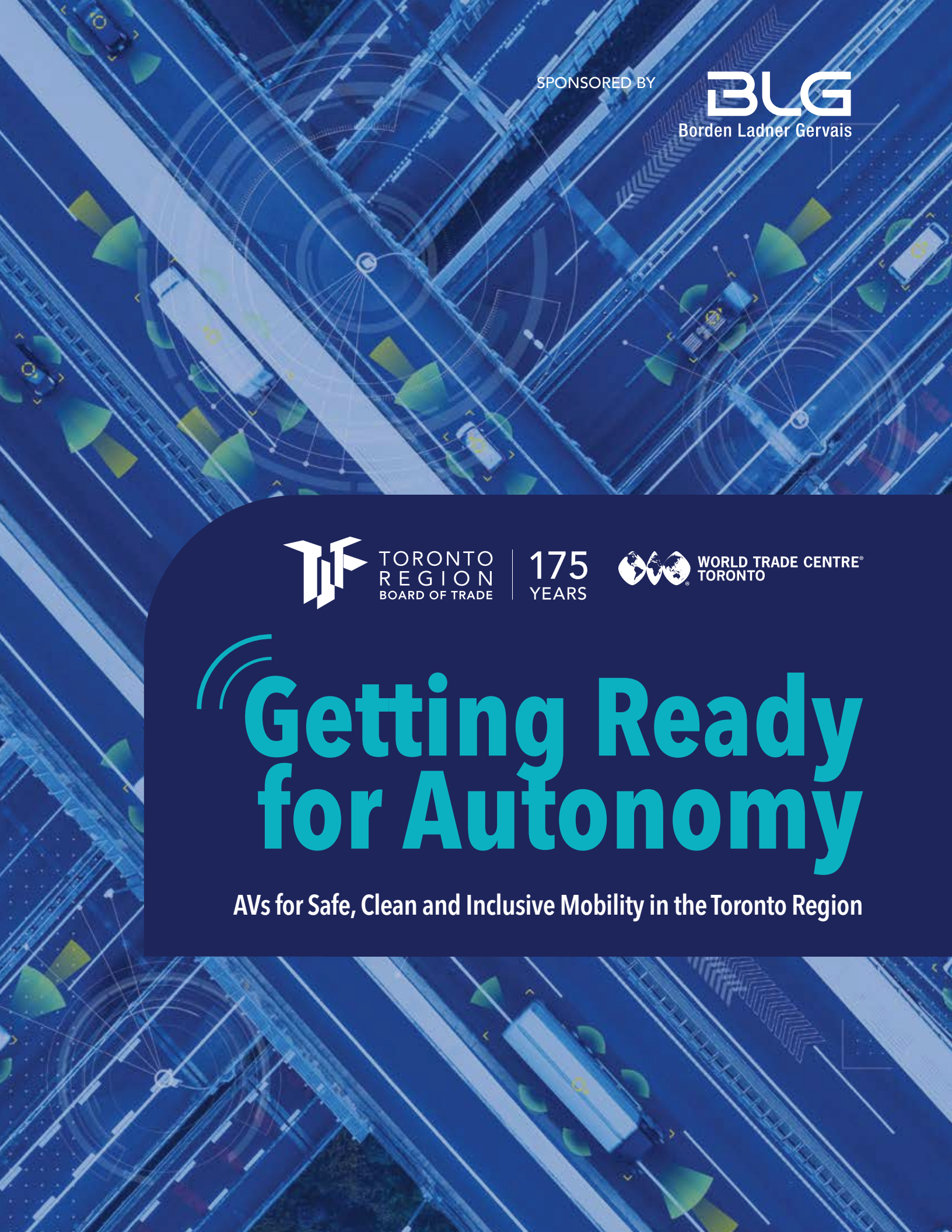

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Getting Ready for Autonomy

AVs for Safe, Clean and Inclusive Mobility in the Toronto Region

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Will Toronto act just as swiftly to deploy AVs at scale, as it did with rail? Or will it be a late adopter, missing out on the potential benefits?

Introduction

The safe, reliable and efficient movement of people and goods throughout our region has been at the heart of the Toronto Region Board of Trade's mission since it was first founded in 1845. At the time, railways were the future of mobility – with the first train leaving Toronto in 1853. The Board seized on the opportunity to expand rail, making sure Toronto businesses could access new markets and receive materials from across the continent. Eventually, rail gave way to cars and roads as the main movers of people and goods. Today, the region is facing its next future-defining mobility shift: connected and autonomous vehicles, referred to in this report as "AVs." The question then becomes: will Toronto act just as swiftly to deploy AVs at scale, as it did with rail? Or will it be a late adopter, missing out on the potential benefits?

Looking at the region's strengths, Toronto is well placed to be one of the first global cities to roll out AVs. Leading research on AVs and the artificial intelligence systems that underpin them—combined with Toronto's flourishing tech community, a strong legacy of automotive manufacturing, and its commitment to innovative developments—mean that the region has many of the ingredients for AV leadership. Creating an autonomous future will make the region a leader in the new economy, stimulate economic growth and inward investment, and create high skilled jobs.

However, active steps will need to be taken to ensure the region's AV readiness. For example, our homes and workplaces, roads and curbsides, and safety regulations and insurance systems have all been designed with traditional automobiles in mind; these assumptions need to change as the way we move around the region changes.

This report makes the case for why and how the Toronto region should speed up the deployment of AVs and looks at the existing strengths of the region. It also examines the steps needed to make this future a reality with 20 recommendations to all levels of government and industry organized across four pillars: people, regulations, management, and infrastructure.

Why Embrace an Autonomous Future

Encouraging the development of connected and autonomous vehicles is about more than bringing the pages of science fiction to reality. Rather, AVs can pack an economic and social punch – helping alleviate many of the Toronto region's most pressing pain-points, as well as generating new opportunities for investment and growth.

Reduced Congestion

Toronto has been ranked as the worst city in North America for commuting, with commuters spending a total of just under two days a year stuck in traffic.[1]

This level of congestion leads to lower productivity, environmental degradation, and a diminished standard of living. It's estimated that in one year, congestion costs the region's commuters $3.3 billion and its businesses $2.7 billion in lost opportunities for growth.[2] AVs can facilitate optimized traffic flow networks, helping vehicles travel at optimized speeds and reducing congestion from inefficient driver behaviour.

Lower Climate Change-Causing Emissions

Transportation is the second largest contributor to greenhouse gas emissions in Toronto, accounting for 38% of the total. Of that, 80% comes from personal vehicle use.[3]

By reducing congestion, AVs will take a considerable chunk of these emissions out of the equation. But if AVs are really going to offer a transformational change to transportation's contribution to emissions then they must be electric vehicles as well. It has been estimated that using Ontario's average grid electricity mix, battery powered vehicles would release only 4% of the equivalent CO2 emissions of a traditional internal combustion engine vehicle.[4]

Potential for Economic Growth

Embracing autonomous mobility in the region also promises economic benefits. The region's strong automotive heritage, combined with its growing strength as a global technology hub, means the region is well placed to attract investment in AVs. For instance, Toronto has already seen a $200 million investment to create Uber's Advanced Technology Group Research and Development Centre.[5] General Motors (GM) created its Canadian Technical Centre in Markham to research and develop AV technologies, as well as other facilities such as an AV test track in Oshawa, due to open spring 2020.[6]

The "passenger economy," created by the value derived from the use of fully autonomous and pilotless vehicles, is projected to be worth $800 billion by 2035, rising to $7 trillion by 2050 if AVs become mainstream.[7] The Toronto region needs to position itself to attract as much of that value as possible.

