Transportation Association of Canada

Connected and Automated Vehicles: A Primer for Canadian Municipalities

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Introduction

The evolution from horse and buggy to the automobile has had a significant impact on the way cities are planned, designed and built, and how people live and work. Experts across the world are anticipating another major change in multi-modal transportation over coming decades with the introduction of connected and automated vehicles (CAVs).

From making transportation safer to transforming transportation networks, development patterns, businesses and our daily lives, CAVs will have far-reaching impacts. Despite the many claims that have been made, there is still much uncertainty surrounding CAVs, including how and when this technology will be commercially deployed, and the benefits and drawbacks of CAVs for a city's transportation network, economy and society as a whole.

This primer provides a high-level overview of CAVs. It attempts to dispel some myths around CAVs and provide some essential information, so that municipal stakeholders can make informed decisions on planning for a future with CAVs.

What are connected and automated vehicles?

CAVs include features of both **connected vehicles** and **automated vehicles**.

A **connected vehicle (CV)** uses wireless communications technologies to communicate with its surroundings. Depending on the features it has installed, a CV may be able to communicate with its occupants, other vehicles and road users, nearby transportation infrastructure including roadways and traffic signals, and the cloud.

An **automated vehicle (AV)**[1] uses a combination of sensors, controllers, onboard computers and sophisticated software to control some driving functions instead of a human driver (e.g. steering, braking, acceleration, and checking/monitoring the driving environment). SAE International has defined six levels of driving automation under standard J3016[2], as shown in Table 1.

Table 1. Levels of driving automation

Level 0	**No driving automation.** The driver performs the entire driving task, even if supported by active safety systems (e.g. automatic emergency braking, blind spot warning, lane departure warning).
Level 1	**Driver assistance.** These features provide steering or brake/acceleration support to the driver (e.g. lane centering or adaptive cruise control). The driver must constantly supervise these features.
Level 2	**Partial driving automation.** These features provide steering and brake/acceleration support to the driver (e.g. lane centering and adaptive cruise control at the same time). The driver must constantly supervise these features.
Level 3	**Conditional driving automation.** The vehicle can "drive itself" under limited conditions (e.g. speed limit, weather, presence of pedestrians or other road users) and will not operate unless all required conditions are met. The human driver is expected to respond appropriately to a request to intervene.
Level 4	**High driving automation.** The vehicle can "drive itself" under limited conditions (e.g. speed limit, weather, presence of pedestrians or other road users) and will not operate unless all required conditions are met. A human driver is not expected to take over the task of driving.
Level 5	**Full driving automation.** The vehicle can "drive itself" in all conditions.

These definitions reflect the latest guidance from SAE International; they have been modified since their introduction in 2016, and may continue to change over time. Additional examples of Level 1 to Level 5 systems are provided in Table 2.

Table 2. Examples of Level 1 to Level 5 systems

Level 1	These technologies have been available in vehicles for the past decade. For example, adaptive cruise control automatically adjusts the vehicle speed to maintain a safe distance from vehicles ahead; it has been commercially available since the mid-1990s, with most vehicle manufacturers now offering vehicles with this feature.
Level 2	Vehicles are now commercially available with technologies capable of steering, braking, accelerating, parking and changing lanes without human intervention in certain conditions, but that still require active driver supervision. Some examples include Tesla's Autopilot, GM's Cadillac Super Cruise, Nissan's ProPilot, and Mercedes-Benz's Distronic Plus.
Level 3	The first vehicle with level 3 technologies is Audi's European 2019 A8 model with "Traffic Jam Pilot." The vehicle can handle driving tasks in very specific cases, although the driver must be prepared to take back manual control immediately if the vehicle alerts them.
Level 4	Waymo (a Google/Alphabet subsidiary) is testing level 4 vehicles without a driver present in controlled conditions in some jurisdictions including Arizona and California. EasyMile and Navya are also demonstrating level 4 automated shuttles. However, these vehicles still require continuous remote monitoring and supervision when in operation.
Level 5	There is no public information on level 5 systems currently being tested.

What technologies are commercially available?

CAV technology is transforming the global automotive industry. Many companies are involved in developing CAV technology, from automakers to technology and telecommunications companies.

