these diverse examples, it is safe to say there is little uniformity or clear best practices in AV policy among cities. Without harmonization of policies across jurisdictions, operators are confronting heterogeneous regulatory landscapes that hinder compliance and interoperability. While these policies are foundationally based in the vision of creating better cities through management and design (for example Portland's reference of complete street policy and placemaking strategy), they are largely broad, patchwork, and vehicular-focused.

Notably, of the cities above, three of four cities (with Portland, OR being the exception) also have a statewide AV framework in place. This speaks to not only the increasingly layered and overlapping regulatory landscape, but also demonstrates that in states where AV policy frameworks have already been developed, cities have the space to focus on more traditional, local implications for autonomous travel. Yet despite the myriad efforts by cities to stand up AV policies, there is little

focus on areas historically within their domain, such as roadway construction and maintenance, digital infrastructure, parking and curb management, and EV charging infrastructure. While some frameworks have touched on "pathways for innovation" to test new mobility solutions (such as in San Jose), there has been less focus on how best to catalyze the policymaking process in an era of new mobility. Further absent from these efforts is integration of AVs with traditional transportation demand management (TDM) programs.

International Case Studies

This regulatory dissonance is not unique to the United States. The issues being faced by U.S. cities and states are being experienced internationally as well—particularly in countries where active AV testing has accelerated. For example, Europe has implemented policies primarily on driving safety and national roadway networks, while Singapore has developed frameworks that mandate strict vehicle performance standards and integration with city transit infrastructure:

- *Germany*: Germany passed an Autonomous Vehicle Bill in 2017 that amended the existing Road Traffic Act, delineating highly and fully autonomous technology and enumerating responsibilities for drivers of highly autonomous vehicles. Yet autonomous vehicle testing policy is currently handled by cities, with the federal government planning to create an infrastructure suitable for Level 5 fully autonomous vehicles and considering national policy in an ongoing manner.[11] This approach has been described as providing a *regulatory sandbox* for cities to experiment with policies, with the city of Monheim implementing the country's first automated shuttle bus line through a partnership with EasyMile,[12] and Berlin developing its own autonomous transit solutions that capitalize on the city's longstanding Mobility-as-a-Service (MaaS) work for on-demand last-mile transit service.[13] The government is working on broad policy to regulate Level 4 AVs at the national level.

- *Netherlands*: In the Netherlands, the national roadway agency, Rikswaterstaat, has a handful of programs focused on autonomous cars and trucks on national roadways.[14] While the focus is to promote safer driving and improved transportation systems management, the program is also closely aligned with national efforts to slow speeds on freeways and reduce greenhouse gas emissions.[15] Preliminary work is also being done to address travel behavior and decision-making to reduce traffic on national roadways.

- *Spain*: In Spain, policymakers have adopted a more industry-forward approach. As part of the Autonomous Ready Spain project, the city of Barcelona and Spain's Ministry of Transportation partnered with Mobileye to deploy 400 fleet vehicles to map and collect granular traffic data through 2019. This data will then inform future policymaking and regulatory roadmaps in a "more efficient and less costly" manner.[16]

- *Singapore*:[17] Singapore is a unique case study, with robust policies in place to foster the development of AV technology. Singapore developed the "Technical Reference 68" policy framework in January 2019, one of the first set of national standards to guide the deployment of AVs.[18] However, the country's approach is largely seen as iterative and incremental, with closed testing in relatively low-population density environments starting in 2015, while the country's Land Transport Authority announced in October 2019 that the whole

of western Singapore (including high-population density neighborhoods) will be opened up for testing AVs in the early 2020s.[19] The government has implemented milestones for closed-track testing to prove roadworthiness, and has articulated specific use cases for AVs such as fixed bus and depot routes, shared mobility-on-demand services, freight and logistics vehicles, and utility operations (e.g. road sweeping).

2. Purpose: The Need for Local Government Policy

As demonstrated in the case studies above, AV policymaking efforts and goals have differed both across and within governments internationally. This has led to an at times incongruent regulatory landscape, with distinct operating and testing requirements across cities and states addressing policy areas outside traditional regulatory scope.

