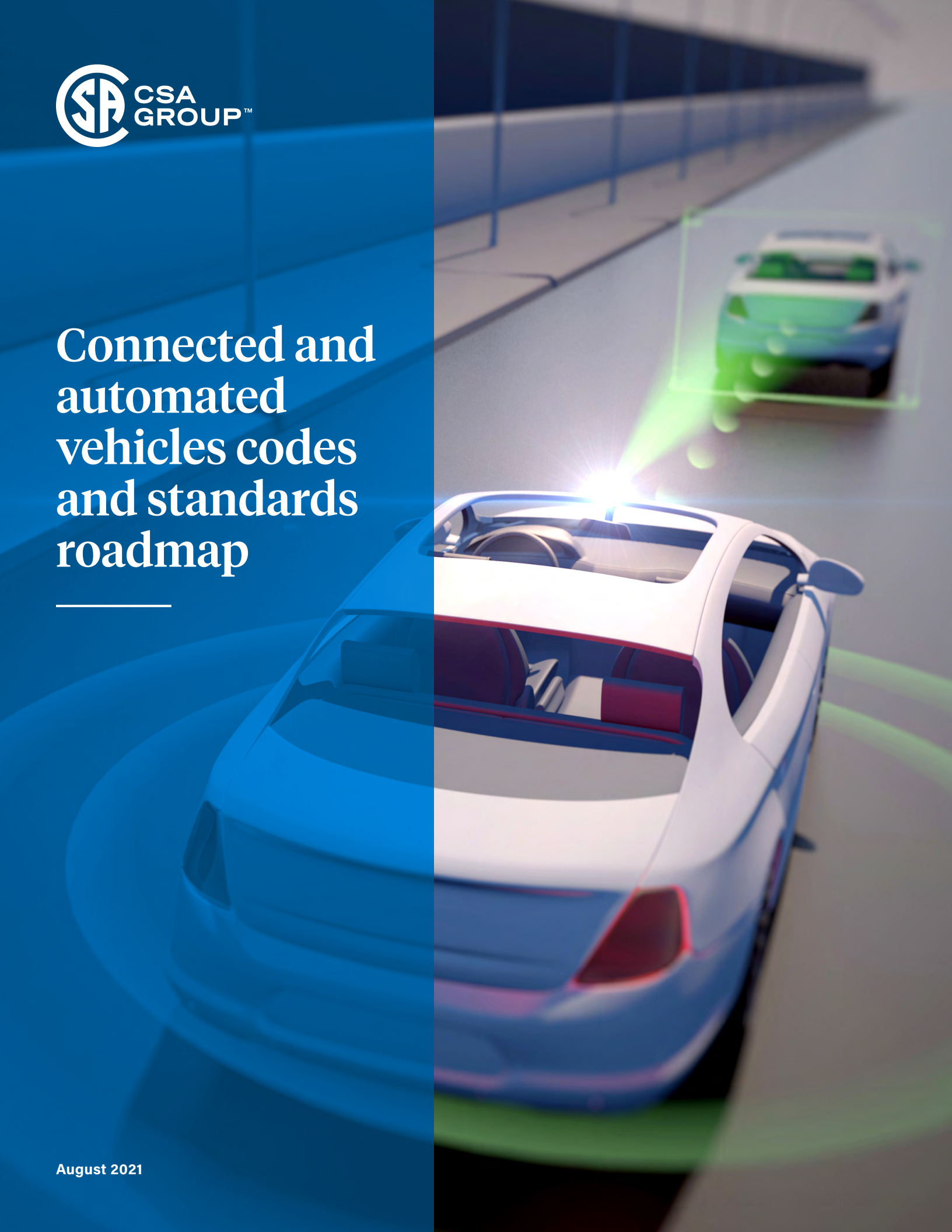
CSA GROUP™

# Connected and automated vehicles codes and standards roadmap



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## Based on contributions from:

**Connected and Automated Vehicle Advisory Council**

**Connected and Automated Vehicle Advisory Council Working Groups**

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# Executive Summary

Connected and automated vehicles (CAVs) will fundamentally change the way people and goods are transported. Safety and security will be necessary for the seamless integration of CAVs on public roads. To support this advancement of rapidly advancing technology, it is important to develop an understanding of the impacts of that CAVs will have on their surrounding environments, as well as an understanding of the existing landscape of relevant codes and standards, which provide guidance for the safety and security of technology and products. In this regard, codes and standards will play a critical role in promoting the safe, secure, and seamless integration of CAVs into the transportation system.

The advancement and impact of CAV technology on the transportation network are both national and international challenges. Various countries, through public agencies and road authorities, have been assessing, planning, and supporting demonstrations and deployments to prepare for connectivity and automation. While planning has been largely conducted nationally, standardization has been occurring internationally. Key standards development organizations (SDOs), such as the ISO, SAE, IEC, IEEE, and others, have already begun updating and/or developing standards related to various aspects of CAVs. Leveraging international standards can help establish consistency and increase global harmonization of safety and security requirements.

This roadmap highlights the numerous standards development activities and efforts being led by several SDOs, which together address many of the common and safety-critical use cases for CAVs. Even with all of these activities, there are known gaps in the existing landscape where future work needs to be focused. Supported by Transport Canada's Program to Advance Connectivity and Automation in the Transportation System (ACATS) and CSA Group Research, CSA Group's Connected and Automated Vehicle Advisory Council (CAVAC) reviewed the vast number of standards and activities, categorized the standards, identified potential gaps, and assigned a priority to the gaps.

This roadmap highlights specific gaps and priorities for CAV standardization that need to be addressed. Additionally, the roadmap provides four key next steps: international participation, development and adoption of standards, integration of standards, and stakeholder engagement. Combined, these activities will help facilitate a codes and standards landscape that meets the needs of the CAV industry. However, gaps will continue to emerge as technology evolves and the industry gains deployment experience. The four key next steps can be used to continually assess and update the codes and standards roadmap. Codes and standards are important tools that can be combined with regulations, policies, and programs to create a framework that supports safe and secure deployment of CAV technology.



# 1 Introduction

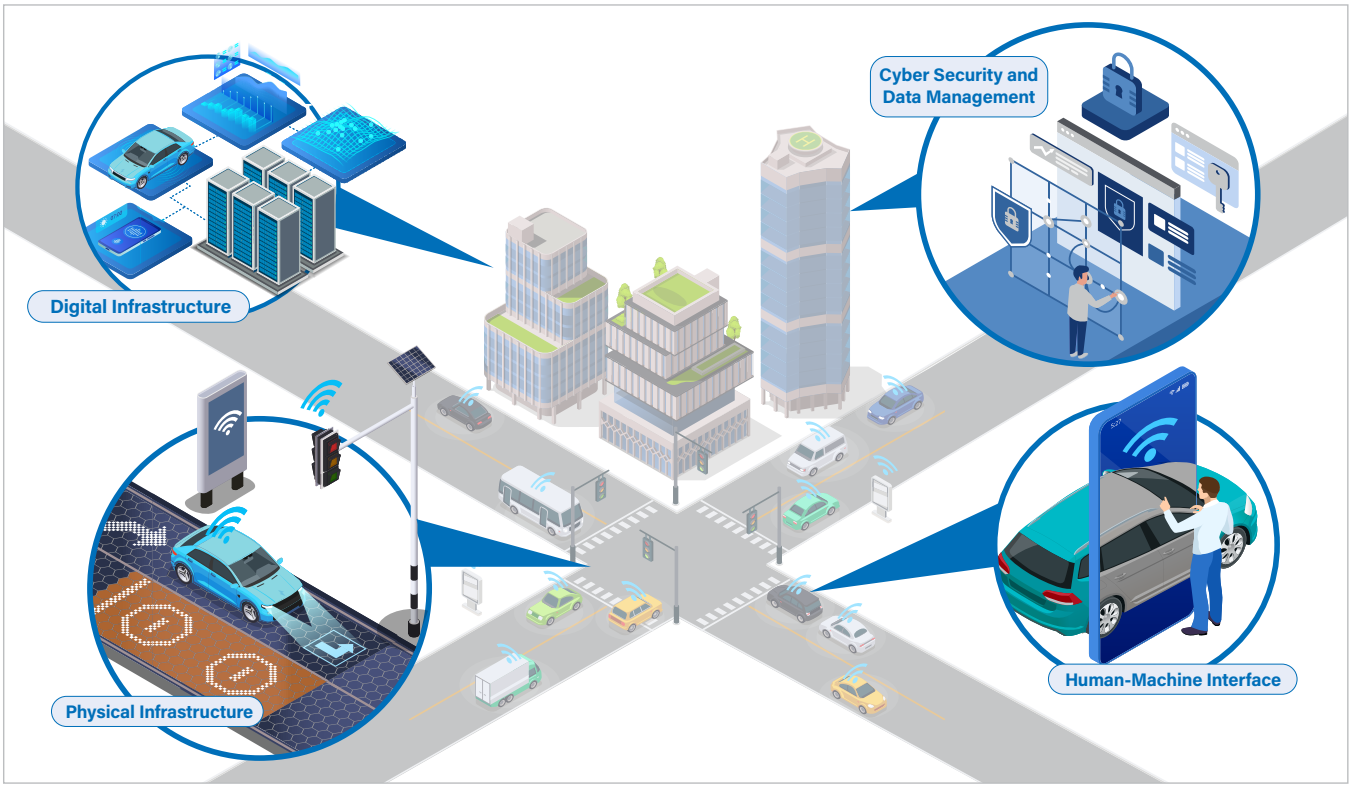
Connected and automated vehicles (CAVs) are expected to be a major disrupting technology for the transportation sector. CAVs utilize the unification of two sets of technology – connectivity and automation. These vehicles have the capability to be connected to a network or to exchange information with each other, as well as with connecting to surrounding road infrastructure, vehicles, and traffic network operators. They also have the capability to automate driving tasks with varying levels of automation.

The adoption and development of CAVs will bring significant changes and will inevitably impact how people and goods are transported from one place to another, facilitating safer and more efficient and sustainable transportation. The technologies have advanced in recent years, and there are vehicles already on the road today with sophisticated technologies and capabilities for connected vehicle (CV) systems and enhanced driver assistance functions, such as adaptive cruise control and assisted lane keeping. It is uncertain what the full impacts of CAVs will be, how the volume of CAVs on the road will increase, or how quickly CAV technologies will continue to advance and be adopted. However, the continued incremental adoption of CAV technologies is inevitable. A consistent set of regulations, codes, and standards are key to facilitating safe adoption and minimizing disruptions in the short and long term.

This roadmap is based on CSA Group's Research Report "Connected and Automated Vehicle Technologies – Insights for Codes and Standards in Canada," which was published in June l 2020 and is available at https://www.csagroup.org/article/research/connected-and-automated-vehicle-technologies-insights-for-codes-and-standards-in-canada/. This research report reviews the existing standards landscape as it relates to relevant categories:

- Digital infrastructure
- Physical infrastructure
- Usage, human-machine interface, accessibility and vehicle aspects
- Cybersecurity, data management, and privacy

A comprehensive literature review, consultation with experts, and interviews with key industry stakeholders provided the seed information to develop insights for CAVs that identify a framework for a roadmap that addresses the needs for codes and standards in Canada, and that maximizes standards harmonization both domestically and internationally. Taking this one step further, the CAVAC established four working groups that contributed to this roadmap initiative by evaluating and providing a categorized list of standards, identifying gaps, and assigning priority to the urgency of each gap, which provided the basic structure of the next steps needed to promote and implement CAVs.




# 2 Standards Landscape for CAV Technologies

## 2.1 Overview

In general, standards are intended to support the safety, compatibility, and interoperability of products, regardless of the supplier, with consistent interactions and processes. Standards provide guidance for communications and data transmission, as well as minimum requirements for safety, security, and privacy.

From a technical perspective, the CAV ecosystem includes diverse industries. The automotive industry, including original equipment manufacturers (OEMs), small and medium-sized enterprises (SMEs), and aftermarket providers, relates to vehicle and on-board equipment; the ITS industry relates to information and communication for advanced applications and operations; the telecommunications industry relates to supporting the exchange of data and information; and the physical infrastructure industry relates to roadway and bridge design, lane markings, signage, and land use.

