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Strategies to Advance Automated and Connected Vehicles

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Strategies to Advance Automated and Connected Vehicles:

Briefing Document



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Briefing Document

This briefing document concisely conveys the key findings of *NCHRP Research Report 845: Advancing Automated and Connected Vehicles: Policy and Planning Strategies for State and Local Transportation Agencies*. The research report and briefing document were created, and the research behind the report was conducted, under NCHRP Project 20-102 (01) by Texas A&M Transportation Institute, RAND Corporation, and Southwest Research Institute (please see *NCHRP Research Report 845* for full authorship and publication information).

NCHRP Research Report 845

NCHRP Research Report 845 assesses policy and planning strategies at the state, regional, and local levels that could influence private-sector automated vehicle (AV) and connected vehicle (CV) choices to positively affect societal goals. The researchers identified and described mismatches between potential societal impacts and factors that influence private-sector decisions on CV and AV technologies. Policy and planning actions that might better align these interests were then identified. Researchers and the project oversight panel identified the promising actions and then conducted in-depth evaluations of the feasibility, applicability, and impacts of 18 strategies. *NCHRP Research Report 845* can be purchased or downloaded from the TRB website (www.trb.org).

Acknowledgment

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AVS AND CVS ARE COMING. WHY SHOULD I CARE?

Private companies producing automated vehicles (AVs) and connected vehicles (CVs) are investing billions in a race to market. New consumer products promise to fix intractable transportation challenges and make our lives easier. New business models in mobility are introducing market-based services and transforming travel behavior. Vehicles that are increasingly automated and connected have the potential to change personal, freight, and public transportation profoundly. Some impacts of those vehicles can be foreseen, others are uncertain, and all are complex.

The benefits to consumers are tangible and immense, but what about society writ large? Social benefits for safety, congestion, emissions, and mobility seem intuitive. At the same time, it is unclear to what degree these issues will be addressed through new vehicle technologies and to what extent these technologies pose risks to public safety, security, health and social equity. Technology will solve some problems, but could also create new ones.

Disruption is upon us. As a public official, how will I respond?

The transportation industry has moved gradually and deliberately forward since the introduction of the modern highway system. New ideas emerge methodically; standards are fine-tuned and evolve at a measured pace. Transportation projects can take a decade or more to implement. On the other hand, the start-up culture moves nimbly, fails quickly, and learns rapidly. Vehicle technology is advancing at a startling, uncontrolled pace.

The transportation community can choose to wait and react. Or, decision makers can reframe the conventional public policy discussion to responsibly and assertively advance AV and CV technologies in light of social interests, adopting the principles of rapid learning and shared knowledge creation.

This document helps decision makers assess and leverage the policy tools they have and consider how to align traditional public policy interests with rapidly emerging AV and CV technologies, even amid a high level of uncertainty.

This document helps decision makers assess and leverage the policy tools they have and consider how to align traditional public policy interests with rapidly emerging AV and CV technologies, even amid a high level of uncertainty. In spite of that uncertainty, the transformational nature of AV and CV technology argues that public agencies should consider the strategies and possible outcomes to effectively manage public interest concerns.

Overseeing the deployment of AV and CV technologies is a natural extension of the longstanding role of government to:

- Ensure safe and efficient operation of public roadways.
- Foster equity across users of the system.
- Mitigate negative effects of transportation.

The strategies provided in this resource can guide policy development that proactively shapes the deployment of these technologies in ways that advance societal benefits while lessening potentially harmful consequences.

Technology Context

For the purposes of this work, an **automated vehicle** is one that takes full control of all aspects of the dynamic driving task for at least some of the time. Using the Society of Automotive Engineers (SAE) taxonomy, *this research focuses on the role of higher levels of AV in mitigating or exacerbating the societal effects of driving*, or in creating new effects. The higher levels of vehicle automation are designated SAE levels 3, 4, and 5 and are referred to in federal policy guidance as highly automated vehicles (HAVs).

High Levels of Driving Automation (SAE 2014)

Level	Name	Description
<i>Automated driving system monitors the driving environment</i>		
3	Conditional automation	The driving mode-specific performance by an automated driving system of all aspects of the dynamic driving task with the expectation that the human driver will respond appropriately to a request to intervene
4	High automation	The driving mode-specific performance by an automated driving system of all aspects of the dynamic driving task, even if a human driver does not respond appropriately to a request to intervene
5	Full automation	The full-time performance by an automated driving system of all aspects of the dynamic driving task under all roadway and environmental conditions that can be managed by a human driver

A **connected vehicle** has internal devices that connect to other vehicles, as in vehicle-to-vehicle (V2V) communication, or a back-end infrastructure system, as in vehicle-to-infrastructure (V2I) communication. V2V applications enable crash prevention, and V2I applications enable telecommunication, safety, mobility, and environmental benefits. Their foundation of data communications enables real-time driver advisories and warnings of imminent threats and roadway hazards.

Dedicated short-range communications standards—the two-way, short-to-medium-range wireless communications capability that permits very high data transmission—are currently the leading medium for:

- V2I safety applications (e.g., red-light violation warnings, curve speed warnings, and work zone warnings).
- V2V safety applications (e.g., forward collision warnings, intersection movement assist, left-turn assist, and do-not-pass warnings).
- V2X or vehicle-to-everything, as in the Internet of Things; for example, a wearable device in a highway worker’s safety vest that warns drivers of the person’s location.

However, non-safety critical applications (e.g., weather advisories and eco-approach and departure at signalized intersections) could also be achieved using other wireless communications.

At present, the V2I and V2V applications solely provide driver alerts; they do not control the operation of the vehicle.

Regulatory Context

In September 2016, the National Highway Traffic Safety Administration released the official Federal Automated Vehicle Policy, issued as “guidance rather than in a rulemaking capacity in order to speed the delivery of an initial regulatory framework and best practices to guide manufacturers and other entities in the safe design, development, testing, and deployment of Highly Automated Vehicles (HAVs).” The policy reaffirms that states retain their responsibilities for licensing and registering vehicles, defining and enforcing traffic law, and regulating insurance and liability requirements and policies. The framework envisions that each state’s AV-related policies and regulations be administered by a single lead agency and associated technology committee. The issues and actionable strategies covered in this document are those that would be relevant to such entities.

How AVs and CVs Could Lead to Positive Societal Outcomes

By what mechanisms might AVs and CVs create desirable outcomes for society, either by encouraging direct positive effects or reducing negative ones? Through inferences based on reviews of the literature, the research team identified ways in which CVs and AVs could lead to those desirable outcomes.

Potential Benefits of Connectivity and Automation

Driving Externality	Connectivity (Full V2X)	Autonomy* (L4,5)	Shared Autonomy (L4,5)**	Electrification***
Safety	Strong benefits	Strong benefits	Strong benefits	Weakest benefits/no impact
Congestion	Strong benefits	Uncertain impact	Some expected benefits	Weakest benefits/no impact
Emissions	Some expected benefits	Weakest benefits/no impact	Weakest benefits/no impact	Strong benefits
Land Use	Weakest benefits/no impact	Uncertain impact	Some expected benefits	Weakest benefits/no impact
Mobility	Weakest benefits/no impact	Strong benefits	Strong benefits	Weakest benefits/no impact



*Autonomy is defined for this purpose as individually owned vehicle.

**Shared Autonomous Vehicles (SAV) are on-demand self-driving vehicles supporting shared rides as part of a privately or publicly managed fleet.

***While not a focus of this NCHRP research, the team provides assumptions of potential benefits of electrification based on known literature.

Even without CVs, AVs could reduce most driver-related errors, which account for a vast majority of traffic crashes, but AVs also might introduce new types of errors.



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TRAFFIC CRASHES

When individuals drive a vehicle, they not only increase their own risk of a crash and its associated costs, they also increase crash risks and costs for other motorists, pedestrians, cyclists, and society in general. V2V safety applications could mitigate these risks by addressing most vehicle crash types if the V2V applications are demonstrably effective and widely used, the driver-vehicle interface performs well, and there is sufficient market penetration. An increase in benefit could be obtained through V2I safety applications. Even without CVs, AVs could reduce most driver-related errors, which account for a vast majority of traffic crashes, but AVs also might introduce new types of errors. Flawed hardware or software could cause accidents due to errors that humans would not make. AVs and CVs both create cybersecurity risks. Level 3 AVs could also introduce risks posed by inattentive drivers who fail to take safe control of the vehicle when needed. Early research suggests that these technologies have promise, but the safety benefits of AVs and CVs are not guaranteed.

CONGESTION

As the number of vehicles on a road increases past a certain density, vehicle speed and throughput decrease, causing congestion. Each additional driver adds to the congestion but does not bear the full cost of that effect. Ultimately, it is unclear how AVs and CVs will affect congestion; the literature in this area shows mixed results for a variety of different traffic measures under varying conditions. Congestion occurs on a regular basis (i.e., recurring) and on a sporadic basis (i.e., non-recurring). CV applications could mitigate non-recurring congestion by reducing delays caused by safety incidents. CV mobility applications could reduce recurring congestion by increasing system efficiency and enabling CV-facilitated truck platoons. Widespread adoption of V2V capabilities, widespread V2I infrastructure, and interoperability among mobility applications would maximize these impacts. AVs that are safer than human drivers could reduce the frequency of crash-related delays. In addition, more closely-spaced AVs could enhance traffic flow. At the same time, a proliferation of on-demand, shared AVs (SAVs) could put more

vehicles on the road and increase congestion. Alternatively, multi-occupancy SAVs could reduce the number of vehicles on the road. Although the travel delay caused by congestion may be redefined if the occupant in an AV can be productive while waiting in traffic, there still might be the need to minimize associated vehicle miles traveled (VMT) growth because it contributes to other negative effects, such as pollution. The net effects of AVs and CVs on congestion have yet to be fully understood or predicted.

POLLUTION

Vehicles emit local air pollutants (e.g., particulate matter, hydrocarbons, nitrogen oxides, and carbon monoxide) and global air pollutants (greenhouse gases). When someone drives a vehicle, he or she reduces the air quality and adds to noise pollution in surrounding areas. That person also imposes the costs of climate change on the global society. AVs could mitigate these effects by leading to reduced vehicle production rates and parking needs, and to increased use of smaller, electric vehicles and eco-driving. On the other hand, by increasing safety and improving the convenience of vehicle travel, AVs and CVs could lower transportation costs, which could increase VMT. While this increase in VMT may facilitate additional economic activity or enhanced quality of life, it may also produce negative environmental impacts that would need to be mitigated.

LAND DEVELOPMENT

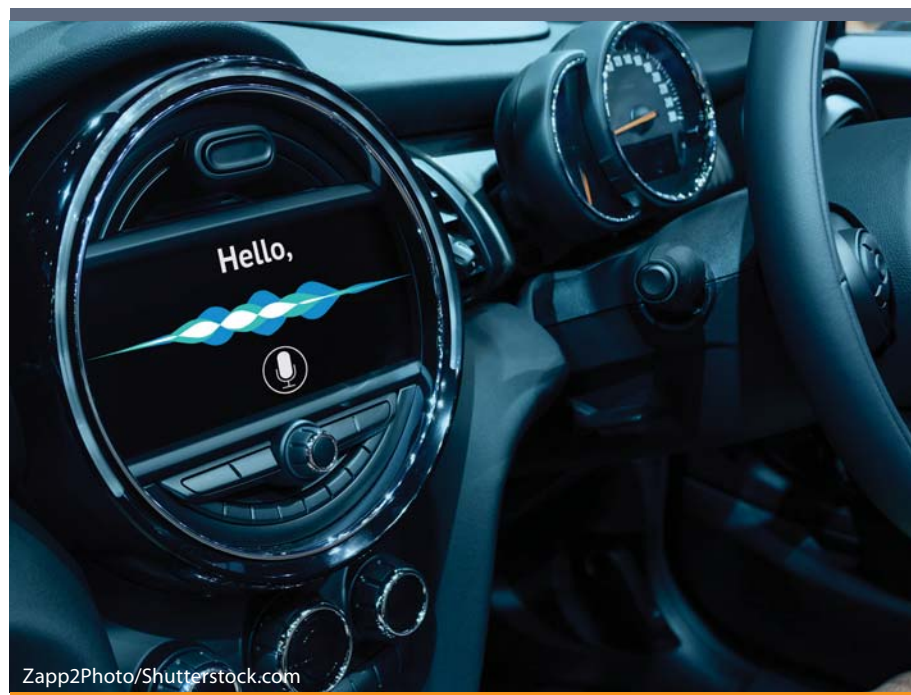
Land devoted to automobile infrastructure and dispersed development patterns—while historically increasing mobility and decreasing travel costs—may also impose negative environmental, economic, and public health effects on society. AVs and CVs could increase safety, improve convenience of vehicle travel, and lower transportation costs, but these effects might lead consumers to take more trips and travel more miles in order to access lower priced land and rural locations, exacerbating inefficient land-use patterns. On the other hand, if fully autonomous (SAE Levels 4 or 5) AVs reduced the need for parking adjacent to destinations, land dedicated to parking in urban areas could be assigned to other, more beneficial uses. The largest effects would be in dense urban areas, where land is very expensive, while impacts might be less substantive in most areas of the country.