Yet there is a nuance often lost in discussions around AV policy. These technologies often promise to deliver greener, safer, and more inclusive miles to the public. Given the potential impact that shared AV transportation will have on urban travel behavior and transportation demand, cities are perhaps best situated to focus on the built environment. As the transportation landscape becomes more dynamic and complex, modal separation is already proving to be a contentious process, particularly at areas of intensive multimodal utilization such as curbs. Cities have a prime opportunity to facilitate the development of the related technologies and policies to be as societally beneficial as possible. One of the most critical ways to do so is a holistic evaluation of the physical transportation landscape.

3. Cities Offer Tangible Policy Areas to Best Prepare for AV Transportation

Cities are positioned to focus their regulatory attention on *tangible* infrastructure-focused efforts, which will ultimately help maximize the benefits of AV transportation and future mobility forms to a much broader segment of the public. These municipal ecosystems will have an outsized role in defining the future of AV policy, based on their unique oversight as both the traditional engineer of roadways and facilitator of the local built environment for transportation.

- *Review of traditional city transportation responsibilities*: In the wake of the tragic Tempe, AZ fatality, safety has since framed the majority of the dialogue on emerging AV transportation policy— including at the city level. This has led many local jurisdictions to focus on vehicle safety, particularly given the public's focus on this incident. Yet as cities develop new policies around AV technology, they are often charting new territory in areas outside of their traditional purview. This regulatory approach by cities is in fact a departure from a focus on issues they have traditionally handled, such as management of the built environment, the right of way, travel behavior, active transportation, and more.

- *Cities have a generational opportunity to shape the built environment*: Cities are perhaps best positioned to address the policy areas that could maximize the benefits of AVs. While *new tech* policy areas are a major focus for city transportation agencies, the true social justice and environmental benefits of AV transportation cannot be unlocked if the built environment and human-centric design is not prioritized in an AV future.

In the context of these two factors, local municipalities and government managers have the capacity to focus on tacit policies that both enable and accelerate AV deployment, but also inform development. AV developers and local municipalities can co-learn and co-evolve policy to shape how these platforms can best serve the public good—policy that is focused on how we can shape urban space while simultaneously addressing systemic issues such as the environment, equity, accessibility, and congestion. The policy recommendations below summarize the areas where cities can be most effectual in catalyzing these positive benefits:

Reimagining Curb Use and Allocation

As autonomous transportation continues to develop, curb use will and must be increasingly dynamic. When considering AV policy frameworks, cities should encourage higher pick-up/drop-off efficiencies that enable greater curb utilization and productivity. This should incorporate flexibility in leveraging existing street space, particularly as this technology evolves. Specific policy steps that cities can take include:

- *Implement curbside designations and signage*: Cities should designate dedicated pick-up and drop-off locations that prioritize shared and/or electric transportation modes, as well as non-automotive travel. Many within the future mobility space have been developing technology solutions that can not only assign quantifiable value to curbside activities in order to maximize efficiency, but that also can allocate curb usage by specific mode and time of day.[20,21] As we have seen during the COVID-19 pandemic, these are essential economic functions for our cities. However, these activities must be done with an eye to sustainability and maximizing traffic flow. For example, in San Francisco's recently released Curb Management Study, the San Francisco Municipal Transportation Agency (SFMTA) is prioritizing access for people and less-carbon-intensive modes, facilitating ease of delivery, and advising lowest curb access priority for modes with the least productivity, such as private car parking.[22]

- *Integrate AVs into drop-off strategy*: As cities reevaluate curb space, the efforts above must include a holistic assessment of the potential impacts of shared AVs and provide a consistent, streamlined curb management process for communities. However, to facilitate the most efficient operations of shared AV technology, these policies must have clear rules and enforcement mechanisms to be most effective—informed by up-to-date data, rationalized towards balanced curb use, and structured to promote fairness and accessibility.

- *Encourage high-productivity curbs*: These policies should also maximize and promote available technology to the greatest extent possible. Possible solutions could include utilization of sensors, digital signage, and integrated navigation apps to communicate real-time information for planners, developers, and engineers. These technologies could allow for a *dynamic curb* that can respond to demand and time-sensitive congestion patterns, with variability based on local policy objectives.[23] This strategy can also be synergistic with efforts to repurpose rights-of-way for other modes of travel such as walking or cycling.

