

ONTARIO

CAV ECOSYSTEM ANALYSIS

2019



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Introduction

With the employment of 205,000+ technology workers in the Toronto-Waterloo innovation corridor alone, second only to Silicon Valley in North America, Ontario has an outstanding history of success in both the automotive and technology industries.¹

Despite the downward trend in automotive manufacturing, Ontario has effectively leveraged its automotive history and strong position in technology development to become a key player and leader in the development of cutting-edge connected and autonomous vehicle (CAV) technologies.

With the advent of these technologies, Ontario has a strategic opportunity to establish its leadership in this emerging field by combining its existing automotive and technology industry expertise with the availability of local supply chains supported by continued research and innovation.

WSP has been retained by the Ontario Centres for Excellence (OCE), and its Autonomous Vehicle Innovation Network (AVIN) initiative, to provide an overview assessment of the CAV ecosystem in Ontario.

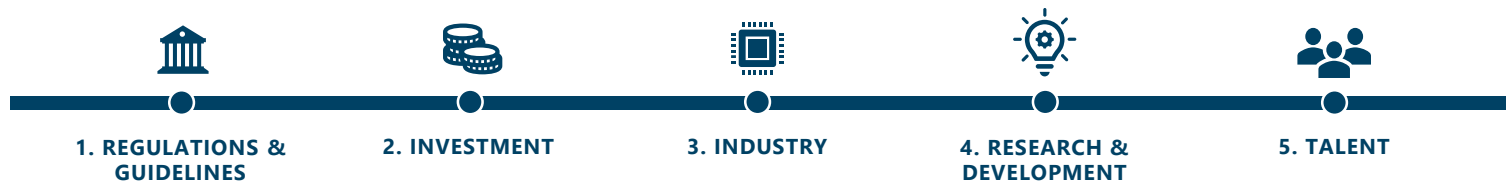
The findings of the study, contained within this report, describe key industry trends in Ontario and globally, and show how Ontario can continue to enhance its strength in the CAV sector.

The report comprises four main sections:

- Background information on CAVs and the Ontario CAV sector;
- A review of Ontario and global CAV activities and initiatives;
- A summary of key findings from the review; and
- A summary of AVIN's role in supporting the Ontario ecosystem.

The findings presented in this report are not intended to be exhaustive, but to provide a strategic overview of key players, initiatives and programs, and high-level inventory of the Ontario ecosystem.

This report reflects our analysis of primary and secondary research, which follows an evaluation framework that comprises five critical and interrelated elements of an attractive and competitive CAV ecosystem.



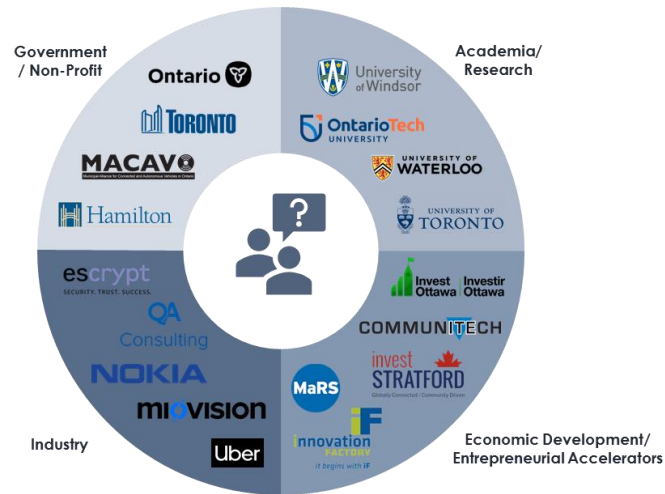
Methodology

Primary research was conducted through a series of industry stakeholder interviews and an online survey. Key players in the Ontario CAV sector provided first-hand and demonstrable insights including:

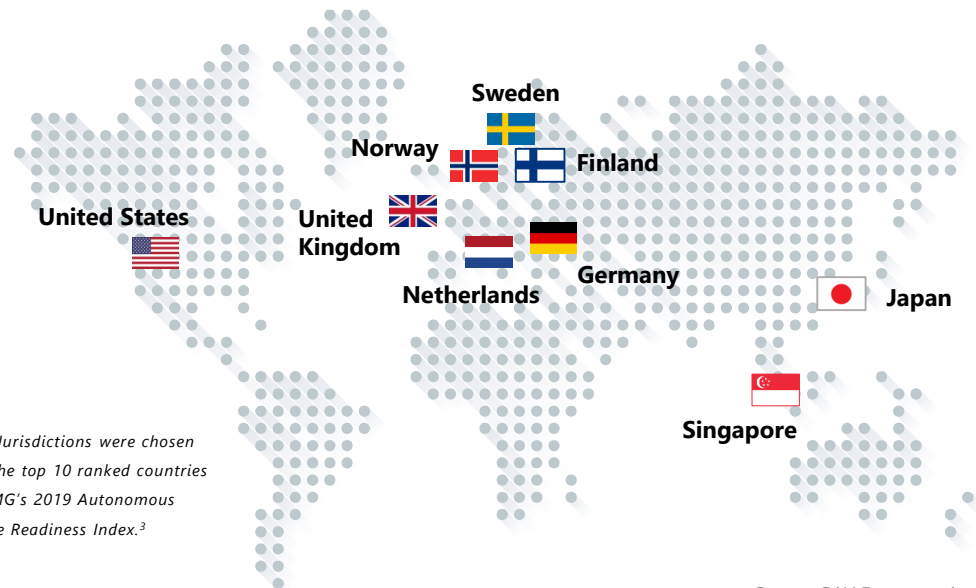
- Current and planned activities, as well as technologies and service offerings, that enable the sector.
- Motivations for pursuing CAV initiatives, specifically in Ontario.
- Scope of resources dedicated to CAV activities and pursuits.
- Strengths and challenges that the sector is currently facing.
- Vision for the future, and opportunities to enable and expand the Ontario CAV ecosystem.

Insight provided from the interviews has been augmented and reconciled with information gathered through parallel secondary research efforts, including a literature review and jurisdictional scan.

Agencies and Organizations Interviewed



Jurisdictions Reviewed



Note: Jurisdictions were chosen from the top 10 ranked countries in KPMG's 2019 Autonomous Vehicle Readiness Index.³

What are Connected and Autonomous Vehicles?

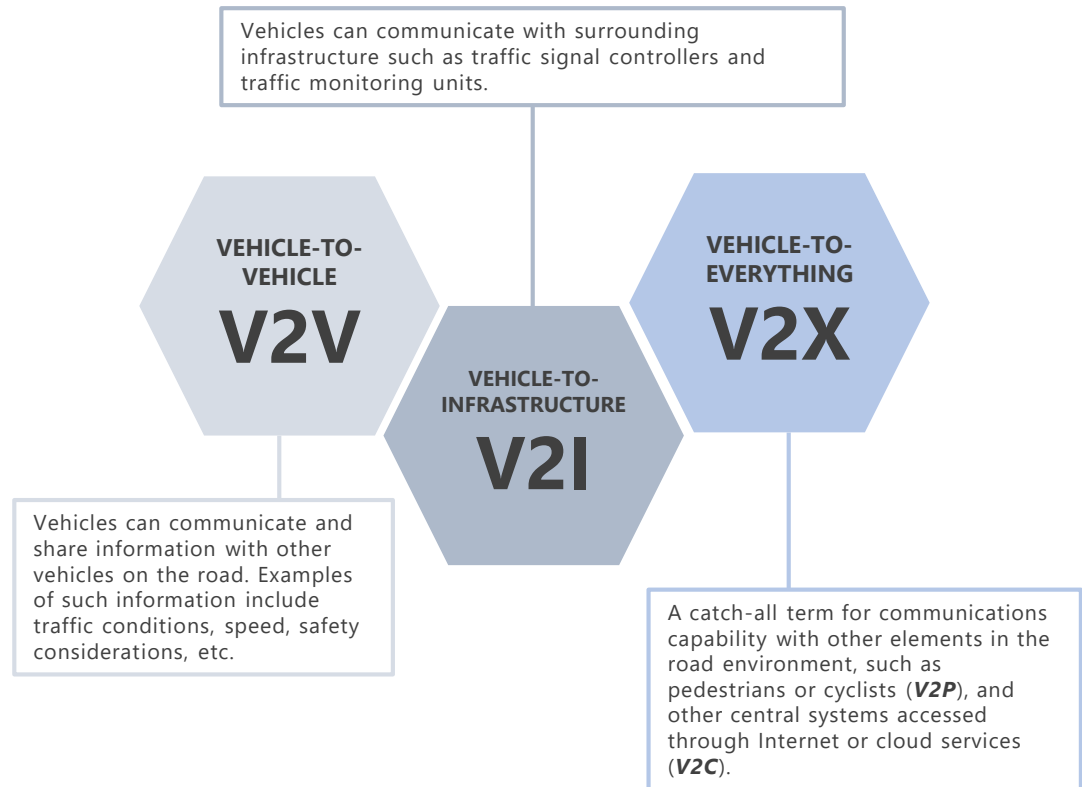
Connectivity and autonomy are two distinct but related main streams of technology.

Connected Vehicles

Connected Vehicles (CVs) are able to gather information from and communicate with other vehicles and their surroundings (e.g. infrastructure, pedestrians/cyclists), enhancing safety and mobility. CVs can provide useful information to surrounding vehicles to help make safer and more informed decisions.²

Connectivity is achieved through established communications technologies, including Dedicated Short-Range Communications (**DSRC**) and cellular communications. Cellular connections, commonly referred to as Cellular Vehicle-to-Everything (**C-V2X**) may use either 4G LTE (Fourth-Generation Wireless Long-Term Evolution) or next generation 5G (Fifth-Generation Wireless) networks.

Vehicle Communication Types



Autonomous Vehicles

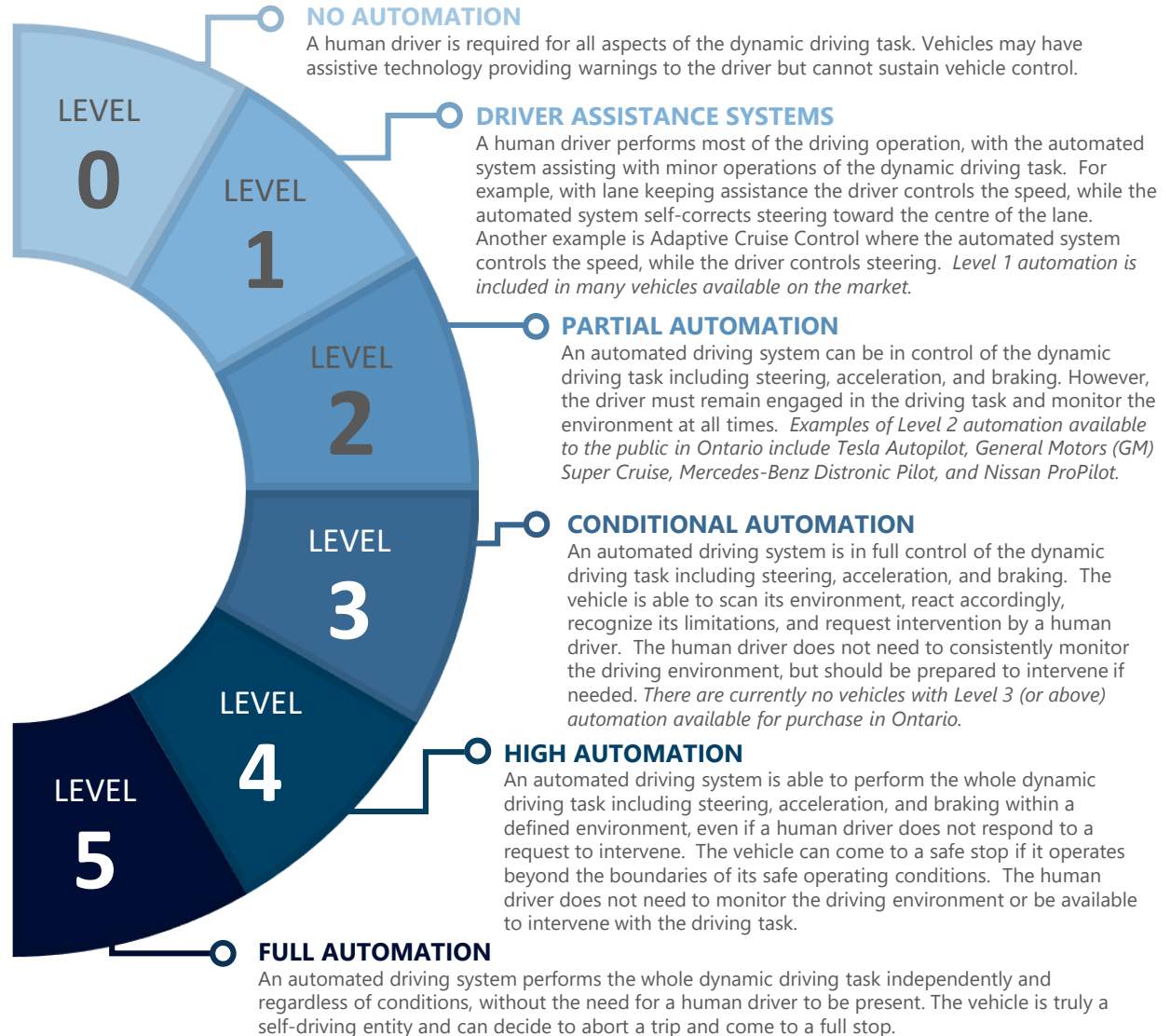
Autonomous Vehicles (AVs) are equipped with onboard equipment (e.g. cameras, LiDAR, radar) to sense the surrounding environment without necessarily communicating with other vehicles or surrounding infrastructure.⁴

An AV combines data and intelligence from its equipment to automate various aspects of the dynamic driving task and navigate through the road network.