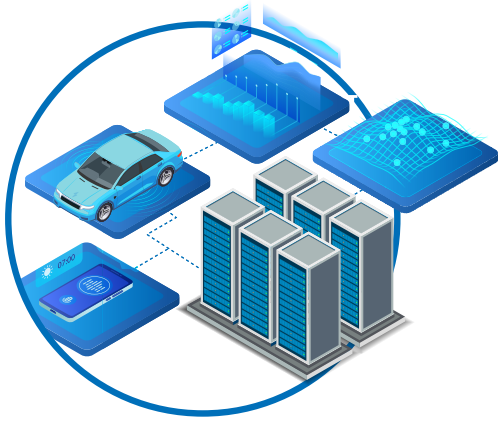
CAV technologies are rapidly evolving and relevant standards are being, or have been, developed by a wide range of international, global, and national SDOs. Examples of the main SDOs leading the development of CAV-related standards include the following:

- International Organization for Standardization (ISO)
- International Electrical and Electronics Engineers (IEEE)
- European Committee for Standardization (CEN)
- European Telecommunication Standards Institute (ETSI)
- SAE International
- National Transportation Communications for ITS Protocol (NTCIP)
- National Electrical Manufacturers Association (NEMA)
- ASTM International
- International Electrotechnical Commission (IEC)
- Institute of Transportation Engineers (ITE)
- American Association of State Highway and Transportation Officials (AASHTO)

**NOTE:** Please refer to Appendix A in the CSA Group Research Report "Connected and Automated Vehicle Technologies – Insights for Codes and Standards in Canada" for further descriptions of each SDO.

The following sections summarize potentially applicable standards and may include pertinent regulations, policies, and programs to support change and foster continued evolution of supporting technologies per category and subcategory.

## 2.2 Standards Applicable by Category



### 2.2.1 Digital Infrastructure

Ensuring that our roads and vehicles have the digital infrastructure available to support the adoption of CAVs will involve sustainable investment and a consideration of standards frameworks to make sure that the experience is consistent across different jurisdictions. Consideration of the available digital connectivity is vital to preparing our infrastructure for CAVs, without it we will not be able to leverage the full potential CAVs have to offer.

Digital infrastructure refers to the equipment that stores and exchanges data to support intelligent transportation services. The following sections highlight applicable/relevant standards and documents related to the digital infrastructure.

#### 2.2.1.1 High Definition, Dynamic Mapping, and Local Dynamic Map

- EN/TS 17268: Intelligent transport systems — ITS spatial data — Data exchange on changes in road attributes
- ETSI EN 302 895: Intelligent Transport Systems (ITS): Vehicular Communications: Basic Set of Applications: Local Dynamic Map (LDM)
- ETSI TR 102 863 V1.1.1: Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Local Dynamic Map (LDM); Rationale for and guidance on standardization
- ISO 14296: Intelligent transport systems — Extension of map database specifications for applications of cooperative ITS
- ISO 17424: Intelligent transport systems — Cooperative systems — State of the art of Local Dynamic Maps concepts
- ISO 19115-1: Geographic information — Metadata — Part 1: Fundamentals
- ISO 19115-2: Geographic information — Metadata — Part 2: Extensions for acquisition and processing
- ISO/AWI TS 22726-2: Intelligent transport systems — Dynamic data and map database specification for connected and automated driving system applications — Part 2: Logical data model of dynamic data (WIP)
- ISO/DIS 17572-4: Intelligent transport systems (ITS) — Location referencing for geographic databases — Part 4: Precise relative location references (precise relative profile)
- ISO/TS 18750: Intelligent transport systems — Co-operative ITS — Local dynamic map
- Navigation Data Standard specification 2019
- SAE J1663: Truth-in-Labeling Standard for Navigation Map Databases
- SAE J2945/A: Standard for Lane-Level and Road Furniture Mapping for Infrastructure-based V2X Applications
- SAE J2945/A: Standard for Lane-Level and Road Furniture Mapping for Infrastructure-based V2X Applications J2945/A (WIP)

#### 2.2.1.2 Position, Navigation, and Timing/Global Navigation Satellite Systems

- ESTI TS 103 246 1 to 5: Satellite Earth Stations and Systems (SES); GNSS based location systems
- ISO 12188 1 & 2: Tractors and machinery for agriculture and forestry — Test procedures for positioning and guidance systems in agriculture — Part 1: Dynamic testing of satellite-based positioning devices

- ISO/TR 22086-1: Intelligent transport systems (ITS) — Network based precise positioning infrastructure for land transportation — Part 1: General information and use case definitions
- SAE1004: Raw Measurements from Global Navigation Satellite System (GNSS) Receivers (WIP)
- SAE1013: Guidelines for resilient GNSS receiver (WIP)
- SAE1014: Standard for Interfacing Resilient GNSS Receivers (WIP)
- SAE1015: Improving the Accuracy, Availability, Integrity, Continuity, or Coverage of Positioning, Navigation, and/or Timing Solutions Using Raw Measurements from Global Navigation Satellite System (GNSS) Receivers (WIP)
- SAE1016: Security and Resilience Recommendations for Positioning, Navigation, and Timing (PNT) Users (WIP)
- SAE2945/7: Positioning Enhancements for V2X systems (WIP)
- SAE6857: Requirements for a Terrestrial Based Positioning, Navigation, and Timing (PNT) System to Improve Navigation Solutions and Ensure Critical Infrastructure Security

#### 2.2.1.3 Vehicle Connectivity – V2V (Vehicle), V2I (Infrastructure), V2P (Pedestrian) / V2H (Human), and V2R (Robot) Device Communications (BSM, SPaT, MAP, RSM) Layers/Protocols

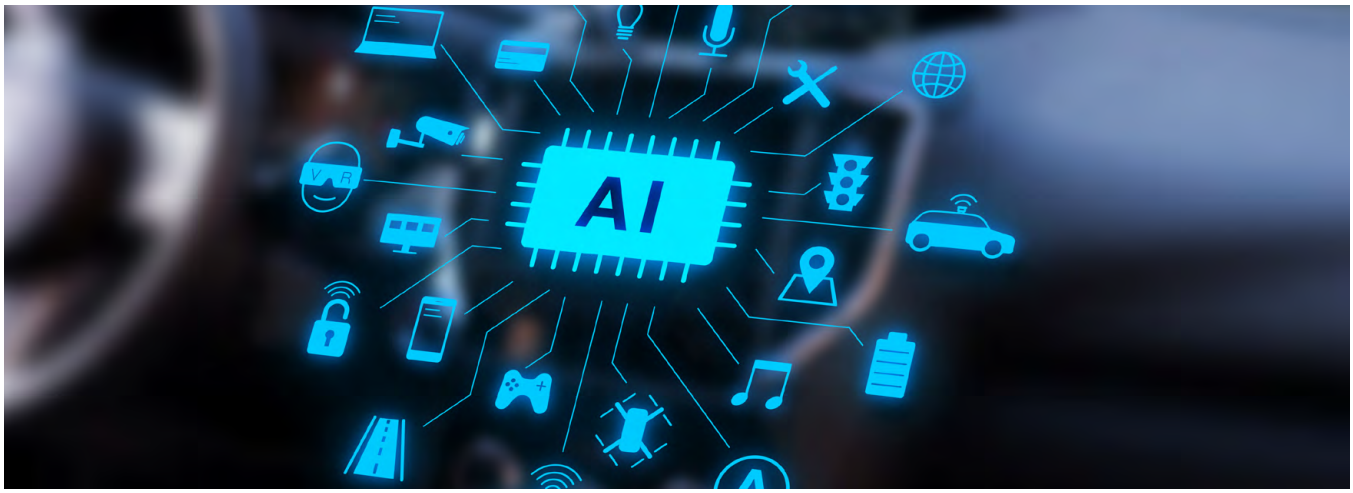
- ASTM E2213: Standard Specification for Telecommunications and Information Exchange Between Roadside and Vehicle Systems — 5-GHz Band Dedicated Short-Range Communications (DSRC), Medium Access Control (MAC), and Physical Layer (PHY) Specifications
- ETSI 102 486-x: Intelligent Transport Systems (ITS); Road Transport and Traffic Telematics (RTTT); Test specifications for Dedicated Short; Range Communication (DSRC) transmission equipment; Part 1: DSRC data link layer: medium access and logical link control; Sub-Part 2: Test Suite Structure and Test Purposes (TSS&TP)
- ETSI 302 895: Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Local Dynamic Map (LDM)
- ETSI EN 302 637-2: Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Part 2: Specification of Cooperative Awareness Basic Service
- ETSI EN 302 637-3: Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Part 3: Specifications of Decentralized Environmental Notification Basic Service
- ETSI EN 302 895: Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Local Dynamic Map (LDM)
- ETSI TR 103300-1 V 2.1.1: Intelligent Transport System (ITS); Vulnerable Road Users (VRU) awareness; Part 1: Use Cases definition
- ETSI TR 102 637-1: Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Part 1: Functional Requirements
- ETSI TR 102 638-1: Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Definitions
- GB/T 102-2 National Regulation: Pedestrian Protection
- IEC 61980-2:2019: Electric vehicle wireless power transfer (WPT) systems — Part 2: Specific requirements for communication between electric road vehicle (EV) and infrastructure
- IEEE 1609.0: IEEE Guide for Wireless Access in Vehicular Environments (WAVE) Architecture
- IEEE 1609.02: Security Services for Applications and Management Messages
- IEEE 1609.12: IEEE Standard for Wireless Access in Vehicular Environments (WAVE) — Identifier Allocations
- IEEE 1609.2.1: IEEE Standard for Wireless Access in Vehicular Environments — Security Services for Applications and Management Messages
- IEEE 1609.20: Guidance document to implement security
- IEEE 1609.2a: IEEE Standard for Wireless Access in Vehicular Environments — Security Services for Applications and Management Messages — Amendment 1

- IEEE 1609.2b: IEEE Standard for Wireless Access in Vehicular Environments — Security Services for Applications and Management Messages — Amendment 2 — PDU Functional Types and Encryption Key Management
- IEEE 1609.3: IEEE Standard for Wireless Access in Vehicular Environments (WAVE) — Networking Services
- IEEE 1609.4: IEEE Standard for Wireless Access in Vehicular Environments (WAVE) — Multi-Channel Operation
- IEEE 1609: Family of Standards for Wireless Access in Vehicular Environments (WAVE)
- IEEE 802.11: IEEE Standard for Information technology — Telecommunications and information exchange between systems Local and metropolitan area networks — Specific requirements — Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications
- IEEE 802.11bd: Evolution of radio access technologies for V2X communications
- IEEE 802.11p: Towards an International Standard for Wireless Access in Vehicular Environments
- IEEE 802.15.4: IEEE Standard for Low-Rate Wireless Networks
- IEEE 802.20: IEEE Standard for Local and metropolitan area networks — Part 20: Air Interface for Mobile Broadband Wireless Access Systems Supporting Vehicular Mobility — Physical and Media Access Control Layer Specification Amendment 1: Management Information Base Enhancements and Corrigenda Items
- ISO 13185-2: Intelligent transport systems — Vehicle interface for provisioning and support of ITS services — Part 2: Unified gateway protocol (UGP) requirements and specification for vehicle ITS station gateway (V-ITS-SG) interface
- ISO 14296: Intelligent transport systems — Extension of map database specifications for applications of cooperative ITS
- ISO 15075: Transport information and control systems — In-vehicle navigation systems — Communications message set requirements
- ISO 15118-1, -2, -3, -8: Road vehicles — Vehicle to grid communication interface — Part 1: General information and use-case definition, Part 2: Network and application protocol requirements, Part 3: Physical and data link layer requirements, Road vehicles — Vehicle to grid communication interface — Part 8: Physical layer and data link layer requirements for wireless communication
- ISO 15628: Intelligent transport systems — Dedicated short range communication (DSRC) — DSRC application layer
- ISO 15662: Intelligent transport systems — Wide area communication — Protocol management information
- ISO 15662: Intelligent transport systems — Wide area communication — Protocol management information
- ISO 17425: Intelligent transport systems — Cooperative systems — Data exchange specification for in-vehicle presentation of external road and traffic related data
- ISO 17515-3: Intelligent transport systems — Evolved-universal terrestrial radio access network — Part 3: LTE-V2X
- ISO 19091: Intelligent transport systems — Cooperative ITS — Using V2I and I2V communications for applications related to signalized intersections
- ISO 21185: Intelligent transport systems — Communication profiles for secure connections between trusted devices
- ISO 21217: Intelligent transport systems — Station and communication architecture
- ISO 21448: Road vehicles — Safety of the intended functionality
- ISO 21735: Intelligent transport systems — Framework architecture for plug and play (PnP) functionality in vehicles utilizing nomadic devices
- ISO 22837: Vehicle probe data for wide area communications
- ISO 24099: Navigation data delivery structures and protocols
- ISO 24103: Intelligent transport systems — Communications access for land mobiles (CALM) — Media adapted interface layer (MAIL)