The Economic Benefits of AVs to Toronto

It is estimated a 90% adoption rate of AVs would result in total annual savings of $6 billion - or 4% of the city's GDP. These would come from:

- $1.2 billion from reduced collisions – a significant saving in healthcare costs
- $2.7 billion from reduced congestion
- $1.6 billion from saved insurance
- $0.5 billion from avoiding parking fees and fines.[8]

Fewer Collisions

The safety potential of AVs to road users is enormous. An estimated 94% of all motor vehicle collisions are due to human error while driving[9] and 65% of near crashes have some form of driver inattention as contributing factors.[10] In Toronto alone, six people are hit by motor vehicles every day.[11] Already, basic automated features such as lane departure warnings are lowering rates of certain crashes by 11% and the rates of injury causing crashes by 21%.[12] If AVs reached high levels of market penetration in Toronto, it is estimated that fatalities and injuries would be reduced by 90%.[13]

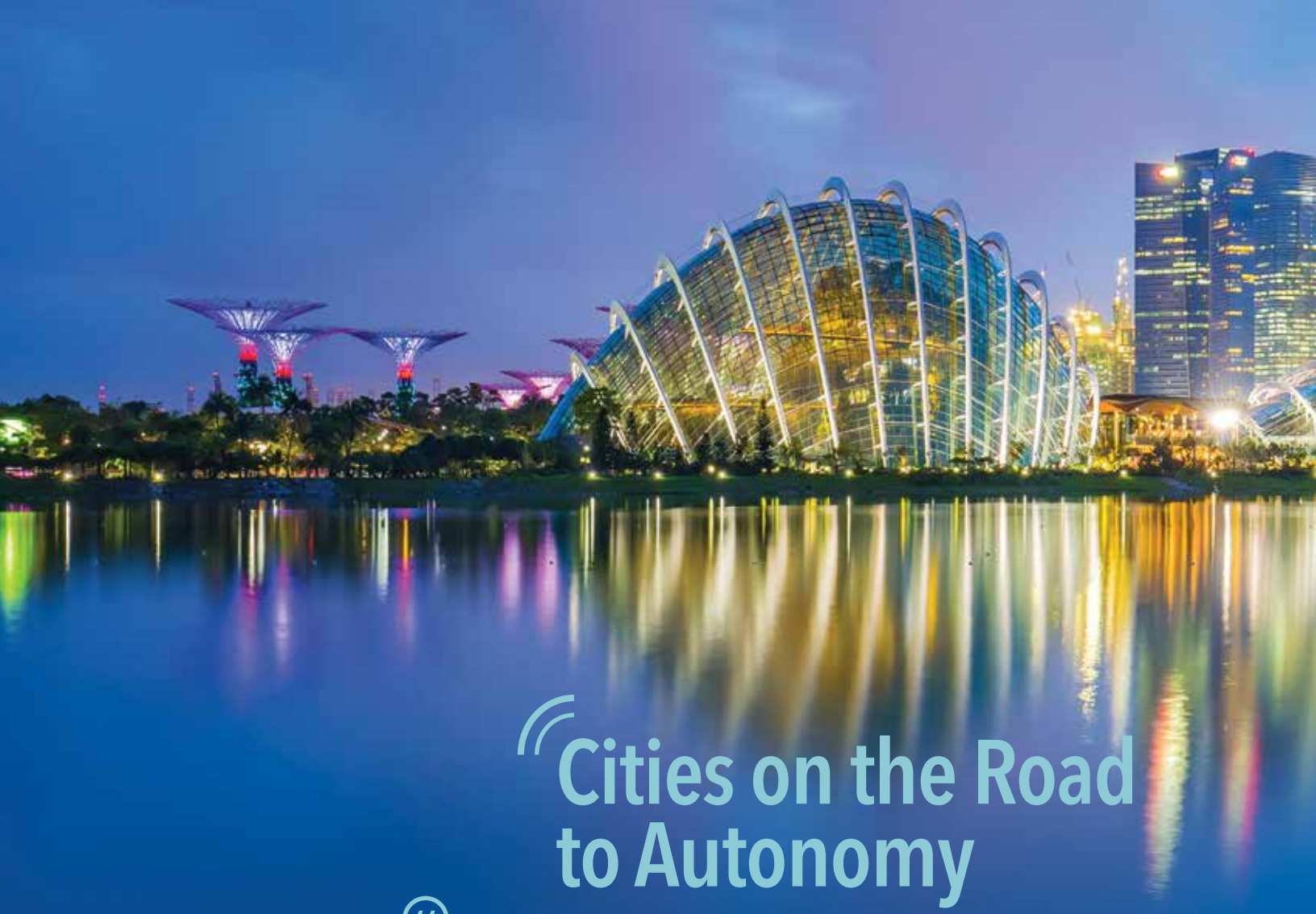
Transit Equity

Within Toronto there are several "transit deserts" – areas with no easy access to subways, street cars, or buses.[14] If integrated into the region's transit network, AVs can provide first and last mile connectivity to communities otherwise in transit deserts. With 60% of GO Transit riders currently driving to stations,[15] either scheduled or on-demand AVs can increase access to transit, reduce pressure for parking and potentially free up Metrolinx's 70,000+ parking spots for transit-oriented development.[16]

Research has also shown that these deserts are disproportionately in Toronto's low income areas.[17] Indeed, the score for transit service and accessibility in high income areas of the city is almost four times higher than low income ones.[18] Low income residents are also less likely to own a car, restricting their access to employment opportunities outside their immediate neighbourhoods. AVs can play an important role in addressing this kind of mobility equity.

Increased Independence

Between 2017 and 2041, the number of seniors in the Toronto region is set to increase by 133%.[19] With this booming seniors population, access to transportation will play a key role in people's social inclusion and independence. AVs can help provide independence to seniors when their ability to drive a vehicle might diminish.[20] By one estimate, by 2030 AVs could significantly improve the quality of life for 75,000 Toronto seniors with severe or very severe disabilities – especially those who would face challenges using today's modes of transit.[21] AVs could also play a major role in facilitating the independence, economic opportunity, and safety of other road users, such as those with impaired vision, provided their needs are duly considered, especially in the design of roadside infrastructure and the accessibility and usability of onboard interfaces.[22]



Cities on the Road to Autonomy

> Singapore incentivizes the development and use of AVs through heavily penalized car ownership to discourage people from driving, with around two-thirds the price of a car being tax.

Cities across the globe are actively preparing for the transition in mobility and driving forward AV deployment. The Bloomberg Philanthropies "Initiative on Cities and Autonomous Vehicles" mapped out 136 cities across the world that are piloting and making policies for AVs.[23] The vast majority of these efforts are focusing on identifying pilot zones for the safe testing of AVs, land use, and transit planning. Other priorities include the sharing of best practices with other cities, updating and reviewing road safety rules, and exploring the possibility of autonomous city fleets.

How they implement these priorities varies from case to case, reflecting differing legal systems, population sizes, and local priorities. Leading cities often have a range of pilots. These are designed not only to test the technology in local settings, a large challenge in itself, but also to test the capacities of local regulators and transit bodies to operate autonomous systems.

