Ontario
MINISTRY OF
TRANSPORTATION

CAV READINESS PLAN

FINAL REPORT
MARCH 2020

DISCLAIMER

The CAV Readiness Plan was developed through collective input from a Steering Committee and a variety of public agency Stakeholders. Information was gathered through research, discussions and presentations. The report does not necessarily reflect the views or opinions of any single agency.

KEY TERMS

Automated Vehicles (AV) – Vehicles that rely only on their onboard equipment and sensors (LIDAR, radar, or camera) to sense its surrounding environment to traverse a transportation network without necessarily communicating with other vehicles or infrastructure; there are different levels of automation ranging from no automation (SAE level 0) to fully automated (SAE level 5) where the vehicle's onboard computers and sensors are responsible for the full driving task.

Bike-sharing – On-demand access to bicycles at various pick-up and drop-off locations for either one-way or round-trip travel. Bike-sharing fleets are usually deployed in a network within a region, city or neighbourhood.

Car-sharing – A service that provides members with access to vehicles by subscribing to a service that provides and maintains a fleet of vehicles or light duty trucks. These vehicles are typically located within neighbourhoods, near transit station, employment centres or university campuses. The users pay a fee for each use of the vehicle and the car-sharing operator provides insurance, gasoline, parking and maintenance.

Commercial Motor Vehicle (CMV) – A vehicle that is built on at least a 3-axle truck chassis that is used to transport goods or heavy freight from an origin to a destination.

Concept of Operations (ConOps) – A user-oriented document that describes system characteristics for a proposed system and how it can be employed to achieve desired objectives from the perspective of a user.

Connected Vehicles (CV) - Vehicles that have the capability to communicate and gather information from its surrounding environment to enhance mobility and safety. They contain onboard communication technology allowing them to communicate with other vehicles and connected infrastructure.

Connected and Automated Vehicles (CAV) – Vehicles that have the capability of both communicating with surrounding vehicles and infrastructure, as well as sensing its surrounding environment to automate the driving task and traverse the transportation network.

Conventional Vehicles – Vehicles that require a driver to be responsible for all driving tasks to safely operate the vehicle. These are the current vehicles on the road with no automation capabilities.

Cybersecurity – The protection of connected systems, such as networks, data, software and hardware from malicious online attacks, preventing sensitive information and data from being tampered with.

Data Management – The process of collecting, processing, validating, storing and protecting data while making it accessible and reliable for users.

First-mile/Last-mile – Term used to describe the movement of people and/or goods from a starting point to a transportation hub (e.g. transit station, freight distribution hub) and vice-versa.

Intelligent Transportation Systems (ITS) – A combination of leading-edge information and communication technologies applied to improve the safety, efficiency, and sustainability of transportation networks, to reduce traffic congestion and to enhance road user experience.

Microtransit – A technology-enabled transit service that is either privately or publicly operated and uses shuttles or vans to provide on-demand or fixed-schedule services with either dynamic or fixed routing.

Mobility Services – A shift away from personally owned modes of transportation and towards the integration of various forms of public and private transportation services (public transit, ride-hailing, car-

share, bike-share etc.) into a single platform that provides real-time information, simplifies trip planning and allows users to pay fares using a single account; also known as Mobility as a Service (MaaS).

Personas – Representative characters of the population with specific attributes, such as mobility patterns, accessibility needs, income etc., that can be used in planning initiatives.

Platooning – A series of vehicles (usually CMV) equipped with driving support systems, driven close together while communicating with each other through vehicle-to-vehicle wireless coupling technology.

Pick-up/Drop-off (PUDO) Area – Designated areas at transit stations, stops or building entrances for passengers to be dropped off and/or picked up by a vehicle, including transit vehicles.

Ride-hailing – The action of ordering a vehicle through a Transportation Network Company or digital application for purposes of receiving transportation services.

Ride-sharing – The action of sharing a vehicle ordered through a Transportation Network Company with another known or unknown person, while sharing the cost of operating the vehicle (similar to car-pooling).

Scenario Planning – A planning process whereby exploratory scenarios are developed and used to understand the implications of emerging trends and assist in planning for various possible future conditions.

Shuttles – Shared vehicles (typically vans or buses) that connect passengers to/from a common origin or destination to the nearest public transit stop/station, retail center, or employment center.

Transportation Network Company (TNC) – Transportation services/companies that use online platforms to match passengers with drivers (or vehicles) to complete a trip. These services could be private (not shared) or shared with multiple unknown passengers in the same vehicle and sharing the cost of operating the vehicle; also known as ride-hailing or ride-sharing services.

Vehicle-to-Everything (V2X) – Connectivity between a vehicle and multiple elements in its surrounding environment, including other vehicles, infrastructure, pedestrians, cyclists, traffic operations centre etc.

Vehicle-to-Infrastructure (V2I) – Vehicles communicating with surrounding infrastructure, such as traffic signal controllers and traffic monitoring units, gathering information on safety, mobility, or environmental conditions.

Vehicle-to-Vehicle (V2V) – Vehicles communicating with other vehicles on the road to share information on traffic conditions, speed, safety considerations, etc.

Vehicle Occupancy – Number of individuals in a vehicle, including the driver/operator categorized as zero-to-single occupancy, low occupancy or high-occupancy.

Vulnerable Road User (VRU) – A pedestrian, cyclist or user of a personal mobility device who is using the roadway.

TABLE OF CONTENTS

TABLE OF CONTENTS

EXECUTIVE SUMMARY

What does the public sector need to do to prepare for a future with connected and automated vehicles? How is the Greater Toronto and Hamilton Area and the area served by Metrolinx consistently preparing for this future? How will people and goods move in this new paradigm? These questions led to the genesis of a project that resulted in the creation of this CAV Readiness Plan.

The arrival of Connected and Automated Vehicles (CAV) is no longer a question. As technology advances, increasing levels of connectivity and automation are becoming more of a reality on public roads. CAV can communicate with other vehicles, surrounding infrastructure and road users, while also using on-board computers and sensors to automate driving tasks and navigate roads. These vehicles have the ability to improve transportation safety, efficiency and sustainability – but these opportunities will also come with challenges.

Planning and coordination are key components to manage the challenges of an evolving transportation system. Timing for widespread public adoption is unclear, but what is clear is that CAV will fundamentally change the movement of people and goods. This CAV Readiness Plan describes how transportation and transit agencies can begin to address this paradigm shift in transportation and focus on preparing for a future towards CAV Readiness.

Steering Committee and Stakeholders

The CAV Readiness Plan for the Greater Toronto and Hamilton Area and area serviced by Metrolinx (GTHA) was prepared by a Project Team working closely with a Steering Committee and Stakeholder group representing the geography's interest and provides a way forward for public agencies. The Steering Committee, comprised of the Ministry of Transportation, City of Toronto, Metrolinx, the Region of Peel and WSP, recognized that the federal program to Advance Connectivity and Automation in the Transportation System (ACATS) represented an opportunity to develop a regional approach to planning for CAV and to build capacity in the area. The Steering Committee met to discuss the scope, provided financial and in-kind contributions and successfully requested partial funding. Over seventy (70) regional Stakeholders, consisting of public agencies, academic institutions, and industry organizations, were engaged through four full day workshops, surveys and document review and provided input and key insight on their transportation needs.

Capacity Building

Background information on CAV technology and emerging transportation trends, including shared mobility services and connected and automated freight applications, was prepared and provided as a primer to the Stakeholder team. Presentations and information sharing were integral parts of the workshops. Stakeholder engagement workshops and surveys gathered key information and insight on the local and regional transportation needs and goals. As timing for CAV saturation is unclear, a Scenario Planning process led to the development of five (5) alternative future scenarios for CAV entering transportation networks, and eight (8) persona profiles which represented different types of CAV users. These scenarios and personas were used to test the robustness of the guidelines. Guidelines were developed for the current environment of 'Few CAVs (pilots, platooning on key highways)' and future saturations defined as 'Mixed' and 'Primarily CAVs'.

CAV Readiness Guidelines

For the past decade and longer, the public sector has been trying to understand what their role will be in a future with CAVs. The CAV Readiness Guidelines provide general principles and tasks to be undertaken by public transportation agencies to prepare for a CAV future. The CAV Readiness Guidelines are divided into five (5) focus areas and shown in **Figure 1**.
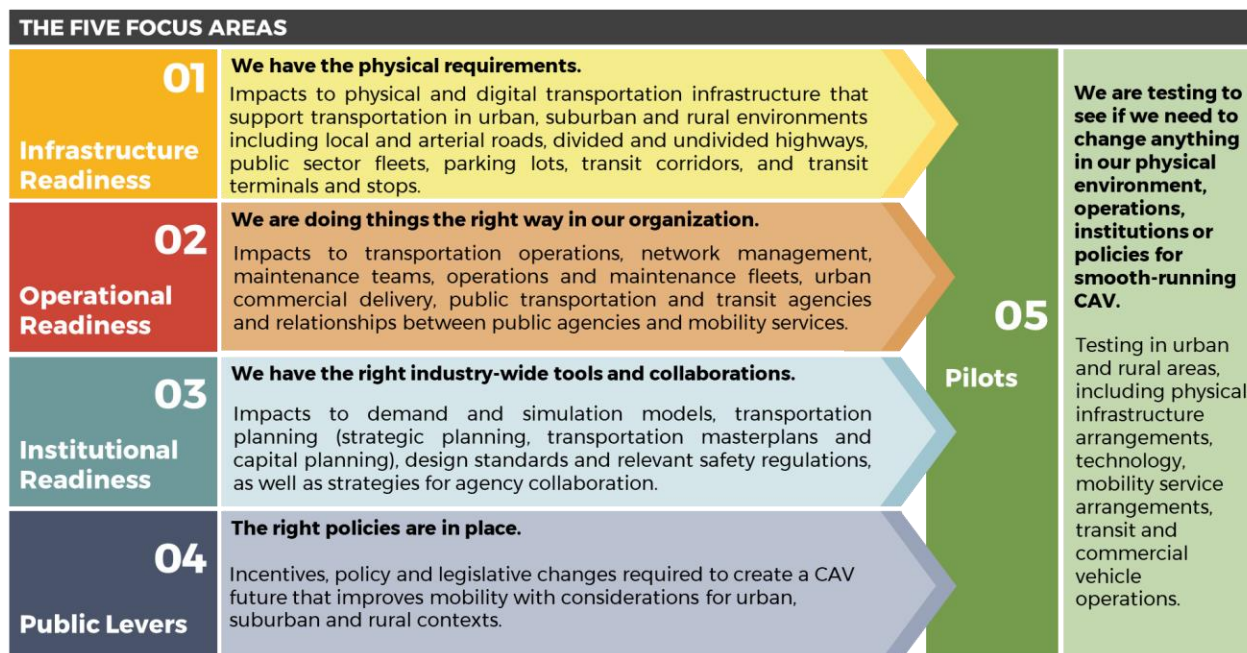
THE FIVE FOCUS AREAS

01 Infrastructure Readiness
We have the physical requirements.
Impacts to physical and digital transportation infrastructure that support transportation in urban, suburban and rural environments including local and arterial roads, divided and undivided highways, public sector fleets, parking lots, transit corridors, and transit terminals and stops.

02 Operational Readiness
We are doing things the right way in our organization.
Impacts to transportation operations, network management, maintenance teams, operations and maintenance fleets, urban commercial delivery, public transportation and transit agencies and relationships between public agencies and mobility services.

03 Institutional Readiness
We have the right industry-wide tools and collaborations.
Impacts to demand and simulation models, transportation planning (strategic planning, transportation masterplans and capital planning), design standards and relevant safety regulations, as well as strategies for agency collaboration.

04 Public Levers
The right policies are in place.
Incentives, policy and legislative changes required to create a CAV future that improves mobility with considerations for urban, suburban and rural contexts.

05 Pilots
We are testing to see if we need to change anything in our physical environment, operations, institutions or policies for smooth-running CAV.

Testing in urban and rural areas, including physical infrastructure arrangements, technology, mobility service arrangements, transit and commercial vehicle operations.

Figure 1: Five Focus areas of the CAV Readiness Guidelines

CAV Programs

The Steering Committee and Stakeholders identified five program areas based on priority and need. The programs were defined and mapped against the applicable guidelines. The five CAV Programs are defined as follows:

1. **CAV Development Streams** – Establishes a number of Task Forces to continue to identify impacts that CAVs will introduce to the transportation network and its users. As not all of the guidelines were addressed in the five program areas, this program area will delve deeper into specific focus areas and through that process eventually address all of the guidelines, for example assess how accessibility needs can be met through CAV.

2. **Development of CAV Modelling Tools -** Develops a System Dynamics Model and identifies necessary demand and simulation model updates to existing long-term transportation planning and operational analysis tools to address CAV in the transportation network. This also includes updates to transportation planning documents to reflect impact of CAVs in the 2031, 2041 and beyond planning horizons.

3. **Pilot Projects Program Management** - Manages pilot projects that will gather data, assess and evaluate CAV and connected infrastructure, identify operational needs, test different designs and strategies, and identify needs for legislation, regulations and policies. By having a coordinated approach to planning and managing pilot projects, information can be shared, and joint pilots developed reducing agency cost and time.

4. **Data Needs and Management Plan** – Defines needs for data standards, data dictionary, message sets, repository and creates a Data Management Plan. Also defines key player roles and responsibilities, a data sharing model, data retention policies, digital infrastructure and security/privacy needs.

5. **Development of a Regional Mobility Platform Strategy -** Develops a strategy that explores fare integration, trip planning applications, public and private mobility service provider partnerships, mobility platform development regulations and the need for a region-wide approach to offering shared mobility services. Policy, data needs, deployment approach, partnership approach and implementation strategy will be prepared.

CAV Liaison Committee

There was agreement that ongoing collaboration and networking is required to implement the programs. An organizational framework was defined for a CAV Liaison Committee with a goal to facilitate discussion and collaboration between public agencies to support CAV technology preparations, implementation and education. The Committee will oversee the establishment of working groups and help bring together interested parties, including Stakeholders from the private sector, national organizations and representatives from academic or research institutes, to implement the CAV Readiness Guidelines and Programs.

Next Steps

The first step for public transportation agencies in the GTHA is to formally establish the CAV Liaison Committee to oversee the implementation of the CAV Readiness, as well as explore funding opportunities and mechanisms for conducting pilot programs and delivering projects. Other agencies across Canada can also use the CAV Readiness Plan as a guide to move forward with CAV preparations for CAV on their public roads.

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1 INTRODUCTION

With advancement in technology expected in the coming years, transportation is set to rapidly change and evolve. Connected and Automated Vehicles (CAV) have the opportunity to introduce many benefits, including improved safety, increased traffic capacity of roadways, improved fuel efficiency, improved traffic flow, reduction in congestion and, ultimately, an overall reduction in Greenhouse Gas (GHG) emissions.[1, 2] Regional governments and transportation agencies will play a significant role in taking steps to help facilitate the integration of CAV with transportation networks. Providing public-sector agencies with the necessary tools to plan for this disruption will play an important role in facilitating the smooth integration of CAV with transportation systems.

The Ontario government has already taken steps to develop a welcoming environment for CAV technology. Ontario Regulation 306/15: Pilot Project – Automated Vehicles,[3] establishes a framework for a 10-year pilot period of on-road testing of automated vehicles for registered participants. In 2019, the legislation was expanded to allow for the testing of cooperative truck platooning and to allow the public to use vehicles manufactured as Society of Automotive Engineers (SAE) Level 3 (conditional automation) without registering as a pilot participant.[4] This paves the way for CAV to legally drive in Ontario, contributing to the effective implementation of strategies and recommendations outlined in the CAV Readiness Plan.

The CAV Readiness Plan for the Greater Toronto Hamilton Area and area serviced by Metrolinx (referred to as the GTHA, for simplicity) describes how transportation and transit agencies can begin to address this paradigm shift in transportation and focus on preparing for a future towards CAV Readiness. The guidelines are transferrable to other agencies across Canada as they prepare for a CAV future.

1.1 BACKGROUND

The CAV Readiness Plan addresses emerging trends in transportation that are introduced by CAV, including shared mobility services (e.g. ride-hailing, car-sharing and microtransit). By understanding these trends, public agencies can prepare for the shift in how people and goods will be transported. **Appendix A** provides more details on the background of CAV including what they are, when they will arrive and what they mean for transit, freight and personal transportation.

CAV are the unification of two distinct but related streams of technology – connectivity and automation. These vehicles have the capability to be connected to a network and exchange information with each other (vehicle-to-vehicle or V2V), as well as with surrounding road infrastructure (vehicle-to-infrastructure or V2I), traffic network operators and road users. In addition, connectivity to a number of other possibilities such as centralized systems and vulnerable road users exists (V2X). CAV also have the capability to rely on sensors and cameras to automate the driving task with varying levels of automation ranging from SAE Level 0 (no automation) to Level 5 (full unrestricted automated driving).[5]

> The term CAV is used in this Plan, as vehicles will be both connected and automated.
>
> In this Plan, CAV are highly to fully automated (SAE Levels 4 to 5).

Some examples of data that can be exchanged between V2V, V2I and V2X are shown in **Figure 2.**
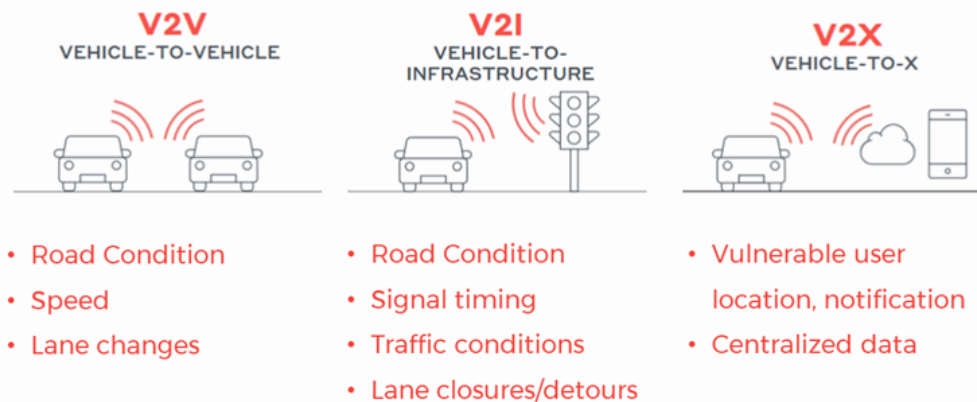
Figure 2: Examples of V2V, V2I and V2X connectivity

Mobility services involve the aggregation of travel modes, information, fare payment, and a service concept (e.g. subscription). These services range from transit, taxi, ride-hailing, car-share and bike-share services.[6] Integrating first-mile/last-mile transportation services with transit, through a mobility platform, could improve trip planning for users, increase travel efficiency, and potentially improve station access while reducing the need for parking and the amount of traffic demand at passenger pick-up/drop-off areas.

Electrification is another disruptor in the transportation space. This was not specifically included within the scope of this project, but there is a general understanding that many CAVs that are highly or fully automated are also likely to be electrical.

1.1.1 ABOUT THE CAV READINESS PLAN

The CAV Readiness Plan for the Greater Toronto and Hamilton Area and area serviced by Metrolinx (GTHA) was prepared by a Steering Committee and Stakeholder group representing the geography's interest and provides a way forward for public agencies. The Steering Committee (**Figure 3**), comprised of the Ministry of Transportation, City of Toronto, Metrolinx, the Region of Peel and WSP, recognized that the federal program to Advance Connectivity and Automation in the Transportation System (ACATS) represented an opportunity to develop a regional approach to planning for CAVs and to build capacity in the area. The Steering Committee met to discuss the scope, provided financial and in-kind contributions and successfully requested partial funding. Throughout the project, committee members met bi-weekly to discuss the progress of the project, review the development of key components of this CAV Readiness Plan and prepare for the workshops.
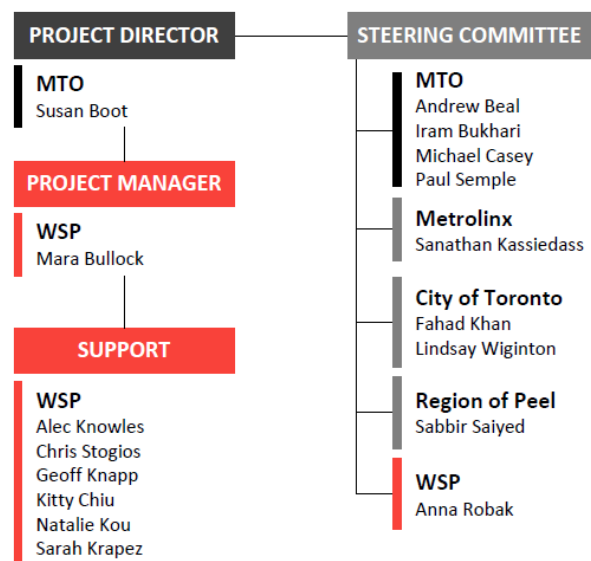
Figure 3: Project team and Steering Committee

Over seventy (70) regional Stakeholders, consisting of public agencies, academic institutions, and industry organizations, were engaged through four full day workshops, surveys and document review and provided input and key insight on their transportation needs.

The development of the CAV Readiness Plan commenced in late August 2018 and followed the project schedule shown in **Figure 4**.

The CAV Readiness Plan **integrates a number of components including potential future CAV scenarios, persona profiles, CAV Readiness Guidelines, CAV Programs, and a governance framework for a regional CAV Liaison Committee.** It provides context for public transportation agencies to begin preparing for CAV on roads; however, there are still outstanding questions that will need to be answered. There may be new considerations that become more relevant in later time-frames with increased CAV presence, as well as considerations that may become less relevant over time. Further discussions will also be needed to identify funding sources for the development and maintenance of transportation infrastructure and technology.
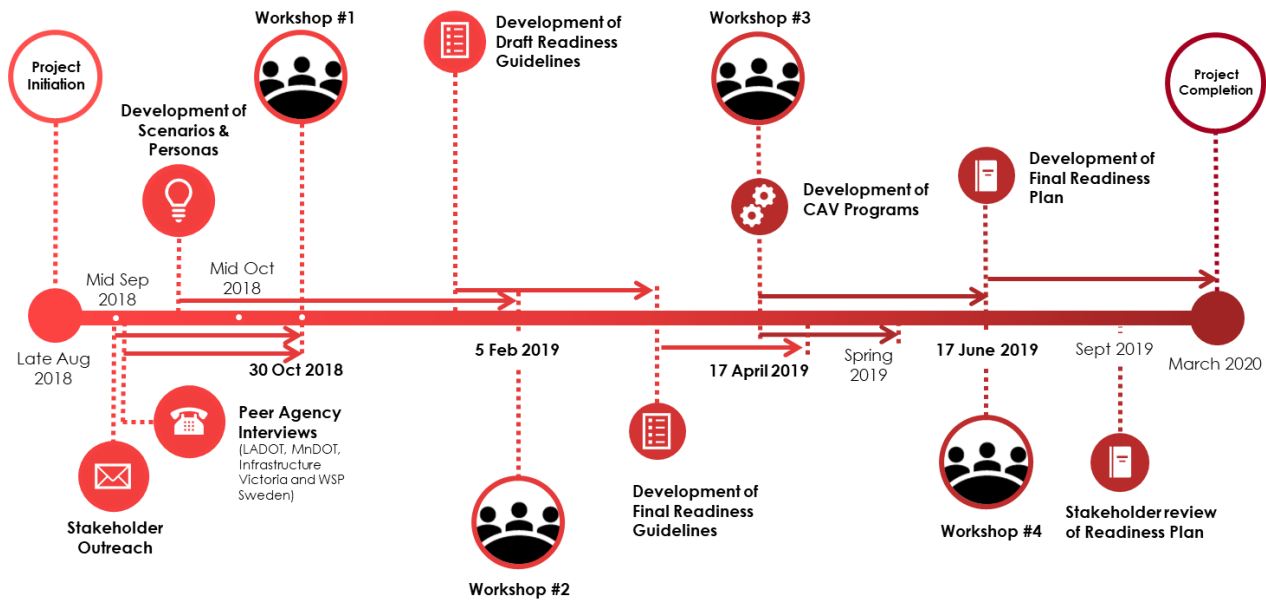
Figure 4: Schedule of the CAV Readiness Plan

1.1.2 EXISTING CAV WORK

A number of initiatives have been undertaken by public agencies to begin preparing for CAV and emerging transportation technologies and integrating them with transportation networks. Many of these initiatives are summarized below.

> *Ministry of Transportation Ontario (MTO):*
> - *Ontario Regulation 306/15* – Automated Vehicles established a pilot framework for on-road testing of AV under controlled conditions.
> - Cooperative truck platooning pilot program on a dedicated network of highways in Ontario to allow for the testing of truck platooning technology.
> - Internal planning initiative on how CAV technology can achieve transportation goals in infrastructure, operations, policy and regulatory frameworks.
> - Pilot project testing communication and data collection of roadside units (RSU) on Highway 401.
> - Greater Golden Horseshoe (GGH) Transportation Plan 2051/2071 considers the impacts, risks and opportunities of CAV on transportation.
> - Highway Infrastructure Innovation Funding Program research, with the University of Toronto, on the impacts of AV systems on transportation demand in GGH and modelling their operation on highways.
> - Council of Ministers report advisor on national policies and guidelines including *The Future of Automated Vehicles in Canada* and *Automated and Connected Vehicle Policy Framework for Canada.*

City of Toronto:

- Automated Vehicle Tactical Plan 2019-2021 developed by the AV Working Group to provide direction to City divisions in preparing for automated vehicles through policies, plans and strategies.
- Minding the Gap Automated Transit Shuttle pilot project testing automated shuttle technology on a new transit route in Toronto, in partnership with TTC and Metrolinx and funded by the ACATS program.

Metrolinx:

- CAV Priority Actions Internal Report (draft) with action items to prepare internal operations for emerging transportation technology.
- Pilot with 407ETR of a CAV application for sharing ramp traffic signal information to Metrolinx buses at Keele and Jane street interchanges.

Region of Peel:

- Goods Movement Strategic Plan (2017-2021) with an action item on implementing a Commercial CAV pilot program.

Transport Canada

- Program to Advance Connectivity and Automation in the Transportation System (ACATS) to provide funding for Canadian jurisdictions to prepare for the technical, regulatory, and policy issues emerging with CAV technologies.
- Published guidance documents on *Testing Highly Automated Vehicles (HAV) in Canada – Guidance for Trial Organizations*, as well as *Canada's Safety Framework for Automated and Connected Vehicles.*
- Testing Cooperative Truck Platooning and V2V communication systems at their testing facility in Blainville, Québec to identify the fuel consumption savings and improvement of road safety.
- Funding the development of a Canadian Security Credential Management System (SCMS) for connected vehicles to ensure the security and trust of connected vehicle communications.

407ETR

- Testing high contrast, high visible pavement marking tape to improve visibility for automated vehicle systems in both wet and dry weather conditions.

Ontario Centres of Excellence (OCE):

- Autonomous Vehicle Innovation Network (AVIN) established to support industry-led research & development projects on cybersecurity, automated driving, connectivity and vehicle testing, through Regional Technology Development Sites (RTDS).
- Annual Ontario CAV Ecosystem Analysis and inventory of funding opportunities in Ontario.[7]

City of Hamilton:

- Dedicated public roads as a CAV test track to test connected and automated vehicle technologies under real road conditions in partnership with AVIN, Innovation Factory, McMaster University and Mohawk College.

Durham Region:

- Durham Region Transit partnered with Pacific Western Transportation to develop a one-year automated shuttle pilot program to determine needs for safe operation of driverless buses.

York Region:

- New mobility concepts (e.g. CAV, shared mobility, ride-hailing etc.) included in 2016 Transportation Masterplan update.

Toronto Region Board of Trade:

- AV Readiness Council that helps companies in the GTHA and creates a marketing tool for the regional industry to attract investors to work in the CAV space.

Municipal Alliance for Connected and Autonomous Vehicles in Ontario (MACAVO):

- Portal for municipalities in the Windsor-Ottawa corridor to identify preferred roads for testing of CAV technology.

Canadian Standards Association (CSA):

- CAV Advisory Council (CAVAC) of public and private sector organizations exploring policy and standard requirements for infrastructure, communication, data management and cybersecurity.

Canadian Urban Transit Research & Innovation Consortium (CUTRIC)

- National Smart Vehicle Demonstration and Integration Trial to integrate interoperable electrified CAV shuttles as first-mile/last-mile applications and standardize CAV technologies for transit vehicle fleet manufacturers.

ITS Canada:

- CAV Technical Committee comprised of ITS Canada members from public, private and academic institutions that monitors, shares and organizes information related to CAV, Smart Cities and ITS technology.

2 PLANNING PROCESS

Research, Scenario Planning and Stakeholder engagement were key elements in the development of the CAV Readiness Plan. The information gathered and subsequent analysis contributed the CAV Readiness Guidelines and Programs addressing the needs of transportation in the GTHA. **Figure 5** depicts the 6 steps that were followed. More details on the project approach can be found in **Appendix B.**
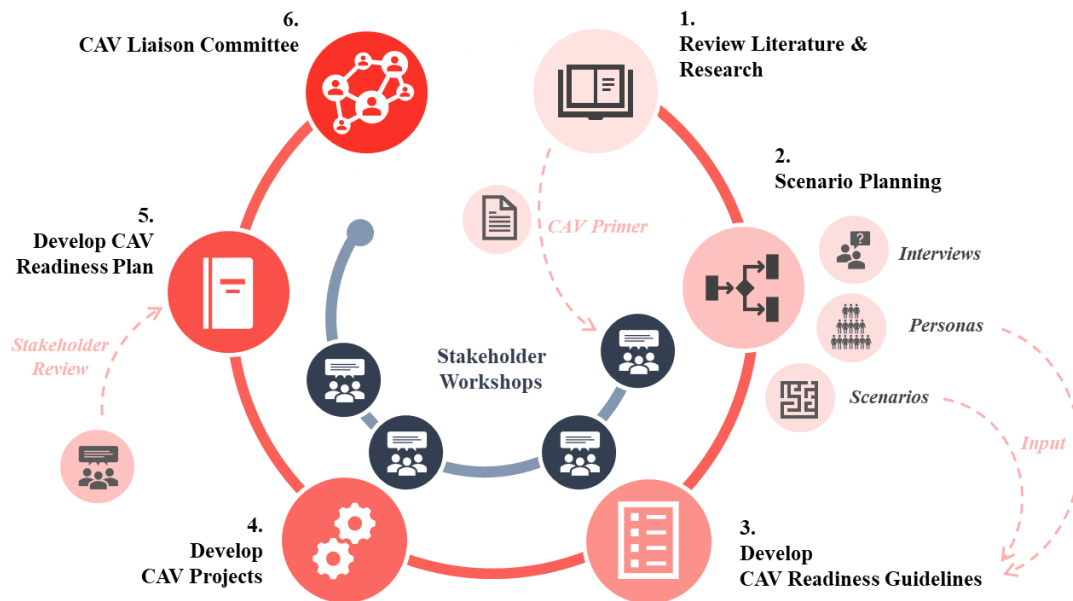

Figure 5: CAV Readiness Plan Approach

1. **Review Literature & Research** – Scanned existing academic and industry literature and research to document the current state of the technology, the anticipated direction it is moving in, as well as steps that have been taken to begin testing and preparing for the integration of CAV onto transportation networks around the world. A CAV Primer (**Appendix A**) was prepared for Workshop 1.

2. **Apply Scenario Planning** – Developed alternative future scenarios for CAV deployment, as well as personas that represented different types of CAV users. These were presented to Stakeholders in Workshop 1 and further refined based on feedback.

3. **Develop CAV Readiness Guidelines** – Developed action items that need to be addressed to support CAV project planning for public agencies and to prepare for a future with CAV. Guidelines were developed for the current environment of 'Few CAV (Pilots, Platooning on key Highways)' and future saturations defined as 'Mixed' and 'Primarily CAV'.

4. **Develop CAV Programs** – Developed five program areas (cross referenced to guidelines) that are primary focus for next steps.

5. **Develop CAV Readiness Plan** – Summarized key information from the research, scenarios, personas, Readiness Guidelines, CAV Programs and a framework for the CAV Liaison Committee into a plan.

6. **Establish CAV Liaison Committee** – This task is outside the scope of this project and includes establishing a committee consisting of Stakeholder representatives across the GTHA with the objective to oversee and coordinate the implementation of the CAV Readiness Plan and Programs, while fostering collaboration.

2.1 STAKEHOLDER ENGAGEMENT AND OUTREACH

A Stakeholder group was established consisting of over 70 representatives from municipal and regional transportation and transit agencies across the GTHA, as well as university researchers and industry transportation organizations, such as the Transportation Association of Canada (TAC) and Intelligent Transportation Systems (ITS) Canada. The Stakeholders actively participated in four (4) workshops (**Figure 6**) , collectively providing over 1000 hours of input, through interactive breakout sessions, online surveys, online interactive tools (e.g. Mentimeter) and document review.

More details on the role of the Stakeholders, the workshops and survey results can also be found in **Appendix B.**

> **Key Stakeholder Feedback**
> Both public agencies and private companies will need to collaborate to integrate CAV on the transportation network.

> **Key Stakeholder Feedback**
> Preparation for CAV needs to commence *now* with pilots and continue to evolve as the technology increases its presence.

Workshop #1
Reviewed proposed CAV scenarios and personas.
Identified final list of personas.

Workshop #2
Presented final scenarios and personas.
Reviewed draft CAV Readiness Guidelines.

Workshop #3
Brainstormed and prioritized CAV Programs.
Reviewed Guidelines with respect to Programs.

Workshop #4
Reviewed draft Program sheets
Brainstormed CAV Liaison Committee objectives.

Figure 6: Descriptions of the four Stakeholder workshops

2.2 SCENARIO PLANNING

As timing for CAV saturation is unclear, a Scenario Planning process led to the development of five (5) alternative future scenarios for CAV entering transportation networks, and eight (8) persona profiles which represented different types of CAV users. A best practice review with international agencies, was conducted to gather insights on CAV related Scenario Planning efforts. The results and lessons learned from this review are detailed in **Appendix C.**

2.2.1 SCENARIOS FOR THE GTHA

Five (5) scenarios were developed to represent possible CAV futures and to test the extremes. Vehicle occupancy was used as a metric in defining the scenarios and was agnostic as to who was providing the service in order to integrate personal vehicles, transit vehicles and shared mobility categories. Deliveries per Capita metrics for inter-city and intra-city deliveries were used to represent commercial vehicles. The base case represented current occupancy and inter-city and intra-city numbers.

- **Base Scenario** - Vehicle occupancy, travel patterns and goods movement characteristics remain similar to present day conditions with CAV technology progressing steadily over time.

- **High Average Occupancy** - Pricing policies have encouraged higher occupancy trips, with shared mobility services growing as a transportation mode.

- **Low Average Occupancy** - Pricing policies have been ineffective in encouraging higher occupancy trips, leading to increased low- and zero-occupancy trips.

- **High Goods Movement/Delivery** - Economic and consumer trends lead to a higher per capita demand on goods movement, resulting in an increase in inter-city deliveries and a substantial increase in intra-city deliveries.

- **Low Goods Movement/Delivery** - Environmental policies increase the cost of goods movement, and the increased use of rail reduces demand for inter-city truck freight; regulations, small delivery centres and alternative delivery modes significantly reduce per-capita demand for intra-city truck deliveries.

The scenarios were broken down into three CAV saturation categories (**Figure 7**) where the Few CAV represents the current state as a result of current legislation in Ontario.

This approach captures the short-term, medium-term and long-term phases of each scenario with respect to the proportion of CAV on roads and emphasizes the need to begin planning for CAV in the early stages of adoption. The various vehicle occupancy and goods movement scenarios were identified independently of each other to allow for the consideration and testing of each scenario separately and identify the boundary conditions of which any combination would also be considered. The scenario characteristics are summarized below in **Figure 8**. More details on the scenario characteristics are provided in **Appendix D.**
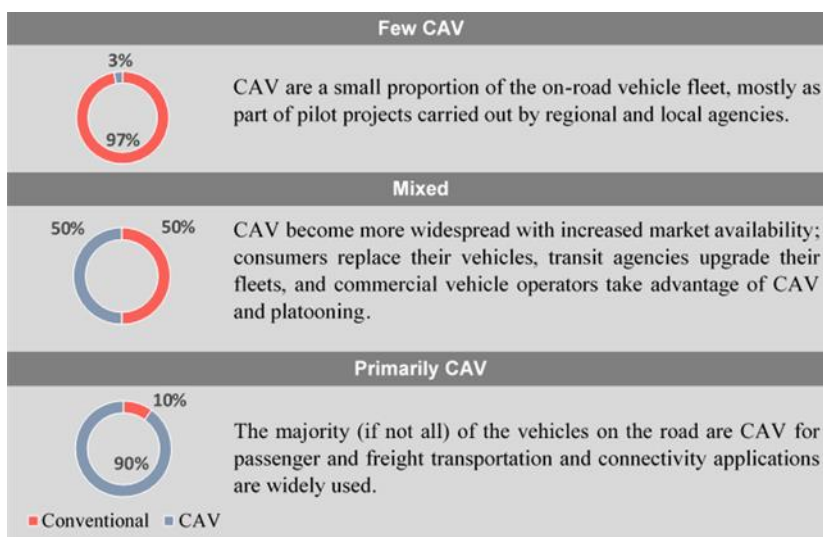

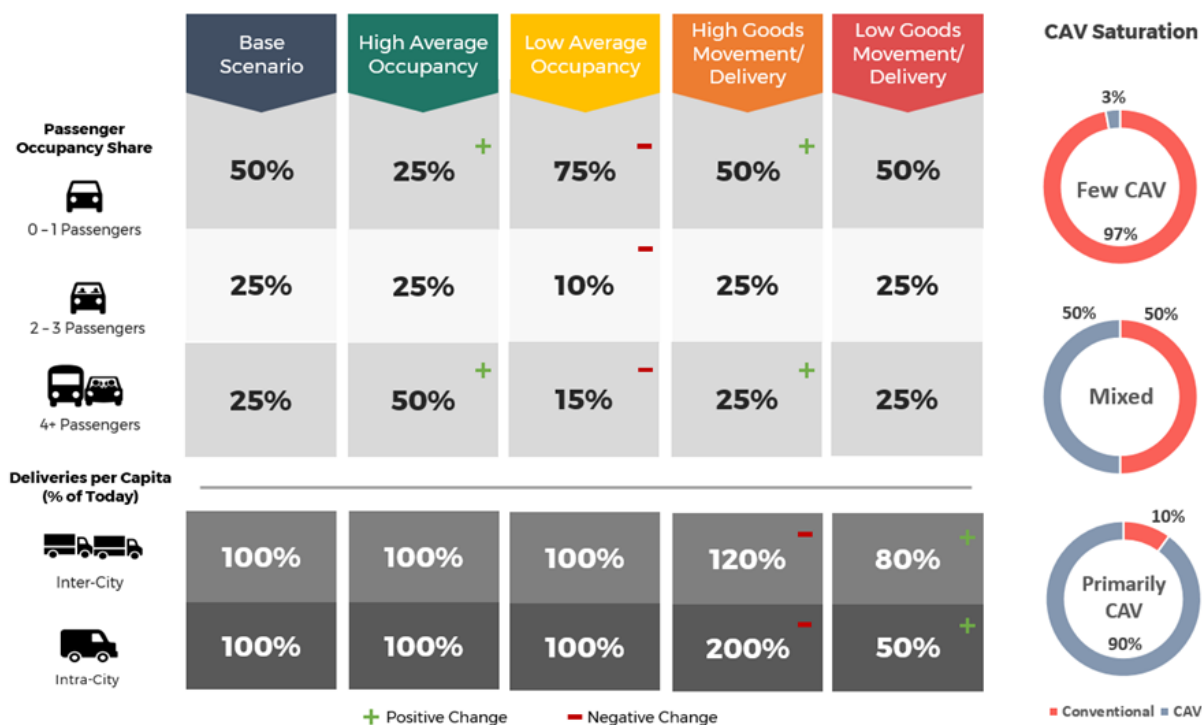**Figure 7: Three CAV saturation categories for the scenarios**

Figure 8: Scenario Characteristics

2.2.2 PERSONAS FOR THE GTHA

Eight (8) personas were developed to test how different types of users would interact with CAV. They represent urban, suburban and rural residents, as well as key age and income groups of interest, where there is an expectation that these characteristics will impact travel behaviour and likelihood to own or rent a CAV (e.g. openness to technology). These personas were used to check the completeness of the guidelines when the needs of these personas were considered. Of all of the personas, the Child generated the biggest gaps in thinking, especially as it related to personal safety. A brief description of each persona is provided below, with more details on the persona characteristics provided in **Appendix D.**

THE CHILD

The Child is under 12-years-old and lives in a rural area with their parents. The parents are employed full-time and the household is classified as middle-income. The parents do not allow the Child to use shared mobility with strangers and therefore, mode choice is limited. The school bus is their daily mode of transport to go to & from school. The Child is healthy and active, and regularly attends after-school activities in the neighbourhood. The Child embraces and is excited to try out new technologies.

The Child is unable to drive and has limited access to financial institutions.

THE COMMUTER

The Commuter lives in the suburbs on their own, is single and graduated from university a few years ago. The Commuter works in an urban area and commutes to work during peak hours. They have a low-income and are focused on repaying student loans. The Commuter is active and goes out with friends in the urban core on weekends. They are interested in technology and are open to using shared mobility.

The Commuter has a driver's license but doesn't own a car and has access to financial institutions.

THE TRANSIT USER

The Transit User lives on their own in the urban core and is highly educated and career-driven. The Transit User is a well-regarded professional in the industry with a high income. Transit is their daily mode choice to commute to and from work within the urban core during peak hours. The Transit User is active and travels within the urban core where transit is available. They like using new technologies and shared mobility.

The Transit User rarely drives, and has access to financial institutions.

THE SHIFT WORKER

The Shift Worker is a single parent and lives in the suburbs with three children. The Shift Worker has multiple jobs in a nearby urban area to support the family. With various working hours, the Shift Worker usually travels during off-peak hours. Mode choice is flexible as long as the affordability and travel time are acceptable. The Shift Worker loves spending time with their three children at home. They are open to new technologies and do not have a strong opinion on shared mobility.

The Shift Worker knows how to drive and has access to financial institutions.

THE STAY AT HOME PARENT

The Stay at Home Parent lives in the urban area with their partner and five-year-old son. The Parent started working after high-school and recently quit their job to become a stay-at-home parent. They drives their children to and from school every day. The Parent stays at home most of the time and enjoys spending time with the family. They are fairly open to new technologies and shared mobility as long as they are secure and safe.