- ISO/FDIS 13400-2: Road vehicles — Diagnostic communication over Internet Protocol (DoIP) — Part 2: Transport protocol and network layer services
- ISO/TS 17424: Intelligent transport systems — Cooperative systems — State of the art of Local Dynamic Maps concepts
- ISO/TS 19091: Intelligent transport systems — Cooperative ITS — Using V2I and I2V communications for applications related to signalized intersections
- ITE RSU Specification
- NEMA TS10 – Connected Vehicle Infrastructure-Roadside Equipment
- NTCIP 1218: Object Definitions for Roadside Units (RSUs) Part 2: Specific requirements for communication between electric road vehicle (EV) and infrastructure
- SAE J 2945/2A: Dedicated Short Range Communications (DSRC) Performance Requirements for V2V Safety Awareness™ ASN File
- SAE J2735: Dedicated Short Range Communications (DSRC) Message Set Dictionary
- SAE J2745/1: Categorization and Properties of Advanced High Strength Automotive Sheet Steels
- SAE J2745/1A: Categorization and Properties of Advanced High Strength Automotive Sheet Steels
- SAE J2745: Categorization and Properties of Advanced High Strength Automotive Sheet Steels
- SAE J2945/1: On-Board System Requirements for V2V Safety Communications
- SAE J2945/1A: Vehicle Level Validation Test Procedures for V2V Safety Communications
- SAE J2945/2S: Dedicated Short Range Communications (DSRC) Performance Requirements for V2V Safety Awareness™ Set
- SAE J2945/8: Cooperative Perception System
- SAE J2945/A: Standard for Lane-Level and Road Furniture Mapping for Infrastructure-based V2X Applications (WIP)
- SAE J2945/D: Road user-to-Road User Courteous Communication (WIP)
- SAE J2945: Dedicated Short Range Communication (DSRC) Systems Engineering Process Guidance for SAE J2945/X Documents and Common Design Concepts
- SAE J3067: Candidate Improvements to Dedicated Short Range Communications (DSRC) Message Set Dictionary [SAE J2735] Using Systems Engineering Methods
- SAE J3131: Automated Driving Reference Architecture (WIP)
- SAE J3161/1: On-Board System Requirements for LTE V2X V2V Safety Communications (WIP)
- SAE J3161/1: On-Board System Requirements for LTE V2X V2V Safety Communications (WIP)
- SAE J3161/1A: On-Board System Requirements for LTE V2X V2V Safety Communications
- SAE J3161: C-V2X Deployment Profiles
- SAE J3161: C-V2X Deployment Profiles (WIP)
- SAE J3161: On-Board System Requirements for LTE V2X V2V Safety Communications (WIP)
- SAE J3186: Application Protocol and Requirements for Maneuver Sharing and Coordinating Service (WIP)
- SAE J3224: V2X Sensor-Sharing for Cooperative & Automated Driving (WIP)
- WIFI Alliance

#### 2.2.1.4 All other V2X Device Communications (V2N, BSM, SPaT, MAP, RSM) Layers/Protocols

- CEN/TS 17297-2: Intelligent transport systems — Location Referencing Harmonisation for Urban-ITS – Part 2: Transformation methods
- CEN/TS 17363: Intelligent transport systems — ECall optional additional data — Linked mobile phone number data concept
- CEN/TS 17380: Intelligent transport systems — Urban-ITS — “Controlled Zone” management for UVARs using C-ITS
- EN 302890-1 V 1.2.1: Electromagnetic compatibility and Radio spectrum Matters (ERM); Transmitting equipment for the Frequency Modulated (FM) sound broadcasting service; Part 1: Technical characteristics and test methods




- ETSI TS 103544-21 V 1.3.1: Electronic Signatures and Infrastructures (ESI); Cryptographic Suites
- ISO 12813:2019: Electronic fee collection — Compliance check communication for autonomous systems
- ISO 15784-2 DAM 1: Intelligent transport systems (ITS) — Data exchange involving roadside modules communication — Part 2: Centre to field device communications using SNMP — Amendment 1: Support for SHA2 encryption
- ISO 17515-3: Intelligent transport systems — Evolved-universal terrestrial radio access network
- ISO/CD 21219-1: Intelligent transport systems — Traffic and travel information (TTI) via transport protocol experts group, generation 2 (TPEG2) — Part 1: Introduction, numbering and versions (TPEG2-INV)
- ISO/DIS 14819-1: Intelligent transport systems — Traffic and travel information messages via traffic message coding — Part 1: Coding protocol for Radio Data System — Traffic Message Channel (RDS-TMC) using ALERT-C
- ISO/DIS 14819-2: Intelligent transport systems — Traffic and travel information messages via traffic message coding
- ISO/DIS 14819-3: Intelligent transport systems — Traffic and travel information messages via traffic message coding — Part 3: Location referencing for Radio Data System — Traffic Message Channel (RDS-TMC) using ALERT-C
- ISO/DIS 15765-5: Road vehicles — Diagnostic communication over Controller Area Network (DoCAN) — Part 5: Specification for an in-vehicle network connected to the diagnostic link connector
- ISO/DIS 17515-2: Intelligent transport systems — Evolved universal terrestrial radio access network (E-UTRAN) — Part 2: Device to device communications (D2D)
- ISO/FDIS 13400-2: Road vehicles – Diagnostic communication over Internet Protocol (DoIP) – Part 2: Transport protocol and network layer services
- ISO/FDIS 20730-1: Road vehicles — Vehicle interface for electronic Periodic Technical Inspection (ePTI) — Part 1: Application and communication requirements
- ISO/TR 21735: Intelligent transport systems — Framework architecture for plug and play (PnP) functionality in vehicles utilizing nomadic devices
- ISO/WD 11992-4: Road vehicles — Interchange of digital information on electrical connections between towing and towed vehicles — Part 4: Diagnostic communication
- SAE J2836/1: Use Cases for Communication Between Plug-in Vehicles and the Utility Grid
- SAE J2847/1: Communication between Plug-in Vehicles and the Utility Grid

#### 2.2.1.5 Connectivity and Latency Aspects of Security Certificate / Credential Updates

- ETSI TS 103 097: Intelligent Transport Systems (ITS); Security; Security header and certificate formats
- IEEE 1609.2.1: Standard for Wireless Access in Vehicular Environments — Security Services for Applications and Management Messages
- IEEE 1609.2: IEEE Standard for Wireless Access in Vehicular Environments — Security Services for Applications and Management Messages
- ISO 21177: Intelligent transport systems — ITS station security services for secure session establishment and authentication between trusted devices
- ISO 21217: Intelligent transport systems — Communications access for land mobiles (CALM) — Architecture
- ISO/TS 21185: Intelligent transport systems — Communication profiles for secure connections between trusted devices
- SAE J2945/8: Cooperative Perception System (WIP)

#### 2.2.1.6 Construction Zone Data Exchange Applications

- ISO 15143-1: Earth-moving machinery and mobile road construction machinery — Worksite data exchange — Part 1: System architecture
- ISO 15143-2:2010: Earth-moving machinery and mobile road construction machinery — Worksite data exchange — Part 2: Data dictionary
- ISO 26262-1: Road vehicles — Functional safety — Part 1: Vocabulary
- ISO/AWI TS 23520: Road vehicles — Equipment exchange — data format specification for operational information relevant for equipment exchange and test conduction
- ISO/AWI TS 15143-4: Earth-moving machinery and mobile road construction machinery — Worksite data exchange — Part 4: Worksite topographical data
- ISO/TS 15143-3: Earth-moving machinery and mobile road construction machinery — Worksite data exchange — Part 3: Telematics data
- SAE J2365: Calculation of the Time to Complete In-Vehicle Navigation and Route Guidance Tasks
- SAE J2395: ITS In-Vehicle Message Priority
- SAE J2399: Adaptive Cruise Control (ACC) Operating Characteristics and User Interface
- SAE J2735_202007: V2X Communications Message Set Dictionary
- SAE J2945/1: On-board Minimum Performance Requirements for V2V Safety Communications
- SAE J2945/1A: Vehicle Level Validation Test Procedures for V2V Safety Communications
- SAE J2945/4: Road Safety Applications
- SAE J2945/A: Standard for Lane-Level and Road Furniture Mapping for Infrastructure-based V2X Applications (WIP)
- SAE J3018: Guidelines for Safe On-Road Testing of SAE Level 3, 4, and 5 Prototype Automated Driving Systems (ADS)
- SAE J3063: Active Safety Systems Terms & Definitions
- SAE J3161/1: On-Board System Requirements for LTE V2X V2V Safety Communications
- SAE J3206: Safety Principles

#### 2.2.1.7 Public Safety Emergency Vehicle Applications

- IEEE 1512.1: Standard for Traffic Incident Management Message Sets for Use by Emergency Management Centers
- IEEE 1512.2: Standard for Public Safety Traffic Incident Management Message Sets for Use by Emergency Management Centers
- IEEE 1512: IEEE Standard for Common Incident Management Message Sets for Use by Emergency Management Centers
- ISO 18317: Intelligent transport systems — Pre-emption of ITS communication networks for disaster and emergency communication — Use case scenarios
- ISO 20530: Intelligent transport systems — Information for emergency service support via personal ITS station — General requirements and technical definition
- ISO 22951: Data dictionary and message sets for preemption and prioritization signal systems for emergency and public transport vehicles (PRESTO)

#### 2.2.1.8 Paved Road Applications

- ISO/AWI 39003: Road Traffic Safety (RTS) — Guidance on safety ethical considerations for autonomous vehicles
- NEMA TS 10: New NEMA Standard to Enable Coexistence of Multiple Communication Technologies for Connected Vehicle Roadside Infrastructure
- prEN 1790: Road marking materials — Preformed road markings
- SAE J2945/C: Traffic Probe Use and Operation
- SAE J2945/D: Road user-to-Road User Courteous Communication (WIP)

#### 2.2.1.9 Unpaved, Gravel Road Applications

- ISO/AWI 39003: Road Traffic Safety (RTS) — Guidance on safety ethical considerations for autonomous vehicles
- NEMA TS 10: New NEMA Standard to Enable Coexistence of Multiple Communication Technologies for Connected Vehicle Roadside Infrastructure
- prEN 1790: Road marking materials — Preformed road markings
- SAE J2945/C: Traffic Probe Use and Operation
- SAE J2945/D: Road user-to-Road User Courteous Communication (WIP)

#### 2.2.1.10 Data Management, Terminologies / Definitions, and Other

- ASTM E2468: Standard Practice for Metadata to Support Archived Data Management Systems
- ASTM E2665: Standard Specification for Archiving ITS-Generated Traffic Monitoring Data
- ISO 14817-1: Intelligent transport systems — ITS central data dictionaries — Part 1: Requirements for ITS data definitions
- ISO 14817-2: Intelligent transport systems — ITS central data dictionaries — Part 2: Governance of the Central ITS Data Concept Registry
- ISO 14817-3: Intelligent transport systems — ITS data dictionaries — Part 3: Object identifier assignments for ITS data concepts
- ISO 19321: Intelligent transport systems — Cooperative ITS — Dictionary of in-vehicle information (IVI) data structures
- ISO 25114: Intelligent transport systems — Probe data reporting management (PDRM)
- ISO/AWI TS 21184: Cooperative intelligent transport systems (C-ITS) — Global transport data management (GTDM) framework (WIP)
- ISO/DIS 23239-1: Road vehicles — Vehicle domain service — Part 1: General information and use case definitions (WIP)
- ISO/TR 14823-2: Intelligent transport systems — Graphic data dictionary — Part 2: Examples
- ISO/WD 21210-1: Intelligent transport systems — IPv6 Networking — Part 1: Common terms, definitions and requirements (WIP)
- ISO/WD 34503: Road vehicles — Taxonomy for operational design domain for automated driving systems (WIP)
- NTCIP 1218 V01: Standard Development Report for NTCIP 1218 v01 Object Definitions for Roadside Units (RSUs)
- SAE J3016: Taxonomy and Definitions for Terms Related to On-Road Motor Vehicle Automated Driving Systems
- WZDx Specification 3.0: Work Zone Data Exchange (WZDx)

