

Report

Discussion Paper on Connected and Automated Vehicles



Prepared for Transportation Association of Canada
by IBI Group
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Executive Summary

This discussion paper is intended to inform efforts by the Transportation Association of Canada (TAC) related to connected vehicles (CVs) and automated vehicles (AVs).

Introduction

In Section 1, the paper introduces two key questions:

- What is TAC’s role in the Canadian CV/AV ecosystem?
- What are the most important technical issues for TAC to address, and what are the associated responsibilities of TAC’s internal bodies?

It outlines the work conducted to answer these questions, and gives important context regarding TAC and its Connected and Automated Vehicles (CAV) Task Force.

Canada’s CV/AV Ecosystem

In Section 2, the paper describes the three main components of Canada’s CV/AV ecosystem (i.e. vehicle system, infrastructure system, road user system), and the linkages between them (see **Exhibit E 1**).

The paper then identifies and discusses four groups of key stakeholders within the three systems (see **Exhibit E 2**): the private sector, technical organizations, standards development organizations, and governments. It also provides a summary of recent CV/AV tests and trials that have been conducted in Canadian jurisdictions.

Exhibit E 1: Core Systems and Linking Elements of the Canadian CV/AV Ecosystem

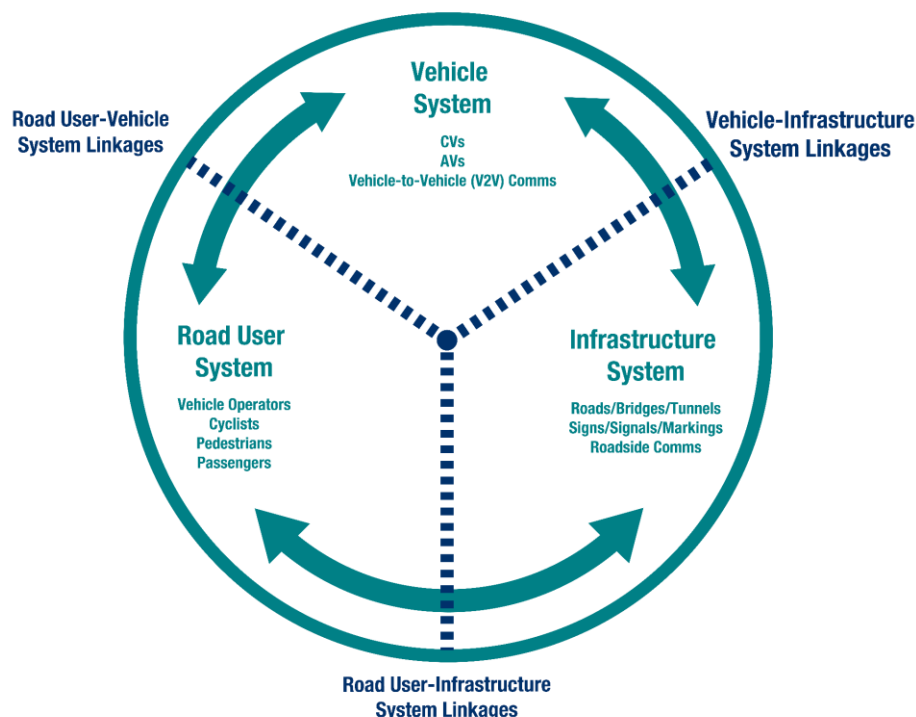
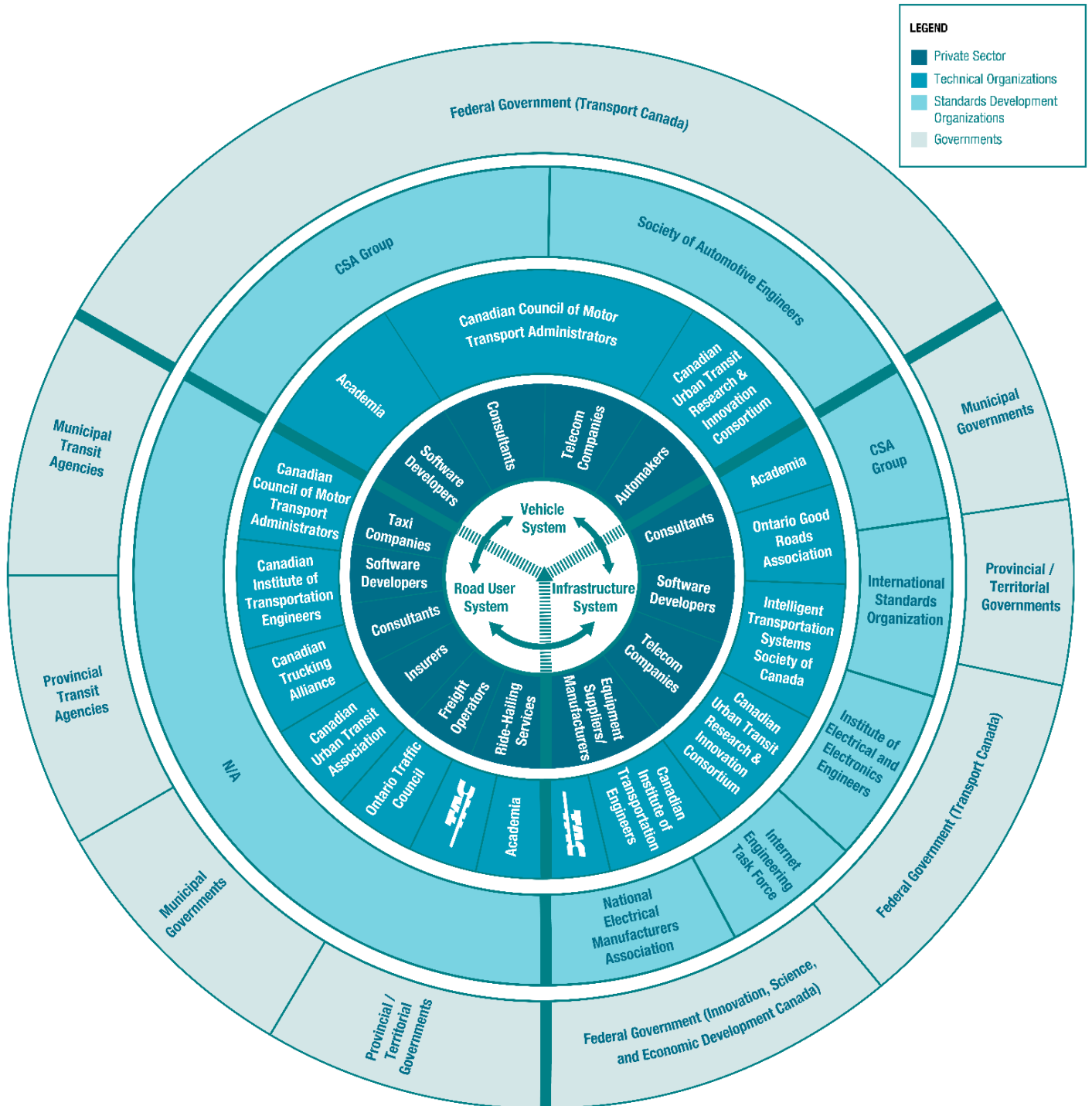


Exhibit E 2: Stakeholders in the Canadian CV/AV Ecosystem

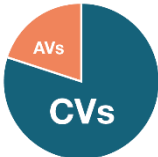
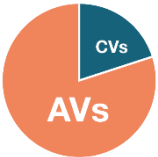


TAC’s Role

In Section 3, the paper identifies and describes two major roles for TAC in the Canadian CV/AV ecosystem (see **Exhibit E 3**):

- Help TAC members enable the operation of CVs and AVs
- Help TAC members manage the use of CVs and AVs

Exhibit E 3: TAC’s Roles in the Canadian CV/AV Ecosystem

KEY DIMENSIONS	RELATIVE EMPHASIS ON CVs OR AVs	RELATIVE TIMELINE
Role A. Help TAC members <u>enable the operation</u> of CVs and AVs		
Road infrastructure Roadside infrastructure Data management		Greater emphasis on <u>short-term</u> and <u>mid-term</u>
Role B. Help TAC members <u>manage the use</u> of CVs and AVs		
Safety for all road users Right-of-way management Special vehicles Community impacts		Greater emphasis on <u>mid-term</u> and <u>long-term</u>

Key Issues and Possible Actions for TAC

In Section 4, the paper identifies four types of actions within these two roles (**Exhibit E 4**):

- Gathering information
- Sharing knowledge
- Developing technical guidance
- Supporting workforce development

















































Within this framework of roles and action types, Section 4 identifies the technical focus areas of TAC that are most closely related, the key technical issues that TAC could address, and a range of possible actions for TAC’s councils and committees. These actions include:

- Engaging with a range of potential partner organizations to acquire and exchange knowledge
- Disseminating lessons learned and emerging guidelines or standards
- Advancing TAC members’ understanding of their roles in data security and privacy
- Identifying gaps in TAC’s technical guidance related to enabling and managing CV/AVs

- Conducting technical projects to develop new guidance
- Identifying needs and opportunities for educating and training Canadian transportation practitioners, and either delivering learning activities or supporting their delivery by others

Finally, Section 4 suggests next steps for TAC’s Secretariat and volunteer bodies, including the development and maintenance by the CAV Task Force of a tracking document to monitor the activities and progress of TAC’s various councils and committees.

Exhibit E 4: Action Framework for TAC

ACTION TYPES		TAC FOCUS AREAS	
Role A. Help TAC members <u>enable the operation</u> of CVs and AVs			
Knowledge	A1. Gather information	 SAFETY  MOBILITY  INFRASTRUCTURE AND ASSET MANAGEMENT	 ENVIRONMENT AND CLIMATE CHANGE  TECHNOLOGY  WORKFORCE DEVELOPMENT
	A2. Share knowledge	 SAFETY  MOBILITY  INFRASTRUCTURE AND ASSET MANAGEMENT	 ENVIRONMENT AND CLIMATE CHANGE  TECHNOLOGY  WORKFORCE DEVELOPMENT
Guidance	A3. Develop technical guidance	 SAFETY  MOBILITY  INFRASTRUCTURE AND ASSET MANAGEMENT	 ENVIRONMENT AND CLIMATE CHANGE  TECHNOLOGY  WORKFORCE DEVELOPMENT
	A4. Support workforce development	 SAFETY  MOBILITY  INFRASTRUCTURE AND ASSET MANAGEMENT	 ENVIRONMENT AND CLIMATE CHANGE  TECHNOLOGY  WORKFORCE DEVELOPMENT
Role B. Help TAC members <u>manage the use</u> of CVs and AVs			
Knowledge	B1. Gather information	 SAFETY  MOBILITY  INFRASTRUCTURE AND ASSET MANAGEMENT	 ENVIRONMENT AND CLIMATE CHANGE  TECHNOLOGY  WORKFORCE DEVELOPMENT
	B2. Share knowledge	 SAFETY  MOBILITY  INFRASTRUCTURE AND ASSET MANAGEMENT	 ENVIRONMENT AND CLIMATE CHANGE  TECHNOLOGY  WORKFORCE DEVELOPMENT
Guidance	B3. Develop technical guidance	 SAFETY  MOBILITY  INFRASTRUCTURE AND ASSET MANAGEMENT	 ENVIRONMENT AND CLIMATE CHANGE  TECHNOLOGY  WORKFORCE DEVELOPMENT
	B4. Support workforce development	 SAFETY  MOBILITY  INFRASTRUCTURE AND ASSET MANAGEMENT	 ENVIRONMENT AND CLIMATE CHANGE  TECHNOLOGY  WORKFORCE DEVELOPMENT

Résumé

Le présent document de travail vise à documenter les efforts de l'Association des transports du Canada (ATC) en matière de véhicules connectés (VC) et de véhicules automatisés (VA).