The Stay at Home Parent has a driver's license and access to financial institutions.

THE DELIVERY TRUCK DRIVER

The Delivery Truck Driver lives in the suburbs with their partner. Their household has a middle-class income. They drive between urban and rural locations daily during peak hours. Staying at home and reading is their favourite activity during free time. The Driver has difficulty hearing and requires hearing aids. They are reluctant to try new technologies.

The Delivery Truck Driver has access to financial institutions.

THE ASSISTIVE DEVICE USER

The Assistive Device User lives in the suburbs with their family. They immigrated from a foreign country and have a language barrier. The household has low-income with more than 5 people. They like staying at home and spending time with their family. Travelling is required occasionally for appointments with limited mode choice options due to wheelchair restrictions. They are typically driven by their family or personal support worker, and occasionally uses specialized transit services. The Assistive Deviuce User has little interest in technology and does not feel comfortable with shared mobility.

The Assisstive Device User is not able to drive and has access to financial institutions.

THE RETIREE

The Retiree lives in an urban area with their partner and dog. As someone who is well-educated and has recently retired, health, quality of life and environment are their major priorities. Their favourite activity is to go for morning and evening walks and listen to the radio at home. The Retiree doesn't travel often, but when they need to, they travel during the off-peak period. They are flexible with transportation modes as long as it's safe and convenient. The Retiree is curious about new things and is open to try new technologies. However, the Retiree is not comfortable with sharing vehicles with strangers.

The Retiree has weak eyesight and no longer drives. They have access to financial institutions.

3 READINESS GUIDELINES

Twenty (20) Readiness Guideline categories, grouped into five Readiness types, were developed to reflect the work to be completed for the public sector to prepare for a CAV future. While developed with input from Stakeholders, these Guidelines are transferable to other agencies in Canada. They include considerations that local and provincial government agencies could reference in upcoming planning and project initiatives, even if coordination is required with national level agencies. They were developed in the context of urban, suburban and rural environments for passenger vehicle, transit and goods movement. Considerations for CAV needs in rural environments are referenced in the guidelines in terms of infrastructure needs, policy requirements and pilot programs with potentially limited availability of technology and infrastructure. The Readiness Guidelines are assigned a unique ID for traceability and tracking. They include the following:

> **Key Stakeholder Feedback**
>
> Assume that the private sector is responsible for ensuring CAV can safely operate on public roads and that the public sector may make some changes to ensure the transportation network is safe for all users.

- **Infrastructure Readiness** considers the impacts transportation operations, network management, maintenance teams, operations and maintenance fleets, urban commercial delivery, public transportation and transit agencies and relationships between public agencies and mobility services. Infrastructure Readiness Guidelines include:

  4.1 Technology (T)
  4.2 Physical Infrastructure (PI)
  4.3 Communications, Privacy, and Cybersecurity (CPC)

- **Operational Readiness** considers the impacts to transportation operations, relationships between public agencies and mobility services, network management, and public vehicle fleets. Operational Readiness Guidelines include:

  5.1 Data Needs and Data Management (DN)
  5.2 Inter-Regional Goods Movement (IEG)
  5.3 Intra-Regional Goods Movement (IAG)
  5.4 Mobility Services (MS)
  5.5 Network Management and Operations (NMO)
  5.6 Public Fleet Management and Operations (PF)
  5.7 Transit Management and Operations (TMO)

- **Institutional Readiness** considers the impacts to demand and simulation models, transportation planning (strategic planning, transportation masterplans and capital planning), design standards and relevant safety regulations, as well as strategies for agency collaboration. Institutional Readiness Guidelines include:

  6.1 Freight Safety and Regulations (FSR)
  6.2 Regional Collaboration (RC)
  6.3 Safety (SY)
  6.4 Standards (STD)
  6.5 Transit Service Planning (TSP)
  6.6 Transportation Planning (TPP)

- **Public Levers** considers incentives, policy and legislative changes required to create a CAV future that improves mobility with considerations for urban, suburban and rural contexts. Public Lever Guidelines include:

  7.1 Bonus/Malus Policy (BMP)
  7.2 Traffic Laws and Regulations (TLR)
  7.3 Infrastructure Policies and Regulations (IPR)

- **Pilots** describe the testing of a variety of use cases in urban and rural areas, including physical infrastructure arrangements, technology, mobility service arrangements, transit and commercial vehicle operations:

  8.1 Pilot Programs (PP)

3.1 CAV SATURATION SCALE

Each action defined within the Guideline descriptions are labelled in accordance with the CAV Saturation Scale shown to the right. Each level of the scale is summarized below:

- **Few CAV** – Initial phases of CAV deployment with CAV and connectivity applications being present primarily through pilot projects and testing programs.

  Current status in Ontario

  CAV Saturation Scale

  ☐ Few CAV

- **Mixed** – Medium-term phases of CAV deployment with conventional vehicles and CAV co-existing on roads with equal deployment and availability of connectivity applications.

  ☐ Mixed

- **Primarily CAV** – Long-term phases of CAV deployment where the majority of the vehicles on the road are CAV and connectivity applications are widely used.

  ☐ Primarily CAV

The highlighted boxes, beside the actions in each guideline, represent the CAV Saturation rate in which that specific action needs to be completed by. Scales that have more than one box coloured are an indicator that the associated action item is progressive. For example, an action item with coloured boxes representing Few CAV and Mixed indicates that the action item is to be completed for the Few CAV and then revisited or updated to accommodate Mixed vehicle operations. A scale that includes boxes that are grey indicates that the timeframe is not related to that specific action item. For instance, an action item that is to be completed by only the Few CAV timeframe will have the Mixed and Primarily CAV boxes of the scale coloured grey.

The guidelines were developed through a bottom up and top down approach for completeness. The bottom up approach, or detailed guideline tables, prepared through consultation with the Steering Committee and Stakeholder group can be found in **Appendix E** and are useful when considering specific focus areas. The top down approach of the guidelines is presented in the subsequent sections.

3.2 GUIDELINE INTEREST

The CAV Readiness Guidelines are described in the subsequent sections (4.0 to 8.0). **Table 1** summarizes the guidelines and shows the associated interest of the various levels of public agencies.

Table 1: Readiness Guideline Interest

Guideline	Federal	Provincial	Regional	Municipal	Transit
Technology (T)					
T-01			✓		
T-02		✓	✓	✓	✓
T-04		✓	✓	✓	✓
T-05		✓	✓	✓	✓
T-06		✓	✓	✓	✓
T-07			✓	✓	
T-08		✓	✓	✓	✓
T-09		✓	✓	✓	✓
Physical Infrastructure (PI)					
PI-01		✓	✓	✓	✓
PI-02		✓	✓	✓	✓
PI-03		✓	✓	✓	✓
Communications, Privacy and Cybersecurity (CPC)					
CPC-01	✓	✓	✓	✓	✓
CPC-02	✓	✓			
Data Needs and Management (DN)					
DN-01	✓	✓			
DN-02	✓	✓	✓	✓	
DN-03	✓	✓	✓	✓	
DN-04	✓	✓	✓	✓	✓
Inter-Regional Goods Movement (IEG)					
IEG-01		✓			
IEG-02		✓			
IEG-03		✓			
Intra-Regional Goods Movement (IAG)					
IAG-01			✓	✓	
IAG-02			✓	✓	
IAG-03			✓	✓	
IAG-04			✓	✓	
Mobility Services (MS)					
MS-01		✓	✓	✓	✓
MS-02			✓	✓	✓
MS-03		✓	✓	✓	✓
MS-04			✓	✓	✓
MS-05		✓	✓	✓	✓
Network Management Operations (NMO)					
NMO-01		✓	✓	✓	
NMO-02		✓	✓	✓	✓
NMO-03		✓	✓	✓	✓
NMO-04			✓	✓	✓
Public Fleet Management and Operations (PF)					
PF-01		✓	✓	✓	✓
PF-02		✓	✓	✓	✓
PF-03		✓	✓	✓	✓
PF-04		✓	✓	✓	✓

Guideline	Federal	Provincial	Regional	Municipal	Transit
Transit Management and Operations (TMO)					
TMO-01					✓
TMO-02			✓	✓	✓
TMO-03					✓
Freight Safety & Regulations (FSR)					
FSR-01		✓	✓		
FSR-02	✓	✓			
Regional Collaboration (RC)					
RC-01		✓	✓	✓	✓
RC-02		✓	✓	✓	
RC-03		✓	✓	✓	✓
Safety (SY)					
SY-01	✓	✓			
SY-02	✓	✓	✓	✓	✓
SY-03	✓	✓	✓	✓	✓
SY-04		✓	✓	✓	✓
Standards (STD)					
STD-01	✓	✓	✓		
STD-02		✓	✓	✓	✓
STD-03	✓	✓	✓	✓	✓
STD-04		✓			
Transit Service Planning (TSP)					
TSP-01		✓	✓	✓	✓
TSP-02					✓
Transportation Planning (TPP)					
TPP-01		✓	✓	✓	
TPP-02		✓	✓	✓	
TPP-03			✓	✓	
TPP-04			✓	✓	
Bonus/Malus Policy (BMP)					
BMP-01		✓			
BMP-02		✓			
BMP-03		✓			
BMP-04		✓	✓	✓	
Traffic Laws and Regulations (TLR)					
TLR-01		✓			
TLR-02		✓	✓	✓	
TLR-03		✓			
Infrastructure Policies and Regulations (IPR)					
IPR-01		✓	✓	✓	
IPR-02			✓	✓	
Pilot Programs (PP)					
PP-01	✓	✓	✓	✓	✓
PP-02		✓	✓	✓	✓
PP-03		✓	✓	✓	✓
PP-04					✓
PP-05		✓	✓	✓	
PP-06			✓	✓	

4 INFRASTRUCTURE READINESS

4.1 TECHNOLOGY (T)

The term 'technology' refers to any type of electronic equipment that may be present at the roadside (existing intelligent transportation system equipment or Roadside Units (RSUs)), located on a person (e.g. cell-phones or wearable devices) or other infrastructure that the CAV may interact with. Currently there is inconsistency in how technology is used across the country or even across the region or province. For example, agencies may use different text or pictogram formats to present information via Variable Message Sign (VMS), while signals indicating a protected left turn may include a green arrow or a flashing green light. Human drivers navigate the network interpreting static and real-time information to make decisions. **With CAV, information can be communicated directly between RSUs and the vehicle to support decision making.** A communication standard needs to be defined to ensure all CAV receive the same information from all connected infrastructure and provide data in a common format. V2I can be used for data collection, increasing safety at intersections, detecting pedestrians and cyclists and transferring information (e.g. road and traffic conditions, signal phases etc.) to and from the vehicles. Interfaces between connected technology and personal technology (e.g. smart phones, wearable, hearing aids, etc.) will also be required.

The Technology Guideline spans all levels of CAV saturation on the transportation network. It starts with pilot programs to identify needs and test the capability of connectivity and then continues to expand geographically and functionally as CAV saturation increases.

Elements of this Technology guideline include the following:

T-01 **Prepare a Provincial ITS architecture to align with updates to the National ITS architecture** that include requirements for CAV. This architecture could include:

    T-01A Inclusion of RSUs (V2I) and interactions with traffic management and transit management centres (V2X) to leverage connectivity to support safety, enhance signal applications, as well as facilitate congestion management, freight and fleet management, incident detection, weather monitoring, traveller information and speed management etc.

    T-01B Inclusion of CAV as dynamic data collection points as they traverse the transportation network, providing new opportunities to dynamically manage the network. CAV could potentially replace the need for data collection elements, including incident detection systems, traffic data collection systems (e.g. travel time, volume, speed), as well as weather and road surface conditions monitoring.

T-02 **Prepare a Concept of Operations document** that outlines how CAV data will be managed to support and enhance the existing network operations (see also NMO-01). It will consider the need for V2I technology to collect and broadcast information to CAV. Initially, the ConOps may identify how technologies may be tested as part of pilot programs along various representative transportation corridors and then identify a future state where the increasing levels of CAV on the road facilitate two-way connectivity (V2I2V) and connectivity with the traffic management centre (V2X). The Concept of Operations will consider the following:

    T-02A Real-time road and traffic conditions, including travel time, delay (including border delay), lane closures, routing and incidents. It may

also include congestion pricing and dynamic speed limit adjustments to manage traffic demand and minimize shockwave formation.

T-02B   Two-way communication between central systems and vehicles, for instance, updates to network maps to include information on changes to road conditions, lane configurations and detour routes for planned and unplanned events.

T-02C   Key intersection information on arterial roads, including signal timing, transit signal priority and presence of pedestrians/cyclists.

T-02D   Goods movement information including pick ups and delivery, movement of vehicles etc.

T-02E   Warnings of pedestrian and cyclist presence to CAV to ensure the automated system (and operator) are aware of their presence and necessary safety measures are taken (e.g. wait for area to clear). These broadcasts should not be considered as a replacement for on vehicle technology to protect vulnerable road user safety.

T-03   **Identify needs for back-up of critical systems and technology infrastructure** to ensure continuity in operations of the transportation network during planned (e.g. maintenance) and unplanned event disruptions.

T-04   **Identify needs for emergency detection/incident management (safety) and evacuation systems.** This may include an automatic alert for emergency services to be dispatched to the scene, as well as dynamic route guidance to redirect traffic. Dynamic route guidance should consider all modes (including freight and rail) and be updated with real-time information for level rail crossings. CAV can also communicate the need for emergency services directly to the emergency/incident management system through V2I connectivity (Note: See Pilot Programs Guideline for more information).

T-05   **Identify needs for technologies and/or RSUs to allow safe network operations** under different weather (e.g. heavy snowfall or rainfall) and road (e.g. high dust situations in construction zones) conditions. Examples of technologies to address weather challenges include integrating road weather forecast models into vehicles for trip planning, installing pavement-embedded sensors to allow pavement marking detection in all-seasons, or collecting sensor data from CAV (e.g. traction, temperature etc.).

T-06   **Identify needs to support a safe transportation network for vulnerable road users** when interacting with CAV. This should take into consideration the Accessibility for Ontario with Disabilities Act (AODA) needs and may include pedestrian and cyclist detection, such as infrared sensors or cameras mounted onto tall poles, as well as road-embedded pressure sensors. The detection technology may be installed at designated intersections/crosswalks, school zones, community safety zones, and public transit areas for testing through a pilot program, and then expanded along the transportation corridor for widespread use with increasing levels of CAV saturation (Note: See Pilot Programs Guideline for more information).

T-07   **Identify needs for vehicle occupancy detection infrastructure** (unless in-vehicle detection available) to track zero-occupancy and high occupancy CAV on the transportation network. This infrastructure can be used to identify eligibility for

use of high-occupancy lanes and/or facilitate incentive programs for high-occupancy trips, while disincentivizing zero occupancy trips.

T-08 **Identify needs for connectivity with personal aid technologies** (e.g. visual or hearing aids) to reflect the needs of vulnerable road users, those with mobility restrictions and disabilities. Existing systems currently used in transit that integrate with personal aid devices can be leveraged. Consider using a unique identification device to address unique user needs (e.g. provide additional time for young children or the elderly to cross etc.).

4.2 PHYSICAL INFRASTRUCTURE (PI)

The widespread adoption of CAV will have an impact on the shape of cities and transportation infrastructure but making informed decisions relating to physical infrastructure needs can create positive impacts. Changes to freeways, highways, roads, parking infrastructure, transit infrastructure and other physical infrastructure needs to be considered and be planned now due to the long capital planning and funding timeframes and infrastructure life cycles. Other infrastructure changes, such as static signs and pavement markings, need to be considered. Vehicle manufacturers and researchers are developing CAV that can reliably function on today's roads and may not need significant infrastructure investments before being deployed. However, present day roads and highways have been designed for human drivers and may not be optimal for increased use of CAV technology, or where CAV and conventional vehicles have to share space. In addition, consistency in pavement markings, static signs and other infrastructure will be important to enhance CAV operation.

Changes to infrastructure will be made over time, as CAV saturation changes and infrastructure needs change. In the long-term, government and transportation agencies will need to consider and make appropriate adjustments to transportation infrastructure and maintenance standards (e.g. Ontario Minimum Maintenance Standards) to accommodate new technology and facilitate their safe integration on roads. This may include adjustments to roadways designs and an increased presence of digital and technology infrastructure. **In the short-term, and during the phase of pilot programs, there are opportunities to implement lower-cost modifications to infrastructure** (e.g. changes to signage, temporary lane separation etc.), **assess existing infrastructure assets** (e.g. bridge loading resistance for platooning trucks) **and test new technology, roadway designs and infrastructure**. Results of pilot programs can inform the needs to determine infrastructure requirements and any significant infrastructure design changes to accommodate CAV.

Elements of the Physical Infrastructure guideline include the following considerations:

PI-01 **Evaluate existing physical infrastructure, the need for updates to minimum maintenance standards and improvements to roadway infrastructure** to maintain a safe transportation network with increasing levels of CAV saturation (from Few CAV to Primarily CAV). This includes considerations for infrastructure improvements required for mixed CAV/conventional vehicle road use. Much of the infrastructure requirements are governed by national and provincial standards; however, municipal agencies could provide input to these standards as part of a larger national collaboration effort. These physical infrastructure improvements may consist of the following (Note: See Pilot Programs Guideline for more information):

    PI-01A New and improved road markings, such as positional sensors and wider, reflective markings, to accommodate machine vision of CAV and ensure that vehicles can safely traverse the transportation network with autonomy during all weather conditions.

PI-01B   Physical changes to highways, arterial roads, intersections, curbsides, lane layouts, and sidewalks to support dedicated CAV corridors (e.g. transit only, CAV only, and truck only) for the safe operation of a mix of CAV and conventional vehicles on the road. This includes maintaining safe conditions for vulnerable road user interactions with CAV at intersections, pedestrian crossings, mixed use trails, as well as in school and community safety zones. Considerations for AODA requirements and needs of young children shall be accommodated.

PI-01C   Physical changes to support a mix of CAV and conventional vehicles using passenger pick-up and drop-off areas at transit stations, stops and terminals. This includes maintaining safe conditions and area layouts to support pedestrian interactions with CAV.

PI-01D   Physical changes to transit stop designs to support the operation of CAV buses and microtransit vehicles (e.g. on-demand transit and ride-hailing services). This includes ensuring passengers can wait at the stop, and board and alight transit vehicles safely

PI-01E   Physical changes to support primarily CAV operations on highway corridors with consideration for conventional vehicles (e.g. dedicated lanes for conventional vehicles), including safety requirements and management strategies for vehicle ingress/egress onto highways.

PI-01F   Physical changes to parking facilities and infrastructure to accommodate automated parking, optimize space and evaluate parking facility size requirements, including considerations for short-term local layover needs of CAV that may also include charging needs. This includes an inventory of parking infrastructure needs and whether parking land can be repurposed for other urban uses.

PI-01G   Physical changes, in the long-term, to support primarily CAV operations on urban roads (e.g. lane layouts). This includes identifying infrastructure needs to ensure safe pedestrian and bicycle interactions with CAV along urban roads, as well as in school and community safety zones.

PI-02   **Assess existing transportation infrastructure and evaluate needs to facilitate commercial CAV operations** (including truck platooning) and urban freight delivery. This may include the following considerations:

PI-02A   Current bridge asset assessment to confirm that platooning trucks will not impact structural loading and that the integrity of the structure is maintained within safe limits as per the relevant structural design standards and codes (CSA A23.3 - Design of Concrete Structures and CISC Handbook of Steel Construction). Pavement infrastructure may also need to be assessed.

PI-02B   Physical changes to support safe movement of vehicles and platooning trucks including an assessment of necessary infrastructure changes to facilitate safe weaving of traffic at ingress/egress points with the presence of CAV and platooning trucks. These interactions will need to be assessed as part of pilot projects to determine the ideal lane arrangement design (Note: See Pilot Programs Guideline for more information).

PI-02C Ongoing infrastructure improvement assessments for urban streets and at intersections with heavy CAV goods movement traffic.

PI-02D Infrastructure requirements assessment to facilitate the testing and eventual widespread use of first-mile/last-mile urban delivery operations (e.g. sidewalk delivery robots) to ensure their operations do not interfere with daily pedestrian movements.

PI-02E Physical changes to support safe CAV operations (commercial and non-commercial), such as dedicated on/off ramps and a dedicated lanes. This also includes specific considerations for any changes to truck inspection stations and infrastructure to accommodate increasing levels of commercial CAV saturation.

PI-03 **Review existing capital plans and projects to determine physical infrastructure needs**, with increasing levels of CAV, including planning, funding and implementation timeframes. Identify any changes that could be made to better integrate advancement in CAV technology in plans and projects.

4.3 COMMUNICATIONS, PRIVACY AND CYBERSECURITY (CPC)

CAV will transform how information and data is shared and protected, as these vehicles will generate large amounts of data and rely on communication with the surrounding vehicles, environment and infrastructure to operate. **Data protection, user privacy and cybersecurity of the increasingly connected transportation network will be a key priority for all levels of government, transportation and transit agencies.** As CAV are deployed, vehicles on the road will be consuming and broadcasting real-time travel data, which raises many privacy and security concerns. These concerns include the potential risk of on-vehicle disruption of computer networks or systems due to cyberattacks, data theft and/or failure of automated driving systems and smart road infrastructure. The development of regulations and installation of digital security infrastructure will need to be considered, as a **lack of safeguards in place could open a highly connected transportation network to privacy and security breaches.** Securing the transportation network is important in the early stages of CAV saturation and needs to evolve with increasing levels of CAV presence on the road and with a larger reliance on connectivity and communication systems.

Elements of the Communications, Privacy, and Cybersecurity guideline include the following:

CPC-01 **Develop policy to specify, test and enforce privacy and security requirements** introduced by CAV connectivity (V2I, V2V and V2X) to maintain the safety, security and integrity of the transportation network. These include the following:

CPC-01A Policy to determine, evaluate and prepare for the potential safety, security and cybersecurity concerns to the public in coordination with the federal government. This includes integrating testing of various cybersecurity, privacy and protection methods into pilot programs, such as exploring the use of a Security Credential Management System (SCMS), or blockchain technology, to protect the transfer of data and information. Once a method is identified that satisfies safety and security needs, necessary regulations and legislation should be developed. Note: Transport Canada is funding the development of a SCMS for Canada.

CPC-01B Policy to ensure compatibility and interoperability with international best practices and ensure strict adherence to data protection, privacy and security laws and regulations. This may include advocating for strict requirements, legislation and regulations, at the federal level, for privacy and security measures included in the design of CAV driving systems.

CPC-02 **Establish, evaluate, advocate for, and agree upon data security, privacy and cybersecurity strategies and methods** to protect data and information transferred via V2V, V2I and V2X to ensure privacy and security is maintained when this information is under a government agency's control. These include the following:

CPC-02A Identification and protection of personal information (e.g. personal identification details, location, trip details, speed etc.).

CPC-02B Identification and protection of goods movement data such as personal and goods data (e.g. driver information, types of goods, schedules etc.).

CPC-02C Digital infrastructure and security protocols (e.g. encryption and blockchain technology) to address cybersecurity and protect connected infrastructure from cyber attacks. The intent of the infrastructure and protocols is to secure communication networks, transportation network control algorithms, software and underlying data against malicious attacks, damage and unauthorized use or manipulation.

CPC-02D Monitor and understand current communication spectrum and channels allocated by Canada's Innovation, Science and Economic Development Canada (ISED) for use with ITS deployments (see the ISED policy here). Note: as of the time of publishing these guidelines, there is 75MHz of the 5.9GHz radiofrequency reserved for ITS.

CPC-02E Understand federal requirements for, and properly obtain, spectrum licences applicable to CAV deployments and applications (e.g. required for site based RSUs).

5 OPERATIONAL READINESS

5.1 DATA NEEDS AND DATA MANAGEMENT (DN)

CAV and their supporting technology are expected to generate much more data than what is currently present in collected datasets. CAV will continuously collect information related to the operation of the vehicle and the surrounding environment, such as vehicle speed, location, condition of road surface, temperature etc. This data may render existing data and collection methods used by transportation agencies obsolete. Not all data will be of value to public agencies; understanding data needs and how to effectively manage the data will need to be resolved. **Key data metrics, such as data definition, format, timeliness, quality, aggregation levels, alerts etc. will need to be defined.**

Pilots offer an early opportunity to be exposed to the data CAV can produce, and represent a prime opportunity to ensure critical information for monitoring the performance of the transportation network can be collected and mandated following widespread deployment of CAV. Pilot data can also be used to inform infrastructure, operational, planning and policy decisions. **As CAV saturation levels increase, data collection and management will need to be reviewed**, as changes will be required to effectively monitor the safety and operation of the transportation network.

Elements of the Data Needs and Data Management guideline include the following:

DN-01 **Develop a consistent data governance model** that identifies public agency data needs, data ownership, accountability, data quality, data quantity, timeliness, data sharing/collaboration and standardized rules for data access and privacy. Developing a data dictionary is also key in defining consistent formats and content for data exchange to meet needs of transportation agencies to measure key performance indicators during pilot programs and during regular operations. A data governance model would address the main streams of data collection, including (Note: See Pilot Programs Guideline for more information):

    DN-01A Data collected from Transportation Network Companies (now) and mobility service operators (later) to capture volume of single passenger and zero occupancy trips.

    DN-01B Data collected by private CAV and public fleets (e.g. transit vehicles, maintenance fleets, emergency vehicles etc.), both as part of pilot programs and regular daily operations with increased CAV saturation.

    DN-01C Data collected from emergency service vehicles (e.g. Fire, Ambulance and Police) to manage real-time interactions with other vehicles and provide priority on the road during emergencies.

    DN-01D Data collected at transit stations/terminals to enhance understanding of station access across all modes, as well as the performance of CAV in pick-up/drop-off areas.

    DN-01E Data collected on CAV freight transportation to allow for a better understanding of vehicle performance on highly used freight routes, as well as goods information (e.g. types of goods). This may require engaging in partnerships with industry operators.

    DN-01F Data collected from passenger and freight rail, as well as rail crossing infrastructure, to monitor interactions between CAV and rail/transit at road/rail crossings.

DN-01G   Data collected by technology designed to monitor road and traffic conditions and interactions between CAV, other vehicles (including emergency vehicles), and road infrastructure.

DN-01H   Data privacy requirements for all data collected from the public, including mobility services applications, transit stations, private vehicles etc.

DN-02   **Develop Big Data management strategies, and data repositories** to effectively and securely collect, process and store large datasets collected by public and private CAV, as well as infrastructure. This may initially be developed to store and analyze data collected by pilot programs and expand with increasing CAV saturation, as data becomes more critical to the daily operations of the transportation network. Data storage requirements, including what is saved, purged, and aggregated, as well as the time durations for these will be addressed.

DN-03   **Define data requirements to evaluate traffic conditions, travel time estimates and overall network and vehicle performance** to support real-time network operations. This includes monitoring the performance and interaction of vehicles on highly used freight routes and transit corridors, and the impact of CAV on existing infrastructure (e.g. curb space). Defining consistent data format requirements will facilitate the full automation of data processing and analysis.

DN-04   **Define public and private sector responsibilities for the development of tools and data information** that may be required by CAV to travel the network (e.g. high-resolution maps or map data specifications). Understanding the roles and responsibilities with developing and maintaining a high-resolution map or spatial data specification will be critical, and includes identifying the following:

DN-04A   Private sector responsibilities in developing and maintaining a centralized open source map or transportation network data specification.

DN-04B   Public sector responsibilities in supporting the development of mapping tools and specifications, as well as providing access to relevant information regarding planned construction closures, temporary detours, real-time road conditions, updated roadway designs, georeferenced by-laws and physical limitations on roadways (bridge heights, weight restrictions etc.).

5.2 INTER-REGIONAL GOODS MOVEMENT (IEG)

Inter-regional delivery refers to the transportation of goods across city and regional boundaries. **CAV technology will revolutionize the freight industry by offering safer and more efficient trucking and optimization of the existing road capacity.** Inter-regional CAV freight operations will primarily take place on regional highways and on local roads surrounding distribution centres, airports and rail yards.

Elements of the Inter-Regional Delivery Guideline include the following:

IEG-01   **Define requirements for pilot programs to assess and evaluate CAV roadside technology as it applies to commercial vehicles** and their operations on the transportation network. Information and data collected from these programs will assist transportation agencies in defining requirements and standards for

commercial CAV operations on mixed use roadways. (Note: See Pilot Programs Guideline for more information).

IEG-02 **Develop operational procedures and guidelines for inter-regional delivery vehicles and truck platooning**, including following distance, engaging and disengaging with platoon to ensure safety and minimize disruption to other vehicles.

IEG-03 **Identify long-distance freight corridors**, including connections to local transportation networks (e.g. local roads surrounding major freight distribution centres and multi-modal hubs) to determine physical boundary needs and other operational standards for limiting the impact of heavy truck traffic on passenger vehicle operations.

5.3 INTRA-REGIONAL GOODS MOVEMENT (IAG)

CAV technology can impact the future of intra-regional delivery (freight trips undertaken within the boundaries of the same region) in two ways: 1) increase of single-item deliveries due to the popularity of e-commerce and the convenience that CAV brings, and 2) delivery consolidation, bundling two or more orders into one delivery. CAV can be operated with limited input from human operators and presents an opportunity to deliver goods to an urban consolidation centre (UCC) during off-peak hours (e.g. overnight, early morning and weekends), reducing traffic congestion during daytime. To optimize urban freight operations and throughput of truck traffic, delivery vehicles can connect with surrounding infrastructure using V2I technology to adapt to road and traffic conditions. **Key operational elements, such as dynamic traffic signal timing adjustments and operational boundaries and limitations in urban environments will need to be defined.** Since urban delivery CAV may operate in an environment with mixed mobility users, such as pedestrians and cyclists, it is critical to define the regulations and policies to ensure their safe integration in the urban fabric.

Elements of the Intra-Regional Delivery Guideline include the following:

IAG-01 **Develop pilot programs to test new methods in intra-regional delivery** (e.g. off-peak delivery programs) with the intent of reducing the impacts on regular daily traffic of vehicles, cyclists and pedestrians. These programs can be implemented as part of urban congestion management plans and will require a review of by-laws and provincial legislation and policy to identify any needs for changes (Note: See Pilot Programs Guideline for more information).

IAG-02 **Determine needs for limiting the impact of intra-regional deliveries, and ensuring a safe transportation network** for passenger vehicles, pedestrian and cyclist traffic. Technology needs can be tested as part of pilot programs and expanded with increasing levels of commercial CAV presence on the roads. This can include:

IAG-02A Review opportunities to optimize signal timings to efficiently move delivery vehicles, to improve travel times, reduce congestion and maintain sufficient passenger vehicle throughput.

IAG-02B Pedestrian and cyclist presence warnings broadcasted to delivery CAV to ensure the automated system and operator are aware and necessary safety measures are taken (e.g. wait for gap in pedestrian and cyclist traffic).

IAG-03 **Consider intra-regional delivery CAV parking requirements** in curbside management and congestion management strategies to identify designated parking locations and dwell time restrictions to facilitate deliveries of goods without impeding traffic or interfering with cyclists and pedestrian movements.

IAG-04 **Establish regulations and/or by-laws to define the safe operation of last mile intra-regional deliveries** (e.g. sidewalk delivery robots), including defining limitations on where and how they could operate safely and assessing the need for dedicated zones where they could operate within. Regulatory requirements can be defined based on needs identified through pilot programs testing this innovation in urban delivery operations.

5.4 MOBILITY SERVICES (MS)

CAV technologies present an opportunity for new business models in mobility services. Transportation Network Companies are set to roll out fleets of on-demand CAV to provide transportation to the public. As on-demand and car sharing services are becoming more prominent and increase their use of CAV technology, operational regulations and legislations will need to be in place to ensure safety and accessibility. Public transit agencies can also explore the potential for new business model opportunities that could arise from CAV technologies. The government and transportation agencies will need to work together to develop a common fare integration framework, and to develop policy and regulations to maintain oversight and governance over both public and private mobility services. **Establishing partnerships with private mobility service providers and integrating public transit fares with mobility service fees could open the opportunity for leveraging privatized transportation services to facilitate improved accessibility to transit services** (e.g. first-mile/last-mile trips), as part of a wide-scale mobility services strategy. A common framework for the provision of mobility within the region can improve operational efficiency, contribute to financial growth and allow a more seamless and convenient travel experience for users.

Elements of the Mobility Services guideline include the following considerations:

MS-01 **Identify the impacts of emerging mobility services and technologies** (e.g. CAV on-demand mobility, ride-hailing, mobility services platforms etc.) on transportation masterplans, mobility, and land-use planning in the region.

MS-02 **Define requirements for a regional mobility platform that includes existing mobility options** (e.g. bike-share, scooter-share, ride-hailing etc.). Existing regional trip planners (e.g. Triplinx) and fare cards (e.g. Presto) can be leveraged.

MS-03 **Establish a legislative, regulatory and policy framework for public and private mobility service providers operating CAV** by defining the role of the public and private sector in terms of maintaining equitable and accessible service to the public, as well as developing best practices to ensure services are provided in the best interest of the public. These best practices would include:

MS-03A Legislation, regulations and by-law updates to reflect technological changes and ensure that the AODA is applied for all new mobility services with consideration of needs for young children and people with disabilities, such as having trained vehicle attendants. This can also include opportunities for integrating specialized/on-demand transit for passengers with disabilities (e.g. explore the possibility of

ride-hailing services providing trips that currently use specialized transit).

MS-03B   Regulations to define legal operation and service coverage area for private CAV ride-hailing/on-demand mobility operators and maintain governance/oversight over mobility services (both public and private) to ensure desirable outcomes for the region.

MS-03C   Policies to manage the pricing of mobility services with respect to public transit to avoid competition driving down transit ridership.

MS-04   **Develop a plan to coordinate with key partners in the region on approaches to building a regional mobility platform.** Initially, new mobility services provided by public agencies and/or integrated with private company services may be tested as part of pilot programs to explore impacts on travel behaviour, then refined and further expanded on as technology and demand for the services evolve. This plan would include:

MS-04A   A Framework for widespread integration of public mobility service platforms and shared mobility services (including CAV microtransit) with public transit services to explore impacts on travel behaviour.

MS-04B   Policies to harmonize and integrate the fee structure for mobility services (e.g. car-share, ride-hailing, bike-share, e-scooters), as well as public transit, into a single platform. This can be achieved through the coordination of public agencies and private mobility service providers to integrate services and fee structures across various service providers and jurisdictional boundaries based on demand and capacity.

MS-05   **Review business models, trip planning needs and enable policies and frameworks to pivot towards a mobility services mentality.** This includes the need for enhanced trip planning services that considers all potential modes of travel, prioritizes high occupancy modes, and dynamically adjusts based on monitoring of user defined key parameters (e.g. cost vs arrival time vs shared vs convenience, etc.).

5.5 NETWORK MANAGEMENT AND OPERATIONS (NMO)

Managing and operating the transportation network will evolve with the presence of CAV on the road. **The strategies presently in place will need to evolve to reflect technological changes and be modified to better manage the transportation network.** The increasing presence of CAV on the road, and the associated supporting technology, creates an opportunity for transportation operators to implement strategies (e.g. dynamic network management) that could improve the overall operation of the system, make it safer and minimize congestion.

Transportation agencies will also need to consider a transition in the skillset of staff responsible for overseeing the management and operation of the network. With connectivity, automation and artificial intelligence, CAV technology will be dependent on data and certain elements of network management and operation will eventually become increasingly more automated. On the job training and development of new skillsets and roles to develop CAV technological expertise, will be required.

Elements of the Network Management and Operations guideline include:

NMO-01   **Develop a Concept of Operations to review network management and operations and how CAV can support traffic demand management**

strategies to manage congestion and network capacity on highways, and urban roads (see also T-01). These updates will evolve over time, adapt to the level of CAV saturation on the road and include the following considerations:

NMO-01A   Scenarios assessing how current network operations will be impacted by CAV, including incident detection and management, congestion management, snow removal, etc., and the identification of needs to update system software and field equipment.

NMO-01B   Strategies to notify CAV of planned and unplanned events (e.g. construction, closures, congestion, collisions etc.), and to update data information tools (e.g. high-resolution centralized maps, or spatial data specifications) to reflect updated traffic/road conditions and weather events to help facilitate CAV movement through those areas.

NMO-01C   Traffic management procedures that make use of real-time data collected on network performance to identify areas of delay and evaluate traffic congestion mitigation procedures.

NMO-02 **Update emergency preparedness strategies** to address requirements with increasing levels of CAV on the transportation network. This would include:

NMO-02A   Updates to evacuation plans to include how CAV will be notified of an evacuation and how centralized maps or data specifications will be updated to reflect real-time emergency detour routes for coordinated evacuation.

NMO-02B   Updates to emergency services allocation strategies to reflect needs of the transportation network. For example, this may include less traffic patrols, as automating enforcement of traffic rules and regulations could free up resources for other police activity.

NMO-03 **Understand evolving skillset requirements for network operation staff through an operational review** and evaluate changes to organizational structure, as well as staffing and training needs. This may include assessing staffing needs, developing skillsets through training to maintain and operate an increasingly connected system, capacity building within all levels of the organization, transitioning employees to take on new roles within the context of network operation, management and maintenance, and updating Standard Operating Procedures (SOP).

NMO-04 **Develop a business case to address changes in revenue structure** surrounding parking fees, speeding tickets and other traffic infractions. This includes developing and investing in new methods for collecting parking fees from CAV without the need for human intervention.

5.6 PUBLIC FLEET MANAGEMENT AND OPERATIONS (PF)

Public sector vehicle fleets are used to deliver essential services for citizens. Some are owned and some are outsourced. This guideline is focused on owned vehicles although requirements may also be incorporated into outsourced services. The range of vehicles operated by the public sector is extremely broad and

includes grass cutting vehicles, snow removal vehicles, maintenance vehicles, fleet vehicles, hazardous spill clean up vehicles, and public transit vehicles, etc. These vehicles underpin the provision of public services, such as road works and maintenance of public space, for all levels of government and transportation agencies. **With the introduction of CAV technology, vehicle fleets owned and operated by government and public agencies will have the opportunity to take advantage of connectivity, automation and electrification.** These fleets could be used to collect data and information about the transportation network and become a part of pilot projects. Initial phases of CAV adoption and saturation will allow public agencies to test CAV for their respective purposes and use the results of these testing programs to inform procurement decisions and invest more in the technology in the future. More efficient public fleet operations will allow the delivery of better services at a reduced cost. With increasing levels of CAV saturation, and the expectation that CAV will most likely be electric vehicles, the public sector will need to establish standards and guidelines for public fleets to ensure safe and efficient management and operations.

Elements of the Public Fleet Management and Operations guideline include:

PF-01 **Upgrade public agency owned assets** (e.g. transit vehicles, maintenance vehicles, snowplows etc.) to CAV along with necessary infrastructure to support their maintenance (e.g. electric charging stations in warehouses). This will be a gradual process over time, including identification of:

    PF-01A Funding streams and opportunities for upgrading assets (e.g. pilot program funding, lump sum funding streams, operational budgets etc.).

    PF-01B Regional/municipal services that could test CAV for initial pilots and testing programs and to inform decisions in later time-frames. This may be followed by an evaluation of which services would benefit from converting to using CAV, such as an assessment of needs for CAV maintenance vehicles due to changes to minimum maintenance standards.

    PF-01C A select number of agency owned vehicles replaced/modified for the purposes of being involved in pilot programs and for data collection purposes.

    PF-01D Public fleet lifecycle assessment in strategic and capital plans to determine the rate at which the fleet can be converted to CAV. This includes the development of a procurement strategy to replace non-CAV agency owned assets with CAV, where appropriate.

    PF-01E Timeline for agency owned assets to be fully replaced with CAV, along with the necessary infrastructure to support their maintenance.

PF-02 **Monitor interoperability and connectivity of vehicle fleets and systems produced by different manufacturers.** This involves ensuring that V2V and V2I standards are consistent and therefore open procurements can be maintained.

PF-03 **Update maintenance procedures, based on vehicle manufacturer requirements, for agency owned vehicle fleets** to include maintenance requirements for operating CAV, such as calibration of sensors, software updates and fueling/charging requirements. This also includes re-evaluating maintenance facility needs, with increasing presence of CAV in the public fleet, to determine changes to fleet maintenance and storage facility requirements (e.g. number of locations and size).

PF-04 **Develop Standard Operating Procedures (SOP) and management guideline**s for different types of public CAV fleets to ensure safe operations and maintenance. This includes the following:

PF-04A Requirements to properly operate and maintain CAV transit vehicles. Fixed route transit vehicles and on-demand transit vehicles will also need new operations procedures to ensure efficient and safe operations. Discussions regarding whether an attendant or operator is on board and how to ensure safety will be required.

PF-04B Requirements to establish and maintain a pooled CAV system that allows employees to reserve and use vehicles, presents an opportunity to share vehicles on an on-demand basis and supports awareness and capacity building. Other considerations include vehicle servicing and reservation management systems that ensure that all necessary information is collected and easily audited, as well as providing automated passenger pick-up and drop-off.

PF-04C Requirements to properly operate and maintain CAV grass cutting and snowplows. For example, snowplow vehicles can provide automatic on-demand services (without operators) when infrastructure detects the need for snow removal on roads and/or sidewalks while automated grass cutting can be more efficient.

PF-04D Requirements for contractors performing public services to use CAV.

5.7 TRANSIT MANAGEMENT AND OPERATIONS (TMO)

With CAV technology, public transit agencies can take advantage of the service efficiencies that connected and automated transportation may introduce. Connected vehicle technologies, such as those on smart buses, are in use already and include on-board devices requesting Transit Signal Priority (TSP) and sharing of real-time location information. **CAV technologies (e.g. automated shuttles etc.) may impact future infrastructure needs and the transit service operations and delivery model.** The need for new and/or upgraded public transit infrastructure or technologies, as well as new operating staffing requirements will have to be identified in the early stages of CAV saturation.

Elements of the Transit Management and Operations guideline include:

TMO-01 **Update transit station demand management strategies** to address increased vehicle traffic (either private CAV or third-party mobility service providers) at transit stations that are picking-up or dropping-off passengers. The strategy may assess the potential impact of emerging mobility options (e.g. CAV, ride-hailing etc.) on station access and traffic and how they can best be integrated with transit services to facilitate first-mile/last-mile operations.

TMO-02 **Coordinate with transportation network operators who are supporting transit services for opportunities to enhance shared mobility.** Consider identification of key transit corridors and opportunities to use data gathered by TNC CAV to support improved travel time and traffic flow. This may be achieved by utilizing V2I connectivity technology between traffic signals and TNC CAV that are providing functionality as part of a first mile/last mile transit service.