The Society of Automotive Engineers (SAE) has categorized AVs into six levels of automation ranging from no automation (Level 0) to fully autonomous (Level 5).⁵

Note: The term 'AV' used throughout the report refers to Level 3 automation and above.

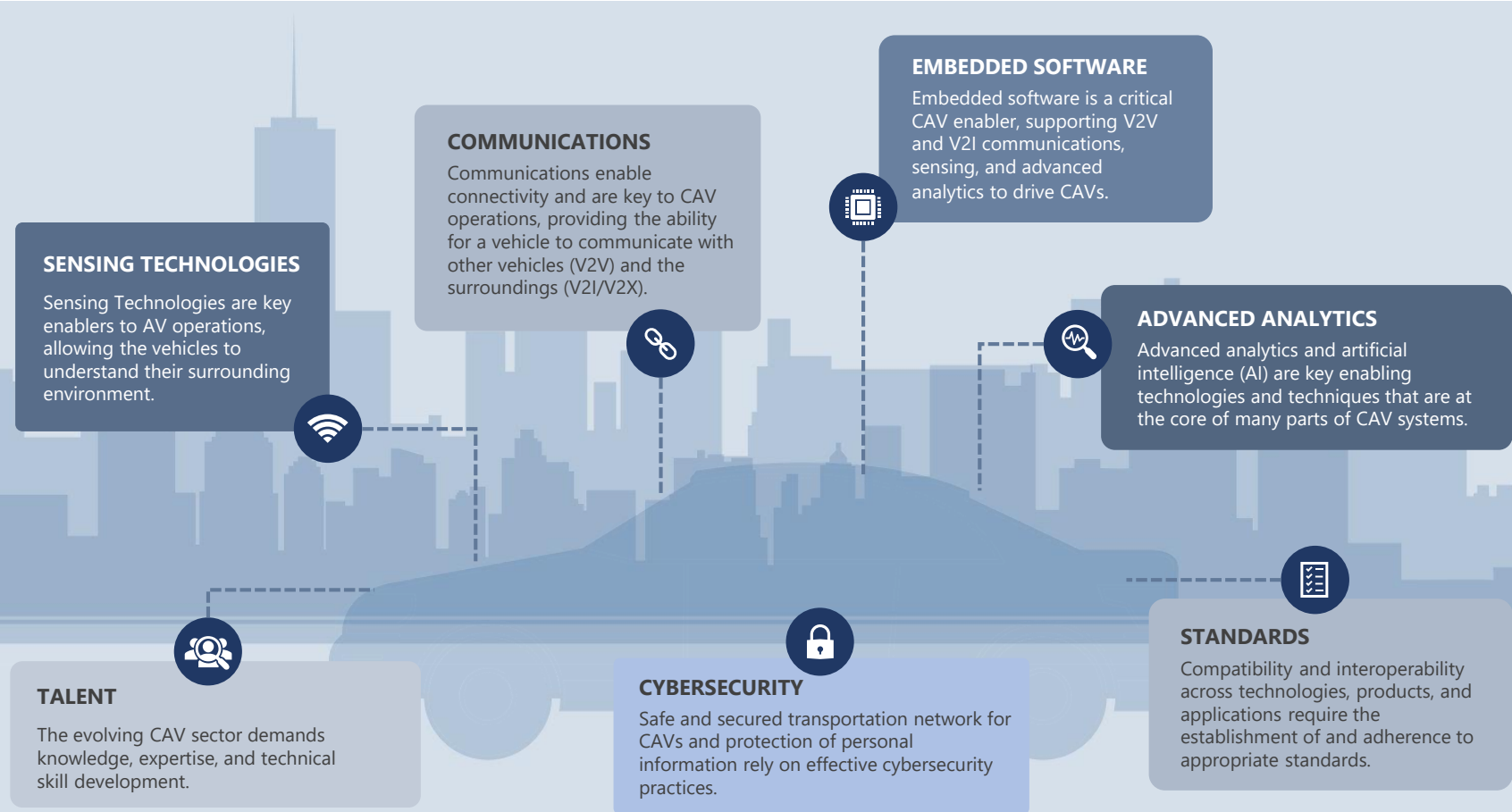
SAE Levels of Vehicle Automation



Connected and Autonomous Vehicles

As CV and AV technologies are complementary, it is most likely that combined CAVs will be much more prominent in the market in the future than separate CV and AV offerings. For that reason, this report focuses on the combined CAV ecosystem, and its primary enabling technologies and critical considerations.

CAVs Key Enabling Technologies and Considerations



COMMUNICATIONS

Communications enable connectivity and are key to CAV operations, providing the ability for a vehicle to communicate with other vehicles (V2V) and its surroundings (V2I/V2X). Critical protocols and network technologies include:

- **DSRC (Dedicated Short-Range Communications):** a technology for vehicle-related wireless communication; industry-proven through a wide range of applications, including tolling and transit signal priority.
- **4G LTE (Fourth-Generation Wireless Long-Term Evolution):** the current standard for wireless broadband communication, with wide network coverage in Ontario.
- **5G (Fifth-Generation Wireless):** the next generation of wireless broadband communication, with promises of lower latency and increased bandwidth and reliability over 4G LTE.

In North America, standards and deployed pilots have focused on DSRC, in part due to its proven and demonstrable performance. More recently, an increasing number of industry and transportation professionals are advocating that connectivity be achieved through 5G, in part due to benefits for wide area V2X and improved performance.

SENSING TECHNOLOGIES

Sensing Technologies are key enablers to AV operations, allowing vehicles to understand their surrounding environment. Relevant technologies include:

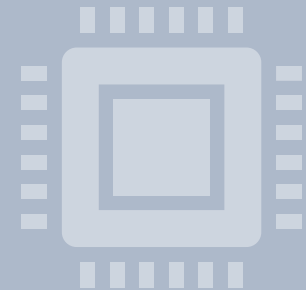
- **Cameras:** passive sensors providing video images (e.g. front view, rear view, and 360°). Because cameras represent light reflected by the surrounding environment, their performance is impacted by environmental conditions including darkness, rain, etc. Camera images generally need to be interpreted through AI to detect and classify objects.
- **Radar (Radio Detection and Ranging):** the detection and localization of objects using radio waves. Although a radar has a limited ability to classify objects, it provides accurate distance estimation to a detected object, and its performance is not affected by the environment. VORAD (Vehicle Onboard Radar) is the common term for radar used in the automotive industry.
- **LiDAR (Light Detection and Ranging):** a laser-based sensing system that emits laser beams at eye-safe levels, used to construct precise and highly accurate 3-D maps of surrounding environments. LiDAR provides accurate distance estimation, and through AI, can detect and classify objects.

Passive sensors sense and measure naturally occurring energy (e.g. cameras sense reflective light). Active sensors, such as radar and LiDAR, provide their own energy source (e.g. radio waves, laser light).

EMBEDDED SOFTWARE

With innovations in V2V and V2I communications and sensing technologies, as well as AI and data analytics, embedded software is a critical enabler to the successful development of CAVs.

Embedded software is computer software written to control machines or devices that are not typically thought of as computers, commonly known as embedded systems. In vehicles, the embedded software is rugged in nature and written for the specific hardware of the vehicle, and can be used for a variety of purposes, such as safety management, engine control, networking, and infotainment. Modern vehicles rely on a steadily increasing number of microprocessors, and a corresponding increase in embedded computing, to support features such as electronic stability control, anti-lock braking systems, collision avoidance, and adaptive cruise control.



ADVANCED ANALYTICS / ARTIFICIAL INTELLIGENCE (AI) / MACHINE LEARNING (ML)

Advanced analytics and artificial intelligence (AI), including machine learning (ML), are key enabling technologies and techniques at the core of many parts of CAV systems. They are responsible for analyzing sensor data, visualizing the surrounding environment, predicting behaviours, and guiding vehicle movements.

Advanced analytics refer to a wide range of analytic tools and techniques, and cover a wide range of analytics, including descriptive, diagnostic, predictive, and prescriptive.

AI is a subset of advanced analytics that simulates human intelligence, and aims to replicate the ability of humans to analyze data, draw conclusions, and interact with humans in a human-like way.

ML is a category of AI, where the system is able to automatically learn, improve, and optimize through experience. By being able to learn and adapt on its own, ML allows predictions to be made at a scale and speed not possible for human analysts to achieve.

CYBERSECURITY

Cybersecurity is vital for the development of a safe and secured transportation network for CAVs, and the protection of personal information.

Cybersecurity protects connected systems, networks, data, and programs (including software and hardware) from cyberattacks, and prevents sensitive information from being tampered with.

With large quantities of data and information being created and stored by CAVs, as well as increased connectivity between transportation infrastructure, cybersecurity is becoming ever more critical and important. Without robust cybersecurity protections, systems and networks are vulnerable to the threat of disruption due to cyberattacks, data theft, and potentially the failure of autonomous driving systems and smart road infrastructure.

STANDARDS

Standards are critical building blocks in the facilitation, development, and deployment of CAVs. They support the compatibility and interoperability across technologies, products, and applications.

Standards are documented specifications and procedures that ensure reliability of materials, products, processes, and services.

A wide range of standards are pertinent to CAVs, including communications protocols, data formats and definitions, security and safety, performance, testing methodologies, and infrastructure and geometric design.

TALENT

Knowledge, expertise, and technical skill development is critical to the success of an evolving industry such as CAVs.

The development of new innovative technologies depends on ready access to talent with the necessary education, training, and skillsets required by industry. Attracting international talent is also a key contributor to the industry. Priority areas of advanced expertise, knowledge, and skills include emerging areas such as embedded software development, AI/ML, and cybersecurity.

Key Players

The key players in the Ontario CAV sector can be aggregated into four categories (see pages 14 – 34 for a more detailed description of specific activities and contributions).

Government

The *Federal Government* plays a large role in national vehicle safety standards, ensuring the security of the transportation network and overseeing telecommunication infrastructure.

The *Provincial Government* and *Municipal Governments* are responsible for the provincial highway network and their local transportation networks, respectively. They are also responsible for the safe and effective integration of CAVs with their infrastructure and with the management of their traffic and transit.

The *Provincial Government* is also responsible for setting the rules of the road in Ontario, as well as, for supporting a strong, innovative economy.



Industry

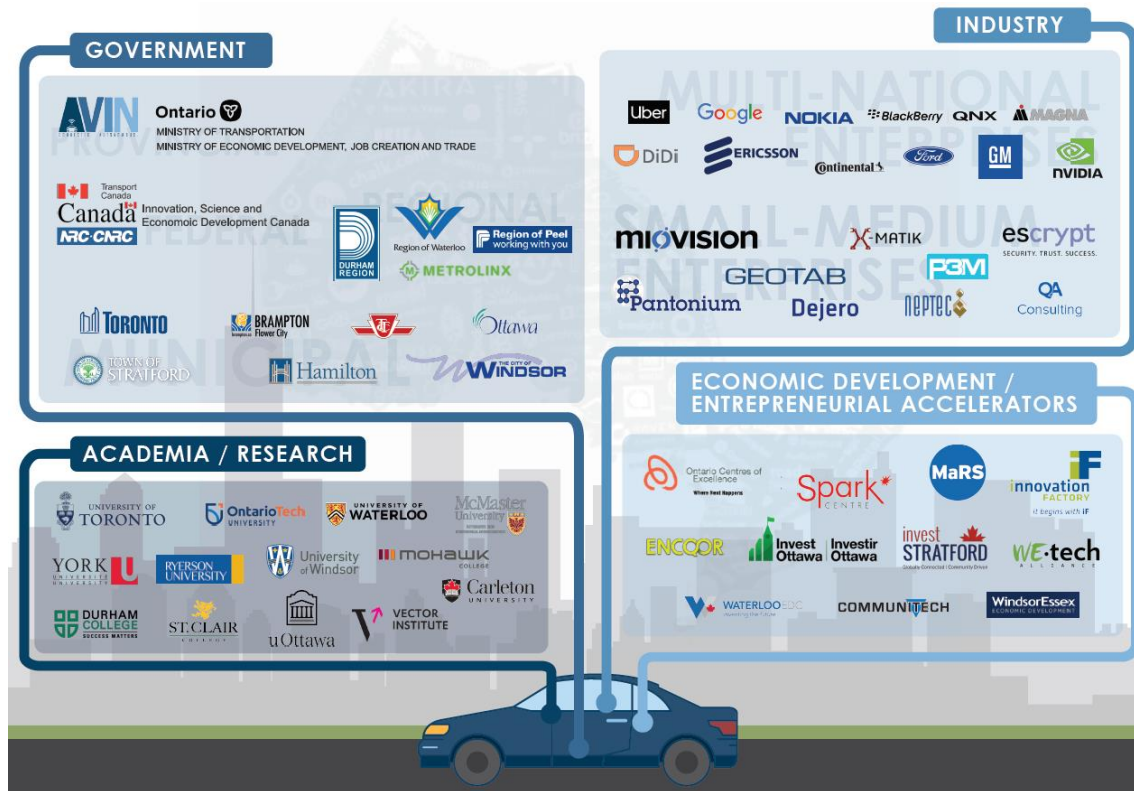
Industry priorities are the development of supporting and enabling technologies and the expansion of CAV-related products and services. Players in this group range from *Small-Medium Enterprises (SMEs)* to large *Multi-National Enterprises (MNEs)*.

