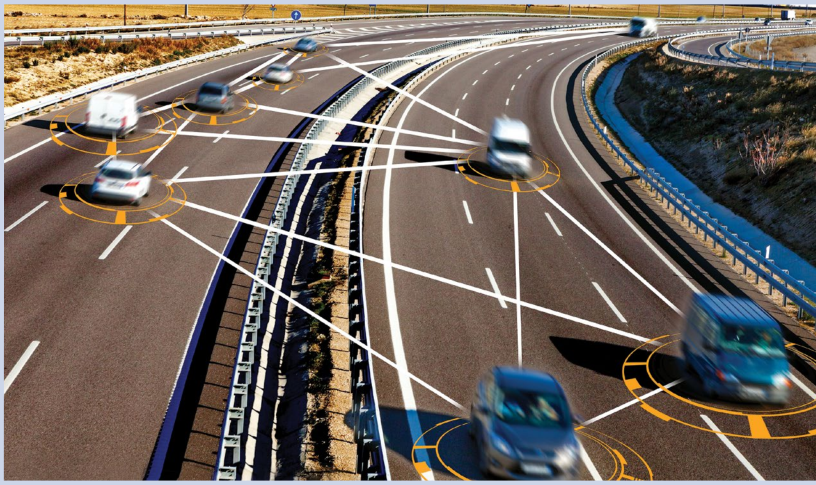

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Preparing for Autonomous Vehicles: A Survey of Local Governments

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NAIOP RESEARCH FOUNDATION

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NAIOP, the Commercial Real Estate Development Association, is the leading organization for developers, owners and related professionals in office, industrial, retail and mixed-use real estate. NAIOP comprises some 20,000 members in North America. NAIOP advances responsible commercial real estate development and advocates for effective public policy. For more information, visit naiop.org.

The NAIOP Research Foundation was established in 2000 as a 501(c)(3) organization to support the work of individuals and organizations engaged in real estate development, investment and operations. The Foundation's core purpose is to provide information about how real properties, especially office, industrial and mixed-use properties, impact and benefit communities throughout North America. The initial funding for the Research Foundation was underwritten by NAIOP and its Founding Governors with an endowment established to support future research. For more information, visit naiop.org/research.

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Contents

Executive Summary . . . 1

Introduction . . . 3

The Pros and Cons of Autonomous Vehicles . . . 5

Local Government Approaches to Autonomous Vehicles: Interview Summaries . . . 8

Preparing for Autonomous Trucks . . . 16

Case Profiles:

- Boston, Massachusetts . . . 17
- Edmonton, Alberta . . . 19
- Pittsburgh, Pennsylvania . . . 21
- Arlington County, Virginia . . . 23

Conclusion . . . 24

Glossary . . . 25

Endnotes . . . 27

Executive Summary

Autonomous vehicle (AV) development has progressed to the point that vehicles are now being tested on public roads, and stakeholders expect they will operate without human supervision in limited areas within the next few years. If AVs are widely adopted, they have the potential to substantially reshape transportation patterns and real estate demand. Municipal governments, through their abilities to set and enforce regulations, will play an important role in determining how transportation and land use evolves in response to AV adoption.

The NAIOP Research Foundation commissioned this report to examine how local governments are preparing for fully autonomous vehicles and to explore how future AV-related policies could affect the commercial real estate industry. The author interviewed eight community leaders from local governments in the United States, Canada and Australia and reviewed recent secondary sources to identify significant trends in AV development and related municipal policies. Many respondents spoke to safety concerns, the importance of integrating AVs into a broader transportation ecosystem, and their potential effects on land use, infrastructure and municipal revenues. Although the AV landscape is continually evolving, the report identifies several key findings that are of interest to developers, landowners and the broader commercial real estate community:

- **Highly automated vehicles will likely be available to the public in the near future, but widespread adoption will take many years.** AVs are already carrying riders as part of their testing and development, and it is probable that AVs will be available to the public in some capacity within the next decade. However, most experts predict that fully automated vehicles, which can operate on any drivable road and in all weather conditions without human intervention, are more than a decade away. Public concerns about AV safety, along with improvements in driver-assistance technologies for human-operated vehicles, may further delay widespread AV adoption.
- **Municipalities vary in their approach to AV adoption but tend to focus on AV safety as their most immediate concern.** Among municipalities where ridesharing and technology firms are testing AVs, some, like Pittsburgh, have established AV testing regulations to supplement state or provincial rules. Others, like Chandler, Arizona, focus more on cooperating with AV developers to identify how best to enforce traffic codes that were created for human drivers. Some municipalities, like Edmonton, have tested autonomous shuttles on a fixed route for future integration into public transit systems.
- **AVs have the potential to significantly affect demand for real estate, depending on how they are owned and operated.** If AVs are primarily operated by ride-hailing services and public transportation agencies, they could significantly reduce traffic and parking requirements and lead to increased density in urban cores. Fleet AVs could be integrated into existing transit networks or leased by commercial property owners to shuttle workers. On the other hand, AV ownership by individuals could encourage longer commutes and leapfrog development. Under either scenario, widespread AV adoption could decrease the premiums that tenants are willing to pay for properties near transit hubs such as subway stations.