Introduction

La partie 1 du document porte sur deux questions principales :

- Quel est le rôle de l'ATC dans l'écosystème canadien des VC-VA?
- Quels sont les enjeux techniques les plus importants que l'ATC doit résoudre et quelles sont les responsabilités des organes internes de l'ATC?

Cette partie décrit également le travail effectué pour répondre à ces questions et présente un contexte important concernant l'ATC et son Groupe de travail sur les véhicules connectés et automatisés (VCA).

Écosystème canadien des VC-VA

La partie 2 du document décrit les trois principales composantes de l'écosystème canadien des VC-VA (c'est-à-dire le réseau des véhicules, le réseau des infrastructures et le réseau des usagers de la route) et les liens qui les unissent (voir la **Figure E 5**).

Ensuite, le document définit et examine quatre groupes de parties prenantes clés au sein des trois réseaux (voir la **Figure E 6**) : le secteur privé, les organisations techniques, les organisations de normalisation et les gouvernements. Il fournit également un résumé des tests et essais récemment réalisés sur les VC-VA dans les provinces-territoires du Canada.

Figure E 5 : Réseaux centraux et éléments de liaison de l'écosystème canadien des VC-VA

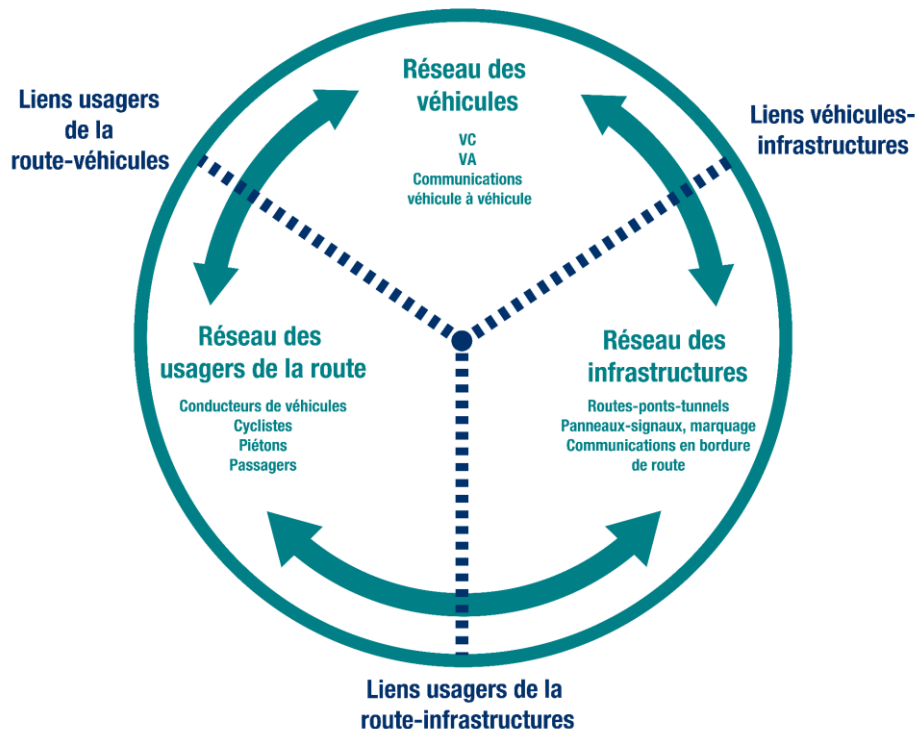
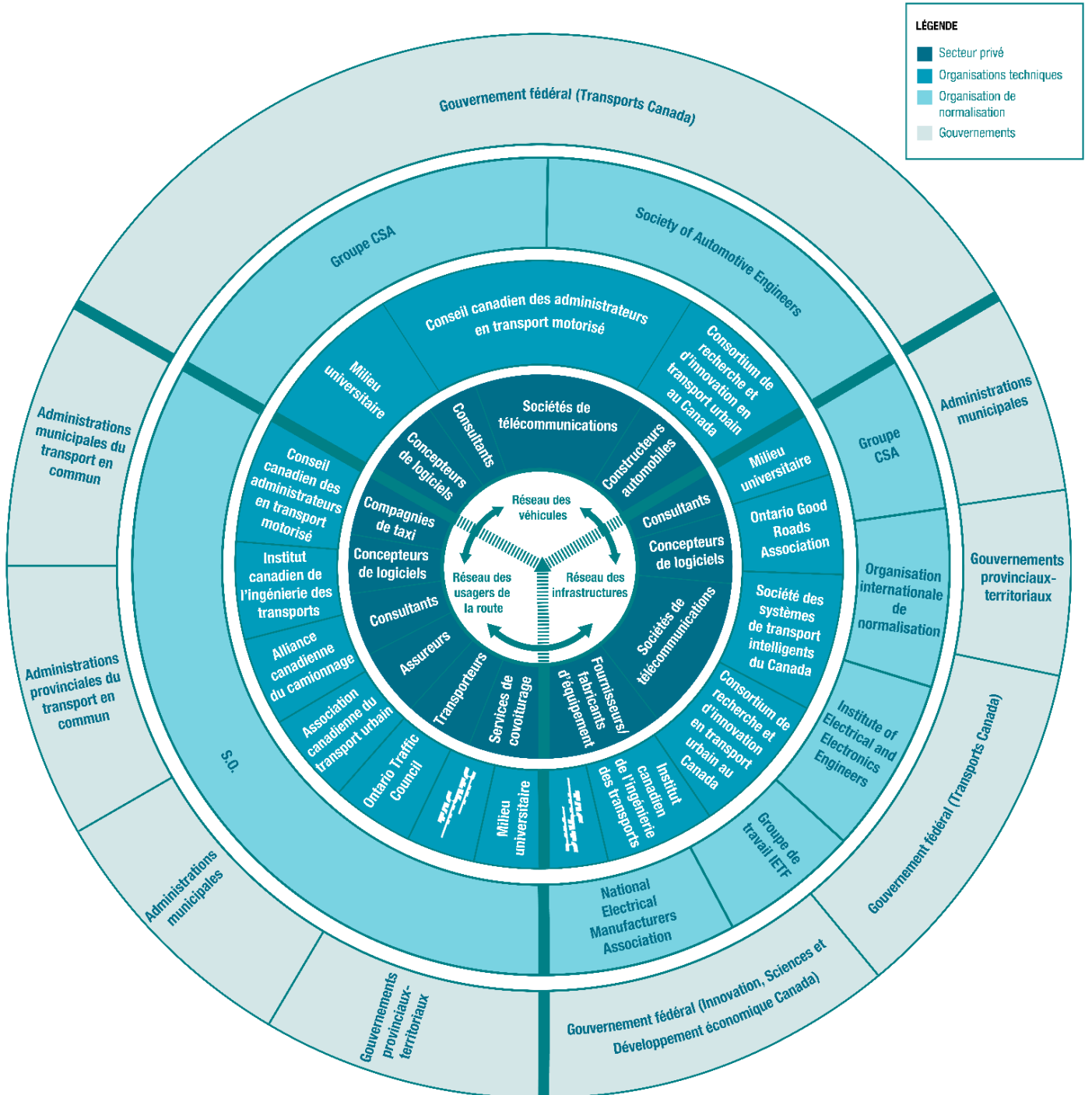


Figure E 6 : Parties prenantes de l'écosystème canadien des VC-VA

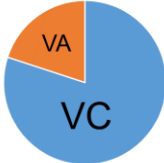
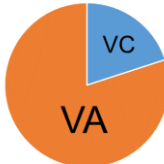


Rôle de l'ATC

La partie 3 du document définit et décrit deux principaux rôles de l'ATC dans l'écosystème canadien des VC-VA (voir la **Figure E 7**) :

- Aider les membres de l'ATC à déployer les VC et les VA.
- Aider les membres de l'ATC à gérer l'utilisation des VC et des VA.

Figure E 7 : Rôles de l'ATC dans l'écosystème canadien des VC-VA

DIMENSIONS CLÉS	ACCENT RELATIF SUR LES VC OU LES VA	ÉCHÉANCIER RELATIF
Rôle A. Aider les membres de l'ATC à <u>déployer</u> les VC et les VA		
<p>Infrastructure routière</p> <p>Infrastructure des abords des routes</p> <p>Gestion de données</p>		<p>Accent accru mis sur le <u>court terme</u> et le <u>moyen terme</u></p>
Rôle B. Aider les membres de l'ATC à <u>gérer l'utilisation</u> des VC et des VA		
<p>Sécurité pour tous les usagers de la route</p> <p>Gestion des emprises</p> <p>Véhicules spéciaux</p> <p>Impacts communautaires</p>		<p>Accent accru mis sur le <u>moyen terme</u> et le <u>long terme</u></p>

Principaux enjeux et actions que peut mener l'ATC

La partie 4 du document définit quatre types d'action à l'intérieur de ces deux rôles (voir la **Figure E 8**) :

- Recueillir de l'information
- Partager les connaissances
- Concevoir des directives techniques
- Appuyer le perfectionnement de la main-d'œuvre

























Dans ce cadre de rôles et de types d'action, la partie 4 indique les domaines d'intervention technique de l'ATC qui sont le plus étroitement liés, les principaux enjeux techniques que l'ATC pourrait traiter et un éventail d'actions possibles pour les conseils et comités de l'ATC. Ces actions sont entre autres les suivantes :

- collaborer avec un éventail d'organisations partenaires potentielles pour acquérir et échanger des connaissances;
- diffuser les enseignements tirés et les lignes directrices ou normes émergentes;

- améliorer la compréhension des membres de l'ATC relativement à leur rôle en matière de sécurité et de confidentialité des données;
- définir les lacunes dans les directives techniques de l'ATC relativement au déploiement et à la gestion des VC-VA;
- réaliser des projets techniques pour concevoir de nouvelles directives;
- définir les besoins et les possibilités en matière d'information et de formation pour les spécialistes canadiens du transport; offrir des activités d'apprentissage ou appuyer les activités offertes par d'autres organismes.

Enfin, la partie 4 présente les prochaines étapes que le Secrétariat de l'ATC et les organismes bénévoles devraient suivre, notamment l'élaboration et la mise à jour par le Groupe de travail VCA d'un document de suivi permettant de suivre les activités et les progrès des divers conseils et comités de l'ATC.