In many ways, the best placed city to move towards AV adoption at scale is Singapore. In a unique position as an independent city-state, Singapore does not have to consider remote and rural populations or multiple levels of government. It has taken advantage of this position to establish important policy and regulatory initiatives, such as its Technical Reference 68 – a set of standards that will help promote the safe deployment of AVs.[24] Singapore has also held short trials of autonomous shuttles, with one on-demand shuttle operating along a 5.7km route from August to November 2019.[25] Additionally, Singapore incentivizes the development and use of AVs through heavily penalized car ownership to discourage people from driving, with around two-thirds the price of a car being tax.[26]

While most cities do not have the flexibility of Singapore, many others are still actively preparing for AVs. London, U.K.'s GATEway project saw a range of different trials conducted that were designed "to understand how people respond to, engage with and accept automated vehicles, as well as exploring the potential impact this technology could have on our cities." Funded as part of a £100 million Intelligent Mobility Fund,[27] the project has had a lasting impact through the creation of the Smart Mobility Living Lab London, which allows advanced testing on both public and private roads.[28]

Paris, meanwhile, is taking a more citywide approach to preparing for AVs, led by its Electric Mobility Agency. Its trials include a dedicated AV lane across the Charles de Gaulle Bridge for the testing of driverless shuttles and another trial involving three shuttles and a partnership between the public transit authority, a for-profit transit operator, and a vehicle maker.[29] The region of Ile-de-France, which includes Paris, also announced in October 2019 that it would be investing €100 million in autonomous vehicle infrastructure with an autonomous mobility service run in time for the 2024 Olympic games.[30] Berlin has adopted a similar cross-governmental approach, with their DIGINET-PS project involving three city agencies, €5 million in funding, and a new 6.3km route that will serve as Germany's first urban test bed for AVs.[31]

Closer to Toronto, within North America a number of U.S. cities have established themselves as early leaders in the testing and deployment of AVs. Boston has seen similar pilots to those in Europe, with a dedicated program focused on 191 acre waterfront industrial district.[32] San Francisco is the home of GM Cruise, where they employ 1,500 people and have been testing their AVs on the city's complex urban roads.[33]

Though it is Phoenix, Arizona, and its suburb Chandler that has emerged as the leading jurisdiction for the testing and deployment of AVs. The city has seen testing from Intel, Uber, and GM, and has been one of the key testing sites for Waymo since 2017.[34] Waymo's cars have been tested in a 100 square mile service area and, since 2018, their autonomous ride-hailing service, Waymo One, has been operating in a smaller geofenced area of around 50 square miles with approximately 1,500 monthly active users.[35] To support the fleet of AVs that service these users, Phoenix is home to a 70,000 square foot depot and teams of technicians, engineers, mechanics, customer service reps, and product managers.[36]

Admittedly, Phoenix offers an ideal environment for AVs to operate in. The lack of rain or snow, large roads with sprawling suburbs, and few pedestrians make it a forgiving physical environment to test autonomous systems.[37] Still, Arizona has some of the most permissive AV regulations in the U.S., allowing the testing of vehicles without any safety driver behind the wheel as long as it follows all traditional traffic laws and regulations.[38]

The Toronto Region AV Ecosystem

The Toronto Region has an existing AV ecosystem that will be a significant factor in accelerating mass AV deployment. The strength of this ecosystem rests on two main pillars – Ontario's historically strong automotive sector and the region's rapidly growing tech sector.

> **Continued support of these types of activities that work to grow and strengthen the AV ecosystem should be an important regional priority.**

The Auto Ecosystem

Various historical and geographic factors have helped Ontario emerge as Canada's automotive manufacturing cluster. Five of the world's largest auto manufacturers – Ford, General Motors (GM), Toyota, Fiat Chrysler Automobiles (FCA), and Honda – have manufacturing branch plants and facilities in the province.

A strong supply chain has grown around these plants. Magna International, the largest contract automobile and parts manufacturer in North America, and Linamar Corporation, Canada's second largest automotive and heavy-duty vehicle parts manufacturer, are both headquartered in the region.

Though the production of vehicles is beginning to decline, Ford[39] and GM[40] have demonstrated their commitment to the region with new investments in research centres that will focus on developing AV technologies. Together they will employ over 1,000 engineers focused on autonomous technologies in the region. The presence of these manufacturers and suppliers positions the region for AV innovation and potentially manufacturing, given there is significant manufacturing capacity, availability of parts and suppliers, and trained industry talent for research and innovation purposes.

The cluster of local automotive and technology talent spurred the creation of the Autonomous Vehicle Innovation Network (AVIN), with support from Ontario's Ministry of Economic Development, Job Creation and Trade (MEDJCT) and Ministry of Transportation (MTO). AVIN's goal is to work with industry, academia, and government to help commercialize new products and services in the automotive and transportation sector, and support Ontario's readiness for the adoption and deployment of these technologies. AVIN's main objectives are to:

- Commercialize connected and autonomous vehicle, transportation, and infrastructure technologies;
- Build awareness, educate, and promote Ontario as a leader;
- Encourage innovation and collaboration;
- Leverage Ontario's talent; and,
- Support regional auto-brainbelt clusters.[41]

Programs coming out of AVIN include the creation of six Regional Technology Development Sites. Ottawa and Windsor are both home to sites, with the final four in the Toronto region:

- Toronto on AI and machine learning to improve AV perception;[42]
- Waterloo on developing high definition 3D mapping and vehicle localization technology to support AV navigation and control;[43]
- Durham focused on Human-Machine Interfaces and user experience for AVs;[44] and
- Hamilton on multimodal and integrated mobility.[45]

Additional projects include the WinterTech AV Development Fund which supports collaborative projects with up to $500,000 to validate, test, prototype, and demonstrate new products and technologies designed to meet the unique demands of winter weather conditions.[46]

The combination of Ontario's automotive capacities and the regional support of the government and organizations such as AVIN positions the Toronto region as a competitive place for AV adoption and testing. Continued support of these types of activities that work to grow and strengthen the AV ecosystem should be an important regional priority.

The Technology Ecosystem

The Toronto region has a vibrant and growing technology sector. According to the Startup Genome report, the region ranks 13th amongst global startup ecosystems – above cities such as Amsterdam, Singapore, Barcelona, and Hong Kong – and has around 15,000 companies with a total ecosystem value of $17 billion, well above the global median of $5 billion.[47]

The region also has a healthy number of incubators and accelerators. These range from incubators supported by universities – such as the University of Waterloo's Velocity, the University of Toronto's Hub Ideation and Experimental Learning Centre, and the variety of incubators supported by Ryerson University – to private incubators supported by technology giants such as IBM Innovation Space and Google for Entrepreneurs.[48]

Some of the largest and most recognizable innovation hubs in the world are also found in the region. The MaRS Discovery District in downtown Toronto is the largest innovation hub in North America with over 1,200 startups in their network.[49] The DMZ at Ryerson University is the top-ranked University incubator in world.[50] Based in Waterloo, Communitech is a public-private innovation hub supporting a community of 1,400 companies.[51]

Part of the reason for the region's successful tech sector is the availability of funding. Between established financial institutions and venture capital funds, companies in technology and innovation sectors have a range of financing options. For example, Radical Ventures is a $471 million fund focussing on investing in AI.[52] Others include: Google Capital, BASF Venture Capital, Sidewalk Infrastructure Partners, and the MaRS Capital Fund.[53]

The combination of automotive and technology ecosystems helps to make the region the ideal setting to produce, test, and bring to market AVs. However, while this is a strong foundation, there are obstacles that need addressing and further steps that need to be taken by the region's governments and businesses to ensure the region's readiness for AVs.

Preparing the Toronto Region for the Future of AVs

To maintain a strong competitive advantage in the growing AV industry, the region has to prepare. It must ensure it has a balanced focus on the following four pillars:

PEOPLE
Nurturing AV-ready talent and public support.

REGULATIONS
Creating favourable AV regulations and standards.

MANAGEMENT
Developing the institutional capabilities to manage AVs.

INFRASTRUCTURE
Building AV-ready infrastructure.

PEOPLE
Nurturing AV-Ready Talent and Public Support

Above all else, talent is an essential component in reaching the successful and beneficial mass deployment of AVs. Innovative problem solving will be required to overcome technical problems, such as coping with snow and other climate conditions.

AV-ready talent and skills are also going to be needed in a much wider sense. This includes having regulators and policy makers who understand the advantages and drawbacks of AVs and how to maximize the former and mitigate the latter. Planners and developers will need to understand the implications of AVs so they design the region's cities and communities.