- **AVs will likely require the installation of new infrastructure, including on commercial properties.** Most AV developers strive to design AVs that can operate on existing roads, but AVs could benefit from the installation of sensors and signals in some locations, such as at complex intersections. Networking AVs together—allowing them to operate remotely or travel closely together—would also require the deployment of new telecommunications infrastructure such as 5G networks, including antenna systems atop commercial buildings.
- **Autonomous trucks will likely increase demand for warehouses located near highways.** Autonomous trucks (ATs) could significantly reduce freight costs and per-unit warehouse costs by facilitating 24/7 warehouse operations. However, the first generation of ATs will require human drivers to take control on city streets and in truck yards. This trend will likely favor warehouses located near highways, which could act as terminals where ATs can transfer loads to human-operated trucks for local delivery to customers or distribution centers. Warehouses may also require additional infrastructure and equipment to accommodate automated truck deliveries.
- **Extensive AV adoption may prompt municipal, state or provincial governments to seek new revenue sources.** If AVs significantly displace human-operated vehicles, they will likely reduce local revenues from sources such as parking and traffic tickets. Widespread electric vehicle (EV) adoption could similarly reduce income from gas taxes. Governments may adopt taxes on vehicle miles traveled (VMT) to recoup lost revenues, discourage long commutes and keep empty AVs off the roads. A VMT tax could affect real estate demand trends, as could congestion pricing.
- **Most respondents expect municipalities to reduce parking requirements and encourage more loading zones.** Ridesharing has already decreased demand for parking in urban cores, and AVs are likely to reduce it even more. Some municipalities are already lowering parking requirements for properties that provide dedicated spaces for ridesharing and AVs. Others have begun to replace street parking with pickup and drop-off zones. Developers can future-proof new parking structures by building them with flat floors that can be easily repurposed if demand for parking declines substantially in the future or if future zoning policies allow for reduced parking ratios. Similarly, developers can prepare for expanded EV adoption by equipping new structures with lines for electricity and data for the future installation of EV charging stations.
- **Data sharing and cooperation among private companies, universities, and local and regional planning organizations is essential to AV implementation.** Local governments are working with AV developers, universities, non-profits, other jurisdictions and the public to prepare for AV adoption. Some governments are appointing chief technology officers or creating new entities to work across traditional departmental silos. Local jurisdictions and commercial real estate developers will need to work together on new AV-related regulations, such as incorporating EV and AV readiness into development proposals and infrastructure improvements.

The effects of AVs on transportation, urban development and land-use decisions will depend largely on how they are used and how widely they are adopted. However, their potential to significantly alter the transportation landscape merits continued attention from municipal leaders and the commercial real estate industry.

Introduction

After years of development, autonomous vehicles (AVs) are now driving on streets around the world. AVs come in many shapes and serve several purposes. These include cars, vans and SUVs designed for ride-hailing services; shuttles for public transit; and a range of vehicles designed to deliver goods to households, offices and warehouses. AV development is a work in progress, and it is not yet clear when AVs will be widely deployed or how they will fit into existing transportation systems. Nonetheless, AVs have the potential to substantially reshape how people move from one location to another, as well as their decisions about where to live, work, shop and play. Consequently, interest in AVs extends beyond the automakers, information technology firms and ridesharing companies engaged in their development.

How local governments respond to the advent of AVs should be of particular interest to the commercial real estate industry. Resulting transportation and land-use decisions will have significant implications for future development. While responses to the appearance of AVs on local roads will vary from community to community, the real estate industry can expect to see municipal policies converge as cities look to each other for effective ways to adapt to AVs. The NAIOP Research Foundation commissioned this report to explore what types of regulatory changes local governments anticipate as AV technology evolves, and how those changes might affect developers and landowners.

The report draws from secondary sources and interviews with community leaders. To get a sense of how municipalities in different geographic locations are preparing for AVs, the author sent a list of questions to more than a dozen cities in North America, Asia and Australia. Eight community representatives agreed to be interviewed.[1] The respondents are from Edmonton, Canada; Arlington County, Virginia; Grand Rapids, Michigan; Detroit, Michigan; Boston, Massachusetts; Chandler, Arizona; and Victoria, Australia. They hold positions related to urban planning or transportation policy and contribute to their communities' preparations for AV adoption. In those municipalities where AV testing is ongoing, these officials are involved in AV oversight.

These interviews reveal that municipalities are considering and implementing policies that address the safety of AVs and their integration into existing transportation networks. Although many uncertainties remain about how quickly and in what ways AVs will be adopted, these communities are also exploring potential implications for parking, curb management and zoning. This report first examines overall trends in AV development and policy and then the themes identified across the eight jurisdictions interviewed for the report. The report also profiles four of these jurisdictions (Arlington County, Boston, Edmonton and Pittsburgh) in greater detail to provide insight into how local context is shaping each municipality's approach to AV-related policies.

Interviewees

Arlington County, Virginia: Paul Mackie, director of research and communications, Mobility Lab, Arlington County.

Boston, Massachusetts: Kris Carter, co-chair of the Mayor's Office of New Urban Mechanics, city of Boston.

Chandler, Arizona: Micah Miranda, economic development director, city of Chandler.

Detroit, Michigan: Mark de la Vergne, chief of mobility innovation, city of Detroit.

Edmonton, Alberta: Howaida Hassan, general supervisor of transportation, city plan, city of Edmonton.

Grand Rapids, Michigan: Josh Naramore, Mobile GR director, city of Grand Rapids.

Pittsburgh, Pennsylvania: Alexander Pazuchanics, assistant director of mobility and infrastructure, city of Pittsburgh.

State of Victoria, Australia: Stuart Ballingall, director future vehicles, Transport for Victoria, State of Victoria.

The Pros and Cons of Autonomous Vehicles

The effects of AVs on transit, land use and urban development will depend on how and how quickly AVs are adopted. Many automakers, entrepreneurs, ridesharing companies and other proponents of AVs have long maintained that a significant share of AVs will ultimately enter the market as shared vehicles operated by ride-hailing services, logistics firms or public transit systems. Generally, advocates maintain that widespread replacement of individually owned, human-operated vehicles by shared AVs will produce several benefits for riders and the public. These include:

- **Increased safety.** Replacing human drivers with fully autonomous vehicles would eliminate most traffic accidents.
- **Less traffic.** Shared AVs would reduce the number of vehicles on the road. Networked AVs could also travel closer together at higher speeds than human-operated vehicles, increasing the pace of traffic.
- **Slower growth in transportation and infrastructure spending.** Fewer vehicles on the road and more efficient traffic flow would increase the efficiency of existing roads and slow the growth of transportation budgets.
- **Reduced need for parking.** Fleet-owned AVs would remain in operation through most of the day and require far fewer parking spaces than individually owned vehicles.
- **Less pollution.** Fewer vehicles on the road would also reduce vehicle emissions, assuming they drive fewer miles in aggregate than the human-operated vehicles they replace. Emissions could be completely eliminated if all AVs are electric vehicles (EVs) connected to a green power grid.
- **Improved access to transportation.** Shared AVs could improve access to transportation for children, the elderly, the disabled and those who cannot afford to own a car.
- **Higher-density development.** Better traffic flow and reduced parking needs would also allow for denser development in urban cores.