Figure E 8 : Cadre d'action pour l'ATC

TYPES D'ACTION		DOMAINES D'INTERVENTION DE L'ATC	
Rôle A. Aider les membres de l'ATC à déployer les VC et les VA			
Connaissances	A1. Recueillir de l'information	 SÉCURITÉ  MOBILITÉ  GESTION DE L'INFRASTRUCTURE ET DES ACTIFS	 ENVIRONNEMENT ET CHANGEMENTS CLIMATIQUES  TECHNOLOGIE  PERFECTIONNEMENT DE LA MAIN-D'ŒUVRE
	A2. Partager les connaissances		
Directives	A3. Concevoir des directives techniques	 SÉCURITÉ  MOBILITÉ  GESTION DE L'INFRASTRUCTURE ET DES ACTIFS	 ENVIRONNEMENT ET CHANGEMENTS CLIMATIQUES  TECHNOLOGIE  PERFECTIONNEMENT DE LA MAIN-D'ŒUVRE
	A4. Appuyer le perfectionnement de la main-d'œuvre		
Rôle B. Aider les membres de l'ATC à gérer l'utilisation des VC et des VA			
Connaissances	B1. Recueillir de l'information	 SÉCURITÉ  MOBILITÉ  GESTION DE L'INFRASTRUCTURE ET DES ACTIFS	 ENVIRONNEMENT ET CHANGEMENTS CLIMATIQUES  TECHNOLOGIE  PERFECTIONNEMENT DE LA MAIN-D'ŒUVRE
	B2. Partager les connaissances		
Directives	B3. Concevoir des directives techniques	 SÉCURITÉ  MOBILITÉ  GESTION DE L'INFRASTRUCTURE ET DES ACTIFS	 ENVIRONNEMENT ET CHANGEMENTS CLIMATIQUES  TECHNOLOGIE  PERFECTIONNEMENT DE LA MAIN-D'ŒUVRE
	B4. Appuyer le perfectionnement de la main-d'œuvre		

List of Acronyms

ACRONYM	MEANING
AASHTO	American Association of State Highway and Transportation Officials
ACATS	Advance Connectivity and Automation in the Transportation System
ACES	Automated, connected, electric and shared
ARC-IT	Architecture Reference for Cooperative and Intelligent Transportation
AV	Automated vehicle
AVIN	Autonomous Vehicle Innovation Network
CAT Coalition	Cooperative Automated Transportation Coalition
CAVCOE	Canadian Automated Vehicles Centre of Excellence
CCMTA	Canadian Council of Motor Transport Administrators
CITE	Canadian Institute of Transportation Engineers
CSA	Canadian Standards Association
CTA	Canadian Trucking Alliance
CUTA	Canadian Urban Transit Association
CUTRIC	Canadian Urban Transit Research & Innovation Consortium
CV	Connected vehicle
DSRC	Dedicated short range communications
ENCQOR	Evolution of Networked Services through a Corridor in Québec and Ontario for Research and Innovation
GPS	Global positioning system
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
ISED	Innovation, Science, and Economic Development Canada
ISO	International Standards Organization
ITE	Institute of Transportation Engineers
ITS	Intelligent Transportation Systems
ITS Canada	Intelligent Transportation Systems Society of Canada
ITSS	Intelligent Transportation Systems Society
LIDAR	Light detection and ranging
MACAVO	Municipal Alliance for Connected and Autonomous Vehicles in Ontario
MTO	Ministry of Transportation Ontario
MUTCD	Manual of Uniform Traffic Control Devices
MUTCDC	Manual of Uniform Traffic Control Devices for Canada

ACRONYM	MEANING
NACTO	National Association of City Transportation Officials
NEMA	National Electrical Manufacturers Association
NIST	National Institute of Standards and Technology
NLC	National League of Cities
NOCoE	National Operations Center of Excellence
OEM	Original equipment manufacturer
OGRA	Ontario Good Roads Association
OTA	Ontario Trucking Alliance
OTC	Ontario Traffic Council
SAAQ	Société de l'assurance automobile du Québec (Quebec Automobile Insurance Corporation)
SAE International	Society of Automotive Engineers International
SPaT	Signal phasing and timing
TAC	Transportation Association of Canada
USDOT	United States Department of Transportation
V2I	Vehicle-to-infrastructure
V2N	Vehicle-to-network
V2P	Vehicle-to-pedestrian
V2V	Vehicle-to-vehicle

1 Introduction

1.1 About the Study

1.1.1 Purpose

This discussion paper is intended to inform efforts by the Transportation Association of Canada (TAC) related to connected vehicles (CVs) and automated vehicles (AVs). It describes Canada's CV/AV ecosystem (**Section 2**), then answers two key questions:

- What is TAC's role in the Canadian CV/AV ecosystem? (**Section 3**)
- What are the most important technical issues for TAC to address, and what are the associated responsibilities of TAC's internal bodies? (**Section 4**)

1.1.2 Approach

This discussion paper reflects the findings from the following three stages of work:

- **Canadian background review, stakeholder interviews, and literature review.** IBI Group established a clear understanding of the existing CV/AV issues within Canada. This was done using the results of a baseline survey of TAC councils and committees in October 2018, a review of Canadian CV/AV literature, and 20 Canadian stakeholder interviews (**Appendix A**).
- **International stakeholder interviews and literature review.** The consultant reviewed the existing CV/AV issues identified by relevant peer organizations in the US and Australia. The review included a review of CV/AV literature, and eight international stakeholder interviews (**Appendix A**).
- **Strategic synthesis.** The consultant identified possible roles for TAC to take in the Canadian CV/AV ecosystem, the key CV/AV issues that TAC could address, and possible actions that TAC could take.

1.2 About TAC

TAC is a not-for-profit, national technical association that focuses on roads and urban transportation. Its 500 corporate members include governments, businesses, academic institutions, and other associations. TAC provides a neutral, non-partisan forum for those organizations and their employees to address transportation challenges by sharing ideas and information, building knowledge, and pooling resources.

TAC's work includes the development of publications that identify best practices and encourage harmonization among member jurisdictions. While TAC does not set standards, it is a principal source of guidelines for the planning, design, construction, management, operation, and maintenance of road, highway, and urban transportation infrastructure systems and services.

1.2.1 Vision and Focus Areas

TAC's corporate *Strategic Plan* (TAC, 2017) identifies TAC's vision as "*Transportation that makes Canada safe, healthy and prosperous,*" and establishes the following six focus areas as TAC's main technical priorities:

- **Safety**—reducing injury and fatalities for all road users
- **Mobility**—providing and operating seamless, multimodal transportation networks and services

- **Infrastructure and asset management**—creating and maintaining safe, secure, and efficient facilities
- **Environment and climate change**—protecting ecology, conserving natural resources, preventing pollution, and mitigating and adapting to climate change
- **Technology**—maximizing the benefits of advanced computing, wireless communications, electrification, and data collection
- **Workforce development**—improving skills development, recruitment and retention, and knowledge management

1.2.2 Mission and Strategic Priorities

TAC's *Strategic Plan* identifies its mission as “*Working together to share ideas, build knowledge, promote leading practices, foster leadership and encourage bold transportation solutions.*” It fulfills this role through day-to-day actions aligned with the following strategic priorities:

- **Collaborate and communicate**—providing a neutral forum for the exchange of ideas and the discussion of technical transportation issues
- **Build knowledge**—developing references and tools, including guidelines and syntheses of practices, to address research and practical needs in the highway, road and urban transportation sectors
- **Disseminate information**—providing a vital source of transportation materials for Canadian practitioners
- **Develop our people**—fostering leadership and contributing to the availability and technical currency of transportation professionals in Canada
- **Manage effectively, now and for the future**—ensuring the sustainability of TAC, with respect to finances, membership, volunteers, and staff

1.2.3 Connected and Automated Vehicles Task Force

In October 2018, TAC's Board of Directors approved the Terms of Reference for a new Connected and Automated Vehicles (CAV) Task Force. This step followed two years of related activity by a working group under the purview of the Traffic Operations and Management Standing Committee, and the emergence of a consensus among TAC volunteers and Board members that the significant challenges and opportunities related to CVs and AVs in Canada require a broad organizational response. The inaugural meeting of the CAV Task Force was held in April 2019.

The CAV Task Force includes up to 34 voting members who represent TAC's volunteer councils, federal/provincial/territorial governments, municipal/regional transportation authorities, and the business/academic sector. The Executive has also invited selected TAC partner organizations to appoint non-voting members.

The CAV Task Force has four key roles, as identified in its Terms of Reference:

- **Connect**
 - provide a forum for TAC councils and committees to share perspectives on CV/AVs
 - help TAC councils and committees identify collective concerns, gaps, and opportunities

- **Inform**
 - collect and share information on CV/AV activities of TAC councils and committees
 - collect and share information on CV/AV activities of external organizations
- **Guide**
 - identify critical gaps for TAC members to address through collaboration
 - encourage TAC councils and committees to integrate CV/AV issues in their work plans and projects
- **Represent**
 - liaise with external organizations to inform them about TAC activities, learn about their activities, and identify shared or divergent interests
 - encourage involvement and membership in TAC by CV/AV industry stakeholders (e.g. automakers, software companies, telecommunications providers)
 - collaborate with external organization on joint initiatives or events

2 Canada's CV/AV Ecosystem

2.1 Overview

Exhibit 2-1 shows the three core systems within the Canadian CV/AV ecosystem:

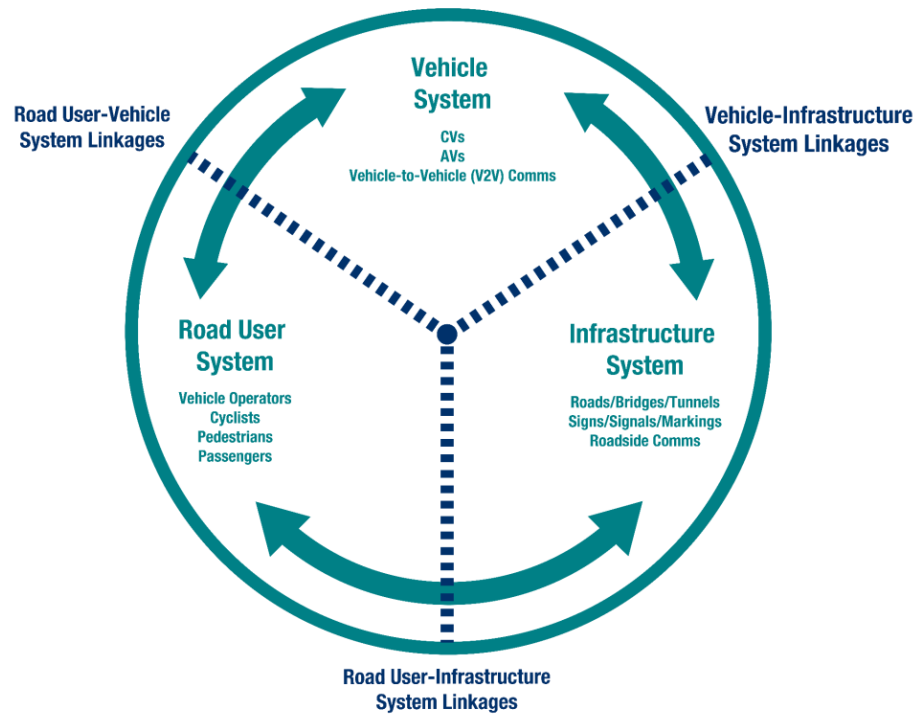
- **Vehicle system**—This includes the various vehicle types (e.g. cars, trucks, motorcycles, transit vehicles, emergency vehicles, etc.) that traverse the road network, and their associated CV/AV technologies. CVs use onboard communications equipment for communicating to the infrastructure system and road user system, and exchanging information on the current state of the systems. The objective of CV deployment is to improve safety and mobility, along with overall operating efficiency through communication. AV systems include onboard sensors (e.g. ultrasound, LIDAR, camera, etc.), which are used to gather information from the surrounding environment (i.e. both infrastructure system and roadway system). This information is combined with GPS data and high-resolution mapping to locate the vehicle along the roadway. AVs use onboard sensors, map data, and software applications to “sense” the infrastructure systems and other road user systems, with the goal of automating the driving experience and increasing safety.
- **Infrastructure system**—This includes the physical assets that make up the road network, including passive and active infrastructure. Examples of passive infrastructure include roads, bridges and tunnels, along with the associated signs and pavement markings. Examples of active assets include traffic signals, pedestrian crosswalks, and dynamic message signs. For CVs, the infrastructure system actively communicates with the vehicle system and the road user system to provide information on the current state of the infrastructure, such as the current state of a traffic signal and the duration of time remaining in the current green display. Traditional passive infrastructure can be enhanced with technology to enable active communication with CVs. As an example, sensors added to bridges can provide information on slippery pavement conditions. From an AV perspective, the infrastructure system is relatively passive, since AVs actively monitor infrastructure through onboard sensors to gather information and determine a course of action. However, the passive infrastructure needs to be recognizable and understandable by AVs under various conditions (day to night transition, inclement weather, etc.).
- **Road user system**—This includes all of the people that traverse the road network. Examples include motor vehicle operators (both human and virtual), as well as vehicle passengers, transit users, pedestrians and cyclists. For CVs, human driver decision making is enhanced by supplemental information provided through CV communications. For AVs, the operator workload is reduced as the level of automation increases, ultimately to fully automated (i.e. at the highest level of automation, no human operator is needed).