MOBILITY

Older adults, youths under age 16, and individuals with disabilities have limited access to desired destinations, activities, and services. The existing transportation infrastructure does not completely address the limited mobility of this population. Levels 4 and 5 AVs could mitigate this negative externality by enabling significant improvements in access and mobility for such individuals. This is particularly true for those who live in areas with few alternative modes. Less-than-full automation (Level 3) and CVs would not reduce this negative externality.

Ultimately, it is unclear how AVs and CVs will affect congestion; the literature in this area shows mixed results for a variety of different traffic measures under varying conditions.

Consumers may be unwilling to pay for expensive technology if much of the benefit goes to others, and consequently, producers may be less willing to develop and market CVs and AVs.



Foundational Research: Social Welfare and Market Economics

The analytical foundation for identifying the potential policy and planning strategies reviewed in this document involved an examination of mechanisms by which AVs and CVs could create desirable outcomes for society. These mechanisms could either encourage positive effects or reduce negative ones. For example, if safe AVs and CVs are developed and marketed by producers and then used widely and responsibly by consumers, the current traffic safety crisis could be mitigated. However in this example, many of the benefits accrue to society rather than to producers or consumers of AV or CV technology. Consumers may be unwilling to pay for expensive technology if much of the benefit goes to others, and consequently, producers may be less willing to develop and market CVs and AVs. This is an example of an *externality*. An externality is an effect produced by either a consumer or producer that affects others, yet is not accounted for in the market price (i.e., occurs external to the market). Externalities have important implications for realizing the benefits of AVs and CVs. AVs and CVs may also result in a range of economic disruptions to groups such as professional drivers, insurance companies, medical facilities, trauma centers, collision repair shops, and other industries. Some of these effects are internal to the market, while others are pecuniary externalities (i.e., operating through market prices) and not real externalities. Because these costs are internal to market decision making, the research excluded pecuniary externalities from the analysis.

Society as a whole could benefit if state, regional, and local governments were to implement policy (e.g., regulations or taxes) or planning strategies (e.g., public education) to internalize these externalities in decision making by consumers or producers. Such instruments or activities could force the market to account for costs that would otherwise not be included.

With social welfare economics as the foundation, researchers identified categories of policy levers. The groups of policy strategies presented below are most common in internalizing externalities within the traditional roles of state, regional and local government:

Economic Instruments: These are policy strategies that provide an explicit price signal by applying a tax, fee, or subsidy to effect a specific outcome.

Examples of Price-Based Economic Policy Instruments		
Fuel Taxes	Value Added Taxes	Vehicle Age Taxes
<ul style="list-style-type: none"> • Carbon taxes • Distance-based taxes (VMT fees) • Fully differentiated VMT fees • Registration fees • Tolls 	<ul style="list-style-type: none"> • Insurance taxes • Circulation taxes • Vehicle sales taxes • Parking fees • Transit subsidies 	<ul style="list-style-type: none"> • Vehicle value taxes • Vehicle size and weight taxes • Vehicle engine size taxes

Regulatory Instruments: With these tools, governing bodies are able to affect behaviors or processes by establishing or changing regulations directly, rather than relying on price signals to encourage socially optimal choices.

Examples of Regulatory Policy Instruments	
Require	Establish or Update
<ul style="list-style-type: none"> • Collision insurance • Pay-as-you-drive insurance • Safety equipment use • Training or certification • Vehicle inspections 	<ul style="list-style-type: none"> • Rules of the road • License requirements

Structure of private rights: Agencies may, if they have the authority, restructure civil and criminal liabilities to shift risk and alter producer and/or consumer behavior.

Service provision: This family of policy instruments generally refers to changes in how a transportation agency provides its current range of transportation services.

Information/education: Transportation agencies may, through any number of mediums and strategies, provide information to consumers to encourage desired behavior.

Financing/contracting/collaboration: In some cases, a private-sector market for a good or service may not exist or cannot exist absent government intervention. In these cases, a transportation agency may need to establish the market itself or work in partnership with the private sector to establish the necessary environment for the market to flourish.

Given the growing public and media interest in AVs and CVs, decision makers can leverage this interest toward prudent support of testing and deployment by aligning policy actions with agency goals—goals that represent societal interests.



Importance of Strategic Goals

Transportation agencies will want to consider how the effects of AV and CV technologies can contribute to broad agency goals. Given the growing public and media interest in AVs and CVs, decision makers can leverage this interest toward prudent support of testing and deployment by aligning policy actions with agency goals—goals that represent societal interests. This is particularly important where investment of public resources is at stake. Associated strategic planning activities undertaken at a high level may include:

- Identification of transportation and societal goals and objectives that may be achieved through AV and CV technologies.
- Development of performance measures that support specific safety, congestion, mobility, and environmental goals that may be supported by AV and CV systems and can be used to track the results of testing and investment in these systems over time.
- Setting the general parameters under which CV and AV deployment can be facilitated to achieve agency and societal goals.
- Contributions toward building the business case for investing in CVs, generating support for adoption of safety and mobility applications, and promoting incentives for producers to improve applications and technology.

High-Level Summaries of Policy and Planning Strategies

To facilitate the alignment of transportation agency goals with AV and CV technologies, a menu of strategies is provided for policy makers to consider. Each strategy is presented in a one-page overview. The purpose of each overview is to offer a snapshot of a policy or planning strategy and an assessment of its utility, which allows decision makers to match outcomes with high-level strategic goals. An in-depth review of key strategies can follow using the detail provided in the accompanying report, *NCHRP Research Report 845: Advancing Automated and Connected Vehicles: Policy and Planning Strategies for State and Local Transportation Agencies*. Eighteen different policy and planning strategies—organized by desired outcome—are provided for policy makers to consider, beginning on page 12.

OUTCOME: To mitigate safety risks through testing, training, and public education:

- Enact legislation to legalize AV testing
- Enact legislation to stimulate CV or AV testing
- Modify driver training standards and curricula
- Increase public awareness of benefits and risks

OUTCOME: To encourage shared AV use:

- Subsidize shared AV use
- Implement transit benefits for SAVs
- Implement a parking cash-out strategy
- Implement location-efficient mortgages
- Implement land use policies and parking requirements
- Apply road use pricing

OUTCOME: To address liability issues that may impact market development:

- Implement a no-fault insurance approach
- Require motorists to carry more insurance

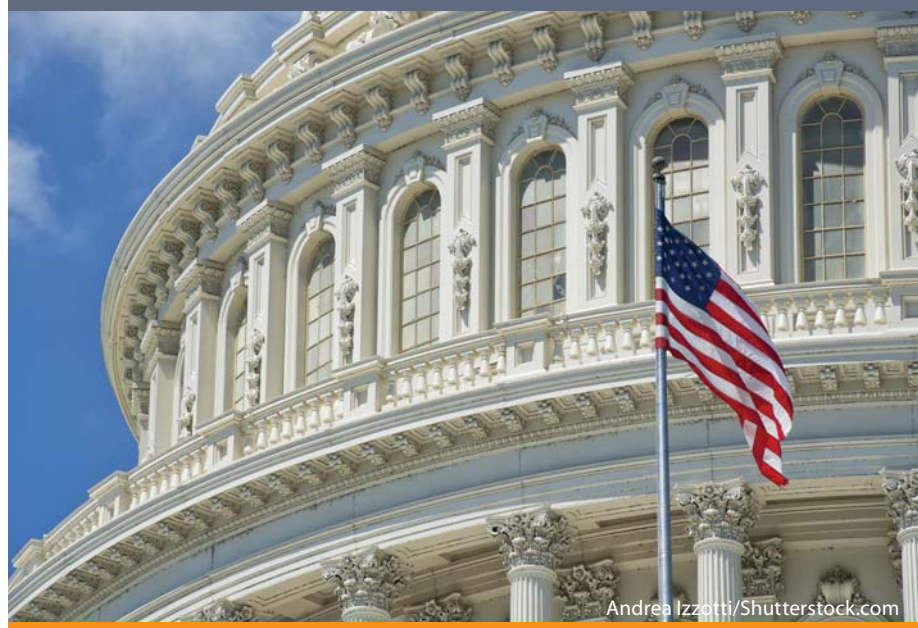
OUTCOME: To enhance safety, congestion, and air quality benefits by influencing market demand:

- Subsidize CVs
- Invest in CV infrastructure
- Grant AVs and CVs priority access to dedicated lanes
- Grant signal priority to CVs
- Grant parking access to AVs and CVs
- Implement new contractual mechanisms with private-sector providers

Each overview offers a general assessment of strategy viability by a range of criteria:

- **Effectiveness:** If the strategy is economic, how well does it internalize external costs into decision making by producers and consumers? If the strategy is not economic, how likely is it to achieve its desired policy outcome?
- **Efficiency:** If the strategy is economic, how well does it recover the costs from the externality? How likely is the strategy to produce a net-positive social benefit outcome?
- **Political Acceptability:** How likely is the general public to accept this strategy? Are any politically powerful stakeholders likely to oppose the strategy? How likely is the strategy to increase costs, place burdens on low-income or socially disadvantaged groups, or result in social inequity?
- **Operational Feasibility:** How disruptive is implementation to the implementing agency? Are new or complex governing structures required? Is it expensive to implement? Are new workforce skills or infrastructure adaptation required?
- **Geographic Impact:** At what geographic scale does this strategy make the most sense?
- **Who:** What level of government would implement this strategy?
- **Hurdles:** Are there any notable barriers to implementation?

In spite of uncertainties, the transformational nature of AV and CV technologies argues that public agencies should consider the strategies and possible outcomes to manage public interest concerns.



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CONCLUSIONS

Public policy making can be challenging within a dynamic and uncertain technological landscape. The private market is highly competitive, and objective information upon which policy can be based is largely unavailable from the developers of this transformational technology. Many OEMs have made bold claims as to their timeframe for making Level 4 AV technology available in new models in the years leading up to 2021*. The timeframe for bringing Level 5 automation technology to market is hard to forecast; however, several studies estimate that Level 5 cars will be available on public roads in the late 2020s**.

At the same time, the federal government has played a significant role in supporting the research, development, and piloting of CV technology. The USDOT Connected Vehicle Pilot Program has examined multiple modes of wireless communication and has continued demonstrations to position Dedicated Short-Range Communications (DSRC)-based CV technology for large-scale deployment. Significant research and standardization has gone into the development of CV technology, specifically related to DSRC. But some companies are developing V2X equipment that uses other forms of wireless communications, including cellular, Wi-Fi, and Bluetooth.

*Korosec, K. 2015. Elon Musk Says Tesla Vehicles Will Drive Themselves in Two Years. *Fortune*.

**Cellan-Jones, R. 2015. Toyota Promises Driverless Cars on Roads by 2020. *BBC News*; Volvo. 2016. Autopilot—Travel Calmer, Safer, Cleaner. <http://www.volvocars.com/au/about/innovations/intellisafe/autopilot>

In spite of uncertainties, the transformational nature of AV and CV technologies argues that public agencies should consider the strategies and possible outcomes to manage public interest concerns. The strategies provided through this research offer considerations for public agency decision makers using the best information available at the time. Technology direction may change, consumers may not adopt certain products, and any number of global economic or environmental drivers could alter the policy course.