TMO-03   **Identify the requirement for having AODA trained attendants on-board transit CAV to assist passengers**. This requirement would be mandatory for on-demand transit services that are carrying young children and persons with disabilities as passengers.

6 INSTITUTIONAL READINESS

6.1 FREIGHT SAFETY AND REGULATIONS (FSR)

CAV technology will bring fundamental changes to the freight movement operations. **It is necessary for transportation agencies to establish standardized operating guidelines and procedures** to accommodate connected and automated freight movements on transportation networks. Working closely with freight operators, transportation agencies need to define operational procedures and regulatory requirements to ensure the safety of the transportation network with the presence of commercial CAV.

Elements of the Freight Safety and Regulations guideline include:

FSR-01 **Establish standards of practice that freight transportation operators need to follow** for the safe operation of commercial CAV on provincial, regional and municipal roadways. This includes:

   FSR-01A Requirements for the presence of commercial CAV operators in the vehicle, including setting a limit for vehicle-to-operator ratio in a platoon, as well as operating hours. Also consider ways to identify CAV operation to the public.

   FSR-01B Requirements for platoons describing allowable time of day of operation, location, speed, and length (or number of commercial CAV). This includes identifying restrictions on commercial CAV operations depending on road classification (e.g. provincial highway, municipal road etc.).

   FSR-01C Requirements for following distance at specific vehicle speeds for commercial CAV engaged in platooning operations.

   FSR-01D Requirements on weight and load type restrictions for commercial CAV operating in platoons and along certain routes in the transportation network. This includes identifying specific requirements on how commercial CAV carrying sensitive goods (e.g. oversized loads, dangerous goods etc.) can operate.

FSR-02 **Review and update Commercial Vehicle Inspection (CVI) procedures**, in coordination with the Federal Government, to accommodate CAV and platooning. This includes:

   FSR-02A Standards and regulations on how commercial vehicles will communicate, provide information and receive messages from inspection staff.

   FSR-02B Procedures on when and how commercial vehicles will disengage platooning technologies and leave the platoon to enter/exit a CVI station.

6.2 REGIONAL COLLABORATION (RC)

Preparing for CAV in the GTHA requires a joint effort between local, regional and provincial transportation agencies as personal travel, shared mobility and goods movement does not recognize boundaries. There is a lot of uncertainty in what the future looks like and when various CAV saturation levels will materialize. Resources are limited and therefore **coordination and collaboration will be key in identifying common**

areas for research and analysis, avoiding duplication in efforts and ensuring consistency across the GTHA. Regional collaboration may come in a variety of forms and will span across infrastructure, operational, institutional and public lever considerations.

Elements of the Regional Collaboration guideline include:

RC-01 **Establish a CAV Liaison Committee comprised of representatives across all levels of public agencies.** This Liaison Committee may build upon the Steering Committee and Stakeholders identified through the CAV Readiness Plan. Identification of a chair or co-chairs, frequency and method of collaboration and commitment from each agency will be important. As CAV mature, the role of the Liaison Committee will gradually evolve.

RC-02 **Develop a Regional Centre of Excellence** that focuses on aggregation of information, knowledge sharing, and coordinated planning initiatives. This may include research, identification of observation areas, development of pilot programs, tracking and evaluation of test results, and sharing of data and lessons learned. The information collected could include:

RC-02A A pilot project registry recording information on Liaison Committee member and private sector projects undertaken through the provincial CAV Pilot Program. This can help maximize test cases, reduce duplication and address the testing needs of other agencies to broaden the knowledge base.

RC-02B Information on network management, incident management and other operational areas to accommodate the gradual increase in CAV saturation on the transportation network.

RC-03 **Explore partnership agreements with the industry**, including Small-Medium Enterprises (SMEs), Multi-National Enterprises (MNEs), manufacturers, private on-demand mobility providers, and academic institutions operating in the province. These partnerships could take on various forms including:

RC-03A Research partnerships to further understand CAV, foster innovation and allow for agencies to benefit from the knowledge developed from industry testing programs already underway.

RC-03B Information sharing partnerships where public agencies could provide access to roadway data and information, while academia and industry partners involved in pilot programs could share data on results that could in policy and regulation development and identify needs for future infrastructure investments.

RC-03C Shared funding opportunities for projects to further advance the development of technology in the province.

RC-03D Cooperation in the provision of public transportation services across the region. For example, coordination between public transit agencies and private on-demand mobility providers to explore opportunities for integrating services, through pilot programs and identifying the overall impacts on regional travel.

6.3 SAFETY (SY)

The continual evolution of CAV technology and increasing presence on the transportation network presents an opportunity to improve road safety by reducing vehicle collisions, fatalities and the risk of injury. Safety covers a wide variety of topics including development of safe infrastructure, operational procedures, safety planning and safety regulations. **Government oversight will be needed, and existing safety frameworks will need to be updated to reflect the advances in technology.** All levels of public agencies will need to work together to ensure the safe operation of their roadways and services, while also advocating for the safe design, testing and deployment of the vehicles and technology. Developing a safe transportation network is evolutionary in the sense that initial testing of safety procedures and considerations will inform future planning initiatives and decisions for the safe operation of transportation under increasing levels of connectivity and automation.

Elements of the Safety guideline include:

SY-01 **Prioritize safety as a key evaluation criterion when approving pilot program requests** from government agencies, industry and academia. An important consideration for transportation authorities is to ensure that proposed pilots (especially if mixed with regular traffic) will not compromise the safety of the public and have additional safety precautions in place. Including emergency service providers in development of a safety plan and desk top planning exercise to plan for emergencies. Data on when the vehicle control is reverted to an operator should be collected to understand safety implications.

SY-02 **Conduct a safety assessment of transportation infrastructure** with the intent to identify potential safety and cybersecurity risks for CAV and determine what necessary measures (e.g. design changes, regulation or by-law updates etc.) need to be taken. This safety assessment may be conducted as a component of pilot programs where data collected from pilot results can be leveraged to inform safety requirements and needs for widespread CAV adoption.

SY-03 **Develop and implement an Action Plan surrounding the safety of transportation and transit networks** with increasing levels of CAV saturation. CAV are being designed to operate on existing roads. The intent of this Action Plan is to further improve the transportation network and make use of opportunities that will be introduced by CAV technology to improve safety. This Action Plan should be a joint effort between public transportation agencies crossing all boundaries and include the following:

SY-03A Regulations on liability, insurance and incident responsibility requirements for CAV operators for transit services, pilot programs, personal and shared use.

SY-03B Public engagement initiatives and polices to educate the public and raise awareness on CAV, the progression of the technology, and motor vehicle safety. This should be a collaborative effort between municipal, provincial and federal governments.

SY-03C Preparations for potential safety concerns to the public, presented by CAV, in coordination with the federal government.

SY-03D Discussion on advocating for updates to the Motor Vehicle Safety Act and safety regulations to include specific design and operational safety requirements for CAV.

SY-03E Strategies for CAV, experiencing problems affecting its ability to safely operate, to move out of traffic lanes and rest in a secured area while minimizing the impacts to traffic. An example is to designate existing safe areas along roads where CAV can resort to during emergencies until events are cleared or human control is secured.

SY-04 **Enforce rules of the road under mixed and full CAV operations** to ensure safe operation of transportation network. This includes evaluating the safety of commercial CAV operating in mixed traffic on dense urban streets and on highways and taking necessary precautions to ensure the overall safety of the transportation network.

6.4 STANDARDS (STD)

The presence of CAV on the transportation network will require agencies to evaluate and consider the impacts on data, security, privacy, physical infrastructure, interoperability, safety, design and maintenance standards. An audit and update of these standards are important to ensure a seamless integration of CAV into the transportation system over varying levels of CAV saturation. **All levels of governments need to review existing standards and identify areas where updates are needed to accommodate CAV operations.** Many of the standards in place will be relevant to CAV operations, while other standards may require updates and evolve over time as CAV increases presence on the transportation network. These updates could be determined based on key needs identified by pilot programs throughout the GTHA.

Elements of this Standards guideline include the following:

STD-01 **Conduct an international scan to evaluate the role that the public sector is taking in the development of data, privacy, security and other standards related to CAV.** Consider the role of the various levels of government versus the private sector and, through liaising with the private sector, define an approach to move forward, including:

STD-01A Analysis of current privacy laws to develop an understanding of their applications and what is required to update them.

STD-01B Recommendations for new open data, privacy and cybersecurity standards, for a connected environment, to address security and privacy issues in accordance with emerging international best practices and standards (e.g. cooperative intelligent transport system (C-ITS) technology standards, EU General Data Protection Standards).

STD-02 **Audit and update various provincial, municipal and regional design guidelines, by-laws and standards** in consultation with industry to reflect new design approaches and changes for CAV. These audits and updates include:

STD-02A Updates to temporary works equipment standards to accommodate V2I connectivity during construction and maintenance projects.

STD-02B Updates to provincial and national standards, in consultation with industry, the federal government, and other national standards organizations, to reflect needs for pilot programs and increasing CAV saturation on roads. These standards include, but are not limited to Ontario Minimum Maintenance Standards, Ontario Traffic Manual (OTM), Ontario Provincial Standards (OPS),

STD-03 **Audit, update and/or develop safety and maintenance standards** for a connected and automated environment with increasing levels of CAV saturation, including:

    STD-03A Standards for smart roadway infrastructure (e.g. incident detection and communication infrastructure) to enhance traffic flow and safety with an increasing presence of CAV. This also includes updates to maintenance standards for safety critical infrastructure (e.g. V2I infrastructure) to reflect the needs of an increasingly connected environment and ensure they are in good operating condition.

    STD-03B Relevant provincial, regional and municipal training standards/certifications related to operating and maintaining public CAV fleets. This also includes a review of federal (Transport Canada) Motor Vehicle Safety Standards for vehicle design and equipment, including technical specifications for vehicle communications, to understand the limitations of the standard and advocate to ensure that any necessary and relevant changes are implemented.

STD-04 **Establish standards to guide the development, implementation and operation of necessary tools for data information and technology needed to support CAV**, such as a high-resolution, centralized map of the transportation network or a spatial data specification containing detailed network information. This includes requirements for the level of detail and type of information to be included on the map or data specification to assist operations of CAV, as well as requirements for maintenance (e.g. frequency of updates, quality of information, etc.).

6.5 TRANSIT SERVICE PLANNING (TSP)

The rise of emerging technologies is bringing a transformation to the public transit sector. CAV technologies can further provide transit agencies with an opportunity to redefine public transportation. They may be able to address first-mile/last-mile trips, whether provided by transit agencies or private mobility service providers and reduce the accessibility barriers to public transit that some users experience.

Generally, transit vehicles have already been connected to infrastructure and management centre; however, with advancement in connectivity, public transit vehicles can also expand to connect to other vehicles on the road. **Policies, procedures and standards on how transit services are delivered, as well as the fare structure are essential to ensure safety, equity and accessibility for all users.** Through pilot programs, transit agencies can test the ability of CAV technologies, evaluate their feasibility, cost, and impacts, as well as identify gaps created in transit service operations. **The impacts of CAV on other capital projects, as well as travel demand in all modes of transportation will also need to be evaluated** and planned for through the development of new transit service strategies or business models.

Elements of the Transit Service Planning guideline include the following considerations:

TSP-01 **Identify the impacts of CAV and associated ride-hailing models** (e.g. first-mile/last mile transportation), and how transit agencies can work together to

achieve a common goal of developing efficient transit services for the public. This includes the following:

TSP-01A Analysis of existing transit services strategies and business models to identify opportunities to incorporate CAV and shared mobility into transit networks while meeting the demands of the public, including underserved users and coverage areas (e.g. time of day and location).

TSP-01B A business case to integrate transit services with on-demand mobility service providers to maintain/attract transit mode share from shifting to other CAV operated modes. For example, private mobility services could provide first-mile/last-mile services, in coordination with public transit, to improve access to major transit stations.

TSP-01C Policies to ensure equal accessibility for mobility and to ensure equity in service levels with barrier free access to transit services. This includes mandating the need for all new CAV transit vehicles to be able to effectively accommodate accessibility needs of users.

TSP-01D Policies to address responsibility and liability concerns when transferring customers from public transit services to private mobility services, especially in the case when the two services are integrated and co-operating to fulfill passenger trips.

TSP-02 **Assess and define requirements for rural and urban transit stop/station design** guidelines to incorporate first-mile/last-mile service requirements for pick-up and drop-off areas, including considerations for accessibility requirements. This assessment can begin in the early stages of CAV saturation, including testing of different design layouts, and then implemented with increasing CAV saturation.

6.6 TRANSPORTATION PLANNING (TPP)

Transportation planning covers a wide variety of subjects relating to the planning and development of transportation infrastructure, as well as forecasting the demand that the transportation network will need to accommodate. CAV introduce new opportunities and potential challenges for planning agencies with respect to identifying, prioritizing, and evaluating projects and programs. Transportation planning documents, including official plans, long-range transportation plans and goods movement plans, will need to be reviewed and updated to include planning for CAV. **New approaches will have to be developed to incorporate CAV technologies into transportation plans and frameworks, transportation models, data analyses and business case evaluations.** Valuable data can be collected and derived from pilot programs, as well as connected traffic, to allow transportation planners to gain a better understanding of the impacts of CAV and the overall transportation network.

Elements of the Transportation Planning guideline includes the following:

TPP-01 **Review and update transportation planning and research initiatives**, **as well as planning documents**, to account for increasing levels of CAV saturation and identify needs for a safe transportation network. The review and update should consider:

TPP-01A CAV and new mobility concepts in business cases for transportation capital projects, as well as in transportation masterplans. This includes an assessment of available funding and updates to by-laws.

TPP-01B Giving priority to high-occupancy vehicles in planning and infrastructure development initiatives to promote sustainable transportation and mitigate the potential increase in congestion due to zero occupant trips.

TPP-01C Changes to the Planning Act, Environmental Assessment Act, provincial growth plan and policy statement to reflect needs and considerations of CAV.

TPP-01D Changes to official plans, regional transportation masterplans and strategic plans to address CAV requirements, including the planning of roads, parking, curbside management, congestion management and interaction of CAV with other road users (e.g. aging populations and persons with disabilities).

TPP-01E Changes to Goods Movement Strategic and Long-term Plans to consider and evaluate technological advances in commercial CAV operations (such as the use of connectivity and platooning), as well as promote innovation in commercial delivery.

TPP-01F Changes to ITS Strategic Plans and Provincial ITS Architectures to include CAV (for concept of operations and feasibility studies), as well as necessary cybersecurity measures. This can help determine what ITS technologies could benefit transportation operations with increasing CAV saturation.

TPP-02 **Update transportation planning, travel demand modelling and traffic simulation practices and requirements to consider CAV and leverage new data** available through updated revealed preference and stated preference surveys. The Transportation Research Board NCHRP Research Report 896 is a key reference for updating regional transportation planning and modelling tools to address impacts of CAV.[8] Collaboration between different agencies across the province would be required to ensure these updates are consistent and reflect the needs of all users. This includes the following:

TPP-02A Stated preference surveys on CAV technology and incorporating questions in the Transportation Tomorrow Survey (TTS). This can be a method used in initial and transitional phases of CAV use to gauge an understanding of the demand they will induce.

TPP-02B A System Dynamics Model to analyze dynamic behaviour of an evolving transportation system with CAV, including economic and social implications and changes that would result from shifts in transportation trends. The model outputs should be used to inform accurate predictions and guide transportation planning initiatives (e.g. updates to travel demand models and simulation tools).

TPP-02C Updates to travel demand and mode choice models (e.g. GTAModel V4.0, GGHM4.0) to incorporate CAV and shared modes in long-term planning and forecasting of demand, capacity and mode choice. The model updates should include consideration

of the impacts of CAV on where people are travelling to/from, how many trips they are making, their mode choice (private, transit, shared), their value of time, vehicle ownership, vehicle occupancy and changes associated with freight delivery.

TPP-02D   Enhancements to simulation software, by pursuing vendors, to implement updates for modelling CAV in mixed traffic conditions. These updates should allow for simulations of the transportation network with varying levels of CAV penetration, connectivity (V2I2V) and commercial vehicle platooning to evaluate and quantify impacts on traffic operations, safety, and curbside behaviour.

TPP-02E   Datasets with consistent information for different timeframes of CAV saturation, to be used as model parameter input values. Key driving characteristics of CAV can be expanded to investigate the impacts of their operations on travel demand and traffic operations. These model parameters can initially be developed from data collected through pilot programs monitoring CAV operations, and then further modified by using real-time traffic data collected by CAV.

TPP-02F   Updates to asset management, maintenance and life-cycle cost analysis models, including considerations for maintenance of infrastructure that could be impacted by increased road use, as well as hardware and software updates for ITS technology.

TPP-03   **Evaluate the impact of CAV on regional employment, land-use and government revenue sources**.   This would involve research and planning initiatives, including:

TPP-03A   Assessment of CAV and related business model impacts on employment and skillset required to work in an increasingly connected and automated transportation industry. This includes the displacement of truck and courier service drivers, taxi/bus drivers, traffic police, parking attendants etc.

TPP-03B   Methods to predict CAV impacts on land-use, such as the need for parking within the urban core, as well as the possibility of urban sprawl, as commuting may become easier and more pleasant with increasing levels of vehicle connectivity and automation.

TPP-03C   Assessment of the fiscal impacts to governments and their revenue sources. This includes forecasting lost revenue from sources that may no longer be steady with CAV (e.g. parking fees, traffic infractions etc.), as well as identifying opportunities to replace lost revenue sources (e.g. pricing zero occupancy CAV, etc.).

TPP-04   **Evaluate community energy plans and electric grid performance**, including a forecast of demand with increased (electric) CAV, telecommunication infrastructure and communication systems. This would include an assessment to determine if any upgrades are required to the electric grid and whether the increased demand can be accommodated with existing resources.

7 PUBLIC LEVERS

7.1 BONUS/MALUS POLICY (BMP)

Advancements in technology often lead to a change in travel behaviour. CAV have the potential to induce a widespread shift in how transportation operates within the region. These vehicles could lead to a shift in mode share and alter the number of vehicle trips, average trip length and demand for personal vehicle travel. These impacts could positively or negatively affect congestion across the region's transportation network and environment.

Transportation and transit agencies can influence travel behaviour within the region by introducing policies for incentives (bonus) or disincentives (malus) to specific travel behaviours. Governments can also influence how land-use is transformed by developers, as CAV could lead to changes to the overall fabric of the urban environment. Bonus/Malus levers could be used to reward the population for reducing trips, taking trips at alternate times, sharing trips, choosing less impactful modes, or penalize them for making choices that increase congestion. These policies can cover a wide variety of topics ranging from promoting higher vehicle occupancy (transit or shared use), aggregation of goods delivery, encouraging the adoption of new types of vehicle powertrain technology such as Electric Vehicles (EV), and influencing the redevelopment of land within the region. These policies will evolve as CAV increase their presence on roads.

Elements of these Bonus/Malus Policy guidelines can include the following:

BMP-01 **Develop a policy to incentivize high-occupancy trips and manage the impacts of low occupancy or zero-occupancy vehicles** through pricing, improved travel time benefits and convenience benefits. This could include:
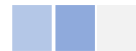
    BMP-01A Mobility or congestion pricing framework (e.g. dynamic pricing, congestion charge etc.) that encourages high-occupancy vehicle and transit trips while discouraging single- and zero-occupancy vehicle trips. This can also include a progressive fee by distance travelled for single-occupancy vehicles. A review and update of the Municpal Act may be requried to provide municipalities with the ability to implement this framework. These policies should ensure that funds collected are used for infrastructure and service enhancements that may be needed to support CAV.

    BMP-01B Increased high-occupancy lanes on the transportation network to reduce travel time for those car-pooling and choosing to ride in high-occupancy modes.

    BMP-01C Dedicated parking for car-pool and high-occupancy vehicles in public parking lots, to attract users through improved convenience.

BMP-02 **Develop a policy to promote the use of public transit** by using mobility services and shared mobility to streamline and complement public transit services. Subsidizing mobility services or integrating it with transit fares could promote the use of on-demand mobility services as a mode to access transit and increase ridership, as opposed to fully replacing transit as a travel mode.

BMP-03 **Develop a policy to influence an increase in development and adoption of electric CAV** to reduce the environmental impact of transportation within the region. These incentives can be in the form of financial credits to electric CAV users, priority parking with free electric charging stations, and improved availability of electric vehicle charging stations throughout the transportation network.

BMP-04 **Establish incentives, in the form of credits, for developers who re-purpose underused land** that is no longer needed to support the transportation network because of CAV. These incentives could promote the conversion of excess parking infrastructure into transit-oriented development or other land-use developments to satisfy needs of the urban areas (e.g. green space, housing, office spaces, neighbourhood facilities etc.) and promote transit and other high-occupancy trips. This also includes any updates needed to the Planning Act to incorporate and define a credit incentives program for developers.

7.2 TRAFFIC LAWS AND REGULATIONS (TLR)

With the advancement of transportation technology, traffic laws and regulations will need to be reviewed to accommodate increasing levels of CAV on the road. Even though CAV will need to adhere to existing laws and rules of the road, there may need to be revisions and updates to allow for legal operation of self-driving cars and pilot program initiatives. These updates are considerations that need to be kept in mind at early levels of CAV saturation to begin paving the way for legal operation of CAV on public roads. However, their widespread implementation and enforcement will become more relevant when automation becomes more prevalent in how the transportation network is operated and how people and goods are moved. **Revisions to traffic laws need to be in place to provide a legal framework to follow during the transition phase with mixed CAV and conventional vehicle traffic, and to enable deployment of CAV.** Assessing existing traffic laws, regulations and driver and vehicle licensing requirements, as well as enforcing these changes will be key in ensuring the lawful and safe operation of the transportation network. These updates will stem from the provincial level, but their enforcement will reach down to the regional and municipal levels, as well.

Elements of the Traffic Laws and Regulations guideline include the following:

TLR-01 **Develop legislation that amends existing traffic laws** and paves the way for CAV to legally drive on provincial, regional and municipal roads and highways, while highlighting how enforcement differs between CAV and conventional vehicles. This would include:

TLR-01A Updates to the Highway Traffic Act and associated regulations on CAV pilot projects and legislative rules regarding safe network operations, cooperative truck platooning, and impaired, distracted and careless driving.

TLR-01B Updates to the Highway Traffic Act to address requirements for maintaining a safe transportation network with mixed CAV and conventional vehicle traffic. This may include broadcasting special traffic requirements (e.g. speed limits, turning restrictions etc.) to CAV to ensure compliance of rules and regulations.

TLR-01C Updates to the Highway Traffic Act to reflect requirements for a transportation network with primarily CAV operations, including considerations for regulating the safe operation of a small

proportion of conventional vehicles that may be present on the transportation network and reducing restrictions on CAV.

TLR-02 **Enforce new traffic laws and regulations** related to pilot programs (few CAV), mixed CAV/conventional vehicle traffic and primarily CAV deployment. The level of enforcement and traffic law needs will differ depending on the level of automation of the CAV, as SAE Level 5 will have different enforcement needs from SAE Levels 2-4. This involves engaging law and by-law enforcement partners to implement legislative and regulatory amendments, including:

TLR-02A Rules for distracted, impaired and careless operation of CAV at the provincial, regional and municipal level.

TLR-02B New traffic laws and regulations for increasing levels of CAV saturation on all roadway classifications (provincial highways, municipal streets and expressways).

TLR-03 **Develop licensing requirements for CAV**, in coordination with other agencies across the nation, to identify needs for updates to traffic laws, licensing and insurance requirements, as well as addressing needs for incident responsibility and liability. This can include:

TLR-03A Amendments to traffic laws and by-laws to include vehicle permits, consistent regulations for ride-hailing services and driver/operator licensing requirements.

TLR-03B Insurance coverage requirements for personal and commercial CAV operations, as part of pilot programs and regular use, as well as defining incident responsibility and liability.

7.3 INFRASTRUCTURE POLICIES AND REGULATIONS (IPR)

CAV will be able to operate with existing infrastructure, but **there may be a need for policies, regulations and strategies to identify the need for changes to physical infrastructure requirements.** This may include implementing changes to road signs and pavement markings, as well as more frequent infrastructure maintenance. As CAV are an evolving area of transportation, the infrastructure requirements will also evolve and the degree to which infrastructure will be impacted will be determined over time. Transportation agencies could assess different physical changes and technologies through pilot programs to update or modify the requirements.

Elements of the Infrastructure Policies and Regulations guideline include the following considerations:

IPR-01 **Develop policies and management strategies** to identify needs for physical infrastructure changes to accommodate a mix of CAV and conventional vehicles in both urban and rural contexts. These strategies may include:

IPR-01A Policy to adapt infrastructure to support CAV deployment. This includes the integration of community benefit agreements for large-scale infrastructure projects to ensure community interests and requirements are considered.

IPR-01B Policy for dedicating parking locations for CAV pilot programs and evaluating the need for on street parking spots, municipal parking lots and parking spots for developments, as CAV could self park outside of core areas.

IPR-01C   Zoning changes required to repurpose land, used for parking infrastructure no longer needed, to other uses (e.g. reclaim parking land and convert to green spaces, housing etc.)

IPR-01D   Curbside management strategies and by-laws for on-street parking and passenger pick-up/drop-off, urban deliveries, and pick-up/drop-off areas at transit stations. The development of this curbside management strategy could include a feasibility study on dedicating properties (e.g. underutilized parking lots) for passenger pick-up/drop-off or urban deliveries to remove interruptions to urban traffic flow resulting from curb space use.

IPR-02   **Update zoning by-laws or other by-laws to drive infrastructure needs**, including identifying updates to the Planning Act.

8 PILOTS

8.1 PILOT PROGRAMS (PP)

Pilot programs play a key role in assessing, evaluating and testing any new technology. With respect to CAV and connected infrastructure, **pilot programs are critical in assessing infrastructure and operational needs of a transportation network**, as well as testing different designs and strategies, and identifying needs for legislation, regulations and policies and for building capacity within organizations. Pilot programs allow testing of a wide variety of topics including physical infrastructure arrangements, ITS technology, mobility service arrangements, transit, and commercial vehicle operations, in both urban and rural areas. **All levels of public agencies, in cooperation with the federal government, should commit to a common approach for the testing and use of CAV** and be open in accommodating trials of CAV on roads to better understand their needs and identify requirements. The development of a pilot project registry will avoid duplication of testing initiatives, allow shared testing opportunities and can allow for lessons and results to be shared. The pilots can also be tied back to the tests associated with each phase described in the technology's Concept of Operations. It is important to note that pilots may not have an infrastructure connectivity component, depending on the nature of the project.

Building upon successful pilots and testing programs will contribute to laying the foundation for the development of future regulations and identify areas of focus for governments and transportation agencies. Pilot programs can be conducted directly by transportation agencies or in cooperation with vehicle manufacturers, academia and other organizations interested in testing new programs that use CAV technology. Government agencies can leverage these industry and academic insights in the short-term to continually update guidelines for CAV testing as needs arise.

Elements of the Pilot Program guideline include the following considerations:

PP-01   **Establish a governance plan outlining a consistent framework and dedicated funding stream** for feasibility studies and pilot programs to satisfy needs of the region, research requirements and to ensure compliance with Ontario O. Reg 306/15: Pilot Project – Automated Vehicles. Specifics of this provincial framework could include:

     PP-01A   Information aggregated on all pilots related to connected infrastructure and CAV pilots within the province, including identification of areas where CAV reverted to manual control to better understand the infrastructure and safety implications.

     PP-01B   Pilot program needs, data needs, key performance indicators and measures of effectiveness, including how public fleets can be used for testing.

     PP-01C   Criteria for evaluating proposed pilot applications from industry, academia and other trial organizations.

PP-02   **Leverage Level 4 and Level 5 pilot programs initiated by the private sector through Ontario's legislation which requires MTO approval to investigate the interaction of connected infrastructure and CAV.** This can cover connectivity with traffic signals, the traffic management centre and pedestrian/cyclist detection infrastructure. These pilot programs will develop an understanding of how CAV can connect with surrounding infrastructure technology and include the following:

PP-02A V2I pilots that test connectivity between traffic signals, the traffic management centre, and CAV to facilitate testing of the interaction of the technologies.

PP-02B Vehicle-to-pedestrian and vehicle-to-cyclist (V2P) connectivity pilots, integrated with CAV pilots, to test interaction of CAV with pedestrians, including broadcasting warnings of the presence of pedestrians and cyclists to commercial CAV when on local roads.

PP-02C Connected (V2I) transit signal priority infrastructure pilots, integrated with CAV pilots to test the interaction of regular traffic with transit vehicles on dedicated transit corridors.

PP-02D Connected (V2I) emergency vehicle signal priority infrastructure pilots, integrated with CAV pilots, to test the interaction of regular traffic with emergency vehicles.

PP-02E Cybersecurity, privacy and data protection methods integrated with connectivity (V2I) and CAV pilots to assess and test various strategies to ensure the integrity and secure operation of the transportation network for all users.

PP-03 **Establish pilot programs that investigate physical infrastructure arrangements, as well as the interaction of CAV with other vehicles and vulnerable road users.** These pilots will be important to test CAV in different infrastructure layouts, evaluate their ability to adapt to temporary road changes due to construction, or incidents etc., as well as assess the safety reliability of the technology. Specific pilot programs may include:

PP-03A Pilots to test temporary physical infrastructure requirements, compatible with CAV, to facilitate navigating around construction sites and other conditions resulting in temporary road/lane closures.

PP-03B Pilots to explore different pick-up/drop-off (PUDO) configurations at transit station/stops and along urban streets to accommodate emerging mobility options that would increase the demand for available curb space.

PP-03C Pilots to assess the interaction of CAV with conventional vehicles on current road layouts, including a pilot project focusing on single lane configurations at higher speeds (e.g. rural highways).

PP-03D Pilots to assess the interaction of CAV with other vehicles (CAV or conventional), pedestrians crossing the road, and cyclists. This includes assessing the performance of CAV interactions with pedestrians and cyclists while considering different age groups, and accessibility requirements (e.g. technology to facilitate the interaction of CAV with the visually and hearing impaired).

PP-03E Pilots to assess the CAV interaction with emergency services and first responders, including their ability to identify emergency services needing priority and clearing a path for passing etc.

PP-03F Pilots to assess the performance of CAV equipment (e.g. sensor detection range, pavement marking detection and communication technology, etc.) under different weather conditions to test possible solutions for interference. For example, pavement-embedded sensors

that allow all-season detection may address the obstruction of road visibility due to snow, and wet reflective markings may address challenges under heavy rainfall.

PP-03G Pilots to explore innovative technologies to support CAV operations, such as smart pavement that can track and communicate vehicle locations for emergencies, traffic conditions, and road conditions, as well as broadcast warnings to CAV when needed.

PP-04 **Establish pilot programs that investigate transit service options within the region.** CAV will introduce new opportunities for the provision of transit services and other mobility services. With transit vehicles making frequent stops and interacting with pedestrians, testing technology and service arrangements will be critical. Specific pilot programs may include:

PP-04A Pilots for transit operations on candidate transit corridors to evaluate the performance of the technology for dedicated transit right of ways in both segregated and un-segregated environments (e.g. Bus Rapid Transit).

PP-04B Pilots to test transit operations with CAV technology, including the testing of automated shuttle bus services, or the implementation of CAV buses on certain routes.

PP-04C Pilots to test different mobility service arrangements, such as integrating services with private rideshare companies to facilitate first-mile/last-mile trips. This pilot would initially be used to test arrangements on a subset of the population to explore travel behaviour impacts on different users and then expanded to broader areas of the population.

PP-05 **Establish pilot programs that investigate commercial vehicle operations** for both inter-regional and intra-regional delivery. CAV create an opportunity for improving the efficiency of the transportation and delivery of goods across the region. Understanding impacts of increasing levels of automation and connectivity on freight transportation and the implications for the broader transportation network are key considerations for agencies. Specific pilot programs may include:

PP-05A Pilots to test how CAV could impact delivery operations. This may include designating specific delivery vehicle stopping locations and pilot networks/corridors/neighbourhoods to test the technology.

PP-05B Pilots to test different delivery strategies (e.g. off-peak delivery, last-mile delivery technologies etc.), to reduce the impact of freight deliveries on vehicle, pedestrian and cyclist traffic within urban areas. This would require cooperation between local transportation agencies and freight operators and a review of by-laws for after hours deliveries and the use of other (robotic) technologies on sidewalks.

PP-05C Pilots to test platooning of long-distance, commercial CAV to identify the limitations of the technology and evaluate the interaction of platooning trucks with other traffic to determine if a dedicated platooning lane is necessary. These pilots can be completed in coordination with freight transportation companies to allow for them to evaluate the advantages/disadvantages of using this technology.

PP-05D   Pilots to test dynamic signal timing adjustments for accommodating urban delivery vehicles to determine the effectiveness in improving travel times, reducing congestion and ensuring passenger vehicle throughput is not compromised.

PP-06   **Establish pilot projects that focus on testing CAV technology uses for municipal maintenance operations.** This includes assessing the performance of CAV for snow clearing, grass cutting, public park maintenance, garbage collection etc.

9 CAV PROGRAMS

9.1 REGIONAL COLLABORATION

Preparing for a future with CAV requires intentional collaboration across various public agencies and with private sector organizations. Inside of each of the individual agencies, there are limits to the amount of time and resources that can be devoted to preparing policies and regulations, infrastructure and daily operations to support implementation of CAV. When combined, the impact of a coordinated effort and collective investment across provincial, regional and local agencies is significant and will help to understand the uncertain future while avoiding duplication in efforts.

The CAV Readiness Plan was led by a Steering Committee (MTO, Metrolinx, City of Toronto, Region of Peel and WSP), which engaged over 70 Stakeholders from GTHA public agencies, academia and relevant industry organizations. The vision is to **continue a coordinated approach to a CAV future through a CAV Liaison Committee that will facilitate discussion and collaboration between public agencies to support CAV technology preparations, implementation and education.** The committee could further help bring together interested parties to implement the programs identified in the CAV Readiness Plan (**Section 9.2**) and work towards fostering the development of a CAV integrated transportation system in the GTHA and surrounding network. Lessons learned and input from other agencies in Ontario and Canada would also be welcomed as part of the initiative of the CAV Liaison Committee.

The following mission statement for the CAV Liaison Committee was derived from Stakeholder feedback through the workshops:

> **Help prepare public sector agencies, in the GTHA and surrounding areas, to connect and collaborate in their efforts to implement CAV technology to achieve their regional transportation goals and objectives**.

9.1.1 RESPONSIBILITIES

Based on the ideas developed in the CAV Readiness Plan, the CAV Liaison Committee will:

- Serve as a focal point to coordinate activities among industry, academia, research organizations and governments.
- Share the CAV Readiness Plan with Stakeholders, public and private industry partners to connect interested parties and facilitate inter-agency collaboration between Stakeholders.
- Develop a common message and approach to building capacity for politicians, councils, senior administrators and interested Stakeholders.
- Provide tactical support for the deployment of pilot projects, testbeds or innovation corridors undertaken by individual agencies through shared forums.
- Maintain a contact list of representatives and CAV leads from various participating agencies.
- Set a term length for the CAV Liaison Committee and revisit its effectiveness in terms of its purpose, role, responsibilities, vision, and structure.
- Assess what activities and structure needs to be established to enable the coordination of activities between various working groups (e.g. appointing a chair and a sub-chair, meeting frequency, etc.).
- Develop performance metrics to assess the progress of projects taken up by various working groups, with regular reporting to the central forum to transfer relevant knowledge between Stakeholders.
- Define a public campaign for a coordinated and targeted effort to build public awareness and educate on CAV related information.

Once the CAV Liaison Committee has been established and the initial responsibilities listed above have been addressed, the Committee may be responsible for the following activities on an ongoing basis:

- Develop and update the framework to help identify CAV Program needs and initiate new projects or working groups (e.g. identifying lead agencies for individual Programs, reviewing partnership opportunities, connecting Stakeholders with similar interests etc.).

- Develop an Advisory Group, external to the CAV Liaison Committee, that provides the prospective from academia, private sector, as well as industry and coordinates with the Toronto Region Board of Trade AV Readiness Council.

- Provide regular updates on existing and new projects to all members including a calendar of CAV events in Ontario.

- Develop and update proposed standard contractual language that local, regional and provincial agencies may choose to include in their procurement documents to ensure uniformity on CAV-related partnerships and Programs.

- Liaise with industry CAV working groups, technical committees, professional associations, legal bodies, insurance agencies and any relevant policy or governing agency to engage in CAV related discussions and share relevant information.

- Support the potential development of a Regional Centre of Excellence that will act as a sharing and collaboration platform to house information on all CAV projects and pilots in the GTHA and, where applicable, across Canada and globally (described in further detail below).

- Other activities defined in the Regional Collaboration (RC) guidelines.

9.1.2 REGIONAL CENTRE OF EXCELLENCE

The CAV Liaison Committee will support the vision of developing a Regional Centre of Excellence with the consideration of hosting a website to:

1. **Serve as an inter-agency collaboration platform** for hosting and sharing information, maintaining a contact list, facilitating trainings, broadcasting announcements, uploading data and sharing study/pilot outcomes and committee-related documents, as well as coordinating planning initiatives. This may include research, identification of observation areas, new pilot program needs, as well as tracking, evaluating and sharing data and lessons learned from CAV initiatives based in the GTHA and, where applicable, across Canada and internationally.

2. **Operate as a public facing resource** to communicate the progress of CAV-related projects and pilots, promote events and act as a library of completed studies and projects. An administrator will be identified by the CAV Liaison Committee to manage the development of the Regional Centre of Excellence website.

9.1.3 GOVERNANCE

It is proposed that the CAV Liaison Committee will be co-chaired by three organizations including the Ministry of Transportation of Ontario, Metrolinx and AVIN. After being established, the co-chairs will coordinate to further refine the vision of the Liaison Committee.

Local and regional municipalities, public transportation and transit agencies, as well as other industry and national Stakeholders will be invited to participate in the CAV Liaison Committee. They will be provided with information on key responsibilities, resources and timelines for participation. Membership will be free, and participants would have the option for renewal or to move to a higher or lower level of participation. Administration staff will be assigned to coordinate updates, meetings and task responsibilities of member agencies.

Where appropriate, external Stakeholders including private industry members, national organizations and representatives from academic or research institutes will be consulted by the CAV Liaison Committee or their working groups. The proposed structure of the CAV Liaison Committee is depicted in **Figure 9**.
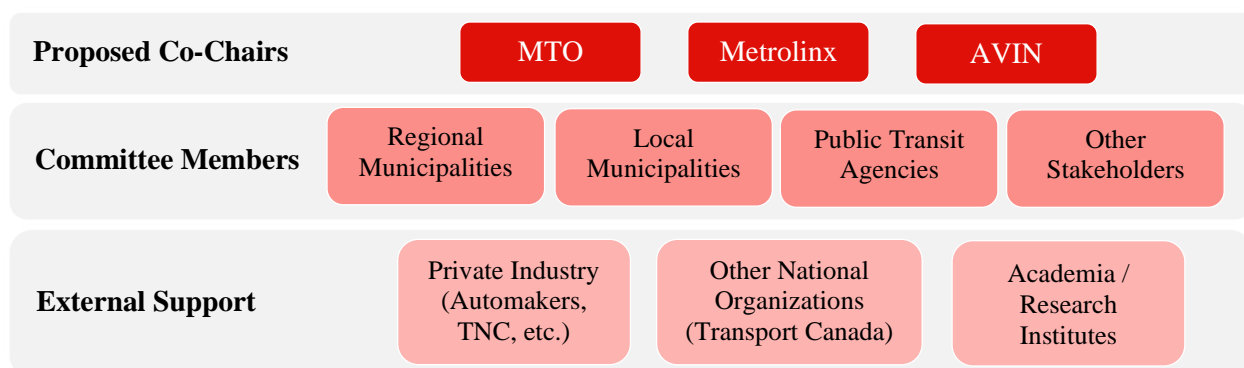

Figure 9: Governance Structure of CAV Liaison Committee

Four types of roles have been defined for the CAV Liaison Committee including co-chair, committee lead or pilot project lead, participating member and observing member. An overview of these roles is highlighted in **Table 2**.

Table 2: CAV Liaison Committee Roles and Responsibilities

Role	Committee Meetings/Discussions	Regional Centre of Excellence
Co-Chair	• Lead role • Manage memberships and sub-committees	• Manager / architect of Regional Centre of Excellence in charge of development and maintenance
Committee Lead/Pilot Project Lead	• Lead role on committees or driving a pilot project • Open access	• Key contributor for individual pilot projects
Participating Member	• Open access to all committees and sub-committees	• Potential Contributor
Observing Member	• Ad hoc access to all committees and limited access to sub-committees	• Potential Ad hoc contributor

The CAV Liaison Committee member agencies may provide staff time, funding, and/or cost-share with other agencies for specific programs that are of benefit and interest to them, on a case-by-case basis. For example, managing and funding a pilot project would be the responsibility of the interested agency. However, input could be solicited from other members of the Liaison Committee, while other agencies with interest in the pilot would be able to cost-share and provide funding, if they choose to do so.

9.2 CAV READINESS PROGRAMS

Five Programs have been identified with **a goal of preparing public transportation agencies in urban, suburban and rural areas to be CAV Ready.** The Readiness Guidelines formed the basis of each Program tasks and the Stakeholder feedback from the workshops helped identify the timing, priority and the most appropriate lead agency.

Each agency will self-fund their involvement in the CAV Programs, and funding arrangements (e.g. single source or cost-sharing), including grants, will be considered for each pilot and resulting project on a case-by-case basis. Each Program sheet was developed to be a standalone representation of the Program defined and includes detailed tasks to support the lead agency's efforts to develop a workplan, detailed budget and deployment strategy in the future, as needed. The tools developed through the CAV Readiness Plan, such as the scenarios and personas, should continue to be referred to and used as the Programs are implemented and delivered. These Programs are described at a high level in the following sub-sections with the full details provided in **Appendix F**:

- Program 1: CAV Development Streams (**Section 9.2.1**)
- Program 2: Development of CAV Modelling Tools (**Section 9.2.2**)
- Program 3: Pilot Projects Program Management (**Section 9.2.3**)
- Program 4: Data Needs and Management Plan (**Section 9.2.4**)
- Program 5: Development of a Regional Mobility Platform Strategy (**Section 9.2.5**)

The identified task leads for each Program will be responsible to track progress and gather support for implementation, as well as to regularly report back to the CAV Liaison Committee.