Exhibit 2-1 also shows the linking elements that join the core systems:

- **Vehicle-infrastructure system linkages**—These include vehicle sensing and navigation, mapping, and vehicle-to-infrastructure (V2I) and vehicle-to-network (V2N) communications.
- **Road user-vehicle system linkages**—These include the driver interface and controls, as well as vehicle-to-pedestrian (V2P) communications.

- **Road user-infrastructure system linkages**—These include rules of the road (i.e. the laws that govern the conduct of road users along the road network, including highway traffic acts).

Exhibit 2-1: Core Systems and Linking Elements of the Canadian CV/AV Ecosystem



The three core systems each involve several stakeholder groups:

- **Private sector**—Businesses conduct research and are actively involved in a variety of different parts of the CV/AV ecosystem. They develop and sell products and services that focus on the vehicle and infrastructure systems, while also providing services (e.g. insurance) in the road user system. The private sector also provides the communications equipment and infrastructure required for CV applications.
- **Technical organizations**—These bring other stakeholders together to collaborate on the research, development and testing of CV/AV technology. Some technical organizations also advocate or support policy development.
- **Standards development organizations**—These bring other stakeholders together to create technical standards for emerging technologies and processes.
- **Governments**—Federal, provincial, and municipal governments provide services to the public and protect the public interest.

Exhibit 2-2 visually summarizes these stakeholder groups, which are then discussed in greater detail in Sections 2.2 to 2.4.

2.2 Vehicle System Stakeholders

This section provides an overview of the key stakeholders in the vehicle system.

2.2.1 Private Sector

Automakers produce cars, trucks, buses, and motorcycles. Automakers, along with automotive equipment manufacturers and suppliers, also provide services and products, either original or aftermarket, to the automotive industry. Products include onboard equipment, electronics, and communications, including dedicated short-range communications (DSRC) and cellular communications.

Consultants provide various services to the automotive industry. This includes vehicle design, communications systems design, and vehicle safety assessment.

Software developers develop and test a wide range of systems, equipment, and services related to CV/AVs. This includes onboard navigation systems, V2I and V2N communications systems, and various detection systems, such as park assist and blind spot detection.

Telecommunications companies develop and test telecommunications infrastructure and provide installation and maintenance services. These companies connect roadside equipment and CVs through V2I and V2N communications, providing a link between the vehicle system and the infrastructure system.

2.2.2 Technical Organizations

Academic institutions conduct CV/AV research, development and testing initiatives. As an example, researchers at the University of Toronto, in partnership with Uber's Advanced Technologies Group, are working on algorithms to help AVs detect and track objects (University of Toronto, 2018b). The University of Waterloo is developing tools to enable self-driving cars, including navigation and object detection (University of Waterloo, 2019), and Carleton University is active in cybersecurity testing for autonomous vehicles (CTV Ottawa, 2019).

The **Canadian Council of Motor Transport Administrators (CCMTA)** is an organization through which federal and provincial/territorial governments collaborate to administer, regulate, and control road safety. CCMTA developed a *White Paper on Automated Vehicles in Canada*, a foundational document for establishing a national AV framework in coordination with US efforts (CCMTA, 2016), as well as guidelines for the testing and deployment of highly automated vehicles (CCMTA, 2018).

The **Canadian Urban Transit Research & Innovation Consortium (CUTRIC)** designs, funds, and initiates mobility and transportation technology projects, such as AV demonstrations. Its membership includes stakeholders from both the public and private sectors, academia, and other technical organizations (CUTRIC, 2019).

2.2.3 Standards Development Organizations

The **CSA Group (Canadian Standards Association)** develops vehicle standards, including some that affect CV/AVs with support from Transport Canada (CSA Group, 2019).

The **Society of Automotive Engineers International (SAE International)** develops vehicle standards (SAE International, 2018a), including the following key CV standards:

- J2395_200202 – ITS In-Vehicle message priority.
- J2735_200911 – (R) Dedicated Short Range Communications (DSRC) Message Set Dictionary.
- J2945/1_201603 – On-Board System Requirements for V2V Safety Communications.
- J2945/2_201810 – Dedicated Short Range Communications (DSRC) Performance Requirements for V2V Safety Awareness.
- J3016_201401 – Taxonomy and Definitions for Terms Related to On-Road Motor Vehicle Automated Driving Systems.

SAE International has also partnered with the American Association of State Highway and Transportation Officials (AASHTO) to develop specifications for pavement markings to accommodate CV/AVs (Hallmark, 2019).

2.2.4 Governments

Transport Canada is the **federal government** department responsible for transportation regulation, policy, and services. It is currently involved in several activities related to the vehicle system, including:

- Transport Canada has established guidelines for the testing and deployment of highly automated vehicles, including minimum standards for operators and the role and responsibilities of each level of government (CCMTA, 2018).
- Transport Canada is implementing some of the 16 recommendations of the 2018 *Driving Change* report produced by the Canadian Senate Standing Committee on Transport and Communications, which is key to developing a national CV/AV policy (Standing Senate Committee on Transport and Communications, 2018).
- The 2019 safety framework for CVs and AVs is a key document for guiding CV/AV policy and testing (Transport Canada, 2019a).

Guidance from the US is critical to Transport Canada continuing to progress with CVs and AVs. The US-Canada Regulatory Cooperation Council CV Working Group helps to obtain this guidance, and covers areas such as cybersecurity, spectrum allocation, standards and architecture, and information dissemination and sharing (Transport Canada, 2016). A cross-border CV security certificate management system proof-of-concept is a key component of this collaboration (AVIN, 2019b). Infrastructure Canada also held the Smart Cities Challenge in 2018, which encouraged municipalities to improve quality of life through connected technology. The City of Montréal was announced as one of the winners, and included innovative means of transport (McGill University, 2019).

2.3 Infrastructure System Stakeholders

This section provides an overview of the key stakeholders in the infrastructure system.

2.3.1 Private Sector

Consultants provide traditional consulting services, which include infrastructure planning and design, construction supervision, and testing and commissioning. With AV adoption, these services will become tailored to AV requirements. Consultants provide design services on technology applications as they relate to infrastructure, which includes CVs. This work includes the design and testing of CV applications, along with future proofing technology applications, such as traffic signal controllers.

Equipment suppliers and manufacturers provide services and products, either original or aftermarket, to the transportation industry. Products include roadside equipment such as DSRC and cellular communication equipment, expanded traffic signal cabinets, and traffic signal controllers, and logic to enable CVs.

Software developers create and test systems, equipment and services including roadside communications and upgraded traffic signal controllers.

Telecommunications companies develop, test, install and maintain telecommunication infrastructure. They connect roadside equipment and CVs through V2I and V2N communications, providing a link between the vehicle and infrastructure systems.

2.3.2 Technical Organizations

Academic institutions conduct CV/AV research, development and testing initiatives. An example is the involvement of Carleton University, the University of Ottawa, Algonquin College and La Cité collegial in the L5 test facility in Ottawa (Ottawa Business Journal, 2019), Ontario Tech University's hosting of an event exploring AV linkages to smart city infrastructure (Ontario Tech University, 2019), and the University of Toronto's study of designing parking facilities for AVs (Nouinejad, 2018).

The **Canadian Urban Transit Research & Innovation Consortium (CUTRIC)** designs, funds, and initiates mobility and transportation technology projects, such as CV standards and cybersecurity studies. Its membership includes stakeholders from both the public and private sectors, academia, and other technical organizations (CUTRIC, 2019).

The **Canadian District (CITE) of the Institute of Transportation Engineers (CITE)** is a community of transportation professionals that provides continuing education programs, networking opportunities, and guidelines, such as the Parking Generation Manual. ITE's AV/CV Steering Committee is within the Transportation Systems Management & Operations Council, and functions as a clearinghouse for all CV/AV discussion. ITE contributes to two key US initiatives: The Signal Phasing and Timing (SPaT) Challenge and the Cooperative Automated Transportation Coalition (CAT Coalition) (ITE, 2019). The SPaT Challenge is an initiative to encourage transportation agencies to deploy CV DSRC infrastructure (AASHTO, 2017). The National Operations Center of Excellence (NOCoE) created the CAT Coalition to bring operators (states, counties, and municipalities), automakers, and OEMs together to address CV/AV deployment issues (NOCoE, 2019a).

The **Intelligent Transportation Systems Society of Canada (ITS Canada)** is a forum for government, consultants, manufacturers and suppliers to facilitate and promote ITS projects, and to educate other stakeholders on the benefits of ITS. ITS Canada is helping Transport Canada update the ITS Architecture for Canada to align with the US Architecture Reference for Cooperative and Intelligent Transportation (ARC-IT). ITS

Canada's Connected/Automated Vehicle Technical Committee examines the technologies and strategies associated with CV/AVs (ITS Canada, 2019a).

The **Ontario Good Roads Association (OGRA)** advocates for, consults with, and trains its members to improve transportation infrastructure delivery.

TAC provides a forum for members to share information, and develops national guidelines and best practices related to road infrastructure and urban transportation systems.

2.3.3 Standards Development Organizations

The **CSA Group** develops standards for roadside equipment, including CV/AV guidelines and standards with support from Transport Canada (CSA Group, 2019).

The **Internet Engineering Task Force (IETF)** develops open standards for the Internet, such as crash notification (IETF, 2017).

The **Institute of Electrical and Electronics Engineers (IEEE)**, and its subunit the **Intelligent Transportation Systems Society (ITSS)**, develop standards related to V2V and V2I in conjunction with SAE International (IEEE Connected Vehicles, 2019), and host conferences on intelligent vehicles (IEEE, 2019), and on connected and autonomous vehicles (IEEE Connected & Autonomous Vehicles, 2019). Key IEEE specifications define DSRC message authentication and encryption, as well as message format and processing (AVIN, 2019b).

The **International Standards Organization (ISO)** develops a wide variety of standards, such as security, data privacy, and data protection (ISO, 2019b), which are critical components of CV operations, and dynamic data and map database specifications for CV/AV driving system applications (ISO, 2019a). This includes a joint standard with SAE for vehicle cybersecurity (AVIN, 2019b).

The **National Electrical Manufacturers Association (NEMA)** develops standards in the transportation industry, such as the standard for traffic signal controller cabinet assemblies. In the CV ecosystem, NEMA established the vehicle-to-infrastructure communication standards for traffic control signals (Business Wire, 2019).

2.3.4 Governments

Innovation, Science, and Economic Development Canada (ISED) Canada is the **federal government** department responsible for supporting Canadian innovation, and administers the procedures involved with CV/AV trials.

Transport Canada is the **federal government** department responsible for transportation regulation, policy, and services. It is currently involved in several activities related to the infrastructure system, including:

- The Program to Advance Connectivity and Automation in the Transportation System (ACATS) has helped to fund CV-related upgrades, trials, and research (Transport Canada, 2019b), including the development of a Security Credential Management System for CVs (AVIN, 2019b).
- Transport Canada is in the process of updating the *ITS Architecture for Canada*. This will primarily be based on the United States ITS Architecture, and will also extend into the US CV reference implementation architecture which is incorporated into the US ITS Architecture.

Guidance from the US is critical to Transport Canada continuing to progress with CVs and AVs. The US-Canada Regulatory Cooperation Council CV Working Group helps to obtain this guidance, and covers areas such as cybersecurity, spectrum allocation, standards and

architecture, and information dissemination and sharing (Transport Canada, 2016). A cross-border CV security certificate management system proof-of-concept is a key component of this collaboration (AVIN, 2019b). Infrastructure Canada also held the Smart Cities Challenge in 2018, which encouraged municipalities to improve quality of life through connected technology.