For state and local transportation agencies, the impacts of AV or CV technologies on their organizations may be highly disruptive and generate a range of uncertainties unique to public agencies:

Institutional: Institutional impacts affect a transportation agency's focus and organizational structure. This includes how an agency prioritizes its responsibilities and allocates its funding. Proliferation of AVs and CVs could increase transportation agencies' focus on non-safety goals, increase responsibility for data integrity, security, privacy, and analytics, and increase reliance on private-sector relationships where agencies lack funding or expertise.

Operational: These are impacts on how an agency develops, maintains, operates, and manages transportation infrastructure and transportation-related services. Proliferation of AV and CV technologies could cause existing intelligent transportation system investments to become outdated, reduce or shift demand for transit and parking services, and increase maintenance requirements. It is uncertain whether the technologies will mitigate or exacerbate current roadway capacity deficits.

Funding and financing: These are impacts to the funding and financing sources available for transportation infrastructure and related services. AV and CV systems could exacerbate funding deficits through increased costs for maintaining and operating roadways. AVs deployed with alternative fuel technologies, such as electricity, would reduce revenues from fuel-based taxes. A proliferation of shared AVs could reduce the amount of revenue from driver licensing, vehicle sales tax, vehicle registration, moving violations, transit fares, and federal funding associated with ridership levels. Conversely, CV technology could potentially increase revenue from road-user charges by providing a technology platform that supports usage-based revenue measurement and reporting.

Ultimately, public policy making for AVs and CVs will be informed through a cycle of learning and leveraging the activities of early-adopter agencies that support testing, evaluation, research, and continuous knowledge creation. Agencies can create a nimble policy-making framework that espouses these principles and sets in place a continual "look ahead" assessment.



POLICY STRATEGY SUMMARIES

Enact Legislation to Legalize AV Testing

Mitigate Safety Risks	Encourage Shared AV Use	Address Liability Issues	Influence Market Demand
-----------------------	-------------------------	--------------------------	-------------------------



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Description

This strategy aims to accelerate the development, adoption, and implementation of automated and connected vehicles by enacting legislation to establish the legality of AV testing. States or local governments could implement a version of the model state policy recently released by the USDOT to avoid any concerns about interstate inconsistencies in regulating AVs.

Technologies targeted/ownership model distinctions

A policy built around the USDOT’s model state policy would focus on highly automated vehicles, or HAVs (SAE Level 4 or 5), as lower-level AVs are already in production or operating on the roads under current federal, state and local laws, with the driver primarily responsible for the vehicle’s safe operation. Current states with AV testing legislation and associated regulations, like California, define automated vehicles in such a way to explicitly exclude lower-level automation, with language exempting systems using advanced driver assistance systems (ADAS) like adaptive cruise control or emergency braking.

How will this help?

Establishing the legality of testing could serve as an advertisement to attract companies to a given state or locality, although the value of this strategy in attracting testing activity is unproven. Conversely, some states have taken the position that AV testing is not necessarily illegal, and have claimed to have a more favorable, less burdensome regulatory environment for testing without it. The safety risk associated with a non-regulatory position has not been quantified.

Implementation issues

The state legislature, along with the agencies it directs to carry out or oversee testing, would bear the responsibility for implementing this strategy. Adopting a regulatory scheme such as the one recommended by USDOT could require significant action by state or local agencies to undertake rulemaking, which would involve assigning resources to accept, review and issue decisions on testing proposals. This would likely require some coordination and collaboration among state and local agencies, as there are often overlapping and shared jurisdictions in transportation management and operations. Some likely challenges to implementation of this strategy are identifying funding sources for implementation, setting up regulatory processes, and training staff. USDOT, through its model state policy, has offered advice for implementation based on the practices of leading states. The guidance is not clear about the role of local governments. NHTSA expects to update its state guidance over time. Achieving consensus on a legislative approach to testing, within the political process, could pose challenges.

Stakeholder benefits/concerns

Stakeholders include vehicle manufacturers and developers, the agencies involved in testing or regulating testing, and the general traveling public. Most consumer surveys indicate a sizable percentage of respondents who are concerned about the safety of AVs, which may be a barrier to adoption.

Optimal timing

This strategy addresses testing AVs, and as such, the optimal timing would be in the near term. AVs are developing rapidly, so policies designed to stimulate testing should occur in the near term, over approximately the next five years.

Effectiveness



Efficiency



Political Acceptability



Operational Feasibility



Geographic Impact

Urban, suburban, rural

Who

Legislature, state and local transportation agencies

Hurdles

Passing enabling legislation, identifying funding sources for rulemaking and administration of testing requirements

Legality

There is no legal barrier to enacting legislation.

EXAMPLES

Nevada became the first state to authorize the operation of highly automated vehicles with AV 511 in 2011, and rules were adopted for licensing and operation. Additional legislation was passed in 2013 and the statutes are reviewed every two years to account for advancements in technology.

California AB 1352, enacted in 2016, authorizes the Contra Costa Transportation Authority to conduct a pilot project testing autonomous vehicles not equipped with steering wheels, brake pedals, accelerators, or operators inside, at specified locations and speeds less than 35 miles per hour.

Establishing the legality of testing could serve as an advertisement to attract companies to a given state or locality, although the value of this strategy in attracting testing activity is unproven.





Enact Legislation to Stimulate CV or AV Testing

Mitigate Safety Risks	Encourage Shared AV Use	Address Liability Issues	Influence Market Demand
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Description

This strategy aims to accelerate the development, adoption, and implementation of automated and connected vehicles by enacting legislation to directly fund testing for CV or AV development.

Technologies targeted/ownership model distinctions

Legislation providing direct funding designed to stimulate testing can target AV or CV technologies, although as the likely implementer of CV systems, state and local governments may wish to prioritize CV spending to gain experience and institutional knowledge with the emerging technology.

How will this help?

Directly funding AV or CV testing could incentivize companies or public agencies to engage in testing AV or CV systems. Funding CV testing would build institutional knowledge and experience with these emerging technologies, which could increase the likelihood of the systems being implemented in the future. Additionally, private companies are already investing large sums to develop and test AVs, but similar investments are not being made in CV systems. As an economic intervention, providing funding for testing would increase testing activities, and as such, would be an effective strategy to advance the societal benefits of the technology. For these reasons, state and local agencies may wish to prioritize their investments in testing CV systems.

Implementation issues

The state legislature, along with the agencies it directs to carry out or oversee testing, would bear the responsibility for implementing the strategy. Some likely challenges to implementation of this strategy include: identifying funding sources for testing activities, training staff, developing new governmental structures or agreements, installing and upgrading communications systems and infrastructure, and integrating data with existing ITS operations. USDOT, through its model state policy and V2I deployment guidance,

has offered advice for implementation. State agencies could also independently fund testing, if they have resources available, or if they procure funding for a federal test bed. In these settings, state and local agencies may have the opportunity to learn how to operate and efficiently run these systems.

In addition, the 2015 federal transportation authorization legislation, known as the FAST Act, could provide a potential funding source for pilot activities. The act loosened restrictions on federal funding categories, like Category 2, to provide wider latitude for local agencies to fund ITS with federal dollars through their MPOs. This change is essential for the direct funding option: state and local agencies – under direction from their policy makers – can use their own state and local funding (or federal dollars) for testing if there is a clear value proposition to doing so, given the many other system needs that require financial resources.

Testing a new system will provide useful information to state agencies about how these technologies function and perform: implementation and operational processes and procedures, data on system effectiveness and efficiency, more accurate cost information – and in addition, the agencies will gain valuable institutional knowledge and experience with the new technologies.

Stakeholder benefits/concerns

Stakeholders include vehicle manufacturers and developers, CV system suppliers and contractors, the agencies involved in testing, and the general traveling public. Legislation to support testing would either require new funding or using existing funds for a different purpose, which may prove contentious, especially in a legislative setting. The policy does not harm stakeholders, but the financial concerns alone resulted in a relatively lower score on political acceptability. This strategy could be perceived as directly benefiting private equipment vendors.

Optimal timing

These policies address testing AVs and CVs, and as such,

Effectiveness



Efficiency



Political Acceptability



Operational Feasibility



Geographic Impact

Urban, suburban, rural

Who

Legislature, state and local transportation agencies

Hurdles

Passing legislation, upgrading or installing new infrastructure, creating new governmental agreements and partnerships

the optimal timing would be in the near term and up to ten years. AVs are developing rapidly, so policies designed to stimulate testing should occur in the near term, over approximately the next five years. CV systems are developing on a longer cycle, so CV testing could begin now but continue throughout the development life cycle, at least now to ten years hence.

Legality

There is no legal barrier to enacting legislation.

EXAMPLE

Utah HB 373, enacted in 2015, authorizes the department of transportation to conduct a connected vehicle testing program outside of an urbanized area, and requires the state DOT to report the results to a committee of the legislature.

Funding CV testing would build institutional knowledge and experience with these emerging technologies, which could increase the likelihood of the systems being implemented in the future.



Modify Driver Training Standards and Curricula

Mitigate Safety Risks	Encourage Shared AV Use	Address Liability Issues	Influence Market Demand
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Description

This strategy addresses the requirements for operating vehicles equipped with CV and AV technologies by establishing, codifying, and enforcing operator/owner/passenger requirements, and modifying driver training standards and curricula to reflect use of CV/AV applications.

Technologies targeted/ownership model distinctions

CV technologies will represent a minimal departure from current driver requirements. Driver training may need to address effective use of the added warnings and roadway information, and testing requirements for driver licenses may be modified to incorporate use of some CV technologies. AVs will have a larger effect on vehicle operator requirements and, therefore, on driver training and licensing. Level 5 AVs may require a complete restructuring of operator licensing, and “licensing” of the vehicles themselves may supplant driver licensing at higher levels of automation.

How will this help?

Reducing the human driver’s direct control of the vehicle can result in reduced situational awareness, skills degradation, and overreliance on automation. Driver training, testing, and license requirements need to reflect the altered role and responsibilities of a driver using Level 3-4 automated vehicles.

Implementation issues

State legislatures codify new training and licensing criteria. NHTSA’s Federal Automated Vehicles Policy recommends that states evaluate their current vehicle operation laws, to avoid unnecessary impediments to safe AV operation, and to update their references to and standards for human drivers where appropriate. Updates to driver license standards within states should be coordinated via the American Association of State Motor Vehicle Administrators (AAMVA) to ensure continued consistency and reciprocity of driver licensing across states. Commercial-vehicle operator license requirements would be addressed by the Federal Motor Carriers Safety Administration (FMCSA). In some states, licensing is managed by the Department of Motor Vehicles (DMV); in others, it is under the Department of Public Safety or the secretary of state. In

many states, DMVs work with state departments of education to implement driver training programs.

Changes could be very disruptive. Changes in licensing will have to accommodate people driving AVs/CVs as well as those driving conventional vehicles for many years to come. Licensing requirements will either have to ensure that a driver can safely drive vehicles at multiple levels of automation, or specify what type(s) of vehicle a driver may operate. Driver training curricula, materials, and standards will need to accommodate new warnings and in-vehicle information channels, or accommodate changing roles and necessary skills for vehicle operators. Many states provide driver training materials in different languages so any changes will have to be incorporated into multiple formats.

New licensing requirements for Level 3-4 AVs will necessitate retraining of driver license examiners, and may require the development of multiple new licensing classes. Level 5 AVs will not require any operational input from vehicle occupants, reducing or eliminating driving instruction and examiners, and potentially eliminating the need for vehicle operator licenses. This could eliminate a significant source of state revenue from licensing, unless other fees are instituted or unless licenses are retained in a different form. Reduced revenues could impact staffing levels at agencies responsible for driver licensing and testing.