Rethinking Mobility Strategies

Autonomous technology also serves as an opportunity for cities to address traditional gaps in first-mile/last-mile connectivity for communities. Shared and on-demand mobility—be it ridesharing services or micromobility platforms—have already changed the nature of transportation, from public transit, to point-to-point travel, to delivery. While the definition of these services ranges, USDOT has provided a definition of microtransit as a form of shared mobility that maps back to explicit changes in transportation behavior:

> IT-enabled private multi-passenger transportation services, such as Bridj, Chariot, Split, and Via, that serve passengers using dynamically generated routes, and may expect passengers to make their way to and from common pick-up or drop-off points. Vehicles can range from large SUVs to vans to shuttle buses. Because they provide transit-like service but on a smaller, more flexible scale, these new services have been referred to as microtransit.[24]

This definition speaks to the capacity for emerging AV solutions to meet transportation demands in ways not previously possible. Future evolutions could provide the public with potentially more attractive and dynamic transportation options, while also serving as a connector to local transit networks. Synergistic policies that focus on choice regarding both on-demand mobility and autonomy could include:

- *Innovative programs to feed trunk lines by incorporating new mobility*: Balancing service and farebox recovery is a perennial challenge for local transit agencies. Many public transportation agencies in the U.S. have already explored integrating new mobility solutions in flexible route/on demand services in locations as diverse as Monrovia (CA), Berlin (Germany), Kansas City (MO), Santa Clara Valley (CA) and Alameda-Contra Costa County (CA) to better serve distal locations in transportation networks. Looking at the Bay Area specifically, the Livermore Amador Valley Transit Authority (LAVTA) has created a new partnership with Uber and Lyft called Go Dublin! that offers $5 off a fare for trips that start and end in Dublin, CA—complementing feeder lines and last-mile transit.[25] The program has been quite successful, allowing LAVTA to launch a new "Go Tri-Valley" program, expanding to Livermore and Pleasanton. The emergence of autonomous transportation could help further address gaps in the transportation network by providing low-cost complements that feed into trunk lines.

- *Support deployment of AVs in communities with less transit availability*: Simultaneously, AV technology can and should be used to promote social equity and job accessibility, particularly in communities that have traditionally been underserved by existing public transit networks. The dynamic nature of AV technology could allow for rapid deployment of flexible transportation alternatives with significantly less fixed capital costs than traditional transit alternatives. Policy should encourage not only the deployment for these use cases, but also consider ways to support the infrastructure needed to facilitate travel by shared and electric AVs.

- *Incorporate autonomous logistics into the built environment in a way that balances total traffic and system efficiency*: AV technology also holds the promise of increasingly reducing the per-parcel cost of last-mile delivery and could be paired with other platforms such as autonomous cargo vehicles, sidewalk delivery robots, and delivery drones.[26] During the COVID-19 pandemic, we have seen a surge in creative and practical applications of automation that serve the

public good, and provide a potential roadmap for how these technologies can be deployed in the future. Cruise engaged in contactless delivery of food to the elderly for local food banks and nonprofits. Nuro focused on delivering prescriptions and medical supplies. Beep used its shuttles to transport COVID-19 tests from test sites to processing locations. These are critical functions of society and represent a use case for how this technology can serve a public good—whether in a crisis or everyday situation.

Standardizing Right of Ways to Increase Road Safety

With regards to physical infrastructure, cities should adopt low-cost, high-impact strategies such as standardizing road signage that can smooth deployment and increase predictability for AV systems. These near-term, easy-to-implement efforts can increase road safety for road users today and support an autonomous tomorrow by creating more uniformity of road cues in a mixed-mode human/autonomous future. Policies can include:

- *Regular maintenance for physical infrastructure:* Regular maintenance and standardization of rights-of-way by city transportation agencies can help easily smooth the path for deployment for AVs. For example: well-defined and maintained lane markings, ideally consistent with respect to width, color, length, and when possible reflectivity, improve vehicle sensor detection. As state and local agencies evaluate future needs of AV technologies from an infrastructure investment perspective, more proactive preventative maintenance can help smooth deployment.

- *Planning for predictable and AV-readable signage*: Cities should collaborate with industry to ensure pavement markings, signage, and traffic signals are AV-ready. For example, Minnesota has already been preparing technology literature on curb, pavement markings, and lane markings.[27,28] Other efforts, such as 3M's Connected Roads program, are exploring dedicated paint only visible in the infrared that can alert AV systems via RFID codes to upcoming construction zones.[29] Cities could begin to standardize such critical infrastructure so that AV machine-learning systems can benefit from predictable roadways and dedicated infrastructure more interpretable by autonomous technology.