#### 2.2.1.11 Sensor Data/ Edge Computing / Measurements and Data within Vehicle

**Sensor Data:**

- ADASIS: ADASIS defines an appropriate interface for exchanging information between the in-vehicle map database, ADAS and automated driving applications
- IEEE P2936: Standard for Test Methods of Automotive Lidar Performance
- IEEE P2020: Standard for Automotive System Image Quality
- ISO 12233: Resolution and spatial frequency responses
- ISO 16505:2019/DAMD 1 — Road Vehicles — Ergonomic and performance aspects if Camera Monitor Systems — Requirements and test procedures — Amendment 1

- ISO IEC 23090-9: Information technology — Coded representation of immersive media — Part 9: Geometry-based point cloud compression (WIP)
- ISO/DIS 23150: Road vehicles — Data communication between sensors and data fusion unit for automated driving functions — Logical interface (WIP)
- ISO/IEC 23090-10: Information technology — Coded representation of immersive media — Part 10: Carriage of visual volumetric video-based coding data (WIP)
- ISO/IEC 23090-5: Information technology — Coded representation of immersive media — Part 5: Visual Volumetric Video-based Coding (V3C) and Video-based Point Cloud Compression (V-PCC) (WIP)
- ISO/IEC FDIS 23090-8: Information technology — Coded representation of immersive media — Part 8: Network based media processing (WIP)
- ISO/IEC/IEEE 21451: Information technology — Smart transducer interface for sensors and actuators — Part 1: Network Capable Application Processor (NCAP) information model
- ISO/WD 11992-2: Road vehicles — Interchange of digital information on electrical connections between towing and towed vehicles — Part 2: Application layer for brakes and running gear
- ISO/WD 24650: Road Vehicles — Sensors for automated driving under adverse weather conditions — Assessment of the cleaning system
- ITU-T SG16: Multimedia
- SAE J3088: Active Safety System Sensors
- SAE J3224: V2X Sensor-Sharing for Cooperative & Automated Driving (WIP)
- SENSORIS: A Global Standardised Interface to Exchange Information between In-Vehicle Sensors and a Dedicated Cloud, as well as between Clouds
- SPIE: International not-for-profit professional society for optics and photonics technology

**Edge Computing:**

- 5GAA Edge computing white paper: Toward fully connected vehicles: Edge computing for advanced automotive communications
- ETSI GR MEC 022: Multi-access Edge Computing (MEC) Study on MEC Support for V2X Use Cases
- ETSI GS MEC 002 section A36: Multi-access Edge Computing (MEC) Phase 2: Use Cases and Requirements
- ETSI GS MEC 030: Multi-access Edge Computing (MEC) V2X Information Service API
- ETSI White paper on Harmonizing standards for edge computing
- ISO/IEC TR 23188: Information technology — Cloud computing — Edge computing landscape
- ISO/IEC TR 30164: Internet of things (IoT) — Edge computing

**Measurements:**

- ARP5290A: Laser Beam Divergence Measurements Techniques Comparison
- ETSI TR 103 562: Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Analysis of the Collective Perception Service (CPS)
- SAE J1843 2018: Accelerator Pedal Position Sensor for Use with Electronic Controls in Medium- and Heavy-Duty Vehicle Applications-Truck and Bus

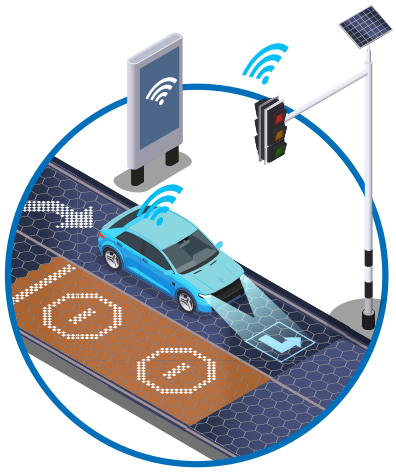
**ASAM Open Simulation Interface:**

- ISO/CD 17215-3: Road vehicles — Video communication interface for cameras (VCIC) — Part 3: Camera message dictionary

**Performance Requirements & Test Procedures:**

- ISO 11067: Intelligent transport systems — Curve speed warning systems (CSWS) — Performance requirements and test procedures
- ISO 11270: Intelligent transport systems — Lane keeping assistance systems (LKAS) — Performance requirements and test procedures
- ISO 15623: Intelligent transport systems — Forward vehicle collision warning systems — Performance requirements and test procedures
- ISO 22179: Intelligent transport systems — Full speed range adaptive cruise control (FSRA) systems — Performance requirements and test procedures (Withdrawn)

### 2.2.2 Physical Infrastructure



Physical infrastructure refers to the physical structures upon which the transportation system operates.

Acknowledging that vehicles are manufactured for global markets, significant international efforts are needed to harmonize physical infrastructure (e.g., traffic signs and road markings) to ensure consistent machine recognition and safety performance. Due to economies of scale, the automotive manufacturing industry has limited ability to customize software and sensor system design for each individual jurisdiction. Therefore, industry-government forums are needed at an international level to support harmonization and enhancement of the physical infrastructure to complement CAV testing.

The following sections highlight applicable/relevant standards and documents related to the physical infrastructure.

#### 2.2.2.1 Signs

- Alberta (AB) Recommended practices guidelines (Alberta Ministry of Transportation)
- British Columbia (BC) Manual of Standard Traffic Signs and Pavement Markings (British Columbia Ministry of Transportation)
- British Columbia (BC) Policy Manual for Supplemental Signs (British Columbia Ministry of Transportation)
- ISO 1203: Photography — Roll film cameras — Back window location
- ISO 20684-10: Intelligent transport systems — Roadside modules SNMP data interface — Part 10: Variable message signs
- Needs Statement 562 — Pavement Markings for Autonomous Driving: Literature Search (Minnesota Department of Transportation)
- New Brunswick (NB) Motor Vehicle Act
- Nova Scotia (NS) Motor Vehicle Act
- Ontario O. Reg. 239/02: Minimum Maintenance Standards for Municipal Highways
- Ontario Traffic Manual — Book 5: Regulatory Signs
- Quebec (QC) Volume V — Traffic Control Devices

#### 2.2.2.2 Traffic Signals

- Alberta (AB) Recommended practices guidelines (Alberta)
- British Columbia (BC) Motor Vehicle Act Regulation
- Manitoba (MB) Standard Drawings for Traffic Signals
- NTCIP 1210: National Transportation Communications for ITS Protocol Field Management Stations (FMS) — Part 1: Object Definitions for Signal System Masters (SSM) published
- NTCIP 1211: National Transportation Communications for ITS Protocol Object Definitions for Signal Control and Prioritization (SCP)
- Ontario (ON) Traffic Manual Book 12
- Quebec (QC) Volume V — Traffic Control Devices

#### 2.2.2.3 Pavement Marking

- Alberta (AB) Recommended practices guidelines (Alberta Ministry of Transportation)
- British Columbia (BC) Manual of Standard Traffic Signs and Pavement Markings (British Columbia Ministry of Transportation) Ontario (ON) Traffic Manual Book 11

#### 2.2.2.4 Temporary Conditions

- Ontario (ON) Traffic Manual Book 7
- Intelligent transport systems — Use of nomadic and portable devices to support ITS service and multimedia provision in vehicles
- Intelligent transport systems (ITS) — Guidance protocol via personal ITS station for advisory safety systems — Part 1: General information and use case definitions
- Transport information and control systems — Traffic Impediment Warning Systems (TIWS) — System requirements

#### 2.2.2.5 Other

- Alberta (AB) Recommended practices guidelines (Alberta Ministry of Transportation)
- ATC 5301: ITS Cabinet
- British Columbia (BC) Pedestrian Crossing Control Manual for British Columbia
- ITE 5201: Advanced Transportation Controller (ATC) Standard
- ITE 5202: (ITE ATC Type 2070) Model 2070 Controller Standard
- NEMA TS 10: 10Connected Vehicle Infrastructure Roadside Equipment
- NTCIP 1201: National Transportation Communications for ITS Protocol Global Object (GO) Definitions
- NTCIP 1202: National Transportation Communications for ITS Protocol Object Definitions for Actuated Traffic Signal Controller (ASC) Units — version 02
- NTCIP 1203: National Transportation Communications for ITS Protocol
- NTCIP 1207: National Transportation Communications for ITS Protocol Object Definitions for Ramp Meter Control (RMC) Units
- Object Definitions for Dynamic Message Signs (DMS)
- Ontario (ON) Traffic Manual Book 15: Pedestrian Crossing Treatments

### 2.2.3 Usage, Human-Machine Interface, Accessibility, and Vehicle Aspects



Advancements in connected and automated vehicle technologies (e.g., vehicle-to–everything, V2X) have a promising future in improving traveller safety by warning drivers of dangerous conditions, providing mobility accessibility and options to a wider population, and producing a better human-to-machine interface and experience.

The following sections highlight applicable/relevant standards and documents related to usage, human-machine interface, accessibility, and vehicle aspects.

#### 2.2.3.1: Usage

- ARIB STD T110: DSRC Basic Application Interface
- ASTM F3244: Standard Test Method for Navigation: Defined Area
- ASTM F3265: Standard Test Method for Grid-Video Obstacle Measurement
- AVSC00001201911: AVSC Best Practice for In-Vehicle Fallback Test Driver Selection, Training, and Oversight Procedures for Automated Vehicles Under Test
- ISO/DIS 20901: Intelligent transport systems — Emergency electronic brake light systems (EEBL) — Performance requirements and test procedures
- ISO/TR 16352: Road vehicles — Ergonomic aspects of in-vehicle presentation for transport information and control systems — Warning systems

- SAE J1725: Structural Modification for Personally Licensed Vehicles to Meet the Transportation Needs of Persons with Disabilities
- SAE J1849: Emergency Vehicle Sirens
- SAE J2094: Vehicle and Control Modifications for Drivers with Physical Disabilities Terminology
- SAE J2395: ITS In-Vehicle Message Priority
- SAE J2602/1: LIN Network for Vehicle Applications
- SAE J2945/2: Dedicated Short Range Communications (DSRC) Performance Requirements for V2V Safety Awareness
- SAE J2945/5: Service Specific Permissions and Security Guidelines for Connected Vehicle Applications
- SAE J2945: Dedicated Short Range Communication (DSRC) Systems Engineering Process Guidance for SAE J2945/X Documents and Common Design Concepts
- SAE J2958: Report on Unmanned Ground Vehicle Reliability
- SAE J3016_2021: Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles
- SAE J3016_2014: Taxonomy and Definitions for Terms Related to On-Road Motor Vehicle Automated Driving Systems
- SAE J3077: Definitions and Data Sources for the Driver Vehicle Interface (DVI)
- SAE J3114: Human Factors Definitions for Automated
- SAE J3134: Automated Driving System (ADS) Marker Lamp
- SAE J3171: Identifying Automated Driving Systems — Dedicated Vehicles (ADS-DVs) Passenger Issues for Persons with Disabilities
- SAE J826: Devices for Use in Defining and Measuring Vehicle Seating Accommodation
- SAE J885: Human Tolerance to Impact Conditions as Related to Motor Vehicle Design

### 2.2.3.2: Human-Machine Interface

Automated driving will profoundly change the role of the driver from actively controlling the vehicle to supervising its actions (so-called "partial automation", SAE Level 2; SAE J3016) or even being ready to act as a fallback level in case the automation reaches its limits (so-called "conditionally automated driving", SAE Level 3). Consequently, an automated driving system's (ADS) human-machine interface (HMI) should effectively support the driver's, passengers', and customers' interactions with the ADS, such as handing control over to the automation, supervising the automation and driving environment, or resuming vehicle control when necessary.