Stakeholder benefits/concerns

Driver testing/licensing/training agencies will likely resist changes due to a lack of understanding and acceptance of advanced vehicle technologies. The law enforcement community will be affected by changes to vehicle licensing requirements in different ways. Enforcing traffic laws is likely to become far more complex. Eventually, less traffic law enforcement may be needed. The American Association of Retired Persons may be a potential champion because of the potential that automated vehicles represent for increased mobility.

Optimal timing

Revisions should be established and implemented prior to widespread availability of highly automated vehicles to the general public. Driver license revisions may be less crucial and time sensitive for CVs.

Effectiveness



Efficiency



Political Acceptability



Operational Feasibility



Geographic Impact

State

Who

State legislators, state licensing/training agencies

Hurdles

Operational issues

Legality

State legislatures have the legal authority to determine driver license requirements for non-commercial vehicles and to set requirements for state driver licensing agencies. Any commercial vehicle-related changes to rules and policies would need to conform to FMCSA’s regulations.

EXAMPLE

A current example is the use of backup cameras during road tests. The prevailing opinion among driver examiners is that in-vehicle backup cameras aid the driver too much and interfere with testing a driver’s skill in safely reversing a vehicle, so use of these cameras is generally forbidden during driver testing, although this technology will soon become standard equipment on all new vehicles. States will need to put significant resources into educating their staff on the benefits of CV and AV technologies and how to test drivers using them.

Driver training, testing, and license requirements need to reflect the altered role and responsibilities of a driver using certain automated vehicles.



Increase Public Awareness of Benefits and Risks

Mitigate Safety Risks	Encourage Shared AV Use	Address Liability Issues	Influence Market Demand
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Description

This strategy aims to increase the public’s awareness of automated and connected vehicle (AV/CV) technologies through education, training, communication, and outreach to stimulate consumer action and supportive public investment. Outreach and educational campaigns could provide a necessary “push” to spur additional investments in AV and CV technologies by both the public and private sectors.

Technologies targeted/ownership model distinctions

Public awareness could apply to all levels of AV/CV technologies and ownership models. Information and education should focus on how the public will benefit from these advances. It is important to make the public aware of and provide access to pilot tests and demonstration projects. This strategy has the potential to affect technology adoption.

How will this help?

Public outreach can easily target all positive and negative impacts of AV and CV depending on the education message. Public education about the safety, congestion, mobility, privacy safeguards, and environmental implications of AV/CV could affect technology adoption and market acceptance. Information about the proper use of the technologies could promote safer use. These messages could also increase support for investment in infrastructure that produces societal benefits. Consumer awareness could lead to use of shared AVs rather than privately owned vehicles, which could have congestion, mobility, and environmental advantages.

Implementation issues

State and local governments engage in public information efforts routinely. Campaigns to encourage safe driving behavior (e.g., using seat belts, avoiding impaired driving, sharing the road with cyclists) or to educate the public on capital investments are common. AV/CV public education, therefore, would not require new workforce capabilities, only

investment in resources to carry out the education activities. Defining the message is the primary challenge. The public has been exposed to commercial messages on AV focused on personal safety benefits and the liberation of the driver to engage in other activities. Given the lack of empirical data on the reliability of the technology, the necessity of connected systems to ensure congestion and environmental benefits, or the value of shared vehicle use in managing demand, what constitutes credible or effective public messaging is still unclear. Joint messages by the private sector and the public sector could enhance credibility and build public trust. The public may see the benefits associated with the public and private sectors working in partnership for greater societal benefits. Field testing and pilots can also be tools to quantify benefits for reliable messaging and increase awareness by giving the public first-hand experience with the technology.

Stakeholder benefits/concerns

Agencies, producers, suppliers, policy makers, and industries in the “crash economy” (insurance, healthcare) all have a stake in the outcome of public education. The messaging must speak to the issues important to a particular audience, and the implementation must be carried out in such a way as to ensure inclusivity and not be perceived as only available to a particular demographic.

Optimal timing

A best practice of public participation is engagement early and often. Testing of these technologies is under way in various cities and states, numerous industry advocates have begun information campaigns, and the USDOT has made CV and AV applications a priority program for outreach. Therefore, it stands to reason that concerted public awareness efforts by state and local agencies should begin now.

Legality

There are no legal or regulatory barriers associated with increasing public awareness. However, the implementing agency should ensure a consistent, fact-based message that

Effectiveness



Efficiency



Political Acceptability



Operational Feasibility



Geographic Impact

Urban, suburban, rural

Who

Any state and local agencies

Hurdles

Developing trusted messages given the uncertainties in technology deployment, benefits, and drawbacks.

instills confidence in their programs to build trust and credibility with the public.

EXAMPLE

The safety success associated with near-ubiquitous seat belt use can be attributed to public education and outreach in combination with regulation and enforcement. For CV and AV, the USDOT and state departments of transportation are building outreach programs that showcase the technologies and allow the public to see how these advancements will impact their lives. For example, the Florida Automated Vehicle initiative is creating a “framework for implementation by engaging stakeholders, developing research and pilot projects and creating awareness of the technologies...” Outreach and education are important components of that initiative.

Agencies, producers, suppliers, policy makers and industries in the “crash economy” (insurance, healthcare) all have a stake in the outcome of public education.



Subsidize Shared AV Use

Mitigate Safety Risks	Encourage Shared AV Use	Address Liability Issues	Influence Market Demand
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Frederic Legrand - COMEO/Shutterstock.com

Description

This strategy intends to subsidize shared autonomous vehicle (SAV) services to ensure alternatives to individually owned autonomous vehicles (AVs) and to support ridesharing and transit services, including paratransit.

Technologies targeted/ownership model distinctions

SAVs require full automation (SAE Levels 4 and 5) for their operation.

How will this help?

Research is beginning to indicate that individually owned AVs may lead to more frequent and longer trips, and mode shifts away from public transit, all of which could lead to increased pollutant emissions and congestion. SAVs could mitigate added total system vehicle miles traveled because of the likelihood of higher vehicle occupancy, higher marginal per-trip cost, serving first/last-mile connections for line-haul mass transit systems, and shorter trips.

Implementation issues

Current transportation network companies (TNCs), such as Uber, Lyft, or Bridj, are a good analog for SAVs. SAVs are on-demand, driverless TNCs. Growth in the TNC market has been market driven, and market forces have worked well. So, subsidies to incentivize SAV operation in urban areas are simply not needed. However, SAVs are not likely to serve certain market segments because of the need to turn a profit. This strategy could entail re-targeting of the subsidies that currently support public transit for specific SAV use cases: first-mile/last-mile service, paratransit service,

transit deserts, and rural areas. Transit agencies are the most likely implementers of a subsidy strategy for specific SAV use cases because of the potential for budget and operating efficiencies. Cities also have a role in policy making to provide a welcoming environment and supportive regulations.

Stakeholder benefits/concerns

If SAV subsidies are re-targeted for specific use cases, SAV operators and users would directly benefit through increased profits and reduced fares. Transit agencies could benefit from budget and operating efficiencies. Conventional taxis, carsharing services, and TNCs would face a disadvantage. Similarly, professional drivers who work for such firms could see their jobs eliminated. The public at large should see benefits in terms of reduced congestion and emissions and increased mobility and transportation equity, though the general public would also be responsible for funding any sales or fuel taxes used as the subsidies.

Optimal timing

Optimal timing for exploration of the SAV subsidies is prior to the initiation of a new SAV service. With current testing in areas such as Pittsburgh, this means exploration in the near term.

Legality

There are no legal or regulatory barriers associated with re-targeting of existing subsidies to transit agencies for specific SAV use cases. However, there is a patchwork of existing regulatory barriers to TNC operations among U.S. cities and counties that may need to be re-visited from a SAV perspective.

Effectiveness	● ● ● ● ●
Efficiency	● ● ● ● ●
Political Acceptability	● ● ● ● ●
Operational Feasibility	● ● ● ● ●
Geographic Impact	Urban, rural
Who	Public transit agencies, cities
Hurdles	Implementation issues (subsidies needed only for special use cases)

EXAMPLE

Current transit agency examples of re-allocating subsidies to TNCs include: Pinellas Suncoast Transit Authority in Florida for first/last-mile connection; Orange County Transit Authority in California for paratransit services for disabled and elderly people; Denver Regional Transit District for rural, less dense areas; and the city of Gainesville, Florida, for serving low-income neighborhoods.

Transit agencies are the most likely implementers of a subsidy strategy for specific SAV use cases because of the potential for budget and operating efficiencies.





Implement Transit Benefits for SAVs

Mitigate Safety Risks	Encourage Shared AV Use	Address Liability Issues	Influence Market Demand
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Jim Lyle/Texas A&M Transportation Institute

Effectiveness	● ● ● ● ●
Efficiency	● ● ● ● ●
Political Acceptability	● ● ● ● ●
Operational Feasibility	● ● ● ● ●
Geographic Impact	Urban
Who	Public transit agencies, employers
Hurdles	Regulatory: Congressional action needed

Description

The strategy extends transit benefits, a type of existing economic incentive provided to individuals to pay for transit or vanpool fares, to cover fares for shared automated vehicles (SAVs) as well. The economic incentive can be provided either as a direct subsidy or as a pre-tax benefit.

Technologies targeted/ownership model distinctions

As on-demand, driverless vehicles that operate as part of a privately or publicly managed fleet, SAVs require high automation (SAE Levels 4 and 5) for their operation.

How will this help?

This strategy targets congestion, land development, and pollution through providing incentives to use shared vehicles instead of driving for commute trips. The assumption is that a fleet of fully autonomous shared vehicles would constitute an alternative to driving alone (i.e., a new form of transit), and that transit benefits would be expanded to allow employees to pay for SAV trips. Transit benefits by themselves are not particularly successful in increasing transit use, as use depends on service provision and user convenience. Transit benefits could be more effective with SAVs, however, as user convenience should be high.

Implementation issues

Transit benefits are already employed by most transit agencies; in all but a few cities, employer participation is voluntary. Employer challenges are fairly minor: making decisions as to how to implement transit benefits, establishing an enrollment process, setting up and maintaining an

account with the transit agency, changing payroll forms if using a pre-tax program, and determining whether to conduct the implementation directly or use a third-party provider. The main impact on employers is the time required to reach decisions.

State and local governments can take several approaches to transit benefits. On the more aggressive side, some states have enacted additional tax advantages for participating employers. However, it is more typical that regional organizations—such as MPOs or transportation management associations, which may be public or private—encourage the use of transit benefits through outreach.

One barrier to more widespread use of transit benefits currently is that individuals cannot choose to participate in a transit agency program; they can participate only if their employer sets up a program. The determining characteristic is whether an employee receives a W-2 form from an employer. Therefore, self-employed persons or contractors cannot set aside pre-tax money to pay for transit fares. One potential change to the law would be to allow individuals to participate directly in transit agency programs on a pre-tax basis, without employer involvement.

Stakeholder benefits/concerns

Since transit benefit programs in their current form have existed for nearly 25 years, there are no particular political concerns about continuing such programs. Several changes could make them slightly controversial. Making them mandatory would probably concern employers, as it could increase the amount they spend on employee benefits. Allowing individuals to participate via pre-tax programs

without the intervention of an employer could lead to a small reduction in tax revenues, although this would likely be popular as it would help individuals reduce what they pay in transit fares.

Optimal timing

Changes to transit benefit programs could develop gradually as SAVs spread.

Legality

Federal tax law governs how transit benefits can be implemented. Only Congress can determine which commute modes are eligible for benefits, determine which individuals are eligible to participate, and set the upper limit on the tax-free dollar amount.

EXAMPLE

Washington State allows employers who provide commute trip reduction incentives, including transit benefits, to take a tax credit against other tax liabilities.

This strategy targets congestion, land development, and pollution through providing incentives to use shared vehicles instead of driving for commute trips.



Implement a Parking Cash-out Strategy

Mitigate Safety Risks	Encourage Shared AV Use	Address Liability Issues	Influence Market Demand
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Effectiveness	● ● ● ● ●
Efficiency	● ● ● ● ●
Political Acceptability	● ● ● ● ●
Operational Feasibility	● ● ● ● ●
Geographic Impact	Urban
Who	Employers
Hurdles	Institutional – few direct benefits for employers to implement

Description

The strategy uses parking cash-out benefits, a type of existing economic incentive wherein employers offer employees the choice between retaining a free parking space and taking a cash payment, to encourage SAV use.