Academia / Research

Universities and colleges have developed research programs in collaboration with industry partners and government agencies, enhancing capacity to train the next generation of skilled workers. In addition to its academic institutions, Ontario is home to research centres, which run research programs and activities in affiliation with industry and universities.

Economic Development / Entrepreneurial Accelerators

Economic development and entrepreneurial accelerators support companies to advance in their field of specialization. Accelerators provide organizations with business advisory services, assist with the identification of funding opportunities, and connect them with talent to grow their employee base.



Note: the diagram above is not intended as a full representation of all key players in the Ontario CAV Ecosystem.

Potential CAV Impacts

Globally, over the past number of years, it has become accepted wisdom – within both the public and private sectors – that CAVs will be a major disruptor to the current transportation network and the economy. What that future will look like, and how quickly it will happen, remains unclear and a source of extensive discussion.

CAVs have the opportunity to introduce many benefits, including an increase in traffic capacity of existing roadway infrastructure, improved traffic flow, improved safety, improved fuel efficiency and, ultimately, an overall reduction in Greenhouse Gas (GHG) emissions.⁶

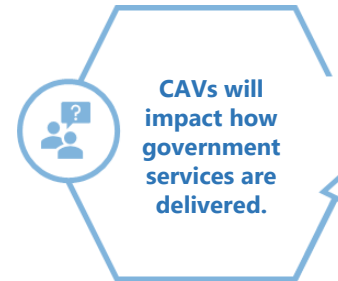
In Canada, CAVs could reduce collisions by more than 90% and save \$37.4 BILLION in monetary costs (does not include societal costs).⁷

The impact of CAVs on traffic congestion is a known topic of debate. CAVs could potentially increase demand and induce increased vehicle kilometres travelled (VKTs) on the road, which could result in increased congestion. Conversely, it is possible that the improved efficiency of CAVs could support higher throughputs on transportation networks, offsetting the effects that increased demand could otherwise have on congestion.⁷

The fabric of urban environments also stands to change as a result of CAVs. Potential decreases in vehicle ownership are expected as a result of individuals using shared vehicles for trips through third party transportation network companies. This could result in a reduced demand for parking and the subsequent repurposing of land in dense urban cores.⁸



A CBC study indicated that through reduced congestion and improved fuel efficiency, CAVs have the potential to reduce the fuel costs, in Canada, by \$2.6 BILLION.⁸



It is expected that there will be a delay between when CAVs are widely available for purchase in the market and when consumers will actually trade in their conventional vehicles for CAVs. There is limited consensus on the adoption rate of CAV technology, with estimated penetration rates typically ranging between 10% and 50% by 2035. Generally, industry estimates of CAV adoption are more optimistic on

the availability of the technology and the timing of adoption, compared to academic sources. Academic sources tend to be more conservative in their predictions which reflect statistical models, stated preference surveys, the current state of the technology, and the projected evolution of transportation authorities' infrastructure and policy.

The impact of CAVs with respect to economics, safety, and the environment will likely be greatest with heavy vehicles and, as such, the adoption of CAVs in the goods movement and transit agencies will likely progress differently than those for personal use.

Moving forward, as wider CAV adoption is realized, and depending on the operational and technical needs as CAV technologies evolve, infrastructure changes and modifications are likely to be needed, and may include:

- Changes to signing and lane markings to support autonomous driving.
- Integration with traffic signals and other control devices to enhance safety and better manage traffic.
- Dedicated lanes and/or facilities for CAVs.

Note: all monetary values mentioned in this report are in Canadian Dollars (CAD) unless otherwise specified.

Consumer Acceptance

The successful development, deployment, and adoption of CAVs rely heavily on public acceptance of the use of the technology and willingness to change their travel behaviour. In turn, consumer acceptance will reflect perceptions about CAV privacy, reliability, safety, and cost.

Key Research Studies

To better understand the consumer acceptance of AVs in the Greater Toronto and Hamilton Area (GTHA), *Transform Lab at Ryerson University* carried out the study *Autonomous Vehicles: Public Policy Considerations and Consumer Interest in the GTHA*, funded by the City of Toronto and Metrolinx. Its findings reflected consumer surveys with over 3,200 participants, ranging in age from 18 to 75, conducted in November 2016, and five focus group studies held in mid-2017 and early 2018.^{11, 12}

“ Focus group participants showed interest in, and **ARE WILLING TO USE, OCCASIONALLY** but are also apprehensive of AVs and **NOT PREPARED TO FULLY ADOPT** broader behavioural changes. ”

– *Driverless Cars in the Greater Toronto and Hamilton Area: Focus Group Findings from 2018*¹¹

“ **HALF** of survey respondents are interested in using AVs. Most respondents are willing to adopt AVs, depending on the **PRICE.** Approximately, **1/3** of respondents indicate interest in sharing an AV with another passenger at a **REDUCED PRICE.** ”

– *Automated Vehicles in the Greater Toronto and Hamilton Area: Overview from a 2016 Consumer Survey*¹²

Canada's AV consumer acceptance was ranked **7 OUT OF 20** and **11 OUT OF 25** countries, in 2018 and 2019 respectively.



– KPMG, *Autonomous Vehicle Readiness Index 2018 & 2019*^{9, 3}

KPMG carries out an annual *Autonomous Vehicles Readiness Index* report, which includes an assessment of consumer acceptance.^{9, 3} In 2016, the *Traffic Injury Research Foundation (TIRF)* also conducted a national survey on driver knowledge, attitudes, perceptions, and practices relating to AV.¹⁰

“ Many Canadians did not anticipate much learning needed to operate an AV. Canadians think it is more **STRESSFUL** to ride in an AV than relaxing, and demonstrated a **LACK OF AV KNOWLEDGE.** ”



– *Traffic Injury Research Foundation, "Senior Drivers & Automated Vehicles: 0 Knowledge, Attitudes & Practices," 2018*¹⁰

Conclusions

Consumers are getting more comfortable and showing an increase in AV acceptance, but clearly there is still a lot of work to be done to educate consumers.

The Autonomous Vehicle Innovation Network (AVIN)

AVIN is a key part of Ontario's auto plan, "Driving Prosperity - The Future of Ontario's Automotive Sector". AVIN is the Government of Ontario's initiative, delivered through the OCE, to support SMEs, post-secondary institutions, and other industry stakeholders to 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:

- Commercialize CAV, transportation, and infrastructure system technologies.
- Build awareness, educate, and promote Ontario as a leader.
- Encourage innovation and collaboration.
- Leverage Ontario's talent.
- Support regional auto-brainbelt clusters.

AVIN is ensuring Ontario's leadership in the automotive and transportation sector and the future of mobility through five program streams and a Central Hub.

PROGRAM AREAS

AV Research and Development (R&D) Partnership Fund (Stream 1 & 2)

Supports projects relating to the development and demonstration of technologies in the CAV sector, in the areas of mass light vehicles, heavy duty vehicles, transportation infrastructure, Intelligent Transportation Systems (ITS), and transit-supportive systems and vehicles.

AVIN Technology Demonstration Zone

Allows Ontario-based companies to test, validate, and showcase CAV technologies with live city infrastructure in Stratford, ON.

(see next page for more details)

6 AVIN Regional Technology Development Sites (RTDSs)

Support Ontario-based SMEs to develop and test CAV technologies.

(see next page for more details)

Talent Development

Provides Ontario college and university students and recent graduates exposure to real world experience. Participants get opportunities to apply their expertise and knowledge to solve industry problems related to CAV technologies.

WinterTech AV Development Fund

Supports collaborative projects with resources to develop, test, validate, and commercialize products that will advance AV R&D concerned with severe winter weather conditions. Collaborative projects must be within the development, prototyping, and validation stage at technology readiness levels 5-7.

CENTRAL HUB

AVIN Central Hub

A dedicated team supporting the delivery and administration of AVIN programming through:

- Connecting and coordination among key players, interested stakeholders, and the public.
- Identification and support of opportunities.
- Promotion of awareness and education of AVIN programs and initiatives, and promotion of Ontario's growing CAV community.

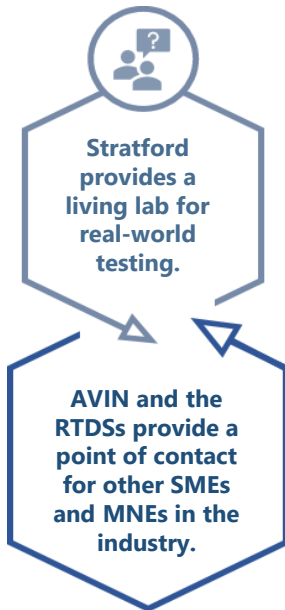


AVIN Technology Demonstration Zone

Located in Stratford, and operated by the Automotive Parts Manufacturer's Association (APMA), the AVIN Technology Demonstration Zone (DZ) promotes a customer-centered and demand-driven approach to the commercialization of innovation in Ontario, providing Ontario-based companies with a competitive development option.¹³

The DZ allows Ontario-based companies to test, validate, and showcase their innovative CAV technologies in a controlled environment, in compliance with laws and regulations, and with a wide variety of everyday, real-life traffic scenarios.¹³

Ultimately, the DZ plans to feature a rolling fleet of 20 vehicles, including 10 passenger vehicles sourced from the five Original Equipment Manufacturers (OEMs) in Ontario, and 10 fleet vehicles from the City of Stratford, including municipal buses and utility trucks.¹³



Stratford will serve as a test city in partnership with AVIN and the APMA, allowing CAV vehicles to operate within the city boundaries, when they are ready.

Stratford also has a four-acre test demonstration track. For three weeks in October 2018, this facility was home to the first live 5G pilot project with OEMs and telecommunication companies as partners.¹⁴



AVIN Regional Technology Development Sites (RTDSs)

Led by local economic development and entrepreneurial support organizations, each Regional Technology Development Site (RTDS) has a specific focus area and provides access to specialized equipment and facilities to encourage innovation and support development and testing of CAV technologies.

Toronto Region RTDS

Focuses on artificial intelligence (AI) and machine learning (ML) to improve CAV perception. Led by MaRS Discovery District, in collaboration with University of Toronto, Ryerson University, and York University.

Ottawa Region RTDS

Focuses on vehicular networks and interoperability of communications, and provides an end-to-end integrated AV test environment. Led by Invest Ottawa, in collaboration with Carleton University, University of Ottawa, Algonquin College, and the City of Ottawa.

Waterloo Region RTDS

Focuses on developing high-definition (HD) 3-D mapping and vehicle localization technology to support AV navigation and control, and safe and efficient CAV operations. Led by Communitech, in collaboration with University of Waterloo, Waterloo Region EDC and Canada's Open Data Exchange.

Durham Region RTDS

Focuses on investigating Human-Machine Interface (HMI) and User Experience for CAV. Includes the Automotive Centre of Excellence (ACE), and a state of the art controlled-environment testing facility to develop and test AV technologies. Led by Spark Centre, in collaboration with Ontario Tech University (OTU), OTU's ACE, Durham College, and the Region of Durham.

Windsor-Essex Region RTDS

Focuses on technologies and commercial AV solutions for border crossings. Testing is supported through a virtual border crossing. Led by Windsor-Essex EDC, in collaboration with University of Windsor, St. Clair College, the City of Windsor, and WETech Alliance.

Hamilton Region RTDS

Focuses on multimodal and integrated mobility using CAV technology such as V2I and integrated mobility applications. Initiatives underway include testing of AV on public roads and the construction of a smart city laboratory. Led by Innovation Factory, in collaboration with McMaster University, Mohawk College, and the City of Hamilton.



Analysis Framework

This ecosystem analysis of the Ontario CAV sector considered the activities and initiatives of government agencies, academic and research institutions, private sector companies (from MNEs through SMEs), and support organizations, including economic development organizations and entrepreneurial incubators and accelerators.