The CAV Programs are intended to guide and initiate the process of addressing the CAV Readiness Guidelines. The Programs and CAV Liaison Committee framework have addressed almost **80%** of the Readiness Guidelines. A table cross-referencing the Guidelines to Programs can be found in **Appendix G.**

9.2.1 PROGRAM 1: CAV DEVELOPMENT STREAMS

PROGRAM DESCRIPTION
Establish a number of Task Forces to continue to identify impacts that CAVs will introduce to the transportation network and its users. The presence of CAV on the GTHA transportation network will require agencies to evaluate and consider the impacts on data, security, privacy, physical infrastructure, interoperability, safety, design and maintenance standards. With these changes that CAV will introduce, it is an important initial step to formally dedicate resources to further explore the technology and begin the preparations for adapting the region to successfully integrate CAV on roads.

TASKS	
1	**Accessibility Assessment** Explore how CAV will change the needs of users with accessibility needs. Assess how accessibility requirements can be met under the operation of CAV on the transportation network.
2	**Vulnerable Road User Assessment** Assess the implications of CAV on vulnerable road users and how their daily transportation needs can be affected in terms of safety, accessibility, and interaction with vehicles, infrastructure and other road users.
3	**Regulations and Standards Development** Review and assess existing design, operations and maintenance standards in the context of CAV and provide key recommendations for necessary amendments or the development of new standards. Explore updates to standards (MUTCD, OTM, OPSS etc.).
4	**CAV Rural Road Assessment** Assess the implications that rural environments will have on CAV to identify needs for physical infrastructure changes to accommodate a mix of CAV and conventional vehicles.
5	**Government / Industry Forum** Assemble representatives from government and industry agencies to discuss CAV-related topics on an as needed basis and reduce silos in the CAV industry.
6	Review and assess the implications of CAV on operations and maintenance activities.

PROPOSED LEAD AGENCY
CAV Liaison Committee will establish a Task Force and identify a lead for each stream. The lead will be responsible for reporting back to the Liaison Committee.

9.2.2 PROGRAM 2: DEVELOPMENT OF CAV MODELLING TOOLS

PROGRAM DESCRIPTION

Develop a series of CAV modelling tools, including a System Dynamics Model, for the Province and update existing long-term transportation planning and operational analysis tools required to address the presence of new mobility technology in the transportation network. The GTAModel V4.0 and Greater Golden Horseshoe Model 4.0 (GGHM4.0) provide valuable inputs to long-term transportation plans and decision-making and will require parameter updates to consider the impacts of CAV and new mobility trends.

The System Dynamics Model will provide insight on potential alternative futures and analyze the complex dynamic behaviour of the evolving transportation system, including economic and social changes that would result from shifts in transportation trends. It would map out high-level, order-of-magnitude, cause and effect relationships between key components and parameters using mathematical algorithms representative of these relationships. These insights would be used to inform updates to long-term travel demand models and simulation tools to identify predictions related to transportation mode choice, route choice, traffic volumes, etc.

The CAV Readiness Plan scenarios could be used as the initial alternative futures tested through the System Dynamics Model. The outcome would identify additional data needs and parameter requirements to capture CAV effects in transportation planning models and simulations. Once the model updates are completed, subsequent iterations of the System Dynamics Model would inform parameter value changes to allow for updated future scenarios to be tested as the basis for policy decisions, transportation demand management strategies, and infrastructure needs with increasing levels of CAV and shared mobility.

TASKS

1	**Research and Literature Review** Conduct research and a literature review to identify cause and effect relationships of transportation, economic, social and policy factors that form the basis for the movement of people and goods within the region with respect to CAV.
2	**Building the System Dynamics Model** Build the overall System Dynamics Model with the researched relationships and calibrate it to provide the necessary outputs to guide transportation planning initiatives, including identifying needs for updates to travel demand models and simulation tools.
3	**Ongoing Data Collection** Develop a methodology to collect data based on the output of the System Dynamics Model (e.g. CAV consumer acceptance, travel behaviour, vehicle speed, acceleration etc.).
4	**Existing Travel Demand Model and Simulation Tool Updates** Update transportation planning, travel demand modelling and traffic simulation practices and requirements to consider CAV and mobility services, leveraging new data opportunities for more accurate predictions and simulations.
5	**Planning Initiatives Updates** Review and update current transportation planning practices, plans, strategies and projections based on results from updated transportation models, as well as new information and data gathered about CAV adoption, and the adoption of emerging business models.

PROPOSED LEAD AGENCY

Ministry of Transportation Ontario

9.2.3 PROGRAM 3: PILOT PROJECTS PROGRAM MANAGEMENT

PROGRAM DESCRIPTION

Establish a pilot project program management approach, coordinated across the region, to develop pilot programs to gather data and test various use cases related to CAV. The goal is to enable sharing of information and efficiency in testing by removing duplication in efforts. These pilot programs will play a key role in assessing, evaluating and testing CAV and connected infrastructure, identifying operational needs of the transportation network, testing different designs and strategies, and identifying needs for legislation, regulations and policies in both urban and rural areas. Public agencies, in cooperation with the federal government, should commit to a common approach for the testing of CAV and be open in accommodating trials on roads to better understand their needs. Each public agency may undertake pilots specific to their needs and interests, while sharing information and identifying opportunities to team up with other agencies on common interests.

Pilot programs can be conducted directly by transportation agencies or in cooperation with vehicle manufacturers, academia and other organization interested in testing new programs that use CAV technology. Pilot programs should be viewed as a resource to inform other project areas, serving as a key component of a feedback loop between other groups and pilots and used as a collaboration tool between different agencies. Government agencies can leverage these industry and academic insights in the short-term to continually update guidelines for CAV testing.

TASKS

1	**Inventory of Pilot Programs** Establish a centralized pilot program directory to track pilot programs within Ontario and that is to be maintained by the Liaison Committee at the provincial level.
2	**Possible Pilots: Physical Infrastructure Needs** Establish pilot programs with performance indicators and review criteria that investigate physical infrastructure arrangements and requirements to facilitate CAV operations.
3	**Possible Pilots: Vehicle Interactions** Establish pilot programs that investigate the interaction of CAV with other vehicles, technology infrastructure, and road users, integrating cybersecurity, privacy and data protection methods, and leveraging opportunities to work with automotive manufacturers and academia.
4	**Possible Pilots: Transit Specific Operations** Establish pilot programs that focus on transit service operations, including assessing new opportunities for the provision of transit services, as well as assessing technology improvements to facilitate transit operations.
5	**Possible Pilots: Commercial Vehicle Operations** Establish pilot programs for inter-regional and intra-regional commercial vehicle operations that assess how CAV will impact freight transportation and the transportation network.
6	**Possible Pilots: CAV Operations** Establish pilot programs that explore how transportation network operations could change with CAV and what opportunities are available for operational improvements.

PROPOSED LEAD AGENCY

CAV Liaison Committee Co-Chairs and individual organizations, that form part of the Liaison Committee. These members would conduct their individual pilot projects and report progress and results back to the Liaison Committee.

9.2.4 PROGRAM 4: DATA NEEDS AND MANAGEMENT PLAN

PROGRAM DESCRIPTION

Develop a consistent regional data management plan that will bring accountability to all parties involved. The plan will define the type of data and its purpose with respect to the needs of planning initiatives and public-agency requirements, the roles and responsibilities of key players, a data sharing model, data retention policies, digital infrastructure needs, security and privacy requirements, as well as a data dictionary.

Pilots offer an early opportunity to be exposed to the data CAV can produce. This data can be used to inform infrastructure, operational, planning and policy decisions. As CAV saturation levels increase, data collection and management will need to be reviewed, as it is expected that changes will be required to monitor the transportation network and improve safety and operation.

A consistent definition of data in the region will allow agencies to compare and analyze the strengths and weaknesses of pilots and deployments. The use of data mining techniques will identify opportunities for operational enhancements and will provide clarity on what data needs to be requested in contracts for pilots and other projects.

TASKS

1	**Initial Research and Needs Analysis** Conduct comprehensive research and a market scan to establish data needs and data management requirements for CAV in Ontario.
2	**Data Standards Needs** Establish needs for enhanced data standards for CAV-related data collection, sharing, access, privacy, and security to be communicated to the federal and provincial governments through the CAV Liaison Committee.
3	**Mapping Needs** Assess needs and define responsibilities, for the private and public sectors, for the development and maintenance of a high-resolution map and/or transportation network spatial data specification for CAV operations.
4	**Data Repository Needs** Define the needs for a data repository to collect, process, store and host large datasets collected by public and private CAV, as well as ITS or communications infrastructure.
5	**Regional Data Management Plan** Develop a plan to present recommended enhancements to data standards, identify key roles and responsibilities of public and private sector agencies and to define a framework that will monitor the performance of data collected against key performance indicators (KPI).

PROPOSED LEAD AGENCY

There may be multiple lead agencies depending on the type of data being considered, but all levels of government will be involved through a Task Force (including MTO, Transport Canada and municipalities).

9.2.5 PROGRAM 5: DEVELOPMENT OF A REGIONAL MOBILITY PLATFORM STRATEGY

PROGRAM DESCRIPTION

Develop a Regional Mobility Platform Strategy, including the enabling governance and operation components. This strategy will explore various considerations including methods of fare integration, opportunities for leveraging existing trip planning applications, partnerships between public and private sector mobility services providers, regulations to guide private-sector development of mobility platforms and the need for a region-wide approach to offering shared mobility services. It is important to note that CAV could contribute to the provision of mobility services, but it is not critical to its implementation. This strategy would also consider leveraging existing mobility service options that do not necessarily rely on CAV technology.

TASKS

1 — **Project Steering Committee**
Establish a working group with designated staff members from partnering agencies to participate in ongoing discussions and document review.

2 — **Literature Review**
Undertake a literature review on the development of regional mobility platforms from both academic and industry sources around the world.

3 — **Mobility Platform Needs**
Develop an Action Plan that identifies trip planning needs, business models, policies and frameworks required to transition to a regional Mobility Platform and integrating CAV, mobility services, and existing transit services.

4 — **Legislative, Regulatory and Policy Recommendations**
Outline a legislative, regulatory and policy framework for public and private mobility service providers participating in the Mobility Platform.

5 — **Data Needs and Management**
Determine requirements for a data governance model specific to data collected from regional mobility service providers, while also considering data privacy requirements.

6 — **Regional Transportation Planning and Model Updates**
Determine the impacts that emerging mobility models and technologies will have on transportation planning, modelling and simulation practices.

7 — **Delivery Partnerships**
Coordinate with key partners in the region on approaches to building a regional Mobility Platform, including identifying potential partnerships with private-sector companies.

8 — **Deployment Approach**
Identify the deployment approach to be used to deliver the Mobility Platform, including pilots, utilization of an alternative procurement approach, or a traditional design-bid-build approach.

9 — **Implementation**
Determine implementation strategies based on the deployment approach identified in Task 8 and complementary work conducted by other GTHA agencies.

PROPOSED LEAD AGENCY

Metrolinx, as the regional public transit authority, as well as the Provincial government.

10 CONCLUSIONS & NEXT STEPS

The arrival of Connected and Automated Vehicles (CAV) is no longer a question. As technology advances, increasing levels of connectivity and automation are becoming more of a reality on public roads. CAV can communicate with other vehicles, surrounding infrastructure and road users, while also using on-board computers and sensors to automate driving tasks and navigate roads. These vehicles have the ability to improve transportation safety, efficiency and sustainability – but these opportunities will also come with challenges. The CAV Readiness Plan is a guidance document that provides a consistent framework of alternative future scenarios, persona characteristics, guidelines and programs. It provides public agencies with tools that are intended to highlight the important considerations for a seamless integration of CAV on public roads.

The first step for public transportation agencies in the GTHA is to formally establish the CAV Liaison Committee. Once established, it will oversee the implementation of the CAV Readiness Plan by initiating work on the key priorities identified in the CAV Programs. There were five CAV Programs that were developed, including:

1. **CAV Development Streams** – Establishes a number of Task Forces to continue to identify impacts that CAVs will introduce to the transportation network and its users.

2. **Development of CAV Modelling Tools -** Develops a System Dynamics Model and identifies necessary demand and simulation model updates to existing long-term transportation planning and operational analysis tools to address CAV in the transportation network.

3. **Pilot Projects Program Management** - Manages pilot projects that will gather data, assess and evaluate CAV and connected infrastructure, identify operational needs, test different designs and strategies, and identify needs for legislation, regulations and policies.

4. **Data Needs and Management Plan** – Defines needs for data standards, data dictionary, message sets, repository, security/privacy needs and creates a Data Management Plan.

5. **Development of a Regional Mobility Platform Strategy -** Develops a strategy that explores fare integration, trip planning applications, public and private mobility service provider partnerships, mobility platform development regulations and the need for a region-wide approach to offering shared mobility services.

Funding opportunities and mechanisms for conducting pilot programs and delivering projects will need to be explored. Collaboration between transportation agencies for jointly funded projects and partnerships with the private sector can open opportunities to funding dedicated to innovation, research and commercialization. Stakeholders who have participated in the CAV Readiness Plan development are encouraged to participate in the Liaison Committee and contribute to fostering regional collaboration. Information will be provided to agencies regarding the opportunities and timelines for participation.

There are additional steps that other provincial and local public transportation and government agencies, beyond the GTHA, could take to implement elements of the CAV Readiness Plan. Despite being developed within the context of the GTHA, the scenarios, personas, Readiness Guidelines and CAV Programs are transferable and applicable to other jurisdictions across Canada. The governance structure for the Liaison Committee could be implemented locally within other regions and opportunities to collaborate with the GTHA Committee could also be identified.

The development of this CAV Readiness Plan has raised awareness amongst public agency Stakeholders on the potential impacts of the technology. It provides important considerations that are necessary to follow through with preparations for CAV on public roads. Participating in the next steps with a focus on regional collaboration and implementation of the five CAV Programs is important to ensure a regional approach in planning for CAV across the GTHA. Transportation is a rapidly evolving industry and it is clear that there is still a lot of work to prepare for a future that safely integrates CAV on transportation networks.

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APPENDIX

A

UNDERSTANDING CAV

TABLE OF CONTENTS

1 UNDERSTANDING CAV

Preparing for an uncertain future with the advancement of CAV technology requires an understanding of all the potential (and feasible) ways the technology can unfold within our region. There is a large amount of literature, often contradictory, around CAV relating to when they will be on the roads, what level of connectivity they will have and under which conditions they will be able to automate the driving task. This appendix provides some background and understanding around the current state of thinking relating to CAV.

1.1 WHY BOTH CONNECTED AND AUTOMATED VEHICLES?

The concept of self driving vehicles has been around for over 30 years and various terms have been used to describe them, including vehicle highway automation or cooperative vehicle highway automation etc. More recently, there have been two streams of development – connected vehicles (CV) and automated vehicles (AV).

In the CV stream, vehicles are connected and gather information from other vehicles and surrounding infrastructure to enhance safety and mobility. Connected vehicles rely on the capability to communicate with infrastructure, such as traffic signals, community/school safety zone signals and traffic management centres (vehicle-to-infrastructure, V2I). The interoperability of vehicle-to-vehicle (V2V) and vehicle-to-everything (V2X) communication will also become prevalent, but V2X connectivity will be dependent on the cooperation between vehicle manufacturers and the availability of the connectivity capabilities of the traffic control and management infrastructure provided by transportation agencies.

In the other stream, an AV relies only on its onboard equipment and sensors (LIDAR, radar, or camera) to sense its surrounding environment without necessarily communicating with other vehicles or infrastructure.[2] An AV combines data and intelligence from all onboard sensors to automate various aspects of the dynamic driving task and navigate through a transportation network. The Society of Automotive Engineers (SAE) classifies automated vehicles into six (6) levels of automation, summarized in **Figure 1.**
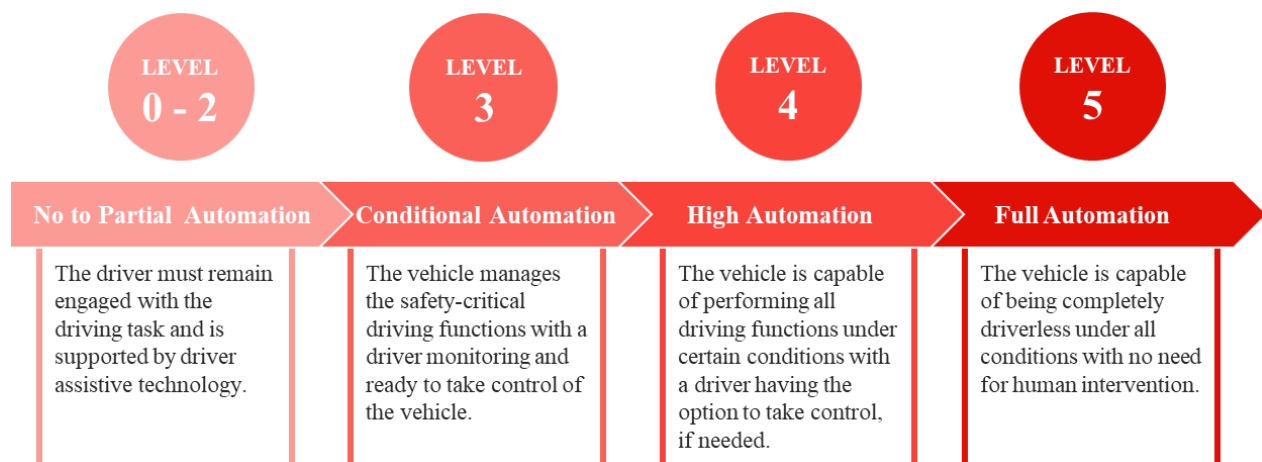

LEVEL 0 - 2	LEVEL 3	LEVEL 4	LEVEL 5
No to Partial Automation	**Conditional Automation**	**High Automation**	**Full Automation**
The driver must remain engaged with the driving task and is supported by driver assistive technology.	The vehicle manages the safety-critical driving functions with a driver monitoring and ready to take control of the vehicle.	The vehicle is capable of performing all driving functions under certain conditions with a driver having the option to take control, if needed.	The vehicle is capable of being completely driverless under all conditions with no need for human intervention.

Figure 1: SAE International Classification of automated vehicle levels[5]

The focus of the CAV Readiness Plan, in terms of automation, focuses on highly to fully automated CAV scenarios that are anticipated to appear in the future. This is based on policy and legislation developed in Ontario indicating the Province's commitment to testing connected and automated vehicle operations.

As technology advances and connectivity becomes more prominent across industries, researchers, vehicle manufacturers and government agencies are finding the benefits of combining the connected and automated streams. Connectivity will be required to achieve reliable highly to fully automated (driverless) systems connected to the internet for map information updates, and live traffic information.[9] Therefore, Connected and Automated vehicles (CAV) is the terminology that is most often being used, despite the type of connectivity and level of automation being classified separately. The National Highway Traffic Safety Administration (NHTSA), as part of the U.S. Department of Transport (USDOT), issued an advanced notice of proposed rulemaking for mandating vehicle-to-vehicle (V2V) connectivity technology on all vehicles manufactured, starting in the near future.[10] The date of when the proposed rule will take effect is still to be confirmed.[11] It is difficult to determine a regulatory pathway for AV in Canada and the U.S., as a self-certification regime for vehicle manufacturers is enforced. Manufacturers certify that their vehicles meet the motor vehicle safety standards of the regulator and are not required to seek permission to deploy new technologies, such as connectivity or automation. In general, vehicles sold in North America are manufactured to meet standards for both Canada and the United States. Therefore, it is assumed that vehicles operating in Canada will adhere to similar regulations, and so the V2V and connectivity mandate proposed by the USDOT is also expected to be adopted in Canada. As a result, all AV in the future will also be connected.

1.2 WHAT IS THE CURRENT LEGISLATION IN ONTARIO?

On January 1, 2016, the Ministry of Transportation Ontario (MTO) released Ontario Regulation 306/15: *Pilot Project – Automated Vehicles*, establishing a framework for on-road testing of automated vehicles for registered participants over a 10-year pilot period. This makes Ontario the only province to have dedicated legislation for AV testing.[3, 4]

As part of the pilot, unless approved for driverless testing, a human operator is required to always be in the driver's seat of the vehicle monitoring the vehicle operations and ready to take control when prompted. The operators of these vehicles still need to adhere to strict requirements, rules of the road and meet the standards of driving in Ontario.

On January 1, 2019, MTO introduced three enhancements to the AV pilot regulation (O. Reg. 306/15) to keep pace with technological advancements. These enhancements include:

- Allow the testing of driverless AVs as part of the pilot, under specific conditions to ensure safety;

- Allow the testing of cooperative truck platoons as part of the pilot, under specific conditions to ensure safety; and

- Exclude originally manufactured SAE Level 3 (conditionally automated) vehicles, eligible for sale in Canada, from being restricted for use only by registered pilot participants. Vehicles that have been retrofitted to SAE Level 3, after sale and not by an Original Equipment Manufacturer (OEM), will continue to be restricted to the pilot program and not permitted for public use.

More information on the pilot program can be found at:

- Ontario Regulation 306/15

- MTO Automated Vehicle Pilot Program

- MTO Cooperative Truck Platooning Pilot

Regional and local transportation agencies will need to work together in a coordinated effort to develop the requirements to facilitate a smooth transition to a connected and automated future. The Ontario AV Pilot regulation indicates that the technology that agencies in the GTHA need to prepare for is towards the high to full automation end of the spectrum (SAE Levels 4 and 5). These vehicles will become more prevalent in the market and on roads over time. The presence of this AV Pilot Regulation indicates that it is time for

the region to begin preparing and rolling out the necessary infrastructure, as well as operational, institutional and public lever changes to accommodate highly automated vehicles on roads.

1.3 WHEN WILL HIGHLY AUTOMATED CAV ARRIVE?

There is no consensus on the adoption rate of CAV technology. There will also be a delay between when the vehicles become available for purchase in the market and when consumers will trade in their conventional vehicles for an automated one. To get an understanding of the background on CAV adoption, the project team conducted a literature review of both industry and academic research. **Figure 2** summarizes research on personal CAV vehicle fleet penetration from the years 2020 to 2050. It is also assumed that transit vehicles will follow a similar trend in CAV saturation, as they are expected to rely on similar automation technology as personal vehicles. Generally, industry estimates of CAV adoption are more optimistic on the availability of the technology and the timing of adoption in comparison to academic sources. The range between the predictions are also quite variable. **Industry predictions state that automation will become a significant disruptor and lead to a rapid increase in CAV adoption over the years.** These predications assume that vehicle manufacturers will have highly automated vehicles available on the market for purchase in the short-term, consumers will invest in the technology and all necessary actors (infrastructure, operational and legislative) will be in place. Academic sources tend to be more conservative in their predictions and are based on statistical models, stated preference surveys, as well as the current state of the technology and how transportation authorities will evolve in terms of infrastructure and policy.
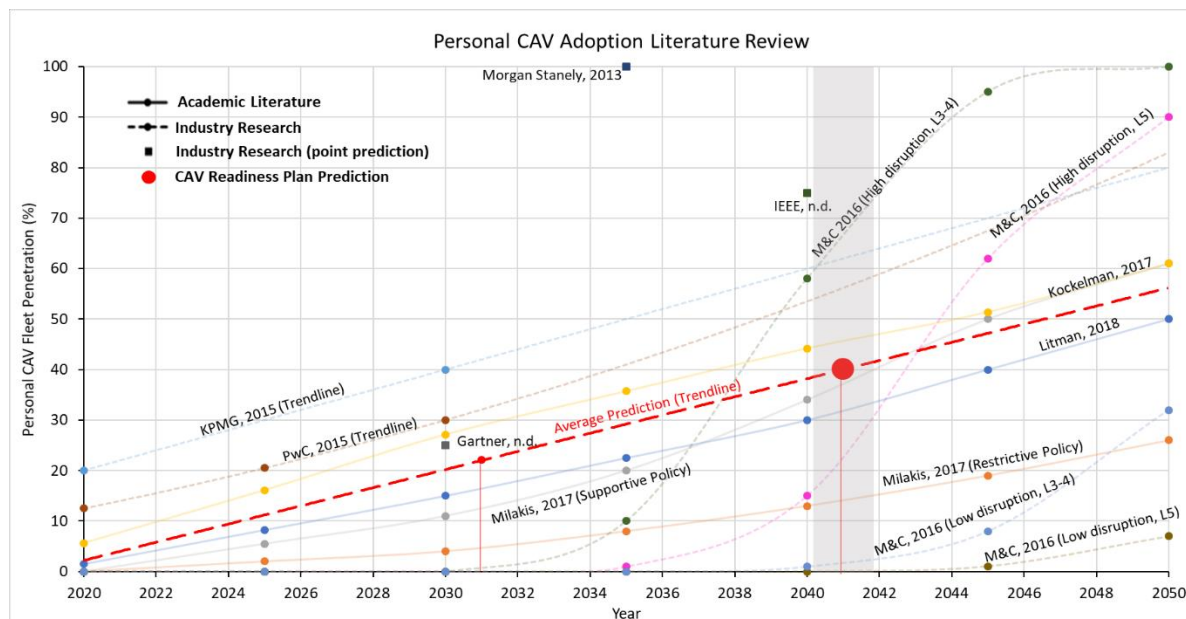

Figure 2: CAV adoption trends of personal vehicles as determined through an academic and industry literature review; CAV adoption refers to the percentage of CAV available and being driven on the road[12-17]

The years 2031 and 2041 are census years that are used by local and regional transportation agencies for planning initiatives. Between these two years, the average of the academic and industry (treating them equally) predicted penetration rates of CAV ranges from 22% in 2031 to 40% in 2041 (red dashed line). Despite these estimates, the development of the technology is moving at a rapid pace and public transportation agencies need to begin preparations now, in the early phases of adoption and during pilot programs, to better integrate CAV on roads and ensure a safe transportation network for all users.

1.4 HOW WILL TRANSIT BE IMPACTED BY CAV TECHNOLOGY?

CAV have the potential to be both a disruptor and an enabler for public transit. A widespread adoption of the technology in transit could attract ridership by improving transit service performance and accessibility. The first and last mile gap between an individual's origin/destination and the nearest transit station is an area where CAV could play an important role. Privately owned CAV could potentially be a disruptor by attracting more frequent single-occupancy trips for first and last mile trips increasing both station pick-up and drop-off (PUDO) area traffic, as well as parking demand.

On the other hand, CAV could be an enabler for transit if they are harnessed for their benefits and opportunities in providing mobility services to the public. Mobility services are a method of mobility that involves the aggregation of transportation modes, travel information, fare payment, technology and/or a service concept (e.g. subscription), but does not necessarily rely on CAV technology. Examples of mobility services could range from public transit, taxi services, ride-hailing services, car-share and bike-share services.[7] Mobility services, such as first and last mile CAV shuttles, as well as the integration of ride-hailing and other shared mobility services with transit through a mobility platform could improve trip planning for users, increase the efficiency of their travel, and potentially improve station access while reducing the amount of traffic demand at PUDO areas and the requirement for parking. CAV transit vehicles could potentially provide cost savings while also offering improved service coverage and reliability both geographically and temporally, as they can cover more space and provide service at times that may be less desirable for vehicle operators or financially unsustainable to operate a formal service.

The CAV Readiness Plan includes guidelines and programs that address many of the considerations necessary to prepare transit services for this transformative trend. For instance, the guidelines help direct transit agencies on the right path to adapt station infrastructure to travel behaviour changes that CAV could induce. More pick-up/drop-off movements and less parking demand could require a re-organization of station access design to accommodate these changes in demand. In the initial phases, various operations and infrastructure set-ups could be tested through pilot projects, paving the way for better preparation when the technology is much more widely available on the road.

1.5 HOW WILL FREIGHT BE IMPACTED BY CAV TECHNOLOGY?

Similar to passenger transportation, freight transportation will also be transformed by CAV technology. The GTHA is home to one of Canada's largest freight hubs, with an estimated $1.8 billion worth of commodities travelling through the Region of Peel daily.[18] This is an indicator that goods movement is a strong driver of transportation demand in the region.

The Organisation for Economic Co-operation and Development (OECD) and the International Transport Forum (ITF) have developed a prediction of the saturation of CAV technology in freight transportation. As can be seen in **Figure 3**, three potential trends (Conservative, Regulated and Disruptive) are considered for urban and long-distance freight. The Conservative trend represents cautious treatment of CAV technology for freight by regional legislators. The Disruptive trend represents advanced use of CAV freight by early market adopters without the resolution of all regulatory barriers and potential operation limitation variations between jurisdictions. Finally, the Regulated trend represents all regulatory limitations being resolved quickly and the quick adoption of the technology by freight transportation operators.[19] An average trend line fitted between the three trends indicates that by a planning horizon year of 2041, roughly 70% of long-distance freight will be handled by CAV, while about 45% of urban freight will be handled by CAV.
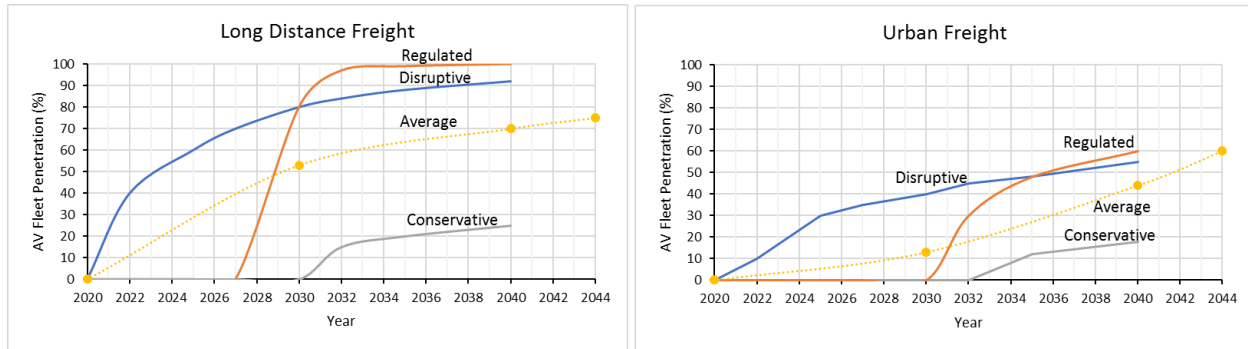
Figure 3: Predicted trends for long-distance and urban freight adoption of automated vehicle technology[19]

1.6 WHY CONSIDER PLATOONING?

One important consideration that can differentiate commercial transportation from passenger transportation is the common use of platooning. Cooperative Truck Platooning can be defined as a series of trucks, equipped with driving support systems, driven close together while communicating with each other through V2V wireless coupling technology.[20] This can significantly improve the efficiency of freight movement in terms of speed and volume and is a concept that has already been regulated by MTO. While the concept of linking multiple vehicles together in close succession already exists in the form of long-combination vehicles, platooning will allow vehicles to be coupled without a physical connection between successive vehicles. This will enable the flexibility in the number of vehicles linked into a single chain, and the flexibility of operations when traveling on urban (e.g., non-highway) roads.

In the development of this CAV Readiness Plan, the underlying assumption was that Commercial Motor Vehicles (CMV) would have the necessary V2V technology to facilitate truck platooning. In addition to Ontario's Automated Vehicle Pilot Program, amended in January 2019, MTO launched a Cooperative Truck Platoon Pilot Program, which is separate from the AV pilot program and is planned to run for eight years for evaluation.

As can be seen in **Figure 4**, MTO has identified highway corridors across the region where limited operation of CAV truck platoons will be allowed to demonstrate compatibility with existing road users and infrastructure, and confirm safe operation on Ontario highways. These corridors will serve as designated pilot areas for CMV operators to engage in cooperative truck platooning while adhering to strict regulations. The platoon needs to be disengaged to allow other vehicles to enter and exit the highway, when entering a truck inspection station, driving within a construction zone, driving past an incident, and when complying with the slow down/move over law to allow for emergency vehicles to pass. Operators will also be limited to not engage in platoon operations under inclement weather and low visibility.[20]
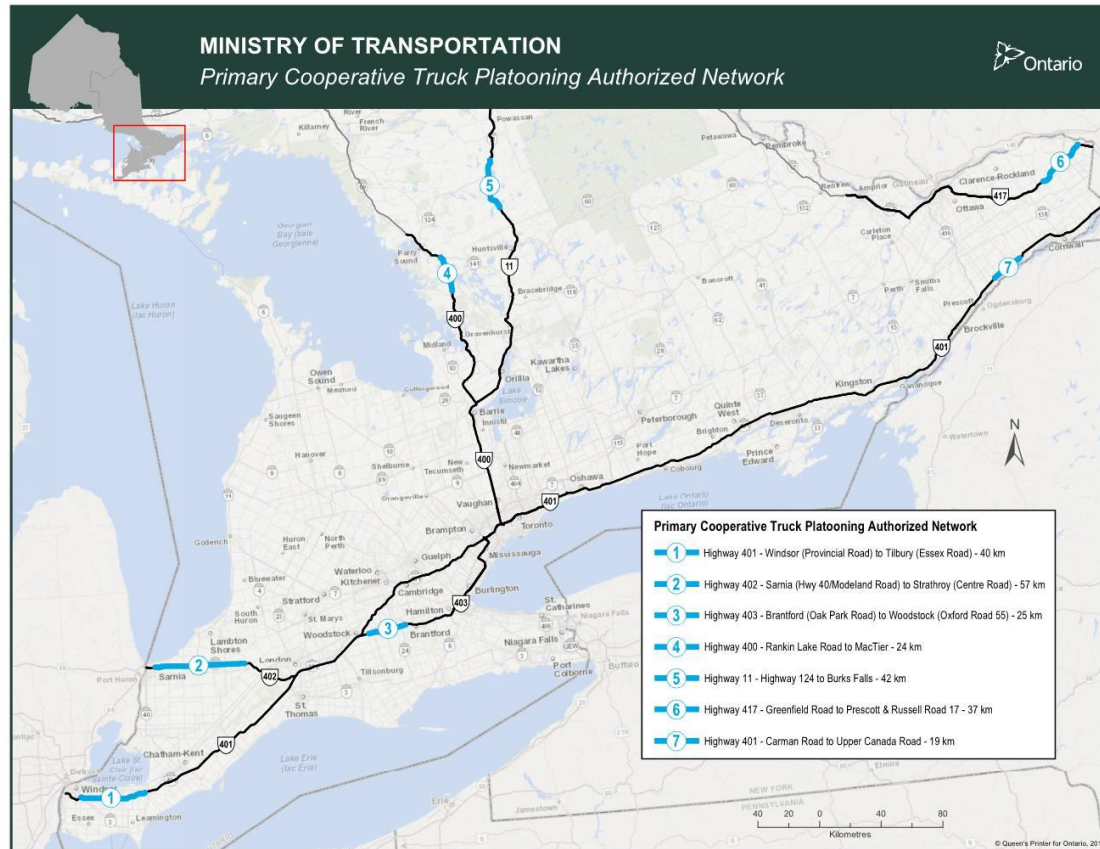
Figure 4: Authorized road network for Cooperative Truck Platooning[20]

Commercial vehicle operators can apply to participate in this program to operate CMV that are equipped with an automated driving system that operates at the SAE Level 1 or 2 with V2V communication capability to exchange information regarding speed, location and heading with other CMV in the platoon.[20] This program serves as the basis for the assumption that the GTHA should consider truck platooning when preparing for the necessary infrastructure that needs to be in place surrounding freight movement within the region.

1.7 WHAT ABOUT DATA FROM CAV?

Many the innovations in the transportation industry are being driven by advancements in data collection, analysis and computing. With advancement in technology, a large amount of data and information is also being generated. This data could enable better understanding of travel behaviours and demand in the region, inform decision-making both operationally and strategically, and allow for better use of emerging technologies in the future.

CAV are expected to generate a large volume of data, well beyond any datasets previously collected, and could serve as a new type of data collection method used by transportation agencies. The use of this data source will depend on whether the necessary V2I infrastructure is installed by transportation agencies. CAV will be able to continuously transmit information on the operations of the vehicle and the surrounding environment, including location, heading, speed, acceleration, outside air temperature, vehicle length, brake system status, etc.[9] This data could be useful for many applications, including the following:

- **Data supplementation for travel demand analysis** – Although CAV cannot replace the socio-economic data of household travel surveys critical to travel demand analysis, CAV data can supplement it to provide accurate travel information. There is potential for CAV data to fill in

data gaps related to path choice, long distance travel, commercial vehicles, and transit. CAV data can be used to validate models and in a before/after comparisons to better understand the effect of different policies on transportation (e.g. effects of mobility pricing on route choice etc.).

- **Data for improved operations analysis** – CAV could provide the necessary data to improve and have a large impact on data sourcing and calibration of operational models (e.g. microsimulation platforms) that model individual vehicle behaviors, rather than fleet behaviours. The data can also be used to complement ITS technologies for evaluating traffic conditions, travel times and interactions with traffic management centres to assist in monitoring the overall performance of the network and improve traffic conditions.

- **Data for improved emissions modelling** – Emissions modelling currently relies on national default factors for various key parameters (e.g. average speed distribution by hour and roadway, engine starts per day, hot soak duration, etc.). Replacing these factors would lead to improved emissions modelling and a better understanding of emission reduction strategies. Although CAV will likely also be electric, they still have the potential to provide local data for many of the key measures needed for emissions modelling and could still improve the accuracy of parameters used in emissions analysis.

APPENDIX

B

PROJECT APPROACH & ENGAGEMENT

TABLE OF CONTENTS

1 PROJECT APPROACH

The development of the CAV Readiness Plan consisted of a combination of research, Scenario Planning and Stakeholder engagement. The information gathered, and subsequent analysis, led to the development of CAV Readiness Guidelines and CAV Programs to begin preparing for a future with CAV. **Figure 1** depicts the project approach that was used deliver the CAV Readiness Plan.
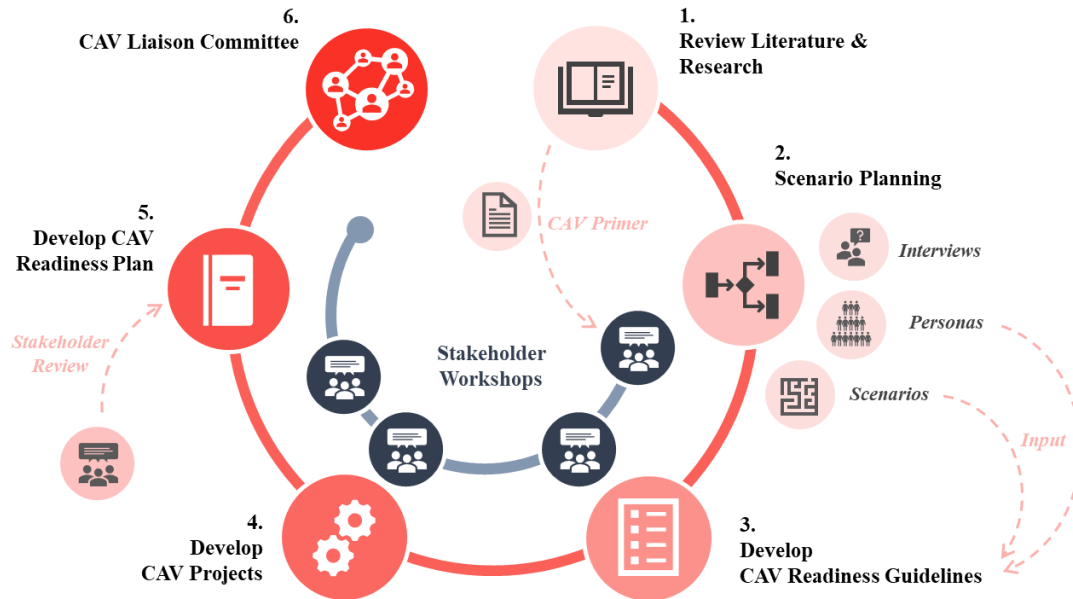

Figure 1: CAV Readiness Plan Approach

1. Review Literature & Research

The project started with a scan of existing academic and industry literature and research. The objective of the scan was to develop an understanding of the current state of the technology, the anticipated direction it is moving in, as well as steps that have been taken to begin testing and preparing for the integration of CAV into passenger and freight transportation networks. This research formed the basis for the assumptions made in the development of the future CAV scenarios and helped identify key considerations that will become more relevant to transportation with increasing prevalence of CAV and other emerging transportation trends and technologies.

2. Apply Scenario Planning

With the future of transportation unknown due to many disruptive technologies and new business models, the Scenario Planning approach was applied to understand the potential impact of different plausible futures on actions and policies of today. As part of the process, five (5) alternative future scenarios for CAV deployment, and eight (8) personas representing various characteristics of the population, were developed. They were presented to Stakeholders and further refined based on feedback.

3. Develop CAV Readiness Guidelines

Over 200 Readiness Guidelines were developed defining actions to be completed to prepare for the arrival of CAV. The Guidelines were reviewed from the perspective of each scenario and persona profile to ensure that they provide representative considerations to address the needs of the potential futures and population characteristics (e.g. accessibility requirements etc.).

4. Develop CAV Programs

Five (5) CAV programs were developed to describe specific initiatives that could be used to address many of the guideline requirements and begin preparations for CAV deployment through pilots, research programs, transportation planning and policy development. Program details were identified, including program description, approach, agencies involved, and funding mechanisms.

5. Develop CAV Readiness Plan

This CAV Readiness Plan was developed as a comprehensive document linking together the research, scenarios and personas, Readiness Guidelines, CAV Programs and a framework for a CAV Liaison Committee (**Figure 2**). It serves as a tool for public agencies to use for preparing for CAV and associated business models and emerging technology.

6. Establish CAV Liaison Committee

A CAV Liaison Committee will be established as the first step to preparing for CAV in the GTHA. The committee will consist of Stakeholder representatives across the GTHA with the objective to oversee and coordinate the implementation of the CAV Readiness Plan and Programs, while fostering collaboration.

Figure 2: Key components that led to the development of the CAV Readiness Plan

1.1 EXISTING PLANS AND GUIDELINES

The CAV Readiness Plan was developed to complement existing CAV planning initiatives that have already been initiated within Canada. The documents reviewed as part of this project and that provided key insight into the development of the CAV Readiness Guidelines, include:

- **Driving Change: Technology and the Future of Automated Vehicles (2018)**[2] – Report developed by the Senate Standing Committee on Transport and Communications discussing the impacts of connected and automated vehicles and necessary considerations related to safety and security.

- **Automated Vehicle Policy Framework for Canada (2019)**[21] – Developed by the Policy and Planning Support Committee (PPSC) working group on Automated and Connected Vehicles. This policy framework provides jurisdictions with policy guidelines to safely test and deploy CAV.