Technologies targeted/ownership model distinctions

As on-demand, driverless vehicles that operate as part of a privately or publicly managed fleet, SAVs require high automation (SAE Levels 4 and 5) for their operation. The assumption is that SAVs would constitute an alternative mode to driving alone to work and parking for free.

How will this help?

This strategy targets congestion, land development, and pollution through providing incentives to use SAVs instead of driving for commute trips. While parking cash-out has been fairly successful where adopted, that also depends on the availability of other commute options. But even making the program mandatory would not necessarily encourage SAV use as the employees might opt for the free parking instead. For unintended consequences, the main concern would likely be fraud. Employees could receive the benefit and continue driving to work if, for example, the employer did not adequately enforce parking restrictions. The main consequence would be to employers, not society overall, but unlike illegal sales of transit benefits there would be no incentive to use SAVs.

Implementation issues

Parking cash-out is currently implemented exclusively by employers. No jurisdiction legally prevents an employer from offering the strategy, but it is not particularly popular

for two reasons: it is not well-known, and many employers would see no financial benefit from discouraging the use of parking. This is because employers who own the parking outright obtain parking through a lease and cannot unbundle the parking costs, or do not have a parking shortage and would not see a financial benefit to reducing the number of employees who drive alone to work. Otherwise, there is not much reason to pursue parking cash-out unless there is some type of mandate to reduce drive-alone commuting. To be effective, it requires some type of verification of who is using employee parking, or else employees may take the cash and continue to use the parking.

It might be possible to extend this model somehow to discourage other types of parking, such as at shopping malls or entertainment destinations. In such a model, persons who arrive via SAVs could get a small incentive payment (e.g., \$5 off a purchase or admission fee). However, this would require reliable information about how travelers arrived at their destination, as self-reported information could be unreliable. Therefore, this strategy would probably remain an employer-based one, as employer-provided parking often requires some type of authorized access and is more reliably verified.

Stakeholder benefits/concerns

Stakeholders for parking cash-out are employers and employees. Many employers would see no financial benefit from discouraging the use of parking. Any mandate for employers to provide parking cash-out would likely be unpopular with employers. It might be popular with employees, depending on their access to SAV fleets and the amount of payment.

Optimal timing

Timing is not particularly important.

Legality

No jurisdiction legally prevents an employer from offering a parking cash-out benefit. Parking cash-out payments are not limited by law, and they are taxable, so employees could use them to pay for rides in an SAV fleet.

EXAMPLE

CALIBRE, in Alexandria, Virginia, provides taxable cash incentives to employees who commute to work via carpools or vanpools that are not eligible for the company's transit subsidy program. Employees who carpool with other employees to one of the company's facilities will each receive \$32.50 per month in taxable income and must agree to accept a shared company provided parking benefit in lieu of an individual company provided parking benefit.

(Source: US EPA, Office of Air and Radiation, Parking Cash Out: Implementing Commuter Benefits as One of the Nation's Best Workplaces for Commuters, March 2005.)

This strategy targets congestion, land development, and pollution through providing incentives to use SAVs instead of driving for commute trips.





Implement Location-Efficient Mortgages

Mitigate Safety Risks	Encourage Shared AV Use	Address Liability Issues	Influence Market Demand
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Natalia Bratslavsky/Shutterstock.com

Effectiveness	● ○ ○ ○ ○
Efficiency	● ● ○ ○ ○
Political Acceptability	● ● ● ○ ○
Operational Feasibility	● ● ● ○ ○
Geographic Impact	Urban
Who	Lenders
Hurdles	Political

Description

Location-efficient mortgages (LEMs) are mortgages available to homeowners whose properties are located close to transit stations. The goal is to offer homebuyers who are willing to live near transit more advantageous loan terms to encourage the purchase of homes near transit, in the hopes that occupants will drive less and use transit more frequently. This strategy extends LEMs to persons purchasing homes in denser urban areas, where shared autonomous vehicle (SAV) fleets would be more likely to operate first.

Technologies targeted/ownership model distinctions

As on-demand, driverless vehicles that operate as part of a privately or publicly managed fleet, SAVs require high automation (SAE Levels 4 and 5) for their operation. Shared-use fleets would operate most efficiently and profitably in dense urban areas.

How will this help?

This strategy targets congestion, land development, and pollution that result from driving by providing incentives to live in denser urban areas, where alternatives to driving are more prevalent.

Implementation issues

LEMs are not currently available in the United States. Two pilot programs ran from the late 1990s to the mid-2000s. The first program was supported by several non-profit organizations and backed by Fannie Mae, and was available in only four metro areas. The second was a simplified version called the Smart Commute Mortgage, eventually available in several dozen areas. In both cases, the lender used an

adjustment factor that increased the amount the prospective buyer was able to borrow. These programs faced several implementation challenges and were eventually withdrawn from the market. Consumer demand was low. Also during the early 2000s, loan underwriting standards were relaxed, making it easier in general for lower-income households to purchase homes.

If a goal of LEMs is to encourage the use of a shared AV fleet to address access to transit stations, the criteria for making an area available to LEM lending could be based on purchasing a home in a denser neighborhood, rather than within a certain radius of a transit station. This is based on the idea that a denser neighborhood would be easier to serve with shared vehicles than a less-dense one.

Stakeholder benefits/concerns

Stakeholders are the lending institutions and prospective homeowners, as well as homeowners with LEMs and other homeowners in the targeted neighborhoods who did not receive LEMs. LEMs to encourage SAV use could have undesirable effects and raise thorny policy questions. First, they could create resentment among existing homeowners in a neighborhood if it becomes known that LEM borrowers were able to secure more-favorable terms. Second, it is possible that LEMs might interact with gentrification in ways that make neighborhoods less affordable. Third, LEMs might generally drive up the price of housing in dense areas. Fourth, they face the challenge of who should be eligible. Fifth, they face the same policy challenge as some affordable housing programs: should the terms be altered when a household's circumstances change? Finally, a related challenge is that it would be difficult to verify how homebuyers are commuting.

Optimal timing

While LEMs could be rolled out as AVs become more available, the timing would be unlikely to matter to AV penetration.

Legality

Federal, state, or local government involvement is not required to implement LEMs.

EXAMPLE

LEMs are not currently available in the United States. Two pilot programs ran from the late 1990s to the mid-2000s. The first program was supported by several non-profit organizations and backed by Fannie Mae, and it was available in four metro areas (i.e., Chicago, Los Angeles, San Francisco and Seattle). The second was a simplified version called the Smart Commute Mortgage, eventually available in several dozen areas. These programs faced several implementation challenges and were eventually withdrawn from the market.

The goal is to offer homebuyers who are willing to live near transit more advantageous loan terms to encourage the purchase of homes near transit.



Implement Land Use Policies and Parking Requirements

Mitigate Safety Risks	Encourage Shared AV Use	Address Liability Issues	Influence Market Demand
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Description

The strategy is to implement land use policies and parking requirements to support market penetration of shared autonomous vehicles (SAVs) at transit nodes and other activity centers. The objective is to minimize the potential for private AVs to exacerbate existing land use externalities that are linked to automobile-oriented land development and to promote SAV use rather than private AV use.

Technologies targeted/ownership model distinctions

SAV-supportive transit-oriented development (TOD) and parking strategies apply to Level 4 and 5 AVs that do not require a driver in the vehicle.

How will this help?

SAV-supportive TOD and reduced parking strategies target the land use impacts associated with car-oriented, suburban development, known as “urban sprawl,” which have had some negative social, equity, and environmental consequences. However, urban sprawl has had positive consequences as well, since housing in these developments is more affordable.

Personal AVs may influence urban sprawl by allowing travelers to disengage from the driving task and increase the demand for distant land, thereby exacerbating the excessive consumption of land for development. Land use policies can enable activity centers and transit hubs that support use of SAVs in order to reduce rates of car ownership, decrease VMT growth, and increase travel options. Although the potential for benefits is high, existing TOD efforts have not dramatically altered car-focused land use patterns.

Implementation issues

Land use zoning is under the control of local governments and dictates what plans and projects can be developed, as well as their form and function. Many cities, communities, and even states have already introduced land use policies and regulations that allow for and enable TOD. The biggest barriers to SAV-supportive development are the existing codes

and regulations that have encouraged suburban, single-use development. Changes to existing land use and development codes typically require an administrative process and involve city councils, planning boards, and public hearings. Similarly, parking is mandated by local zoning or development departments and changes to those parking requirements will face the same challenges as TOD.

Stakeholder benefits/concerns

Stakeholders include property owners, developers, and local residents. Transit agencies are also common partners in TOD projects. New code or zoning requirements may impose costs or be perceived as a burden, and may be opposed by developers. The public is likely to have mixed acceptance levels, depending on the location and the impact of the strategy on homeowners. Neighbors of TOD may have concerns about increased local congestion and changes to neighborhood character. TOD is gaining support from federal, state, and local planning and transportation programs that may contribute to wider acceptance in the long term. Reduced parking requirements may face similar challenges but could be supported by developers if the strategies reduce construction costs. TOD development can face barriers such as high financial risks, class and racial prejudices, and local concern about gentrification.

Optimal timing

Both strategies have been implemented in cities already, and the impacts of AV technology on existing development is increasingly under consideration by planners. Local and state planners can begin to evaluate how SAVs would fit into existing or planned TOD efforts immediately. TOD and parking strategies can begin before AVs are even on the market, because they could incentivize shared mobility providers and AV manufacturers to develop vehicles for the SAV market. If and when SAVs are introduced, there may be an evolutionary period before a significant shift in travel habits or vehicle ownership would occur.

Legality

Many cities, communities, and even states have already introduced land use policies and regulations that allow for

Effectiveness	● ● ● ● ●
Efficiency	● ● ● ● ●
Political Acceptability	● ● ● ● ●
Operational Feasibility	● ● ● ● ●
Geographic Impact	Urban
Who	Local government agencies, MPOs
Hurdles	Political, objections by private developers and local residents

and enable TOD and reduced parking. This may require changes to zoning ordinances or development codes.

EXAMPLE

The City of Evanston, Illinois, a Chicago suburb, maintains a carsharing parking reduction clause in its zoning code for the inclusion of carsharing at development sites. Specifically, the code permits a reduction in the minimum number of required parking spaces for projects that require at least five off-street parking stalls and provide at least one on-site carsharing parking space. Developers are permitted a reduction of one space for projects requiring five to 10 parking spaces. For projects entailing more than 10 off-street parking spaces, a parking reduction of 10 percent is permitted for the inclusion of carsharing. To be eligible, the developer must present a long-term lease with the carsharing operator and a description of carsharing services provided.

The strategy is to implement land use policies and parking requirements to support market penetration of shared autonomous vehicles at transit nodes and other activity centers.





Apply Road Use Pricing

Mitigate Safety Risks	Encourage Shared AV Use	Address Liability Issues	Influence Market Demand
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Description

This strategy would employ direct pricing for the use of roadway infrastructure by automated and connected vehicles (AV/CVs). Pricing would be applied to achieve specific objectives related to the impacts — both positive and negative — of AV and CV systems.

Technologies targeted/ownership model distinctions

Pricing can be applied to any technology or service to align travel behavior or purchase behavior with agency objectives. In the case of encouraging SAVs, pricing could be levied on a per trip or per mile basis, with lower charges for multi-occupancy SAVs and higher charges for other vehicle types. Furthermore, the penetration of both AV and CV technologies within the general vehicle fleet could ease the implementation of pricing, since these vehicles are likely to be equipped with technologies that allow charges to be levied and collected without the need for aftermarket components such as tolling tags or transponders.

How will this help?