On the other hand, many municipal planners and academics are concerned that AV adoption could look quite different from this ideal. If AVs were to be predominately owned and operated by individuals, many of these benefits would likely disappear. Individually owned AVs would likely produce a more comfortable commute for riders. That might encourage migration to less expensive housing farther from urban centers. Increasing sprawl could, in turn, negate the traffic benefits of more efficient driving. Individually owned AVs could produce even more traffic than individually owned traditional vehicles, as owners might choose to leave them in circulation instead of finding and paying for parking. If owners opt for gas-powered AVs rather than EVs, then AVs could collectively produce more emissions than the traditional vehicles they replace. Whether AVs are individually owned or shared, they could reduce demand for traditional modes of public transportation and possibly lower the premium that tenants are willing to pay for real estate located near public transportation hubs, such as subway stations.[2]

SAE's Six Levels of Vehicle Automation[3]

Level 0 – No Driving Automation. The driver controls the vehicle at all times.

Level 1 – Driver Assistance. Most functions are still controlled by the driver, but a specific function (like steering or acceleration) can be done automatically by the vehicle when a driver-assistance mode is engaged. While in this mode, a vehicle will automatically match speeds on the highway or stay within its lane.

Level 2 – Partial Driving Automation. A vehicle's automated systems control both steering and acceleration while the driving automation system is engaged. A driver performs all other vehicle functions and must always be ready to take control of the vehicle.

Level 3 – Conditional Driving Automation. When engaged, a vehicle can take full control over steering, acceleration and braking. This mode can only be engaged in specific conditions (e.g., daytime highway driving in clear weather), and will disengage when those conditions no longer exist. A driver must take over full control when requested by the vehicle.

Level 4 – High Driving Automation. As with Level 3, a vehicle can take full control over steering, acceleration and braking when this mode is engaged, and the vehicle can only be automated under specific conditions. A driver does not necessarily have to take immediate control over the vehicle when conditions no longer allow for automation, but if they are unwilling or unable to do so, the vehicle will safely disengage from traffic (e.g., pull over and wait for a driver to take over). Pedals and steering wheels may be omitted from Level 4 automated shuttles and taxis.

Level 5 – Full Driving Automation. The vehicle can navigate without human intervention to a predetermined destination over roads that have not been adapted for its use and in all normal driving conditions.

Not only does it remain to be seen how AVs will be owned and operated, the timeline for their deployment also remains unclear. Contrary to earlier predictions of fully functional AVs by 2019 or 2020, AV developers are now pushing back their projections for the release of AVs to the public. Ford Motor Company predicts that it will release a Level 4 AV that will "operate without a steering wheel, gas pedal or brake pedal within geo-fenced areas as part of a ride sharing or ride hailing experience" by 2021.[4] However, Nissan predicts that truly autonomous vehicles will not be available within the next decade, and Waymo (formerly the Google self-driving car project) has indicated that it does not expect a Level 5 vehicle to be available in the near future.[5]

Safety concerns are likely the greatest single challenge facing AVs. The public has long been concerned about the dangers AVs could pose to occupants, pedestrians or other drivers. These fears were exacerbated when an AV operated by Uber struck and killed a pedestrian in 2018, prompting many municipalities and states to review their AV testing regulations.[6] A longitudinal Deloitte survey reveals that a significant share of consumers believe AVs will not be safe. After declining from 74 percent of consumers who held this view in 2017 to 47 percent in 2018, the Deloitte survey ticked back up to 50 percent in 2019.[7] Unless AV developers can make significant progress in demonstrating to the public that AVs are not dangerous, safety concerns will likely remain a significant deterrent to AV adoption.

The work that AV developers have put into improving AV safety may also be indirectly undermining their advantage over human-operated vehicles. Many safety features initially developed for fully autonomous vehicles are now being integrated into human-operated ones. These include automatic emergency braking systems, expected on most new cars by 2022, and adaptive cruise control systems that use highly detailed maps, onboard sensors and artificial intelligence (AI) to perform most driving functions while allowing a human driver to take control of a vehicle in more complex situations. Some analysts believe that as human-operated vehicles become safer, fully autonomous vehicles will become comparatively less attractive, postponing their adoption or limiting their market share.[8]

While much remains uncertain about how AVs will be used in the future, municipalities have good reason to begin preparing for their adoption. In those locations where AV testing is underway, municipal authorities generally recognize a need for policies that ensure these tests are conducted safely. In addition, urban planners and transportation authorities recognize the importance of factoring AVs into their long-term plans. City master plans and transportation plans can guide land use and infrastructure decisions over the course of a decade or longer, and those decisions continue to shape urban development for subsequent decades. Though the effects of AV adoption remain unclear, many planners and analysts believe that a proactive approach to AVs will improve the outcomes of ongoing planning decisions.

Local Government Approaches to Autonomous Vehicles: Interview Summaries

Several themes that were supported by secondary research emerged from the interviews. Respondents' approaches to AV adoption varied, but a majority were concerned with safety, integrating AVs into existing transit networks, impending land use changes, infrastructure needs, and potential lost revenues from fuel taxes and fines.

Regulating AV Safety

While municipalities can play an important role in regulating AV testing at the local level, national and state/provincial governments ultimately exercise greater authority over AV regulation. National governments are generally responsible for establishing overarching safety standards for motor vehicles. Individual states and provinces within the United States, Canada and Australia regulate insurance and licensing of drivers and vehicles, and they play a significant role in determining the circumstances under which AVs can operate within their jurisdictions. For example, the Australian state of Victoria requires AV developers to obtain a testing permit, adhere to trial guidelines and report incidents to the state.[9]

While a municipality's regulatory authority varies from country to country and even between individual states or provinces, local governments play an active role in shaping how AV companies test their vehicles on local roads. Each municipality adopts its own approach to AV testing, as revealed in the case studies later in this report. However, most of the municipalities in this report that allow AV testing restrict it to neighborhoods that present less challenging driving conditions or are less densely populated. Other common regulations include restricting the times or weather conditions in which AVs can operate, requiring human operators in the vehicle, and requiring AV companies to report safety data, such as crash incident reports and statistics on how frequently a human operator must take over the vehicle. These measures allow municipalities and AV developers to establish that AVs can operate safely in favorable conditions before they are allowed to operate in more challenging or dense environments. Increased transparency can also help the public become more comfortable with AV testing.

Even in those localities where state or provincial policies effectively prohibit municipalities from enacting their own regulations, as in Arizona, municipalities can benefit from active engagement with companies performing AV tests. For example, the city government in Chandler has worked with Waymo to ensure that the company's AVs comply with local traffic laws and to determine how to administer traffic tickets to AVs and their human operators.