Perhaps most importantly, society-at-large will need to understand, support, and be ready for the changes that AVs will bring. According to a study conducted by CAA South Central Ontario (CAA SCO) among its members, 26% are not familiar at all with AVs and a further 64% don't know much about them or are only somewhat familiar. 3 out of 10 members today are very or somewhat interested in learning more.[54] Citizens and consumers will need to trust AVs to transport them and their loved ones around the region. Reliability (i.e. trust in the technology) was the top issue identified by 80% of CAA members.[55] They will need to be incentivized to make mobility decisions that build on the strengths of AVs, rather than those which might exacerbate problems such as congestion.

AV readiness will also need to encompass the changes that will happen to employment over the coming decades. In 2016, there were 113,190 people employed as various types of drivers in the region – taxi and delivery drivers, freight and transit drivers, etc. This figure also does not include ride-share drivers whose primary job is not driving. Over time, all of these residents will have their professions transformed by the arrival of autonomous vehicles. It is important that governments and employers are prepared to retrain and reskill people for new in-demand jobs. Other related professions, such as auto service technicians (of which there are 33,430 in the region, as of 2016) will also see their roles evolve with the deployment of AVs.[56]

Still, the region's talent base is well placed for AVs. In Toronto, 64% of people aged 25 to 64 have a post-secondary education.[57] The region is home to many research institutions, such as the University of Toronto, Waterloo University, Ryerson University, McMaster University, Ontario Tech University, and York University. All of these highly regarded institutions rank amongst the top in the country and have significant science, technology, engineering, and mathematics (STEM) programs that have contributed to the 25,000+ annual STEM graduates in the region.[58]

This domestic talent pipeline, combined with an immigration system that facilitates the attraction of high-skilled foreign workers, has contributed to the region establishing itself as North America's third best market for tech talent.[59] The region has around 300,000 tech workers and added over 80,000 tech jobs from 2014-2019, making it North America's fastest growing tech market.[60] This talent pool is at the center of attracting AV investment in the region.

But existing talent pipelines will not be enough alone. Thousands of additional engineers will be required to work in the AV ecosystem on both cars and infrastructure. These people will need to be cross-functional – not just well-versed in specific auto components but also with skills in mathematics, physics, AI, robotics, data science, and software. New roles will be created like AV and EV vehicle mechanics, and remote-support staff for fleet maintenance.[61] There are already more than 213,000 estimated workers across Canada in the AV industry, with expected growth of 34,000 jobs by 2021 – double the job growth rate seen across the entire Canadian economy.[62] AVs will bring challenges to the region's employment markets but also major new opportunities. Ultimately, the AV industry can act as a key foundation to develop and attract talent which will be in-demand for industries across the region's growing innovation economy.

REGULATIONS

Creating Favourable AV Regulations and Standards

As with any emerging technology, regulations and standards are crucial in facilitating the deployment of AVs. This will be a work in progress as autonomous technologies and their use develops, but getting an innovation-friendly regulatory stance from the start will be a launchpad to help the Toronto region get ahead of its competitors internationally.

Government Regulation

In Canada, all three levels of government – federal, provincial, municipal – play an actual or potential regulatory role in governing AV operations on public roads (see figure 2). Although three levels of government dictating different aspects of AV regulation may seem daunting, the region has benefited from political will and vision to establish enabling legislation for the testing of AVs and the development of the local AV ecosystem.

Federally, Transport Canada is responsible for the Canada Motor Vehicle Safety Standards (MVSS) which outlines requirements, safety standards, technical standards, and testing methods for all vehicles manufactured in Canada or imported into Canada. Many of the AVs used in pilots are not compliant with the MVSS since they are designed and manufactured without steering wheels or brake pedals.[64] As a result, exemptions are required to import an AV into Canada for a pilot.[65] The mass deployment of AVs in the Toronto region will require these standards to be updated to encompass AVs without the need for further exemptions. As discussed further below, harmonization with the U.S. will be crucial given the integrated North American market.

Government responsibilities in relation to AVs

FEDERAL

- Setting and enforcing Motor Vehicle Safety Standards for new or imported vehicles and motor vehicle equipment
- Investigating and managing the recall and remedy of non-compliances and safety-related motor vehicle defects nationwide
- Public education on motor vehicle safety issues
- Monitoring and developing rules on privacy and cyber security
- Setting and enforcing compliance with technical standards related to wireless technologies integrated in vehicles and roadside infrastructure

PROVINCIAL/TERRITORIAL

- Testing and licensing human drivers and registering motor vehicles in their jurisdictions
- Enacting and enforcing traffic laws and regulations (including trials)
- Conducting safety inspections
- Regulating motor vehicle insurance and liability
- Public education on motor vehicle safety issues
- Adapting provincially-owned infrasctructure to support AV deployment
- Planning for future transportation projects (i.e., highway management, transit)

MUNICIPAL

- Enacting and enforcing bylaws
- Advocating for and accommodating testing
- Enforcing traffic laws and regulators
- Adapting infrastructure to support AV deployment
- Managing passenger transportation (including public transit, taxis and ridesharing services)
- Managing and creating new logistics for traffic control and parking enforcement
- Public education on motor vehicle safety issues

Figure 2[63]

Privacy is another area that is federally regulated and an area of significant public worry – over half of CAA SCO's members identified privacy concerns as an issue with AVs.[66] AVs produce huge amounts of data from their cameras and sensors over the course of just a few minutes of driving and much of this data may count as personal information under Canada's privacy law, the Personal Information Protection and Electronic Documents Act (PIPEDA). While some provinces have provincial personal information protection legislation that is deemed substantially similar, Ontario does not.[67] This may change with the provincial government currently working on its Data Strategy.[68] It is important that future provincial legislation is both interoperable with other provinces and with other international regulatory regimes, such as the European Union's General Data Protection Regulation (GDPR), and that is not duplicative of other Canadian legislation in a way that creates new regulatory burdens for businesses.

Where provinces have authority is in regulating what types of vehicles can operate on public roads. Such legislation typically includes language requiring a human driver to operate the vehicle at all times, serving as a barrier to AV deployment. Ontario was the first province to take steps to regulate AVs on public roads.[69] Since January 2019, these have been updated to permit driverless AV testing on public roads under certain conditions, as well as the testing of cooperative truck platoons, and exclusion of certain AVs from required permits if the vehicles were originally manufactured with a driving automation system and are eligible for sale in Canada.[70]

Municipalities are responsible for regulating which roadway vehicles are able to operate within their geographic boundaries through zoning. This includes dictating where and how the public transit service is operated, and regulation of taxis and ride-hailing services. Municipalities are also responsible for regulating roadway infrastructure and may take ultimate responsibility for much of the AV infrastructure that will be needed to enable an autonomous future.

It is important that future provincial legislation is both interoperable with other provinces and with other international regulatory regimes, and that is not duplicative of other Canadian legislation in a way that creates new regulatory burdens for businesses.

MACAVO: The Municipal Alliance for Connected and Autonomous Vehicles in Ontario

The Ontario Good Roads Association (OGRA) was created in 1894 to support Ontario's municipalities through education and best practices during the transition from horses to "horseless carriages" (a.k.a. cars). That transition not only brought about a tremendous transportation revolution, it quite literally transformed our cities. As we now stand at the doorstep of the next major transportation revolution, it is very much in OGRA's DNA to support municipalities to not only prepare for but also thrive in the world of self-driving transport.

To materialize this next level of support, OGRA has created a new group of municipalities under the brand of "Municipal Alliance for Connected and Autonomous Vehicles in Ontario" (MACAVO). This volunteer-based group consists of municipal leaders looking to collaborate and learn from one another, embark on diverse activities and projects, and effectively stay ahead of the curve when it comes to AV preparedness. MACAVO's most recent project is called the "Windsor-Ottawa Preferred Corridor," in which 33 municipalities participated and collectively identified over 5,000 kms of municipal roads – the longest known network of municipal roads in the world today.