#### *2.2.3.2.1 B.1. Driver/occupant internal interface (Internal: Driver, Occupant)*

- ARIB STD T110: Dedicated Short-Range Communication Basic Application Interface
- ETSI TR 102 762: Human Factors (HF); Intelligent Transport Systems (ITS); ICT in cars
- FHWA-HRT-16-056: Cooperative Adaptive Cruise Control Human Factors Study: Experiment 1— Workload, Distraction, Arousal, and Trust
- GRE-64-07, ITS-19-07: Design principle for ADAS: keeping drivers in loop
- ISO 12214: Road vehicles — Direction-of-motion stereotypes for automotive hand controls
- ISO 15006: Road vehicles — Ergonomic aspects of transport information and control systems — Specifications for in-vehicle auditory presentation
- ISO 16121-1: Road vehicles — Ergonomic requirements for the driver's workplace in line-service buses — Part 1: General description, basic requirements
- ISO 17287: Road vehicles — Ergonomic aspects of transport information and control systems — Procedure for assessing suitability for use while driving
- ISO 17488: Road vehicles — Transport information and control systems — Detection-response task (DRT) for assessing attentional effects of cognitive load in driving
- ISO 20035: Intelligent transport systems — Cooperative adaptive cruise control systems (CACC) — Performance requirements and test procedures
- ISO 21956: Road vehicles — Ergonomics aspects of transport information and control systems — Human machine interface specifications for keyless ignition systems



- ISO 2575: Road vehicles — Symbols for controls, indicators and tell-tales
- ISO 26022: Road vehicles — Ergonomic aspects of transport information and control systems — Simulated lane change test to assess in-vehicle secondary task demand
- ISO TR 21959 – 1: Road vehicles — Human performance and state in the context of automated driving — Part 1: Common underlying concepts
- ISO/ DIS 15765-5: Vehicle control
- ISO/ TR 21959 -2 2020: Road vehicles — Human performance and state in the context of automated driving — Part 2: Considerations in designing experiments to investigate transition processes
- ISO/AWI TR 21959-2 Z015-10: Road vehicles — Human performance and state in the context of automated driving — Part 2: Considerations in designing experiments to investigate transition processes
- ISO/DIS 20901: Emergency electronic brake light systems (EEBL)
- ISO/TR 16352: Road vehicles — Ergonomic aspects of in-vehicle presentation for transport information and control systems — Warning systems
- ISO/TR 17427-10: Intelligent transport systems — Cooperative ITS — Part 10: Driver distraction and information display
- ISO/TR 21974: Naturalistic driving studies — Vocabulary — Part 1: Safety critical events
- ISO/TS 16951: Procedures for determining priority of on-board messages presented to drivers
- ISO/TS 17426: Intelligent transport systems — Cooperative systems — Contextual speeds
- NHSTA 2010-0053, UN WP-160-34: Visual manual driver distraction guidelines for in-vehicle electronic devices
- NHSTA 2014-0022-0533: Discussion of HMI warning needs to effectively communicate with drivers
- NHSTA DOT HS 812 360: Human factor design guidance for driver vehicle interface
- SAE J2365: Calculation of the Time to Complete In-Vehicle Tasks
- SAE J2395 (Recommended Practice): In-Vehicle Message Priority
- SAE J2396: Definitions and Measures of Driver Visual Behavior
- SAE J2399: Adaptive Cruise Control (ACC) User Interface
- SAE J2400: Forward Collision Warning Systems User Interface
- SAE J2808: Blind Spot Monitoring System (BSMS) User Interface
- SAE J2988: Speech Input and Audible Output
- SAE J3077 (Informational Report): Definitions and Data Sources for the Driver Vehicle Interface (DVI)
- SAE J3114: Human Factors Definitions for Automated Driving and Related Research Topics
- UN WP-153-01, WP 29-150-22, GRB-52-01, GRB-64-59 (Canada), GRSP-103-15: Guidelines on establishing requirements for high priority warning signals

#### *2.2.3.2.1 B.2. External human interface (Externals interface: pedestrians, public, road service, police, vulnerable road users, V2V-H, etc.)*

- ISO/AWI TR 23720: Road Vehicles — Methods for evaluating other road user behavior in the presence of automated vehicle external communication
- ISO/DIS 23132: Road vehicles — Extended Vehicle (ExVe) time critical applications — General requirements, definitions and classification methodology of time-constrained situations related to Road and ExVe Safety (RExVeS)
- ISO/NP TR 23735: Road vehicles — Ergonomic design guidance for external visual communication from automated vehicles to other road users

#### *2.2.3.2.3 B.3. HMI (Interface design, colour, text, voice, shape)*

- ETSI TS 103544-17 V 1.3.1: Publicly Available Specification (PAS); Intelligent Transport Systems (ITS); MirrorLink®; Part 17: MirrorLink® over Wi-Fi Display (WFD)
- ETSI TS 103544-2 V 1.3.1: Publicly Available Specification (PAS); Intelligent Transport Systems (ITS); MirrorLink®; Part 2: Virtual Network Computing (VNC) based Display and Control
- ETSI TS 103544-20 V 1.3.1: Publicly Available Specification (PAS); Intelligent Transport Systems (ITS); MirrorLink®; Part 20: Internet Accessibility
- ISO/DIS 2575: Road vehicles — Symbols for controls, indicators, and tell-tales
- ISO/TS 14198: Road vehicles — Ergonomic aspects of transport information and control systems — Calibration tasks for methods which assess driver demand due to the use of in-vehicle systems
- ISO/WD TS 5283: Road vehicles — Ergonomic aspects of driver monitoring and system interventions in the context of automated driving
- SAE J1757/1: Standard Metrology for Vehicular Displays
- SAE J2830: Comprehension Testing of In-Vehicle Icons
- SAE J2831: In-Vehicle Alphanumeric Messages (Text Format)

#### *2.2.3.2.4 B.4. V2X/V2I interface*

- Intelligent Transport Systems — Interface Protocol and Message Set Definition between Traffic Signal Controllers and Detectors
- ISO 14827-1 & 2: Transport information and control systems — Data interfaces between centres for transport information and control systems — Part 1: Message definition requirements & Part 2: DATEX-ASN
- ISO 15118-2 & 3: Road vehicles — Vehicle-to-Grid Communication Interface — Part 2: Network and application protocol requirements & Part 3: Physical and data link layer requirements
- ISO/TR 17452: Intelligent transport systems — Using UML for defining and documenting ITS/TICS interfaces
- SAE J2735: Dedicated Short Range Communications (DSRC) Message Set Dictionary
- SAE J2945: Dedicated Short Range Communications (DSRC) Systems Engineering Process Guidance for SAE J2945/X Documents and Common Design Concepts.

### 2.2.3.3: Accessibility

CAVs can play an important role in helping the elderly, disabled, and other individuals who cannot drive stay more connected with their friends, family, and community and remain self-sufficient for as long as possible. Interfaces between mobile devices (and mobile device peripherals, such as refreshable Braille, hearing aids, and other assistive technologies), vehicle controls, and mobility aids (e.g., wheelchairs) will need to be envisioned, standardized, and deployed. Such collaboration is necessary to ensure there are no gaps in mobility from door-to-car-to-door. Further, the accessibility and usability of on-board vehicle interfaces as well as automated driving algorithms must be designed to accommodate users and pedestrians with sight loss, hearing loss, and other disabilities. The following standards are relevant:

- ISO 15008: Road vehicles — Ergonomic aspects of transport information and control systems — Specifications and test procedures for in-vehicle visual presentation

- SAE J1725: Structural Modification for Personally Licensed Vehicles to Meet the Transportation Needs of Persons with Disabilities
- SAE J1903: Automotive Adaptive Driver Controls, Manual
- SAE J2092: Testing of Wheelchair Lifts for Entry to or Exit from a Personally Licensed Vehicle
- SAE J2093: Design Considerations for Wheelchair Lifts for Entry to or Exit from a Personally Licensed Vehicle
- SAE J2094: Vehicle and Control Modifications for Drivers with Physical Disabilities Terminology
- SAE J2249: Wheelchair Tiedown and Occupant Restraint Systems for Use in Motor Vehicles
- SAE J2395: ITS In-Vehicle Message Priority
- SAE J2831: Development of Design and Engineering Recommendations for In-Vehicle Alphanumeric Messages
- SAE J2988: Guidelines for Speech Input and Audible Output in a Driver Vehicle Interface
- SAE J3163: Taxonomy and Definitions for Terms Related to Shared Mobility and Enabling Technologies

#### 2.2.3.4: Vehicle Aspects

Vehicle aspects of CAVs are generally addressed by OEMs such as safety, security, privacy, trust, transparency, reliability, and quality assurance; however, there are other topics that may require exploration, such as impact of aftermarket products (product safety, functionality, and installation), testing and certification of sensors, testing and certification of platooning systems, ADS testing best practices, inspection and maintenance, and data simulation. The following standards are relevant:

- ETSI TR 103 298: Intelligent Transport Systems (ITS); Platooning; Pre-standardization study (WIP)
- ETSI TR 103 299: Intelligent Transport Systems (ITS); Cooperative Adaptive Cruise Control (CACC); Pre-standardization study
- ISO 20035: Intelligent transport systems — Cooperative adaptive cruise control systems (CACC) — Performance requirements and test procedures
- ISO TC 204 WG14: Vehicle/roadway warning and control systems
- ISO/TR 20545: Intelligent transport systems — Vehicle/roadway warning and control systems — Report on standardisation for vehicle automated driving systems (RoVAS)/Beyond driver assistance systems
- SAE J2945/6: Performance Requirements for Cooperative Adaptive Cruise Control and Platooning (WIP)
- SAE J3148: Multi-Vehicle System Operational Efficiency Experimental Test Method (WIP)
- SAE J3149: Guidelines for Safer On-Road Testing of Prototype Automated Multi-Vehicle Truck and Bus Systems (WIP)
- SAE J3150: Taxonomy and Definitions for Automated Multi-Vehicle Truck and Bus Systems (WIP)
- SAE J3300/3: Driving Level Skill Certification — Automated driving

### 2.2.4 Cybersecurity, Data Management, and Privacy



Modern vehicles have become highly complex systems and new vehicle technologies are continuing to emerge at a rapid pace. The shift to CAVs in Canada is well underway, bringing with it enormous potential safety benefits for Canadians. At the same time, increased levels of automation and connectivity features create new cybersecurity risks that have underscored the importance of prioritizing cyber resilience in Canada's transportation system.

There are similar challenges relating to ITS infrastructure as well with new technologies and higher

levels of connectivity. As the CAV ecosystem becomes increasingly sophisticated and interconnected, cyber-attack surfaces grow. Given the potential severity of damage that can be caused by even a single hacking incident, it is critical to introduce redundant safety components/protocols.

One way to counter the hackers' ability to send false vehicle location to the various sensors (e.g., causing the vehicle to perhaps drive into oncoming traffic), is by installing external (preferably hardware-based) ground-truthing or benchmark/location-verification elements at several key locations within the infrastructure and/or buildings. Such external elements can help provide an independent extra layer of security, giving the vehicle's on-board sensors the ability to verify data before taking action.

The following sections highlight applicable/relevant standards and documents related to cybersecurity, data management, and privacy.