Integrating AVs into Transit Networks

Although respondents recognize that it is unclear how AVs will be predominately owned and operated, most were optimistic that they would largely be used within ride-hailing networks as it currently appears that AVs will be unaffordable for most individuals. Respondents also observe that while AVs could cannibalize demand for public transportation, they also had the potential to increase use of public transportation by contributing to a more seamless transit network. AVs could offer a solution to public transportation's first-mile/last-mile challenge by shuttling individual riders to and from transit hubs where they can take more efficient modes of transportation. Officials hope that a more seamless network would expand demand for public transportation and further reduce traffic.

> "Automated shuttles could fill the first-mile/last-mile gap or reduce some of the inefficiencies with traditional fixed route[s].
>
> **JOSH NARAMORE, MOBILE GR DIRECTOR, GRAND RAPIDS**

Although riders might theoretically connect to public transportation through ride-hailing services or even personally owned AVs, some municipalities are also considering the possibility of integrating autonomous shuttles into their public transportation networks. For example, Edmonton recently tested autonomous shuttles in partnership with Pacific Western Transportation, which operates the city's municipal buses. Although Chandler is better known for its partnership with Waymo, it is also evaluating the possibility of operating autonomous shuttles to connect the city's main employment centers. The State of Victoria also supports AV shuttle trials. Grand Rapids recently launched an autonomous shuttle pilot program that ferries passengers along an existing bus route.[10] Detroit already hosts privately operated AV shuttles that circulate riders around the city's central business district. To work around limited parking and urban congestion, the property management company Bedrock contracted with May Mobility to shuttle the firm's workers from distant parking lots to downtown office buildings and to transport them to company events.[11]

Effects on Parking and Curb Management

Municipal planners expect that AVs will significantly affect demand for parking and curb space. Most respondents anticipate or are already making changes to their policies concerning parking ratio requirements and curb use.

Interviewees generally expect that widespread AV adoption will reduce demand for on-street and surface parking, particularly in urban cores. Switching from individually owned traditional vehicles to shared AVs would result in a net drop in parking demand, while automated systems could allow AVs to stay in circulation or route them to larger or more distant parking structures when not in use. Parking structures devoted to AVs could also be more space-efficient; individual parking spaces would not require room for humans to enter or exit a vehicle, and vehicle-to-vehicle (V2V) communication would allow AVs to coordinate double parking.[12]

Many communities have already changed parking and curb-use patterns due to the expansion of ride-hailing services, growth in e-commerce and greater density in urban cores. While AV adoption is expected to accelerate recent trends, the expansion of ride-hailing services and rapid growth in e-commerce deliveries have prompted many municipalities to revisit their approach to "curb management," shorthand for policies regarding on-street parking, loading zones and passenger pickup/drop-off zones. While planners expect AVs to increase demand for pickup and drop-off zones and decrease demand for on-street parking, it is unclear how large an impact AVs will have on demand, or how quickly demand patterns will change.

> "I think it's less autonomous vehicle-driven, no pun intended. I think that it's a lot more in relation to or in response to trends in electrification and the sharing economy, but I think we are actively looking at curb management and curb utilization. The way that we do pickup and drop-off loading zones, there's a real question of [whether] our curb is priced and used in the most efficient or optimal way.
>
> **MARK DE LA VERGNE, CHIEF OF MOBILITY INNOVATION, DETROIT**

To better understand these trends, some municipalities have started tracking parking and curb-use changes. For example, Grand Rapids actively measures curb use, road-carrying capacity and on-street parking to better forecast demand patterns and make informed planning decisions. The city is updating its master plan and evaluating different scenarios for AV deployment to identify how AVs may affect future land-use decisions.

In several cases, municipalities have begun to update their policies in response to changes in demand for curb space and parking. Jurisdictions are imposing maximum parking ratios or reducing minimum parking ratios. Some are encouraging or requiring that new developments include pickup and drop-off zones, and others are identifying areas that might be zoned in the future for shared AV parking structures. From 2007 to 2018, 115 North American cities dropped their parking minimums, and experts expect this trend to continue, especially in denser urban areas.[13]

Source: Getty Images

Chandler, Arizona, is among the first cities to revise its zoning code to encourage the use of ridesharing and AVs. Under the new zoning code, developers of commercial and multifamily properties can reduce minimum parking space requirements by up to 40 percent by adding passenger loading zones. In addition, the city's zoning administrator may reduce parking requirements in a zone by up to 40 percent if a parking demand study reveals a decrease in demand due to AVs and ridesharing.[14] These reduced parking requirements should expand the amount of land available for other uses.

Widespread AV adoption could also help cities design streets that are safer for pedestrians, bicyclists and scooters. If AVs fully replace human-operated vehicles, planners could likely narrow lanes substantially without affecting safety. Most respondents also expect that AV adoption will help municipalities reduce the amount of on-street parking, though local retailers are likely to resist this change. These two trends could allow planners to create new bike lanes and widen sidewalks.

If AVs do result in a significant decline in demand for parking space, it could create new opportunities to redevelop parking structures. For example, underground parking structures could be repurposed as storage areas for office and multifamily buildings. New storage-fee revenues could replace lost parking revenues. If electric AVs (or EVs in general) are widely adopted, fuel stations may present additional opportunities for redevelopment, though there could be unique environmental-remediation challenges.

In planning for potential increased AV and ridesharing adoption, developers may wish to future-proof new parking structures. For example, although Grand Rapids is building a new parking structure in its retail district, it will have flat floors that can be adaptively reused in the future. Some private-sector developers are also preparing for future adaptive reuse of parking structures by increasing their floor-to-floor heights and avoiding sloped-floor ramps.[15]

Forecasting Infrastructure Needs

Widespread AV adoption may require municipal investments in new sensors and signaling equipment and would likely affect demand for traditional infrastructure. Electric AV adoption would also require additional investments in electric grid development.

Since AVs are currently being tested to work with the present state of transportation infrastructure, they primarily depend on onboard sensors and AI. Most AVs, such as those operated by Waymo in Arizona, use a combination of cameras, radar and light detection and ranging (LIDAR) to sense their surroundings. Sensor data is fed into an onboard computer that relies on AI to direct the vehicle. While AVs currently do not need advanced street infrastructure to operate, they do generally require clearly painted lanes, pavement markings and intersections. Transportation planners may also opt to allow AVs that operate on a fixed route as a shuttle service to use lanes that are otherwise dedicated to bus rapid transit.