- *Advanced and standardized alerts around construction zones:* Facilitating easier AV navigation of construction zones is another area where cities can lead. In many cities across the U.S., there are minimal—if at all existent—alerts regarding ongoing construction zone locations and statuses. Important changes to physical infrastructure, such as planned construction and changes in signage, could be aggregated and published digitally for AV operators to plan around. These efforts would increase overall road safety and even smooth vehicle flow with proactive alerts.

Incorporating Transportation Electrification into City-level Priorities

Alongside physical infrastructure, cities should also integrate efforts to electrify the transportation sector and increase adoption of EVs into future urban mobility strategies. In anticipation of an autonomous future, cities are well-poised to encourage the adoption of zero emission modes that maximize the social benefits of this technology. Possible policies include:

- *Adopt local incentives for EVs, with special consideration given to people living in communities of concern:* Cities should work to broaden access to EVs as urban mobility evolves. In states such as California, Zero-Emission Vehicle mandates have helped accelerate both industry maturation and technology development and are poised to significantly decarbonize transportation. This model has set a precedent for EV market development nationally. Yet despite there being programs in place to support vehicle financing for low-income residents, many communities still face significant EV cost barriers—and are often the most affected by environmental pollution from gasoline vehicles. As the industry continues to mature, trade-in EVs are becoming more prevalent. In the Bay Area, nonprofits have created programs, such as Peninsula Clean Energy's DriveForward Electric Program, to assist in vehicle cost for low-income residents.[30] Cities should explore new rebate programs that complement existing state-level and nonprofit programs to further lower the costs of EV—a synergistic policy with AV deployment.

- *Modernize parking minimums to balance ADA-compliant charger installations*: As cities develop more robust electrification programs, it will be important to provide EV-ready parking spaces that allow for flexibility in accommodating charger constraints while also meeting Americans With Disabilities Act (ADA) standards. California implemented new guidance for ADA-compliant EV charging spaces in January 2017.[31] However, many cities still face legacy parking minimum requirements that complicate the space constraints of ensuring ADA-compliant charging. As cities in California and the broader U.S. grapple with this tension between parking minimums and new requirements for ADA-compliant EV chargers, cities should evaluate these legacy requirements around parking and ensure that accessibility is prioritized as part of broader electrification.

- *Prioritize* make-ready *requirements for new construction*: The success of transportation electrification—be it for human-driven or automated vehicles—depends on electrical infrastructure being in place to facilitate EV adoption. While state-level electrification incentives, such as the California Electric Vehicle Incentive Program (CALeVIP), have been successful in encouraging charger installation, insufficient *behind-the-meter* electric infrastructure is a perennial challenge. Many buildings lack wiring to handle the load of multiple DC fast chargers, while others do not have power availability clearly mapped to easily identify capacity for additional chargers. While responsibilities for electrical building codes are often shared between cities and states, cities are uniquely positioned to address urban building codes, often where the bulk of electrification can occur. To operationalize this goal, cities can: require that any building retrofits include electrical upgrades to handle DC fast charging; require Level 2 infrastructure in new homes; waive permit fees for panel upgrades for existing homes to install EV charging capabilities; and explore the conversion of on-street parking meters to charging stalls.

Consider Positive-Sum Road Design to Reduce Speeds

As cities begin to shift away from built environments designed around personal vehicle ownership, planners are exploring new road designs that reduce vehicle speeds and increase non-auto mode share. However, as part of these efforts, cities should also consider the network effects of car-free zones: restricting access to vehicles in some areas of a city may increase travel times, congestion,

and energy consumption across the city as travelers reroute. Physical interventions for street design, such as curb cuts, curb daylighting, narrowed lanes, speed barriers, and lane dividers can all reduce vehicle speeds without overly disrupting traffic flows. These designs may be similar to the design thrusts our cities have seen during the COVID-19 pandemic. Specific policies might involve:

- *Car-free zones*: Car-free zones in central business districts have long been considered as a net social benefit for cities.[32,33] Cities around the world have begun exploring these policies, including Barcelona, Madrid, and Oslo. In the wake of the COVID-19 pandemic, many U.S. cities have also implemented similar interventions, including San Francisco (which also closed Market Street to private vehicles in early 2020),[34] Oakland,[35] Chicago,[36] and Seattle[37]—with some of these expected to be permanent. These physical interventions can allow for safer and more sustainable travel that is supportive of commerce. Used synergistically with thoughtful pick up and drop off strategies, such policy can work in an interoperable manner with AV technology while creating more livable cities.