#### 2.2.4.1 Privacy

- Auto Alliance: Consumer Privacy Protection Principles (CPPP) for Vehicle Technologies and Services
- California Connected Device Law
- California Consumer Privacy Act (CCPA)
- EU ePrivacy Regulation (upcoming)
- ISO 16461: Intelligent transport systems — Criteria for privacy and integrity protection in probe vehicle information systems
- ISO 24100: Intelligent transport systems — Basic principles for personal data protection in probe vehicle information services
- ISO/IEC 20889: Privacy enhancing data de-identification terminology and classification of techniques
- ISO/IEC 29100: Information technology — Security techniques - Privacy framework
- ISO/IEC 29101: Information technology — Security techniques — Privacy architecture framework
- ISO/IEC 29134: Information technology — Security techniques — Guidelines for privacy impact assessment
- ISO/TR 12859: Intelligent transport systems — System architecture — Privacy aspects in ITS standards and systems
- ISO/TR 17427-7: Intelligent transport systems — Cooperative ITS — Part 7: Privacy aspects
- ISO/TR 17427-8: Intelligent transport systems — Cooperative ITS — Part 8: Liability aspects
- NIST Privacy framework
- Personal Data Protection Act 2012
- Personal Information Protection and Electronic Documents Act (PIPEDA)
- The Canadian Privacy Act

#### 2.2.4.2 Data Handling

- ASTM E2259: Standard Guide for Archiving and Retrieving ITS-Generated Data
- ASTM E2468: Standard Practice for Metadata to Support Archived Data Management Systems
- General Data Protection Regulation (GDPR)
- ISO 11898-1: Road vehicles — Controller area network (CAN) — Part 1: Data link layer and physical signalling
- ISO 14823: Intelligent transport systems — Graphic data dictionary
- ISO 14823-2: Intelligent transport systems — Graphic data dictionary — Part 2: Examples
- ISO 14827-1: Transport information and control systems — Data interfaces between centres for transport information and control systems — Part 1: Message definition requirements
- ISO 14827-2: Transport information and control systems — Data interfaces between centres for transport information and control systems — Part 2: DATEX-ASN
- ISO 14827-3: Transport information and control systems — Data interfaces between centres for transport information and control systems — Part 3: Data interfaces between centres for intelligent transport systems (ITS) using XML (Profile A) between centres for intelligent transport systems (ITS) using XML (Profile A)
- ISO 20078-1: Road vehicles — Extended vehicle (ExVe) web services — Part 1: Content



- ISO 22951: Data dictionary and message sets for preemption and prioritization signal systems for emergency and public transport vehicles (PRESTO)
- ISO 24099: Navigation data delivery structures and protocols
- ISO 24531: Intelligent transport systems — System architecture, taxonomy and terminology — Using XML in ITS standards, data registries and data dictionaries
- ISO 24978: Intelligent transport systems — ITS Safety and emergency messages using any available wireless media — Data registry procedures
- ISO 25100: Guidance on project management
- ISO/DIS 21219-1: Intelligent transport systems — Traffic and travel information (TTI) via transport protocol experts group, generation 2 (TPEG2) — Part 1: Introduction, numbering and versions (TPEG2-INV) (WIP)
- ISO/TR 11769: Intelligent transport systems — Communications access for land mobiles (CALM) — Data retention for law enforcement
- ISO/TR 21707: Intelligent transport systems — Integrated transport information, management and control — Data quality in ITS systems
- ISO/TR 24529: Intelligent transport systems — Systems architecture — Use of unified modelling language (UML) in ITS International Standards and deliverables
- ISO/TR 24532: Intelligent transport systems — Systems architecture, taxonomy and terminology — Using CORBA (Common Object Request Broker Architecture) in ITS standards, data registries and data dictionaries (Withdrawn)
- ISO/TS 19082: Intelligent transport systems — Definition of data elements and data frames between roadside modules and signal controllers for cooperative signal control
- ISO/TS 20026: Intelligent transport systems — Cooperative ITS — Test architecture
- ISO/TS 20452: Requirements and Logical Data Model for a Physical Storage Format (PSF) and an Application Program Interface (API) and Logical Data Organization for PSF used in Intelligent Transport Systems (ITS) Database Technology
- ISO/TS 21219-24: Intelligent transport systems — Traffic and travel information (TTI) via transport protocol experts group, generation 2 (TPEG2) — Part 24: Light encryption (TPEG2-LTE)
- ISO/TS 29284: Intelligent transport systems — Event-based probe vehicle data
- NTCIP 1102: National Transportation Communications for ITS Protocol Octet Encoding Rules (OER) Base Protocol
- NTCIP 1209: National Transportation Communications for ITS Protocol Object Definitions for Transportation Sensor Systems (TSS)

- SAE J1698/1: Event Data Recorder — Output Data Definition
- SAE J1698/2: Event Data Recorder — Retrieval Tool Protocol
- SAE J1708: Serial Data Communications Between Microcomputer Systems in Heavy-Duty Vehicle Applications
- SAE J2353: Data Dictionary for Advanced Traveler Information Systems (ATIS)
- SAE J2630: Converting ATIS Message Standards From ASN.1 to XML
- SAE J3077: Definitions and Data Sources for the Driver Vehicle Interface (DVI)
- SAE J3161/1A: On-Board System Requirements for LTE V2X V2V Safety Communications (WIP)

#### 2.2.4.3 Cybersecurity

- ASN.1 FOR MISBEHAVIOR REPORTING
- AutoSAR CP Release 4.3.1: Classic Platform Release Overview
- AUTOSIG: Automotive SPICE
- Best Practices — Auto-ISAC
- Bosch CAN 2.0 specification
- Bosch CAN FD Protocol specification (Controller Area Network Flexible Data-Rate)
- Certificate Policy for Deployment and Operation of European Cooperative Intelligent Transport Systems (C-ITS)
- C-ROADS Security and Governance 1.7.1
- C-ROADS Security Requirements & Specifications 1.7.1
- Cyber Security Law (CSL)
- Cybersecurity Act 2018
- ETSI TS 36-521 (Release 14): LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) conformance specification; Radio transmission and reception; Part 1: Conformance testing (3GPP TS 36.521-1 version 14.3.0 Release 14)
- ETSI TS 36-523 (Release 14): LTE; Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Packet Core (EPC); User Equipment (UE) conformance specification; Part 1: Protocol conformance specification (3GPP TS 36.523-1 version 14.1.0 Release 14)
- Federal Motor Vehicle Safety Standard (FMVSS) No. 150 Vehicle-to-Vehicle Communication Technology for Light Vehicles
- FIPS 140-2: Security Requirements for Cryptographic Modules
- IEC 62443: Security for industrial automation and control systems — Part 4-1: Secure product development lifecycle requirements
- IEEE 1609.12: IEEE Standard for Wireless Access in Vehicular Environments (WAVE) —Identifier Allocations
- IEEE 1609.2.1(CAMP): IEEE Standard for Wireless Access in Vehicular Environments — Security Services for Applications and Management Messages
- IEEE 1609.2: IEEE Standard for Wireless Access in Vehicular Environments — Security Services for Applications and Management Messages
- IEEE 1609.2a, .2b: IEEE Standard for Wireless Access in Vehicular Environments — Security Services for Applications and Management Messages — Amendment 1
- IEEE 1609.3: IEEE Standard for Wireless Access in Vehicular Environments (WAVE) — Networking Services
- IEEE 1609.4-2016: IEEE Standard for Wireless Access in Vehicular Environments (WAVE) — Multi-Channel Operation
- IEEE 802.11: (802.11p): IEEE Standard for Information technology — Telecommunications and information exchange between systems Local and metropolitan area networks — Specific requirements Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications
- IEEE P1556: Security/Privacy of Vehicle/RS Communications including Smart Card Communications
- IEEE/ISO 802.2: ISO/IEEE International Standard — Information processing systems — Local area networks — Part 2: Logic Link Control
- IPA: Approaches for Vehicle Information Security
- ISA-62443-4-2: Security for industrial automation and control systems, Part 4-2: Technical security requirements for IACS components

- ISO 14229-1: Road vehicles — Unified diagnostic services (UDS) — Part 1: Application layer
- ISO 15764: Road vehicles — Extended data link security (withdrawn)
- ISO 17427-5: Intelligent transport systems — Cooperative ITS — Part 1: Roles and responsibilities in the context of co-operative ITS architecture(s)
- ISO 20078-2: Road vehicles — Extended vehicle (ExVe) web services — Part 2: Access
- ISO 20078-3: Road vehicles — Extended vehicle (ExVe) web services — Part 3: Security
- ISO 26262-2:2018: Road vehicles — Functional safety — Part 2: Management of functional safety
- ISO/AWI 24089: Road vehicles — Software update engineering
- ISO/IEC 19790: Information technology — Security techniques — Security requirements for cryptographic modules
- ISO/IEC 27001: Information security management
- ISO/IEC 33001:2015 Information technology — Process assessment — Concepts and terminology
- ISO/IEC JTC1 SC27: Information security, cybersecurity and privacy protection (WIP)
- ISO/NP TS 5083: Road vehicles — Safety and cybersecurity for automated driving — Design, verification and validation
- ISO/PRF TR 4804: Road vehicles — Safety and cybersecurity for automated driving systems — Design, verification and validation
- ISO/SAE DIS 21434: Road vehicles — Cybersecurity engineering
- ISO/TR 11766: Intelligent transport systems — Communications access for land mobiles (CALM) — Security considerations for lawful interception
- ISO/TR 17427-6: Intelligent transport systems — Cooperative ITS — Part 6: "Core system" risk assessment methodology
- ISO/TR 17427-9: Intelligent transport systems — Cooperative ITS — Part 9: Compliance and enforcement aspects
- ISO/TS 21177: Intelligent transport systems — ITS station security services for secure session establishment and authentication between trusted devices
- ISO/WD PAS 5112: Road vehicles — Guidelines for auditing cybersecurity engineering (WIP)
- ITU X.1371: Security threats to connected vehicles
- ITU X.1372: Security guidelines for vehicle-to-everything (V2X) communication
- ITU X.1373: Secure software update capability for intelligent transportation system communication devices
- MIIT: National Guidelines for Developing the Standards System of the Telematics Industry
- NEMA Standards Publication TS 10:2020
- NEMA TS 2: Traffic Controller Assemblies with NTCIP Requirements
- NEMA TS 8: Cyber and Physical Security for Intelligent Transportation Systems (ITS)
- NHTSA — Cybersecurity Best Practices for Modern Vehicles
- NHTSA: Automated Driving Systems 2.0
- NIST Cybersecurity Framework (CSF)
- NTCIP 1103: National Transportation Communications for ITS Protocol Transportation Management Protocols (TMP)
- NTCIP 1201: National Transportation Communications for ITS Protocol Global Object (GO) Definitions — version 02
- NTCIP 1202 (v3): National Transportation Communications for ITS Protocol RS: Object Definitions for Actuated Signal Controllers (ASC) Interface
- NTCIP 1211 (v2): National Transportation Communications for ITS Protocol Object Definitions for Signal Control and Prioritization (SCP)
- NTCIP 1218 v01: Object Definitions for Roadside Units (RSUs) (WIP)
- SAE 2945/1: On-Board System Requirements for V2V Safety Communications
- SAE J1760: Data Security Services
- SAE J1939-91: Network Security
- SAE J2735: Dedicated Short Range Communications (DSRC) Message Set Dictionary
- SAE J2945/1A: On-Board System Requirements for V2V Safety Communications



- SAE J2945/5: Service Specific Permissions and Security Guidelines for Connected Vehicle Applications
- SAE J3061: Cybersecurity Guidebook for Cyber-Physical Vehicle Systems
- SAE J3061-1: Automotive Cybersecurity Integrity Level (ACsIL) (WIP)
- SAE J3101: Hardware Protected Security for Ground Vehicles
- SAE J3138: Diagnostic Link Connector Security
- SAE J3161/1: On-Board System Requirements for LTE V2X V2V Safety Communications
- SAE J3161: C-V2X Deployment Profiles (WIP)
- Security Credential Management System (SCMS)
- TMDD: Traffic Management Data Dictionary (TMDD) Standard for the Center-to-Center Communications
- UNECE WP.29 CYBERSECURITY REGULATION (CSMS)
- USDOT FHWA-JPO-17-589:2017 RSU 4.1: RSU 4.1 (Packaging Environment Attributes, Data Logging, SNMP Commands, Time Source accuracy, SPaT/MAP/WSA Messaging, Immediate Forwarding / Store&Repeat) for RSUs
- USDOT/Volpe NIST Cybersecurity Framework CAV profile

## 3 Critical Needs and Potential Gaps in Codes and Standards

Section 2 of this roadmap highlighted the vast number of standards that have been published or are in development. The CAVAC Working Groups (WGs) have identified additional needs, gaps, and priorities.

The following sections are structured based on the CAVAC WGs' findings: digital infrastructure; physical infrastructure; usage, human-machine interface, accessibility, and vehicle aspects; and cybersecurity, data management, and privacy. Each section identifies gaps and priorities and uses the following categories to denote approximate start dates for standards development:

- **High (H): 0–2 years:** Gaps in standards and codes that are deemed critical and essential to the current standards landscape.
- **Medium (M): 3–4 years:** Gaps in standards and codes that are necessary, but not critical for the current standards landscape.
- **Low (L): 5 + years:** Gaps in standards and codes that are beneficial, but not necessary for the current standards landscape.
- **Other (O):** Gaps that may or may not be considered as required standards and may potentially be considerations for MUTCD/MUTCDC or other guidelines.