Standards Development

An important element of achieving AV readiness will be through the adoption of common AV standards to encompass both the technologies in the vehicle and in infrastructure, such as 5G technologies.[71] In the absence of common standards there is likely to be consumer confusion about AVs' capabilities. It also makes it more difficult for developers and governments to procure and install the right kind of infrastructure to facilitate AVs.[72] The existence of commonly accepted international standards will be an essential prerequisite before regulations can be updated to fully encompass AVs.[73]

Canada's integration in the North American auto market, and the substantial overlap in regulations with the U.S., constrains its ability to lead the development of standards for AVs.[74] Nevertheless, initiatives are underway that will help move forward Canada's readiness for AVs. Since 2016, the Canada-U.S. Regulatory Cooperation Council (RCC), has been working to develop a Connected Vehicles Work Plan. It seeks to: "support the interoperable deployment of connected vehicles through collaborative standards development, research and testing, information-sharing, and implementation activities (i.e. security certificate management system, equipment certification, cybersecurity)."[75] Separately, CSA Group has received Transport Canada funding under the Advance Connectivity and Automation in the Transportation System (ACATS) program to develop guidelines and a standardization roadmap for the safe deployment of AVs.[76]

Insurance for AVs

As AVs become more common, an insurance system that is structured to respond to AVs will also be important. Currently, vehicles are insured under the assumption that human error is the primary cause of motor vehicle collisions. This needs to change to ensure that vehicles remain insured whether a human driver is operating it or it is driving autonomously to determine liability and make sure innocent victims of collisions receive compensation.[77] Issues with insurance implications was identified by a majority of CAA SCO members (79%).[78]

Currently, AVs on the region's roads under the existing Ontario AV Pilot Program are required to have a $5 million liability coverage, rising to $8 million if it has a capacity of 8 or more passengers.[79] In a situation where there are no commonly agreed AV standards this places insurers under a difficult burden to assess the prospective AVs and operators. The high liability requirement needed before testing approval is granted also acts as a potential barrier to entrance for AV developers who either are not able to self-insure or demonstrate the scale that makes them financially viable long term.

Moving beyond trials and pilots will require an updating of the legislative framework to account for the shifting liability caused by AVs. The U.K. has led the way with a 2018 act that established the principle that the insurer is liable whether it is operated by a driver or is in an autonomous mode.[80] This single insurance policy approach ensures that the existing automotive insurance framework remains the primary means of recovering compensation rather than through product liability against vehicle manufacturers.[81] An additional step that would support an AV-ready system would be through the sharing of data between vehicle manufacturers, regulators, and insurers to enable the quick resolution of claims and enable better regulatory decisions long term.

Figure 3: The MACAVO Map showing roads where municipalities are:

- Green: encouraging testing of AVs
- Yellow: open to AV testing in certain circumstances
- Red: discouraging testing of AVs

The selected roads shown were screen captured from MACAVO's real-time map on February 22, 2019 and may have changed partially or completely since the last screen capture.

MANAGEMENT

Developing the institutional capabilities to manage AVs

Realizing the vision for the Toronto region's autonomous future will depend on the actions of regional governments. They will set the priorities in road use and development within the region's cities and their procurement practices will guide the speed and ambition of AVs integration into public transit systems. Overcoming the barriers to governmental cooperation within the Toronto region is going to be necessary to ensure the benefits of AVs are shared.

Governmental Vision

Governments across the region need to share the vision for the contribution that AVs can make if their deployment is to be successful. In this, the region is well placed, in large part thanks to Toronto's Automated Vehicles Tactical Plan.

In October 2019, Toronto City Council approved the Plan, the first of its kind for a North American city.[82] It outlined how the city should prepare for and could influence the direction of anticipated AV technology in the coming decades and is meant to ensure Toronto is well-placed both in terms of the opportunities of AVs and in mitigating the potential risks.

The Plan adopts seven directions, each supported by specific goals, actions, and key performance indicators:

- Social Equity and Health (barrier-free access, mobility equity, and health);
- Environmental Sustainability (reducing both vehicle emissions and waste);
- Economic Sustainability (attracting industries, investment, and employment);
- Privacy (protecting the public's privacy);
- Road Safety and Security (adopting automated systems that create a net benefit to road safety and security);
- Integrated Mobility (encourage space-efficient and active modes of travel); and,
- Transportation System Efficiency (increasing system capacity and managing system demand).

While the Plan's vision is up to 2050, it also includes details on immediate steps to ensure that Toronto is AV-ready by 2022. These include five individual projects: an automated shuttle trial in Scarborough, creating transportation innovation zones for the testing and trial of AVs and infrastructure, developing AV testing response and incident preparedness (TRIP) protocols, undertaking public education initiatives, and further research and development.[83]

> **Fortunately, there is political consensus on the importance of building an AV future in the Toronto region.**

The City of Toronto's AV Tactical Plan is a welcome document to set out the city's agenda for AVs and list opportunities for private sector investment and collaboration. It is important that it continues to get support and financial backing at the levels needed if it is to translate its goals into a reality.

Political Fragmentation

While Toronto's Plan is ahead of other cities across North America, there are 34 municipalities in the greater Toronto region, and it will be crucial that there is alignment. Political and transit fragmentation increases the risk that there might be divergent aims and strategies when it comes to AVs, weakening the region's position against comparators. London, U.K., for example, is made up of 32 local authority districts but has all transportation policy across all districts under the authority of the London Mayor and the agency Transport for London. This arrangement means that there is a consistent approach to AVs in place across the entire city.[84] Similarly, in Montreal the Metropolitan Regional Transportation Authority (ARTM) is responsible for planning, organizing, financing, and promoting public transit and roads in the Montreal Metropolitan Community, an area of 82 municipalities.

Fortunately, there is political consensus on the importance of building an AV future in the Toronto region. Besides Toronto's Plan, other municipalities have made decisions relevant to planning for AVs. Both the City of Hamilton's[85] and the Regional Municipality of York's[86] Transportation Master Plans include acknowledgements that growing use of autonomous vehicles is expected during the time frames covered by the plans and that more planning is needed. Hamilton has additionally approved a Connected & Autonomous Vehicles Test Bed as part of its involvement in the AVIN Regional Technology Demonstration Sites, discussed above.[87]

Some regional planning is already underway. Under the same federal ACATS program that is supporting a standardization roadmap, Ontario's Ministry of Transportation (MTO), Metrolinx, the City of Toronto and the Region of Peel have been working on a project to establish a common and consistent planning framework for AVs in the region.[88] This work is an example of the kind of collaboration and information sharing that will be crucial if AVs are going to be successfully deployed and if the region is going to be competitive internationally as a leading place to attract AV-related investment.[89]