The framework for the analysis has been developed and organized around the following five key factors that together shape an attractive and competitive CAV ecosystem (see descriptions below):

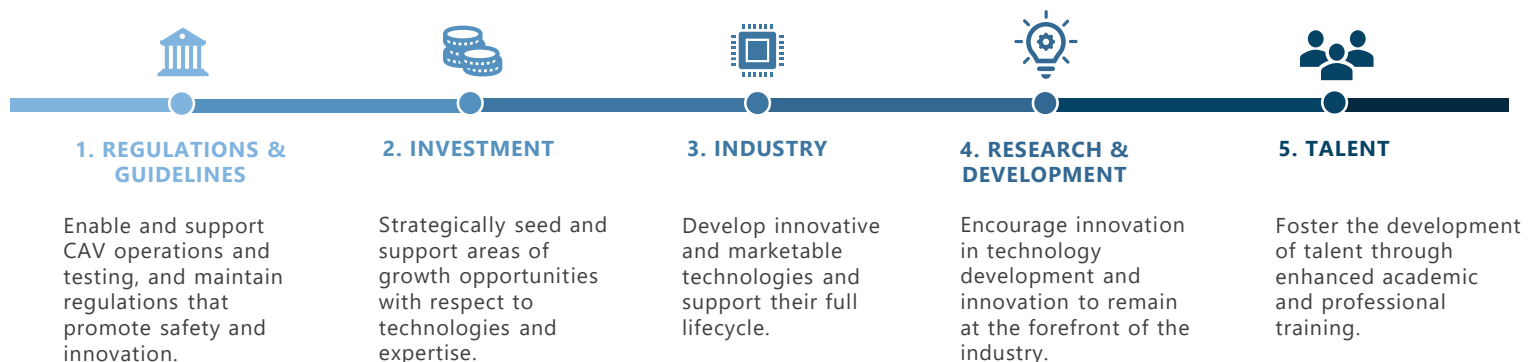
- Regulations and guidelines
- Investment
- Industry
- Research and development
- Talent

Approach

Our assessment of the Ontario CAV sector is divided into separate sections focusing on each of the key factors. Each section includes an overview of relevant activities and initiatives in Ontario, followed by a high-level summary of examples of comparable global activities. The countries included for the global perspective differ between sections, but all sections do include reference to U.S. activities and initiatives.

Each section concludes with a summary of Ontario's strengths, challenges, gaps, and opportunities as they relate to the key factor, as well as an overall qualitative assessment of the position of the Ontario CAV sector.

Because of the interrelationships and interdependence among the key factors, many of the ongoing and planned activities and initiatives in Ontario are mentioned in multiple sections, highlighting how they relate to the relevant key factor.





Ontario Regulations and Guidelines

Provincial Vision

The Government of Ontario has announced a commitment “to growing the economy and creating good jobs for Ontarians through developed resources to assist companies with doing business in the province”.¹⁵

In February 2019, Ontario released its newest automotive plan *Driving Prosperity – The Future of Ontario’s Automotive Sector*, with three pillars for action to strengthen and build on Ontario’s presence as a North American leader in automotive manufacturing and position the province as a leader in the development, commercialization, and adoption of advanced mobility and manufacturing technologies.¹⁶



We are committed to supporting Ontario’s auto manufacturing sector and the hundreds of thousands of families across the province that rely on it.



Todd Smith, Minister of Economic Development, Job Creation and Trade ²³

Pillars for Action for Ontario’s Automotive Sector

COMPETITIVE BUSINESS CLIMATE	INNOVATION	TALENT
<p>COSTS & TAXES FOR BUSINESSES</p>	<p>SUPPORT TECHNOLOGY AND INNOVATION IN NEW MOBILITY TO ENHANCE THE ECOSYSTEM</p>	<p>PROMOTE CAREER OPPORTUNITIES IN ADVANCED MANUFACTURING</p>
<p>FOSTER INVESTMENT & PARTNERSHIPS</p>	<p>PROMOTE TECHNOLOGY ADOPTION FOR SMEs </p>	<p>LEVERAGE INPUT FROM INDUSTRY </p>
<p>MODERNIZE REGULATIONS AND RED TAPE</p>	<p>SUPPORT R&D AND TECHNOLOGY DEVELOPMENT</p>	<p>ENHANCE & PROMOTE EMPLOYMENT & TRAINING PROGRAMS </p>
<p>SUPPORT DIVERSIFICATION IN MARKET</p>	<p> COMMERCIALIZATION OF TECHNOLOGY</p>	<p>STRENGTHEN ONTARIO’S TECHNICAL EDUCATION OPPORTUNITIES</p>

Permitting CAV Testing

In January 2016, *Ontario Regulation 306/15: Pilot Project – Automated Vehicles*, took effect, making Ontario the first Canadian jurisdiction to regulate the testing of automated vehicles on public roads.¹⁷ Updated in January 2019, the regulation now allows for driverless AV testing under specific safety conditions.

The Province has also established a *Cooperative Truck Platooning Pilot Program*, and released conditions for permitting vehicles with V2V communications to travel close together as a pilot to “demonstrate their potential, compatibility with existing road users and infrastructure, confirm their overall safety, while operating on Ontario’s roadways”.¹⁸ Beyond the requirements for safe operation, these guidelines also define an approved network for permitted testing operation.

Frameworks and Guidelines for Safe Testing CAVs

To support the growing CAV industry and ensure that technologies are developed and implemented safely, the Government of Canada, with input from Ontario, has established the following frameworks and guidelines for CAV testing:

- *Canadian Jurisdictional Guidelines for Safe Testing and Deployment of Highly Automated Vehicles* ¹⁹
- *Testing Highly Automated Vehicles (HAV) in Canada – Guidance for Trial Organizations* ²⁰
- *Canada’s Safety Framework for Automated and Connected Vehicles* ²¹
- *Safety Assessment for Automated Driving Systems in Canada* ²²

Support from All Levels of Government & Non-Profit Organizations

Both the Federal and Provincial Governments have demonstrated motivation to encourage the growth and strengthening of the CAV ecosystem, and have established an environment that supports lower levels of government, academic and research institutions, and industry players, including OEMs, MNEs, and SMEs.

The Ontario Good Roads Association (OGRA), a registered non-profit lobby group that represents the transportation and public work interests of municipalities, has organized the Municipal Alliance for Connected and Autonomous Vehicles in Ontario (MACAVO), to focus on facilitating municipal CAV efforts. MACAVO has worked with over 60 forward-thinking municipalities to develop a *Preferred AV Test Corridor between Windsor and Ottawa*, which identifies preferred local roads for CAV testing activities in over 30 Ontario municipalities.



Planning for CAVs

The potential posed by CAVs is understood by the Ministry of Transportation of Ontario (MTO) and Ontario municipalities, with many of the larger jurisdictions proactively developing dedicated planning documents for CAVs in their region, or incorporating considerations for planning for CAVs into recent master plans.

In collaboration with Transport Canada, Ontario co-chairs a national working group called the Federal/Provincial/Territorial (FPT) Governing Council on Automated and Connected Vehicles. Established by the Council of Ministers Responsible for Transportation and Highway Safety, this group is mandated to focus on alignment of efforts and an integrated approach on AVs/CVs among the group members from federal and provincial governments across Canada. This working group's report *The Future of Automated Vehicles in Canada*²⁴ provides transportation authorities with an overview of short, medium, and long-term policy implications resulting from the presence of CAVs on public roads. The group has also published a *National Automated and Connected Policy Framework for Canada* that provides policy principles for safe testing and guidance on issues to help jurisdictions across Canada properly prepare for CAV deployment.

MTO is examining how CAV technology can be adapted to help meet the Province's broader transportation goals in a number of key areas such as infrastructure and operations (e.g. highways, transit, data), as well as, the policy and regulatory framework.

The City of Toronto has documented a draft *Automated Vehicle Tactical Plan* listing priority issues, tactics, and actions needed to plan for AVs over the short-term between 2019 to 2021.

Both the Regional Municipality of York and the City of Hamilton have included considerations and action plans for CAVs in their recent Transportation Master Plans.^{25, 26}

GTHA and Kitchener-Waterloo Corridor CAV Readiness Plan

MTO, Metrolinx, the City of Toronto, and the Region of Peel are working together to complete the *CAV Readiness* project to enhance planning and capacity building for CAVs. The ACATS-funded project (see page 19), aims to establish a common / consistent planning horizon and framework in the GTHA and Kitchener-Waterloo corridor through the development of alternative CAV scenarios, readiness guidelines, and potential projects.

Over the course of this project's development, over 60 stakeholders from different levels of government have been actively engaged, providing input to the project and engaging in education and capacity building of public sector planners and practitioners.

GTHA and K-W Corridor CAV Readiness Plan Participating Stakeholders





Global Perspective – Regulations and Guidelines



United States

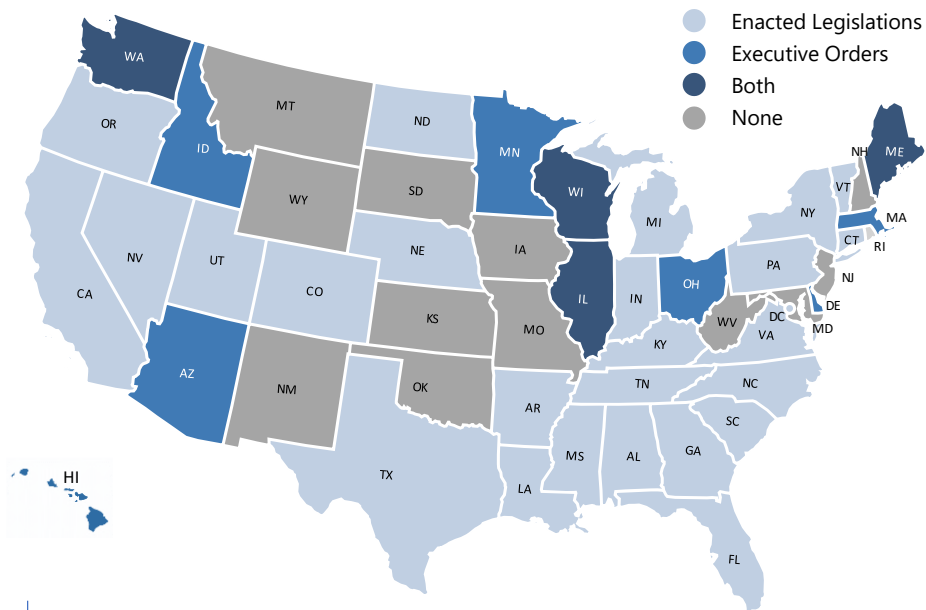
The United States has been active in developing and enacting legislation and policy frameworks in support of CAVs. Nevada was the first state to initially authorize the operation of autonomous vehicles in 2011. Since then, 26 other states have passed legislation, seven have had Governor's issue executive orders, and four others have both that are related to AVs. These legislations and executive orders relate to encouraging the safe development, testing, and operation of vehicles with AV technology on public roads.²⁷ In 2018, 17 AV-related bills were enacted in 15 states, including the State of Alabama, California, Kentucky, and Oregon, and eight executive orders were issued in six states, including the State of Florida, Arizona, and Idaho.

In October 2018, Illinois' Governor issued an executive order to direct the Illinois Department of Transportation to lead an *Autonomous Illinois* initiative and establish a testing program to facilitate legal testing and programs on public roads or highways. The Ohio's Governor also signed an executive order in January 2018 to establish DriveOhio, an initiative to organize and accelerate smart and connected vehicle projects. Another order in May 2018 allowed AV testing and pilot programs in the state, provided that the companies register with DriveOhio.²⁷

New legislation released in California in 2018 allows for fully autonomous vehicles to operate on public roads without the presence of an engineer and test driver. This has attracted large-scale firms such as Tesla and Waymo to commercialize their AV programs in California.²⁸ The State of Washington also enacted legislation in 2018 to convene an executive and legislative working group to develop policy recommendations for AV operations.²⁷

In the U.S., individual States are responsible for determining liability rules for CAVs and allocation of liability among owners, operators, and manufacturers. The investigation of the 2016 fatal crash involving Tesla Autopilot determined that Level 3 autonomy is limited, and human drivers are expected to maintain awareness and control if needed. A number of states, including Michigan, Nevada, and Washington, have legislation specific to CAVs.

States with AV related Enacted Legislation and Executive Orders



In early 2015, the CCMTA AV Working Group co-chairs participated in the American Association of Motor Vehicles Administrators (AAMVA) Autonomous Vehicle Best Practices Working Group to support the development of the U.S. Department of Transportation (USDOT)'s National Highway Transportation Safety Administration's (NHTSA) Federal Policy for Safe Testing and Deployment of Automated Vehicles.

In October 2018, the USDOT released the *Preparing for the Transportation Future: Automated Vehicles 3.0* (formerly known as *Automated Driving System 2.0: A Vision for Safety*), to expand the scope to include all surface on-road transportation systems including advancing multimodal safety, reducing policy uncertainties, and outlining a process to work with the USDOT. Other topics covered include preparing for automation through guidance and pilot programs and enhancing and protecting freedoms enjoyed by citizens.²⁵ It also encourages a consistent regulatory operating environment across the U.S.