## 3.1 Digital Infrastructure

| Topic | Identified Gap | Priority (H / M / L / O) |
|---|---|---|
| **Construction Zone Applications** | Create list of data types related to items that typically occupy a road during construction and maintenance (e.g. cones, temporary signs) | **H** |
| **Construction Zone Applications** | Standardize lane closure and work zone information and basic elements | **H** |
| **Construction Zone Applications** | Standardize digital tags to be worn by on-site workers. Should be detectable by all CAVs in real-time. | **H** |
| **High-Definition Distance Measurement (HDDM) & Local Dynamic Map (LDM)** | Adoption of ISO/AWI TS 22726-2 WIP<br>Intelligent transport systems — Dynamic data and map database specification for connected and automated driving system applications — Part 2: Logical data model of dynamic data | **H** |
| **Sensor Edge Measurements** | Quantifying sensor performance degradation as a function of weather | **H** |
| **Sensor Edge Measurements** | Maximum latency for edge computers for processing data and dispatching actuation signals | **H** |
| **V2X Main Layers & Protocol** | Lack of full scale production Security Credential Management System | **H** |
| **V2X Main Layers & Protocol** | Further analysis is needed to ensure the accuracy, security, and trust of received messages by an automated or active safety system in the receiving vehicle. SAE J2945/1 and J3161/1 are written at the level of "to detect potential crash threats and alert the driver". As such they are not designed so that the receiving vehicle acts on the message itself – as in automatically or robotically apply the brakes or perform a manoeuvre. | **H** |
| **HDDM & LDM** | Adoption of ISO 19115-1 2014<br>Geographic information — Metadata — Part 1: Fundamentals | **M** |
| **HDDM & LDM** | Navigation Data Standard specification 2019 | **M** |
| **HDDM & LDM** | Standardized map data quality and performance characteristics | **M** |
| **V2X Main Layers & Protocol** | Further work is needed to analyze use of V2X (basic safety messages) as one of a plurality of sensors to enhance safety in the vehicle. SAE J2945/1 and J3161/1 are performance specifications designed in absence of any safety sensors. The BSM (basic safety message) consists of only map-plotted precise location/heading/time (based mostly on GNSS). | **M** |
| **Connectivity Latency Security Certificate** | There is a potential gap of which the profiling certificate should be downloaded over Wi-Fi in addition to the existing ITS-band and cellular over-the-top methods. | **L** |
| **HDDM & LDM** | Adoption of ETSI TR 102 863 V1.1.1 (2011-06)<br>Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Local Dynamic Map (LDM); Rationale for and guidance on standardization | **L** |
| **Positioning, Navigation, & Timing (PNT) and Global Navigation Satellite System (GNSS)** | Hyberization of GNSS with other sensor data | **L** |

| Topic | Identified Gap | Priority (H / M / L / O) |
|---|---|---|
| **V2X Main Layers & Protocol** | Performance of V2P/V2H needs further work. The balance of low latency, high accuracy, and low power for battery performance is not satisfied by just reusing the V2V/V2I technologies. | **L** |
| **Construction Zone Applications** | Basic work zone elements | **O** |
| **Construction Zone Applications** | Baseline work zone information | **O** |
| **Gravel Road Application** | Resource sectors are of considerable importance to Canada and there are no use cases or application standards for gravel road application. Some of the paved road applications could be applicable to gravel roads; however, the driving conditions and traffic rules are significantly different due to undivided narrow roads. | **O** |
| **HDDM & LDM** | CEN/TS 17268 2018<br>Intelligent transport systems – ITS spatial data – Data exchange on changes in road attributes | **O** |
| **Public Safety Applications** | Common Incident Management Message Set seems out of date | **O** |
| **Sensor Edge Measurements** | The scope of SAE J3224 "V2X Sensor-sharing for cooperative and automated driving" was double-checked and it is not suitable for sharing the raw sensor data between entities (cars/roadside units/etc.); instead, sharing information about objects on the road is based on the existing or expanded J2735 data dictionary. There is sensor data, but what is "shared" over wireless is highly processed. There is a gap in the sharing of actual sensor data (raw or compressed) between entities. | **O** |
| **V2X Main Layers & Protocol** | Lack of certainty with respect to communication technologies and spectrum allocation, specifically as it relates to DSRC and C-V2X. | **O** |
| **V2X Main Layers & Protocol** | There is a wide variety of relevant standards that are continuing to evolve within the industry, and a wide variety of technology providers from OEMs through SMEs. As deployments and applications move from testing/pilots to more permanent interoperable solutions, there will be an increased need for device certification. | **O** |

## 3.2 Physical Infrastructure

| Topic | Identified Gap | Priority (H / M / L / O) |
|---|---|---|
| **Signs** | Retroreflectivity requirements to enable best results in detection and reading of road signs in all-weather conditions | **H** |
| **Signs** | Minimum technical requirements of sensors to reach road signs effectively | **H** |
| **Signs** | Road signs for "No Turn on Red" and speed limits (e.g., multiple speed limits on one sign for night/day/truck/minimum speed) | **H** |
| **Signs** | Road signs for speed zone ahead (R2-4(CA)) or ending of a certain speed limit (R3 (CA)) which are not covered by the MUTCD. These road signs, as well as many other unique road signs in various states, should also be included in the consideration by the committee for a development of uniformity recommendation. | **H** |
| **Signs** | Minimize/eliminate confusing speed limit signs on parallel routes | **H** |
| **Signs** | Standardize refresh rate of variable/changeable message signs to avoid flickering (improve AV ability for recognition) | **H** |
| **Signs** | Sign placement (distance from roadside, angle of the sign, etc.) and maintenance (foliage, damaged sign) | **H** |
| **Pavement Marking** | Use continuous markings for all work zone tapers | **H** |
| **Pavement Marking** | Standardize the colour of pavement markings on construction sites | **H** |
| **Pavement Marking** | Use high contrast markings on light-coloured pavements; contrast and reflectivity standards for pavement markings (including improving brightness and quality of dashed lines to match solid lines). Must ensure contrast ratio for night-time visibility of between 5-to-1 and 10-to-1 between pavement markings and surrounding substrate. | **H** |
| **Signs** | Speed limit requirements for statutory speeds (ON) and blanket speed zones (BC). This would ensure AVs would always have a point of reference for speed limits. | **M** |
| **Signs** | Standardize variable speed limit message sign – refresh rate, size, colour, font | **M** |
| **Signs** | OTM Book-5 should be updated to include required roadside signs where AVs are being assigned to pilot in | **M** |
| **Pavement Marking** | Standardize pavement markings width dependent on the speed of the roadway for increased visibility | **M** |
| **Pavement Marking** | Include chevron markings in gore areas (AB and BC already have best practices/ standards in place) | **M** |
| **Temporary Conditions** | Requirements for reporting temporary or moved traffic control signs (e.g. stop sign, temp traffic signal); or a new sign or message easily perceived by AVs to recognize such | **M** |
| **Signs** | Lighted signs for time-of-day-dependent lane directionality (e.g., a centre lane that changes travel directions based on morning/evening commute; some cities use green/red arrows, some use green/red circles in over-lane lighted signs) | **L** |
| **Signs** | For any R1-5 / R1-6 Yield Here to Pedestrian signage, ensure there is a stop line or yield demarcation accompanying it | **L** |
| **Pavement Marking** | Use dotted edge-line extensions along ramps | **L** |

## 3.3 Usage, Human-Machine Interface, Accessibility, and Vehicle Aspects

| Topic | Identified Gap | Priority (H / M / L / O) |
|---|---|---|
| **Driver/Occupant Internal Interface** | Amend the guidelines for Canadian roads regarding the connected vehicle user interface – NHSTA has developed HMI guidelines for light, medium, and heavy-duty vehicles | **H** |
| **Driver/Occupant Internal Interface** | Automated vehicle user interface – CACC/ platooning | **H** |
| **Driver/Occupant Internal Interface** | Automated vehicle occupant monitoring | **H** |
| **Driver/Occupant Internal Interface** | Automated vehicle user interface – driver monitoring and warning display | **H** |
| **HMI Design** | Connected vehicle user interface – standardized symbols amendment to ISO/DIS 2575 | **H** |
| **V2X/V2I Interface** | Road signage database – Canadian road context | **H** |
| **Driver/Occupant Internal Interface** | CV HMI – guidelines for Canadian roads – NHSTA developed guidelines need to be investigated and tailored to Canadian roads' needs | **H** |
| **Driver/Occupant Internal Interface** | AV HMI – CACC/ platooning – DOT have developed HMI for CACC/ truck platooning | **H** |
| **Driver/Occupant Internal Interface** | AV – occupant monitoring | **H** |
| **Driver/Occupant Internal Interface** | AV HMI – driver monitoring display | **H** |
| **Human-Machine Interface (HMI) Design** | Connected vehicle user interface – symbols – amendment to ISO/DIS 2575 | **H** |
| **Driver/Occupant Internal Interface** | Connected vehicle user interface – guidelines required for industrial unpaved roads, undivided roads, and half-lane roads with pull outs about every 500 m to 1 km. About 60% of the roads in Canada are un-paved roads used by industrial and recreational traffic. V2X applications on these roads differs from urban roads. The interface warnings required will be different but could be adopted from the current proposed design. | **M** |
| **Driver/Occupant Internal Interface** | Automated vehicle user interface – haptic control with embedded touch controls | **M** |
| **Driver/Occupant Internal Interface** | Automated vehicle user interface – touch screens with possible haptic feedback | **M** |
| **Driver/Occupant Internal Interface** | Automated vehicle user interface – in-vehicle voice interaction | **M** |
| **External Human Interface** | Automated vehicle and external communication interface – amendment to 23720 & 23735 Canadian context | **M** |
| **HMI Design** | Automated vehicle user interface – standardized symbols amendment to ISO/DIS 2575 | **M** |

| Topic | Identified Gap | Priority (H / M / L / O) |
|---|---|---|
| **V2X/V2I Interface** | Communication between Light Commercial Vehicle (LCV) and other road users | **M** |
| **V2X/V2I Interface** | Communication between LCV and other road users – need to investigate Canadian truck configurations: Part 1, turning curves; Part 2, lane change; Part 3, platooning | **M** |
| **Driver/Occupant Internal Interface** | CV HMI – industrial road applications. Use cases on industrial roads in Canada is different than on urban roads; therefore, HMI for industrial road use cases need to be standardized or guidelines need to be developed for implementation. | **M** |
| **Driver/Occupant Internal Interface** | AV HMI – haptic control | **H** |
| **Driver/Occupant Internal Interface** | AV HMI – touch screens | **M** |
| **Driver/Occupant Internal Interface** | AV HMI – voice-based interaction | **M** |
| **Driver/Occupant Internal Interface** | Automated vehicle user interface – augmented reality head-up display | **M** |
| **Driver/Occupant Internal Interface** | Automated vehicle user interface – gesture control interaction (identified in BSI CAV standards roadmap on page 17) | **L** |
| **Driver/Occupant Internal Interface** | Automated vehicle user interface – AI assistance | **L** |
| **Driver/Occupant Internal Interface** | AV HMI – augmented reality head-up display | **L** |
| **Driver/Occupant Internal Interface** | AV HMI – gesture-based interaction | **L** |
| **Driver/Occupant Internal Interface** | AV HMI – AI assistance | **L** |
| **Driver/Occupant Internal Interface** | AV HMI – Autopilot | **L** |
| **External Human Interface** | Automated vehicle and external communication interface – amendment to ISO/AWI TR23720 & ISO/AWI TR23735 Canadian context | **L** |
| **HMI Design** | Automated vehicle user interface – symbols – amendment to ISO/DIS 2575 | **L** |

### 3.4 Cybersecurity, Data Management, and Privacy

| Topic | Identified Gap | Priority (H / M / L / O) |
|---|---|---|
| **Cybersecurity** | Certificate policy for SCMS | **H** |
| **Cybersecurity** | ISO/SAE 21434 is a management system standard for auto OEMs. One could imagine a similar cybersecurity management system for ITS infrastructure owner/operators. That may look more like a profile of the general IT cybersecurity management system ISO 27001 with some concepts from 21434. (A more thorough gap analysis of 27001 for ITS IOOs would need to be performed.) | **H** |
| **Cybersecurity** | CAV training data standard | **H** |
| **Cybersecurity** | Security Engineering methodology tailored for road mode (we can learn from other modes, e.g., rail and ICS industry) | **M** |
| **Cybersecurity** | Similar standard for UAS, MASS, other emerging automated mobility modes as ISO/SAE 21434 | **M** |
| **Cybersecurity** | Security Assurance Level (SAL) or Security Integrity level (SIL) for ITS | **L** |

# 4 CAV Road Ahead – Next Steps

With a vast existing codes and standards landscape, plus many known gaps and priorities, the codes and standards groundwork for CAVs is currently being laid and ongoing development initiatives are underway. As technology evolves and industry learns from deployment experience, codes and standards will have to be upgraded and maintained to evolve with the technology and usage. To continue and support the deployment of CAVs, it is highly recommended that the gaps identified in the previous sections be verified and addressed as per the assigned priorities. The following next steps will provide opportunities to move the development of standards initiatives forward. Additionally, these steps will help shape future iterations of a codes and standards roadmap.