Source: Getty Images

Although the current generation of AVs relies primarily on self-contained systems, further developing AV communication systems will be critical to unlock their full potential. Theoretically, V2V communications between AVs improve their safety and allow them to group closely together in traffic, reducing congestion. Networking AVs would also allow for their remote operation by individuals, ride-hailing companies or public transit systems. Effective communication across an AV network would be particularly important for ride-hailing companies and public transit systems, as AVs could provide these operators with real-time traffic data that would allow the operators to improve dispatch and routing decisions. Some AV projects are already testing V2V communications, such as the recent autonomous shuttle trial in Edmonton. The operators of that trial anticipate that the shuttle's V2V communications network would give them the flexibility to both operate within a route and travel to individual riders' destinations as needed.[16]

AVs would also likely benefit from municipal investments in sensor and signaling infrastructure. Sensors mounted on traffic signals, lights and buildings could collect and relay information on vehicle location, speed and direction to help AVs negotiate complex intersections. This infrastructure could also provide real-time data on current traffic conditions to AV networks and human operators. In turn, planners could use data collected from sensors and AVs to better design investments in infrastructure and transportation.

All these forms of communication would require additional investments in telecommunications infrastructure to transmit large volumes of data between vehicles and across sensor networks. Dedicated short-range communication (DSRC), similar to Wi-Fi, and fifth-generation cellular technology (5G) are the two wireless technologies most likely to support V2V and vehicle-to-infrastructure (V2I) networks. State and provincial jurisdictions looking for federal guidance and funding have been exploring the standardization and deployment of Wi-Fi systems to facilitate connectivity for V2I communication. At the same time, telecommunications companies are investing heavily in rolling out 5G networks. Investments in each type of network are expected to be costly; financial firm Greensill recently projected that global investments in 5G infrastructure alone could reach $2.7 trillion by 2020.[17] Commercial property owners may ultimately benefit from increased demand for tower and rooftop leases to support the telecommunications equipment needed for these new networks.

AV adoption could also shape future investments in more traditional infrastructure. If AVs allow for more efficient use of existing infrastructure, they could reduce demand for future investments in roads and bridges. Municipalities may also avoid investing significant sums in traditional traffic signals and signage if they anticipate a need to invest in more advanced sensor and signal networks.

Municipalities that want to encourage the adoption of electric AVs know they will need to encourage the development of infrastructure to support EV charging. For example, the city of Chandler is encouraging developers to consider pre-piping electric conduits to allow for the installation of charging stations. Vancouver, British Columbia, now requires all new multifamily buildings to install EV charging stations for their residents.[18] In order for EV adoption to become widespread, municipalities will also need to coordinate with utilities to ensure that the electric grid can support a large number of electric charging stations.

Revenue Implications

Widespread adoption of AVs could significantly affect local government revenue sources. While income sources and revenue composition vary between municipalities, states and provinces, most local governments collect revenues related to motor vehicles. This includes licensing and registration fees, vehicle excise taxes, parking fees and gasoline taxes, as well as traffic and parking tickets. A recent survey of the 25 largest cities in the United States revealed that they collect an average of $129 per capita in annual taxes and fees related to parking, traffic citations and registration.[19] If AVs are widely adopted as shared vehicles, fewer vehicles on the road would translate to reduced revenue from each of these sources. Full AV adoption would likely result in the elimination of revenues from traffic and parking tickets. Widespread adoption of electric AVs (or EVs in general) would also substantially reduce revenues from gasoline taxes.

Some respondents note that imposing a vehicle-miles-traveled (VMT) tax might be one way for local governments to recoup lost revenues from these sources. A VMT tax could also discourage traffic caused by longer commutes and "deadheading"—when vehicles remain in traffic while not carrying passengers. Respondents note that collecting a VMT may require the installation of sensor networks, and in most jurisdictions a VMT would probably need to be established at the state, provincial or federal level. Municipal governments could potentially build on a broader VMT tax system by collecting congestion taxes on vehicles when they travel through an urban core.

AV Policy Collaboration

While local governments develop and implement policies to ensure that AV implementation is aligned with local needs and priorities, they also actively seek collaboration with other levels of government and the private sector.

Respondents underscore the value of collaboration on AV-related policies within and between cities, states and provinces. As noted earlier, regulation of AV testing and implementation requires coordination between different levels of government. In addition, municipalities often collaborate with state or provincial governments or with regional planning organizations to identify and implement AV-related policies that will improve transportation or contribute to regional economic development. For example, Chandler has worked with partner municipalities and organizations across the Phoenix metropolitan area to coordinate AV-related policies to maximize their economic benefit to the region. Local governments may also learn about policy initiatives at the national level or in other cities through participation in national associations related to municipal government, transportation or urban planning.

> "There's some pretty key direction coming from municipalities saying that we want to grow up, not so much out[...] How do we work with the real estate development community to ensure that as this technology comes, it doesn't stand in the way of that type of city goal?
>
> **HOWAIDA HASSAN, GENERAL SUPERVISOR OF TRANSPORTATION, CITY PLAN, EDMONTON**

Waymo has located its AV depot for the Phoenix metropolitan area in Chandler, Arizona.

Source: Waymo

In addition to collaboration between governments at different levels, respondents note that municipalities must effectively coordinate AV-related planning among their own departments. For example, Detroit's chief of mobility innovation works closely with transportation fleet managers and coordinates with the city's police, fire and public works departments.

Local governments are also looking to universities and the private sector as important partners in AV implementation. Those municipalities that host AV trials work closely with AV developers to ensure that regulations are followed, to evaluate AV capabilities and to forecast their potential implications. Some respondents note that they work closely with universities as either developers of AV technology or as experts who can inform municipal policies.

Although automotive, information technology, logistics and mobility service firms play the most direct role in AV development, respondents also recognize that the real estate industry will play an important role in AV adoption in the future. Developers and landowners will have to adapt to any significant change in transportation patterns and resulting changes in demand for space. Additionally, developers will need to work closely with municipalities on shifting regulations regarding their properties' abilities to accommodate AVs and EVs, including those that inform development proposals.

Preparing for Autonomous Trucks

Municipalities interested in AVs have primarily focused on autonomous passenger vehicles and smaller delivery vehicles such as vans or light trucks, leaving regulation of autonomous freight trucks to states, provinces or national agencies. Within the United States, some states—including Arizona, Florida, Virginia and Louisiana—have allowed autonomous truck (AT) testing or have already authorized the commercial use of ATs.