Connected vehicles

The availability of CV systems in North American production vehicles is currently limited. General Motors was the first to introduce CV technology in North America, in the 2017 Cadillac CTS. Ford has announced its intention to deploy CV technology in all new U.S. vehicles starting in 2022[3]. However, several companies offer aftermarket onboard units (i.e. radio equipment to convert a vehicle into a CV) and roadside units (RSUs) that can communicate between traffic management systems and equipped vehicles. There are some 60 active CV trials across North America, involving more than 15,000 vehicles and 6,000 RSUs. Many more trials are planned in both North America[4] and around the world, that will continue to progress CV technology development.

Automated vehicles

The availability of AV systems must be understood in the context of the levels of automation (as described above) and the type of vehicle.

While level 1 technologies are available in most passenger cars, and level 2 and 3 technologies are starting to become commercially available, there is considerable uncertainty and conflicting information over the timeframes for developing, commercializing and deploying fully automated vehicles (sometimes referred to as "driverless" vehicles).

Some experts believe a fully driverless AV will be available within the next five years, while others believe this is decades away. The reality is that automobile manufacturers and technology companies still face many technical challenges, because driving in a dynamic environment is a highly complex task. A vehicle with a level 5 automated driving system must be able to interpret its environment and make safe driving decisions entirely on its own. It must recognize and anticipate external actions – from a child kicking a ball onto the road, to small and large animals entering the right-of-way – and navigate in unexpected conditions including construction zones, unmarked roads, and roads covered in snow or fallen leaves.

A likely scenario is a phased deployment of AV systems, starting with well-defined and less complex environments such as divided highways or closed campuses, those with stable warm climates (no snow), and those with supportive infrastructure such as AV-friendly signs and CV infrastructure. Later deployments could expand into to more complex environments such as busy pedestrian streets, rural roads, and areas with snowy conditions.

Low-speed automated shuttles are a good example of this evolution. Most require an on-board attendant to monitor the shuttle and take control in complex situations. However, level 4 automated shuttles (i.e. shuttles that can operate without an on-board attendant) are being demonstrated in very limited environments and conditions[5,6].

It is also important to recognize these shuttles are intended for use by institutions, or transit and commercial fleet operators, rather than individuals. The shuttles operate on a fixed route, require advanced programming of the route, signage and infrastructure upgrades (in some cases), and continuous monitoring.

The most wide-ranging impacts of AVs will be felt when levels 4 and 5, which do not require a human driver, are commonplace. For example, fleets of driverless taxis or delivery vehicles that can pick up and drop off passengers or groceries, without the presence of a driver.

How could they be used?

CAVs can be used for purposes other than carrying people, and related technologies are being tested for freight and delivery vehicles, utility vehicles (e.g. snowplows, waste trucks), and off-road vehicles for farming, mining and forestry.

Some examples of how CAVs are being tested and deployed in urban areas include:

- **Automated scanning.** Vehicles can act as probes and automate the process of scanning the environment for key information and data.
- **Automated pick-up or delivery.** Vehicles can deliver or pick up requested items to or from a designated location.
- **Cooperative truck platooning.** Convoys of two or more freight trucks can be connected by wireless data technology; currently, some level of driver assistance is involved.
- **Driverless taxis.** Vehicles can automatically pick up and drop off passengers.
- **Low-speed automated transit shuttles.** Vehicles can transport passengers between specific locations along a route, often with a specific focus as a first-mile/last-mile solution around transit stations.
- **Utility vehicles.** Vehicles can perform operations such as garbage collection, snow removal or asphalt paving, to help ensure worker safety.

How might they impact transportation and society?

CAVs have the potential to improve the safety, efficiency and accessibility of transportation, but their broader social impacts are uncertain. For example, while they could make individual trips more efficient, they could also lead to more congestion; they could either help or hinder public transit. Such impacts are the subject of research and debate around the world. A few issues of notable interest are described below.

Safety

CAVs are expected to make transportation safer by reducing collisions. According to data from Transport Canada's National Collision Database, driver behaviour was a contributing factor in approximately 86% of collisions causing death and injury in Canada[7]. CAVs could help reduce the number and severity of crashes in Canada first by helping human drivers make better decisions on the road, and eventually by taking over the driving task. While CAVs are expected to reduce collisions, they will not eliminate them entirely, and new technical issues (e.g. damaged sensors) could lead to new causes of collisions.