## 4.1 International Participation

CAVs and the related infrastructure will increasingly incorporate new features and components that improve the robustness of the system. The future of CAVs is bright and offers the long-term promise of mobility that improves safety and transport operations while lowering the negative impact on the environment. CAVs will provide a common interface that will improve the economy of scale to reduce cost and thus improve the integration of advanced functions in CAVs globally. Therefore, at this point, there is a need to see a more standardized and active CAV ecosystem. At the international level, different standards developing organizations exist with the intent to inform wider industry thinking and accelerate the successful introduction of exciting new technology.

International standards may be widely adopted at the regional or national level and referenced or used by manufacturers, trade organizations, purchasers, consumers, testing laboratories, regulators, and other interested parties. Since these standards generally reflect the best experience of industry, researchers, consumers, and regulators worldwide, and cover common needs in a variety of countries, standards constitute one of the important bases for the removal of technical barriers to trade.

Countries across North America, Europe, and Asia are actively preparing for CAVs. Activities range from the development of guidance documents and frameworks, to legislation and regulations, as well as encouragement of R&D and advancement of the industry to ensure safe testing and operation of CAVs across both the private and public sectors. With

respect to Canada, great advances have been made in advancing CAVs and leveraging the early work accomplished globally to mitigate potential risks.

CAV technologies are rapidly evolving and relevant standards are being, or have been, developed by a wide range of international, global, and national SDOs. Although there have been efforts to date in Canada and internationally, there is considerable work remaining to be done. While the efforts to plan for CAV deployments are often focused nationally, standards development activities are largely being conducted internationally.

Many international SDOs have active technical committees and working groups that are relevant to CAVs, either directly or indirectly, and help oversee the development and evolution of relevant standards and protocols. For example, ISO has three technical committees (TCs) relating to the standardization of road vehicles and their equipment (TC 22), the standardization of ITS (TC 204), and the standardization of geographic information (TC 211). TC 204 itself has 12 active working groups with their own focus areas.

Other relevant technical committees and working groups from international SDOs include:

- CEN Technical Committee 301 Road Vehicles and Technical Committee 278 Intelligent Transport Systems
- ISO Technical Committee 204 Intelligent Transport Systems and Technical Committee 22 Road Vehicles
- SAE International Technical Committees on Communications (V2X) and Technology (DSRC, C-V2X) and On-Road Automated Driving (ORAD)

Technical committees and working groups include international member participation. There is active coordination with other groups and activities, as well as partnerships and co-participation in development efforts. Using TC 204 as an example, there are currently 29 participating countries and 30 observing countries, as well as active liaisons with other SDOs and organizations (e.g., IEEE, SAE).

The harmonization of codes and standards is critical to ensure the consistent development and implementation of CAVs and related technologies. Harmonization supports common technical understanding and designs, as well as interoperability of systems across international borders. The trend of international standards development activities will continue for the CAV industry. This makes international participation critical to support harmonization.

Countries that do not participate in the development of standards will have to utilize standards that others have developed or develop their own national standards. Participation and engagement need to be coordinated by national stakeholders; such participation and engagement could be an invaluable means of testing new ideas and of assessing the needs of stakeholders, industry and technology trends, and strengths and vulnerabilities relative to competitors represented in the development process. Canada must continue to actively participate in international standardization activities.

## 4.2 Development and Adoption of Standards

While standards continue to be developed for CAVs, Section 3 of this roadmap demonstrates the significant number of standards gaps that need to be addressed, noting the 32 high priority, 24 medium priority, 17 low priority, and 8 other priorities identified. Technology is advancing very quickly and standards supporting this technology need to advance at the same pace to avoid confusion and to provide guidance. To assist in filling standards gaps, countries can work together to expedite the development process, adopt published standards, address the high-priority gaps first, and work simultaneously to develop urgently needed standards. Before developing national standards, interim solutions, such as technical specifications or guidelines, can be developed to address critical gaps. These interim solutions can be validated through use by industry stakeholders and help develop codes and standards.



Standards development, harmonization, and adoption of international codes and standards, especially within regions with shared borders such as in North America, will play a critical role in working towards the consistent development of the technology, improving opportunities for interoperability, and simplifying requirements across the automotive and technology sectors.

National standards apply to the country in which they are developed even though they may be adopted or referenced by another country. National standards may also be submitted to international SDOs for international consideration and approval. National SDOs as well as other approved bodies administer mirror committees which are responsible for developing national positions for a particular standard and which then present their positions and/or proposals to the relevant international committees (ISO, IEC, CEN, etc.) for consideration. The role of mirror committees is to form positions in their corresponding technical committees (TCs). If international standards do not exist or are not relevant, national TCs will review proposals for new standards and develop standards to address gaps. If TCs publish a new standard that they feel may benefit other countries, they will propose it to the mirror committee which then decides whether there is market demand; if there is market demand, the mirror committee will submit the standard to the appropriate international committee for review and acceptance. Canada needs to determine where to develop national TCs that will be necessary to develop and maintain new standards or to adopt international standards.

## 4.3 Integration of Standards

The previous sections demonstrate that there are numerous standards published, more standards in development, and gaps that need to be addressed. Although there have been standardization efforts in Canada and internationally to address aspects of infrastructure safety, there is a lack of relevant safety installation requirements for the CAV infrastructure.

As deployments become more widespread in various jurisdictions, CAV stakeholders will need a consistent set of requirements to promote public safety and industry growth. A Connected and Automated Vehicle Code (CAV Code) has been identified as an effective approach to establish installation requirements by adding the appropriate context for the relevant standards and how the standards need to be applied to promote a safe and interoperable CAV infrastructure. As with other mainstream utilities (i.e., electrical, gas, and plumbing), model codes have been developed by stakeholders and adopted by relevant authorities to promote the public safety, health, and general welfare of society. For CAVs, a code document can be used to integrate various requirements and provide the appropriate context for various stakeholders. It is critical to provide consistent installation requirements to the relevant authorities that have jurisdiction, which will complement Transport Canada's Safety Framework.

A CAV Code will be valuable to manufacturers, infrastructure owner/operators, and regulators who will be able to reference the document to further promote interoperability across Canada. Interoperability through

uniform installation requirements can be extended further by developing a binational code for use in Canada and the United States, as neither country has yet to develop infrastructure installation requirements.

For these reasons, a CAV Code that compiles applicable standards is needed to properly integrate the varying requirements that must be in place to implement safe and secure deployment. A common CAV Code applicable in Canada and the US, and developed in coordination with the US, could help address concerns with harmonization and interoperability within the North American market. As an industry that is continuing to rapidly evolve with standards being developed and updated in lock step, it will be important that frequent revisions be made to the CAV Code.

## 4.4 Stakeholder Engagement

Standards development requires engaged, active stakeholders. All of the above steps require stakeholder engagement, but there is a need for a specific action to conduct regular dialogue and engage stakeholders for broader coordination purposes. The codes and standards landscape is complex, and the technology is rapidly progressing.  Stakeholder engagement can help bridge the gap to provide standards solutions to align with technology and deployment readiness. Furthermore, stakeholder engagement will help address the activities proposed in this roadmap and update the roadmap as necessary to meet industry needs.

As noted above, national stakeholders need an understanding of international standardization activities. While national participation in international standardization is critical in and of itself, participation has even greater value if the outcomes and actions from the international participation are shared with the broader stakeholder community to increase understanding of these activities. Broad knowledge and participation related to international activities will increase the ability to harmonize requirements with international community, where deemed appropriate.

The gaps and priorities identified above suggest that increased standards development and adoption activities will need to commence soon. The technical committees assigned to these activities will be focused on the development or adoption of standards and the integration of these standards into a CAV Code. As development ramps up, the opportunity for these committees to strategically assess the codes and standards landscape and provide high-level planning will likely diminish. Other issues may surface with deployment that may not be within the scope of the relevant committees, and these may need to be discussed by relevant stakeholders in order to understand the role of codes and standards needed to address the issues. The deployment of CAVs raises several issues relevant to policymakers, manufacturers, and the public, such as privacy, insurance, urban planning, labour, and accessibility. There will also be ongoing questions about how testing and certification of various standards may be requested or required by CAV stakeholders. Technological developments, deployment challenges, and other emerging challenges will need to be shared with the codes and standards stakeholders in order to maintain the appropriate prioritization of standardization activities.

There remains a need for a committee to provide a more strategic, coordinated approach to continue to address the steps above and update the roadmap for codes and standards development. CAVAC has been established by CSA Group to serve in an advisory role and it can continue to play this role for the CAV industry. CAVAC can continue to be a forum for discussing international participation, harmonization, deployment challenges, new technology, and progress on codes and standards in development. An advisory body would address and maintain the roadmap to ensure standardization can play the appropriate role in the safe and efficient deployment of CAVs.

In addition to broad stakeholder engagement, there are also needs to be specific stakeholder engagement. Most notably, as CAV deployments increase, it will be progressively important to engage with the regulator stakeholders to understand the challenges faced and how codes and standards can help reduce deployment issues. While regulators do participate in CAVAC, additional opportunities to seek input should be undertaken to increase the amount of regulatory input. Stakeholder engagement will be a critical component to the support of codes and standards development within the CAV industry.

# 5 Conclusion

CAV technologies are anticipated to provide significant benefits relating to safety, accessibility, and efficiency, but work remains to standardize how CAVs will be safely integrated into the current transportation network, as the adoption and the prevalence of CAVs increase. Codes and standards will play a key role in the safe integration of CAVs into the transportation system. This roadmap has highlighted the many different standards development activities and efforts that are being led by several SDOs, which together address the many common and safety-critical use cases for CAVs. However, many gaps and priorities were identified through engagement of CAV industry stakeholders. Standards are important tools that can be combined with regulations, policies, and programs to support change and foster continued evolution of supporting technologies.

This roadmap is an initial step in the process of developing an understanding of the existing standards landscape and advance standardization initiatives to support CAVs and relevant infrastructure, communications, data management and privacy, cybersecurity, and vehicle technology. International SDOs have formed technical committees and working groups to address many of the emerging trends in transportation technology and to focus on reviewing and updating existing standards, identifying gaps, and developing new standards, where necessary. These efforts need to continue in order to further reflect developments in technology and to leverage the benefits of CAVs within the transportation sector. A focus on international cooperation and standards harmonization will promote the interoperability of CAV technology, focus on consistent safety regulations, and diminish trade barriers.

Canada should continue to play a key role in international activities and further consider how these international efforts align with national objectives and needs to further influence international standards development. In doing so, the adoption of an international standards process will be streamlined as Canada will have already contributed Canadian requirements. Where international gaps exist and no clear plans exist to fill these gaps, national standards need to be developed. Supporting authorities implementing and deploying a new technology requires a comprehensive and contextual document compiling requirement. This will require stakeholder coordination and must align with the United States. Active cooperation and alignment of efforts with US counterparts will increase interoperability and shared knowledge, which is critical considering the shared border that supports the automotive industry.

Transportation is a rapidly evolving industry, and although many efforts have been initiated to begin preparing for connected and automated technology, there is significant work ahead. It is important that the necessary codes and standards are in place to guide the industry, promote safety, and foster the innovation and growth of CAV technology. To get there, this roadmap provides four key next steps: international participation, development and adoption of standards, integration of standards, and stakeholder engagement. With these activities, codes and standards can help enable the safe deployment of CAVs.

## CSA Group

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