Source: Waymo

A focus on regulating ATs at the state and federal levels may reflect the reality that freight trucks move through multiple municipal jurisdictions and require uniform regulation and oversight. Municipal governments are also less involved in AT oversight because ATs are not yet advanced enough to be tested on city streets. Currently, AT technology developers are focused on creating AT systems that can operate on highways. TuSimple is currently testing ATs on Arizona highways, Daimler Trucks is testing them on Virginia thoroughfares in partnership with Torc Robotics, and Starsky Robotics is testing them on Florida highways.[20]

At their current stage of development, ATs still require a human driver to take over when operating on city streets and to navigate truck yards. Starsky Robotics has also developed a system that allows human drivers to remotely operate ATs when they exit a highway.

Kam Simmons, Director of Public Policy and Government Affairs at Starsky Robotics, spoke about innovations in autonomous trucking at NAIOP's I.CON West 2019 conference. According to Simmons, ATs will increase demand for warehouses and distribution centers near highways because logistics firms will want to minimize the need for human drivers to operate ATs once they exit the highway. These warehouses could function as truck terminals where a locally based human driver could pick up goods for transport on city streets.

Simmons believes that ATs could eventually lower the cost of truck freight shipments to below current costs for maritime shipments. He expects limited driverless service routes to be available in late 2020 or early 2021, and dedicated service with complete automation throughout a truck's journey to be available within five years.

A recent McKinsey report on ATs projects a slightly more conservative timeline, forecasting the arrival of fully autonomous trucks in 2027 or later, but it identifies additional implications of AT adoption for warehouse design and operation. The firm projects that ATs will allow warehouses to operate 24/7, improving e-commerce fulfillment and reducing per-unit warehousing costs. To achieve these efficiencies, warehouses will likely require new equipment at entrances and docks to accommodate ATs.[21]

Case Profiles

Boston, Massachusetts

Boston has closely integrated its approach to AVs into a broader transportation plan. The city began planning related to AVs in 2016 as part of the US Department of Transportation's Smart City Challenge. This coincided with an update to Boston's transportation plan that began with constituent outreach in 2015 and culminated with the release of the city's Go Boston 2030 Vision and Action Plan in 2017.[22] According to Kris Carter, co-chair of the Mayor's Office of New Urban Mechanics, Boston's plans for AVs will support the city's broader goals of a safer transportation system that prioritizes access and reliability.

Boston has launched an AV testing program that has partnered with two companies (Nutonomy and Optimus Ride) and has begun exploring the potential impact of AVs on city infrastructure. The tests provide insight into how companies are implementing AV technologies and the reasons behind their methods. This can, in turn, inform Boston's policies and planning decisions. The Office of New Urban Mechanics works with several city departments to facilitate this initiative. The office also coordinates partnerships with the Massachusetts Area Planning Council and neighboring municipal governments. Cambridge, Summerville and Quincy are partnering with Boston on AV policy development and testing programs.

Source: Metropolitan Area Planning Council.
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The Office of New Urban Mechanics has observed that while AVs have the potential to support Boston's transportation system, without adequate planning they could contribute to sprawl and congestion.[23] Carter notes that AVs also present a significant risk-management challenge. Consequently, much of the office's AV testing regulations are focused on safety protocols. Although he expects limited commercial deployment of AVs by 2020, Carter predicts that widespread public adoption of AVs will not take place for decades.

AVs are part of a broader evolution in mobility choices affecting land use and parking in Boston. Ride-hailing services have already increased demand for pickup and drop-off locations and contributed to a significant drop in parking occupancy on nights and weekends. This shift in demand has led to discussions about lowering parking ratios in current neighborhood planning projects.

Boston also anticipates that AV adoption could significantly affect city revenues, much of which comes from an annual 2.5 percent excise tax on vehicles. Boston has limited control over this rate, which is set by the state government. Carter anticipates that increased AV adoption could result in an annual loss of $140 million in city revenue from declining excise tax collections, as well as lower collections from parking meters and parking fines.

In addition to regulating AV testing, the Office of New Urban Mechanics is exploring ways to improve curb management, develop infrastructure to support AVs and manage intersections to ensure AVs can operate safely. The office is currently piloting curb changes and pickup/drop-off zones in partnership with transportation companies. The Boston Planning and Development Agency's Smart Utilities initiative supports infrastructure development that will be important for AV implementation, including the installation of fiber-optic cable, adaptive signaling technology and smart street lights.[24] Carter observes that these technologies will provide AVs with the information and signals they need to safely negotiate left-hand turns at complicated intersections.

In addition to seeking public input into its transportation plan, the city of Boston has sought to generate public interest in autonomous vehicles and related technologies. Outreach initiatives have included a robot block party and AV "petting zoo," which attracted approximately 6,000 participants. Advocates for disabled and senior residents have also expressed support for AVs as they may provide freedom for those constrained by traditional transportation systems. Additionally, local universities are engaged in AV-related research, teaching and experimentation. For example, MIT offers a class on "Deep Learning and Self-Driving Cars" and maintains a research center focused on self-driving technology.[25]

Edmonton, Alberta

Edmonton's approach to AVs emphasizes their integration with public transit and the city's ongoing efforts to promote EV adoption. Edmonton prioritized the development of an AV strategy in its Smart City Strategy in 2017[26] and subsequently committed to studying AVs and their implications for transportation policy in its Smart Transportation Action Plan in September 2018.[27] As part of this commitment, Edmonton partnered with Pacific Western Transportation to test electric autonomous shuttles in the fall of 2018. According to Howaida Hassan, general supervisor of transportation, the city is also examining the potential implications of AV adoption as it develops a plan for automated, connected, electronic and shared mobility systems over the next two years.

In partnership with the city of Calgary and Pacific Western Transportation, Edmonton supervised its first test of AVs in October and November 2018. The goals were to obtain feedback from Edmonton residents on AVs and conduct cold-weather AV testing at the University of Alberta.[28] Pacific Western Transportation tested a 12-person autonomous shuttle that was developed by EasyMile. The electric shuttles featured a ramp for ease of access and were supervised by a human operator to ensure safety. They also were equipped with sensors and signaling technology that allowed networked communications between the vehicles. More than 2,500 people rode the shuttles during the testing period, and 688 riders completed a subsequent survey to inform Edmonton's AV strategy.[29]

The ELA operated on a fixed route within a designated testing area in Edmonton.