Cybersecurity Implications for Institutions and Governments

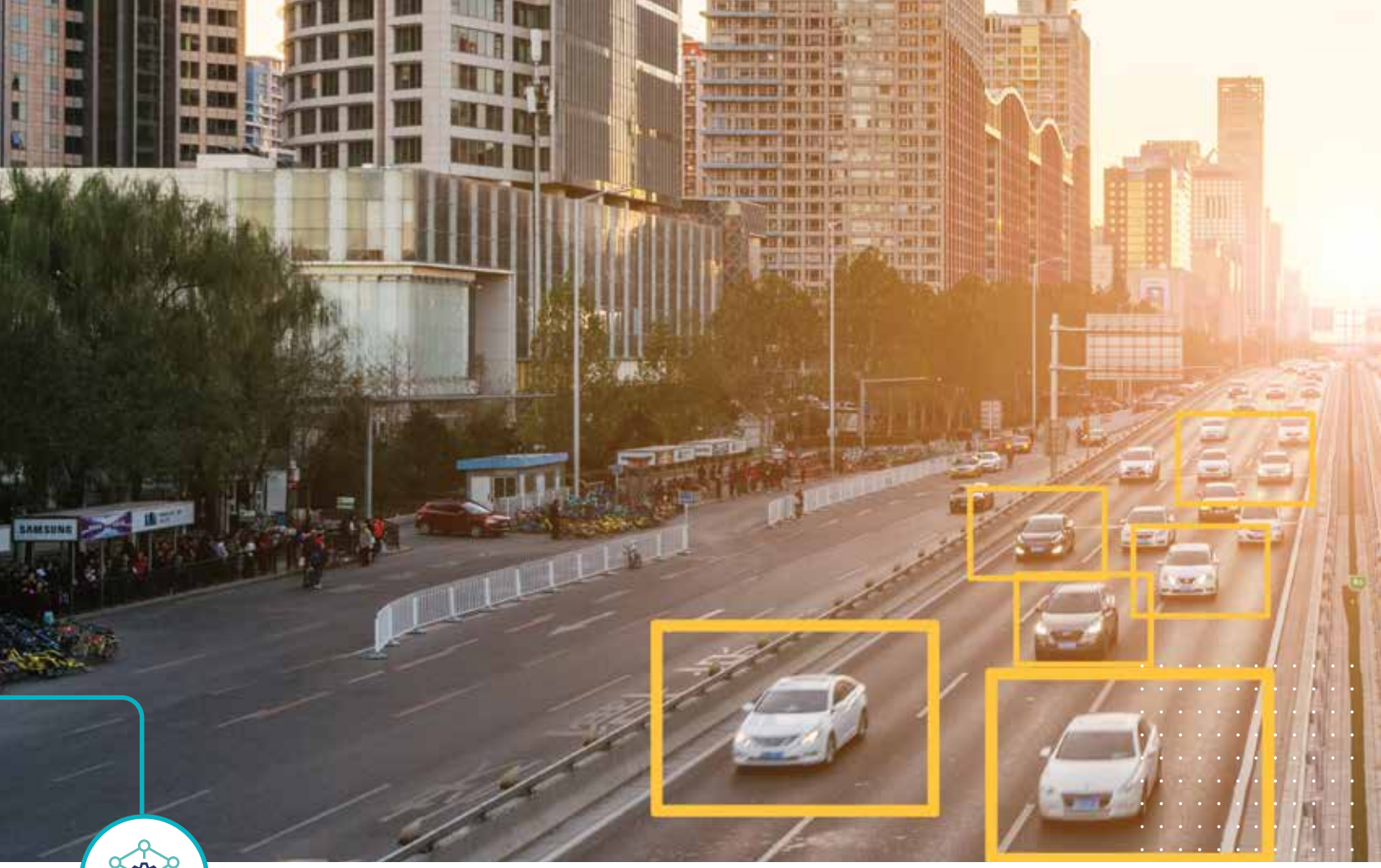
AVs are technological systems that generate huge amounts of data and as they are deployed on larger scales the risk of cyber attacks also increases.

Factors influencing cybersecurity risks in a connected city area are the:

- Convergence of the digital and physical world through linked information technology and operational technology infrastructure;
- Lack of interoperability standards to facilitate adequate communication across multi-manufacturer and multi-aged systems; and,
- Integration of multiple services across the Internet of Things (digitally connected everyday devices) and digital platforms.[90]

Cybersecurity risks will have implications for AV manufacturers, institutions, and governments. Local organizations, such as municipalities or transit authorities, will need to understand existing risks and gaps related to their operations and commercial products. Talent will need to be trained and retained to enable these bodies to meet evolving threats that might affect their vehicles, systems, and infrastructure. 69% of CAA SCO members also identified cyber security as a major area of concern.[91]

Properly addressed, known cybersecurity risks could become a regional opportunity. Given consumer demand for cyber secure vehicles and infrastructure, and a rapidly evolving threat landscape, active steps to develop the region's cybersecurity talent will help support the region's competitiveness as a place to research and deploy AVs.[92]



INFRASTRUCTURE

Building AV-ready infrastructure

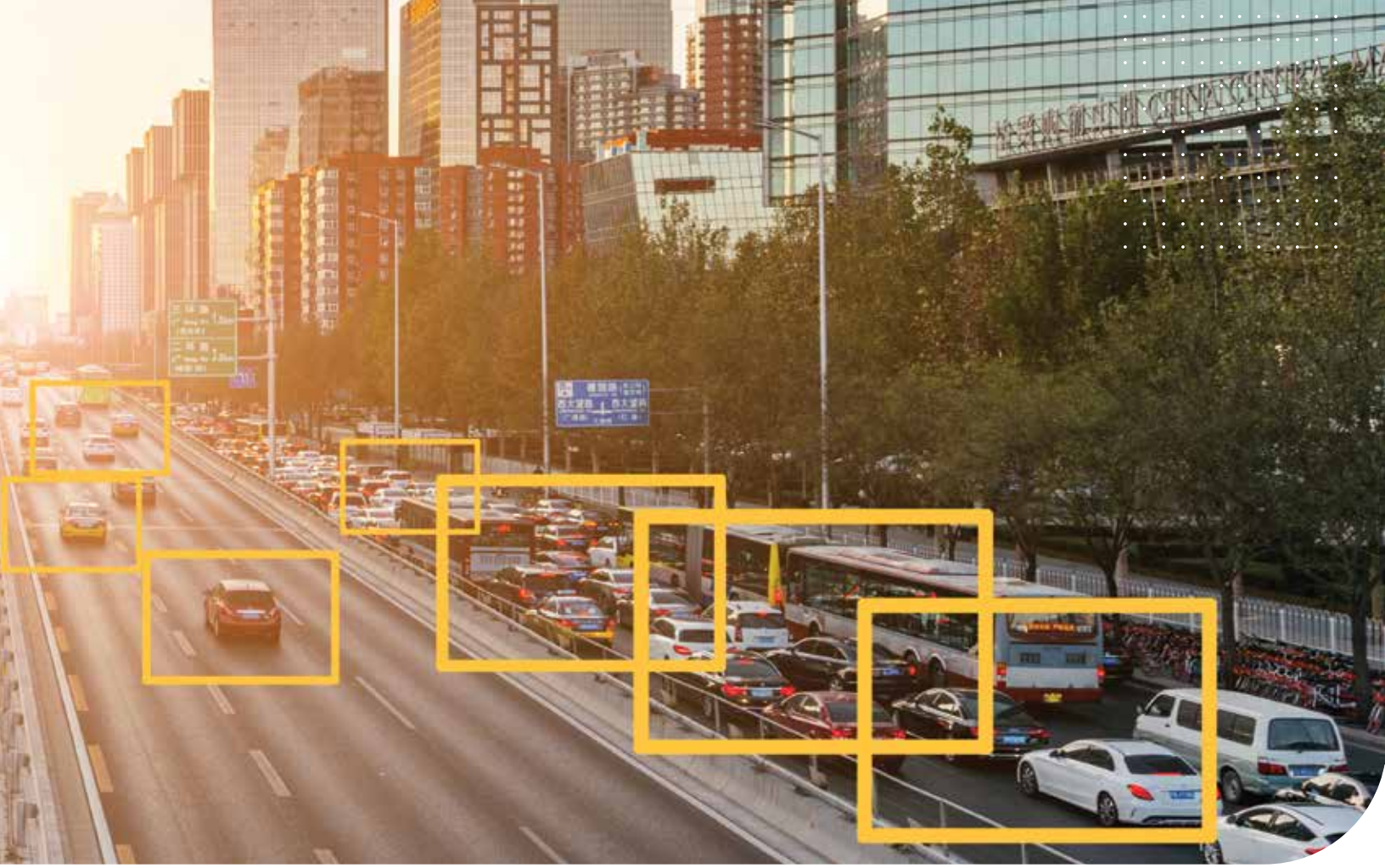
AVs are being developed for the infrastructure that exists today, but AV-ready infrastructure will have an important role to play in achieving their full potential benefits. Connectivity infrastructure will be essential for vehicles to communicate with each other, roadside infrastructure, and other road users. Continued investment in the province's clean energy grid will help deliver the environmental benefits when paired with the construction of charging infrastructure needed for EVs. Finally, it will be necessary to rethink how traditional road infrastructure is used and managed as well as how we design our region's physical spaces in general to prepare for the mass adoption of AVs.