Provincial/territorial governments own and operate physical and technological infrastructure for roadways. The Ontario government worked with Deloitte to research the implications for CV/AV data access, ownership, privacy, and security (Deloitte, 2018), and supports the Autonomous Vehicle Information Network (AVIN), which is an agency established by the Ontario government that is focused on supporting technological innovation in Ontario, including CV and AV trials (AVIN, 2019a). AVIN provides funding and guidance to both private sector companies and public sector agencies interested in undertaking CV and AV trials.

Canada's federal, provincial and territorial governments are joint members of the Coordinating Council on Automated and Connected Vehicles, which reports to the Council of Ministers Responsible for Transportation and Highway Safety. The Coordinating Council (formerly a working group) has produced reports outlining key CV/AV issues and recommendations for federal, provincial and territorial governments (PPSC Working Group on Connected and Automated Vehicles, 2018), and a policy framework for Canada that clearly defines the roles and responsibilities of each level of government in the Canadian CV/AV ecosystem (PPSC Working Group on Connected and Automated Vehicles, 2019).

Municipal governments own, operate, and maintain road infrastructure including:

- physical infrastructure such as highways, roads, bridges, tunnels, signs and pavement markings
- technological infrastructure such as freeway management systems, toll systems, border crossing systems and traffic signal control systems
- transit infrastructure such as rapid transit lines, stops, stations and maintenance facilities

Some municipalities also participate in municipal associations, such as the Municipal Alliance for Connected and Autonomous Vehicles in Ontario (MACAVO), whose goal is to help jurisdictions prepare for CVs and AVs through the coordination of CV/AV research, testing, policies, and communications (OGRA, 2016). In addition to pilot projects, some municipalities are planning for the arrival of AVs. The City of Toronto is creating a tactical plan to prepare for AVs (City of Toronto, 2019), and the City of Vancouver is considering AVs in the development of future road infrastructure through its 2040 Transportation Plan (City of Vancouver, 2019).

2.4 Road User System Stakeholders

This section provides an overview of the key stakeholders in the road user system.

2.4.1 Private Sector

Consultants provide a wide range of consultancy and design services, including within the fields of architecture, planning, engineering, and technology. With AV adoption, consultants provide design services in these fields related to road users that includes safety assessments, mitigation measures, streetscape plans, and complete street designs (i.e. how can AVs be safely accommodated into the existing road network?). With CV adoption, consultants provide design services in these fields that includes safety

assessments, wayfinding studies, and accessibility studies (i.e. how can the benefits of CVs be maximized for all road users?).

Freight operators transport goods.

Insurers provide compensation in the event of a roadway incident.

Ride-hailing services, such as Uber and Lyft, provide taxi-like services through mobile apps.

Software developers create and test systems, equipment and services including data management, personal data security, and cybersecurity.

Taxi companies transport people.

Telecommunications companies develop, test, install and maintain telecommunications infrastructure. They connect roadside equipment and CVs through V2I and V2N communications, providing a link between the vehicle and infrastructure systems.

2.4.2 Technical Organizations

Academic institutions conduct CV/AV research, development and testing related to road users. For example, the City Centre for Automated and Transformative Transportation Systems at the University of Toronto (University of Toronto, 2018a) is examining pricing models for AV use.

The **Canadian Council of Motor Transport Administrators (CCMTA)** is an organization through which federal and provincial/territorial governments collaborate to administer, regulate, and control road safety. CCMTA developed a *White Paper on Automated Vehicles in Canada*, a foundational document for establishing a national AV framework in coordination with US efforts (CCMTA, 2016), as well as guidelines for the testing and deployment of highly automated vehicles (CCMTA, 2018).

The **Canadian District (CITE) of the Institute of Transportation Engineers (ITE)** is a community of transportation professionals that provides continuing education programs, networking opportunities, and guidelines. ITE's AV/CV Steering Committee is within the Transportation Systems Management & Operations Council, and functions as a clearinghouse for all CV/AV discussion. ITE also contributes to the SPaT Challenge and the CAT Coalition (ITE, 2019).

The **Canadian Trucking Alliance (CTA)** represents members of the Canadian trucking industry and advocates on their behalf in the development of government policies, regulations, and legislation. The Ontario Trucking Alliance (OTA), which is part of the CTA, has commented on the impacts of automated vehicles on the trucking industry (OTA, 2018).

The **Canadian Urban Transit Association (CUTA)** involves transit system operators, governments and suppliers. CUTA has provided expertise to the Senate of Canada on AV policy (Standing Senate Committee on Transport and Communications, 2018).

The **Ontario Traffic Council (OTC)** coordinates efforts to improve traffic management in Ontario by reaching out to members of the enforcement, engineering, and education sectors.

TAC provides a forum for members to share information, and develops national guidelines and best practices related to multimodal transportation planning, traffic operations, and road safety.

2.4.3 Governments

Provincial/territorial governments are responsible for regulating road users through licensing and the rules of the road for provincial roadways. Each province has a provincial Highway Traffic Act that regulates use of the rights of way and defines the penalties for violating the rules of the road. The provinces of Ontario (MTO, 2019) and Quebec (SAAQ, 2019) have used the AV framework from the federal government to implement legislation that will allow for AV testing on public roads. The province of Alberta is also in the process of updating their regulations to allow for AV testing on public roads. In other provinces, legislation for CV and AV testing is being developed.

Municipal governments are responsible for allocating right-of-way to different modes, regulating road use through tools such as turn restrictions, parking regulations, truck route designations, and curbside management. They also deliver emergency services and waste collection services.

Provincial transit agencies and **municipal transit agencies** own and operate transit systems, and some are testing low-speed AV shuttles as a first/last mile solution, which are discussed in the next section.

2.5 Canadian Tests and Trials

CV/AV trials and testing are critical to successful CV/AV evolution and ultimate large-scale deployment. There have been several major CV/AV tests and trials in Canada, including:

- **Evolution of Networked Services through a Corridor in Québec and Ontario for Research and Innovation (ENCQOR)** is a partnership between the provinces and several major technology companies that focuses on the development of a 5G corridor, a key initiative in the implementation of CV infrastructure (ENCQOR, 2019).
- The **Windsor-Ottawa Preferred CAV Test Corridor** is organized by OGRA and OGRA's sub-organization MACAVO (OGRA, 2019). This corridor is a collaboration between more than 30 municipalities to create a test corridor over 5,500 kilometres long.
- Through **AVIN**, six regional technology development sites have been established in Ontario, where new CV/AV technologies are being developed and tested (AVIN, 2019d). One is the AVIN Technology Demonstration Zone in Stratford, Ontario, which gives Ontario-based CV/AV companies a site to test, validate, and showcase their products (AVIN, 2019c). The Stratford site also has a Wi-Fi network that covers the entire city, which is ideal for testing CVs. In Ottawa, two CV/AV test tracks exist, with one on public roads in Kanata, and one on private roads in the Greenbelt (Invest Ottawa, 2019).
- Edmonton and Vancouver, alongside the Province of Alberta and the Universities of Alberta and British Columbia, are supporting CV development by hosting **ACTIVE-AURORA**, Canada's first CV testbed (University of Alberta, 2019). This program includes several technology trials including at-grade rail crossings, proactive freeway control, traffic signal optimization, and CV/AV impacts on fire rescue and police services.

- Low-speed AV shuttle services have been tested in several Canadian cities, including:
 - **Beaumont, AB**—service in mixed traffic along a major arterial (City of Beaumont, 2019)
 - **Calgary, AB**—service between the Calgary Zoo and Telus Spark Science Centre along a private service road (City of Calgary, 2018)
 - **Candiac, QC**—service in mixed traffic on public roads (Keolis, 2018)
 - **Montréal, QC**—service between Olympic Stadium and a Metro station on public roads (CTV Montreal, 2018)

3 TAC’s Role

Generally speaking, based on the information presented in Section 1.2, TAC:

- provides a membership-based forum for knowledge creation and exchange in the roadway and urban transportation sectors
- carries out technical projects on issues of national scope with funding partners determined on a case-by-case basis
- has minimal direct involvement in transportation system funding, policy, legislation, regulation, and implementation

TAC activities are primarily concerned with the infrastructure and road user systems shown in **Exhibit 2-2**, rather than the vehicle system. Some TAC members are involved in the vehicle system (e.g. Transport Canada regulates vehicle safety requirements), but they pursue this involvement through channels outside TAC. Furthermore, many stakeholders in the CV/AV ecosystem have little involvement with TAC (e.g. auto manufacturers, telecommunications providers, insurance companies).

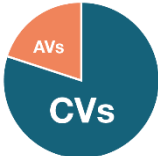
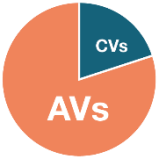
The arrival of CVs and AVs requires TAC to expand its role as experts in addressing transportation challenges related to the infrastructure and road user systems. It is important that TAC’s role in the Canadian CV/AV ecosystem aligns with its vision statement and focus areas (Section 1.2.1), and well as its mission statement and strategic priorities (Section 1.2.2).

With this context in mind, it is suggested that TAC has two main roles in the Canadian CV/AV ecosystem:

- **Help TAC members enable the operation of CVs and AVs** (Section 3.1)
- **Help TAC members manage the use of CVs and AVs** (Section 3.2)

Exhibit 3-1 clarifies the distinctions between these roles, which are discussed further in Sections 3.1 and 3.2.

Exhibit 3-1: TAC’s Roles in the Canadian CV/AV Ecosystem

KEY DIMENSIONS	RELATIVE EMPHASIS ON CVs OR AVs	RELATIVE TIMELINE
Role A. Help TAC members <u>enable the operation</u> of CVs and AVs		
Road infrastructure Roadside infrastructure Data management		Greater emphasis on <u>short-term</u> and <u>mid-term</u>
Role B. Help TAC members <u>manage the use</u> of CVs and AVs		
Safety for all road users Right-of-way management Special vehicles Community impacts		Greater emphasis on <u>mid-term</u> and <u>long-term</u>

3.1 Help TAC Members Enable the Operation of CVs and AVs

TAC can support the creation of a safe, secure and efficient road infrastructure system, with a focus on the following dimensions:

- **Road infrastructure**—signs, pavement markings, geometric design
- **Roadside infrastructure**—traffic signals, dynamic message signs, beacons
- **Data management**—sharing, privacy and security

This role emphasizes CV-related (rather than AV-related) issues, and short- to mid-term opportunities. It also involves many uncertainties, some of which are listed below:

- **CV/AV timelines**—When will vehicle technologies and regulatory frameworks be in place to create the need and expectation for the supporting infrastructure?
- **CV/AV attributes**—What will be the operational design domain of AVs (i.e. in what environments are certain features enabled), and what do they require in terms of signage and pavement markings?
- **Government regulation**—Which aspects of CV/AV infrastructure will be covered by government regulations, and how they will be covered? Will DSRC or 5G technology be used as the CV communications standard?
- **Security and privacy requirements**—With a vast amount of data expected to be produced by CV/AV infrastructure, how should this data be managed to protect public interests? Will new forms of computing, such as edge computing, be needed to safely and efficiently manage and analyze the data? How should this data be used to improve operations for all road users while maintaining privacy?
- **Costs and funding**—when will major expenditures be required? How will governments acquire the necessary additional funding needed to implement and maintain CV/AV infrastructure? Will the private sector contribute funding?