- **Canadian Jurisdictional Guidelines for Safe Testing and Deployment of Highly Automated Vehicles (2018)**[22] – Published by the Canadian Council for Motor Transport Administrators (CCMTA), these guidelines provide a series of considerations and recommendations to support Canadian jurisdictions and lower levels of government (including provincial, regional and local municipalities) in developing CAV testing programs to prepare for the deployment of emerging transportation technologies. The document discusses the roles and responsibilities of federal, provincial/territorial and municipal governments in testing CAV as well as guidelines for governments and manufacturers to follow.

- **Testing Highly Automated Vehicles (HAV) in Canada – Guidance for Trial Organizations (2018)**[23] – Published by Transport Canada, this guidance document serves as a complement to the Canadian Jurisdictional Guidelines. It clarifies for trial organizations the role of federal, provincial and territorial levels of government involved in facilitating trials, while also establishing Canada as a destination for trials of highly automated vehicles (HAV). The trial guidelines establish a set of voluntary minimum safety practices and expectations that trial organizations are expected to follow for the temporary trials of AVs and AV systems.

- **Canada's Safety Framework for Automated and Connected Vehicles (2019)**[24] – Published by Transport Canada, this document provides information to Stakeholders on a stable policy direction for safely deploying CAV on public roads in Canada. It provides an overview of Canada's current legislative, regulatory and standards programs.

- **City of Toronto Draft Automated Vehicle Tactical Plan (2019-2021)**[25] – Developed by the City of Toronto Integrated Working Group on Automated Vehicles, the tactical plan provides a list of guidelines for the City to follow to integrate automated vehicles within its transportation network considering aspects of social equity, environmental sustainability, economic sustainability, privacy, road safety, integrated mobility, and transportation system efficiency.

- **Region of Peel Goods Movement Strategic Plan (2017 – 2021)**[18] – Developed by the Region of Peel, the Goods Movement Strategic Plan identifies opportunities and plans for the implementation of a CAV Commercial Vehicle Pilot as an action item.

2 STAKEHOLDER ENGAGEMENT

Stakeholder engagement and outreach was a key component in collecting input at various points during this project. The working sessions helped guide the development of the CAV Readiness Plan that served the needs of the Stakeholders and their expectations for a consistent planning framework preparing the region for CAV.

A Stakeholder group was established and consisted of over 70 representatives from transportation and transit agencies across the GTHA. The members of the agency Stakeholder group are shown on the map in **Figure 3**. The objective of this group was to provide input into the preparation of a CAV Readiness Plan and participate in four workshops over the course of this project's development. The project team worked with the Stakeholders and gathered their input through the workshop breakout sessions, online surveys, online interactive tools (e.g. Mentimeter) and document review/comments to integrate their needs and thoughts into the development of the CAV Readiness Plan.

Figure 3: Map of CAV Readiness Plan Stakeholder Group

2.1 STAKEHOLDER WORKSHOPS

Stakeholders participated in a total of four (4) workshops (**Figure 4**) over the course of the development of the CAV Readiness Plan. These workshops had two purposes:

1.) **Gather input and feedback** from Stakeholders on the CAV Readiness Plan development based on their experience and their agency's interests.

2.) **Educate Stakeholders** on potential CAV technology impacts and the considerations that will need to be taken to prepare for them.

Workshop #1
Reviewed proposed CAV scenarios and personas.
Identified final list of personas.

Workshop #2
Presented final scenarios and personas.
Reviewed draft CAV Readiness Guidelines.

Workshop #3
Brainstormed and prioritized CAV Programs.
Reviewed Guidelines with respect to Programs.

Workshop #4
Reviewed draft Program sheets
Brainstormed CAV Liaison Committee objectives.

Figure 4: Descriptions of the four Stakeholder workshops

The Stakeholders indicated early-on in the engagement process that they preferred more interactive workshops with less time spent on presentations. The project team responded by adjusting their strategy and organized the workshops with more time focused on engaging activities allowing for discussion and opportunities to work directly with the material of the CAV Readiness Plan.

The use of breakout sessions and discussion groups was valuable to contributing to the Stakeholders' understanding of CAV and the development of the CAV Readiness Plan. The Stakeholders believed that specific working session focusing on the scenarios, personas, CAV Readiness Guidelines and Programs was beneficial for:

- Fostering discussion on the impacts of CAV amongst different agency representatives to gain insights and identify shared goals and opportunities.

- Sharing knowledge on the topic from the perspective transit, regional, municipal and provincial agencies.

- Providing valuable feedback on the content of the CAV Readiness Plan and the draft materials presented.

The project team also dedicated workshop time for knowledge sharing presentations with invited guest speakers. Stakeholders were given the opportunity to provide input on the topics of these sessions.

Knowledge Sharing Topic Recommendations

- Cybersecurity and data privacy.
- Connectivity technology (5G vs. DSRC).
- Data collection, management, ownership and governance.
- V2I and connected vehicle deployment lessons from pilot projects in U.S.
- Management of risk, liability and insurance considerations.
- Updates on existing plans, ACATS projects and pilot programs in Canada and the GTHA.
- Private sector perspective on CAV industry (e.g. automotive manufacturers, telecommunication providers etc.).

From these recommendations, the project team invited speakers to present at the workshops in between the breakout session activities. The knowledge sharing presentations included updates from peer agency representatives, as well as industry representatives highlighting their work and involvement in the CAV technology sector. Knowledge sharing topics and guests included:

- **Ministry of Transportation Ontario** – Enhancements to Ontario's AV Pilot Program Regulation.
- **Transport Canada** – Update on projects awarded funding through the ACATS program.
- **City of Toronto** – Update on Minding the Gap Automated Transit Shuttle pilot project.
- **Region of Peel** – CAV and Goods Movement activities in the Region of Peel.
- **Borden Ladner Gervais (BLG) LLP** – Comparison of connectivity technology, 5G vs. DSRC.
- **Toronto Region Board of Trade** – Preparations for an AV Readiness Council.
- **General Motors (GM) Canada** – Overview of GM's activity in CAV programs and initiatives.
- **WSP USA** – Lessons learned from ongoing CAV pilot projects in the U.S.

Figure 5 presents images from various Stakeholder workshops showing attendees: (a, b) collaborating in brainstorming ideas for CAV Programs; (c) responding to questions on the Mentimeter platform; (d) reviewing the CAV Readiness Guidelines and; (e) listening to a knowledge sharing session on CAV pilots in the U.S.

Figure 5: Images from Stakeholder workshops showing attendee participation

2.2 STAKEHOLDER SURVEYS

2.2.1 EXPECTATION OF CAV READINESS PLAN

The results from Stakeholder group surveys solidified the approach undertaken by the project team to further develop scenarios, personas, CAV Readiness Guidelines and Programs. The Stakeholder feedback clearly identified expectations for topics that the CAV Readiness Plan should address:

- **Timeline Requirements** – Timeline for the rollout of CAV technology and the implementation window of the CAV Readiness Plan based on the evolution of CAV.

- **Policy/Legislation for CAV** – Outline of the government's role in a CAV future and the policies that need to be focused on over the short, medium and long-term to support a safe transportation network with CAV.

- **Infrastructure for CAV** – Impacts of CAV on existing infrastructure, design and maintenance plans, the road and transit infrastructure gaps and the needs for the short, medium and long-term.

- **Planning for CAV** – Strategies for agencies to consider CAV in planning initiatives, minimize negative impacts on transportation and work towards a consistent approach for CAV planning.

- **CAV Readiness Plan outcome and legacy** – Needs for implementing actions identified by the CAV Readiness Plan, including areas of responsibility between the public and private sector, requirements for CAV pilots, and critical near-term actions to prepare for CAV.

2.2.2 ROLE OF THE PUBLIC AND PRIVATE SECTORS

Figure 6 reveals that the majority (76%) of the Stakeholders identified that both the public agencies and the private sector companies will have to work together to integrate CAV with transportation networks. However, it is still evident that the Stakeholders expect technology companies to develop CAV technology that works well with existing transportation infrastructure, at least in the early phases of CAV adoption.

Stakeholders also provided input on infrastructure changes their agencies would be willing to make to accommodate CAV on public roads, transit systems and freight networks. Examples of responses included:
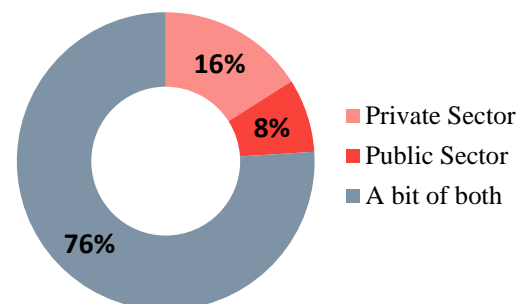
Figure 6: Proportion of responsibility to integrate CAV with transportation networks

Operations & Road Infrastructure
- Updates to infrastructure and design standards.
- Updates to asset management and maintenance guidelines.
- Open data for mapping, signs and road markings.
- Pavement embedded vehicle guidance technology.
- Provision of dedicated lanes on certain municipal routes and on provincial highways.
- Fleet vehicle upgrades (e.g. transit, maintenance).

Communications/Connectivity Infrastructure
- Upgrade of communications and signalization infrastructure for V2I communication.
- Increase in availability of high-speed internet infrastructure (e.g. wireless receivers).
- Technology for real-time data collection from CAV.

2.2.3 PARTICIPATION IN THE CAV LIAISON COMMITTEE

At the final workshop the Stakeholders were surveyed on their intended participation with the CAV Liaison Committee. Almost all Stakeholders that responded indicated that their agency would likely participate in the CAV Liaison Committee in various capacities, as shown in **Figure 7.** Also, **78%** of the Stakeholders indicated that a fixed term length (1 or 2 years), after which the role would be re-evaluated, would make it easier to commit to participating.
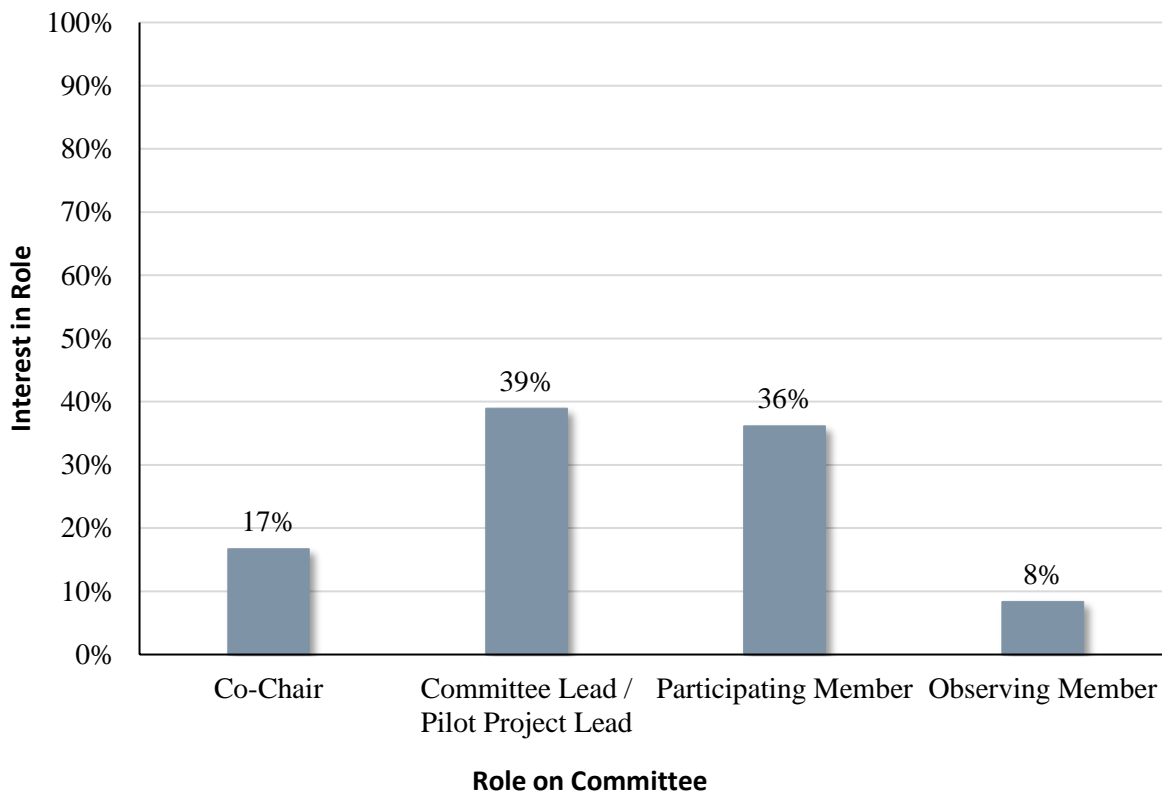

Figure 7: Stakeholder interest in various roles of participation in the CAV Liaison Committee

The Stakeholders were also asked what information they would need for senior management to decide on whether to formally get involved with the CAV Liaison Committee. The responses were summarized below:

> **Information needed to Participate in CAV Liaison Committee**
>
> - Terms of Reference indicating level of staff time required, timeline and key responsibilities and outputs/deliverables (x 8 responses)
> - Final CAV Readiness Plan report (x 5 responses)
> - Direct objectives that will benefit agency and taxpayers (x 5 responses)
> - Support from higher level government
> - Letter with specific invitation and request for participation outlining objectives and benefits of participation (x 2 responses)

2.2.4 ACCOMPLISHMENTS OF THE CAV READINESS PLAN

A key piece of feedback for the project team to compare if the objectives of the CAV Readiness Plan were achieved was to ask the Stakeholders what they believed was accomplished through the project. **Figure 8** shows the result of the survey, where Stakeholders were able to select all applicable project accomplishments. The results indicate that most Stakeholders believed that the CAV Readiness Plan and workshops identified clear steps to begin preparing for CAV in the GTHA, provided them with an understanding of the technology and complemented existing plans and strategies for CAV preparations.
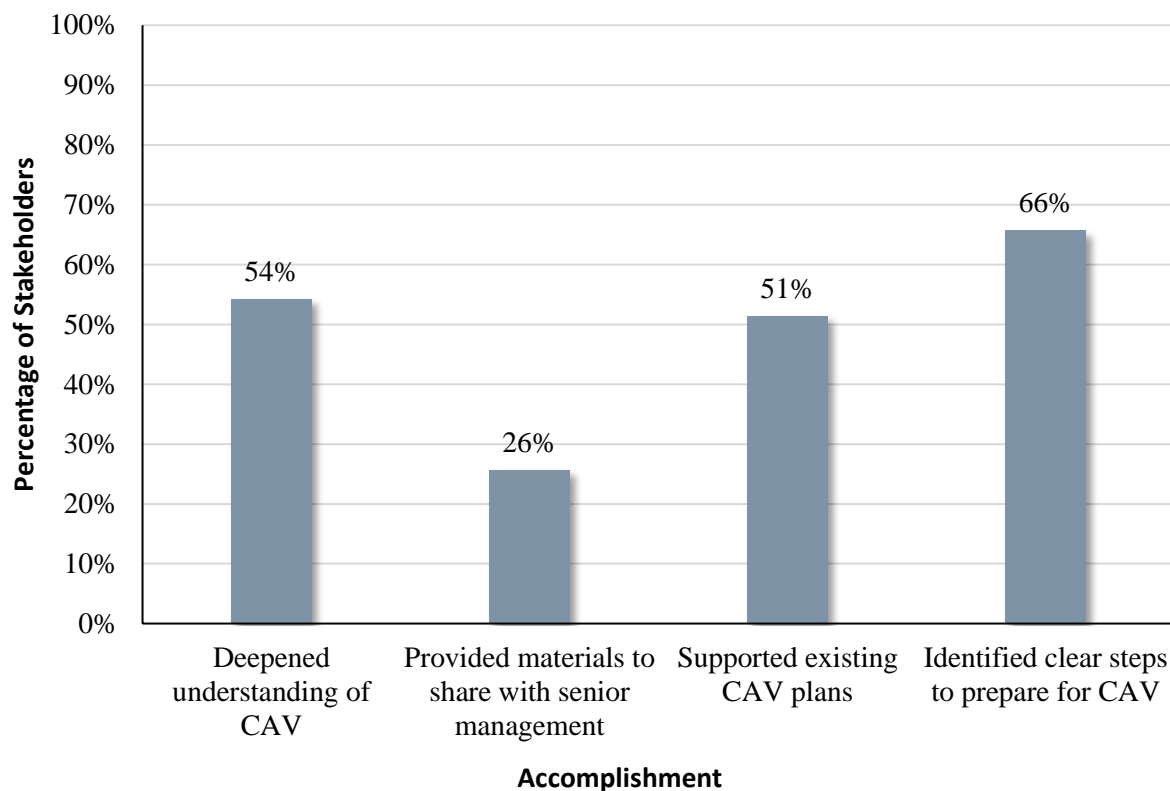

Figure 8: Key accomplishments of the CAV Readiness Plan from the perspective of the Stakeholders (multiple selections permitted)

Other key accomplishments identified by the Stakeholders included the following:

> **Other Key Accomplishments of the CAV Readiness Plan**
>
> - **Networking and collaboration** – brought agencies together heading in the same direction and broke down silos, while creating a platform to discuss CAV from different perspectives.
> - **Inter-agency communication and information exchange** – opened lines of communication with other agencies and developed an awareness of other agency CAV related studies and projects.
> - **Action items** – Created momentum on preparing for CAV and developed actions and a list of future possible initiatives.
> - **Challenges and opportunities** – Identified the challenges and opportunities the GTHA faces to make the CAV portfolio successful.

2.2.5 LEVEL OF PREPAREDNESS FOR CAV

Another key piece of feedback provided by the Stakeholders was their agency's perspective on their level of preparedness for CAV entering transportation networks. As can be seen in **Figure 9**, at the beginning of the project the Stakeholders identified that current preparations are limited and **agencies were not as ready to have CAV on roads**. By the end of the project**, the Stakeholders responded with a slight increase in their level of preparedness, and an increased awareness of the all work that needs to be done to prepare for CAV.**
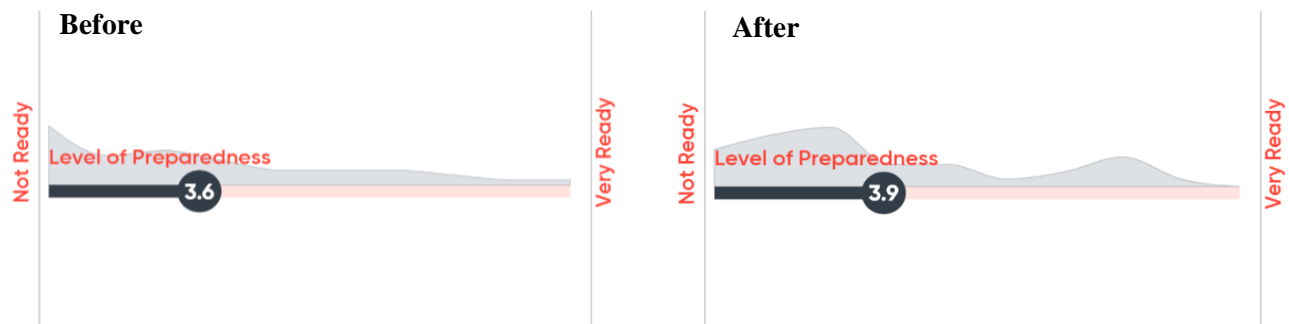

Figure 9: Stakeholder level of preparedness for CAV before and after the development of the CAV Readiness Plan; scale of 1 (not ready) to 10 (very ready)

As seen in **Figure 10**, the Stakeholders felt **their engagement in the development of the CAV Readiness Plan was successful in increasing their knowledge on CAV and their impacts on the transportation network.** It has initiated the process of moving forward with a consistent approach to preparing for CAV on roads, while also increasing awareness of the challenges and opportunities ahead.

Figure 10: Stakeholder level of knowledge of CAV impacts; scale of 1 (less knowledge) to 10 (more knowledge)

APPENDIX

C

SCENARIO PLANNING BEST PRACTICES SUMMARY

TABLE OF CONTENTS

TABLE OF CONTENTS

1 INTRODUCTION

As a main component of the CAV Readiness Plan, the project team reached out to organizations globally to gather insights on their planning efforts related to CAV and the use of Scenario Planning to envision the possible futures of CAV. Four (4) interviews were conducted through teleconference in October 2018, with the following agencies:

- **Infrastructure Victoria**: Advice on Automated and Zero Emissions Vehicles Infrastructure (October 2018)[26]
- **MnDOT**: Connected and Automated Vehicles Strategic Plan (July 2019)[27]
- **LADOT**: Urban Mobility in a Digital Age Strategy (August 2016)[28]
- **WSP Sweden**: Future City (ongoing)

The interviews were held by teleconference with representatives from each agency. The following questions were used to guide the interview discussion:

- **Question 1**: What motivated your organization to undertake the project and incorporate scenario planning concepts to envision the future of CAV?
- **Question 2**: How did your organization determine the scenarios used in this project? What were the scenarios and how were these scenarios used?
- **Question 3**: Which considerations (societal, economic, environmental, mode share etc.) were included in your organization's work to define future scenarios for CAV?
- **Question 4**: What horizon year(s) is your organization using to plan for CAV, and why?
- **Question 5**: How and when does your organization plan to update these scenarios in the future?
- **Question 6**: How were stakeholders engaged during the project's development and execution?
- **Question 7**: What steps has your organization taken to implement the outcomes of this project? What steps are planned?
- **Question 8**: If you were to start the Scenario Planning process again, knowing what you know now, what would you do differently?

The findings presented in this memo represent insight shared by interviewees through the teleconference interviews. Where beneficial, findings from publicly available documents released by the four agencies were also incorporated.

2 INFRASTRUCTURE VICTORIA, MELBOURNE, AUSTRALIA

2.1 INTERVIEW DETAILS

Infrastructure Victoria (IV) is an independent statutory authority that provides expert advice to the Government of Victoria and guides decision-making on infrastructure needs and priorities. Following the identification of this agency's recent work relating to automated and zero emission vehicles, an interview was held by teleconference on October 11, 2018.

2.2 ADVICE ON AUTOMATED AND ZERO EMISSIONS VEHICLES INFRASTRUCTURE

In October 2017, the Special Minister of State formally requested IV to provide advice on what infrastructure is required to prepare for and enable the implementation of automated and zero emissions vehicles over the long-term. IV was given a 12-month timeframe to complete this project and the final report *Advice on Automated and Zero Emissions Vehicles Infrastructure* was published in October 2018.[26]

Part one of the project was a future scenarios report (**Figure 1**) that explored seven (7) alternative potential future scenarios, which formed the basis of the advice report.

Part two of the project was a final report that included details on different types of infrastructure, including transportation, information and communication technology (ICT) infrastructure and energy. It was supported by evidence and analysis on the current state of transportation and provided recommendations for key.[26]
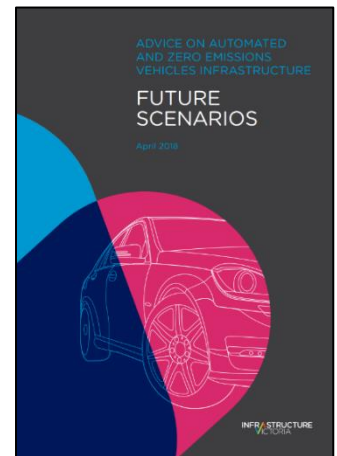
Figure 1: Advice on Automated and Zero Emissions Vehicles Infrastructure: Future Scenarios Report

2.3 SCENARIO PLANNING

2.3.1 *PURPOSE*

Scenario Planning helped IV conceptualize alternative futures and test the impacts of a range of key uncertainties. Modelling and other research exercises were used to determine the appropriate actions on when and how IV should deploy infrastructure to support automated and zero-emissions vehicles.

IV highlighted the value of planning various infrastructure projects in parallel, such as transportation, ICT, energy and land-use areas. IV also emphasized the importance of considering what environment their citizens desire to live in and how infrastructure is valued from their perspective.

2.3.2 *DEVELOPMENT OF SCENARIOS*

IV acknowledged the limitations of scenario analysis and that not all uncertainties could be captured or answered by this process. As such, their scenarios were designed to complement each other and to isolate the impact of different variables by testing extreme cases. The scenarios focused on three major areas:

Automation

- Driverless vehicles vs. vehicles with drivers

Ownership Model

- Private ownership vs. public ownership

Emission

- Zero emission vehicles vs. gasoline vehicles

It is important to note that IV did not separate Automated Vehicles (AV) and Connected Vehicles (CV) since AV without connectivity are reactive and operate similarly to conventional vehicles. For instance, both AV without connectivity and conventional vehicles read, interpret and respond to the environment (e.g. turning movements and traffic signals) around them in a similar manner. Furthermore, there is very limited infrastructure changes required if AV are not connected. On the other hand, connectivity introduces proactivity in a vehicle's decision making as they are continuously receiving and broadcasting valuable information with other vehicles and infrastructure.

Seven (7) scenarios were created for the horizon year of 2046 (**Figure 2**):

1. **Electric Avenue**
2. **Private Drive**
3. **Fleet Street**
4. **Hydrogen Highway**
5. **Slow Lane**
6. **High Speed**
7. **Dead End (Base Case)**

Scenario *7: Dead End*, was developed as the base case scenario (i.e. Nothing Happened) for IV to make effective comparisons between scenarios. Following stakeholder input, an 8th scenario was developed to incorporate shared mobility to understand how the inner and outer areas of Melbourne will be impacted by this means of transportation. For example, how will Melbourne look like if the inner city experiences an

Figure 2: IV's seven (7) scenarios

increase for on-demand services and private ownership dramatically decreases (25% privately owned and 75% shared); while outer city residents prefer to use their own vehicles (75% privately owned and 25% shared)?

Each scenario was evaluated with comprehensive transportation modelling and research. IV highlighted that they intentionally avoided the development of any scenario that resembles a utopian or dystopian future, as it would be too difficult to relate to and therefore, decrease the credibility of the data.

IV selected 2046 as the horizon year for this study since it is an appropriate distance into the future that will useful for planning and aligns with the transportation model timeframe and the State of Victoria's 30 Year Strategy.

2.3.3 STAKEHOLDER ENGAGEMENT

Over 100 national (Australian) and international stakeholders were involved in this project.[29] On top of local stakeholder outreach, the IV project team travelled abroad to meet with stakeholders from governments and private companies who are active in planning for automated and zero emission vehicles from seven (7) different cities, including:

- Phoenix, Arizona, United States

- Tokyo, Japan
- Dubai
- Singapore
- Amsterdam, Netherlands
- Gothenburg, Sweden
- Helsinki, Finland

Through these meetings, IV learned about the key factors these cities used to drive their decision making and what has been done in the past and/or is currently underway to introduce automated and zero emission vehicles.

An outcome of this stakeholder engagement was the high level of interest shown for understanding what a mixed scenario would look like, demonstrating the significance of the Slow Lane scenario (i.e. a mix of driverless and human driven vehicles, as well as a mix of electric and gasoline vehicles).

IV's outreach for this project also included two public consultation sessions. The first workshop was held in March 2018 to understand what the key challenges and focus areas for the future of mobility are from the public's perspective. IV highlighted that it would be unproductive to ask for the public's vision for the scenarios at this stage, and thus, questions such as "where do you want to go and what do you value?" were more relevant to this study. The second consultation was held in August 2018 to present the scenarios and analysis and identify gaps and collect feedback. Due to the tight project timeframe, IV was not able to incorporate an educational campaign in the scenario development process.

2.4 NEXT STEPS

The scenarios will be incorporated into the State of Victoria's 30 Year Strategy to determine the most realistic scenario(s) and to plan for them. At this time, IV does not plan to update the scenarios, but will refine and include new scenarios in the future as needed.

2.5 RECOMMENDATIONS

When asked what recommendations they would have for the CAV Readiness Plan, IV first recommended that the scenarios should be defined as early as possible. Once the high-level scenarios are defined, the many questions relating to the specifics of each scenario can start being answered. For example, the definition of AV uptake (whether it is an S curve or an exponential curve) would make a significant difference in the social economic impacts. Examples of questions that can be asked, include:

- Who will adopt AVs first? And, how quickly?
- Which areas will carry the largest impact?
- If electric vehicles (EV) are adopted by everyone within a certain area, will the energy grid in that area be overloaded due to the increased demand of energy?

One of the important hurdles IV encountered during their transport modelling analysis, using the Melbourne Activity Based Model, was to determine the flow factor, which defines the distance between vehicles. Their model initially demonstrated a 200% improvement in flow for AV in comparison to human driven vehicles. In the end, IV decided to use a 75% improvement flow factor in their scenarios and 25% as an additional test point. These variables were held constant across all scenarios where possible to allow for effective comparison between scenarios. IV indicated that over 30 variations of the different scenarios were modelled,[30] which generated valuable and positive results for comparison.

IV highlighted the importance to use the base scenario as a foundation for comparison with other scenarios. IV also ensured that their scenarios were not drastically negative or positive to support more realistic

futures. IV designed their scenarios to be mutually exclusive so they can be easily differentiated. All assumptions are thoroughly outlined in the Evidence Based Report.[31]

How were the lessons learned applied to the CAV Readiness Plan?

Despite the nature of their work involving modeling, IV's recommendations were valuable to the CAV Readiness Plan development in terms of providing insights for more realistic alternative futures and simplifications to scenarios. With the feedback and comments provided by Stakeholders through workshops and online surveys, the project team simplified the scenarios carried forward in the CAV Readiness Plan.

3 LOS ANGELES DOT, LOS ANGELES, UNITED STATES

3.1 INTERVIEW DETAILS

In 2016, the Los Angeles Department of Transportation (LADOT) published the *Urban Mobility in a Digital Age Strategy* (**Figure 3**), which laid the foundation to incorporate new mobility trends, such as shared mobility and automated vehicles, into their department planning and operations. The Strategy provides public policy recommendations, near-term actions and a series of pilot projects.[28]

Following the identification of LADOT's work relating to new mobility, an interview was held by teleconference on October 17, 2018.
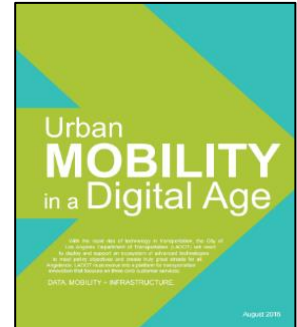
Figure 3: Urban Mobility in a Digital Age Strategy

3.2 PLANNING FOR CAV

3.2.1 *PURPOSE*

With the rise of transportation technologies, LADOT recognized the need to prepare for three (3) evolving technology-based customer service areas, including:

1. Data as a Service
2. Mobility as a Service
3. Infrastructure as a Service

LADOT established a framework to navigate these three areas, as well as to support and deploy advanced technologies. AVs were identified as one of the five (5) key strategies.

3.2.2 *PLANNING FOR CAV*

Five (5) Transportation Technology Strategies, as shown in **Figure 4**, were developed with policy recommendations and specific actions according to three timeframes: today (0-2 years), tomorrow (3-5 years) and future (6+ years). Strategy five, "Prepare for an Automated Future", provided four (4) policy recommendations that focused on innovation, interoperability, data and infrastructure, including:

1. Call for mobility innovation in California (Planned / Underway);
2. Collaborate regionally to promote interoperability;
3. Launch a taskforce on data monetization strategies; and
4. Advocate for new approaches to financing infrastructure projects.

Figure 4: LADOT's Five Transportation Technology Strategies[28]

LADOT selected 2028 as the horizon year to align with other planning efforts for the 2028 Summer Olympics in Los Angeles. **Table 1** shows the near-term actions that were identified through the Strategy.

Table 1: Actions to Prepare for an Automated Future[28]

Today (0-2 years)	• Develop a business plan for a city AV fleet (planned/ underway). • Create a dedicated staff position focused on connected and automated vehicle technology (planned/ underway). • Implement blind spot detection systems for public transit vehicles (proposed). • Expand LADOT connected bus technologies fleet-wide. • Invest in lane markings that enhance effectiveness of lane departure warning and prevention systems.
Tomorrow (3-5 years)	• Create better access to ATSAC data and enhance transparency of network prioritization for planning. • Develop an AV road network along transit and enhanced vehicle networks. • Launch a Data as a Service program to provide real-time infrastructure data to connected vehicles.
Future (6+ years)	• Convert the public transit vehicle fleet to fully automated

3.2.3 *STAKEHOLDER ENGAGEMENT*

LADOT conducted a series of interviews with a broad range of national stakeholders and subject matter experts to provide inputs to the strategy, such as the National Association of City Transportation Officials (NACTO).

3.3 NEXT STEPS

The *Urban Mobility in a Digital Age Strategy* aims to be a flexible and adaptable strategy that can be applied to new modes or technologies that may have an impact on LADOT's mandate. For example, the strategy does not account for electric scooters but is still applicable. The strategy is mainly used to inform policy planning and to support the delivery of new urban mobility projects and programs.

Through this strategy, LADOT streamlined their procurement process by establishing a list of pre-approved contractors in six (6) different categories with approximately 100 companies on the bench list. The expertise areas of these companies range from electrification, connectivity, transport consulting and data analysis. This allows LADOT to initiate pilot projects directly with these pre-approved companies on an as need basis. LADOT stated that there is no known cap for the number of projects that can be procured or the project values.

3.4 RECOMMENDATIONS

LADOT highlighted that instead of working to understand the details of every technology, priority should be placed on efforts to engage with the community and technical experts. Engaging with the right stakeholders will keep discussions focused on the impact of specific technologies and how it relates to the operational responsibilities that LADOT is concerned about, for example, public health and mobility.

How were the lessons learned applied to the CAV Readiness Plan?

The project team used a similar stakeholder engagement approach to LADOT when organizing the breakout sessions for the workshops. Stakeholders were grouped according to areas of expertise and interest (provincial, regional, municipal and public transit) to provide feedback on topics specific to their domain. For instance, Stakeholders with a focus in freight movement were grouped together to discuss and provide feedback on how CAV would impact freight transportation. Likewise, transit-oriented Stakeholders were grouped together to provide insights on the transit related topics of the project.

The project team also considered LADOT's four (4) policy recommendations to prepare for an automated future when developing the CAV Readiness Guidelines, to encourage innovation and identify focus areas. Some of the focus areas include pilot programs, regional coordination, data management and physical infrastructure.

4 MNDOT, MINNESOTA, UNITED STATES

4.1 INTERVIEW DETAILS

Recognizing the rapidly emerging changes in the transportation technologies, Minnesota Department of Transportation (MnDOT) initiated a *Connected and Automated Vehicle Strategic Plan* to identify key strategies to address challenges arise in Connected, Automated, Shared, Electric Vehicles, as well as pricing options. [29] Following the identification of this project, an interview was held by teleconference on October 19, 2018.

4.2 OVERVIEW

The Connected and Automated Vehicle Strategic Plan (**Figure 5**) developed scenarios to help MnDOT and its partners understand a range of potential CAV futures and assess how CAV could affect Minnesota. The scenarios provided a better understanding of a range of potential CAV futures, and supported decision making in current and future long-range planning, regulatory, programming, design, operations, and business planning efforts. The study included a series of workshops with MnDOT and other stakeholders statewide to share information about the scenarios and gather input on strategies to maximize the benefits of CAV and minimize adverse impacts.

Recommendations with key actions were developed to address questions associated with nine (9) major topics: Statewide Approach, Long-Range Planning, Immediate Capital Investments, Research and Development, Regulation, Operations, Strategic Staffing, Multimodal and Communication.
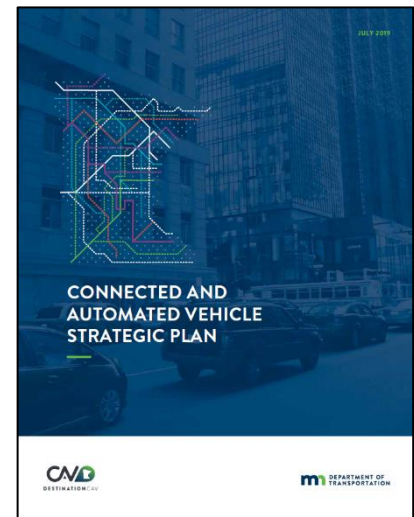
Figure 5: MnDOT CAV Strategic Plan Overview

4.3 SCENARIO PLANNING

4.3.1 *PURPOSE*

The Connected and Automated Vehicles (CAV) Strategic Plan is a combined effort across different departments and teams within MnDOT. The representative interviewed expressed the need to incorporate CAV into long-range transportation plans. Traditional long-range planning assumes that current knowledge about future conditions is relatively reliable; however, this may not always be the case when addressing future uncertainties. Scenario Planning establishes a framework to respond to a dynamic and uncertain situation.

MnDOT also made the CAV Strategic Plan a priority by creating a task force to implement short term goals (i.e. research, investment or training in the near term).

4.3.2 *DEVELOPMENT OF SCENARIOS*

MnDOT used the six (6) CAV scenarios and assumptions developed by the Federal Highway Administration (FHWA) as a starting point and adjusted the scenarios and assumptions to reflect their local context and concerns. Factors and considerations were isolated to evaluate the results more effectively.

Five key levers were used to describe each scenario, including:

1. **Connectivity** – V2V, V2I, V2X
2. **Automation**
3. **Sharing** – Mobility services, ride-hailing
4. **Electrification**
5. **Cooperation** – Interoperability (built on FHWA's work)

Four (4) scenarios, shown in **Figure 6,** were developed for the CAV Strategic Plan:

1. **Advancing Technology**
2. **Connected Infrastructure**
3. **Private Automation**
4. **Integrated Mobility**

Figure 6: Scenario 1(top left); Scenario 2 (top right); Scenario 3 (bottom left); Scenario 4 (bottom right)

The horizon year of 2040 was selected for this project as it lines up with other planning horizon years within MnDOT. However, MnDOT stated that they are not focusing on designing for a specific year, but instead are working to frame the concept of a future year.

4.3.3 *STAKEHOLDER ENGAGEMENT*

MnDOT hosted a series of workshops to explore how CAV could change transportation and life in Minnesota over the next 20 years. A total of twelve (12) workshops were held in cities across the state between late 2018 and early 2019 to gain insight on how alternative CAV futures may impact Minnesota transportation, as well as the associated opportunities and challenges.[29] MnDOT reached out to Stakeholders statewide to understand if there are any differences in their perspectives from different cities. One (1) pilot workshop was held with planning partners and agencies to gather feedback on the proposed approach and the details of scenarios prior to formal Stakeholder outreach.

The series of workshops were in an interactive format with breakout sessions. The participants were asked to discuss the foreseen opportunities and challenges for each of the future scenarios.

The scenarios were pre-determined before presenting to the public. However, MnDOT was prepared to update them if necessary. The target audience of the workshops were industry partners; however, all workshops were open to the public. The following web links lead to MnDOT's educational materials that describes each of the scenarios:

- Scenario 1: https://vimeo.com/295441417/0f25eac130
- Scenario 2: https://vimeo.com/291167626/c4b1bae550
- Scenario 3: https://vimeo.com/295387620/2e183088db
- Scenario 4: https://vimeo.com/291168278/bfe30c7cfd

4.4 NEXT STEPS

Scenario Planning was MnDOT's first project on CAV. Using the scenarios developed, MnDOT adjusted the recommended strategies, updated the priorities and removed inapplicable strategies, to ensure they remain strategic, innovative and collaborative in planning for CAV regardless of future outcomes.

In addition, MnDOT intends to present the scenarios to the public using educational materials on an interactive website. They recognize the value in starting the conversation and setting a direction early, instead of holding off until specific roles and actions for public agencies are identified.

4.5 RECOMMENDATIONS

MnDOT provided insights in their scenario development process, educational materials and commitment to engage stakeholders state-wide.

MnDOT's first recommendation to the CAV Readiness Plan project team was to allocate extra time to develop the scenarios. They spent approximately one and a half months to develop scenarios using the FHWA scenarios as their initial framework, with an additional month for adjustments, which was longer than expected. However, it was necessary and useful to spend the amount of time to solidify the scenarios as they are critical to subsequent conversations in the study process.

The second recommendation was to test the engagement approaches to gather feedback prior to any formal outreach. MnDOT hosted a pilot workshop prior to the series of Stakeholder workshops. This was critical to their team as it allowed them to understand how the audience might react and what adjustments would be beneficial to better communicate their message and facilitate the conversations.

How were the lessons learned applied to the CAV Readiness Plan?

The CAV Readiness Plan project team considered the advice provided by MnDOT and allocated time to consider Stakeholders' input to modify and update the scenarios and personas. The team also engaged the Stakeholders through online surveys. The first survey was sent out after workshop #1 to collect feedback on the workshop structure and breakout activities, which was used to improve the engagement approaches for subsequent events. The second survey was sent out prior to workshop #2 to understand Stakeholders' expectations on the CAV Readiness Plan, to compare to the vision of the project team and Steering Committee.

5 SWEDEN

5.1 INTERVIEW DETAILS

WSP Sweden is leading the Future City project for Sweden, which focused on developing and analyzing urban planning scenarios for 2030. The project involved five (5) local municipalities and ten (10) to fifteen (15) private companies within Sweden. Using tools from the WSP Scenario Planning Toolbox, three (3) workshops were held to enable participants from the public and private sectors, such as municipalities, traffic agencies, consultancies and local businesses, to contribute to the Scenario Development process.

To leverage this experience, an interview was requested with the internal project team in Sweden. The interview was held by teleconference on October 17, 2018.

5.2 SCENARIO PLANNING

5.2.1 *PURPOSE*

"How will Sweden look like in the future?" is a question that is often being asked in Sweden. To answer that question, the Future City project aimed to develop a set of scenarios that would establish a roadmap for Sweden's municipalities, traffic agencies, consultancies and local businesses to envision the future. This project aimed to help Stakeholders better understand how the future may look and be better positioned for potential future challenges. To develop alternative scenarios that address Stakeholder concerns and ensure the study provides valuable information, WSP Sweden used a participant-driven scenario development process. Instead of having a set of predetermined scenarios, a wide range of stakeholders were invited to three (3) workshops to brainstorm and develop the scenarios together.

5.2.2 *DEVELOPMENT OF SCENARIOS*

Four (4) Future City scenarios were developed through the workshops. The following lists outline the goals and outcomes of each workshop.

Workshop 1:

- Guided participants to identify a list of trends and determined the level of certainty and influence, which were converted into a table (see **Table 2**).
- Split the trends into four (4) categories depending on their certainties and influences (see **Figure 7**).
- Used certain trends with big influence and uncertain trends with big influence to form the basis for the scenarios at a later stage.