Source: Video still from *Edmonton Journal*

Edmonton's goals for its Smart Transportation Action Plan include reducing the city's carbon emissions, improving accessibility to transportation and making transportation more people-centric. According to Hassan, whether AVs effectively meet these objectives will depend on how widely they are adopted and the extent to which they are integrated into the sharing economy. She also sees AVs as having the potential to improve transit safety and to supplement other modes of public transport by providing first-mile/last-mile (FMLM) transportation. The Edmonton Transit System is preparing a study on how new mobility options such as AVs can be used to bridge the current FMLM gaps in public transit service.

As part of the city's efforts to reduce carbon emissions, Edmonton developed an EV strategy in 2017 that anticipated a future with shared electric AVs.[30] The city has installed EV charging stations at city buildings, but Hassan expects that Edmonton will also need to work with private utility companies to modernize the power grid.

Edmonton is considering how AV and EV adoption will affect future land-use decisions. The city is evaluating current parking ratio requirements, investigating how it can incentivize shared parking among different types of users and assessing how it can best accommodate smart transportation technologies. While AVs and shared cars will likely reduce parking space requirements, their impact will depend on how widely they are adopted. The city is re-evaluating its approach to curb management and is considering a requirement for future developments to provide parking dedicated to ridesharing and pickup and drop-off zones. Overall, Hassan expects that much of the existing surface parking in Edmonton's core will eventually be repurposed. EVs' need for regular recharging will also affect future parking locations.

Edmonton is working to determine future funding needs related to AV adoption. Hassan expects that electric AVs and an overall increase in EV adoption will substantially diminish revenue the city derives from Alberta's gas tax. These taxes may eventually be replaced by a road-use fee or vehicle mileage tax.

Pittsburgh, Pennsylvania

Pittsburgh is notable for being an early host to AV companies that now conduct extensive testing on public roads. Pittsburgh has a long history of AV development due to Carnegie Mellon University's research into AV technology in the 1980s and the university's participation in the Defense Advanced Research Projects Agency's Urban Challenge, an AV design competition in 2007.[31] The city attracted national media attention when it became the site for early widespread AV testing by Uber, which initially offered AV ride-hailing services in the city in 2016. Pittsburgh created the Department of Mobility and Infrastructure in 2018 to guide the city's AV initiatives.

Source: Uber

In March 2019, Pittsburgh outlined new guidelines for AV testing to improve safety, transparency and data sharing. The guidelines also tasked the Department of Mobility and Infrastructure with developing AV policies that would enhance walking, bicycling and public transit; encourage the use of higher-occupancy and lower-emission AVs; lower transportation costs; improve access to transit; and minimize disruption to city finances, services and the operation of public streets.[32] According to Karina Ricks, the department's director, an Uber AV accident that led to a woman's death in Tempe, Arizona, in March 2018 gave new urgency to the development of municipal AV guidelines.[33] Following Pittsburgh's new reporting requirement, Aptiv, Argo AI, Aurora, Uber and Carnegie Mellon University revealed that they collectively were testing 55 self-driving vehicles on Pittsburgh streets in April 2019.

Alexander Pazuchanics, Pittsburgh's assistant director of mobility and infrastructure, thinks that more efficient use of existing transit systems and infrastructure will be a key future benefit of AV deployment. He expects that a significant long-term challenge will be evaluating how to prioritize AVs and other modes of transit, and adapting land use and infrastructure planning accordingly. For example, the city must evaluate the future implications of AV adoption when planning a significant investment in infrastructure, such as a new bridge.

Effective planning could also incentivize the development of AV fleets for multi-passenger use, encouraging denser, transit-oriented development. However, Pazuchanics also worries that AVs could instead incentivize continued greenfield development and sprawl.

In the short term, Pazuchanics sees AV safety as a more immediate challenge. AVs must demonstrate that they improve everyone's safety before they are widely adopted.

As in other cities, Pittsburgh is adjusting its approach to land use and parking. One of the city's goals is to decrease the volume of single-occupancy vehicle travel. To that end, the city is adjusting its approach to parking minimums and maximums and is encouraging the development of amenities to make walking, cycling and public transit more desirable. The city is also evaluating whether its current curb-management policies promote optimal transit. To support electrification of AVs and human-driven vehicles, Pittsburgh is working with public utilities and private developers to encourage the development of charging infrastructure across the city.

Pazuchanics recognizes that Pittsburgh will likely have to adjust how it collects revenues as a result of increasing AV implementation. The city receives a significant share of its revenues from a relatively high parking tax, which is designed to encourage walking, biking and public transit use. However, this revenue source is likely to decline with increased adoption of ridesharing and AVs.

Pittsburgh cooperates with the Pennsylvania state government on the regulation of AVs. Pazuchanics observes that although the state has most of the regulatory authority over AVs, Pittsburgh provides AV developers with additional guidance to account for the city's density, narrow streets and high volume of pedestrians and bicyclists. Pittsburgh also collaborates on the development of AV-related policies with the National Association of City Transportation Officials, Transportation for America and other cities that were finalists or semifinalists in the US Department of Transportation's Smart City Challenge in 2016. The city is also working with other jurisdictions in the surrounding 10-county region to update a long-term regional transportation plan.

Arlington County, Virginia

Arlington County, an inner-ring suburb of Washington, D.C., has become a national leader in transit-oriented development and transportation planning. For more than forty years, county leaders and planners have developed a united vision of walkable, high-density, mixed-use corridors. Within its 26 square miles, the county offers multimodal transportation options such as subway, bus, bike share, car sharing and ride hailing. Mobility Lab, a research and education organization jointly funded by Arlington County and state and federal transportation agencies, has been examining AVs for several years as part of a larger transportation demand-management strategy.

Paul Mackie, director of research and communications at Arlington's Mobility Lab, says the county could possibly deploy AVs in the next five years in the form of fleets or shuttles to assist commuters to and from transit hubs. Mackie notes that he would like to see limited adoption of personal AVs, because they would add to traffic congestion.