- *Vision Zero synergies*: Similarly, many cities are evaluating and implementing Vision Zero programs to eliminate or drastically reduce road fatalities—with a particular focus on pedestrians and cyclists. These programs were initially adopted by cities globally in the early 2010s and have since been rolled out in over 20 U.S. cities. AVs can considerably improve road safety and reduce human driving errors that lead to traffic fatalities. AVs should be considered as a complementary solution to many of the Vision Zero programs in place across the United States. City governments should consider autonomous technology as a potential asset in these efforts to achieve a future of zero traffic fatalities.

Reimagining and Repurposing Parking for Human-Centric Use

In the longer-term, a potential decrease in personal vehicle ownership and adoption of AV travel will decrease demand for parking. In this regard, AVs present unique opportunities to reevaluate how streets are used—by whom, how, and to what ends. Most transportation planning over the last half-century has conflated the basic purpose of transportation—providing access to destinations—with the simplistic goal of moving vehicles at high speeds with little impedance. AVs could foster a society-wide evaluation of the use of streets, and how such use impacts equity, the environment, social cohesion, happiness, economic growth, health, and resiliency.

As noted above, this ability to harness creative use of streets has been emphasized as a part of the *slow streets* and car-free zone policies rolled out during the COVID-19 pandemic. Yet such policy efforts should not end there. Even before the crisis, efforts had been put in place to focus on reusing street space to support carbonless modes of travel, such as San Francisco's Car Free Market Street.[38] Cities should double down on such policies—particularly given the power they hold in controlling the allocation of streets as a valuable asset. This will allow cities to utilize this space more creatively, including:

- *Lane thinning and parking reductions*: Given the reduced parking needs from shared AV fleets and anticipated future vehicle rightsizing, an autonomous future could be an opportunity to redesign our roads.[39] While complex from a public perspective, one solution could be reducing lane widths to 8–10 feet in the United States—about 2–4 feet less than a standard

12 foot lane. This width can be easily navigable by autonomous vehicles and, at slower speeds, by human-driven vehicles. At the same time, removal of parking lanes on one or both sides of the street can allow for reallocation of 8–10 feet on the street to walking, cycling or transit. This space can also be allocated to increased use of green space and parklets.

- *More efficient curb space*: At the same time, this reallocation of space allows for more efficient pickup and drop-off zones beyond the initial efforts proposed above. This is particularly timely, given the anticipated impact that the COVID-19 pandemic will have on the use of public space and transportation assets. Research from the City of Austin found that bundling parking supply reallocation with deliberate repurposing of curb space can result in gains in public transit efficiencies.[40] Such allocation decisions can also provide space for creative solutions that serve new transit and shared fleet platforms, including dedicated MaaS vehicle or transit lanes, sidewalk extensions, increased bike and car share locations, or curbside queuing locations for food and delivery services.

- *Thinking shared*: Finally, future autonomous vehicles—particularly those in residential locations—allow for a radically new approach to the use of streets and network level demand for personal vehicle ownership. AVs can and should be made to operate in shared use environments and, in this light, streets could even evolve to become a more integrated gathering space for cities. Early urban design proposals include repurposing streets for such uses as small-unit housing, recreation, commerce, or sustainability initiatives and groundwater recharging. With cities such as Barcelona already exploring these proposals, the current prominence of these initiatives opens up the door to completely revise how we use and experience the *street*, and particularly how it accommodates mobility. Cities can spearhead initiatives that work towards this vision.

4. Call to Action for Cities and Communities

Cities and communities have an intrinsic interest to engage with industry and articulate a shared vision for our urban future. Given the opportunities that shared AV transportation promises for our cities, city transportation agencies have a unique window to define their own role and chart an equitable, green, accessible, and inclusive transportation vision fundamentally rooted in policy areas where they have expertise. Figure 2 provides a summary of potential policies based on their cost and ease of implementation. These policies and starting point for that dialogue and action. Yet with autonomous technology continuing to improve, cities are well-positioned to spearhead a constructive dialogue on the future of the urban environment to best capture the net positive impact of these vehicles for social good.