3.2 Help TAC Members Manage the Use of CVs and AVs

TAC can support the optimization of benefits to stakeholders in the road user system, with a focus on the following dimensions:

- **Safety for all road users**—ensuring the safety of all road users, particularly vulnerable road users, including pedestrians and cyclists
- **Right-of-way management**—allocation of road and curbside space to different modes and user groups
- **Special vehicles**—optimizing CV/AV use by transit systems, emergency vehicles, taxi and ride-hailing services, trucks, and other road users
- **Community impacts**—quantifying the effects on public health, social equity, cost of travel, environmental quality, economic development, and land use

This role emphasizes issues related to AVs more than CVs, and mid-term to long-term opportunities. It also involves many uncertainties, some of which are listed below:

- **CV/AV timelines**—When, and in what markets, will transportation authorities need to act in anticipation of, or in response to, AV capabilities and market penetration?
- **CV/AV attributes**—What will be the main capabilities and limitations of CVs and AVs with respect to operational design domains, operating characteristics

(e.g. vehicle headways, lateral space requirements), and safe interaction with other road users?

- **AV ownership and operation**—What AV ownership and operating models (e.g. private vs. public, individual vs. shared) best serve public goals? What business models are feasible and expected to emerge?
- **AV regulation, pricing and management**—What strategies are governments willing and able to use that can mitigate the potential negative impacts of AVs on public health, social equity, congestion, emissions, and urban sprawl (e.g. induced travel demand, zero-occupancy vehicle use)?

















































4 Key Issues and Possible Actions for TAC

This section identifies the most important technical issues for TAC to address, and suggests possible actions for TAC to undertake. **Exhibit 4-1** shows that for each of the two roles identified in Section 3, there are two main types of actions:

- **Knowledge**—gather information about CVs and AVs from TAC members and partners, and share experiences and analysis with TAC members
- **Guidance**—develop technical guidance required by stakeholders, and support any needs for education and training

Exhibit 4-1 also shows the TAC focus areas (see Section 1.2.1) that are most closely related to each role and action type. Sections 4.1 and 4.2 provide more detail on the key technical issues and possible responses by TAC and its volunteer groups in each area.

Exhibit 4-1: Action Framework for TAC

ACTION TYPES		TAC FOCUS AREAS	
Role A. Help TAC members <u>enable the operation</u> of CVs and AVs			
Knowledge	A1. Gather information	 SAFETY  MOBILITY  INFRASTRUCTURE AND ASSET MANAGEMENT	 ENVIRONMENT AND CLIMATE CHANGE  TECHNOLOGY  WORKFORCE DEVELOPMENT
	A2. Share knowledge	 SAFETY  MOBILITY  INFRASTRUCTURE AND ASSET MANAGEMENT	 ENVIRONMENT AND CLIMATE CHANGE  TECHNOLOGY  WORKFORCE DEVELOPMENT
Guidance	A3. Develop technical guidance	 SAFETY  MOBILITY  INFRASTRUCTURE AND ASSET MANAGEMENT	 ENVIRONMENT AND CLIMATE CHANGE  TECHNOLOGY  WORKFORCE DEVELOPMENT
	A4. Support workforce development	 SAFETY  MOBILITY  INFRASTRUCTURE AND ASSET MANAGEMENT	 ENVIRONMENT AND CLIMATE CHANGE  TECHNOLOGY  WORKFORCE DEVELOPMENT
Role B. Help TAC members <u>manage the use</u> of CVs and AVs			
Knowledge	B1. Gather information	 SAFETY  MOBILITY  INFRASTRUCTURE AND ASSET MANAGEMENT	 ENVIRONMENT AND CLIMATE CHANGE  TECHNOLOGY  WORKFORCE DEVELOPMENT
	B2. Share knowledge	 SAFETY  MOBILITY  INFRASTRUCTURE AND ASSET MANAGEMENT	 ENVIRONMENT AND CLIMATE CHANGE  TECHNOLOGY  WORKFORCE DEVELOPMENT
Guidance	B3. Develop technical guidance	 SAFETY  MOBILITY  INFRASTRUCTURE AND ASSET MANAGEMENT	 ENVIRONMENT AND CLIMATE CHANGE  TECHNOLOGY  WORKFORCE DEVELOPMENT
	B4. Support workforce development	 SAFETY  MOBILITY  INFRASTRUCTURE AND ASSET MANAGEMENT	 ENVIRONMENT AND CLIMATE CHANGE  TECHNOLOGY  WORKFORCE DEVELOPMENT

4.1 Help TAC Members Enable the Operation of CVs and AVs

This section identifies key technical issues and possible responses that relate to the following key dimensions of this role (see Section 3.1):

- road infrastructure
- roadside infrastructure
- data management

4.1.1 Knowledge

A1. Gather information

CV/AV development

Monitor key technical organizations that monitor CV/AV development relevant to the Canadian context. Canadian organizations of interest include the Canadian Automated Vehicles Centre of Excellence (CAVCOE), ITS Canada, CITE, CUTA, CUTRIC, AVIN, ENCQOR.

International organizations or initiatives of interest include the United States Department of Transportation (USDOT, which outlines its AV plans in its Automated Vehicles 3.0 report) (USDOT, 2018), AASHTO, Austroads (which has a program focusing on CV/AV research, guidelines, and deployment), the CAT Coalition (which brings road owner-operators together with automakers and OEMs to address CV/AV deployment issues), the Connected Vehicle Pooled Fund Study, ITS America's CV and AV Working Group, the OmniAir Consortium (for which CV standards are a key topic), the National Institute of Standards and Technology (NIST, which is developing CV/AV research and standards) (Yoon, 2019), Virginia DOT's Connected and Automated Vehicle Program (Virginia DOT, 2019), the Ann Arbor Connected Vehicle Test Environment in Michigan (University of Michigan Transportation Research Institute, 2019), and the Automated, Connected, Electric, and Shared (ACES) Northwest Network, which is a coalition of private companies, manufacturers, legislators, and municipalities committed to furthering the role of these technologies in addressing transportation issues in communities across Washington State, Oregon, and British Columbia.

CV communication standards (e.g. DSRC vs. 5G) are an important issue that will likely be determined by the US Federal Communications Commission through legislation. Since the transportation systems of Canada and the US are integrated, the same communications standards will apply to both countries.

Consider direct discussions between TAC and external organizations, attendance by TAC representatives at their conferences, or invited presentations by their representatives at TAC technical meetings, to identify common goals, initiatives, and possible collaborations.

Maintain TAC involvement in the national Coordinating Council on Automated and Connected Vehicles, the CSA Group's Connected and Automated Vehicle Advisory Council, and similar collaborative bodies.

CV/AV testing and implementation

Assemble information from agencies that are conducting CV and AV pilot projects (e.g. those in Section 2.5). Agencies participating in the SPaT Challenge would also be valuable sources of information, and other US agencies that have deployed CV infrastructure include New York City, Tampa, and Wyoming (USDOT ITS JPO, 2019), as well as California, Georgia, Michigan, Ohio and Utah. Review the report *Autonomous Vehicle Pilots Across America* by the National League of Cities (NLC), which identifies pilot projects in the US (NLC, 2018).

A2. Share knowledge

CV/AV lessons learned

Share the key outcomes of agency experiences with CV/AV testing and implementation. Possible mechanisms include presentations at TAC technical meetings, preparation and publication of briefings or detailed syntheses, and the delivery of webinars and conference sessions.

Emerging standards, guidelines and practices to enable CV/AV operation

Maintain a reference list of important Canadian and international guidance, to inform activity by TAC councils, committees and members. Alert TAC members to guidance that directly governs or influences Canadian practices. Other guidance may help to illustrate a gap, or provide a model for the development of future Canadian guidance.

Data security and privacy

The NIST has established a cybersecurity framework (NIST, 2019), which also applies to CV communications. Review cybersecurity research and standards prepared by the NIST to understand the evolution of CVs, and when large-scale CV deployment could take place.

Educate TAC members about data security standards by inviting experts to provide webinars or present at TAC technical meetings. Possible invitees include the OmniAir Consortium, the US-Canada Regulatory Cooperation Council (which covers cross-border issues including cybersecurity, spectrum allocation, ITS architecture, standards and information dissemination and sharing), and members of the CAT Coalition or NOCoE.

Investigate data privacy issues related to CVs (e.g. how privacy agreements are structured, how to ensure compliance, who manages the data). Data privacy practices should follow the rules established for consumer privacy and proprietary and confidential business information.

4.1.2 Guidance

A3. Develop technical guidance

Comparisons between Canadian and American guidance

Interoperability and the advanced state of development and testing in the United States require a re-examination of TAC guidelines and best practices documents that build upon their American equivalents. This includes publications such as USDOT design standards and the *Manual of uniform Traffic Control Devices* (MUTCD). For example, the USDOT has stated that the MUTCD will be updated to consider CV/AVs (Hallmark, 2019). Develop a roadmap for required changes to TAC publications based on their American equivalents.

Review the report *Preparing Local Agencies for the Future of Connected and Autonomous Vehicles* (Hallmark, 2019), which provides a detailed look at the infrastructure needs of agencies as CV/AVs arrive.

Review of existing TAC guidance

Conduct a methodical review of existing guidance through TAC councils and committees to identify publications require updates to address the operating needs of CV/AVs. This includes publications such as the *Manual of Uniform Traffic Control Devices for Canada* (MUTCDC). Key components of these publications that may require updates could include (Hallmark, 2019):

- geometric design (including roads, roundabouts, medians)
- pavement markings
- road signs (design, placement)

- traffic signals
- pavement design and load management
- asset management
- maintenance practices

Identification of new required guidance

Identify subjects for which TAC currently does not provide guidance, but where such guidance would be helpful and within TAC's mandate through TAC councils and committees. Key issues could include:

- data capture, management and sharing—involving technical practicalities such as data storage space, and process issues such as those discussed in *Managing Mobility Data* (NACTO, 2019) which provides a framework for sharing, protecting and managing CV/AV data
- communication infrastructure
- cybersecurity
- high-resolution mapping—which may require data of a type and level of detail that is not currently provided by agencies, to support AV operation

Technical projects

Based on the identification of needs for new or updated guidance, TAC councils and committees can follow established processes for the development and delivery of technical projects, whether conducted by volunteers or by consultants, with the support of pooled funds.

A4. Support workforce development

Skill and training requirements to support CV/AV operation

Reach out to other technical organizations that have developed the expertise needed to enable CV/AV operation, including US DOT, Utah DOT, Georgia DOT, and New York City DOT. These agencies can help identify needed skills, the kinds of training that can help, and lessons learned from training programs. Skills that will be needed to enable CV/AV operation in Canada include:

- communications technology
- data security and privacy—including the principles of privacy by design, a critical component of CV/AV data privacy developed by the Information and Privacy Commissioner of Ontario (Information and Communications Technology Council, 2017)
- upgrading existing traffic control equipment and implementing new traffic control equipment
- understanding data produced by CV/AVs (AVIN, 2018)

Where the appropriate training is best provided by external organizations (e.g. government agencies, post-secondary institutions), transfer supporting information to them and encourage action.

Training availability

Develop training curriculum and materials through volunteer or pooled-fund technical projects, and deliver webinars or seminars as part of TAC's Learning Program.

4.2 Help TAC Members Manage the Use of CVs and AVs

This section identifies key technical issues and possible responses that relate to the following key dimensions of this role (see Section 3.2):

- safety for all road users
- right-of-way management
- special vehicles
- community impacts

4.2.1 Knowledge

B1. Gather information

CV/AV development and research

Monitor research into various aspects of CV/AV management, including the key dimensions listed above. Much of the information would be conceptual or speculative, especially with respect to the more advanced adoption of AVs—for example, public vs. private ownership models, shared vs. personal use vehicles, limited vs. extensive operation design domains, various forms and degrees of parallel transit service provision, alternative approaches to mobility pricing, possible interactions between AVs and vulnerable road users, and so on. Much of the information would also be developed in support of policy analysis or investment prioritization (i.e. non-technical priorities of TAC's governmental members that will guide eventual technical activities). Examples may include:

- ITS America's report *Driverless Cars and Accessibility* explores how to ensure that all road users benefit from AVs (ITS America, 2019b).
- NACTO's *Blueprint for Autonomous Urbanism* (NACTO, 2017) examines how existing rights-of-way and curb spaces can be most effectively used in an AV context.
- The iCity Centre for Automated and Transformative Transportation Systems at the University of Toronto has produced research dedicated to address the large-scale impacts of disruptive transportation technologies, including CVs/AVs (University of Toronto Transportation Research Institute, 2019).
- The OmniAir Consortium is a hub for work to develop 5G-based CV applications for pedestrians.