Other guidelines include the Automated Vehicle Testing Guidance released by Pennsylvania in July 2018, which attracted Aurora as the first company to be authorized to test AVs on state roads in October 2018.



Germany

Germany is one of the first European Union members to pass regulations regarding CAVs.²⁹ In 2017, an Autonomous Vehicle Bill was enacted to modify the German Road Traffic Act, allowing drivers to pass off control to a vehicle, and addressing the requirements and rights of the driver. Germany currently allows for technology and auto-manufacturer firms, with special permits, to test vehicles on roads where the drivers can release control of the steering wheel.²⁹

In 2018, the Ethics Commission of the Federal Ministry of Transport and Digital Infrastructure released the world's first guidelines addressing ethical questions for self-driving vehicles, however questions remain relating to liability.²⁹ It is expected that this law will be updated and revised to adapt to growing technological changes and data protection considerations.³⁰



Netherlands

The Netherlands are implementing a legal framework to facilitate the testing and operations of AVs. In September 2018, the government approved the *Experimenteerwet zelfrijdende auto* (law governing the experimental use of self-driving vehicles) to allow testing of AVs on public roads without drivers, provided the vehicles are monitored remotely.³¹

A *Driving License for a Vehicle* is also being prepared in cooperation between the Dutch Vehicle Authority, the main road authority and the central office for driving exams, assessing the extent to which a vehicle can make safe and predictable autonomous driving behaviour that aligns with human performance.³²



Singapore

Singapore is a leader in policy and legislation when it comes to AVs. The government has taken steps to proactively investigate the possibilities of the future of mobility and prepare for the regulatory environment required to facilitate an autonomous future.

A test centre led by the Centre of Excellence for Testing and Research of AVs (CETRAN), was opened in November 2017 to develop standards and ensure the safe deployment of AVs on public roads. Operators are required to have a qualified safety driver who will be able to take control of the vehicle in an emergency and hold third-party liability insurance, or place a security deposit with the Land Transport Authority.

In 2019, Singapore released the *Technical Reference 68 (TR 68)* outlining a set of national standards for the safe deployment of fully driverless vehicles.³ The guidelines cover topics including vehicle behaviour, functional safety, cybersecurity, and data formats. *TR 68* is provisional in nature and will continue to be refined as AV technology matures and with feedback from the industry.



United Kingdom

The United Kingdom (UK) has been active in initiating steps to develop supportive legislation and national strategies to address CAVs. In 2017, the UK passed the Vehicle Technology and Aviation Bill that sets out how the liability for accidents involving AVs should be apportioned.³³ The Law Commissions of England, Wales, and Scotland are currently in the three-year process of reviewing the UK's legal framework for AVs with implementation expected in March 2021.³⁴ There has also been a coordinated effort across the country to develop CAV strategies, business plans, and policy road maps.³



Assessment of Regulations and Guidelines in Ontario

Ontario Strengths

Ontario was the first Canadian jurisdiction to regulate testing of automated vehicles on public roads, and through *Ontario Regulation 306/15: Pilot Project – Automated Vehicles*, Ontario has established an environment of regulatory openness that is globally competitive. The regulation supports private sector AV driving pilots and testing, and provides an attractive region for industry and academia CAV-related pursuits by facilitating operational testing of new technologies and solutions.

Ontario has contributed to the development of federal frameworks and guidelines that provide direction for safe testing and deployment of CAVs.

The *Cooperative Truck Platooning Pilot Program* leverages Ontario's openness for AV testing and provides direction for V2V communication testing for truck platoon pilots on specific stretches of provincial highways. Similar testing is ongoing in other countries, such as the U.S., the Netherlands, Singapore, and Sweden.

“
Going forward, we will continue working with the sector, as well as municipalities and the federal government, on longer-term priorities.
 ”

MTO and a number of the larger municipalities have begun developing strategies and plans to prepare for greater adoption of CAVs.

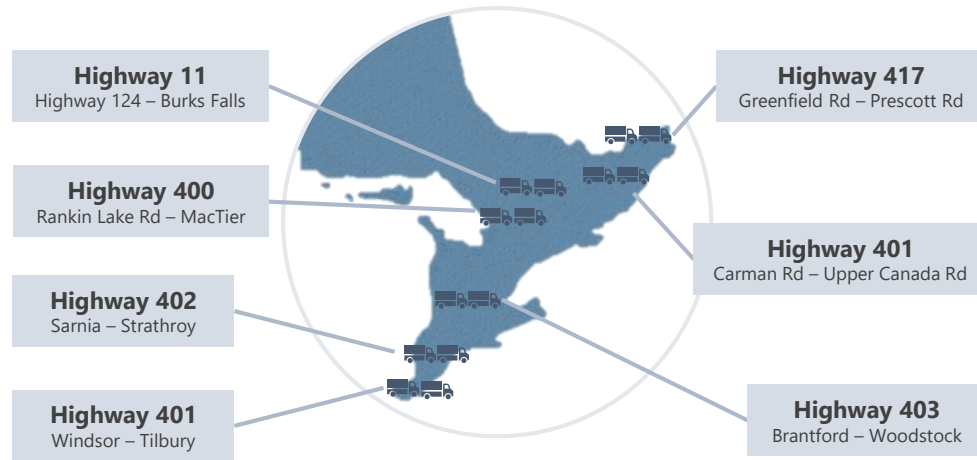
OGRA has also established MACAVO, which focuses on facilitating municipal CAV activities that could support smaller forward-thinking municipalities that do not have dedicated resources for CAV planning.

Todd Smith, Minister of Economic Development, Job Creation and Trade ²³

Approved Participants for Testing AV Technologies in Ontario



MTO Cooperative Truck Platooning Authorized Network (June 2019)



Challenges and Gaps in Ontario

The Ontario and Federal Governments have established regulations and guidelines for safe testing of CAVs in Ontario. This facilitates R&D necessary to develop the technology and to enable an understanding of how to prepare for a wider adoption of CAVs. Ontario is in a similar position to other jurisdictions, where pilot testing of CAVs is vital, as input, to other regulatory and guideline planning efforts relating to CAVs.

The following provides a summary of a number of the ongoing regulatory and guideline related efforts. These will be revised and updated as new information is learned. The approach that is being undertaken in Ontario is also being applied by other jurisdictions.

- Legal frameworks relating to insurance and liability are being studied and considered by the insurance industry and the government, with considerations of moving from driver liability to product liability. To date Canadian AV pilots have been undertaken with global liability insurance or as self-insured by the vehicle manufacturer.
- Regulations and guidelines for supporting infrastructure, including signage and road markings, are being studied by transportation associations, standards groups, and government agencies.

Infrastructure is not ready for CAVs, and public-sector role is not clear.

Municipalities are looking to Transport Canada and MTO to understand legal framework.

- Potential privacy issues and the protection of personal information are being considered with respect to cybersecurity needs for CAV operations and data sharing.
- Data dictionary standards are being developed by Standards Developing Organizations (SDOs) with input from industry, government, and academia.
- Data ownership and rights to use of data, generated by CAVs, is being considered by government agencies, particularly as it relates to data traditionally collected by transportation agencies, such as traffic speeds and travel times.

To date, in Ontario, the public is aware of CAVs primarily through the media reporting on investment initiatives and ongoing testing activities, both good and bad, rather than through concerted public education efforts.

With AV testing on public roadways, there is a need for public education.

Opportunities for Ontario

As a frontrunner with CAVs in Canada, Ontario has the opportunity to set the standard and lead other provinces towards a national framework that aligns with the directions being taken in Ontario.

Continued active involvement and input from the CAV sector, including government, industry, and academia is necessary for ongoing policy and planning activities.

A public outreach and engagement program would meet the need to educate the public of testing activities in the province, and ensure that the material is curated and relevant.



Assessment – Regulations and Guidelines



Ontario is currently a global leader with respect to providing an open and welcoming environment for CAV R&D and testing. Similar to other jurisdictions, there are a number of ongoing policy and planning efforts to prepare for public adoption of CAVs.



Investment in Ontario

Provincial Vision

Ontario has announced its ongoing commitment to supporting investment in the automotive sector, as outlined in its new automotive plan *Driving Prosperity – The Future of Ontario's Automotive Sector*. The province has established funding programs targeting technology development and talent development, such as its investment in the Vector Institute for AI, and increased funding for AVIN.¹⁶

AVIN Funding

AVIN is a key action to support the innovation pillar of the *Driving Prosperity* plan. Funding provided through the AVIN initiative ensures that SMEs have the support and tools needed to develop products and services, to meet global demand, and to ensure that Ontario is at the forefront of adoption and deployment. AVIN-funded projects require that industry contributes to total project costs, as shown below.

Examples of AVIN Funding

AV R&D Partnership Fund

AVIN contributes one-third of eligible project costs for approved projects up to a maximum of \$100,000 for projects up to 12 months in duration under Stream 1, and a maximum of \$1,000,000 for projects up to 24 months in duration under Stream 2.

WinterTech AV Development Fund

AVIN contributes one-third of eligible cost, up to \$500,000, for approved projects related to severe winter weather conditions up to 24 months in duration.

Technology Demonstration Zone & Regional Technology Development Sites

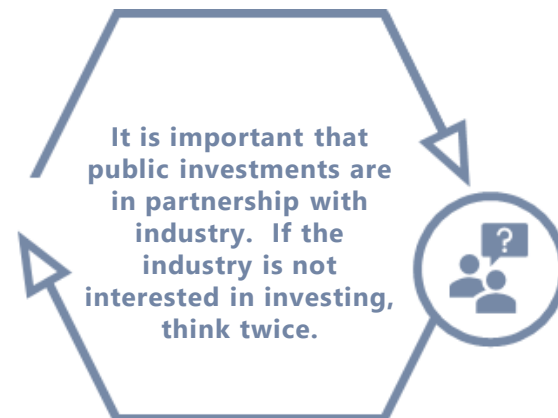
For the DZ and each of the 6 RTDSs, AVIN is contributing up to \$5,000,000 in funding, with a minimum 1-1 match from industry and other partners.

Talent Development

AVIN provides \$10,000 in funding towards four-month Internships valued at \$20,000, and \$35,000 in funding towards 12-month Fellowships valued at \$85,000.

Advance Connectivity and Automation in the Transportation System (ACATS)

Transport Canada's *Advance Connectivity and Automation in the Transportation System (ACATS)* program was created to help Canadian jurisdictions get ready for the technical, regulatory, and policy issues emerging as Canada introduces these technologies, and has committed up to \$2.9 million in grant and contribution funding over four years across Canada. Of that, nearly \$1.5 million in program grants have been awarded to Ontario-based applicants, including MTO, the City of Toronto, Carleton University, University of Ottawa, and the CSA Group.



Pooled and Matched Funds

The CAV-focused funding available in Ontario through the AVIN and the ACATS programs require some form of matching funding from the recipients and/or industry partners. With capital and time investments from the recipients, greater resources and equity may be available to pursue innovation and R&D efforts, while also ensuring commitment to the research efforts.

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CAV SECTOR ANALYSIS

Industry Investment

With established automotive and technology sectors and an environment open to CAV testing, there are many examples of self-funded CAV-based industry investments.

Since the beginning of 2018, GM has announced more than \$345 million in investments for its Canadian Technical Centre in Markham. GM also recently announced repurposing of its Oshawa manufacturing plant into a supplier of after-market parts for existing vehicle models, as well as dedicating 55 acres of the property to create a test track for AVs and advanced technologies.³⁵

In May 2018, Magna announced that it was committing \$300 million in research and development, focusing on electrification and AVs.

OEMs, MNEs, and SMEs are also partners in key programs developed through the various AVIN Regional Technology Development Sites throughout Ontario.³⁷

Examples of Technology Investment in Ontario related to CAV Industry

BlackBerry | **QNX**

\$40M
funding from the Strategic Innovation Fund

Create **800**

new jobs and maintain

300

positions in the next 10 years

Pledged over **\$300M** investment and addition **\$5M** on cybersecurity

Investment in Canadian AI start-ups is on the rise. 2017 saw **US\$252M** of venture capital flow into Canadian AI companies, representing a

460%

year-over-year increase.

GM

Committed over **\$345M** in its Canadian Technical Centre in Markham, Ontario since 2018.

\$337.9M Investing on building the Ottawa R&D Hub and other satellite engineering centres across Ontario

Ford

Ontario and federal governments will contribute

\$102.4M

each to help finance the projects.