Workshop 2:

- Formed four (4) scenarios using the two trends of economic growth and rate of digitalization (see **Figure 8**).
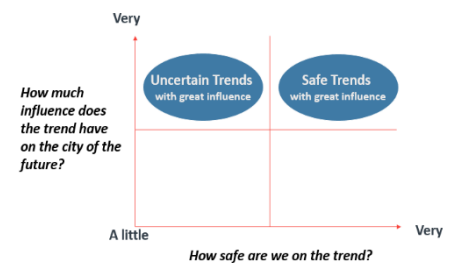- Established the future conditions based on the two trends and described characteristics of each.
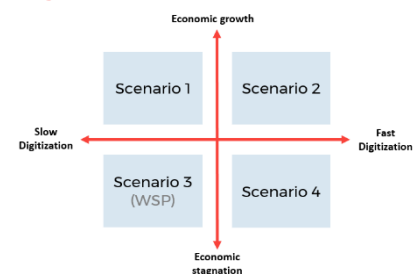
Figure 7: Level of Certainty and Influence Degree Matrix

Figure 8: Workshop 2 Scenarios

Workshop 3:

- Provided participants with a consolidated description of scenarios. For example, the "fast digitalization with economic stagnation" was described with the following narrative:

  "Sweden has fallen in recession. It has led to high unemployment and pressure on public finances is big. The country has simply not followed the fast-technological development and many job opportunities have been replaced by automation. To save money, we are therefore trying to live cheap. Gaps between rich and poor are large and for many it has become too expensive to live in the largest cities, leading to a search of accommodation in the countryside. One-person households have become popular and many people are working in repairing old products and services rather than consuming new."

- Performed consequence analysis of each scenario to test the following impacts:
  — Influence of Future City in a small, medium or large scale.
  — Timeframe (i.e. coming within the next 3-10/11-20/21+ years).
  — Influence on small/medium/large cities.
  — Influence on individuals, cities, municipalities, regions, or society as a whole.
  — The horizon year of 2030 selected for this project.

Table 2: Examples of Identified Trends

Certain trends with large influence	Uncertain trends with large influence
• Urbanisation • Digitalization • E-shopping • Automation • Changed mobility	• Form of accommodation • Opposition to car • Autonomous vehicles and influence • New mobility schemes (carpool, bike-share) • Lower purchasing power

5.2.3 STAKEHOLDER ENGAGEMENT

Three (3) workshops, comprised of 30 to 40 participants from both the public and private sectors, were held for the Future City project. There was a diverse representation, as participants held various roles at their respective organizations, including municipalities, traffic agencies, consultancies (e.g. economists, engineers and architects) and retail (e.g. grocery stores and pharmacy companies).

5.3 NEXT STEPS

The scenarios helped stakeholders conceptualize the plausible futures for each city involved in the Future City project. These scenarios act as a tool to help public agencies incorporate possible futures into their daily operations, strategic planning and capital planning, as well as to ensure their initiatives and projects are future proof and adaptable.

5.4 RECOMMENDATIONS

Many Stakeholders were involved in the Future City project. WSP Sweden noted that this level of engagement was important to bring these Stakeholders into the conversations and allow them to express their opinion. WSP Sweden also noted the importance of having distinctive and solid scenarios that can be easily differentiated.

The project goal was to allow the participants to develop their own scenarios, as they were the end users. Through the workshops, participants identified a list of trends and associated certainties and influences to develop the scenarios, and identify associated consequences. WSP Sweden did not develop any scenarios prior to the workshops, nor rewrite/ change them after the workshops. Since the scenario development process was participant-driven, it brought the risk of not carrying a clear direction for the project; however, this approach provided the participants an opportunity to develop scenarios that are more applicable to their use. WSP Sweden highlighted the benefits of considering when and how experts and Stakeholders should be involved in the early stages of the scenario development process.

How were the lessons learned applied to the CAV Readiness Plan?

A total of 48 participants attended the CAV Readiness Plan workshop #1. It was agreed that the level of engagement provided through the workshop format was appropriate to bring valuable insights to the project and will continue to be applied for future engagements. Due to the differences in the project scope of work, it was determined that the participant-driven approach used by WSP Sweden to develop the scenarios would not be the best approach for the CAV Readiness Plan. However, a large amount of time was provided for the Stakeholders (during the workshop and in the following week) to review and provide comments on the draft scenarios and personas. In workshop #2, the draft Readiness Guidelines were also given to Stakeholders to review individual sections in groups (related to area of expertise) and provide input. This was similar to WSP Sweden's approach in ensuring the "end user" Stakeholders were directly involved in the revision and finalization of the CAV Readiness Plan.

6 WHAT WAS LEARNED?

Four organizations from the United States, Australia and Europe were interviewed for their insights into their vision on CAV, efforts related to Scenario Planning and Stakeholder engagement. The following is the summary of a few key takeaways from the discussions, augmented with the CAV Readiness Plan project team's experience with Scenario Planning:

- **Develop a solid base scenario and distinctive alternative scenarios:** Through the interviews, the peer agencies provided insights in developing realistic and simplified alternative futures. This is also the feedback that was heard from the CAV Readiness Plan Stakeholders. A strong and solid base scenario sets a foundation for Scenario Planning and allows for easier comparison between scenarios. The alternative scenarios should be distinctive from each other, while remaining realistic. It is important to understand what the most prevalent drivers for change are and to keep the number of scenarios to a minimum.

- **Document the evidence and assumptions:** Evidence, including research, facts and assumptions, generate valid conclusions and adds credibility to the analysis. Without evidence, claims will only register as opinions. Through the CAV Readiness Scenario Planning process, research was conducted to develop an understanding of CAV technology and develop the necessary assumptions.

- **Ask the right people and right questions:** The project team recognized the importance to understand the target audience and engage them in the process. The purpose of the CAV Readiness workshops was to introduce the project and its objectives, and to encourage participants to investigate the issues and provide input. Preparing the right questions that target Stakeholders from different areas of expertise allowed the project team to benefit from their professional knowledge, while at the same time promoting meaningful and relevant conversations.

- **Listen to Stakeholder feedback:** The project team allocated adequate time to adjust the project approach following Stakeholder workshops to ensure the work reflected the feedback and input provided. The project team also adjusted the way feedback was collected and allocated sufficient time for Stakeholders (during workshop and after) to review and provide comments on draft materials.

APPENDIX

D

SCENARIO PLANNING

TABLE OF CONTENTS

1 SCENARIO PLANNING

1.1 WHAT IS SCENARIO PLANNING?

With the future of transportation unknown due to many disruptive technologies and business models, Scenario Planning has become a common way to look at a variety of possible futures. Scenarios are alternative futures that describe the interrelationships between trends and other areas of impacts (e.g. passenger and freight transportation, mode split, levels of automation and connectivity). Scenario Planning includes the examination these scenarios to understand the implications of a technology or trend, and prepare for possible future conditions. The Scenario Planning process also utilizes personas or profiles to illustrate the impact of each scenario on various segments of the population.

Scenarios that incorporate CAV are increasingly considering shorter horizons than what has been considered in the past. For example, consider Transport Canada's 2030 vision for safe, secure, green, innovative and integrated national transportation system that supports economic growth, job creation, and Canada's middle class. This vision includes supporting increasing presence of CAV technology and its use on public roads to improve safety, reduce congestion, increase mobility, protect the environment and support economic opportunities for Canadian businesses.[32, 33]

Defining the infrastructure and operational readiness components for transit stations, highways, and arterial roads, as well as public levers enables the establishment of key building blocks that can support a variety of scenarios and allow agencies to have some confidence in what they can do to plan for an uncertain future.

1.2 SCENARIO ASSUMPTIONS

A series of assumptions were made based on research and literature discussing the current state of the technology, predicting the future trends that are anticipated to be followed, and exploring the effects on the transportation network of a region. The various vehicle occupancy and goods movement scenarios were identified independently of each other to allow for the consideration and testing of each scenario separately and identify the boundary conditions of which any combination would also be considered. It is important to note that as time and technology evolves, scenario outcomes could also evolve. There may be needs to update the assumptions used in the scenarios.

1.2.1 CAV ON-ROAD SATURATION

Taking the predictions from the literature, three CAV saturation levels were identified in the scenarios: Few CAV, Mixed and Primarily CAV. **Stakeholders identified the need for CAV scenarios to be broken down into phases of vehicle saturation, as opposed to horizon years, to capture the short-term, medium-term and long-term needs of the technology.**

The intent of these three saturation levels (**Figure 1**) was to cover the gradual adoption of the CAV technology over time to identify the specific guidelines and programs that are applicable depending on the CAV proportion of the on-road vehicle. This method allows road authorities to implement the recommendations based on their expectations of CAV commercialization and adoption.

The CAV Readiness Guidelines do not specify a specific time-frame on implementation, but rather identify the relevant saturation level that is applicable to the action item.
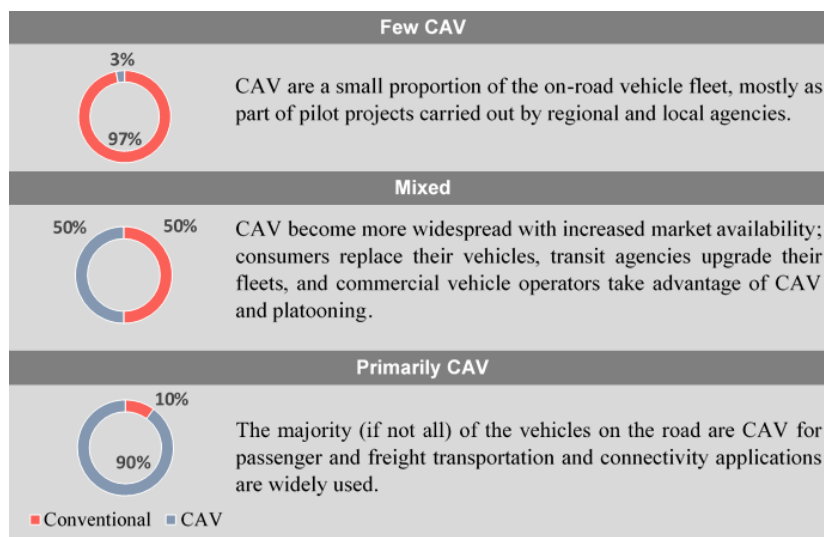

Figure 1: Three CAV saturation categories for the scenarios

1.2.2   OCCUPANCY WITH CAV TECHNOLOGY

Vehicle occupancy is the indicator used to differentiate between personal trips, shared trips and transit trips to capture the mode shift trends that CAV could introduce on transportation networks through a wide range of outcomes. **Figure 2** presents the vehicle occupancies of each scenario. For the Base Scenario, the zero-to-single and two-to-three passenger vehicle occupancy share was derived from mode share estimates for the GTHA from the 2016 Transportation Tomorrow Survey (TTS). The four plus occupancy mode consists of mass transit, micro-transit, shared ride-hailing, carpooling and other high-occupancy services. The value was derived from the transit mode share estimate of the Greater Golden Horseshoe Model (GGHM).
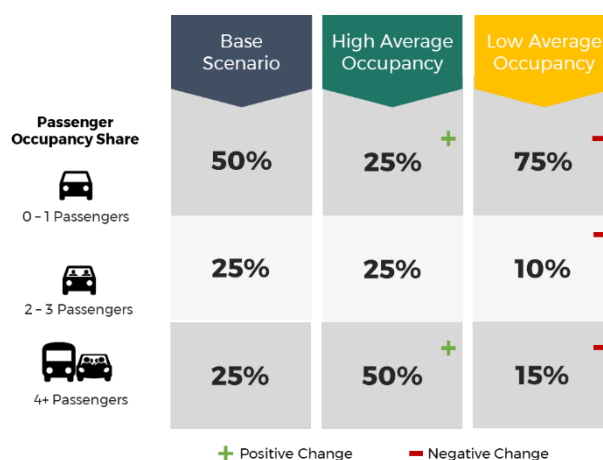
Figure 2: Vehicle occupancies for the scenarios

The mode share between single and multi-occupant vehicles (including shared vehicles and transit) is anticipated to shift according to how policy is developed to support shared mobility. Vehicles with zero-to-single occupancy are anticipated to continue to perform most passenger trips on the road in the Base Scenario. High and Low Average Occupancy scenarios can be used to consider the two possible extremes in vehicle occupancy that could materialize.

Literature indicates that CAV may lead to the use of personal vehicles by those unable to operate a conventional vehicle (such as youth, elderly, and persons with vision impairment or physical disabilities), with a possible shift away from public transit and shared mobility, as well as additional trips for circulation or self- parking of zero-occupant vehicles.[34] This would result in an increase in zero-to-single occupancy trips and thus lead to a future (scenario) with low average occupancy and greater traffic congestion.

The implementation of mobility pricing and other regulations or bonus/malus incentives could also serve as a tool to help reduce the number of zero-to-single occupancy vehicles on the road. A high occupancy scenario captures this possible shift away from zero-to-single-occupancy vehicles with an increase in the proportion of vehicles with four or more passengers. These policies could also lead to the rise in popularity

of ride-hailing services (e.g., Transportation Network Companies) and new business models anticipated to be integrated with transit services by filling the first-mile/last-mile gap between home/work and the transit station and increasing the mode share of multi-occupant trips.

1.2.3 FREIGHT WITH CAV TECHNOLOGY

The division of truck freight vehicle kilometres travelled (VKT) in the GTHA into long-distance (e.g., inter-city) VKT, versus urban freight (e.g., intra-city) VKT, was estimated using the MTO provincial passenger and freight model (TRESO). The model estimates that the trip share, by VKT, is 85% urban and 15% long-distance freight. In this study, three scenarios surrounding freight transportation are considered and shown in **Figure 3**. In the Base Scenario, the amount of freight deliveries (both long-distance and urban) is set to be equivalent to present day (100%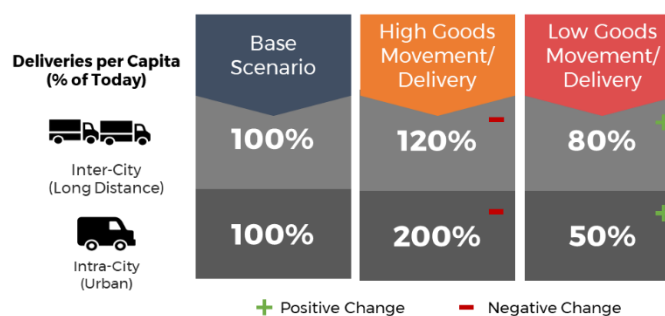 of present-day deliveries) on a per-capita basis. To account for freight deliveries either increasing or decreasing on a per-capita basis, each of a High and Low Goods Movement scenario could be considered. With the continued growth of e-commerce and global trade, deliveries and goods movement will likely continue to rise. Some of the important questions that need to be considered are whether consumption increases or decreases, whether deliveries will replace passenger trips (e.g. ordering online instead of travelling to stores to make purchases), or whether the average quantity of goods delivered per freight vehicle trip increases, decreases, or flatlines.

Figure 3: Freight deliveries per capita for each scenario

The High Goods Movement scenario would see an increase in long-distance and urban deliveries from present day values. Macroeconomic and consumption trends could lead to a larger demand in both long-distance and urban goods movement. Urban delivery could see a larger increase than long-distance freight due to the potential trend of increased e-commerce activity with greater frequency of deliveries of orders in small batches. However, in an uncertain future with a possible decrease in trade and deliveries, the macroeconomic and consumer trends could lead to a potential reduction in freight transportation.

The Low Goods Movement scenario can address these uncertainties by estimating a reduction in the proportion of long-distance and urban deliveries from the Base Scenario. Long-distance freight could potentially be better served more efficiently with other modes of transportation (e.g. rail) shifting goods-movement away from roads. Urban goods delivery could further be impacted as mobility pricing and curbside management policies that are implemented within city cores could make more costly and inconvenient to have frequent deliveries, leading to deliveries being organized differently and grouped into larger batches.

1.3 SCENARIOS FOR THE GTHA

Bringing together the assumptions, a set of five (5) scenarios (**Figure 4**) were finalized to characterize the conditions and variables associated with the various manifestations of CAV development and adoption to support modelling, evaluation, and planning activities. These scenarios were developed in consultation with Stakeholders and a review of existing future mobility scenarios developed for the City of Toronto,[35] Metrolinx's 2041 Regional Transportation Plan,[36] York Region's 2016 Transportation Masterplan,[37] and Ontario's Greater Golden Horseshoe (GGH) Transportation Plan 2051/2071.[38]

The goal of the scenarios is to identify what a future with CAV in the GTHA may look like to identify the steps that public agencies will need to take to prepare for this technology on the roads. They can be used

as a tool in their planning and policy development initiatives for CAV transportation. The scenarios were also used to inform the development of the CAV Readiness Guidelines and Programs and to check them to ensure that considerations for the various potential alternative futures were considered.

Figure 4: Five Scenarios for the GTHA

1.3.1 SCENARIO 1: BASE SCENARIO

The Base Scenario sets the foundation in which each alternative scenario builds upon. It models passenger occupancies and goods movement characteristics similar to present day conditions, as CAV technology progresses steadily through pilots. Goods movement increases proportionately to population growth and truck platooning is introduced for longer-haul freight trips.

The Base Scenario conditions include the following:

- CAV technology progresses steadily; CAVs eventually displace most conventional vehicles.

- Travel patterns evolve but remain similar to travel patterns today. Half of all passenger trips (ignoring active transportation) are completed as single-occupant vehicle trips, with the other half completed in vehicles with 2+ passengers (including transit).

- CAV pilots become more prevalent for personal travel, public transit, and goods movement, leading to a predominantly-CAV future.

- Inter- and intra-urban freight trips increase only in keeping with population growth; truck platooning is introduced for inter-urban freight trips.

- CAVs increasingly rely on curbside access for pick-up/drop-off activities; parking quantity, access and location evolve to account for zero-occupancy trips.
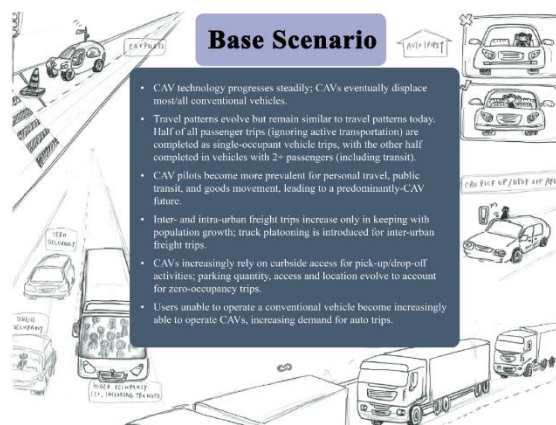
- Users unable to operate a conventional vehicle become increasingly able to operate CAVs, increasing demand for auto trips.

1.3.2   SCENARIO 2: HIGH AVERAGE OCCUPANCY

The High Average Occupancy scenario includes conditions where pricing policies are implemented to encourage higher occupancy trips, encouraging mobility services to grow to become the most common means of accessing transportation services. Goods movement increases proportionately to population growth and truck platooning is introduced for longer-haul freight trips.

The High Average Occupancy scenario conditions include the following:

- Early CAV pilots indicate increasing demand for single-occupant travel; transportation agencies introduce mobility pricing to incentivize high-occupancy travel.

- Mobility services platforms become the most common means of accessing transportation services, and the convenience of avoiding vehicle ownership pushes high-occupancy shared-use vehicles and transit to be the preferred modes.

- Few zero-occupant vehicle trips occur. Shared CAVs pick up and drop off passengers continuously, with limited need for urban parking or dwelling. Huge demand for curbside pick-up/drop-off space compels strong regulation or pricing of curb space.

- Inter- and intra-urban freight trips increase only in keeping with population growth; truck platooning is introduced for inter-urban freight. Reduced congestion on roads enables quick and reliable deliveries.
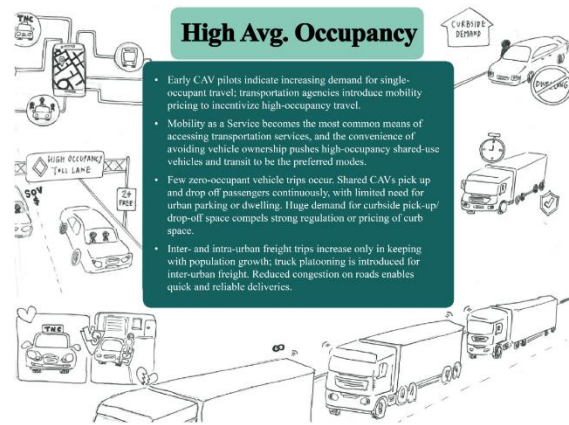
1.3.3   SCENARIO 3: LOW AVERAGE OCCUPANCY

The Low Average Occupancy scenario describes conditions where policies designed to encourage higher occupancy trips is ineffective, leading to an increase in low- and zero-occupancy trips. Goods movement increases proportionately to population growth and truck platooning is introduced for longer-haul freight trips.

The Low Average Occupancy scenario conditions include the following:

- Policy to promote shared mobility and high-occupancy vehicle trips is disjointed and ineffective. With no mobility pricing, and a fading gas tax as cars go electric, public transit funding and ridership declines. Few tangible incentives exist for travellers to avoid zero- and single-occupancy vehicle trips.

- The accessibility and service offerings available to all citizens through CAV technology has led to a growth in demand for personal transport.
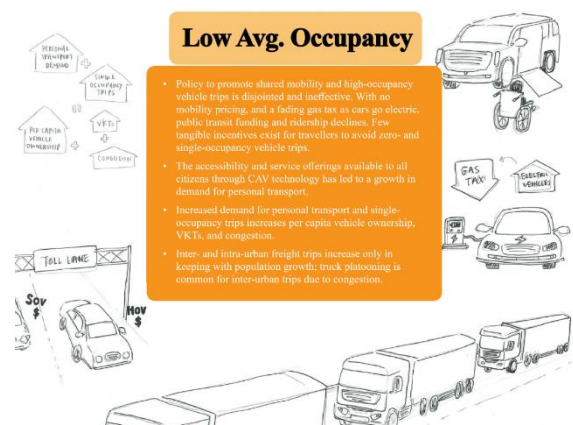
- Increased demand for personal transport and single-occupancy trips increases per capita vehicle ownership, VKT, and congestion.

- Inter- and intra-urban freight trips increase only in keeping with population growth; truck platooning is common for inter-urban trips due to congestion.

1.3.4 SCENARIO 4: HIGH GOODS MOVEMENT

The High Goods Movement scenario describes future economic and consumer trends that lead to a higher per capita demand on goods movement, resulting in urban deliveries to increase substantially. Passenger travel patterns evolve in a similar manner to what is presently observed.

The High Goods Movement scenario conditions include the following:

- Macroeconomic and consumer trends fuel continued growth in per-capita demand for goods movement, and CAV technology enables cheap ("free") shipping to become the norm due to the absence of regulation and mobility pricing.

- Demand for long-distance ("inter-city") freight increases modestly per capita, in keeping with per-capita consumption of goods. Platooning is standard for highway trucking.

- While consumption has increased modestly, the per-capita number of urban deliveries has increased hugely as average package size decreases, due to "free" shipping on small packages.

- Passenger travel patterns evolve but remain similar to travel patterns today; users unable to operate a conventional vehicle become increasingly able to operate CAVs, increasing demand for auto trips.
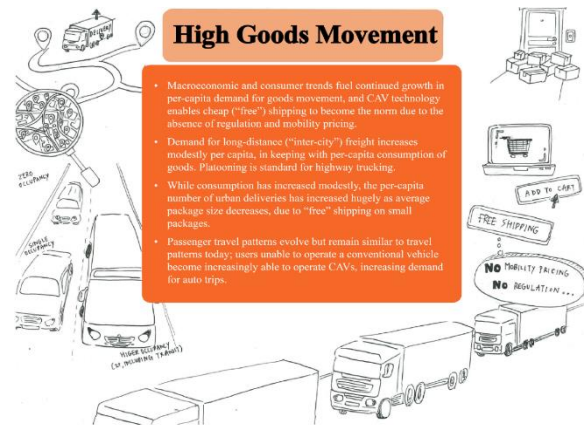
1.3.5 SCENARIO 5: LOW GOODS MOVEMENT

The Low Goods Movement scenario describes a future where environmental policy has increased the cost of goods movement, which, combined with a renewed interest and expansion in rail shipping, has modestly reduced demand for long-distance truck freight. Additionally, this scenario describes how regulations, small delivery centres and alternative delivery modes, significantly reduce per-capita demand for urban truck deliveries. Passenger travel patterns evolve in a similar manner to what is presently observed.

The Low Goods Movement scenario conditions include the following:

- Environmental policy has increased the cost of goods movement, which, combined with a renewed interest and expansion in rail shipping, has modestly reduced demand for long-distance truck freight.

- Regulations related to curbside management restrict truck parking and dwell times. Reduced demand for goods, combined with a greater number and better distribution of small delivery centres,

and alternative delivery modes such as aerial and sidewalk drones, has significantly reduced per-capita demand for urban truck deliveries.

- Passenger travel patterns evolve but remain similar to travel patterns today; users unable to operate a conventional vehicle become increasingly able to operate CAVs, increasing demand for auto trips.
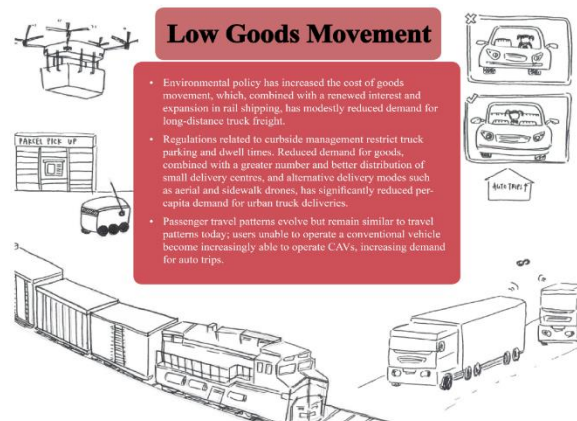
1.4 PERSONAS FOR THE GTHA

A total of eight (8) personas were developed through the Scenario Planning process to test how different segments of the population will interact with CAV. These personas represent urban, suburban and rural residents, as well as key age and income groups of interest, where there is an expectation that these characteristics will impact their behaviour and specifically their likelihood to own or rent a CAV (e.g. openness to technology). These personas are presented as a reference point for population characteristics. They were used in the development of the CAV Readiness Guidelines and Programs to check that the needs and mobility requirements for the various characteristics of the population were considered.

For each persona, a series of key attributes, most relevant to CAV use, were defined (**Table 1**). These attributes and the eight personas are described in the following sections. Narratives were also developed for each of the personas to provide context on their mobility attributes.

Table 1: Persona attributes most relevant to mobility and CAV use

Key Attributes		Other Attributes
Mobility Restrictions/Barrier Travel with equipment (wheelchair); Hearing barrier or language barrier	**Mobility Pattern** Peak, frequent/not frequent; Off-Peak, frequent/not frequent	Life Stage Household size Driver's license
Vehicle Reliance for Work Yes or No (e.g. bus, taxi, truck, personal vehicle)	**Openness to Technology** Low; Medium; High	Educational background Employment Status
Income/Wealth $ (Low); $$ (Medium); $$$ (High)	**Openness to Shared Mobility** Low; Medium; High	Access to financial institutions
Flexibility to change modes Yes or No (e.g., flexibility to change modes during inclement weather, increased congestion etc.)	**Typical Travel Pattern:** Within ⟳ ; Between ⟷; **UC** – Urban Core; **U** – Urban; **S** – Suburban; **R** – Rural	Lifestyle Home location Work location Activity location

1.4.1 PERSONA 1: THE CHILD

The Child is under 12-years-old and lives in a rural area with their parents. The parents are employed full-time and the household is classified as middle-income. The parents do not allow the Child to use shared mobility with strangers and therefore, mode choice is limited. The school bus is their daily mode of transport to go to & from school. The Child is healthy and active, and regularly attends after-school activities in the neighbourhood. The Child embraces and is excited to try out new technologies.

THE CHILD

Mobility Restrictions/ Barriers: N/A
Vehicle Reliance for Work: No
Flexibility to change modes: No
Household Income/ Wealth: $$
Mobility Pattern: Peak, Frequent
Openness to Technology: High
Openness to Shared Mobility: Low
Typical Travel Pattern: ⟳ R

The Child is unable to drive and has limited access to financial institutions.

1.4.2 PERSONA 2: THE COMMUTER

The Commuter lives in the suburbs on their own, is single and graduated from university a few years ago. The Commuter works in an urban area and commutes to work during peak hours. They have a low-income and are focused on repaying student loans. The Commuter is active and goes out with friends in the urban core on weekends. They are interested in technology and are open to using shared mobility.

The Commuter has a driver's license but doesn't own a car and has access to financial institutions.

1.4.3 PERSONA 3: THE TRANSIT USER

The Transit User lives on their own in the urban core and is highly educated and career-driven. The Transit User is a well-regarded professional in the industry with a high income. Transit is their daily mode choice to commute to and from work within the urban core during peak hours. The Transit User is active and travels within the urban core where transit is available. They like using new technologies and shared mobility.

The Transit User rarely drives, and has access to financial institutions.

1.4.4 PERSONA 4: THE SHIFT WORKER

The Shift Worker is a single parent and lives in the suburbs with three children. The Shift Worker has multiple jobs in a nearby urban area to support the family. With various working hours, the Shift Worker usually travels during off-peak hours. Mode choice is flexible as long as the affordability and travel time are acceptable. The Shift Worker loves spending time with their three children at home. They are open to new technologies and do not have a strong opinion on shared mobility.

The Shift Worker knows how to drive and has access to financial institutions.

1.4.5 PERSONA 5: THE STAY AT HOME PARENT

The Stay at Home Parent lives in the urban area with their partner and five-year-old son. The Parent started working after high-school and recently quit their job to become a stay-at-home parent. They drives their children to and from school every day. The Parent stays at home most of the time and enjoys spending time with the family. They are fairly open to new technologies and shared mobility as long as they are secure and safe.

THE STAY AT HOME PARENT

- Mobility Restrictions/ Barriers: N/A
- Vehicle Reliance for Work: No
- Flexibility to change modes: Yes
- Household Income/ Wealth : $$
- Mobility Pattern: Peak, Frequent
- Openness to Technology: Medium
- Openness to Shared Mobility: Medium
- Typical Travel Pattern: U

The Stay at Home Parent has a driver's license and access to financial institutions.

1.4.6 PERSONA 6: THE DELIVERY TRUCK DRIVER

THE DELIVERY TRUCK DRIVER

- Mobility Restrictions/ Barriers: Hearing Barrier
- Vehicle Reliance for Work: Yes
- Flexibility to change modes: No
- Household Income/ Wealth : $$
- Mobility Pattern: Peak, Frequent
- Openness to Technology: Low
- Openness to Shared Mobility: Low
- Typical Travel Pattern: S ↔ R ↔ U

The Delivery Truck Driver lives in the suburbs with their partner. Their household has a middle-class income. They drive between urban and rural locations daily during peak hours. Staying at home and reading is their favourite activity during free time. The Driver has difficulty hearing and requires hearing aids. They are reluctant to try new technologies.

The Delivery Truck Driver has access to financial institutions.

1.4.7 PERSONA 7: THE ASSISTIVE DEVICE USER

The Assistive Device User lives in the suburbs with their family. They immigrated from a foreign country and have a language barrier. The household has low-income with more than 5 people. They like staying at home and spending time with their family. Travelling is required occasionally for appointments with limited mode choice options due to wheelchair restrictions. They are typically driven by their family or personal support worker, and occasionally uses specialized transit services. The Assistive Deviuce User has little interest in technology and does not feel comfortable with shared mobility.

THE ASSISTIVE DEVICE USER

- Mobility Restrictions/ Barriers: Travels with Equipment (Wheelchair), Language Barrier
- Vehicle Reliance for Work: No
- Flexibility to change modes: No
- Household Income/ Wealth : $
- Mobility Pattern: Peak, Not Frequent
- Openness to Technology: Low
- Openness to Shared Mobility: Low
- Typical Travel Pattern: N/A

The Assisstive Device User is not able to drive and has access to financial institutions.

1.4.8 PERSONA 8: THE RETIREE

THE RETIREE

Mobility Restrictions/ Barriers: Weak eyesight

Vehicle Reliance for Work: No

Flexibility to change modes: Not always

Household Income/ Wealth : $$$

Mobility Pattern: Off Peak, not Frequent

Openness to Technology: Medium

Openness to Shared Mobility: Low

Typical Travel Pattern: N/A

The Retiree lives in an urban area with their partner and dog. As someone who is well-educated and has recently retired, health, quality of life and environment are their major priorities. Their favourite activity is to go for morning and evening walks and listen to the radio at home. The Retiree doesn't travel often, but when they need to, they travel during the off-peak period. They are flexible with transportation modes as long as it's safe and convenient. The Retiree is curious about new things and is open to try new technologies. However, the Retiree is not comfortable with sharing vehicles with strangers.

The Retiree has weak eyesight and no longer drives. They have access to financial institutions.

APPENDIX

E

CAV READINESS GUIDELINES TABLES

CAV Saturation	Local and Arterial Roads (including school/community safety zones, connections to intermodal terminals, airports, complete streets etc.)	400-Series Highways, Gardiner, DVP & QEW (including connections to intermodal terminals, airports etc.)	Provincial Highways	Public Sector Owned Fleets	Parking lots	Transit Corridors	Transit Terminals and Stops
Few CAV (Pilots, Platooning on key highways)	• Data collection needs defined for pilots so that agencies can understand where CAV reverted to manual control to understand infrastructure implications (including recording technological malfunctions and near-misses) • Infrastructure for an emergency detection/incident management (safety) system (including interaction with emergency services) • Agency data collection requirements defined to monitor impact of CAV on existing infrastructure (e.g. to monitor curb space use, road performance and key areas for concern with poor weather) • Integration of V2I pilots (including connectivity with signals) with CAV pilots to facilitate testing of technology • Integration of vehicle-to-pedestrian/cyclists (V2P) pilots with CAV pilots to test interaction of CAV with pedestrians • Pilots to test pedestrian and cyclist detection infrastructure at designated intersections/crosswalks and in school zones, community safety zones, and public transit bus areas • Vehicle occupancy detection infrastructure (e.g. to track zero-occupancy and HOV CAV), unless in-vehicle detection and communication available • Infrastructure requirements for first/last mile urban deliveries (e.g. to accommodate sidewalk robots) • Pilots to test temporary physical infrastructure requirements compatible with CAV to facilitate navigating around construction sites • Updated temporary works (OTM Book 7) equipment for V2I (e.g. during construction, maintenance) • Digital infrastructure for cybersecurity to protect connected infrastructure from cyber attacks • Back-up sensors and systems in place to ensure continuity of operations during planned and unplanned event disruptions	• Data collection needs defined for pilots so that agencies can understand where CAV reverted to manual control to understand infrastructure implications (including recording technological malfunctions and near-misses) • Agency data collection requirements defined to monitor impact of CAV on existing infrastructure (e.g. to monitor road performance and key areas for concern with poor weather) • Assess current bridge and pavement assets to confirm that platooning trucks don't impact structural loading • New and improved pavement required for CAV (e.g. smart pavement, magnetic, embedded sensors) • New and improved road markings (e.g. positional sensors, reflective markings) • Integration of V2I pilots with CAV pilots to facilitate testing of technology • Vehicle occupancy detection infrastructure (e.g. to track zero-occupancy and HOV CAV), unless in-vehicle detection and communication available • Pilots to test temporary physical infrastructure requirements compatible with CAV to facilitate navigating around construction sites • Updated temporary works (OTM Book 7) equipment for V2I (e.g. during construction, maintenance) • Digital infrastructure for cybersecurity to protect connected infrastructure from cyber attacks • Back-up sensors and systems in place to ensure continuity of operations during planned and unplanned event disruptions	• Data collection needs defined for pilots so that agencies can understand where CAV reverted to manual control to understand infrastructure implications (including recording technological malfunctions and near-misses) • Agency data collection requirements defined to monitor impact of CAV on existing infrastructure (e.g. to monitor road performance and key areas for concern with poor weather) • Assess current bridge and pavement assets to confirm that platooning trucks don't impact structural loading • Integration of V2I pilots with CAV pilots to facilitate testing of technology • Pilots to test temporary physical infrastructure requirements compatible with CAV to facilitate navigating around construction sites • Updated temporary works (OTM Book 7) equipment for V2I (e.g. during construction, maintenance) • Digital infrastructure for cybersecurity to protect connected infrastructure from cyber attacks • Back-up sensors and systems in place to ensure continuity of operations during planned and unplanned event disruptions	• Some agency owned assets (transit vehicles, maintenance vehicles, employee vehicles, snow plows etc.) upgraded to CAV for testing and data collection purposes, along with the necessary infrastructure to support their maintenance (i.e. electric charging stations in warehouses) • Re-assess needs for CAV maintenance vehicles due to any changes to minimum maintenance standards • Ensure connectivity of systems between fleet vehicles produced by different manufacturers (i.e. discuss interoperability between fleet vehicle OEMs and system manufacturers prior to procurement) • Ensure capability of CAV transit vehicle communication between different transit agencies and manufacturers to facilitate interaction on the road and in transit terminals (i.e. development of communication standards for transit vehicles)	• Data collection needs defined for pilots so that agencies can understand where CAV reverted to manual control to understand infrastructure implications (including recording technological malfunctions and near-misses) • Agency evaluate if dedicated parking spots required for pilot CAV.	• Data collection needs defined for pilots so that agencies can understand where CAV reverted to manual control to understand infrastructure implications (including recording technological malfunctions and near-misses) • Data for regional physical limitations on roadways (bridge heights, roundabout restrictions etc.) • Pilots for connected (V2I) transit signal priority infrastructure • Agency data collection requirements defined to monitor impact of CAV on existing infrastructure (e.g. to monitor curb space use, road performance, and key areas for concern with poor weather) • Integration of V2I pilots with CAV pilots to facilitate testing of technology • Identify candidate corridors for transit CAV pilot (e.g. CAV BRT pilot)	• Pilot to explore different station PUDO configurations and arrangements to accommodate emerging mobility options (this could inform later guidelines for CAV) • Data collection needs defined for pilots so that agencies can understand where CAV reverted to manual control to understand infrastructure implications (including recording technological malfunctions and near-misses) • Agency data collection requirements defined to monitor impact of CAV on existing infrastructure (e.g. to monitor curb space use, road performance and key areas for concern with poor weather) • Integration of V2I pilots with CAV pilots to facilitate testing of technology • Bus stop design guidelines and transit interface with terminals for microtransit vehicles
Mixed CAV/Conventional	• Necessary infrastructure (V2I) in place to support safety for a mix of conventional and CAV vehicles for curves, level crossings, defined/undefined pedestrian crossings, signals, intersections (including multi-use paths) etc. • Necessary infrastructure (V2I) to increase the ability to provide transit-signal priority with CAV • Necessary pedestrian and cyclist detection infrastructure (including V2P) along the corridor • Ongoing assessment of infrastructure improvement requirements at intersections with heavy CAV goods movement traffic as technology advances • Curbside management strategies for on street parking, deliveries, pick-up/drop-off areas etc. (e.g. dedicating properties for these areas) • Physical changes in place to support the mixed fleet sharing the road (i.e. lane layouts and restrictions) in a safe manner, including pedestrian and bicycle interactions with CAV, as well as CAV in school and community safety zones	• Necessary infrastructure (V2I) in place to support safety for a mix of conventional and CAV vehicles (V2I) for curves, congestion, incidents etc. • All assets reviewed to confirm that platooning trucks don't have a negative impact and any physical changes in place to support safe movement of platooning trucks along the corridor and at ingress/egress points • Physical changes in place to support the mixed fleet sharing the corridor (i.e. dedicated lanes for CAV, platooning only lane), considering safety requirements (e.g. physical barriers between dedicated and general-purpose lanes to protect for lane friction) and how ingress/egress is managed	• Necessary infrastructure (V2I) in place to support safety for a mix of conventional and CAV vehicles (V2I) for curves, signals, intersections, congestion, incidents etc. • All assets reviewed to confirm that platooning trucks don't have a negative impact and any physical changes in place to support safe movement of platooning trucks along the corridor and at ingress/egress points • Physical changes in place to support the mixed fleet sharing the corridor (i.e. lane layouts and restrictions), considering safety requirements and how ingress/egress is managed	• Procurement strategy standards in place to replace non-CAV agency owned assets (transit vehicles, maintenance vehicles, employee vehicles etc.) with CAV where appropriate, along with the necessary infrastructure to support their maintenance (i.e. electric charging stations in warehouses)	• Parking lot physical layout optimized where appropriate for CAV automated parking • Inventory of parking infrastructure needs in terms of quantity and distribution	• Physical changes in place to support the mixed fleet sharing the road (i.e. lane layouts and restrictions) in a safe manner, including pedestrian and bicycle interactions with CAV • Necessary infrastructure (V2I) in place to support safety for a mix of conventional and CAV vehicles for curves, level crossings, intersections and physical environment (including bridges etc.)	• Rural and urban transit stop/station design guidelines incorporating first/last mile service requirements for PUDO (including accessibility considerations) • Physical changes in place to support the mixed fleet sharing the road (i.e. lane layouts and restrictions) in a safe manner, including pedestrian and bicycle interactions with CAV
Primarily CAV	• Necessary infrastructure in place for V2I2V (repeaters) or V2C or V2E to gather and broadcast information • Physical changes in place to support the small % of conventional vehicles using the road (i.e. lane layouts and restrictions) in a safe manner, including pedestrian and bicycle interactions with CAV, as well as CAV in school and community safety zones • Evaluate existing physical infrastructure (i.e. lane widths, pavement markings, signs etc.) for compatibility with CAV operations	• Necessary infrastructure in place for V2I2V (repeaters) or V2C or V2E to gather and broadcast information • Physical changes in place to support primarily CAV in the corridor and consideration for conventional (i.e. dedicated lanes for conventional), considering safety requirements and how ingress/egress is managed • Evaluate existing physical infrastructure (i.e. lane widths, pavement markings, signs etc.) for compatibility with CAV operations	• Necessary infrastructure in place for V2I2V (repeaters) or V2C or V2E to gather and broadcast information • Physical changes in place to support the small % of conventional vehicles using the road (i.e. lane layouts and restrictions) in a safe manner. • Evaluate existing physical infrastructure (i.e. lane widths, pavement markings, signs etc.) for compatibility with CAV operations	• Replacement of agency owned assets (transit vehicles, maintenance vehicles, employee vehicles etc.) with CAV, along with the necessary infrastructure to support their maintenance (i.e. electric charging stations in warehouses)	• Necessary infrastructure in place for V2I2V (repeaters) or V2C or V2E to gather and broadcast information • Physical changes in place to support the small % of conventional vehicles using the road (i.e. lane layouts and restrictions) in a safe manner, including pedestrian and bicycle interactions with CAV. • Evaluate existing physical infrastructure (i.e. lane widths, pavement markings, signs etc.) for compatibility with CAV	• Necessary infrastructure in place for V2I2V (repeaters) or V2C or V2E to gather and broadcast information • Physical changes in place to support the small % of conventional vehicles using the road (i.e. lane layouts and restrictions) in a safe manner, including pedestrian and bicycle interactions with CAV • Evaluate existing physical infrastructure (i.e. lane widths, pavement markings, signs etc.) for compatibility with CAV operations	• Necessary infrastructure in place for V2I2V (repeaters) or V2C or V2E to gather and broadcast information • Physical changes in place to support the small % of conventional vehicles using the road (i.e. lane layouts and restrictions) in a safe manner, including pedestrian and bicycle interactions with CAV • Evaluate existing physical infrastructure (i.e. lane widths, pavement markings, signs etc.) for compatibility with CAV operations