The most economically efficient form of pricing, that which truly internalizes the costs of driving, would be marginal cost trip pricing that takes into account any number of societal transportation costs including congestion, pollution, and noise. Pricing could be applied to achieve specific objectives related to impacts of AV/CV systems that minimize the impacts of driving, such as limiting increases in overall travel demand, limiting distance traveled for housing, discouraging parking in urban centers, and promoting shared AV use. As a direct economic instrument, pricing is very efficient at recovering the societal costs of driving. Because pricing can be structured to account for any number of factors (congestion, pollution, etc.) it is more likely to result in

a net-positive beneficial outcome as it can achieve numerous transportation policy objectives. Pricing in general represents one of the best policy actions for internalizing the costs associated with transportation by using price signals to modify behavior.

Implementation issues

The implementation of a new pricing system will increase agency responsibility for operating and administering the system. A new system may also result in the generation of new revenues.

Stakeholder benefits/concerns

Agencies, drivers, producers, suppliers, consumers, back-office administrators, policy makers, and local business owners all have a stake in the outcome of pricing applications. Transportation pricing, regardless of the specific mechanism, can generate equity concerns because it imposes new costs on travelers. One of the most common reasons for the failure to implement pricing systems is lack of political support stemming from public opposition.

Road user charges are among the most unpopular of pricing applications in society. In general, drivers do not support paying more for transportation, and road user charges are viewed as being particularly onerous because the public is not accustomed to knowing exactly what it is paying for transportation in the form of fuel taxes.

Optimal timing

There is no optimal timing for this strategy. Road pricing is already being implemented in a number of forms to address public policy concerns outside of those associated with AV/CV deployment, most notably system management and revenue generation.

Effectiveness



Efficiency



Political Acceptability



Operational Feasibility



Geographic Impact

Urban, suburban, rural

Who

All state and local agencies

Hurdles

Public and political opposition

Legality

Since road pricing is considered a fee or tax, implementation would require legal authority through legislative action.

EXAMPLES

Oregon's OReGO Program began in 2015 and allows for up to 5,000 volunteer drivers to pay a road usage charge of 1.5 cents for each taxable mile driven.

The state of Tennessee, in their 2016 AV testing legislation, included a provision that creates a per-mile tax structure for autonomous vehicles.

Pricing applications are currently implemented in numerous forms throughout the United States. Road pricing can be applied regardless of automated or connected vehicle technology.



Implement a No-fault Insurance Approach

Mitigate Safety Risks	Encourage Shared AV Use	Address Liability Issues	Influence Market Demand
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Dmitry Kalinovskiy/Shutterstock.com

Description

If automated and connected vehicle (AV/CV) technology reduces the perceived responsibility of the driver, a no-fault approach to assigning financial responsibility for crashes may appear more attractive. A no-fault approach to auto insurance allows crash victims to recover damages from their own auto insurers rather than from another driver.

Technologies targeted/ownership model distinctions

This strategy would apply to all AV/CV technologies and passenger vehicles, but probably not to commercial trucking or transit because they typically use different kinds of insurance and are regulated by different statutes.

How will this help?

Some fear that civil liability will deter the efficient development and adoption of AV/CV technology because of the perception that these technologies are inconsistent with the conventional attribution of fault in automobile crashes and the concern that the liability system inefficiently burdens new technology. However, the conventional fault-based system of crash liability is likely to be able to adjudicate the responsibility for such crashes, with a larger proportion of the responsibility falling on the auto manufacturers. The case for no-fault automobile insurance depends on how important it is to (1) clarify liability and (2) reduce manufacturer liability. At this point, it is not clear whether these goals are worthwhile.

No-fault insurance would likely clarify liability and, depending on the statutory language, reduce or eliminate manufacturer liability. If one believes that the tort system creates externalities, reducing tort liability would reduce externalities. However, no-fault automobile insurance in the United States had the unintended consequence of substantially increasing insurance costs. It is possible that the same would be true for a new no-fault approach, though there may be ways to control this.

For this externality to affect AV/CV adoption, it must uniquely apply to new technologies. If tort judgments are too high across the board, this may result in suboptimal

outcomes, but it will not especially slow the adoption of AV/CV technology. If a state passed a no-fault law that prevented suits against manufacturers, this impact, assuming it exists, would be reduced.

No-fault insurance could actually slow adoption of AV/CV technology under a conventional fault-based system rather than accelerate it. If AV/CVs are much less likely to be at fault, then their insurance costs are likely to be comparatively lower under a conventional fault-based system. In that case, instituting a no-fault system may actually reduce incentives to adopt AV/CV technology because purchasers would not recoup the full benefits of crash reduction if most of the avoided crashes are ones in which the operator would have been found at fault.

Implementation issues

The strategy is substantially disruptive to the existing automobile insurance system in states that do not already have a no-fault system. If liability protection was extended to automobile manufacturers, this would be a disruptive change even in states that currently have no-fault systems. States without experience in no-fault systems may encounter challenges as the relevant agencies, policy makers, and courts learn about this approach. Consumers, courts, lawyers, insurers, and claims adjusters would also have to learn about the new approach.

Stakeholder benefits/concerns

Different auto insurers are likely to oppose or support no-fault statutes depending on their perceived comparative advantage in those states. If the statutes included a provision that exempted manufacturers from liability, this would obviously benefit manufacturers. Plaintiff attorneys would almost certainly oppose this strategy because it would reduce access to the courts and prevent some lawsuits against otherwise culpable motorists and manufacturers. Insurance companies are also powerful stakeholders, but their position depends on the specific company. Historically, consumer groups have not been particularly supportive of no-fault statutes.

Optimal timing

The policy is not especially time sensitive.

Effectiveness ○○○○○
Efficiency ○○○○○
Political Acceptability ○○○○○
Operational Feasibility ○○○○○
Geographic Impact State
Who State legislatures and state insurance agencies
Hurdles Political feasibility; powerful stakeholder groups

Legality

A state legislature most likely has legal authority to enact a no-fault statute. However, if the statute precluded lawsuits against manufacturers, plaintiffs may challenge it as violating state constitutional rights regarding access to courts and jurisprudential doctrines on the separation of powers. It is difficult to predict whether those challenges would ultimately succeed, but the litigation would likely delay implementation.

EXAMPLES

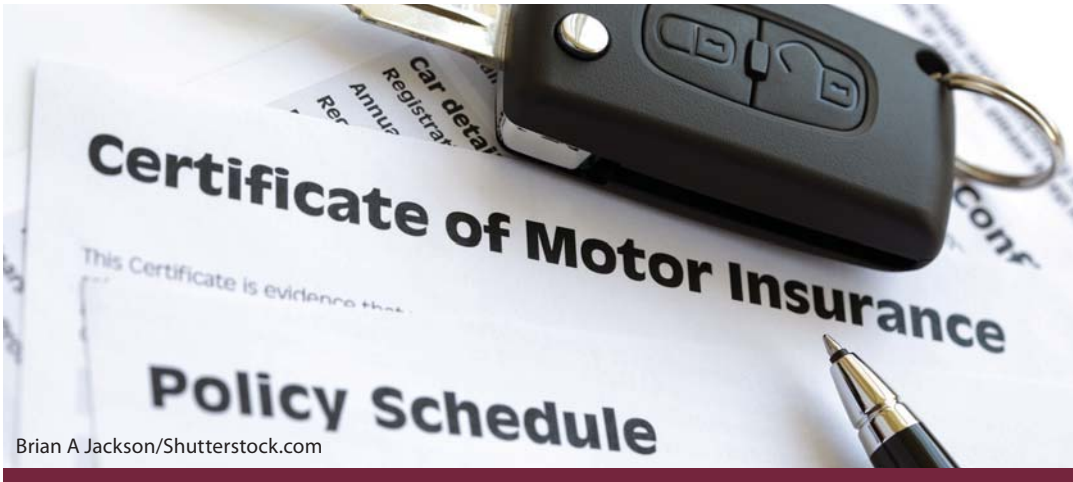
Currently, 12 states and Puerto Rico have no-fault insurance laws: Florida, Hawaii, Kansas, Kentucky, Massachusetts, Michigan, Minnesota, New Jersey, New York, North Dakota, Pennsylvania, and Utah. Three of those states—Kentucky, New Jersey and Pennsylvania—give residents the choice of picking no-fault insurance or opting out in favor of “full tort” coverage (no limit on damages). But for insurance customers in the other nine states, opting out of no-fault coverage is not an alternative.

A no-fault approach to auto insurance allows crash victims to recover damages from their own auto insurers rather than from another driver.



Require Motorists to Carry More Insurance

- Mitigate Safety Risks
- Encourage Shared AV Use
- Address Liability Issues**
- Influence Market Demand



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Effectiveness	● ● ● ● ●
Efficiency	● ● ● ● ●
Political Acceptability	● ● ● ● ●
Operational Feasibility	● ● ● ● ●
Geographic Impact	State
Who	State legislatures and state insurance agencies
Hurdles	Popularity with general public; enforcement of insurance minimums

Description

In many states the motorists are only required to carry \$30,000 or less in liability insurance. With the value of a statistical life being approximately \$9M, this leaves a vast gap between the harms that are regularly inflicted by drivers and the amount available for recovery. This gap discourages the purchase of safer automated and connected vehicles (AV/CVs) because it has the effect of subsidizing vehicles that are more dangerous to others.

Technologies targeted/ownership model distinctions

Raising mandatory insurance minimums would encourage the adoption of technology that results in safer vehicles. To the extent that AVs and CVs are safer than those driven by humans, it will encourage their adoption.

How will this help?

Many motorists are either not insured at all or under-insured, making them essentially judgment proof: they are impossible to sue because they do not have sufficient assets to pay a judgment against them. Other motorists and pedestrians can be harmed without the motorist having to pay for damages, resulting in a de facto subsidy to dangerous vehicles and motoring behavior. One strategy to offset this effect is to require motorists to carry more insurance. Without enforcements, however, the strategy may have unintended consequences — namely increased incidences of consumers not purchasing any insurance. It may also exacerbate existing inequalities because many of the urban poor have very high automobile insurance costs.

Implementation issues

This strategy could be pursued on either a state or federal level, but more likely at the state level. This change would be fairly incremental rather than radical. If it occurred at the state level, it would not fundamentally alter existing laws or relationships. It is possible that federal legislation could also accomplish the same thing. This would have the advantage of accomplishing the goals of reducing this negative

externality by passing a single piece of legislation, as well as reduce the patchwork quality of existing laws. States have historically regulated all forms of insurance, so a federal bill would represent a more dramatic change.

Stakeholder benefits/concerns

The web of stakeholders is complex and includes consumer advocates who may be alarmed about mandatory increased purchase requirements. While insurers might support state laws that require the purchase of more insurance, they also may fear additional regulation. Many individual consumers are likely to oppose the increased costs associated with higher mandatory insurance requirements. Trial lawyers are likely to support this change. Victims of car crashes and the lawyers who represent them are likely to benefit from this strategy. The societal benefits that result from increased incentives to adopt safer automobile technology are diffuse. Policy makers may accept this approach based on this outcome.

Urban jurisdictions typically have the most expensive insurance as a function of the claims history (including both likelihood of crash and jury verdicts). This results in very high auto-insurance premiums for many of those least able to pay them. This, in turn, leads to widespread failure to obtain insurance, which can lead to a vicious cycle of increased insurance rates.

Optimal timing

The policy is not especially time sensitive.

Legality

The enforcement of insurance requirements has historically been a problem. Increasing the insurance minimums is likely to exacerbate that problem and lead to more non-compliance. Determining the best method to enforce existing and increased insurance requirements is outside the scope of this paper, but needs to be acknowledged as an important obstacle to this strategy.

EXAMPLE

In 2013, Ohio elevated its minimum liability coverage for drivers. Both industry and consumer groups opposed the action because premiums were expected to increase by at least 25 percent, prompting some people to drop coverage. Under the prior requirements, drivers in Ohio needed liability coverage that would pay up to \$12,500 per person to cover injuries and medical costs, up to \$25,000 per accident, and up to \$7,500 property damage per accident. Only one state — Florida — had a lower injury liability limit than Ohio. And only four states — Pennsylvania, New Jersey, Massachusetts and California — had lower property damage limits. The new requirements are \$25,000 per person or up to \$50,000 per accident. The property damage liability coverage must be at least \$25,000 to cover damage to other drivers' vehicles or any other property besides one's own.