Connectivity

At the heart of infrastructure preparedness for AVs is connectivity. Connectivity for AVs can be achieved through different technologies such as wi-fi based Dedicated Short-Range Communications (DSRC) or through cellular 5G networks. While connectivity will potentially be realized in stages, an ultimate aim will be to facilitate road safety by helping vehicles communicate with their full environment, enabling them to react to risks before they would ever be visible to human drivers.

DSRC and 5G have various advantages and disadvantages. The former is an established short to medium range communications technology, designed for vehicle-to-vehicle and vehicle-to-infrastructure communications.[93] However, its uptake has been slower than expected.[94] 5G, in comparison, is an emerging technology but one that will have transformative impacts across all sectors of the economy.[95] Crucially for mobility, 5G will have incredibly low rates of latency and increase reliability compared with existing technologies, helping ensure the safety of AVs on the region's roads.[96]

However, the infrastructure for 5G is not currently in place. While AVs may use a combination of technologies for connectivity, it is certain that the Toronto region will need to build its 5G infrastructure for connected mobility at scale. Here the region has a number of advantages. The ENCQOR 5G project is a $400 million joint initiative from the governments of Canada, Ontario, and Québec focused on research and innovation in 5G. In partnership with Ericsson, Ciena, Thales, IBM Canada, and CGI, the project established the first Canadian pre-commercial corridor of 5G digital infrastructure.[97] This is a useful step in enabling the commercialization of 5G and the rollout of 5G-enabled AVs, but it needs to be supported by continued investment, especially from the federal department of Innovation, Science and Economic Development, to ensure ubiquitous national 5G coverage.



Clean Energy Grids & Charging Infrastructure

If AVs are going to make a major contribution to reducing carbon emissions, then they need to be electric and the local energy grid needs to be clean. If the electricity fuelling AVs is not low carbon, then emissions are simply moved further upstream in the supply chain to greenhouse gas emitting power generation plants. In this instance, no real lifecycle emissions reductions occur.

The Toronto region is well placed as a jurisdiction to deploy clean AVs. In an effort to combat climate change, Ontario has invested heavily in renewable and clean energy. In 2016, the province generated 33.4% of its energy requirements from renewable sources, with 91.7% of its electricity generated using non-emitting sources.[98] All of these factors combine to establish Ontario as a leader in green electricity grids.

There is a further advantage to the electrification of mobility in Ontario: surplus baseload. The province produces more electricity than is used, amounting to a waste in 2016 of the equivalent of powering 760,000 homes for one year.[99] When supply exceeds demand, electricity generation is curtailed – a situation that will continue over the next few years.[100] Increasing the use of electricity in the transportation system, for example through the wide adoption of electric AVs, would enable the better utilization of Ontario's power generation and could actually contribute to lowering electricity bills for consumers.[101]

Aside from clean energy sources, there are other barriers to enable a transition to electric AVs. Research has identified the lack of access to sufficient and convenient charging stations has been an impediment to the adoption of electric vehicles in Toronto.[102] A high upfront cost to install charging infrastructure – between $50,000-$100,000 for the fastest chargers – has restricted their proliferation.[103] Currently there are only 143 charging stations within 15km of Queen St. & Bay St. in Toronto, with 752 charging outlets.[104] This number will need to grow significantly, including in condo buildings and residential neighborhoods, to really make electric powered mobility feasible at scale.

The City of Toronto has released an electric vehicle strategy, designed to address these and other barriers. It includes specific recommendations to speed up the development of charging infrastructure, including potential rebates or tax incentives for installing chargers. It will be especially important to ensure areas that are otherwise "transit deserts" receive charging infrastructure. Currently, the vast majority of charging stations in Toronto are clustered in the downtown core. If electric AVs are to plug some of the region's gaps in transit, then infrastructure will need to be built in those areas rather than just in areas otherwise well served by existing transit options. The strategy also includes recommendations to encourage the use of electric vehicles in shared mobility – something which would have a great deal of overlap with the increasing deployment of AVs as part of transit systems.[105]

> **Other steps to make roads AV-ready could include introducing roadside sensors on lanes, curbs, and sidewalks that would communicate with AVs and warn them of hazards.**

Preparing Physical Infrastructure for AVs

Existing and new physical infrastructure – from the region's homes and workplaces, its roads and curbsides, and its traffic lights and parking garages – will need to evolve to take account for the deployment of AVs. This built environment is one that has been primarily designed around traditional cars. It is estimated that there are between 4-8 parking spots for every car in North America and that these cars are parked 95% of the time.[106] While Toronto itself has maintained a relatively rare position in North America with a dense downtown population and a large transit system, the wider region is often much more dependent on cars, illustrated by the number of car commuters.[107]

As AVs are deployed in greater numbers, the built environment will need to evolve over time. Roads need to be designed to be as efficient as possible with AVs. Updated road markings are one necessary step. Bad weather, such as snowfall, can make it difficult for lasers and radar to read the road.[108] Here, technologies such as machine-readable, radar-reflective road markings made out of plastic can make roads safer for AVs. Markings such as these are already being trialled in the region on Highway 407.[109] Other steps to make roads AV-ready could include introducing roadside sensors on lanes, curbs, and sidewalks that would communicate with AVs and warn them of hazards.[110] These initiatives should be integrated in Intelligent Transportation Systems (ITS). Already being used on roads across the world to manage traffic flows and provide predictive insights around travel times, construction and weather implications, ITS will be an important enabler of the mass deployment of AVs.[111]

Including these innovations in existing roadside infrastructure will take a long time but planners need to be considering these requirements for future developments immediately. How risk is assessed in procurement might need reconsidering, weighing the uncertainties of the exact shape of an autonomous future against the potential of first-mover advantage and the pressing need to prepare.

Preparedness can be accelerated through the use of dedicated AV lanes. Already China is beginning to pilot dedicated AV lanes on newly built highways that incorporate connected sensors.[112] As is explored further below, toll roads in the region, such as Highway 407 ETR, could provide ideal testbeds to roll out these technologies given they are environments with controlled entrances and more sensors than most other parts of the road network.[113]

Rolling out AV technology in public transit ahead of wider adoption is another potential avenue for the region to become an autonomous leader. Autonomous technology is well established in transit. For instance, the Skytrain in Vancouver is one of the oldest and longest fully automated rapid transit systems in the world.[114] Recent years have seen an acceleration of these projects, with fully automatic metro lines expected to account for 48% of new project kilometers by 2022 versus 10% in 2018.[115] Rail projects are in many ways simpler to automate, given their fixed route and more restricted operational environment.

A final infrastructure preparedness issue is the design of homes and workplaces across the region. Whereas previously a parking garage might have been the standard addition to a new-build house, much like a parking lot by the local train station, the wide adoption of AVs, especially in ride-sharing fleets, presents new possibilities and needs for urban design. Currently a normal two-way street uses 60% of its space for cars (either driving space or parking), rising to 90% on busier thoroughfares.[116] In an AV future, this ratio could be flipped. Innisfil's proposed new community to be built around a new GO station offers a vision for what an urban space that puts shared mobility and autonomy at its heart could look like.[117] Instead of parking, space will be set aside for accessible drop off points for AVs. Charging infrastructure will need to be included from the start, in homes and in public spaces. With Toronto being the fastest growing city in North America, there is an urgent need to build new homes for the region's residents and it is important these developments are planned from the start with an autonomous future in mind.[118]

Making Highway 407 ETR the "AV Highway of the Americas"

Action is needed on a broad range of fronts to make the Toronto region AV ready. But these do not have to happen in a piecemeal way. There are already existing smart assets that can and should be leveraged to accelerate the pace of AV adoption.