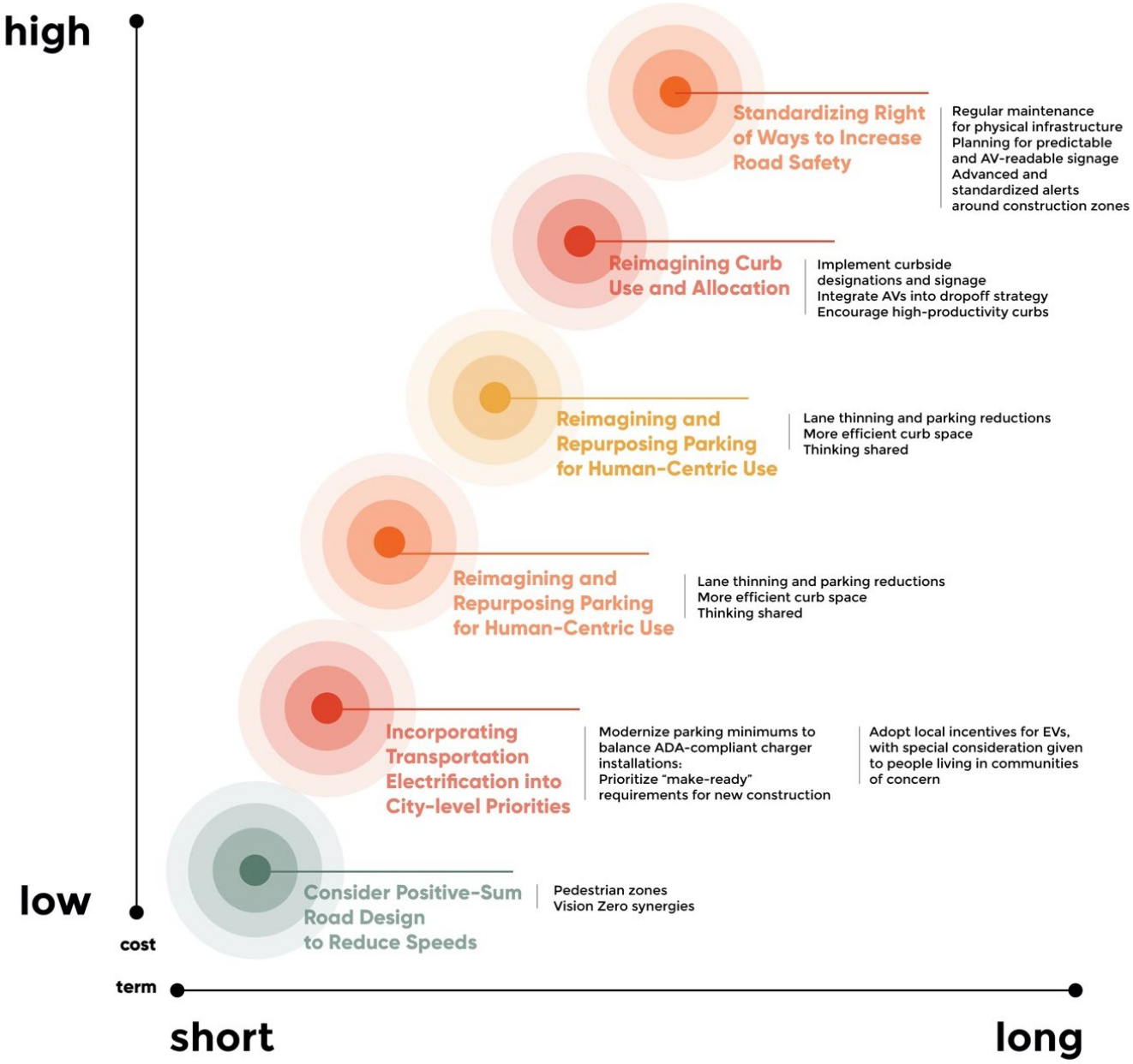

Figure 2. A Policy Summary Mapping a Low-Cost, Near-Term to Higher-Cost, Longer-Term Policy Opportunities

Endnotes

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Project Page

For more details about the study, the project page can be accessed at transweb.sjsu.edu/research/2055

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