CV/AV testing and implementation

Monitor trials and pilot projects involving Level 4 AVs, and the preparations being made by agencies, including relevant tools and processes. Many jurisdictions or organizations of interest are identified in Section 4.1.1. In Canada, jurisdictions involved in AV preparation include the provinces of Ontario (MTO, 2019) and Alberta (Senick, 2019), and the City of Toronto (City of Toronto, 2019).

B2. Share knowledge

CV/AV lessons learned

Share the key outcomes of research and agency experiences with CV/AV management. Possible mechanisms include presentations at TAC technical meetings, preparation and publication of briefings or detailed syntheses, and the delivery of webinars and conference sessions. Some initial examples could include:

- MTO could explain the policies and regulations it is enacting to manage AVs on public roads.
- NLC could explain its report *Micromobility in Cities* (NLC, 2019) which examines what cities have done to accommodate emerging mobility models, and the challenges they have faced.

Emerging standards, guidelines and practices to manage CV/AV use

Maintain a reference list of important Canadian and international guidance, to inform activity by TAC councils, committees and members. Alert TAC members to guidance that directly governs or influences Canadian practices. Other guidance may help to illustrate a gap, or provide a model for the development of future Canadian guidance.

4.2.2 Guidance

B3. Develop technical guidance

Review of existing TAC guidance

Relevant TAC councils could conduct a methodical review of existing guidance to identify publications that, in light of current knowledge, require updates to address the effective management of CV/AV use. Key issues may be limited at present due to the low market penetration of CV/AVs and a lack of understanding of the implications of greater adoption, but they will likely expand over time. Those issues could include:

- model rules of the road
- pedestrian crossing controls
- speed management and traffic calming
- work zone safety
- signal priority for special vehicles (e.g. transit, emergency responders)
- road safety engineering
- transit service design and implementation
- transportation demand management
- data collection for the movement of people
- transportation system funding and governance
- congestion measurement
- winter maintenance
- greenhouse gas emission reduction

Identification of new required guidance

TAC councils and committees could also identify subjects on which TAC currently does not provide guidance, but where such guidance would be helpful and within TAC's mandate. Key issues (mostly speculative) could include:

- curbside management
- dynamic traffic signal management
- signal priority for shared-use AVs
- mobility pricing strategies
- accessibility and equity strategies
- impacts on parking and site access provision
- governance of private-sector mobility services, such as California's requirement that AV companies must produce an annual report on operations (Information and Communications Technology Council, 2017)

Notable is the degree of complex connectivity among many issues, including:

- The market penetration of SAE Level 4 and Level 5 automation, and the availability and use of vehicle features like automatic braking, will influence saturation flow rates and traffic signal timing.
- The convenience and cost of travel by AVs, combined with their average occupancy and trip length, will determine the impacts on congestion and energy consumption and the need for additional management strategies to minimize undesirable impacts.

The provision of guidance on some of these issues may necessarily be preceded by the need for focused research that could be conducted through TAC.

Technical projects

Based on the identification of needs for underlying research and analysis, or for new or updated guidance, TAC councils and committees can follow established processes for the development and delivery of technical projects, whether conducted by volunteers or by consultants, with the support of pooled funds.

B4. Support workforce development

Skill and training requirements to support CV/AV management

As discussed in Section 4.1.2, TAC can approach other technical organizations (especially in the United States) that have knowledge to share about workforce development to support CV/AV management. However, these skills and training requirements may evolve more slowly than those needed to enable CV/AV operation.

The report *Autonomous Vehicles and the Future of Work in Canada* (Information and Communications Technology Council, 2017) investigates the specific occupations and associated skills that are expected to be critical to managing AV use, and the key findings could be presented to TAC members through a webinar.

Where the appropriate training is best provided by external organizations (e.g. government agencies, post-secondary institutions), transfer supporting information to them and encourage action.

Training availability

Develop training curriculum and materials through volunteer or pooled-fund technical projects, and deliver webinars or seminars as part of TAC's Learning Program.

4.3 Next Steps

This discussion paper is intended to inform discussion, planning, and action by TAC's Secretariat, councils, and committees. Ideally, each volunteer body will use it to identify relevant issues and appropriate responses including technical projects that lie within their mandates. While many possible issues and actions are suggested in Sections 4.1 and 4.2, this discussion paper does not identify specific priorities for each council and committee; those groups will be responsible for identifying and prioritizing possible actions.

The principal role of the CAV Task Force will be to serve as a hub for collaboration and information exchange between volunteer groups, and between TAC and external organizations. It may also conduct technical projects (whether volunteer or funded, and in all cases with the Secretariat's assistance) on subjects that transcend individual council or committee mandates, where it is equipped to do so.

It is recommended that the CAV Task Force build on this discussion paper by assembling and maintaining a document that tracks its objectives and activities, and those of each council and committee, on related issues. This would help TAC's internal and external stakeholders to follow the organization's collective response to advancements in technology, policy, and practice. Updating such a tracking document twice yearly, in conjunction with TAC's spring and fall technical meetings, would ensure its currency and utility. The necessary communications with the CAV Task Force would also act as a prompt for other volunteer groups to continuously consider the support they can provide to enhance TAC's role in Canada's CV/AV ecosystem.

5 References

- AASHTO. (2017). *AASHTO Connected & Automated Vehicle Focus Area*. Retrieved from http://transops.s3.amazonaws.com/uploaded_files/AASHTO%20CAV%20-%20April%2018%20webinar%20ver2.pdf
- AVIN. (2018). *Data in the Context of CAVs: Types and Operational Opportunities*. Retrieved from [https://www.oce-ontario.org/docs/default-source/publications/avin_quarterly-specialized-report_december-2018-\(2018-12-21\).pdf](https://www.oce-ontario.org/docs/default-source/publications/avin_quarterly-specialized-report_december-2018-(2018-12-21).pdf)
- AVIN. (2019a). *AVIN*. Retrieved from <https://www.avinhub.ca/>
- AVIN. (2019b). *Data in the Context of CAVs: Challenges and Recommendations*. Retrieved from [https://www.oce-ontario.org/docs/default-source/publications/avin_quarterly-specialized-report_final-\(2019-05-17\).pdf?sfvrsn=2](https://www.oce-ontario.org/docs/default-source/publications/avin_quarterly-specialized-report_final-(2019-05-17).pdf?sfvrsn=2)
- AVIN. (2019c). *Demonstration Zone*. Retrieved from <https://www.avinhub.ca/demonstration-zone/>
- AVIN. (2019d). *Regional Technology Development Sites*. Retrieved from <https://www.avinhub.ca/regional-technology-development-sites/>
- Business Wire. (2019). *NEMA to Develop Standards for Vehicle-to-Infrastructure Communications*. Retrieved from <https://www.businesswire.com/news/home/20190417005244/en/NEMA-Develop-Standards-Vehicle-to-Infrastructure-Communications>
- CCMTA. (2016). *Automated Vehicles in Canada*. Retrieved from https://ccmta.ca/images/publications/pdf//CCMTA_WhitePaper_Automated_Vehicles_in_Canada_2017.pdf
- CCMTA. (2018). *Canadian Jurisdictional Guidelines for the Safe Testing and Deployment of Highly Automated Vehicles*. Retrieved from <https://ccmta.ca/images/publications/pdf//CCMTA-AVGuidelines-sm.pdf>
- City of Beaumont. (2019). *Autonomous Shuttle Pilot*. Retrieved from <https://www.beaumont.ab.ca/583/Autonomous-Shuttle-Pilot>
- City of Calgary. (2018). *Autonomous Vehicle Pilot: Embracing the Future of Transportation with Autonomous Vehicle Testing*. Retrieved from <http://www.calgary.ca/General/Pages/SmartCity/Autonomous-Vehicle.aspx>
- City of Toronto. (2019). *Automated Vehicles Tactical Plan*. Retrieved from <https://www.toronto.ca/services-payments/streets-parking-transportation/automated-vehicles/draft-automated-vehicle-tactical-plan-2019-2021/>
- City of Vancouver. (2019). *Automated and Connected Vehicles: Implications for Vancouver and Next Steps*. Retrieved from <https://council.vancouver.ca/20161214/documents/cfsc4presentation.pdf>
- CSA Group. (2019). *Driving Connected and Automated Vehicle Technology Forward through Standardization*. Retrieved from <https://www.csagroup.org/article/driving-connected-automated-vehicle-technology-forward-standardization/>
- CTV Montreal. (2018). *Olympic Park Testing Electric, Self-Driving Shuttles for Tourists*. Retrieved from <https://montreal.ctvnews.ca/olympic-park-testing-electric-self-driving-shuttles-for-tourists-1.4087709>
- CTV Ottawa. (2019). *Autonomous Cars Tested Against Cyber-Attacks by Carleton Students*. Retrieved from <https://ottawa.ctvnews.ca/autonomous-cars-tested-against-cyber-attacks-by-carleton-students-1.4376558>
- CUTRIC. (2019). *CUTRIC*. Retrieved from <http://cutric-crituc.org/home>
- Deloitte. (2018). *Implications of Connected and Autonomous Vehicles in Ontario: Insurance and Data Access and Security*. Retrieved from <https://www2.deloitte.com/ca/en/pages/consulting/articles/connectedvehiculesontario.html>
- ENCQOR. (2019). *ENCQOR*. Retrieved from <https://www.encqor.ca/>
- Hallmark, S. (2019). *Preparing Local Agencies for the Future of Connected and Autonomous Vehicles*. Retrieved from <http://www.dot.state.mn.us/research/reports/2019/201918.pdf>