Uber

Investing **\$200M** in the Toronto Hub over the next 5 years

Creating **300** new positions

Google

Invested over **\$10M** fundamental AI research in the past year

ENCQOR

\$400M public-private investment & partnership

ERICSSON
ciena
THALES
CGI **IBM**

Makes Canada a global innovation leader and secures over middle class jobs, **4,000** including **1,800** specialized 5G jobs, over the next 5 years

MAGNA

Committed **\$300M** in R&D, focusing on electrification and AVs

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Other Support for Research and Development

Both the Ontario and Federal Governments offer other funding opportunities to support R&D efforts, for academia and large and small industry players, including the following:

- The *Strategic Innovation Fund* supports the industrial and technology industries, such as the \$40 million funding that BlackBerry QNX received to develop embedded software and self-driving car technologies, and provide skills training for staff.³⁸
- National Research Council (NRC) is committed to supporting small and medium-sized enterprises to innovate with technology, including CAV related research through its *Industrial Research Assistance Program (IRAP)*³⁹, as well as university-based research through *Natural Sciences and Engineering Research Council of Canada (NSERC)*.⁴⁰
- The *Ontario Research and Development Tax Credit* and federal *Scientific Research and Experimental Development (SR&ED)* programs are designed to provide tax credits for qualifying research and development work.⁴¹
- The *Highway Investment Funding Program (HIFP)*, administered by MTO, provides funding in \$50,000-60,000 increments for relevant academic research projects.

“

The race for a top spot in the new economy has already begun, and if we want to see Canadians take the lead, we need to have their backs. That is why our government is investing \$40 million in BlackBerry QNX to design and develop a new software platform for the cars of today and tomorrow. This investment will create 800 good, middle class jobs for Canadians, make our cars safer and more secure, and further position Canada as a global hub for innovation.

”

The Rt. Hon. Justin Trudeau, Prime Minister of Canada ³⁶



Global Perspective – Investment



United States

The United States has committed a significant amount of investment into the CAV industry, both from public and private sector sources. The federal government has committed to allocating \$4 billion USD (\$5.3 billion CAD) over 10 years, to support the development and adoption of AVs.⁴² More than \$135 million USD (\$181.7 million CAD) alone has been invested in Michigan for the MCity project,⁴³ and GM has invested over \$100 million USD (\$134.6 Million CAD) in its Michigan facilities for upgrades to support the Cruise CAV program.⁴⁴

In California, start-up companies, such as Nauto and Drive.AI, have raised millions of dollars in capital investments for developing self-driving technology.⁴⁵ This year, Uber announced that it has secured a \$1 billion USD (\$1.3 billion CAD) investment in its self-driving car unit from Japan's SoftBank.⁴⁶



Germany

The automotive industry in Germany is planning a significant investment in electric vehicles (EVs) and AVs.⁴⁷ More than €40 billion (\$60.2 billion CAD) will be spent over the next three years on e-mobility, and another €18 billion (\$27.1 billion CAD) has been dedicated to CAV driving and digitization by the German car industry association (VDA).⁴⁷ The German government also plans to invest €80 million (\$120.5 million CAD) in AVs before 2020.⁴⁸



Japan

Japan is making large strides in CAV investment and is encouraging private sector investment ahead of its 2020 Olympic games.⁴⁹

Toyota announced in March 2018 that it had invested \$2.8 billion USD (\$3.8 billion CAD) in a new company aimed at developing software for autonomous driving.⁵⁰ There has also been significant investment in CAVs through partnerships between international automakers,⁵¹ as Renault, Nissan, and Mitsubishi have invested up to \$1 billion USD (\$1.3 billion CAD) in a partnership to fund mobility start-ups with a focus on connectivity, automation, artificial intelligence, and electrification.⁵²



Assessment of Investment in Ontario

Ontario Strengths

There are many examples of industry players investing heavily in Ontario, underscoring the perception that Ontario provides a strong market for industry through a combination of technology, business, a wealth of talent, open regulations, and support from the government.

The Government of Ontario has been proactive in capitalizing on the economic and job creation potential of CAVs. Under the *Driving Prosperity* plan, Ontario is investing in innovation through AVIN programming, which not only drives the development of the sector as whole, but provides economic benefit to the province. Strategic investments, such as funding RTDSs with different focus areas, have enabled Ontario to target and manage testing and development related to identified technology needs. Recent RTDS-related openings include the following:

- Ottawa L5 private AV test track in Ottawa
- Virtual Reality CAVE at the Institute for Border Logistics and Security (IBLS) facility in Windsor
- Automotive Centre of Excellence (ACE) research and testing facility at the Ontario Tech University in Durham

In addition to the Ontario investment through AVIN, the initiative stimulates additional private sector investment with a requirement for industry co-investment at a minimum ratio of 2:1. This requirement for matching funding amplifies provincial dollars in order to drive further investment support for companies. This validates the belief that Ontario provides a strong market for the automotive industry to flourish.

Many Ontario government agencies and organizations have participated in the AVIN and ACATS programs, leveraging available funding and investing their own time and resources to pursue CAV initiatives and studies.

In addition to the CAV-focused programs, both the Provincial and Federal Governments have committed significant investments in support of enabling technologies and considerations, such as AI, 5G, embedded software, and cybersecurity.

Challenges and Gaps in Ontario

Competition for investments is a key challenge for Ontario. Michigan, for example, which also has a strong automotive sector as the home of many OEMs, has established CAV pilot initiatives and enjoys the benefit of sharing a domestic market with many other key players.

Opportunities for Ontario

Marketing to the strengths of Ontario, which includes highlighting its strength in critical areas, such as its technology clusters and access to talent, is key to competing with other North American and global ecosystems.

Developing and determining a CAV growth strategy, for example status quo, accelerate or pivot, would allow Ontario to match funding and target priorities, accordingly.

Strategic investment is important and should continue to include support for R&D and testing, as well as, future needs studies relating to infrastructure and development of policies, regulations, and standards.



Assessment – Investment



There is significant investment in the CAV sector in Ontario, with a strong balance from both the public and private sectors, and with beneficiaries across the sector, including industry, government, and academia. Moving forward, investment should keep pace with relative growth of other industry leaders globally.



Industry in Ontario

Provincial Vision

Key action items noted in Ontario's new automotive plan *Driving Prosperity – The Future of Ontario's Automotive Sector*, emphasize the need for ensuring a competitive business environment for industry. Action items include modernizing and reducing regulatory business requirements, and reducing business and tax costs.¹⁶

Automotive Sector

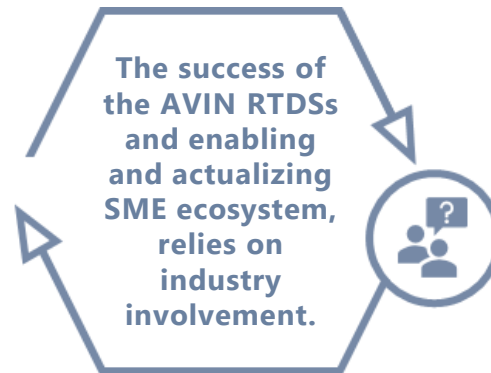
Ontario's automotive industry continues to remain strong overall with the active presence of four global automakers, including Toyota, Honda, Ford, and Fiat-Chrysler. The sector is also represented by a supply chain base of automotive parts firms including Magna International and Bosch, supported by a skilled workforce. Both Ford and GM have large research, development, and engineering hubs in Ontario that will continue to propel the province forward in maturing the CAV sector. Moreover, GM recently announced re-purposing of its Oshawa manufacturing plant to create a test track for AVs.³⁶

Technology Sectors

Technology expertise is distributed throughout the province, including clusters in Ottawa and between Toronto and Waterloo. The Toronto-Waterloo innovation corridor alone has been identified as second only to Silicon Valley in importance in North America¹ and ranks within the top 20 technology clusters in the world.⁵⁵

Homegrown successes, such as Magna International and BlackBerry QNX, continue to have a strong presence in Ontario. Many other global MNEs have chosen to invest in Ontario as part of their manufacturing, R&D, and innovation initiatives, such as Uber, DiDi, Thales, Nokia, and NVIDIA.

Ontario also has numerous homegrown SMEs that focus on CAVs and the supporting enabling technologies. These companies, like Miovision and QA Consultants, cover a wide variety of subjects, and actively join partnerships with MNEs and leading research institutes in the province, particularly as part of the AVIN RTDSs. Key areas that these SMEs focus on include AI, cybersecurity applications, Internet of Things (IoT) technology, and software testing for CAVs.



Convergence of Automotive and Technology Sectors

Ontario's unique convergence of automotive and technology expertise gives Ontario a major advantage in designing and building the next generation of vehicles. It is estimated that there are over a hundred thousand direct jobs, plus thousands more spin-off jobs, from auto manufacturing, and more than 200 companies in Ontario are already developing CAV technologies.¹⁷ Along the 800-km corridor from Ottawa to Windsor alone, there is a wealth of expertise in connected and AV technology, artificial intelligence, connectivity, cybersecurity, and quantum computing.⁵³

Ontario ranked as North America's second largest auto-producing region for 2018, building approximately 2 MILLION VEHICLES

200+ companies including GM, Ford, Google, Uber, Apple, and BlackBerry QNX are developing CAV technologies in Ontario.¹⁷

Ontario is the home of **700+** auto parts firms, and **500+** tool, die, and mold makers.¹⁷

QNX software is now embedded in more than 120 MILLION VEHICLES globally.⁵⁴

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Economic Development / Entrepreneurial Support Ecosystem

Ontario is home to many economic development organizations and entrepreneurial accelerators, which provide entrepreneurs, SMEs, and to a lesser degree MNEs, with support and business advisory services, including:

- Start-up incubation
- Business mentorship
- Global business attraction
- Local business retention, sector development, and commercialization.

The Ontario Network of Entrepreneurs (ONE) represents member innovation organizations, including Communitech, Innovation Factory, Invest Ottawa, MaRS Discovery District, and Spark Centre, which are leads for AVIN RTDSs.

These organizations have been critical to the genesis of the RTDS initiatives, not simply as incubator support for participating companies and SMEs, but for bringing the right players to the table, making introductions and fostering relationships, and overall management of the program.

The federal Scale-Up Platform will support 30 companies in southern Ontario to grow and achieve revenue objectives of

\$100 MILLION

or more by 2024.⁵⁰

Canada ranks as the **4th** largest innovation hub in the world for cybersecurity with Ontario leading the country.⁶¹

Over the last 10 years, Communitech has helped transform the regional economy by supporting more than 3,000 companies and helping them attract

\$1.7 BILLION in investment and create **OVER 16,000** new jobs.⁵⁵



Global Perspective - Industry



United States

The United States is home to many companies that are leaders in CAV development with mainstream U.S. auto-manufacturers working towards establishing an AV fleet and ride-hailing services.³ GM is investing in Michigan and upgrading its facilities to support GM's plan to commercialize its Cruise CAV program.⁵⁶ In California, many start-ups are raising capital to further develop self-driving technologies.⁵⁶

Auto manufacturers and their suppliers are the largest manufacturing sector in the United States contributing close to 3% of the nation's GDP.⁵⁷ Many international auto manufacturers choose to assemble vehicles in the United States, and Fiat Chrysler Automobiles (FCA US), Ford, and GM are the leaders in R&D in the country.⁵⁷



Singapore

In Singapore, the Land Transport Authority has signed agreements with companies to develop solutions for autonomous platooning of transport containers from one port terminal to another. Singapore has also recently issued a request for information for the development of self driving utility vehicles for waste collection and road sweeping.⁵⁸



Sweden

The Swedish government, in partnership with the private sector, has developed a program called *Drive Sweden* and is supporting the development of a test facility for AV technologies with the goal of creating an international standard for testing driverless vehicles.⁵⁹

Sweden's reputation for innovative technology and high-quality transportation and mobile network infrastructure is one of its major strengths, making it one of the highest-ranked nations for readiness for changes to transportation.³ In September 2018, Swedish vehicle maker Volvo was granted permission to test their self-driving cars in Gothenburg.⁶⁰



REGULATIONS & GUIDELINES



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Assessment of the Industry in Ontario

Ontario Strengths

Ontario has a well-established automotive sector, attracting global automakers to set up manufacturing plants and R&D facilities in the province. The sector is well supported by an integrated supply chain of automotive parts firms and tool, die, and mold makers.

Southern Ontario is among only three start-up ecosystems in the world that are strong in four of the most in demand areas in technology today, including **ARTIFICIAL INTELLIGENCE AND BIG DATA, ADVANCED MANUFACTURING AND ROBOTICS, FINANCIAL TECHNOLOGY, and LIFE SCIENCES.**⁵⁵

Ontario is a global leader in technology and innovation. The province is home to a full spectrum of companies, from large MNEs to smaller SMEs and start-ups, that are active in the R&D of CAVs and a breadth of enabling technologies.

The convergence of automotive and directly relevant technology expertise gives Ontario a strong position in the CAV sector.

There are a wide range of economic development corporations and entrepreneurial accelerators in place to support and grow Ontario's technology and innovation sectors.

Challenges and Gaps in Ontario

Although Ontario is a leading automotive producing region in North America, Ontario is not the headquarter location for any global OEM automotive manufacturer.

Not all Ontario-headquartered companies, or those with significant presence in Ontario, locate their manufacturing and R&D programs in Ontario.

“ **Most of their products are sold to the U.S., so then you have a currency issue. You'd rather be building vehicles in the currency in which you'll be selling them.** ”

*Kristin Dziczek, Vice-President of Industry, Labour and Economics at the Center for Automotive Research in Ann Arbor, Michigan*⁶²

Opportunities for Ontario

Successful results from current CAV activities will enhance Ontario's reputation and marketing efforts, leading to new industry players choosing Ontario, as well as existing players expanding their efforts in Ontario.