Congestion, travel demand and travel patterns

CAVs have the potential to decrease congestion by reducing collisions, and by using roadways more efficiently (e.g. by taking advantage of real-time information on traffic conditions, or by allowing level 4 or 5 vehicles to drive closely together).

On the other hand, by making transportation cheaper, more accessible and convenient, CAVs could increase the number of vehicles on the road and the distances they travel:

- Persons who currently do not drive, or for whom travel options are limited (e.g. older adults, children under age 16, individuals with disabilities), may want to take advantage of these new mobility options.
- If CAVs are cheap, plentiful and convenient they could attract users away from walking, cycling, transit and carpooling.
- If people can do other activities (including sleep) in CAVs, they might accept longer commutes.
- Zero-occupancy trips (i.e. where no one is in the vehicle) would become a possibility.

Energy use

The range of possible CAV impacts on energy demand is very wide. A 2016 study funded by the U.S. Department of Energy's Vehicle Technologies Office stated that "the future impact of new mobility systems, including connected and automated vehicles, could range from a 60% decrease in overall transportation energy to a 200% increase."[8]
A reduction in travel demand, making vehicles lighter (e.g. by removing safety and control systems needed by vehicles with human drivers), more efficient driving, and the use of ridesharing were the main contributors to the lower energy bound. Increases in travel demand, faster travel, and empty miles all contribute to the higher energy bound. Different studies and models may come up with different upper and lower limits, and the uncertainties around transportation demand, vehicle use and vehicle technologies are significant and unresolved.

Land use

People commuting in an AV may have a higher tolerance for longer commutes since they can spend time in the vehicle working, resting or recreating. This may lead people to live further away from their regular destinations, increasing the potential for exurban development that increases congestion and infrastructure costs.

At the same time, the advent of fully automated vehicles may reduce the need for vehicle storage and allow parking space to be reallocated to higher value uses. This could lead to relaxed parking requirements in land use by-laws, the redevelopment of parking lots, and the opportunity for more compact communities.

Public transit

Bus automation could allow different service types such as micro-transit, bus platoons, and low-speed automated shuttles for first-mile/last-mile applications. It could also allow a reduction in the number of bus and other transit vehicle operators, or their reallocation to customer service or other functions; in theory this could reduce transit operating costs, but it must be recognized that bus operators also have valuable roles in validating fares, providing security, and acting as first responders in emergencies.

Driverless rail systems are already in operation, including Vancouver's SkyTrain which opened in the 1980s. They can operate without a driver because they do not face any road crossings or pedestrian conflicts, but future technologies could also allow driverless trains to operate without grade separations.

What is the role of government?

Canada's various orders of government carry out a variety of important activities related to CAVs, as summarized in Table 3.

What is the role of the private sector?

Activities of businesses related to CAVs include:

- Conducting research into different technologies
- Funding development and conducting tests of vehicles and equipment
- Selling and servicing vehicles and vehicle components
- Providing consulting services
- Providing services to road users including insurance and cloud computing
- Providing communications equipment and infrastructure

How can Canadian municipalities prepare?

The dominant form of transportation in Canadian cities is the personal automobile. A major change to the capabilities and use of automobiles will have significant implications for a city's transportation networks, land use patterns and finances. However, there is still a great deal of uncertainty about if, how and when higher-level CAVs will be widely adopted by the general public, and about the extent of their impacts (see the preceding section *"How might they impact transportation and society?"*).

Table 3. Government roles and responsibilities related to CAVs in Canada

Federal	Provincial/Territorial	Municipal
Setting and enforcing safety standards for new or imported motor vehicles and motor vehicle equipment Investigating and managing the recall and remedy of non-compliances and safety-related motor vehicle defects Public education on motor vehicle safety issues Monitoring and developing rules on privacy and cyber security Setting and enforcing compliance with technical standards related to wireless technologies integrated in vehicles and roadside infrastructure	Testing and licensing human drivers and registering motor vehicles in their jurisdictions Enacting and enforcing traffic laws and regulations (including trials) Conducting safety inspections Regulating motor vehicle insurance and liability Public education on motor vehicle safety issues Adapting provincially-owned infrastructure to support AV/CV deployment Planning future transportation projects	Enacting and enforcing bylaws Advocating for and accommodating testing Enforcing traffic laws and regulations Adapting infrastructure to support AV/CV deployment Managing passenger transportation (including public transit, taxis and ridesharing services) Managing and creating new logistics for traffic control and parking enforcement Public education on motor vehicle safety issues