- IEEE. (2019). *IV 2019*. Retrieved from <https://iv2019.org/>
- IEEE Connected & Autonomous Vehicles. (2019). *2019 IEEE 2nd Connected and Automated Vehicles Symposium: IEEE CAVS 2019*. Retrieved from <http://ieee-cavs.edu.umh.es/>
- IEEE Connected Vehicles. (2019). *5GAA C-V2X testing event in Europe successfully demonstrates multi-vendor interoperability*. Retrieved from <http://sites.ieee.org/connected-vehicles/2019/04/14/5gaa-c-v2x-testing-event-in-europe-successfully-demonstrates-multi-vendor-interoperability5gaa-announced-today-that-multiple-technology-providers-of-cellular-v2x-c-v2x-have-successfully-demonstrated/>
- IETF. (2017). *Next-Generation Vehicle-Initiated Emergency Calls*. Retrieved from <https://datatracker.ietf.org/doc/rfc8148/>
- Information and Communications Technology Council. (2017). *Autonomous Vehicles and the Future of Work in Canada*. Retrieved from https://www.ictc-ctic.ca/wp-content/uploads/2018/01/ICTC_-Autonomous-Vehicles-and-The-Future-of-Work-in-Canada-1-1.pdf
- Invest Ottawa. (2019). *Ottawa L5 Testing Facilities*. Retrieved from <https://www.investottawa.ca/ottawal5/>
- ISO. (2019a). *Intelligent transport systems -- Dynamic data and map database specification for connected and automated driving system applications -- Part 1: Architecture and logical data model for harmonization of static map data*. Retrieved from <https://www.iso.org/standard/73747.html?browse=tc>
- ISO. (2019b). *Road vehicles — Extended vehicle (ExVe) web services — Part 3: Security*. Retrieved from <https://www.iso.org/obp/ui/#iso:std:iso:20078:-3:ed-1:v1:en>
- ITE. (2019). *Connected/Automated Vehicles*. Retrieved from <https://www.ite.org/technical-resources/topics/connected-automated-vehicles/>
- ITS America. (2019b). *Driverless Cars and Accessibility*. Retrieved from https://static1.squarespace.com/static/596fb16003596e0fa70a232f/t/5c9bab319b747a61663ac9bc/1553705778370/ITSAmerica_Driverless+Cars+Accessibility+Mobility_April2019.pdf
- ITS Canada. (2019a). *Connected/Automated Vehicle Technical Committee*. Retrieved from https://www.itscanada.ca/about/technical_committees/connected_automated_vehicle_technical_committee/index.html
- Keolis. (2018). *Keolis Candiac*. Retrieved from <https://keoliscandiac.ca/en/>
- McGill University. (2019). *Montreal wins the Smart Cities Challenge*. Retrieved from <https://www.mcgill.ca/centre-montreal/channels/news/montreal-wins-smart-cities-challenge-297205>
- MTO. (2019). *Ontario's Automated Vehicle Pilot Program*. Retrieved from <http://www.mto.gov.on.ca/english/vehicles/automated-vehicles.shtml>
- NACTO. (2017). *Blueprint for Autonomous Urbanism*. Retrieved from https://nacto.org/wp-content/uploads/2017/11/BAU_Mod1_raster-sm.pdf
- NACTO. (2019). *Managing Mobility Data*. Retrieved from https://nacto.org/wp-content/uploads/2019/05/NACTO_IMLA_Managing-Mobility-Data.pdf
- NIST. (2019). *NIST Cybersecurity Framework*. Retrieved from <https://www.nist.gov/cyberframework>
- NLC. (2018). *Autonomous Vehicle Pilots Across America*. Retrieved from <https://www.nlc.org/sites/default/files/2018-10/AV%20MAG%20Web.pdf>
- NLC. (2019). *Micromobility in Cities*. Retrieved from https://www.nlc.org/sites/default/files/2019-04/CSAR_MicromobilityReport_FINAL.pdf
- NOCoE. (2019a). *Vehicle to Infrastructure Deployment Coalition*. Retrieved from <https://transportationops.org/V2I/V2I-overview>
- Nouinejad, M. B. (2018). *Designing parking facilities for autonomous vehicles*. Retrieved from <https://www.sciencedirect.com/science/article/pii/S0191261517305866#!>
- OGRA. (2016). *Municipalities Create Alliance to Actively Promote Connected and Autonomous Vehicle Testing and Integration within our Communities*. Retrieved from https://www.ogra.org/images/eBlast/HeadsUp_Alert/HTMLs/OGRA_eBlast_Heads%20Up%20Alert_11172016.html

- OGRA. (2019). *Ontario Municipalities Create World's Longest, Preferred Corridor for Testing of Autonomous Vehicles (AVs) and Related Technologies between Windsor and Ottawa*. Retrieved from https://www.ogra.org/images/eBlast/HeadsUp_Alert/HTMLs/Ottawa_WindsorCorridor/OGRA_eBlast_Heads%20Up%20Alert_Windsor%20Ottawa.html
- Ontario Tech University. (2019). *How the emerging autonomous vehicle industry will profoundly change human mobility*. Retrieved from <https://news.uoit.ca/archives/2019/04/how-the-emerging-autonomous-vehicle-industry-will-profoundly-change-human-mobility.php>
- OTA. (2018). *OTA Submits Considerations for MTO AV/Platooning Pilot*. Retrieved from <http://ontruck.org/ota-submits-considerations-for-mto-av-platooning-pilot/>
- Ottawa Business Journal. (2019). *Ottawa's L5 Test Facility Aims to Pave the Way for a Driverless Future*. Retrieved from <https://obj.ca/article/ottawas-l5-test-facility-aims-pave-way-driverless-future>
- PPSC Working Group on Connected and Automated Vehicles. (2018). *The Future of Automated Vehicles in Canada*. Retrieved from <https://comt.ca/Reports/The%20Future%20of%20Automated%20Vehicles%20in%20Canada%202018.pdf>
- PPSC Working Group on Connected and Automated Vehicles. (2019). *Automated and Connected Vehicles Policy Framework for Canada*. Retrieved from <https://comt.ca/Reports/AVCV%20Policy%20Framework%202019.pdf>
- SAAQ. (2019). *Modes of Transportation in an Autonomous Vehicle*. Retrieved from <https://saaq.gouv.qc.ca/en/road-safety/modes-transportation/autonomous-vehicles/>
- SAE International. (2018a). *Dedicated Short Range Communications (DSRC) Performance Requirements for V2V Safety Awareness*. Retrieved from https://www.sae.org/standards/content/j2945/2_201810/
- Senick, J. (2019). *Experts say Alberta provides proper testing ground for driverless vehicles*. Retrieved from <https://globalnews.ca/news/4891646/alberta-ideal-for-driverless-vehicle-testing/>
- Standing Senate Committee on Transport and Communications. (2018). *Driving Change: Technology and the Future of the Automated Vehicle*. Retrieved from https://sencanada.ca/content/sen/committee/421/TRCM/Reports/COM_RPT_TRCM_AutomatedVehicles_e.pdf
- TAC. (2017). *Transportation Association of Canada Strategic Plan*. Retrieved from http://www.tac-atc.ca/sites/default/files/site/doc/about-us/tac_2017strategicplan_en.pdf
- Transport Canada. (2016). *Canada-U.S Regulatory Cooperation Council (RCC) Connected Vehicles Work-Plan*. Retrieved from <https://www.tc.gc.ca/eng/acts-regulations/tc-usdot-871.html>
- Transport Canada. (2019a). *Canada's Safety Framework for Automated and Connected Vehicles*. Retrieved from https://www.tc.gc.ca/en/services/road/documents/tc_safety_framework_for_acv-s.pdf
- Transport Canada. (2019b). *Projects Funded by the Program to Advance Connectivity and Automation in the Transportation System*. Retrieved from <http://www.tc.gc.ca/en/services/road/innovative-technologies/automated-connected-vehicles/project-funded-programs.html>
- University of Alberta. (2019). *Centre for Smart Transportation*. Retrieved from <https://www.ualberta.ca/engineering/research/groups/smart-transportation/research/projects/connected-vehicles>
- University of Michigan Transportation Research Institute. (2019). *Ann Arbor Connected Vehicle Test Environment*. Retrieved from <http://www.aacvte.org/>
- University of Toronto. (2018a). *Autonomous vehicles and road user fees*. Retrieved from <https://uttri.utoronto.ca/news/autonomous-vehicles-and-road-user-fees/>
- University of Toronto. (2018b). *Uber Seeks Top Toronto Talent with \$200-Million Investment*. Retrieved from <https://www.utoronto.ca/news/uber-seeks-top-toronto-talent-200-million-investment>

- University of Toronto Transportation Research Institute. (2019). *iCity-CATTS*. Retrieved from <https://uttri.utoronto.ca/research/research-groups/icitycattshome/>
- University of Waterloo. (2019). *Wave Laboratory*. Retrieved from <http://wavelab.uwaterloo.ca/>
- USDOT. (2018). *Preparing for the Future of Transportation*. Retrieved from <https://www.transportation.gov/sites/dot.gov/files/docs/policy-initiatives/automated-vehicles/320711/preparing-future-transportation-automated-vehicle-30.pdf>
- USDOT ITS JPO. (2019). *Connected Vehicle Pilot Deployment Program*. Retrieved from <https://www.its.dot.gov/pilots/>
- Virginia DOT. (2019). *Connected and Automated Vehicle Program*. Retrieved from https://www.virginiadot.org/programs/connected_and_automated_vehicles.asp
- Yoon, S. &. (2019). *Analysis of Automatic through Autonomous – Unmanned Ground Vehicles (A-UGVs) Towards Performance Standards*. Retrieved from https://ws680.nist.gov/publication/get_pdf.cfm?pub_id=927496

Appendix A – Stakeholder Interview Questionnaire and Response Contact List

Questions asked:

1. Describe your role and your agency's role with respect to CVs/AVs.
2. Describe your agency's CV/AV program – mandate/vision, trials, legislation, standards, etc.
3. What were the main issues/challenges that your agency faced with respect to CVs/AVs in the past 3 years (top 3)?
4. What are the current/future issues/challenges you face with respect to CVs/AVs (top 3)?
5. What are your expectations of/advice to TAC with respect to CVs/AVs? This could include activities/programs, something to be aware of, lessons learned, etc.

The following is a list of respondents who participated in the stakeholder interviews.

Organization	Respondent	Position
Transport Canada	Ken Moshi	Senior Analyst
Alberta Ministry of Transportation	Sarah Korpan	Policy Advisor, Emerging Technologies and Foresight
	Joan Mmbaga	Senior Policy Advisor, Emerging Technologies
BC Ministry of Transportation and Infrastructure	Kenedee Ludwar	Director, Traffic & Highway Safety Engineering
	Brigid Canil	Director, Electrical and ITS Engineering
New Brunswick Department of Transportation and Infrastructure	Richard Beaugregard-Long	Functional Planning Analyst, Project Development and Asset Management Branch
New Brunswick Department of Public Safety	Chris O'Connell	Registrar of Motor Vehicles, Motor Vehicle Branch, Justice and Public Safety
Northwest Territories Department of Infrastructure	Muhammad Abu Bakar	Senior Project Officer, Transportation Division
Nova Scotia Department of Transportation and Infrastructure Renewal	Mike Croft	Manager, Traffic Engineering and Road Safety
Ministry of Transportation Ontario	Sheri Graham	Manager, Traffic Office, Provincial Highways Management Division
	Susan Boot	Head, Information Technology Section
Ministère des Transports du Québec	David Johnson	Intelligent Vehicle Counsellor
City of Calgary	Andrew Sedor	Business Development Coordinator - Transportation Strategy, Transportation
Ville de Montréal	Hugues Bessette	Chief, Arterial Network Division
City of Ottawa	Kornel Mucsi	Program Manager, Transportation Planning
	Greg Kent	Manager, Traffic Management
City of Toronto	Ryan Lanyon	Chair, AV Working Group
City of Vancouver	Joanna Clark	Citywide Transportation Planner
	Geoffrey Keyworth	Transportation Planner
Halifax Regional Municipality	Marcus Garnet	Senior Planner, Regional and Community Policy, Planning and Development
	Tanya Davis	Strategic Transportation Planning Program Manager

Organization	Respondent	Position
Canadian Trucking Alliance	Geoffrey Wood	Senior Vice President, Policy
Canadian Automobile Association	Jason Kerr	Director, Government Relations
Canadian Council of Motor Transport Administrators	Allison Fredette	President and Chief Executive Officer
Canadian Urban Transit Association	Wendy Reuter	Vice President, Member Value
Canadian Vehicle Manufacturers Association	Mark Nantais	President
	Karen Hou	Manager, Environment, Health and Safety
National Research Council	Barry Pekilis	Program Thrust Leader, Intelligent Transportation Systems
CSA Group	Brent Hartman	Program Director, Alternative Energy Vehicles
	Peter Glowacki	Program Manager, Alternative Energy Vehicles
Ontario Centre of Excellence – Autonomous Vehicle Innovation Network	Raed Kadri	Director, Automotive Technology and Mobility Innovation
Utah Department of Transportation	Blaine Leonard	Technology and Innovation Engineer, SPaT Lead
Virginia Department of Transportation	Virginia Lingham	Office of Strategic Innovation
Austroads	Niko Limans	Principal Engineer / Project Manager, Cooperative ITS
	Nick Koukoulas	Chief Executive
American Association of State Highway and Transportation Officials	King Gee	Director, Engineering and Technical Services
National Association of City Transportation Officials	Corinne Kisner	Deputy Director
ITS Australia	Susan Harris	Chief Executive Officer