Although already a strong component within Ontario's technology sector, AI continues to be a rapidly growing and important industry.



Assessment – Industry



Ontario has an established, strong, and diversified presence of CAV industry players. There is potential for even further growth including attracting new players, expanding the work of existing players, and growth in other areas as technologies evolve.



Research and Development in Ontario

Provincial Vision

Ontario's new automotive plan *Driving Prosperity – The Future of Ontario's Automotive Sector*, highlights the importance of support R&D and specifically recommends an action item that would increase funding for AVIN's Talent Development program, supporting internships and fellowships for Ontario students' research into connected and autonomous vehicles.¹⁶

Industry Research and Development

Many automotive manufacturers and MNEs have selected Ontario as a base for their research and development activities. GM has set up their Canadian Technical Centre in Markham and plans to create an autonomous vehicle test track in Oshawa (see page 20).^{35, 36}

Ford is in the process of establishing a Research and Engineering Centre in Ottawa, dedicated to the development of automated driving technology including infotainment, driver-assist, and other connected car modules.⁶³

The National Research Council of Canada (NRC) recently opened a Manufacturing and Automotive Innovation Hub in London, Ontario. This new facility was designed to support the Canadian automotive industry, helping automotive manufacturers adopt advanced manufacturing techniques and develop new vehicle technologies.¹³

Stakeholders within the CAV space in Ontario have also been cooperative and open to developing partnerships with each other, demonstrated by the number of partnerships that have already been developed between OEMs/MNEs and SMEs and academia. For example, Ontario Tech University's ACE facility has partnered with many private sector companies to share their facilities and resources to further the development of products.⁶⁴



Increasingly, the world's most promising researchers in deep learning and other AI subfields are looking at Canada as a hub with many opportunities to collaborate, advance research, and develop applications."



Geoffrey Hinton,
Vice President and
Engineering Fellow,
Google Brain Team



Toronto and the Greater Toronto Area are epi-centres of machine learning and one of the world's foremost hubs for AI research and development. Home to not only world-class talent, but also some of the most innovative start-ups in the artificial intelligence field.



Dr. Larry Heck,
Co-Head of Global Artificial
Intelligence Research, Samsung



Dara Khosrowshahi,
CEO, Uber



Toronto is a place where we as a company innovate, and innovation is really what Uber is all about.



CAV SECTOR ANALYSIS

Academic Research

Ontario is home to 26 colleges and 21 universities, representing a substantial commitment to research programs focusing on CAVs and supporting technological developments in the industry.³⁷ These research programs focus on a variety of CAV-related topics including:

- Investigating the impacts of CAV on transportation planning, travel behaviour, and transportation demand
- Developing and testing enabling technologies to facilitate vehicle connectivity and automation



CARLETON UNIVERSITY is actively involved in automated vehicle technology. A focus for research funding is in the security of CAVs through the identification and analysis of risks and vulnerabilities associated with potential cyber-attacks. Research includes the development of advanced security solutions to tackle threats.

THE AUTOMOTIVE CENTRE OF EXCELLENCE (ACE) at Ontario Tech University is a place where industry, researchers, and students collaborate to develop, test, and validate vehicle technology innovation with an array of testing equipment, including one of the largest and most sophisticated climatic wind tunnels.



THE CENTRE FOR ANALYTICS AND ARTIFICIAL INTELLIGENCE ENGINEERING (CARTE) at the University of Toronto focuses on applying analytics and AI to practical challenges, such as video analytics and autonomous driving.

THE I-CITY CENTRE FOR AUTOMATED AND TRANSFORMATIVE TRANSPORTATION SYSTEMS (CATTS) aims to build the foundational analytical tools necessary to measure and assess the performance of the transportation system. Individual projects focus on quantifying the effects of transformative transportation technology, developing tools to enable positive change, and guiding the transformation process toward economic, social, and environmental sustainability.



THE HUB FOR APPLIED RESEARCH IN ARTIFICIAL INTELLIGENCE (AI Hub) at Durham College provides industry partners with access to technical expertise, testing facilities, and platforms. It also offers companies student talent, supporting companies to increase productivity and growth through a focus on the human-machine interface (HMI) and user experience technology.

THE MCMASTER INSTITUTE FOR TRANSPORTATION AND LOGISTICS at McMaster University builds alliances with both private and public stakeholders to advance evidence-based solutions for the sustainable movement of goods and people, including research on disruptive and emerging mobility technologies such as CAVs.



THE MCMASTER CENTRE FOR SOFTWARE CERTIFICATION (McSCert) at McMaster University specializes in research on developing tools and methods to create safe and secure software to ensure the safety and reliability of automated and electric vehicles.



WATERLOO CENTRE FOR AUTOMOTIVE RESEARCH (WATCAR) at the University of Waterloo contains a wide variety of CAV facilities, groups, and labs related to transportation systems, communications, machine intelligence, robotics, and autonomous vehicles.

THE REAL-TIME EMBEDDED SOFTWARE GROUP at the University of Waterloo concentrates on research into real-time embedded software systems at the intersection of software technology, embedded networking, and applied formal methods.

THE CENTRE FOR AUTOMOTIVE RESEARCH (CAR) at York University is a research and education centre that offers an extensive range of automotive engineering services to vehicle and component manufacturers including topics on connectivity, light-weighting, powertrain technology, and software.



TRANSFORM LAB at Ryerson University researches impacts of CAVs on land-use, travel behaviour, and consumer acceptance. The transportation engineering research group also researches the use of big data and virtual reality to identify the infrastructure plans needed for the safe integration of CAVs on urban streets.

Pilot Programs and Demonstrations

In addition to the testing at the six AVIN Regional Technology Development Sites (RTDSs), the following pilot programs and testing initiatives are operational or planned:

AVIN TECHNOLOGY DEMONSTRATION ZONE

Allows Ontario-based companies to test, validate, and showcase their innovative CAV technologies in a controlled environment, in compliance with laws and regulations, against a wide variety of everyday, real-life traffic scenarios.³⁵

(see Page 12 for more details)



ENCQOR 5G TESTBED

Evolution of Networked Services through a Corridor in Quebec and Ontario for Research and Innovation (ENCQOR) is a public-private investment and partnership set to build a corridor of 5G wireless test beds through Ontario and Quebec. The testbed will allow SMEs to plug into an early 5G platform for research and development, and give innovators a chance to experiment with new ideas that are possible through recent breakthroughs in communication technology. Partners include the Governments of Canada, Ontario, and Quebec and private sector digital technology companies, including Ericsson, Ciena Canada, Thales Canada, IBM Canada, and CGI.⁶⁵



CITY OF TORONTO MINDING THE GAP

As part of the ACATS program, the City of Toronto, the Toronto Transit Commission (TTC), and Metrolinx are working together to deliver a pilot project on automated transit shuttle. This pilot project will include the deployment of a new transit route within Toronto in late 2020 for a six- to twelve-month period. The goal of the pilot is to test and assess CAV technologies' ability to meet key service needs in public transit, such as providing last mile services. The driverless transit services will be served using new automated shuttle vehicles that carry up to 12 passengers. On-board ambassadors will be present at all times to ensure safety operations and interfere with operations when necessary. The location of the pilot is currently unknown. The University of Toronto and Ryerson University will support the pilot project by monitoring and evaluating the shuttle service.⁶⁶



CITY OF OTTAWA ECODRIVE I & II

In 2017, the City of Ottawa partnered with Transport Canada and MTO to deliver the Assisted Commercial Vehicle Eco-Driving Pilot Project in two phases. The first phase, EcoDrive I, was a one-year program that focused on testing the impacts of I2V technologies on commercial vehicle operations. The 6 km-long testing corridor, located along Hunt Club Road, between Cleopatra Drive and Uplands Drive, includes 12 connected traffic signals that are operated by the City's signal and traffic control system and Traffic Technology Services' (TTS) analysis system. These systems allowed I2V using cellular connection and provided information on traffic signal timing to the testing vehicles operated by Purolator and Crepin Cartage. Study findings show an overall reduction in fuel consumption and CO₂ emissions output as a result of the smoother driving operations. The second phase, EcoDrive II, has expanded the testing area to a connected network with 1,200 signal controllers.⁶⁷



Private sector companies and academic research institutes have also taken advantage of *Ontario Regulation 306/15 for Automated Vehicle Pilot Projects* to independently test CAV technologies on the Ontario road network (see Page 17 for list of permitted participants).⁶⁸



Global Perspective – Research and Development



United States

The United States is active in connected and autonomous technology R&D:

- The Michigan Department of Transportation, Ford, GM, and the University of Michigan tested technology facilitating V2I and V2V connectivity along a 190-km (120 mile) stretch of freeway.⁶⁹
- A public-private partnership led by the University of Michigan developed a CAV hub called MCity; this test facility simulates urban and suburban environments for the deployment of connected vehicles and infrastructure.⁷⁰
- The USDOT established the *Connected Vehicle Pilot Deployment Program* to investigate and support the advancement of CV technology.⁷¹ This program aims to discover what barriers remain to the deployment of CVs and determine methods to address these barriers, while also documenting lessons learned and developing a template for testing other early CV technology deployments.⁷¹
- The USDOT has awarded funding, collectively worth more than \$45 million USD (\$60.6 million CAD), to three pilot sites in New York City, Wyoming, and Tampa Bay to implement and test connected vehicle applications and technologies tailored to meet their region's unique transportation needs.⁷¹
- Uber has invested heavily in self-driving cars with up to \$457 million USD (\$615 million CAD) in R&D expenses for its self-driving car unit.⁷²
- Waymo, Google's self-driving car project based in California, has focused on further developing its AV driving platform, using vehicles assembled by traditional automakers.⁷³



Finland

Finland focuses its research on ensuring AVs operate effectively in winter conditions:

- In December 2017, VTT, a government research organization, demonstrated its robot car Martti driving autonomously on a snow-covered road.⁷⁴ Further work on this will also include off-road and night time driving.³
- A 5G network established in the northern town of Oulu is used as a testing environment for CAV applications through a partnership between the University of Oulu, Oulu University of Applied Sciences, and VTT Technical Research Centre.⁷⁵
- Trials of truck platooning in icy conditions using Scania trucks made in Sweden are being carried out.³



Germany

Germany has a strong background in R&D for the automotive industry; since 2010, almost 25% of jobs related to CAVs were research and development roles.¹⁰ German auto-manufacturers continue to heavily invest in CAV R&D:

- Bosch, Audi, and Continental have filed the highest number of patents worldwide with respect to AV driving.⁷⁶
- BMW opened a new facility in Germany in 2018 to work towards the systematic development of autonomous driving, creating a test environment that uses simulations to develop and train autonomous driving programs and facilitate real world testing.⁷⁷



Japan

Japan has launched *The Cross-Ministerial Strategic Innovation Promotion Program (SIP)* to facilitate industry-academia-government cooperation for the implementation of advanced autonomous driving systems.⁷⁸ Under this program, large-scale operational field testing has been conducted between October 2017 and March 2019 with participation from both Japanese and foreign organizations, including automotive parts manufacturers and universities.⁷⁸

Research and development of CAV technology is making progress in a variety of traffic environments, including central Tokyo's Metropolitan Expressway, the Shin-Tomei Expressway, and throughout various regions of Japan.⁷⁸



Norway

In October 2018, Ruter, the mass transit provider in Oslo, announced that it is going to test autonomous buses in partnership with a Danish supplier with the aim of having up to 50 mini-buses in service by 2021.⁷⁹ Additionally, the national road administration has also begun testing autonomous truck platooning in northern Norway, and a pilot program with AV taxis are set to start in 2019.⁹



Assessment of Research and Development in Ontario

Ontario Strengths

R&D activities in Ontario have continued to evolve over the last year, and are set to continue to expand over the coming years. Similarly, a number of new pilot programs have already begun and it is anticipated that this trend will continue to increase at a fast pace, particularly with the relaxation of regulations in the province.

Industry players of all sizes and focus areas have continued to choose Ontario as a base to grow their research and development programs.

Universities and colleges in Ontario are involved in developing cutting edge research programs focusing on CAV and associated technologies.

AVIN's RTDSs are a focal point of much of the direct CAV-focused R&D efforts. The RTDSs bring together industry, academics, and the public sector, allowing them to collaborate and collectively share domain knowledge and findings, not just within individual RTDSs, but among RTDSs. As each RTDS has a focus area, their outputs, products, and findings are of value to other RTDSs.

Challenges and Gaps in Ontario

There are a number of pilot programs and demonstrations, as well as, other testing activities being undertaken in Ontario (see Page 17). However, they are on a small to medium scale, and no large scale or long-term pilots are currently planned.

AV pilots, such as the one the City of Toronto has started working on, are planned as temporary. There are no current plans for a more permanent AV shuttle, such as one that may operate on a private campus.

Although Ontario has established an authorized network where cooperative truck platoon testing is permitted, no testing has yet occurred.