One bold way to do this would be to make Highway 407 ETR the "AV Highway of the Americas." Operated and managed by 407 Express Toll Route (ETR), the highway is already a technological trailblazer as the world's first electronically operated toll highway. With over 1,000 cameras that make use of an extensive fiber optic network, it is a controlled highway unlike other provincial roads. Monitored around the clock by 407 ETR staff, and stretching across the region for 108 kilometres, it is a regional asset ready for the testing and deployment of AVs unlike any other.

Designating the 407 ETR as an AV highway, with AV-ready infrastructure and eventually a dedicated AV-only lane, would put the Toronto region ahead of any other city in North America. Making the highway a testbed for roadside infrastructure that is connected and communicating with AVs, as well as for the use of AVs itself, will give the region a significant advantage over competitor jurisdictions for AV investment and jobs, especially as companies seek to test their technology in adverse weather conditions.

This designation should be done with a platform approach, one that would enable interested AV companies to test vehicles and infrastructure at scale with reasonable commercial terms. At a time when standards for AV-ready infrastructure are still in development, their use across the 407 ETR will help set the pace and enable companies to hone their products in a way smaller trials could not, also helping homegrown AV developers reach scale and financial viability faster than they could have otherwise.

Similarly, a project of this scale would be a game-changer in the development of AV talent and skills in the region. The creation of the AV highway should be paired with a strong skills component that supports both research-focused talent and helps provide pathways for existing workers to develop new AV skill sets.

Given the 407 ETR crosses multiple municipalities across the region, the highway's on and off ramps can be the launching point for these municipalities to build out their own AV test sites on complex urban streets. AV-ready intersections can be installed around these ramps as the foundation for wider AV designated zones. The 407 ETR can become an artery for AV-enabled transit across the region, and AV corridors can extend from the highway into municipal transit hubs to help provide additional connectivity to the region's residents. By embracing the potential of AVs in freight, for example through truck platooning, the 407 ETR can also bring about new solutions for the movement of goods.

The 407 ETR can become an artery for AV-enabled transit across the region, and AV corridors can extend from the highway into municipal transit hubs to help provide additional connectivity to the region's residents.

Finally, an AV highway would also provide the opportunity to build a regional AV data trust that would support responsible data use and trusted sharing of non-proprietary data. The ability of transit authorities, municipal planners, AV manufacturers, infrastructure providers, insurers, and other stakeholders to access data generated by AVs will be important in enabling informed decision making to improve safety and cut congestion, among other benefits. This could also become a platform for developing the cybersecurity resilience that will be essential to the safe use of AVs.

Making the 407 ETR the "AV Highway of the Americas" is an important step to enable AV readiness in the region and to propel Toronto into the top tier of global smart cities.

Summary of Recommendations

A balanced focus across the four pillars of people, regulation, management, and infrastructure is necessary to ensure the Toronto region is one of the first places in the world to deploy AVs at scale. Below, 20 recommendations are outlined to the Government of Canada, Government of Ontario, municipal governments from across the region, as well as to business directly. Decisive action on these will firmly place the Toronto region amongst the top ranks of innovative cities globally.

PEOPLE

1. Increase federal and provincial investment into graduate training programmes across the Toronto region to develop and expand the talent pipeline in AV-related subjects. Where possible this should leverage private investment and partnerships, such as with the Vector Institute.
2. Businesses, supported by the Government of Ontario and regional post-secondary institutions, should provide the pathways for existing workers to develop new AV technology skill sets. Post-secondary institutions also need to proactively embed in curricula an understanding that re-training will be a career-long requirement given the increasing speed of technological change.
3. The Government of Ontario should create a Toronto Region Autonomous Vehicle Skills Institute that is designed to provide undergraduate, post-graduate, on-the-job, and life-long learning opportunities on AV-related topics, either within an existing post-secondary institution or as an online portal.
4. Federal, provincial, and municipal governments should commit to a concerted and continual effort to ensure that the public is well educated about what to expect from AVs on the region's roads and take into consideration public concerns when drafting AV related policies. This should include the funding of public education initiatives such as the Transport Canada-funded CAA website on autonomous vehicles as an important myth-buster on AVs.[119]

Post-secondary institutions also need to proactively embed in curricula an understanding that re-training will be a career-long requirement given the increasing speed of technological change.

REGULATION

5 All levels of government share a degree of regulatory responsibility for AVs and must ensure relevant regulations are updated to allow for the rapid technological advancements in mobility brought about by AVs. Most notably, the federal MVSS should be updated to allow for AVs without the need for exemptions.

6 Canada alone cannot set the pace on AVs. Federal departments, such as Transport Canada, and agencies, such as the Office of the Privacy Commissioner of Canada, should collaborate in the development of standards and regulations with other Canadian public bodies and their international partners to ensure their interoperability. The Canada-U.S. Regulatory Cooperation Council is a good example of proactive international collaboration that moves forward AV deployment.

7 The Office of the Privacy Commissioner of Canada and the Privacy and Information Commissioner of Ontario should work proactively with the AV industry, governments, and insurers to ensure there is a supportive legal framework and clear industry guidance in place to enable AV data sharing with accountability on its use.

8 Technical and skills capacity should be built within the region's governments and transit bodies to enable data collection and analytics from smart technologies across the Toronto region to optimize the transportation network. Municipalities and other stakeholders should explore the feasibility of a regional AV data trust to support responsible data use and trusted data sharing.

MANAGEMENT

9 Municipalities, the Government of Ontario, the Government of Canada, transit operators and AV companies should build off ACATS funded work to establish a consistent regional dialogue around shared learning and perspectives to maximize the potential economic and societal benefits and avoid private and public or inter-governmental fragmentation.

10 A single point of contact in municipalities should be named to deal with industry interaction to provide a straightforward and navigable system. Furthermore, approval decisions for trials should be made in a timely manner.

11 Regional institutions and governments should conduct training efforts to understand cybersecurity risks, including an overview of an organization's cybersecurity responsibilities and an understanding of how to integrate purpose-built privacy and security designs into all commercial products or services, including vehicular products and transportation services.

INFRASTRUCTURE

12 All levels of government should agree on an industry-informed shared directive to enable 5G networks for AVs. The federal 5G auction should be timely and ensure competition and choice to help make 5G services accessible.

13 Federal automotive standards should prioritize low latency as a crucial enabler of safe AVs and all levels of government should help support and facilitate the building of the local cellular networks that will be essential for this.

14 The Government of Ontario and the electricity sector should set a policy goal to maintain or increase its supply of non-emitting electricity to ensure that emissions from electric AVs are not just moved from the tailpipe to the power station.

15 Municipalities across the region should use regulatory and planning levers and financial incentives to encourage the installation of electric-charging infrastructure in new and existing developments. Emphasis should be placed in building charging infrastructure in areas that are "transit deserts" that could benefit from AVs for first mile/last mile transit.

16 Building on recommendation 8, data collected in an AV data trust should be used in a responsible way to begin mapping, modelling, and assessing the zoning of AV thoroughfares, including AV dedicated lanes and streets or other AV allocations of city space.

17 Municipalities and other stakeholders should leverage federal and provincial infrastructure funding in order to build-out smart-enabled roadways.

18 Existing and expanding intelligent infrastructure should be used to hasten the deployment of AVs and supporting technology. This could include using smart assets in the region as testbeds for AVs and AV enabling roadside infrastructure. Highway 407 ETR should be the first example of this.

19 Regional transit authorities should explore where they can procure and deploy autonomous technologies on their vehicles to improve safety and efficiency. Transit expansion projects should incorporate AV transit corridors and new stations should include AV-ready accessible drop off points.

20 Municipalities should work with industry to ensure the region is building AV-ready homes and workplaces designed to utilize the potential of AVs to cut congestion and improve safety.

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