CAV Saturation	Network Management: Arterials (Staff & Systems)	Network Management: 400-Series Highways, Gardiner, DVP & QEW (Staff & Systems)	Network Management Provincial Highways (Staff & Systems)	Public Agency Operations and Maintenance Fleet	Urban Commercial Delivery	Public Transportation and Transit Agencies (Including leased fleets, dedicated fleets and shared mobility services)	Private Shared Mobility Services
Few CAV (Pilots, Platooning on key highways)	• Collaboration between regional agencies on pilot projects, procedures and preparation measures to avoid duplication (i.e. development of a pilot project registry) of V2I and CAV trials • Coordinated data sharing relationships (i.e. big data portal) between regional agencies, province and industry partners to enable streamlined sharing of CAV data • Big Data management strategy to securely collect, process and store large datasets collected by CAV (from public fleets and/or private vehicles) • Established data security and cybersecurity methods to protect data and information transferred between systems • Established data collection & management methodologies and identification of key performance measure parameters for pilots and testing programs • Updated traffic management strategies surrounding areas of major trip generators (e.g. airports) • Evaluate pilots from safety and operations perspective • Understanding organizational changes, skillsets, structure and new staffing needs • Be willing to make existing, relevant information available for the development of standard high resolution, centralized mapping data, by private sector companies, broadcasted to vehicles and updated to reflect real-time road conditions and weather events, as well as georeferenced agency by-laws and standards (e.g. SLR, WWP) • Notification of CAV of planned and unplanned events (i.e. construction, closures, congestion, collisions) including updates to high resolution, centralized mapping data to reflect planned construction and road closures to facilitate CAV movement through those areas, as well as report road conditions and weather events • Pilot to test CAV interaction with emergency services (e.g. clearing path for passing etc.) • Guidelines to enforce rules of road under mixed CAV operations to ensure safe operation of transportation network	• Collaboration between regional agencies on pilot projects, procedures and preparation measures to avoid duplication (i.e. development of a pilot project registry) of V2I and CAV trials • Coordinated data sharing relationships (i.e. big data portal) between regional agencies, province and industry partners to enable streamlined sharing of CAV data • Big Data management strategy to securely collect, process and store large datasets collected by CAV (from public fleets and/or private vehicles) • Established data security and cybersecurity methods to protect data and information transferred between systems • Established data collection & management methodologies and identification of key performance measure parameters for pilots and testing programs • Guidelines surrounding safe operation of commercial CAV and truck platooning (e.g. following distances) including considerations for commercial CAV carrying sensitive goods (i.e. oversized loads, gas, nuclear etc.) • Updates to commercial vehicle inspection procedures, in coordination with the Federal Government, to accommodate CAV and platooning • Updated traffic management strategies surrounding areas of major trip generators (e.g. airports) • Evaluate pilots from safety and operations perspective • Understanding organizational changes, skillsets, structure and new staffing needs • Be willing to make existing, relevant information available for the development of standard high resolution, centralized mapping data, by private sector companies, broadcasted to vehicles and updated to reflect real-time road conditions and weather events, as well as georeferenced agency by-laws and standards (e.g. SLR, WWP) • Notification of CAV of planned and unplanned events (i.e. construction, closures, congestion, collisions) including updates to high resolution, centralized mapping data to reflect planned construction and road closures to facilitate CAV movement through those areas, as well as report road conditions and weather events • Pilot to test CAV interaction with emergency services (e.g. clearing path for passing etc.) • Guidelines to enforce rules of road under mixed CAV operations to ensure safe operation of transportation network	• Collaboration between regional agencies on pilot projects, procedures and preparation measures to avoid duplication (i.e. development of a pilot project registry) of V2I and CAV trials • Coordinated data sharing relationships (i.e. big data portal) between regional agencies, province and industry partners to enable streamlined sharing of CAV data • Big Data management strategy to securely collect, process and store large datasets collected by CAV (from public fleets and/or private vehicles) • Established data security and cybersecurity methods to protect data and information transferred between systems • Established data collection & management methodologies and identification of key performance measure parameters for pilots and testing programs • Guidelines surrounding safe operation of commercial CAV and truck platooning (e.g. following distances) including considerations for commercial CAV carrying sensitive goods (i.e. oversized loads, gas, nuclear etc.) • Pilot project assessing the interaction of CAV with conventional vehicles in single lane layouts at higher speeds • Pilot to test CAV interaction with emergency services (e.g. clearing path for passing etc.) • Evaluate pilots from safety and operations perspective • Understanding organizational changes, skillsets, structure and new staffing needs • Be willing to make existing, relevant information available for the development of standard high resolution, centralized mapping data, by private sector companies, broadcasted to vehicles and updated to reflect real-time road conditions and weather events, as well as georeferenced agency by-laws and standards (e.g. SLR, WWP) • Notification of CAV of planned and unplanned events (i.e. construction, closures, congestion, collisions) including updates to high resolution, centralized mapping data to reflect planned construction and road closures to facilitate CAV movement through those areas, as well as report road conditions and weather events • Pilot to test CAV interaction with emergency services (e.g. clearing path for passing etc.) • Guidelines to enforce rules of road under mixed CAV operations to ensure safe operation of transportation network	• Identification of regional/municipal services that could make use of CAV (e.g. snow removal, transit, employee vehicles etc.) for initial pilots and testing programs (to inform decisions in later time-frames) • Big Data management strategy to securely collect, process and store large datasets collected by public CAV fleets	• Guidelines for commercial CAV pilots to better understand how CAV technology could impact delivery operations and by-laws (i.e. stopping locations, designated pilot networks/corridors/neighbourhoods) • Guidelines to include commercial CAV in peak and off-peak delivery pilot projects • Guidelines to collect CAV freight data in pilots to allow for better understanding of vehicle performance on highly used freight routes through partnerships between government agencies and industry operators • Guidelines to test the dynamic adjustment of traffic signal timings for improved travel time and traffic flow of commercial CAV through freight corridors, making use of V2I connectivity infrastructure implemented as a pilot • Guidelines to evaluate and implement safety considerations surrounding commercial CAV operating on dense urban streets • Guidelines for last mile urban commercial deliveries (i.e. sidewalk robots, food deliveries via robots) and where/how they could operate safely	• Automated transit pilot projects in segregated and un-segregated environments • Collaboration between regional agencies on pilot projects, procedures and preparation measures to avoid duplication (i.e. development of a pilot project registry) of V2I and CAV trials • Coordinated data sharing relationships (i.e. big data portal) between regional agencies to enable streamlined sharing of CAV data • Big data management strategy to securely collect, process and store large datasets collected by CAV (from public fleets and/or private vehicles) • Established data security and cybersecurity methods to protect data and information transferred between systems • Guidelines for enhanced station access data collection to enhance understanding of station access across all modes • Guidelines for pilots and testing programs to better understand how CAV technology could change transit operations (i.e. automated shuttles, CAV buses on certain routes) • Pilot testing different mobility service arrangements on a subset of the population to explore travel behaviour impacts on different users • Transit station demand management strategy to accommodate third party mobility services • Understanding organizational changes, skillsets, structure and new staffing needs	• Coordination between public agencies and private mobility service providers to integrate services/fee structure with public transit • Coordination between public agencies and private on-demand mobility providers to run test-pilot of integrating private on-demand mobility with public transit and to collect/share data to explore the travel behaviour impact on regional travellers • Explore operating agreements between agencies, public and private

CAV Saturation	Network Management: Arterials (Staff & Systems)	Network Management: 400-Series Highways, Gardiner, DVP & QEW (Staff & Systems)	Network Management Provincial Highways (Staff & Systems)	Public Agency Operations and Maintenance Fleet	Urban Commercial Delivery	Public Transportation and Transit Agencies (Including leased fleets, dedicated fleets and shared mobility services)	Private Shared Mobility Services
Mixed CAV/Conventional	• Demand management approaches in place to balance demand and capacity and manage congestion for both CAV and conventional • Procedures to direct traffic under normal widespread CAV operating conditions • Updated emergency preparedness (i.e. evacuation plans) to incorporate CAV including notification and coordinated evacuation (emergency detour routes to be included in base mapping)	• Demand management approaches in place to balance demand and capacity and manage congestion for both CAV and conventional • Procedures to direct traffic under normal widespread CAV operating conditions • Updated emergency preparedness (i.e. evacuation plans) to incorporate CAV including notification and coordinated evacuation (emergency detour routes to be included in base mapping)	• Demand management approaches in place to balance demand and capacity and manage congestion for both CAV and conventional • Procedures to direct traffic under normal widespread CAV operating conditions • Updated emergency preparedness (i.e. evacuation plans) to incorporate CAV including notification and coordinated evacuation (emergency detour routes to be included in base mapping)	• Evaluation of regional/municipal services that could make use of CAV based on pilot results • Updated maintenance procedures for agency owned CAV (i.e. calibration of sensors, fueling/charging requirements/locations etc.)	• Adjustment of traffic signal timing requirements to accommodate commercial CAV and make use of V2I connectivity for improved travel time and traffic flow • Guidelines to define limitations on commercial CAV within urban boundaries to ensure safe operations (especially in areas with pedestrians)	• Pilot testing different mobility service arrangements to explore travel behaviour impacts on different users • Adjustment of traffic signal timing requirements to accommodate transit signal priority by making use of V2I connectivity with transit CAV for improved travel time and traffic flow	
Primarily CAV	• Demand management approaches in place to balance demand and capacity and eliminate congestion • Enforcement in place for CAV to ensure compliance with rules of road and safe operation of transportation network • Reduced restrictions on CAV operations as there will be less of a requirement to protect interactions with conventional vehicles • Update emergency services allocation (e.g. less traffic patrols, as automation could free up resources for other police activity)	• Demand management approaches in place to balance demand and capacity and eliminate congestion • Enforcement in place for CAV to ensure compliance with rules of road and safe operation of transportation network • Reduced restrictions on CAV operations as there will be less of a requirement to protect interactions with conventional vehicles • Update emergency services allocation (e.g. less traffic patrols, as automation could free up resources for other police activity)	• Demand management approaches in place to balance demand and capacity and eliminate congestion • Enforcement in place for CAV to ensure compliance with rules of road and safe operation of transportation network • Reduced restrictions on CAV operations as there will be less of a requirement to protect interactions with conventional vehicles • Update emergency services allocation (e.g. less traffic patrols, as automation could free up resources for other police activity)	• Guidelines for changes to fleet maintenance and storage facility location and/or expansion/contraction (i.e. re-evaluation of facility needs with CAV fleet)			

CAV Saturation	Design & Operating Guidelines and Standards	Planning (TMP, Strategic Plans, Capital Planning, Operations)	Models, Inputs and Data Needs
Few CAV (Pilots, Platooning on key highways)	• OTM, MUTCD, Geometric Design Standards, OPSS, OPSD, TAC design guidelines etc. audited in consultation with industry, and updated accordingly, to reflect new design approaches and changes for CAV based on pilots (e.g. updating OTM Book 12 to reflect key features of V2I for controller devices) • Municipal/Regional design standards, by-laws, HOV design guidelines, pedestrian and cyclist design standards, parking standards etc. audited, and updated accordingly, to reflect new design approaches and changes for CAV based on pilots • Understand updates to vehicle standards and equipment, including technical specifications for vehicle communications etc., and any necessary changes to training standards/certifications related to maintenance of public CAV fleets • Review privacy and cybersecurity standards, in consultation with industry, and revise accordingly to match best practices in a connected environment	• Consistent provincial framework for evaluation of proposed pilot applications and testing framework including identification of necessary data needs, key performance indicators and measures of effectiveness • Review of existing capital plans and projects to determine their relevance and need for CAV • Evaluate the potential impact of emerging mobility options (including CAV) on station access and traffic and how they can facilitate first/last-mile solutions • Best practices for mobility service provision by public and private sector providers operating CAV, including fare integration across service providers and jurisdictional boundaries • Improved inter-regional cooperation (through a Regional centre of excellence) to initiate, operate, track, and evaluate pilot test results, observation areas, and facilitate coordinated planning initiatives, research and pilot programs • Review official plans, regional transportation masterplans and strategic plans to account for CAV and their requirements to operate safely (i.e. the planning of roads, parking, curbside management, congestion management, how CAV can use the road etc.) • Updates to the regional/local Goods Movement Strategic and Long-term Plans to consider platooning, commercial CAV operations and promote innovation in commercial delivery • Updates to regional ITS Architecture and ITS Strategic Plans to include CAV (for concept of operations and feasibility studies) and necessary cybersecurity measures • Evaluate impact of CAV on employment and roles, land-use and provincial/municipal revenue sources • Evaluate community energy plans and electric grid performance, including a forecast of demand with increased (electric) CAV, telecommunication infrastructure/communication systems • Research and develop plans on what public agencies and governments can do to minimize any potential negative impacts of CAV and develop policies accordingly	• Explore data sharing agreements with peer agencies and industry partners/academic institutions active in testing CAV • Model input parameters and values to represent platooning and CAV operations in statistical and traffic simulation models (i.e. to develop parameter input values for key driving characteristics of CAV based on pilots monitoring CAV operations) • Incorporate CAV and shared modes into demand models to initiate long-term planning and forecasting of impacts on demand, capacity mode choice etc. • Updates to demand and mode choice models for CAV operations (i.e. stated preference surveys) to better understand mode choice/costs, demand etc. • Pursue simulation software enhancements to permit modelling of CAV (including platooning and connectivity) in mixed traffic conditions • Simulation model to determine curbside behaviour changes and interaction of CAV (including transit vehicles) with each other in mixed traffic conditions • Simulation models for real-time traffic flow analysis and V2I2V connectivity • Data governance model/strategy and data dictionary defining data needs to be collected during pilots (e.g. travel patterns, network performance, emissions etc.) • Cooperation between local agencies to understand data needs, standards, and extracting data from private companies
Mixed CAV/Conventional	• OTM, MUTCD, Geometric Design Standards, OPSS, OPSD, TAC design guidelines etc. audited in consultation with industry, and updated accordingly, to reflect new design approaches and changes for CAV • Municipal/Regional design standards, by-laws, HOV design guidelines, pedestrian and cyclist design standards, parking standards etc. audited, and updated accordingly, to reflect new design approaches and changes for CAV based on pilots • Maintenance standards in place for safety critical V2I • Standards for smart roadway infrastructure (communication between vehicles and everything) to enhance traffic flow and improve safety	• Assess and modify transit services strategy and business model to meet demands of public • Define approach on how to consider CAV assessments and new mobility concepts in business cases for new transportation capital projects and preparation of transportation masterplans, including assessment of funding and updates to by-laws • Assess public fleet lifecycle in strategic and capital plans to determine the rate at which fleet can be converted to CAV	• Real-time traffic data of CAV operations to calibrate model parameters • Simulation model of network with varying levels of CAV penetration and truck platooning to evaluate and quantify their impacts (in terms of traffic operations, safety etc.) • Simulations and models using data collected in pilots to expand on investigating the impacts of CAV operations and changes to future travel demand (in terms of private, public and freight transportation) on the transportation network • Updates to demand and mode choice models for CAV operations (i.e. stated preference surveys and updates to TTS) • Guidelines to update model for infrastructure, hardware/software updates, asset management and maintenance under CAV operations
Primarily CAV	• OTM, MUTCD, Geometric Design Standards, OPSS, OPSD, TAC design guidelines etc. audited in consultation with industry, and updated accordingly, to reflect new design approaches and changes for CAV • Municipal/Regional design standards, by-laws, HOV design guidelines, pedestrian and cyclist design standards, parking standards etc. audited, and updated accordingly, to reflect new design approaches and changes for CAV based on pilots		

CAV Saturation	Legislation & Regulations	Policy (Provincial)	Policy and Regulations (Municipal)	Policy and Regulations (Transit)	Bonus-Malus Incentives
Few CAV (Pilots, Platooning on key highways)	• Legislation that would pave the way for self-driving vehicles to legally drive on provincial/municipal streets and highways • Legislation/by-laws to reflect technological changes and ensure accessibility act (i.e. AODA) is applied for all new mobility services • Legislation to address privacy and security issues introduced by CAV (i.e. protect data transmitted, prevent hacking etc.) • Updates to Highway Traffic Act to include CAV pilot projects (i.e. legislate rules regarding safe CAV operations, commercial CAV platooning, impaired/distracted driving etc.) and highlight how enforcement differs between CAV and conventional vehicles • Regulations specifying measures needed for cybersecurity, sharing of data between vehicles, infrastructure etc. • Updates to Planning act, Environmental Assessment act, growth plan and provincial policy statement	• Advocate for the establishment of national CAV design and operational vehicle safety requirements • CAV licensing, liability/insurance coverage requirements and standards around incident responsibility for pilot projects • Open data standards for data collected during pilot tests, and policy to address data security and privacy issues arising from the collection of data by CAV • Engage law enforcement partners for the enforcement of traffic laws and regulations surrounding CAV pilot tests (on provincial roadways) • Policy on running trials of CAV on roads to better understand their needs and identify requirements • Policy to integrate testing and enforcement of cybersecurity and privacy measures (including the use of blockchain technology) into V2I pilots • Policy to determine, evaluate and prepare for the potential safety, security and cybersecurity concerns to the public presented by CAV in coordination with the Federal government • Action Plan to minimize any potential negative impacts of CAV (e.g. regulations for liability and insurance) • Policy to engage the public, educate them and raise awareness on CAV and motor vehicle safety (including interaction with CAV) • Policy to ensure equal accessibility for mobility (as per AODA) and ensure equity in service levels with barrier free access • Policy to identify requirements that CAV must meet as part of trial programs (i.e. requirement of driver present and not distracted, ability to safely transition to manual operation etc.) • Enforce rules for distracted and impaired operation of CAV (OPP level) • Policy for platooning vehicles (or trucks) in terms of location, length, speed and time of day • Guidance for safety standards for CAV (i.e. standards for vehicle design, infrastructure, data and communications) • Dedicated funding stream for pilots and long-term (for vehicle/infrastructure pilots and feasibility studies)	• Engage law/by-law enforcement partners for the enforcement of traffic laws, by-laws and municipal regulations surrounding CAV pilot tests (on municipal/regional roads) • Policy on accommodating trials of CAV on roads to better understand their needs and identify requirements • Policy to engage the public, educate them and raise awareness on CAV and motor vehicle safety (including interaction with CAV), in cooperation with the Province • Policy to ensure equal accessibility for mobility (as per AODA) and ensure equity in service levels with barrier free access • Open data standards for data collected during pilot tests, and policy to address data security and privacy issues arising from the collection of data by CAV • Action Plan to minimize any potential negative impacts of CAV on the transportation system and municipal services • Policy preparing agencies for emerging mobility models and technologies (e.g. CAV on-demand mobility, ride-sharing, mobility services platforms etc.), and how these will change transportation masterplans, the way people and goods move and land-use planning in the region • By-laws on where CAV could park (i.e. organize CAV to park next to each other in a parking lot) and designate waiting areas for dwelling along public roads (including for commercial CAV) • Dedicated funding stream for pilots and long-term (for vehicle/infrastructure pilots and feasibility studies)	• Policy on a business case to update transit fare price structure and integration with mobility service providers to maintain/attract transit mode share from shifting to other CAV operated modes • Policy to engage the public, educate them and raise awareness on CAV and motor vehicle safety (including interaction with CAV), in cooperation with the Province • Policy to manage the pricing of mobility services vs. public transit • Policy to ensure equal accessibility for mobility (as per AODA) and ensure equity in service levels with barrier free access • Regulations to maintain governance/oversight over mobility services (both public and private) to ensure desirable outcomes for the region as a whole • Action plan to determine what transit agencies can do to minimize any potential negative impacts of CAV on their services • Policy for the harmonization of fee structure for mobility services into a single platform with public transit • Framework for widespread integration of public MaaS platforms and shared mobility services (including CAV microtransit) with public transit services to explore impacts on travel behaviour • Regulation to reserve capacity (or bandwidth/frequency etc.) of road/communication technology for transit/high occupancy services (e.g. if intersections are flooded with communications from private vehicles) • Policy for addressing responsibility/liability when transferring customer from transit to private service • Dedicated funding stream for pilots and long-term (for vehicle/infrastructure pilots and feasibility studies)	• Policy for incentivizing/disincentivizing high occupancy trips and/or the adoption of electric powered CAV • Policy for municipalities and other parking providers to incentivize use of (electric) high occupancy CAV (i.e. equip parking lots with CAV-designated parking stalls and/or other equipment) • Policy to use mobility services and shared mobility as an opportunity to streamline public transit
Mixed CAV/Conventional	• Updates to Highway Traffic Act to address mixed traffic of CAV and conventional vehicles • Regulations on following distance rules for CAV to ensure safe operation of platooning • Legislation to regulate the safe operation of conventional vehicles in a transportation network with majority CAV	• CAV licensing (including driver's license requirements and vehicle license plates), liability/insurance coverage and regulations around incident responsibility • Enforcement of new traffic laws and regulations for mixed CAV deployment, as well as safety inspections (on provincial roadways) • Policy to adapt infrastructure to support CAV deployment • Policy/regulation for enforcing rules of roads with mixed traffic of CAV and conventional vehicles • Policy to give high-occupant vehicles priority in planning and infrastructure for CAV	• Enforcement of new traffic laws, by-laws and regulations for mixed CAV deployment (on municipal streets) • Policy to adapt infrastructure to support CAV deployment • Parking policies on the number of on street parking spots, municipal parking lots and parking spots required for developments as CAV could self park outside of core areas • Policy, and zoning changed required, to repurpose land previously used for parking to other use (i.e. reclaim parking land and convert to green spaces, housing etc.) • Policy to give high-occupant vehicles priority in planning and infrastructure for CAV • Policy for a business case for changes in the revenue structure surrounding parking fees, speeding tickets etc. • Policy on how revenue from parking fees and infractions will be collected for self-parking CAV • Policy on the re-purposing of parking infrastructure no longer needed • Policy/regulation for enforcing rules of roads with mixed traffic of CAV and conventional vehicles • Regulations to define legal operation for private CAV ride-sharing/on-demand mobility operators • Regulations to address innovation in urban delivery operations (i.e. regulations surrounding last-mile deliveries on pedestrian walkways with robotic vehicles) • Policy to ensure large-scale infrastructure projects for CAV integrate community benefit agreements	• Plan to coordinate with key partners in the region on approaches to a regional MaaS system • Policy preparing agencies for emerging mobility models and technologies (e.g. CAV on-demand mobility, ride-sharing, MaaS platforms etc.), and how these will change the way people move in the region • Policy for a business case on on-demand mobility as a long-term station access mode	• Policy for subsidizing mobility services when used in coordination with public transit, to contribute to transit, as opposed to take away from it (e.g. promote using on-demand mobility to access transit stations) • Policy/regulations to manage zero-occupancy CAV (i.e. to disincentivize ghost rides) • Establish developer credits for re-purposing land (e.g. empty parking garages)
Primarily CAV	• Updates Highway Traffic Act for full CAV operations	• Enforcement of new traffic laws and regulations for full CAV deployment, as well as safety inspections (on provincial highways)	• Enforcement of new traffic laws and regulations for full CAV deployment (on municipal streets and expressways)		

APPENDIX

F

DETAILED CAV PROGRAM SHEETS

TABLE OF CONTENTS

PROGRAM NAME	PROGRAM #
CAV DEVELOPMENT STREAMS	1

PROGRAM DESCRIPTION	PRIORITY/TIMING
The CAV Development Streams program consists of the CAV Liaison Committee establishing a number of Task Forces to continue to identify impacts that CAVs will introduce to the transportation network and its users. The presence of CAV on the GTHA transportation network will require agencies to evaluate and consider the impacts on data, security, privacy, physical infrastructure, interoperability, safety, design and maintenance standards. With these changes that CAV are set to introduce, it is an important initial step to formally dedicate resources to further explore the technology and begin the preparations for adapting the region to successfully integrate CAV on roads. The CAV Development Streams will be responsible for further developing the following areas: • Explore how CAV will change the needs of users with accessibility needs; • Assess the impact that CAV may have on vulnerable road users (e.g. pedestrians, cyclists, persons with disabilities etc.); • Assess the impact that rural environments will have on CAV; • Explore updates to standards (MUTCD, OTM, OPSS etc.); • Coordinate with private sector stakeholders. The anticipated impacts of CAV to infrastructure, operations and institutional structures will be significant. The further development of these streams will work to address some of the key impact areas for CAV and will develop a roadmap that best protects the interests of the most vulnerable segments of the population as well as the public.	☐ Early Wins ☑ **Short Term (0-5 years)** ☐ Medium Term (5-15 years) ☐ Long Term (15+years)

PROPOSED LEAD AGENCY
CAV Liaison Committee will establish a Task Force and identify a lead for each stream. The lead will be responsible for reporting back to the Liaison Committee.

TASKS

Task 1   Accessibility Assessment

Assess how accessibility requirements can be met under the operation of CAV on the transportation network.

Task 1a) Establish an Accessibility Task Force consisting of representatives of key stakeholders from municipal, regional and provincial agencies (including transportation and other relevant portfolios and departments), as well as accessibility organizations, associations, and private companies (i.e. vehicle manufacturers).

Task 1b) Review and identify potential challenges that CAV could introduce regarding accessibility requirements and standards, including equity of service, and accommodation of users' special needs for services provided by CAV (i.e. CAV uses for transit etc.). Part of this assessment includes developing and distributing a User's Survey to gather more information on challenges faced by individuals and to identify how they may be impacted by CAV.

Task 1c)	Review the Accessibility for Ontarian with Disabilities Act (AODA) and provide recommendations for incorporating updates to reflect new technology requirements and CAV operations.
Task 1d)	Advise on the development of pilot projects that focus on testing CAV to ensure programs adequately test interactions with various accessibility use cases, as well as advise new supporting infrastructure designs to consider accessibility requirements.
Task 1e)	Engage with other task forces, working groups and committees focusing on vulnerable road users (e.g. group delivering ACATS-funded study by Canadian National Institute for the Blind), standards updates, public education and stakeholder outreach to coordinate on the inclusion of accessibility needs throughout their work and assessments.

Task 2 Vulnerable Road User (VRU) Assessment

Assess the implications of CAV on vulnerable road users and how their daily use of the transportation network can be affected in terms of safety, accessibility, and interaction with vehicles, infrastructure and other road users.

Task 2a)	Establish a VRU Task Force consisting of representatives of key stakeholders from municipal and regional transportation agencies with wide range of expertise including road user safety and active transportation, as well as other organizations that may advocate for different VRUs (e.g. CNIB, agency advisory panels etc.).
Task 2b)	Define the group of individuals that are to be considered as a VRU in the assessment and ensure that interactions with this user group are sufficiently tested through pilot programs. For example, VRUs can be defined as non-motorized road users who have an increased safety risk and require special attention in road safety policy, planning and design. This group may include pedestrians, cyclists, motor-cyclists, and persons with disabilities or reduced mobility capabilities.
Task 2c)	Identify and review existing road infrastructure, technology (RSUs) standards and regulations with respect to VRU and identify and prioritize gaps that may arise from CAV operations and their interactions with VRU that will require further research and consideration to be addressed (e.g. potential safety concerns, traffic regulations, etc.).
Task 2d)	Conduct a safety needs assessment for the protection and safe interaction of VRU with CAV and through research, identify what technology may be needed to enhance safety for all users (e.g. pedestrian detection technology, way-finding infrastructure, physical barrier infrastructure, integration with hearing aids, wearables, visual projections of hazards at intersections etc.).
Task 2e)	Conduct a human factors study on the how VRU will interact with the physical infrastructure, technology and CAV. This should take into consideration AODA needs and how VRU will cross intersections, ingress/egress from CAV etc.
Task 2f)	Develop a concept of operations that illustrates how various technologies (e.g. pedestrian and cyclist detection technology, results from 2d)), as well as physical infrastructure designs and layouts (e.g. wayfinding, pedestrian signage, dedicated lanes, protective infrastructure, etc.) will create a safe and efficient VRU and CAV interaction.

Task 3 Regulations and Standards Development

Review and assess existing design, operations and maintenance standards in the context of CAV and provide key recommendations for necessary amendments or the development of new standards. This review shall include, at a minimum, physical infrastructure changes relating to road, surface parking lots,

parking structures, sidewalks, dedicated lanes, pavement markings, curbs, curbside management, vehicle charging, regulatory and advisory static signs (as defined by OTM Book 5 and 6, MUTCD and OPSS), technology (communications, signals, repeaters, etc.), temporary conditions (e.g. OTM Book 7), minimum maintenance standards and planning requirements as defined by the Planning Act and relevant policy documents.

Task 3a)	Establish a Standards Development Task Force consisting of representative municipal, regional and provincial agency departments, as well as other subject matter experts (e.g. academia) to conduct an ongoing assessment of transportation related design, safety, security and data standards with consideration of advanced technology and automation. This Task Force will coordinate with similar committees or task forces established by other provinces / territories or national associations (e.g. TAC).
Task 3b)	Identify which standards are relevant to CAV operation and propose amendments to applicable standards, while also considering that these amendments cannot be developed in isolation and acknowledging that harmonization between Canadian and United States jurisdictions will facilitate Research & Development, testing and deployment within an integrated market.

Task 4	**CAV Rural Road Assessment**
	Assess the implications that rural environments will have on CAV to identify needs for physical infrastructure changes to accommodate a mix of CAV and conventional vehicles.
Task 4a)	Establish a CAV Rural Road Assessment Task Force consisting of members from rural regional and local municipalities to develop policies, design requirements and management strategies that will identify needs for physical infrastructure changes to accommodate a mix of CAV and conventional vehicles in rural contexts.
Task 4b)	Complete a market scan to assess how rural conditions have been considered elsewhere in North America and globally and engage with peer agencies as necessary.
Task 4c)	Using the needs identified in 4a), provide input to pilots to ensure adequate testing in rural areas is performed, as well as to pilots focused on single lane configurations at higher speeds (e.g. rural highways) and taking into consideration gravel road conditions, rural infrastructure and maintenance.
Task 4d)	Develop a framework for ongoing assessments of rural infrastructure improvement requirements for heavy goods movement corridors.

Task 5	**Government / Industry Forum** –
	Assemble representatives from government and industry agencies to discuss CAV-related topics on an as needed basis and reduce silos in the CAV industry.
Task 5a)	Create a forum for government and industry to connect experts across the public and private sectors to have conversations and share information, with opportunities for sub-forums to be opened to have focused discussion on specific topics such as mobility as a service or vehicle to infrastructure interactions. This forum shall meet according to a frequency that is appropriate for the topic at hand, however a quarterly arrangement should be initially planned. This forum may also include an education component regarding new technologies or new projects, as well as tracking of testing completed under different pilots.
Task 5b)	Review and assess the roles and responsibilities of both public and private agencies relating to CAV.

Task 5c)	Identify areas where industry sees a need for new or revised standards or regulations.	
Task 6	**Operations and Maintenance Development** –	
	Review and assess the implications of CAV on operations and maintenance activities	
Task 6a)	Develop a CAV Operations Task Force consisting of operations staff from municipal and provincial organizations, enforcement services (commercial carrier and RCMP, OPP, local / regional Police), emergency services and potentially, towing companies and insurance agencies. The objective of this Task Force is to identify current operations activities such as fixed route transit services, enforcement, network management, incident management, robot package delivery etc. that will be impacted by CAV and begin discussions on how these activities will be managed. This Task Force may consider opportunities for sub committees to be developed according to focus areas, such as goods movement, shared mobility and personal mobility.	
Task 6b)	Develop a CAV Maintenance Task Force consisting of operations staff from municipal and provincial organizations. The objective of this Task Force is to identify current maintenance activities such as snow removal, salting, pavement repairs / patching, lane marking, signal/communications infrastructure repair times, charging facilities etc. that will be impacted by CAV and to begin discussions on how these activities will be managed.	
Task 6c)	Develop a concept of operations that includes business rules and key operational requirements for the CAV future, including maintenance requirements.	

APPLICABLE GUIDELINES

Safety (SY) – All guidelines are applicable (SY-01 to SY-04)

Standards (STD) – All guidelines are applicable (STD-01 to STD-04)

Network Management and Operations (NMO) – All guidelines are applicable (NMO-01 to NMO-04)

Physical Infrastructure (PI) – All guidelines are applicable (PI-01 to PI-03)

Communications, Privacy and Cybersecurity (CPC) – All guidelines are applicable (CPC-01 to CPC-02)

Transit Service Planning (TSP) – All guidelines are applicable (TSP-01 to TSP-02)

Pilot Programs (PP) – All guidelines are applicable (PP-01 to PP-06)

Technology (T) – Pedestrian and Cyclist Detection (T-02E), Interaction of Pedestrian and Cyclists with CAV (T-06), and CAV Interface with Personal Aid Technology (T-08)

Mobility Services (MS) – Updating Legislation to Reflect Technological Changes (MS-03A)

Inter-regional Goods Movement (IEG) – Assess Commercial CAV Technology (IEG-01), and Identify Long-distance Freight Corridors (IEG-03)

Freight Safety & Regulations (FSR) – Standards of Practice for Freight Operators (FSR-01)

Infrastructure Policies and Regulations (IPR) – All guidelines are applicable (IPR-01 to IPR-02)

AGENCIES INVOLVED

☑ Provincial Government

☑ Regional Government (list all)	☑ Public Transit Agencies (list all)
• All regional government	• All public transit agencies

☑ Municipalities (list all)
       • All municipalities
	☑ Others (list all)
	       • OCE AVIN
	       • TAC
	       • Transport Canada
	       • CSA
	       • CNIB
	       • Private Sector

INTERDEPENDENCIES	SCHEDULE
Program 3: Pilot Projects Management Program **Program 4:** Data Needs and Management	Start March 2020

HIGH LEVEL CAPITAL COST	HIGH LEVEL ANNUAL O&M COSTS
High level costs are provided for Tasks that may be completed by the private sector **Task 1**: To be completed by agency or assigned Task Force **Task 2**: Task 2a) and 2b) to be completed internally; Task 2c) and 2d) likely to be completed with an external consultant costing $100,000 to $250,000; Task 2e) cost to be determined by a safety specialist; Task 2f) likely to be completed by an external consultant costing $250,000 to $500,000 **Task 3**: To be completed by agency or assigned Task Force **Task 4**: To be completed by agency or assigned Task Force **Task 5**: To be completed by agency or assigned Task Force **Task 6**: Task 6a) and 6b) to be completed internally; Task 6c) likely to be completed by an external consultant costing $250,000 to $500,000.	Ongoing costs from participation in committees / Task Forces to be carried by agency.

FUNDING MECHANISM
Each agency will self fund their involvement and pooled funding and grants will be considered for each external project. Alternatively, an agency sponsor will be identified.

PROGRAM DESCRIPTION	PRIORITY/TIMING
This program consists of developing a series of CAV modelling tools, including a System Dynamics Model, for the Province and necessary model updates to existing long-term transportation planning and operational analysis tools (e.g. travel demand models and traffic simulation packages) required to address the presence of new mobility technology in the transportation network. The existing planning tools, such as the GTAModel V4.0 and Greater Golden Horseshoe Model 4.0 (GGHM4.0), provide value inputs that inform long-term transportation plans and decision-making. However, given the complexity of new mobility technology and the uncertainty surrounding the impacts of CAV on our transportation systems, the development of a System Dynamics Model would be a valuable exercise.	☐ Early Wins ☑ **Short Term (0-5 years)** ☐ Medium Term (5-15 years) ☐ Long Term (15+years)

A System Dynamics Model would analyze the complex dynamic behaviour of the evolving transportation system, including economic and social implications and changes that would result from shifts in transportation trends. It relies on the understanding of interdependent variables to inform decision-making and strategy development from an overall system perspective. The System Dynamics Model would develop and map out high-level, order-of-magnitude, cause and effect relationships between key components, such as parameters including level of automation, demand for CAV, cost of CAV ownership, cost of CAV travel, safety, personal CAV adoption rate, commercial CAV adoption rate, ownership rate, etc., using mathematical algorithms representative of these relationships. The goal of System Dynamics is not to predict an exact outcome, but provide insight on potential alternative futures. These insights would be used to inform updates to long-term travel demand models and simulation tools to identify predictions related to transportation mode choice, route choice, traffic volumes etc.

Additionally, this program requires research to build an understanding of the implications that CAV and shared mobility services will have on travel behaviour within the region. The scenarios developed as part of the CAV Readiness Plan could be used as a basis for the alternative futures to be tested through this System Dynamics Model. The outcome of this analysis would identify additional data needs and parameter requirements to capture these effects in long-term transportation planning models and simulations. Once the updates to transportation planning models and simulation tools are completed, the results of subsequent iterations of the System Dynamics model would inform parameter value changes to allow for updated future scenarios to be tested and form the basis for policy decisions, transportation demand management strategies, and infrastructure needs in a future with increasing levels of CAV and shared mobility.

PROPOSED LEAD AGENCY

Ministry of Transportation of Ontario

TASKS

Task 1   Research and Literature Review

Conduct research and a literature review of academic and industry sources to identify cause and effect implications of transportation, economic, social and policy factors that form the basis for the movement of people and goods within the region with respect to CAV. A key reference would be the Transportation

Research Board's NCHRP Research Report 896: Updating Regional Transportation Planning and Modelling Tools to Address Impacts of Connected and Automated Vehicles.[8]

Task 1a) Engage with research institutions (e.g. University of Toronto, Ryerson) and other public transportation agencies, who are engaged in research and transportation planning work related to CAV and shared mobility, to discuss methodologies that have been developed and assumptions that have been made as part of existing work.

Task 1b) Identify and understand the relationships between emerging transportation technologies (including cost, safety, adoption rate of CAV), new business models (e.g., shared mobility services), and traveller behaviour (e.g., ownership, mode choice, route choice, value of time, etc.). This includes identifying the most impactful economic, social and policy factors that influence traveller behaviour and decisions, as well as determining methods to quantify these relationships with respect to adoption of CAV technology and shared mobility.

Task 1c): Identify the impacts that CAV technology will have on land-use, including considerations of the need for parking within the urban core, as well as urban sprawl.

Task 1d) Identify the impacts that CAV and shared mobility will have on government revenue sources. This includes researching and identifying methods to forecast lost revenue from sources that may no longer be steady with CAV (such as parking, traffic infractions etc.), as well as identifying opportunities and policies to replace lost revenue sources (i.e. pricing zero occupancy CAV, etc.) and allocate any gained revenue.

Task 1e) Identify data needs that will be required to fill gaps in regional transportation models to better quantify the relationships between emerging transportation technologies, business models and their transportation, economic and social impacts.

Task 2 **Building the System Dynamics Model**

Build the overall System Dynamics Model with the researched relationships and calibrate it to provide the necessary outputs to guide transportation planning initiatives, including identifying needs for updates to travel demand models and simulation tools. This also includes ensuring that the System Dynamics model meets the needs of all transportation agencies that may be using different modelling frameworks.

Task 2a) Identify and define the various transportation, economic, social, environmental and policy factors that will be included in the System Dynamics Model, and the general cause and effect relationships between related factors.

Task 2b) Develop the mathematical algorithms, based on research, that define the cause and effect relationships between the various factors. This includes defining the alternative future scenarios or strategies that are to be tested and quantified.

Task 2c) Assess the model framework and outputs to ensure that the results produced are reasonable and justifiable given the time and geography of interest. This will include identifying criteria to evaluate the output based on research and consultation with subject matter experts.

Task 2d) Identify recommended updates to travel demand models and simulation packages, based on the outputs of the System Dynamics Model. This includes identifying updates to parameters, new parameters and data to be collected for travel demand modelling, as well as identifying algorithm and programming needs to be communicated to traffic simulation platform vendors for development.

Task 2e) Iterate through updates to the System Dynamics model, as needed, based on data obtained from ongoing data collection campaigns (Task 3) and updated model outputs (Task 4).

Task 3	**Ongoing Data Collection**	
	Develop a methodology to collect data based on the output of the System Dynamics Model. This includes collecting data on consumer acceptance of CAV, willingness to purchase, and travel behaviour, as well as data on the specific changes that CAV will have on vehicle driving operations and characteristics (e.g. acceleration, speed, following distance, etc.).	
	Task 3a)	Develop and conduct a stated preference (SP) survey with an acceptable sample size of the region's population to gather this information directly from the public, as well as updating the Transportation Tomorrow Survey (TTS) framework to include questions related to emerging technologies, mobility services and new business models. In the meantime, until the next TTS in 2021, a satellite survey focusing on emerging technology could be conducted and fused with the existing TTS dataset. This data collected will inform the updating of existing travel demand models and the development of newer transportation planning and forecasting tools for the region.
	Task 3b)	Develop a dataset to provide consistent information on key driving characteristics of CAV to update and/or calibrate driving behaviour parameters in traffic simulation software packages to better investigate the impacts of their operations on travel demand and traffic operations. These model parameters can initially be developed from data collected through pilot programs monitoring CAV operations, and then further modified by using operational data collected by CAV during widespread operations.
	Task 3c)	Conduct ongoing and frequent data collection campaigns (aligned with census years) to continually monitor transportation trends and to gather updated data for updates to models.
Task 4	**Existing Travel Demand Model and Simulation Tool Updates**	
	Update transportation planning, travel demand modelling and traffic simulation practices and requirements to consider CAV and mobility services and leverage the new data opportunities that are present to inform more accurate predictions and simulations. This includes engaging planning agencies to identify their needs to inform updates to their own modelling tools.	
	Task 4a)	Identify and update regional transportation planning tools and models used by various transportation agencies across the region that will need to be updated to reflect CAV and mobility service operations (e.g. GTAModel 4.0 and Greater Golden Horseshoe Model 4.0 (GGHM4.0)). These updates would be based on the output of the System Dynamics Model and the data collected through SP surveys and/or an updated Transportation Tomorrow Survey (TTS). Following these updates, these models should have enough information to develop accurate predictions that reflect emerging transportation technologies and understand where people are travelling to/from, how many trips they are making, what is their value of time, how many trips are made by shared services, and what is the updated vehicle ownership model. The models should also capture any impact on vehicle occupancy and changes associated with freight delivery.
	Task 4b)	Identify macroscopic, mesoscopic, and microscopic simulation tool updates that are required to incorporate CAV and mobility services. This consists of identifying simulation software package updates (e.g. algorithms, programming updates) and parameter changes to effectively simulate CAV driving characteristics, organization/communication, policies/protocols, and operations. This also includes parameter changes to better integrate updated demand model outputs with simulation packages to capture emerging transportation technologies, including capability to handle mobility services in demand matrices.
	Task 4c)	Identify updates to existing forecasting models, including those for revenue and land-use planning, to account for the impacts that CAV and associated business models (e.g. shared

mobility services) will have on government revenue, transit ridership and revenue, and land-use planning initiatives.