Raising mandatory insurance minimums would encourage the adoption of technology that results in safer vehicles.



Subsidize CVs

Mitigate Safety Risks	Encourage Shared AV Use	Address Liability Issues	Influence Market Demand
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Description

This strategy seeks to encourage the adoption and penetration of connected vehicle (CV) technology by providing subsidies for CV equipment.

Technologies targeted/ownership model distinctions

This strategy would target both original equipment manufacturers (OEMs) and after-market CV technology, and could apply to all ownership models (privately owned, “shared-vehicle,” etc.). Subsidies could be provided for new vehicle purchases with fully integrated CV technology or for CV retrofit “kit” installation, and could potentially originate from a variety of third parties, including insurance agencies.

How will this help?

This strategy will primarily target the impacts related to traffic crashes, congestion, and pollution. Reducing costs of required equipment can encourage producers to develop and sell safe CV equipment that will be integrated into vehicles and roadside infrastructure. It can also encourage consumers to then purchase vehicles and after-market equipment that incorporates V2V/V2I safety, mobility, and environmental applications.

Implementation issues

Federal, state, and local governments are no strangers to offering subsidies to encourage behavior. Electric vehicle (EV) purchases are a recent example, with individuals being able to claim a \$7,500 federal income tax credit, as well as additional state and local credits and other incentives (access to carpool lanes and reduced rates for EV charging). Potential challenges to this strategy include a general lack

of public knowledge of the benefits of CV technology. With the forthcoming NHTSA rulemaking requiring in-vehicle integration of CV equipment for new light-duty vehicles, subsidization could alleviate price increases associated with the required equipment. However, additional outreach to educate those in the market for new vehicles on why they should take advantage of the subsidies will escalate the overall costs. And as is always a concern with providing economic incentives, reduced revenue can potentially put a strain on funding for other programs.

Stakeholder benefits/concerns

The stakeholders for this strategy include, but are not limited to, federal, state, and local governments and transportation organizations; vehicle OEMs, suppliers, and dealerships; CV equipment manufacturers; and insurance agencies. Benefits to those stakeholders include increased adoption of CV technology that can significantly reduce traffic crashes and associated congestion and pollution, even at low levels of penetration. However, increased expenditures resulting from the economic incentives can have negative effects on funding for other programs.

Optimal timing

NHTSA’s forthcoming rulemaking for in-vehicle CV equipment for light-duty vehicles will make the next few years an ideal time to begin an incentive/subsidization program to encourage new CV-equipped vehicle purchases. General Motors has preemptively committed to integrating the technology in select 2017 models, and other OEMs may follow suit. An incentive model similar to that for electric vehicles could be implemented, and could be phased out based on the number of vehicles purchased, to encourage early redemption to increase penetration.

Effectiveness



Efficiency



Political Acceptability



Operational Feasibility



Geographic Impact

Urban, suburban, rural

Who

Any state and local agencies

Hurdles

Political feasibility: allocation of funds with unknown return on investment

Legality

While there are no explicit barriers to providing subsidies for technology adoption, challenges to government decisions are frequent. Incentives will likely require authorization and legislation at their respective level (federal, state, local, etc.).

EXAMPLE

To make environmentally friendly vehicles more appealing to consumers, all-electric and plug-in hybrid cars purchased in or after 2010 may be eligible for a federal income tax credit of up to \$7,500. The credit amount will vary based on the capacity of the battery used to power the vehicle. State and/or local incentives may also apply.

Reducing costs of required equipment can encourage producers to develop and sell safe CV equipment that will be integrated into vehicles and roadside infrastructure.



Invest in CV Infrastructure

Mitigate Safety Risks	Encourage Shared AV Use	Address Liability Issues	Influence Market Demand
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Description

This strategy aims to encourage development and adoption of connected vehicle (CV) technologies by supporting deployment of important physical and digital infrastructure that enables an advanced, connected transportation system.

Technologies targeted/ownership model distinctions

CV infrastructure primarily refers to Dedicated Short-Range Communications (DSRC) radio equipment, but can also refer to the supporting infrastructure needed for deployment, such as backhaul communications, CV data analytics, and CV-equipped traffic signal controllers. CV infrastructure investment could apply to all levels of AV/CV technologies and ownership models. Connected vehicles will realize the benefits of infrastructure-based information, whether using original equipment manufacturer (OEM) or after-market devices. Connected AV systems could make use of enhanced situational awareness provided by CV infrastructure.

How will this help?

This strategy will primarily target the impacts of congestion and traffic crashes, with potential impact on pollution. With increased saturation of CV-equipped vehicles, CV infrastructure could allow these vehicles to realize the benefits of V2V and V2I safety applications, which could prevent many common vehicular crashes that could not be prevented due to limited individual AV sensing range. CV infrastructure can facilitate traffic harmonization strategies that reduce congestion, which could affect vehicular emissions and fuel economy. CV infrastructure investment also directly benefits the DOT stakeholders who will be the recipients of the wealth of data created by a CV-enabled transportation system.

Implementation issues

While the federal government is actively funding pilot deployments of CV technology, the investment in CV infrastructure will ultimately fall to state and local entities, whose budgets are already thinly stretched. A strong case can be made to leverage CV and AV technology to increase safety and efficiency of existing roads. Increased levels of CV market penetration can exact significant results; however, the investment in a new digital infrastructure is a significant paradigm shift. The investing organizations will likely be

forced to prioritize where CV equipment may be most beneficial. There has been no indication of proposed rulemaking requiring CV infrastructure, and standardization for CV infrastructure information is in its infancy. Installation costs associated with CV infrastructure are also higher than in-vehicle integration, as power and backhaul equipment are also required. USDOT has developed V2I deployment guidance for state and local transportation agencies, which includes information on use of Federal-aid programs to fund deployments that meet eligibility requirements.

Stakeholder benefits/concerns

The benefits to the investing organizations are potentially far-reaching, primarily improving the safety and efficiency of their transportation systems for users, though at a potentially significant cost. As the USDOT CV pilots progress, much information will be gathered to provide recommendations and lessons learned to stakeholders considering CV infrastructure investment benefits.

Optimal timing

With the performance-based initiatives in the MAP-21 legislation, states and MPOs are looking to establish safety targets, and could be open to considering how investment in CV infrastructure may help them meet those goals. The federal government is leading the way in terms of CV research and pilot deployment. Standardization of infrastructure messaging and performance is beginning, and as the CV pilots and AV testing progress, stakeholders will have data to help plan and justify the expenses and deployment. The next few years will be critical to the execution of this strategy. NHTSA's proposed rulemaking related to in-vehicle CV integration is a positive step; however, market penetration may progress slowly, so there is still time for state and local transportation planners to learn about CV technology and its potential benefits to make informed decisions on investing in infrastructure.

Legality

There are no known legal or regulatory barriers to transportation organizations investing in technology to improve their roadways. However, as with all significant investments that are largely funded by their users, the investing agencies will benefit from providing concrete evidence to the benefits that the users will see from the investments.

Effectiveness



Efficiency



Political Acceptability



Operational Feasibility



Geographic Impact

Urban, suburban, rural

Who

State DOTs, cities, toll agencies, MPOs

Hurdles

Funding availability, understanding benefits, AV compatibility

EXAMPLES

Michigan DOT has established a 125-mile test bed for connected vehicle technology in Southeast Michigan, and sees CV infrastructure investment as key to creating an environment supportive of V2I testing. MDOT is supporting equipped vehicles that engage in the system through a combination of partnerships and state vehicle fleets. Through its Data Use Analysis and Processing (DUAP) program, MDOT is pioneering the collection and fusion of CV data with a range of data sources.

Arizona DOT operates a connected vehicle test bed using DSRC in Maricopa County. The test bed was deployed to test and demonstrate signal priority, ramp meter priority, emergency vehicle applications, truck priority for freight movement, and applications for pedestrian and cyclist safety and mobility.

The benefits to the investing organizations are potentially far-reaching, primarily improving safety and efficiency, though at a potentially significant cost.



Grant AVs and CVs Priority Access to Dedicated Lanes

Mitigate Safety Risks	Encourage Shared AV Use	Address Liability Issues	Influence Market Demand
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Description

This strategy grants priority access to AVs and CVs in dedicated lanes on roadways. Longer trips served by freeways could support the ability of AVs and CVs to travel at close spacing and/or form fast-moving, densely spaced, platoons. For special urban districts, exclusive lanes for SAVs could support reduction of VMT in the district, depending upon the shared ride requirements imposed.

Technologies targeted/ownership model distinctions

Higher level AVs and CVs with V2V capability will have the ability to form platoons that could benefit from exclusive lanes. The strategy works under any ownership model. Urban districts that designate lanes for exclusive AV use would likely do so in support of shared AVs, and may impose ridership requirements to gain public benefits in exchange for the loss of street space for other uses.

How will this help?

The potential for fast and safe travel on dedicated lanes for AVs or CVs would naturally encourage the purchase of AVs and CVs. The improvement in traffic flow and throughput improves social welfare through reduced congestion, reduced travel times, lower emissions, and reduced vehicle operating costs. As long as there are sufficient AVs or CVs to fill the exclusive lane, the benefits would exceed the costs, because a dedicated lane could move many more vehicles much faster, relieving congestion on other lanes. For commercial vehicles, platoons in dedicated lanes could save fuel, reducing emissions. If the intent is to increase market penetration of equipped vehicles, success will depend on road operators' willingness to dedicate lanes to AVs and CVs. If the intent is to reduce VMT in a restricted district or area (like an urban center), success will depend on how well the supply of SAVs matches demand.

Implementation issues

The most common form of dedicated lanes is managed lanes (MLs), which vary in size, allowed uses, and ownership.

Allowing closely spaced AVs and CVs would likely require the owners of the lanes to work with the FHWA to ensure minimum standards are met such as 45 mph speed in the lanes for 90% of the peak period. Lane owners would also likely have to work with state legislatures in the case where a lane was dedicated to AVs/CVs only. The best candidates would be those lanes with many travelers using the lanes for long trips. However, one implementation issue would be the different operating responsibilities for CVs and AVs in maintaining platoons. For a CV, the driver is responsible for maintaining vehicle headways, but for a Level 4 or 5 AV, the vehicle would be responsible for this aspect of operation, thus potentially creating alternative regulatory regimes. Financial documents for existing MLs may need to be modified to allow this new user group – especially if the preferential treatment includes a toll discount which would impact the revenue stream. For urban district conversion of lanes exclusively for SAVs or urban freight delivery, implementation challenges arise when restricting use to one travel mode within areas already experiencing high demand. For minimal cost, the potential societal benefits are very large. But deployment will require the right situation. For managed lanes, it will require long distance trip patterns; for urban districts, it will require the right market conditions for SAV. For both cases, displaced users will create a political challenge.

Stakeholder benefits/concerns

Stakeholders include AV and CV manufacturers, the owners, operators, users, and financiers of MLs, and any displaced users of converted lanes. Among the various options for priority lane designation, political acceptability will be lowest for the conversion of a general use lane to a dedicated-use lane.

Optimal timing

To incentivize market adoption, optimal timing would be in the near term. For lane dedication that involves displaced users and local residents, political challenges will likely dictate the timing.

Effectiveness	● ● ● ● ●
Efficiency	● ● ● ● ●
Political Acceptability	● ● ● ● ●
Operational Feasibility	● ● ● ● ●
Geographic Impact	Urban
Who	State and local road operators
Hurdles	Political, operational

Legality

Allowing platooning of AVs (Levels 3, 4 and 5) or CVs (V2V) on MLs will require enabling legislation. If the lane was dedicated to AVs and CVs only, then it is likely state and local legislative authority would be required. Issues such as following distance requirements will need to be examined and potentially revised.

EXAMPLE

In one example, clean vehicles were granted access to HOV lanes normally restricted to vehicles with two or more occupants. Of the 3,500 plug-in electric vehicle owners surveyed in California, 3,000 were allowed to use HOV lanes. Most indicated that HOV lane access was their primary motivation for buying the car. This is a clear example where travel time savings motivated the purchase of a specific type of vehicle.