At this point, Arlington County does not foresee much disruption to its streetscape from the advent of AVs. Most changes would focus on lanes, intersections and curb management. However, the county is looking closely at parking. In response to falling demand, parking minimums are already being eliminated in some areas of the county. Ideally, the use of AV fleets and shuttles will allow cities to relocate parking spaces from valuable land in high-density nodes to remote areas. This could reduce traffic in densely populated nodes and create more pedestrian-friendly neighborhoods.

Mackie believes real estate developers will play a large role in adapting the form and function of buildings in response to AV adoption. With reduced demand for parking, land could be used much more efficiently.

Although Arlington County does not currently host on-road AV testing, it has taken several steps to prepare for AVs. Mobility Lab plans a study on consumer attitudes toward AVs. It also seeks to collaborate with local universities to look at how AVs could be best used, examine ways of deploying connectedness technology (e.g., beacon-and-sensor guidance systems) and understand the big-data aspects of transportation planning. Mobility Lab is also starting to explore AV-related partnerships with other levels of government and is engaging with non-profit associations including the Eno Center for Transportation, the American Planning Association and the National League of Cities.

Conclusion

Substantial advances in technologies that support vehicle automation have allowed AV testing to migrate from closed tracks to public streets. These advances have also raised expectations that fully automated vehicles able to operate on public streets without human supervision will be available to consumers, public transit agencies and ridesharing services in the near future. Although it is probably only a matter of time before fully automated vehicles are available to the public, much remains uncertain about how widely AVs will be adopted and how they will be integrated into existing transportation systems. AVs might be primarily owned by individuals or by ridesharing services, or they might remain a niche form of transportation as driver-assistance technologies make conventional vehicles safer. Public concerns about AV safety may further delay their widespread adoption.

Nonetheless, many municipal governments are exploring how AV adoption may affect future land-use policies and transportation plans. Many of these decisions are likely to have significant implications for local and regional residential and commercial real estate markets. In some cases, municipalities are already adopting policies that affect new development. Ultimately, these policies and plans will be driven by the evolution of AV technology and consumer preferences.

As this report has demonstrated, there are some similarities in the ways that municipal governments are preparing for AV adoption, but also many areas where they differ. It is likely that a consensus will eventually emerge on key topics such as AV safety regulation, and that municipal policies regarding parking minimums will converge. However, long-term municipal land-use and transportation policies will continue to reflect local economic and demographic contexts and other characteristics that are unique to each city.

Those municipalities that have been proactive in adapting to AV testing and adoption have also generally sought public input and collaboration from the private sector when formulating new policy. This openness presents developers, building owners and other professionals with opportunities to provide input on AV-related policies that could have significant implications for commercial real estate. Everyone involved in the commercial real estate community needs to understand how AVs are being developed and adopted, and how their local communities are preparing for this evolution of the transportation ecosystem.

Glossary

5G: fifth-generation cellular technology, touted as the next wave after 3G and 4G. 5G will provide enhanced mobile broadband cellular service along with very reliable low-latency communication. The latter is essential for safe autonomous vehicle operation. 5G will be able to transmit massive machine-ready data, which will be essential for smart city analysis.

AV or Autonomous Vehicle: a vehicle that uses a combination of sensors, cameras, radar and artificial intelligence (AI) to travel between destinations without a human operator. Sometimes called self-driving or driverless cars, AVs are being developed by technology companies and automobile manufacturers and at the moment, do not depend on connectivity with infrastructure other than GPS.

Closed Loop: a limited-access transit corridor. A closed loop can be restricted to AVs to allow them to pick up and drop off passengers to facilitate mobility and avoid conflict with other vehicles.

CV or Connected Vehicle: a vehicle that is connected to other vehicles and infrastructure, including traffic signals and the internet, to gather information regarding the behavior of other vehicles and traffic conditions.

DSRC: or dedicated short-range communication, is a means of communication among connected vehicles and infrastructure. Many believe 5G and DSRC will be complementary, but more now view 5G as the dominant technology. Ford and Qualcomm envision a city integrated with 5G V2X technology. [34]

First Mile and Last Mile or FMLM: transit systems usually have dedicated routes and pickup and drop-off points for riders. For a rider, first mile refers to travel from their origin to a transit hub, and last mile refers to travel from a transit hub to their destination. Transportation planners regularly look for ways to facilitate FMLM transportation. AVs may help ferry riders to and from transit hubs. In the context of supply chain management, the last-mile problem refers to transporting goods from a distribution center to consumers. Logistics firms may also turn to AVs for this link in the supply chain.

Fleet AVs: refers to a group of autonomous vehicles operated by a company that provides mobility services to individuals or households.

Geofencing: a geofence is a system of sensors that can detect, identify and potentially communicate with persons or vehicles that transit a specific space. Some jurisdictions are using this technology to track pickup and drop-off activity.

IoT or Internet of Things: the network that allows devices, including vehicles, home appliances and other physical equipment, to send and receive data and communicate with each other.

Mobility: a collective term for multiple ways of getting around including walking, bicycles, docked and dockless bicycles, scooters, vans, buses, light rail, subways, ride hailing, shared vehicles and autonomous vehicles.

Personal AV: an autonomous vehicle used by an individual owner.

Platoon: a group of AVs that can travel closely together at high speed. Each vehicle communicates with the other vehicles in the platoon. There is a lead vehicle that determines the platoon's speed and direction; following vehicles respond to the lead vehicle's movement.

Ride-hailing Service: a method for door-to-door transport such as Uber or Lyft that is often used as an alternative to a taxi service. Facilitated by an online application, drivers use their own or fleet-owned vehicles to pick up customers and deliver them to a destination.

Sensors: cameras, radar, laser-based systems and electronic devices that monitor the environment and provide input to the artificial intelligence that operates an autonomous vehicle.

Smart City: an urban area that uses the internet of things, sensors and technology to collect data and enhance the lives of residents and visitors. Cities may provide residents with mobile applications that provide access to information so that users can avoid traffic jams, find parking or report information regarding road conditions or trash collection. Publicly collected data on transportation choice and energy consumption can also improve municipal business decisions and inform policy.

Vehicle Miles Traveled Tax or VMT Tax: a tax levied on motorists based on miles traveled. A VMT tax can be increased in dense urban areas to reduce congestion.

V-to-V, V-to-I, V-to-X or V2V, V2I and V2X: acronyms to describe communication between vehicles and other objects. Specific types of communication are V2V (vehicle-to-vehicle), V2I (vehicle-to-infrastructure) and V2X (vehicle-to-other device, such as a cellphone carried by an individual).

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