Source: Policy and Planning Support Committee Working Group on Automated and Connected Vehicles, *Automated and Connected Vehicles Policy Framework for Canada*, 2019

Many cities face a dilemma. They do not want a transportation technology to be adopted by the public without regulations, guidelines or a plan to safely use the technology. At the same time, cities do not want to invest prematurely in infrastructure or services to support a technology that may never be adopted, nor to over-regulate emerging technologies and possibly stifle the progress or benefits of innovation. For example, *Time* magazine predicted in 2001 that the Segway "will be to the car what the car was to the horse and buggy"; and in hindsight, cities would have made poor investments by designing and building networks for Segways rather than more proven modes of travel.

Despite the uncertainties around CAVs, here are some things we do know:

- **The 21st century transportation system is data-driven.** CAVs will generate an abundance of data, and will depend on data (e.g. high-definition digital maps, traffic signal timings, traffic speeds and volumes) to navigate safely. Frameworks for data privacy, ownership, management and exchange will be needed.

- **We need to attract new talent and train existing talent.** To manage future traffic management systems, cities need highly qualified personnel whose skillsets range from traditional civil and transportation engineering to computer and software engineering, and who offer expertise in data analytics, radio communications and cybersecurity.
- **Local policies can shape how CAVs are deployed.** Cities will need to develop measures to encourage CAV deployment and use that are in alignment with community goals and objectives.

Cities could undertake a range of activities to prepare for CAVs, some low-cost and others more ambitious, as suggested in Table 4.

Table 4. Possible municipal activities to prepare for CAVs

Low cost	Medium cost	High cost
Monitor CAV impacts in other countries leading in CAV development, such as: USA, Netherlands, Japan, Singapore, Germany and the U.K. Establish interdepartmental working groups to assess potential impacts of CAVs on city planning and service delivery, and plan responses Attend webinars and online training courses offered by industry and professional organizations Review research reports, discussion papers and newsletters by academic institutions, industry and professional organizations, e.g. TAC, TRB, IEEE, SAE Join project working groups or steering committees	Conduct an inventory of core traffic control devices (e.g. signal controllers) Membership on project working groups or steering committees Fund studies independently or in partnership with others through pooled-fund mechanisms Attend in-person or digital conferences and trade shows Support staff skills training and certification	Undertake pilot deployments of vehicles such as automated shuttles Add or upgrade infrastructure such as roadside units

What is the role of TAC?

TAC has identified two major roles for itself related to CAVs:

- **Help its members enable the operation of CAVs.** This focuses on road and roadside infrastructure and data management, and emphasizes CVs (rather than AVs) over a shorter-term timeframe.
- **Help its members manage the use of CAVs.** This focuses on safety for all road users, right-of-way management, special vehicles, and community vehicles, and emphasizes AVs (rather than CVs) over a long-term timeframe.

For more information

TAC's website offers a number of helpful resources including a discussion paper, an inventory of Canadian initiatives, a lexicon, and a list of key publications and online information hubs.

Endnotes

[1] A variety of terms (e.g. self-driving, autonomous, driverless, highly automated) have been used by the media, industry, government and others to describe various forms of automation in road vehicles. This primer uses "automation" and "automated vehicles" to be consistent with TAC's Lexicon of Terms: Connected and Automated Vehicles (September 2019).

[2] https://www.sae.org/news/2019/01/sae-updates-j3016-automated-driving-graphic

[3] https://medium.com/cityoftomorrow/how-talking-and-listening-vehicles-could-make-roads-safer-cities-better-f215c68f376f

[4] https://www.transportation.gov/research-and-technology/operational-connected-vehicle-deployments-us

[5] https://easymile.com/vehicle-solutions/ez10-passenger-shuttle

[6] https://navya.tech/en/navya-reaches-a-new-milestone-in-autonomous-mobility-with-the-first-fully-autonomous-level-4-operation-on-a-closed-site/

[7] https://tc.canada.ca/en/road-transportation/innovative-technologies/automated-connected-vehicles/automated-connected-vehicles-101

[8] https://www.energy.gov/eere/articles/technologies-will-transform-transportation-system

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