The potential for fast and safe travel on dedicated lanes for AVs or CVs would naturally encourage the purchase of AVs and CVs.



Grant Signal Priority to CVs

Mitigate Safety Risks	Encourage Shared AV Use	Address Liability Issues	Influence Market Demand
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Anna Grigorjeva/Shutterstock.com

Description

Traffic signal priority for AVs and CVs involves sophisticated signal timing algorithms that estimate the arrival of platoons of AVs and CVs and coordinate the signal timing to give these platoons green light priority and increase throughput. The goal is to decrease delay at the signal for all vehicles, but particularly AVs and CVs, as a way to stimulate consumer action toward market penetration.

Technologies targeted/ownership model distinctions

All levels of connectivity and automation could benefit from this as long as there was connectivity to the infrastructure. As such, it is considered a CV application. This policy would require a high percentage of connected vehicles in the traffic stream to reduce overall delay. With sufficient numbers of equipped vehicles, the policy could work well in both private- and shared-ownership models.

How will this help?

CV priority would be a more complex version of transit signal priority. The call for CV priority could come from any number of platoons at any time approaching from all directions. Conversely, during periods with very little traffic, the signal may be able to provide green for any approaching CV, saving time, fuel, and operating costs for those vehicles. This strategy will require a large percentage of the fleet to be equipped to obtain benefits that would exceed costs, as the travel time savings will be minimal and can only be used when conditions are right. Given the minimal travel time benefits that would result, it is unlikely that this policy would be a driving force to increase market penetration of CVs.

Implementation issues

Providing CVs priority treatment at signalized intersections would be led by the agency responsible for operating

a traffic signal system. Many such agencies currently grant some priority treatment to transit. The overall impact would depend a great deal on the market penetration of CVs. If CVs represent a small portion of the traffic, then granting those individual calls for green might increase overall delay, negatively impacting many non-CV drivers. Additionally, during periods of peak congestion and saturated flows, priority treatment would likely not improve traffic flow; any benefit to the CV owner would be negligible. This strategy could be an extension of the current practice of transit signal priority. The technical and financial challenges are minimal, but the potential positive impact is also minimal. The only operational limitation pertains to the algorithms that prioritize CVs, which have not been developed.

Stakeholder benefits/concerns

Stakeholders include the owners and operators of the traffic signals plus all travelers on the roadway network. All income groups and disadvantaged groups stand to benefit, although higher income groups would likely see more benefit as they are more likely to afford an equipped vehicle. Implementation may require tradeoffs among road users; e.g., the deployment of priority treatment for CVs may increase delay for transit users and non-equipped vehicles. Equity issues could arise in offering privileged service to higher-income owners of CVs to the detriment of captive transit riders, especially where transit priority treatment is currently provided.

Optimal timing

Traffic signal priority requires a traffic signal to be able to receive a signal request message from the platoon and act on it by giving priority to the platoon. Most traffic signal controllers installed in the last 15 to 20 years have this ability. The ability for platoons to send this signal has not been developed, nor have any algorithms that guide when the signal will grant priority.

Effectiveness



Efficiency



Political Acceptability



Operational Feasibility



Geographic Impact

Urban, suburban

Who

State and local transportation agencies that operate traffic signals

Hurdles

Political

Legality

There are no expected legal barriers to this strategy, as state and local agencies have authority to operate traffic signals.

EXAMPLE

Transit signal priority (TSP) is an example of an operational strategy that places priority on moving buses or streetcars through traffic-signal controlled intersections. In Portland, Oregon, TSP was implemented on more than 240 intersections (roughly 25% of the city), resulting in a 5% to 12% travel time reduction for transit vehicles. The basic principle of operation: if the vehicle arrives on a green indication, the green is extended 5 to 30 seconds. If the vehicle arrives on red, the phases for the other approaches of the intersection are shortened.

The goal is to decrease delay at the signal for all vehicles, but particularly AVs and CVs, as a way to stimulate consumer action toward market penetration.



Grant Parking Access to AVs and CVs

Mitigate Safety Risks	Encourage Shared AV Use	Address Liability Issues	Influence Market Demand
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Description

This policy strategy grants priority reserved parking in a desirable location to automated and connected vehicles (AVs and CVs) to accelerate market penetration.

Technologies targeted/ownership model distinctions

Parking priority would give preferential parking spots to AVs (SAE Levels 3, 4, 5) and to CVs (V2V and V2I).

How will this help?

Theoretically, parking priority for AVs and CVs would be an incentive to consumers to purchase personal AVs or use shared AVs, thereby increasing the numbers of AVs and CVs and realizing their safety, congestion, environmental, and mobility benefits. CVs (V2I or V2V) could also alert the vehicle to available parking spots, which might benefit society through reduced VMT from parking searches. The alerts could come from the infrastructure or from other vehicles that sense open spaces. This is similar to some smart phone apps that provide this information to travelers, such as ParkMe (www.ParkMe.com) or SFPark (sfpark.org).

Implementation issues

State and local entities have authority over parking garages and on-street parking. Prototype policies for preferential parking are currently implemented for EVs. Many national, state and city governments have tried to advance the uptake of electric vehicles (EVs) and reduce oil consumption, climate-related emissions, and local air pollution through preferential parking. Most parking that would be impacted by priority parking for AV/CV would lie with private property owners. Some employers now offer preferential parking for low-emission and fuel-efficient vehicles or for vehicles used in carpooling or ridesharing as part of transportation demand management initiatives. These policies work best in a large parking facility with a lot of non-desirable spaces.

AVs are distinct, and may not easily follow the EV or car-pool/rideshare model for preferential parking. AVs can be self-parking. Once the traveler leaves the AV, the vehicle can self-park in the least preferred locations such as the top floor of a garage or back areas, reducing the desirability of preferred parking. Further, AVs can use much smaller parking spots and vehicles can be “stacked” since there is no need for the doors to open. Due to these impacts, high value spaces could be reserved for different types of traditional vehicles. Preferred parking spaces may be provided at key transportation hubs to encourage travelers to use public transit. But as noted above, self-parking AVs reduce the value of this incentive. There may be value in shared vehicles having preferential curb access in some instances. There may be a higher utility to the CV-owner or user for preferential parking since the vehicle may not be self-parking. But the capability to receive real-time alerts as to open parking spaces may reduce the incentive.

Many parking facilities are owned and operated by municipalities, airports, and transit stations, and parking fees are a significant revenue source for these organizations. In the event that AV/CV technology reduces the demand for high-cost parking, the revenue streams may be reduced.

Stakeholder benefits/concerns

Stakeholders include travelers and the owners and operators of parking facilities. The impact is likely to be positive (reduced traffic congestion due to reduced parking search times and increased parking spots due to smaller space needs to park an AV). All income groups and disadvantaged groups stand to benefit. With shared AVs, it is likely that these benefits would be more widely dispersed. This strategy could be considered an incremental change since it is simply adjusting who is allowed to park in certain spaces.

Optimal timing

This strategy pertains to a near term scenario where the market penetration of AVs and CVs is relatively small.

Effectiveness	● ● ● ● ●
Efficiency	● ● ● ● ●
Political Acceptability	● ● ● ● ●
Operational Feasibility	● ● ● ● ●
Geographic Impact	Urban
Who	Local government
Hurdles	Effectiveness

Legality

Local jurisdictions that operate parking facilities would have the legal authority to put such a program in place.

EXAMPLE

To facilitate car-sharing (e.g., Zipcar, Car2Go), cities have provided parking spaces for free to car-sharing services. In 2012, Washington, DC offered universal parking passes for 200 car-share vehicles to promote one-way car-sharing in the district. In Austin, Texas, both Car2Go and Zipcar have designated spaces in the downtown area, which are marked by posted signs. Additionally, Car2Go vehicles may park at City of Austin metered spaces for free. Car share vehicles are still subject to most posted signs, and are not allowed to park in no-parking zones, fire zones, commercial zones, etc.

This policy strategy grants priority reserved parking in a desirable location to automated and connected vehicles (AVs and CVs) to accelerate market penetration.





Implement New Contractual Mechanisms with Private-sector Providers

Mitigate Safety Risks	Encourage Shared AV Use	Address Liability Issues	Influence Market Demand
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Description

This strategy aims to establish new contractual mechanisms with private-sector providers to incentivize market development for AV and CV technologies, one example of which is a public-private partnership (PPP or P3). PPPs or other arrangements that include/require reinvestment of potential revenue to deploy CV- and AV-enabling technologies could facilitate adoption and penetration. This approach also creates an ecosystem that could lead to innovation.

Technologies targeted/ownership model distinctions

These mechanisms could target all levels of AV/CV technologies and ownership models, especially CV technology and shared AVs. Connected vehicles using either original equipment manufacturer (OEM) or after-market equipment will broadcast immense amounts of data that could be collected anonymously by roadside infrastructure and made available in a data marketplace. This could include vehicle probe data (position, speed, etc.), giving insight into throughput and traffic patterns, and other information such as CV application incidences (forward collision warnings, curve speed warnings, etc.). The CV infrastructure itself could similarly be a data source to the marketplace.

How will this help?

This strategy can potentially target all impacts of driving by encouraging and facilitating the deployment of CV and AV systems and technologies, which can lessen the impacts of traffic crashes, congestion, pollution, land development, and mobility. Producers could be encouraged to further develop CV technology, including V2V and V2I safety and mobility applications, as well as connected AVs. Private, shared vehicle operators and new TNC models could operate shared AVs; and consumer purchases of higher level AVs, including connected AVs, could harmonize traffic flow and reduce incidents.

Implementation issues

P3 arrangements have historically created net-positive benefits for stakeholders and users, often times accelerating the completion of a needed function or facility. However, they

are generally perceived as a more expensive mechanism to realize those benefits, including deployment of technology. Identifying a suitable revenue stream to support the marketplace for AV and CV technology could be challenging. With a PPP established for toll or managed roadways, toll revenue could be leveraged for such an investment. Additionally, the data generated by CVs and connected AVs could be a valuable asset for planning and operations, and could be a significant revenue stream.

Stakeholder benefits/concerns

The primary stakeholders for this strategy include the state and local agencies and private organizations that will enter into these agreements. Many examples of PPP arrangements involve design, construction, and maintenance of toll and managed roadways (which can be controversial), and data marketplace models have not been tested. Whenever public assets are monetized, concerns are raised about disproportionate impacts to lower income drivers and transit users. Furthermore, as traditional PPP relationships are typically established for segments of roadways, the perceived benefits are highly localized. As such, P3 relationships that include CV and AV elements may need to occur on a more system-wide level. Data privacy must also be considered, so all entities would need to ensure that any user-generated data would be anonymized.

Optimal timing

Implementation of these new approaches or business models could benefit adoption and deployment of CV and AV technologies in the near-term, since transportation agencies generally have limited budgets for technology development and deployment, and could make use of funding made available from private organizations through these arrangements. Once revenue streams are flowing, the private organizations can recoup their investments and begin to identify new investment opportunities. A new business model may be needed, which could delay the feasibility of this approach.

Legality

Innovative contractual approaches and business models must adhere to relevant, existing legal frameworks for contracts and agreements, which can vary widely among states.

Effectiveness



Efficiency



Political Acceptability



Operational Feasibility



Geographic Impact

Urban

Who

Transportation agencies in urban areas: state DOTs, cities, toll authorities, public transit agencies

Hurdles

Viable business models, legal and governance, political acceptability

EXAMPLE

Utah DOT uses 30-year resource sharing agreements to coordinate fiber-optic broadband network development in the public right of way (ROW) along its state roads. State law was created in 2008 defining shared-use agreements specific to telecom services and longitudinal access to UDOT ROW. UDOT maintains a policy that keeps the ROW open at all times for telecom providers to get easy access to complete continuous build outs, which also ensures that no single company gets exclusive access to the ROW. UDOT installs conduit during all roadway projects anticipating future connection to local communities with fiber optics and broadband. This encourages telecoms to provide access to local communities, and gains access to the telecom's fiber network through a resource sharing agreement.

Arrangements that include/require reinvestment of potential revenue to deploy CV- and AV-enabling technologies could facilitate adoption and penetration.

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