Opportunities for Ontario

A number of the CAV sector players interviewed identified a clear opportunity for Ontario to become the go-to location for all-season CAV testing. Ottawa in particular highlights their range of seasonal temperatures, as well as the availability of snow stores from municipal snow removal, that can extend the testing season. Additionally, OTU's ACE facility can support a wide range of environmental testing.

Ontario is a central hub for goods movement, which can provide opportunities for further research and testing related to CAVs for freight and heavy vehicles.

With continued operations and testing at the RTDSs, as well as other testing activities in Ontario, there will be opportunities for further collaboration and coordination, and for analysis and comparison of findings.



Assessment – R&D

Ontario has a well-established environment of R&D, which continues to evolve and increase, and has the AVIN RTDSs as focal cluster points for CAV R&D. However, while Ontario's R&D compares favourably globally, there continues to be room for further growth.



Talent in Ontario

Provincial Vision

Ontario has announced a goal of establishing a talent pipeline with the next generation of highly-skilled manufacturing workers. The government investments in Raise AI and the Vector Institute are enabling steps to meeting that goal.¹⁶

As a complementary strategy, AVIN's Talent Development program provides internship and fellowship opportunities to students and recent graduates from Ontario colleges and universities, for practical experience at Ontario-based companies or academic institutions.

Academic Programs and Graduates

Within Ontario-based academia, many institutions now have relevant CAV research programs and initiatives to support students and researchers in developing knowledge in CAVs and enabling technologies:

- Ontario is home to two of the top 25 global computer science programs, with University of Waterloo ranked 15th and University of Toronto ranked 25th.⁸⁰
- The University of Toronto ranks among the top 20 global universities and University of Waterloo graduates are the second most frequently hired by Silicon Valley companies.
- Recognizing the need to develop extended skills that are outside of the traditional Science, Technology, Engineering, and Mathematics (STEM) areas, the University of Toronto and York University have developed specialization courses and programs to provide students with learning opportunities that focus on CAV technologies, such as development of CAV software, and AI.
- Sponsored graduate programs and research projects are also available in select institutions.

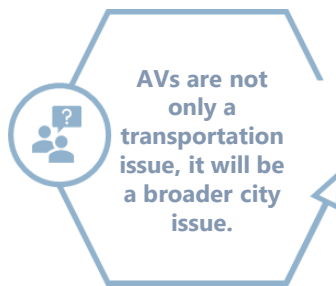


Public Sector Planners and Practitioners

Toronto was the first Ontario municipality to have staff dedicated to their CAV activities, although most large municipalities have staff that include CAVs as part of their portfolio of responsibilities, and the demands on these staff are quickly increasing.

Today, MTO, as well as the Cities of Toronto, Ottawa, and Hamilton, have established CAV working groups and have one or more staff whose responsibilities relate primarily to CAVs.

Many other municipalities may have one or more staff with CAV issues as part of a larger portfolio; these staff would be responsible to represent the municipality for CAV activities (e.g. regional workshops), and report back to a larger group as necessary. These demands, particularly for larger municipalities, are increasing as needs for considering CAVs in local and regional planning increase, and more municipalities become involved in pilot testing and demonstration activities.



The City of Toronto is an example of a municipality that has looked to academia for assistance with research and capacity building for staff.

Attracting Companies and Talent

With a high presence of both technology companies and technology-based institutions, as well as expanding demonstration and pilot projects, incubators, and innovation hubs, and STEM-based academic programs, Ontario is a prime centre for talent attraction, not just within Canada, but in North America.



- The Global Liveability Report 2017 & 2018



Global Perspective – Talent



United States

Universities in the United States play an active role in involving graduate students in research initiatives focusing on CAVs and supporting technology and infrastructure, helping them develop the skills they need to go on to industry positions.

Universities such as the Massachusetts Institute of Technology (MIT), University of Florida, Stanford University, University of Michigan, and Carnegie Mellon, among many others, all offer programs related to automotive research or supportive technology development, including AI. ^{81, 82, 83, 84}



Global

Beyond the United States, Tsinghua University in China, Seoul National University in Korea, and Oxford University in the United Kingdom are also making strides in connected and autonomous vehicle research, contributing to the development of trained individuals in this new industry.⁸⁴

In Germany, CAVs are a focus for research at universities, but there have also been specific courses developed on autonomous driving. The Technical University of Munich has been offering a course on autonomous driving since 2014.⁸⁵



Assessment of Talent in Ontario

Ontario Strengths

With many respected academic and research institutions, and a focus on STEM and emerging areas such as software programming, AI, and cybersecurity, Ontario is well positioned to meet its goal of establishing a talent pipeline.¹⁷ In addition, with its vibrant technology industry, and active and open research and testing environments, Ontario is equipped to attract outside talent to help drive and expand the Ontario CAV sector.

Challenges and Gaps in Ontario

Talent is generally developed through education and experience and, as such, capacity building outside of the players directly involved with the development and testing of CAV technologies is more difficult. This is a common challenge in the public sector, not only in Ontario but also other jurisdictions, where an understanding of CAV technologies, and the potential impacts of CAVs, is needed to plan and prepare for CAVs.

“
Need to create, acquire, and retain talent.
”

Grant Courville, QNX

Opportunities for Ontario

There is opportunity to build capacity, within Ontario, beyond the strong talent base being created through academia and R&D. Expanded involvement in demonstrations and pilots, as well as, planning activities, will result in more planners and practitioners being directly involved in the industry, further building capacity.



Assessment – Talent

Ontario is a global leader in developing technology talent through education and demonstrable R&D, but like other regions, talent and capacity will be further built through direct involvement as the CAV sector evolves and develops.

The identified areas of strengths, challenges and gaps, and opportunities have been distilled into 11 key findings.



Key Findings

Regulatory and Guideline Readiness:

1. Through the *Ontario Regulation 306/15: Pilot Project – Automated Vehicles*, Ontario has established an environment of regulatory openness that establishes the province as globally competitive.
2. To varying degrees, Ontario's municipalities have started planning and preparing for CAVs, with MTO and the City of Toronto preparing strategies and plans.
3. As is the case in other jurisdictions, regulatory and guideline efforts continue and adjust as the industry and technologies evolve.

Investment Availability:

4. There are a variety of funding sources available and significant investment from all sectors in Ontario.
5. Ontario faces competition for investment from the U.S. and globally.

Industry Bench Strength:

6. Ontario has a convergence of strong established automotive and technology sectors, with expertise in many enabling technologies.
7. Ontario has a strong network of economic development corporations and entrepreneurial accelerators that support innovation and the industry.

Robust R&D Context:

8. Ontario's universities and colleges are globally competitive and are developing leading edge research programs relating to CAVs and enabling technologies.
9. There are a number of pilots and demonstrations in Ontario, although they are generally on a smaller scale than some examples in the U.S. (e.g. MCity, Waymo).
10. AVIN is creating focal points of R&D and testing in Ontario, bringing together key players across the CAV sector.
11. Ontario is a global leader in academic and research talent. This talent and capacity will continue to be built as the sector continues to evolve and expand in Ontario.

Conclusions and Opportunities:

Ontario checks off all of the required boxes for a strong CAV ecosystem, and given the size of Canada and the region, it is well positioned globally. The AVIN initiative is helping Ontario to secure this position, and can continue to facilitate the growth and address challenges, as described on the next page.



Regulations and Guidelines

AVIN's Central Hub and supporting staff are actively involved in supporting the CAV sector by:

- Synthesizing knowledge and highlighting policy challenges for the sector through quarterly specialized reports; and
- Participating in studies and collaborative initiatives to plan and prepare for CAVs.

Moving forward, AVIN has opportunities to continue to engage with public sector planners and practitioners, providing insight on lessons learned and best practices, as well as, helping build consensus and alignment among agencies in Ontario through Central Hub activities.

The RTDSs and DZ, as well as, the R&D and WinterTech Funds, support and facilitate focused R&D and testing. These initiatives provide demonstrable experience and understanding of the capabilities and needs of CAVs, which are vital inputs into ongoing regulatory and guideline efforts.

Media of AVIN events, such as Ecosystem Meet-ups and announcements around the RTDSs, provide opportunities to engage and educate the public.



Investment

Through its suite of funding programs and commitment of Central Hub resources, AVIN is strategically investing to meet the needs of a healthy CAV ecosystem, including supporting R&D and testing across all levels of industry and academia, and the development of talent in needed emerging technology areas.

The benefits of AVIN's seed funding is evident as it stimulates the growth of Ontario's CAV sector and encourages other key players across the sector to commit their own investments.

As illustrated with the addition of AVIN's WinterTech program, an assessment of industry reaction and adjustment to funding and resource allocation are important for continued strategic investment. The industry and technologies are evolving and AVIN has the opportunity to periodically reassess priorities, identify potential gaps, and react accordingly.



Industry

Apart from seeding investment to stimulate the growth of the CAV industry, AVIN is playing a key role of making introductions and connecting industry players across the entire CAV sector, such as the following:

- The RTDSs and DZ are bringing together all levels of industry players, academia and local public agencies. It was noted by SMEs that these relationships were beneficial above and beyond the testing at the sites.
- The Ecosystem Meet-ups convened by AVIN's Central Hub bring together a wide spectrum of industry experts, CAV planners and practitioners, and allow for exchange of ideas and development of mutually beneficial relationships.

Continued active engagement with the industry will allow progressive relationship building and strengthen collaboration, as well as, provide the opportunity to continue to promote Ontario as a place for industry growth and expansion.



Research and Development

Centred around hubs of industry, academic talent, and progressive municipalities, the RTDSs have quickly become focal points for collaborative CAV-related R&D. With a particular focus area at each RTDS, there are a number of benefits, including:

- AVIN and its partners can prioritize R&D efforts;
- Like-minded players are able to collaborate and work together; and
- Outputs, products and findings can be shared collaboratively with other RTDSs.

It should be noted that the RTDSs also provide opportunities for others, beyond its core partners, to test CAV related technologies in real-world and controlled environments, using leading-edge communications.

Through its R&D Partnership Fund programs, AVIN is able to support other R&D initiatives and efforts outside of the RTDSs, helping SMEs and others with different focus areas or home locations.



Talent

AVIN's Talent Development program directly supports the development of talent in Ontario by providing seed funding towards internships and fellowships to college and university students and recent graduates. Through the program, there are opportunities to build talent through demonstrable experience and application of knowledge, with a focus on key emerging technologies.

Beyond the Talent Development program, all the other AVIN programs support capacity building and development of talent through direct R&D and testing experience, collaboration, and engagement.

ACRONYMS

4G	Fourth-Generation Wireless	LTE	Long-Term Evolution
5G	Fifth-Generation Wireless	MACAVO	Municipal Alliance for Connected and Autonomous Vehicles in Ontario
ACATS	Advance Connectivity and Automation in the Transportation System	McSCert	McMaster Centre for Software Certification
ACE	Automotive Centre of Excellence	ML	Machine Learning
AI	Artificial Intelligence	MNE	Multi-National Enterprise
APMA	Automotive Parts Manufacturer's Association	MTO	Ministry of Transportation of Ontario
AV	Autonomous/Automated Vehicles	NHTSA	National Highway Transportation Safety Administration
AVIN	Autonomous Vehicle Innovation Network	NRC	National Research Council
C-V2X	Cellular Vehicle-to-Everything	NSERC	Natural Sciences and Engineering Research Council of Canada
CAR	Centre for Automotive Research	OCE	Ontario Centres for Excellence
CARTE	Centre for Analytics and Artificial Intelligence Engineering	OEM	Original Equipment Manufacturer
CATTS	Centre for Automated and Transformative Transportation Systems	OGRA	Ontario Good Roads Association
CAV	Connected and Autonomous/Automated Vehicles	ONE	Ontario Network of Entrepreneurs
CENTRAN	Centre of Excellence for Testing and Research of AVs (<i>Singapore</i>)	OTU	Ontario Tech University
CV	Connected Vehicles	R&D	Research and Development
DSRC	Dedicated Short-Range Communications	RTDS	Regional Technology Development Site
DZ	Demonstration Zone	SAE	Society of Automotive Engineers
EV	Electric Vehicle	SDO	Standards Developing Organization
FPT	Federal/Provincial/Territorial	SIP	Strategic Innovation Promotion Program (<i>Japan</i>)
GHG	Greenhouse Gas	SME	Small-Medium Enterprise
GTHA	Greater Toronto and Hamilton Area	SR&ED	Scientific Research and Experimental Development
HAV	Highly Automated Vehicle	STEM	Science, Technology, Engineering and Mathematics
HD	High-Definition	TR 68	Technical Reference 68 (<i>Singapore</i>)
HIFP	Highway Investment Funding Program	UK	United Kingdom
HMI	Human-Machine Interface	U.S.	United States
IBLS	Institute for Border Logistics and Security	USDOT	U.S. Department of Transportation

ACRONYMS

V2C	Vehicle-to-Centre
V2I	Vehicle-to-Infrastructure
V2P	Vehicle-to-Pedestrian
V2V	Vehicle-to-Vehicle
V2X	Vehicle-to-Everything
VKT	Vehicle Kilometres Travelled
WATCAR	Waterloo Centre for Automotive Research

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