Task 4d) Assess transportation demand model and simulation results and determine the need to iterate through the System Dynamics Model (Task 2) on an ongoing basis to monitor the relevance of current model parameters, using the results as input to develop a new scenario and/or strategy to be tested.

Task 4e) Develop a monitoring framework for the CAV Liaison Committee to assess the need for future model updates and to incorporate updates based on new data collected and updated outputs of the System Dynamics model.

Task 5 Planning Initiatives Updates

Review and update current transportation planning practices, plans, strategies and projections based on results from updated transportation models, as well as new information and data gathered about CAV adoption, and the adoption of emerging business models.

Task 5a) Update transportation planning and travel demand projections for planning years 2031 and 2041 for various transportation agencies in the region based on the results of the System Dynamics Models and the updates transportation demand models and simulations

Task 5b) Identify the impacts of CAV on commercial deliveries and use model outputs to provide recommendations for updates to Goods Movement Strategic and Long-term plans to include these impacts and provide guidance on how to address any perceived challenges surround the safe operation of commercial CAV or opportunities to improve the efficiency of freight transportation across the region with CAV technology.

Task 5c) Identify ITS needs through simulation models and provide recommendations for updating ITS Strategic Plans, as well as Regional ITS Architectures to include CAV. This includes identifying what technologies would benefit the operations of a transportation network with increasing levels of CAV.

Task 5d) Consider the implications of CAV and new mobility concepts on transportation capital projects and preparation of transportation masterplans. This includes considering the development of business cases for updating official plans, regional transportation masterplans (e.g. GGH Transportation Plan), public transit service delivery plans, and other strategic plans, as necessary, to address CAV requirements (e.g. planning of roads, parking, curbside management, congestion management, etc.) based on the results of research conducted and updated model outputs. Ensure these updates are communicated to all relevant transportation agencies to be incorporated in their plans.

APPLICABLE GUIDELINES

Transportation Planning (TPP) – All guidelines are applicable (TPP-01 to TPP-04)

AGENCIES INVOLVED

☑ Provincial Government

☑ Regional Government (list all)	☑ Public Transit Agencies (list all)
• All regional government	• All public transit agencies
☑ Municipalities (list all)	☑ Others (list all)
• All municipalities	• Academia

INTERDEPENDENCIES	SCHEDULE
Program 1: CAV Development Streams	Start September 2020

HIGH LEVEL CAPITAL COST	HIGH LEVEL ANNUAL O&M COSTS
High level costs are provided for tasks that may be completed by the private sector. **Task 1:** $50,000 to understand data needs, complete literature review, and conduct other research as necessary to inform the System Dynamics model. **Task 2:** $30,000 to calibrate the System Dynamics model **Task 3:** $60,000 to conduct stated preference survey to collect data. **Task 4**: $175,000/model to update each travel demand model. Associated cost for simulation package updates are to be carried by vendors. **Task 5:** $50,000 to facilitate connections and updates to other regional plans.	Once the System Dynamics Model is developed, operation and maintenance costs may include an estimate of $60,000 to update and calibrate the System Dynamics Model every two years, as well as other costs to further develop, update various travel demand models, planning tools, and long-range plans.

FUNDING MECHANISM
Each agency will self-fund their involvement and pooled funding and grants will be considered for each external project. Alternatively, an agency sponsor will be identified.

PROGRAM NAME	PROGRAM #
PILOT PROJECTS PROGRAM MANAGEMENT	3

PROGRAM DESCRIPTION	PRIORITY/TIMING
Pilot Projects can be instrumental in providing proof of concepts and testing new operational paradigms to gain technical, operations and maintenance experience. This program includes the program management of a series of pilot projects that will gather data and test various use cases related to CAV. Having a program management approach that is coordinated across the region in a systematic way will enable sharing of information, efficiency in testing by removing duplication in efforts in different municipalities and therefore enable more testing of different use cases. These pilot programs will play a key role in assessing, evaluating and testing CAV and connected infrastructure, identifying operational needs of a transportation network, testing different designs and strategies, and identifying needs for legislation, regulations and policies. They will allow testing of a wide variety of topics including physical infrastructure arrangements, ITS technology, mobility service arrangements, transit and commercial vehicle operations, in both urban and rural areas, as well as user experiences in interacting with CAV. All levels of public agencies, in cooperation with the Federal government, should commit to a common approach for the testing and use of CAV and be open in accommodating trials of CAV on roads to better understand their needs and identify requirements. Each public agency may undertake pilots specific to their needs and interests, while sharing information and identifying opportunities to team up with other agencies on common interests. Building upon successful pilots and testing programs will contribute to laying the foundation for the development of future regulations and identify areas of focus for governments and transportation agencies. Pilot programs can be conducted directly by transportation agencies or in cooperation with vehicle manufacturers, academia and other organization interested in testing new programs that use CAV technology. Pilot programs should be viewed as a resource to inform other project areas, serving as a key component of a feedback loop between other groups and pilots and used as a collaboration tool between different agencies. Government agencies can leverage these industry and academic insights in the short-term to continually update guidelines for CAV testing as needs arise.	☐ Early Wins ☑ **Short Term (0-5 years)** ☐ Medium Term (5-15 years) ☐ Long Term (15+years)

PROPOSED LEAD AGENCY
CAV Liaison Committee Co-Chairs and individual organizations, that form part of the Liaison Committee. These members would conduct their individual pilot projects and report progress and results back to the Liaison Committee.

TASKS

Task 1   **Inventory of Pilot Programs**

Establish a centralized pilot program directory to track pilot programs within Ontario. The Liaison Committee will coordinate with the individual agencies responsible for the pilot programs to maintain the directory at the provincial level. Each pilot program should identify the relevant CAV Readiness Guidelines that it is addressing. Pilot program leads should meet periodically (every four to six months) to share the task results, lessons learned and identify gaps, issues and any new program requirements.

Task 1a)	Develop a centralized guideline tracking system to identify and keep track of which pilot programs are addressing which guideline(s) to ensure that the necessary testing is being completed from all perspectives.
Task 1b)	Develop a framework to measure success of Pilot Projects in the form of a check-list that identifies how pilot projects are evaluated, what criteria is used and whether an acceptable outcome was achieved.
Task 1c)	Identify the mandatory data required to be submitted by private sector entities that are requesting to undertake a pilot under the Ontario O. Reg. 306/15: Pilot Projects – Automated Vehicles. Identify the data format and requirements so that all data can be evaluated from a consistent framework. Identify optional data elements as well.
Task 1d)	Conduct an inventory (in terms of what is being tested, progress, results etc.) of existing pilot programs that have been developed or are planned across the province (e.g. City of Toronto AV Shuttle Pilot, Ottawa connected signals pilot, Commercial vehicle pilot in Peel Region etc.) to develop an understanding of the current state of testing in Ontario and be available as a resource for other groups and agencies.
Task 1e)	Identify a wish list of research questions, data needs and testing gaps that could be addressed by pilot programs, for example a dedicated CAV lane on the highway, urban intersection safety (CAV, pedestrian, cyclist interactions). Prioritize the list and identify key performance indicators, measures of effectiveness, consistent data collection requirements and formats, as well as testing locations to address a variety of testing scenarios (e.g. interaction of CAV with infrastructure, connectivity technology, etc.). Identify the agency that will take the lead and funding for each pilot. This also includes forming partnerships with industry and academia to develop mutually beneficial pilot programs, as well as leveraging pilot programs initiated by private sector companies to share knowledge, results and data.
Task 1f)	Develop a central repository and dedicated funding stream for pilot programs while reviewing opportunities that arise through pilots that have been submitted under the Ontario O. Reg. 306/15: Pilot Projects – Automated Vehicles. This includes identifying needs for ongoing pilot programs, as well as developing criteria to evaluate pilot program applications and identify regulatory requirements (e.g. licensing, liability/insurance coverage etc.) that will be needed by proposed pilot programs.
Task 1g)	Identify how information gathered from pilots could be used to inform infrastructure, operational and regulatory decision making, as well as safety requirements. This includes developing measurable milestones to be achieved by the pilot programs and providing progress reports on updates and results.
Task 2	Possible Pilots - Physical Infrastructure Needs – Define pilot programs that investigate physical infrastructure arrangements and requirements to facilitate CAV operations. Develop performance indicators and review criteria. The following are some potential pilots that have been identified in this area:
Task 2a)	Temporary Conditions (All road types) – Determine temporary physical infrastructure requirements for CAV navigating around construction sites and temporary road/lane closures. This includes determining what technology will be needed (e.g. interfacing with temporary barriers), what physical markers, what map upgrades and how it will be implemented.

Task 2b) CAV-User interactions – Explore different pick-up/drop-off (PUDO) configurations and arrangements at transit station/stops and along urban streets to accommodate emerging mobility options (e.g. CAV, ridesharing) requiring available curb space to facilitate passenger pick-up and drop-off.

Task 2c) Rural CAV - Assess the interaction of CAV with conventional vehicles on existing road layouts, including a focus on rural highways, to identify physical layout hazards (gravel roads that have no painted road markings) that may need to be addressed to facilitate safer operation of mixed traffic.

Task 2d) Limited Access CAV Operation – Explore how CAV could safely travel on high speed, limited access corridors (for example 400 series highways). Determine if a dedicated lane would support safe operation in a mixed environment and how that could be accomplished (conversion of HOV lanes). Identify how ingress/egress to lane and to corridor could be completed safely. Identify suitable locations (e.g. specific sections of highway) to implement a dedicated CAV lane. Incorporating infrastructure needs for dedicated CAV lanes can be integrated with planned road improvements within the region.

Task 2e) Urban Arterial CAV Operation – Explore how CAV could safely travel on urban arterial roads while considering pedestrian, cyclist, shared mobility, commercial delivery, emergency services, on-street parking and other interactions. Identify suitable locations (e.g. specific sections arterial corridors) to implement a dedicated CAV lane. Incorporating infrastructure needs for dedicated CAV lanes can be integrated with planned road improvements within the region.

Task 3   Possible Pilots –Vehicle Interactions

Establish pilot programs that primarily focus on the interaction of CAV with other vehicles, technology infrastructure, and road users (e.g. pedestrians and cyclists). This includes leveraging opportunities to work with automotive manufacturers and academic partners to facilitate the testing of CAV technology. Integrate cybersecurity, privacy and data protection methods to ensure the integrity and secure operation of the transportation network for all users. Develop performance indicators and review criteria. The following are some potential pilots that have been identified in this area:

Task 3a) CAV-User Interactions – Explore the interaction of CAV with other road users. This includes assessing the performance of CAV interactions with pedestrians crossing the road, cyclists riding alongside them, and yielding the right of way when needed. Different accessibility requirements for vulnerable road users will also be considered (e.g. testing technology to facilitate the interaction of CAV with visual and hearing impaired). A component of this assessment also includes measuring user acceptance / expectations with respect to their interactions with CAV technologies.

Task 3b) CAV-Emergency Services – Assess the interaction of CAV with emergency service vehicles. This includes testing their ability to identify emergency services needing priority and clearing a path for passing. This could also study interaction with dispatchers in the event of a CAV being in a collision. What information is required to be shared with dispatchers and how is this interface achieved?

Task 3c) CAV-ITS Devices – Test the performance of connected infrastructure (Roadside Units (RSU)) and their interaction with CAV (V2I). This includes testing connectivity with traffic signals, the traffic management centre and pedestrian/cyclist detection infrastructure, as well as assessing the performance of technology that detects pedestrian and cyclists and

broadcasts this information to other vehicles (i.e. CAV, transit vehicles and commercial vehicles).

Task 3d)   CAV-Signal Priority – Test transit signal priority (V2I) infrastructure to explore the interaction of regular traffic with transit vehicles on dedicated transit corridors. Repeat such a test with emergency vehicle signal priority (V2I) technology

Task 4   Possible Pilots – Transit Specific Operations

Establish pilot programs that focus on transit service operations. This includes assessing new opportunities for the provision of transit services (new mobility services), as well as assessing technology to facilitate transit operations. Develop performance indicators and review criteria. The following are some potential pilots that have been identified in this area:

Task 4a)   Bus Rapid Transit – Identify candidate transit corridors and evaluate the performance of V2I technology for dedicated transit right of ways, such as automated Bus Rapid Transit. This includes conducting a study for both segregated and unsegregated environments.

Task 4b)   First Mile/Last Mile Integration – Assess the impacts CAV technology will have on transit operations and the provision of transit services. This includes testing CAV buses on certain identified routes, leveraging results obtained from the CAV Shuttle Pilot, and testing different mobility service arrangements (e.g. integrating private ridesharing services with mainstream transit for first/last-mile trips).

Task 5   Possible Pilots – Commercial Vehicle Operations

Establish pilot programs that focus on commercial vehicle operations for both inter-regional and intra-regional deliveries. This includes assessing how increasing levels of automation and connectivity will impact freight transportation and the implications for the broader transportation network. Develop performance indicators and review criteria. The following are some potential pilots that have been identified in this area:

Task 5a)   CAV – Identify specific commercial vehicle pilot locations to best assess CAV technology impacts on commercial vehicle operations. This would include a mix of both urban (downtown core) and suburban areas to cover bother inter-regional and intra-regional goods movement.

Task 5b)   Delivery Methods – Assess different delivery strategies (e.g. off-peak delivery programs, last-mile delivery technology/robotics) to explore the impacts of new freight delivery methods on vehicle, pedestrian and cyclist traffic within urban areas. This would also require an assessment of by-law changes/requirements to facilitate after hour deliveries and the use of other technologies (i.e. robot delivery technology) on public roads and sidewalks.

Task 5c)   Delivery Signal Priority – Assess the effectiveness of dynamic signal timing adjustment that leverages the use of connectivity technology to accommodate the presence of urban delivery vehicles. This includes evaluating this operation strategy in terms of improvement in travel times, congestion reduction and passenger vehicle throughput.

Task 5d)   Platooning – Engage commercial vehicle operators to jointly test commercial vehicle platooning for long-distance freight CAV to identify limitations of the technology in situations of interaction with regular traffic (e.g. at ingress/egress points on highways). This includes identifying additional safety measures required for platooning trucks, as well as assessing the need for segregating platooning commercial CAV into dedicated lanes.

Task 6   Possible Pilots – CAV Operations

Establish pilot programs that explore how transportation network operations could change with CAV and what opportunities are available for operational improvements. Develop performance indicators and review criteria. The following are some potential pilots that have been identified in this area:

Task 6a)   Winter Operations – Identify how CAV could impact winter operations on all classes of roads and sidewalks, including identifying opportunities for converting services to using CAV, such as automated snow removal.

Task 6b)   Incident Management – Coordinate with Emergency Service providers and insurance companies to consider different opportunities for incident management on all classes of roads and with different combinations of CAV and conventional vehicles. For example, if two zero occupant CAV are involved in a collision are emergency services required? Or will just towing the vehicles (if required) be sufficient?

Task 6c)   Congestion Management – Identify different network operations responses to managing congestion in mixed use cases. For example, how do CAV adjust to longer than normal travel times? How will HOV lanes function – will shared mobility CAV be able to use these lanes with conventional car-pool vehicles? How can congestion pricing be implemented?

APPLICABLE GUIDELINES

Pilot Programs (PP) – All guidelines are applicable (PP-01 to PP-06)

Physical Infrastructure – Evaluate existing physical infrastructure for safe operation of transportation network (PI-01) and Physical changes in place to support platooning truck interactions at ingress/egress points (PI-02B)

Data Needs and Data Management (DN) – Identify Data Needs (DN-01)

Communications, Privacy and Cybersecurity (CPC) – Obtain spectrum licenses applicable to CAV (CPC-02E)

Inter-Regional Goods Movement (IEG) – Requirements for pilot programs for commercial CAV operations (IEG-01)

Intra-Regional Goods Movement (IAG) – Pilot programs for Intra-Regional Delivery (IAG-01) and Needs to limit impact of Intra-Regional deliveries on passenger vehicle operations (IAG-02)

Public Fleet Management and Operations (PF) – Upgrade public agency owned assets (PF-01)

Transit Management and Operations (TMO) – Identify key transit corridors for transit signal priority (TMO-02)

Regional Collaboration (RC) – Aggregation of information, knowledge sharing and coordinated planning initiatives (RC-02)

Traffic Laws and Regulations (TLR) – New traffic laws and regulations related to pilot programs (TLR-02) and Licensing and insurance/liability requirements for CAV (TLR-03)

AGENCIES INVOLVED

☑   Provincial Government

☑ Regional Government (list all)	☑ Public Transit Agencies (list all)
• All regional government	• All public transit agencies
☑ Municipalities (list all)	☑ Others (list all)
• All municipalities	• Member of Data Needs and Management Plan Project Program
	• AVIN
	• Automotive Manufacturers

- Commercial Vehicle Operators
- Academia
- Incubators (e.g. Innovation Factory, Invest Ottawa, Communitech, MaRS)
- Telecommunications companies

INTERDEPENDENCIES	SCHEDULE
Program 1: CAV Development Streams **Program 4:** Data Needs and Management Plan	Task 1 to be completed from 2020 to 2021 Schedule for Tasks 2-6 to be determined as they are planned

HIGH LEVEL CAPITAL COST	HIGH LEVEL ANNUAL O&M COSTS
High level costs are provided for tasks that may be completed by the private sector. **Task 1 –** $100,000 - $250,000 to inventory all pilots and coordinate with Liaison Committee to identify high level pilot performance metrics, preliminary pricing, lead sponsor and possible funding opportunities. **Tasks 2-6 –** To be determined as pilots are planned.	Cost of staff to maintain data in pilot repository, perform analysis of pilot effectiveness and coordinate pilot programs.

FUNDING MECHANISM
A single source of funding (i.e. agency sponsor) may be identified to fund each pilot project with contributions from participating agencies and project grants.

PROGRAM NAME	PROGRAM #
DATA NEEDS AND MANAGEMENT PLAN	4

PROGRAM DESCRIPTION	PRIORITY/TIMING
Recognizing that CAV and their supporting technologies will generate terabytes of data, this program will develop a consistent regional data management plan that will bring accountability to all parties involved. The plan will define the type of data and its purpose with respect to the needs of planning initiatives and public-agency requirements, the roles and responsibilities of key players, a data sharing model, data retention policies, digital infrastructure needs, security and privacy requirements, as well as a data dictionary. Pilots offer an early opportunity to be exposed to the data CAV can produce. Data collected form pilots can be used to inform infrastructure, operational, planning and policy decisions. As CAV saturation levels increase, data collection and management will need to be reviewed as it is expected that changes will be required to monitor the transportation network and improve safety and operation. This program will address a number of questions that agencies have related to data needs and management, including: • What information is needed? • What information is available? • What are the privacy concerns? • What standards should be used? • How will the data support operation? A consistent definition of data in the region will allow agencies to compare and analyze the strengths and weaknesses of pilots and deployments. They, will be able to use data mining techniques to assess opportunities for operational enhancements, and have clarity on what data needs to be requested in contracts for pilots and other projects.	☐ Early Wins ☑ **Short Term (0-5 years)** ☐ Medium Term (5-15 years) ☐ Long Term (15+years)

PROPOSED LEAD AGENCY
There may be multiple lead agencies depending on the type of data being considered, but all levels of government will be involved through a Task Force (including MTO, Transport Canada and municipalities).

TASKS

Task 1	**Initial Research and Needs Analysis**
	Conduct comprehensive research and a market scan to establish data needs and data management requirements for CAV sector in Ontario.
Task 1a)	Conduct a scan of literature and industry reports, as well as reach out to peer agencies, to understand the type of data required for CAV operation and establish what data will be collected by the main streams of data collection (e.g. mobility service operators, private CAV and public fleets, transit stations and terminals, CAV freight and intelligent transportation system infrastructure). Undertake an exercise to define use cases for CAV-related operations (including network operations, communication with infrastructure, maintenance needs, performance reporting etc.) and document data inputs / outputs for each. Record all data needs in an inventory to document data definition, data type, quality, latency, source, availability etc.

Task 1b) Identify gaps and data needs based on the data that is currently available / managed by government agencies. Update data inventory with availability, status and source information. Using the findings from the gap analysis, coordinate with the CAV Liaison Committee to integrate data needs into the framework for pilot projects to ensure that the necessary data is being collected – acknowledging that the data needs for pilots may be different.

Task 1c) Investigate data privacy and cybersecurity concerns for CAV operation and develop a framework to address these issues in accordance with international best practices and standards (e.g. cooperative intelligent transport system (C-ITS) technology standards, European Union General Data Protection Standards), as well as exploring the use of emerging technologies (e.g. blockchain) to protect the transfer of data.

Task 1d) Define digital infrastructure requirements needed to collect data, as well as to enable V2I communication, using the findings from Tasks 1a), 1b) and 1c). This includes defining details on the type of infrastructure needed, their location, timeline for installation, and any partnership opportunities.

Task 1e) Undertake business case assessment of outstanding data requirements to determine which parties (public versus private sector) are best suited to collect and manage data, as well as to determine digital infrastructure investment needs.

Task 1f) Assess labour force and academic programs for skills training for collecting, managing, analyzing, visualizing and storing data.

Task 1g) Assess need for an open source platform for select CAV-related data to be provided to partnering agencies and stakeholders (e.g. industry, research institutes, academia and public), and assess infrastructure requirements to host the platform (e.g. network cloud).

Task 2   Establish Data Standard Needs

Establish needs for enhanced data standards for CAV-related data collection, sharing, access, privacy, and security to be communicated to the federal and provincial governments through the CAV Liaison Committee. Consensus on data standards and needs will need to be achieved across agencies to ensure all data requirements are covered and facilitate streamlined and consistent data management strategies.

Task 2a) Review existing documentation for data standards at the federal and provincial level, as well as international standards (e.g. ISO). Identify needs for additional standards to be adopted by the federal government to reflect the type and magnitude of data collected by CAV for data collection, sharing, access, privacy and security.

Task 2b) Liaise with mobility service providers to help them understand their data management standards and define a recommended data standard for them to collect and transmit data and to integrate it into a Regional Mobility platform.

Task 2c) Develop a data dictionary to define the format, nomenclature and structure of data that will inform which key performance indicators (KPIs) are to be collected both during pilot programs and during regular operations.

Task 2d) Undertake outreach to peer agencies globally that have implemented updates to their standards in anticipation of CAV.

Task 2e) Develop recommended language to be considered for use in federal and provincial data standards and participate in the development of these standards.

Task 3	**Establish Mapping Needs**

Assess needs and define responsibilities for the development / maintenance of high resolution map and/or transportation network spatial data specification for CAV-related operations. Although this may be driven by the private sector, public agencies play a role in identifying their needs and providing oversight over the development of necessary mapping tools.

Task 3a)	Establish a Mapping Coordination Task Force, with representative from various agencies, to identify current mapping resources and new mapping needs.
Task 3b)	Initiate conversations with private sector companies to define responsibilities / needs and discuss opportunities for how mapping data will be shared (e.g. open source or manufacturer-specific) and who will be responsible for hosting and updating the map or data specification.
Task 3c)	Undertake a business case assessment of high resolution mapping and/or network spatial data specification requirements to analyze which parties (public versus private sector) are best suited to develop and maintain the maps and their data. The details of the business case are to be defined by the Mapping Coordination Task Force.

Task 4	**Establish Data Repository Needs**

Define the needs for a data repository to effectively and securely collect, process, store and host large datasets collected by public and private CAV, as well as intelligent transportation or communications infrastructure.

Task 5	**Develop Regional Data Management Plan**

Develop a plan to present recommended enhancements to data standards, identify key roles and responsibilities of public and private sector agencies and to define a framework that will monitor the performance of data collected against KPIs (e.g. quality and latency of high-resolution maps).

APPLICABLE GUIDELINES

Data Needs and Data Management (DN) – All guidelines are applicable (DN-01 to DN-04)

Communications, Privacy and Cybersecurity (CPC) – All guidelines are applicable (CPC-01 to CPC-02)

Network Management and Operations (NMO) – All guidelines are applicable (NMO-01 to NMO-04)

Technology (T) – Prepare concept of operations (T-02)

Mobility Services (MS) – Legislative, regulatory and policy framework (MS-03)

Regional Collaboration (RC) – Regional Centre of Excellence (RC-02) and Partnership Agreements with Industry and Academia (RC-03)

Inter-regional Goods Movement (IEG) – Requirements for pilot programs (IEG-01)

Intra-regional Goods Movement (IAG) – Requirements for pilot programs (IAG-01) and Regulations and/or by-laws to define the safe operation of last mile intra-regional commercial deliveries (IAG-04)

Standards (STD) – International scan of standards developed by public sector (STD-01) and Standards to guide the development of tools to support data information and technology needed by CAV (STD-04)

AGENCIES INVOLVED

☑ Provincial Government

☑ Regional Government (list all)	☑ Public Transit Agencies (list all)
• All regional government	• All public transit agencies
☑ Municipalities (list all)	☑ Others (list all)

INTERDEPENDENCIES	SCHEDULE
Program 1: CAV Development Streams **Program 3:** Pilot Projects Program Management **Program 5:** Development of a Regional Mobility Platform Strategy	January 2020 – December 2021

HIGH LEVEL CAPITAL COST	HIGH LEVEL ANNUAL O&M COSTS
High level costs are provided for tasks that may be completed by the private sector. **Task 1:** $250,000 to $500,000 depending on scope of outreach and number of facilitated workshops. **Task 2:** $250,000 to $1,000,000 depending on role of existing standards, skill set within Liaison Committee and ability to leverage work being done at Federal or international level. **Task 3: $**150,000 to $400,000 depending on the state of current research and development. **Task 4:** $75,000 to $200,000 depending on ability to leverage work undertaken by other agencies. **Task 5:** $150,000 to $300,000 depending on the number of consultations/facilitated workshops with industry.	Once the data repository has been set up, there will be ongoing operations costs to maintain the database, monitor incoming data and manage permissions with partners.

FUNDING MECHANISM
Each agency will self fund their involvement and pooled funding and grants will be considered for each external project. Alternatively, an agency sponsor will be identified.

PROGRAM NAME

DEVELOPMENT OF A REGIONAL MOBILITY PLATFORM STRATEGY

PROGRAM

5

PROGRAM DESCRIPTION	PRIORITY/TIMING
This program consists of developing a Regional Mobility Platform Strategy, including the governance and operation components needed to enable the platform. This strategy will identify and evaluate the needs for creating a mobility platform led by either public agencies or the private sector. The strategy will explore various considerations including methods on fare integration (i.e. mobile ticketing platform, app-based Presto etc.), opportunities for leveraging existing trip planning applications (i.e. Triplinx), partnerships between public and private sector mobility services providers, regulations to guide private-sector development of mobility platforms and the need for a region-wide approach to offering shared mobility services. It is important to note that CAV could contribute to the provision of mobility services, but it is not critical to its implementation. This strategy would also consider leveraging existing mobility service options that do not necessarily rely on CAV technology. Additionally, this Strategy will identify and provide recommendations to address potential privacy issues, as well as consider accessibility requirements of all user groups, user preferences (travel time, cost, modes) and identify methods to promote sustainable user behaviour. The development of a Strategy will set the Region up for success by establishing a framework for how transportation across the Region will occur in the future. This will benefit user mobility by leveraging existing transit services within the region and allowing for potential opportunities of new technology and business models to be harnessed (e.g. ride-sharing, car-sharing, bike-sharing, carpooling etc.). This will enable a mobility solution that supports inclusion and diversity, and compliments public transit as opposed to compete with it. In addition, Regional Mobility Platform Strategy will address the following strategies from Metrolinx's Regional Transportation Plan: • **Strategy 3:** Optimize the Transportation System Priority Action 3.4. – Develop and implement a mobility as a service strategy • **Strategy 5:** Prepare for an uncertain future Priority Action 5.1 – Develop a regional framework for on-demand and shared mobility	☐ Early Wins ☑ **Short Term (0-5 years)** ☐ Medium Term (5-15 years) ☐ Long Term (15+years)

PROPOSED LEAD AGENCY

Metrolinx, as the regional public transit authority, as well as the Provincial government.

TASKS

Task 1   **Project Steering Committee**

Establish a working group with designated staff members from partnering agencies with commitment to participate in ongoing discussions and document review.

    Task 1a)   Obtain a mandate and directive from the relevant government authorities to establish a Regional Mobility Platform Strategy working group with representatives from various public agencies.

Task 1b)	Develop a governance structure for the integration and provision of transit and mobility services across the region.	

Task 2	**Literature Review**
	Undertake a literature review on the development of regional mobility platforms from both academic and industry sources around the world.

Task 2a)	Conduct scan of relevant policies, plans and strategies from the GTHA and K-W agencies to develop a baseline understanding of priorities for a future transportation system of which a Mobility system will be integrated within.
Task 2b)	Conduct a best-practice review of other jurisdictions within Canada, such as TransLink, as well as other international jurisdictions (such as the United States, Europe and Australia) that have already implemented a regional mobility services platform or are in the process of planning and developing one. This also includes interviewing private sector companies (such as WHIM) for lessons learned, as well as undertaking a review of research for potential changes to policies and legislation.

Task 3	**Mobility Platform Needs**
	Define high level needs for a regional mobility platform through an Action Plan that identifies trip planning needs, business models and enabling policies and frameworks required to transition to a Mobility Platform in the region that integrates CAV, mobility services (including active modes of transportation), and existing transit services, while minimizing any potential negative impacts. Facilitated workshops across the Region and use of journey mapping would illustrate the concept for operation for the Mobility Platform.

Task 3a)	Through industry engagement (i.e. interviews), define needs for a regional mobility platform that includes existing mobility options (i.e. bike-share, scooter-share, transportation network companies etc.), while also leveraging existing regional trip planners (e.g. Triplinx), and fare card systems (e.g. Presto).
Task 3b)	Review and define trip planning and fare integration needs for a Regional Mobility Platform, including identifying the need for enhanced trip planning services that consider all potential modes of travel and dynamically adjust based on user defined key parameters (e.g. cost vs arrival time vs shared etc.), as well as the fare pricing structure across different transportation modes and mobility services.
Task 3c)	Conduct a business case analysis on updating transit fare price structure, exploring new methods of payments, integrating transit services and fares with on-demand mobility service providers (e.g. rideshare, bikeshare, etc.), and revenue-sharing models between transit providers and mobility service partners.
Task 3d)	Identify user preferences, including time, cost, number of transfers, modes etc. This might include undertaking a user survey to gather input on what the user preferences would be or running targeted focus groups.
Task 3e)	Assess and modify transit services strategies, business models and policies to meet the demands of the public, including identifying opportunities where a regional mobility services model could assist in servicing underserved users, coverage areas, while maintaining passenger equity in service level and barrier free access to mobility services. This includes mandating the need for all new CAV mobility service vehicles to be able to accommodate accessibility needs of users effectively.

	Task 3f)	Identify areas where new policies are required to address responsibility and liability concerns when transferring customers from public transit services to private mobility services.
	Task 3g)	Identify areas where new policies are required to provide incentives for high occupancy trips.
Task 4	**Legislative, Regulatory and Policy Recommendations**	
	Outline a legislative, regulatory and policy framework for public and private mobility service providers participating in the Mobility Platform	
	Task 4a)	Develop and update legislation, regulations and by-laws to reflect technological changes and ensure that the Accessibility for Ontarian with Disabilities Act (AODA) is applied for all new mobility services, including consideration of needs for young children.
	Task 4b)	Define legal operation and service coverage area for private CAV ridesharing/on-demand mobility operators, as well as maintain governance/oversight over mobility services (both public and private) to ensure desirable outcomes for the region.
	Task 4c)	Develop policies regarding mobility pricing, curbside management, vehicle registration, mobility service operation and integration with public transit services. This also includes identifying potential policy recommendations to incentivize high occupancy trips and promoting the use of public transit by complimenting it with mobility services.
Task 5	**Data Needs and Management**	
	Determine requirements for a data governance model specific to regional mobility services for data collected from transportation network companies and mobility service providers, while also considering data privacy requirements.	
	Task 5a)	Define data needs to capture information regarding vehicle location, vehicle occupancy of mobility service vehicles etc., as well as other traffic performance information.
	Task 5b)	Identify data privacy requirements for mobility services applications, regarding passenger details, financial transactions, origin and destination locations, as well as ownership and data accessibility.
	Task 5c)	Develop data dictionary for all data needs.
Task 6	**Regional Transportation Planning and Model Updates**	
	Determine the impacts that emerging mobility models and technologies will have on transportation planning, modelling and simulation practices. The details of these updates are captured in Program 2 – Development of CAV Modelling Tools.	
	Task 6a)	Identify transportation planning trends and strategies that will need to be revised with the implementation of a Regional Mobility system, including ongoing and future transportation planning studies within the region (i.e. Regional Transportation Plan, GGH Transportation Plan etc.).
	Task 6b)	Develop strategies and plans regarding the integration of mobility services within the region's transportation network and transit system and include in revisions of transportation masterplans and land-use planning initiatives.
Task 7	**Delivery Partnerships**	
	Identify and coordinate with key partners in the region on approaches to building a regional Mobility Platform. This includes identifying potential partnerships with private-sector companies.	

Task 7a)	Explore partnership agreements with the industry, including Small-Medium Enterprises (SMEs), private on-demand mobility providers, and academic institutions operating in the province to assist in developing a regional Mobility Platform.
Task 7b)	Identify opportunities for cooperation in the provision of public transportation services across the region. For example, seek coordination opportunities between public transit agencies and private on-demand mobility providers to explore opportunities for integrating services.

Task 8	**Deployment Approach**
	Identify the deployment approach that will be used to deliver the Mobility Platform. This could include deployment of a pilot, utilization of an alternative procurement approach (e.g. design-build-maintain-operate, or integrated project delivery), or a traditional design-bid-build approach.
Task 9	**Implementation**
	Pending the approach determined in Task 8 and complementary work undertaken by other agencies in the GTHA, the implementation tasks will vary. They could include preparation of system requirements, tender package development etc. or it could include a series of Pilots to test different components of a future Mobility Platform. The following describes some of the pilots that may be considered including integrating transit services with private rideshare companies and other mobility service providers. The purpose of these pilot programs would be to explore the impacts of integrated mobility services on a regional platform on travel behaviour and to test it as a new business model.

Task 9a)	Develop a framework for evaluating and approving transit pilot programs. This includes identifying pilot program needs, location and design, data needs, key performance indicators and measures of effectiveness, as well as requirements that mobility service providers (including those operating CAV) must meet. This includes licensing, liability/insurance coverage requirements, the requirement of a driver being present and not distracted and the ability to safely transition to manual operation if needed.
Task 9b)	Establish a funding stream dedicated for feasibility studies and pilot programs for transit services, including the integration of CAV and mobility service platforms with existing transit services
Task 9c)	Develop pilot programs testing different mobility service arrangements, such as integrating services with private rideshare companies to facilitate first and last mile trips. Initially, these pilots would be used to test arrangements on a subset of the population to explore travel behaviour impacts on different users. Following lessons-learned and analysis, the pilot projects can be expanded to broader areas of the population (e.g. testing the use of mobility services and Mobility platforms by different user profiles, accessibility needs and age), and more complex trips.

APPLICABLE GUIDELINES

Communications, Privacy and Cybersecurity (CPC) – All guidelines are applicable (CPC-01 to CPC-02)

Technology (T) – Develop a Concept of Operations (T-02A)

Data Needs and Management (DN) – Develop a data governance model for data collected (DN-01A-F)

Mobility Services (MS) – All guidelines are applicable (MS-01 to MS-05)

Regional Collaboration (RC) – Develop Regional Centre of Excellence (RC-02) and Partnership Agreements with Industry and Academia (RC-03)

Transit Service Planning (TSP) - Action plan to address impacts of CAV (TSP-01)

Transportation Planning (TPP) – Update Transportation, modelling and simulation practices (TPP-02)

Bonus/Malus Policy (BMP) – Policy to manage congestion (BMP-01) and Policy to Promote Public Transit Use (BMP-02)

Pilot Programs (PP) – Regional Framework and Funding for Pilot Programs (PP-01), Testing Mobility Service arrangements (PP-04C) and Testing CAV with different user profiles (PP-06)

AGENCIES INVOLVED

☑ Provincial Government

☑ Regional Government (list all)	☑ Public Transit Agencies (list all)
• All regional government	• All public transit agencies
☑ Municipalities (list all)	☑ Others (list all)
• All municipalities	

INTERDEPENDENCIES	SCHEDULE
Program 2: Development of CAV Modelling Tools	Tasks 1-7 to be completed from 2020 to early 2021 Schedule for Tasks 8-9 to be determined as they are planned

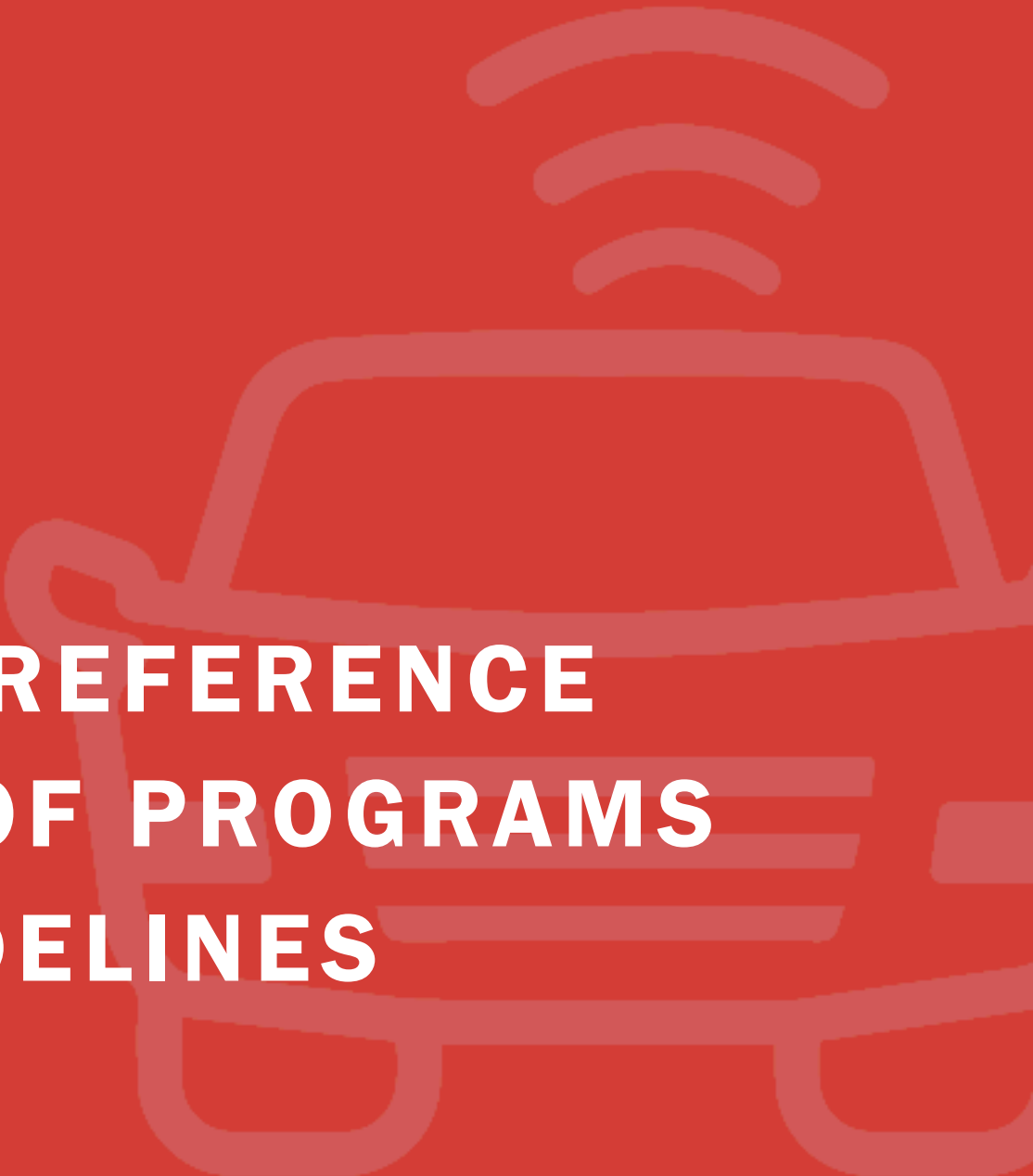| HIGH LEVEL CAPITAL COST	HIGH LEVEL ANNUAL O&M COSTS
High level costs are provided for tasks that may be completed by the private sector. **Task 1 –** Completed internally between agencies. **Task 2 –** $50,000 - $75,000 to complete study. Note: could be grouped with Task 2. **Task 3 –** $200,000 - $300,000 to identify needs and undertake simple user engagement. Developing and analysing output from detailed focus groups would be completed separately. This would include engaging with the Project Steering Committee. **Task 4** – Assume this would be completed internally. **Task 5** – $50,000 - $75,000 to identify and define a data dictionary. **Task 6** – $250,000 to update transportation masterplans and land-use plans (more detailed costing in **Program 2** – Development of CAV Modelling Tools). **Task 7** – Assume this would be completed internally. There may be output from Task 2 that could feed into this task. **Task 8** – $25,000 – $50,000 depending on amount of engagement with Project Steering Committee, and potentially IO, that is required. **Task 9** – Cannot be costed at this point.	Once the Regional Mobility Platform is in place, there will be ongoing operations costs to maintain the relationships with the providers, maintain the platform, update data with service changes etc.

FUNDING MECHANISM

Each agency will self fund their involvement and pooled funding and grants will be considered for each external project. Alternatively, an agency sponsor will be identified.

G

CROSS REFERENCE TABLE OF PROGRAMS TO GUIDELINES

Summary

There are 74 high-level Guidelines in the CAV Readiness Plan. A total of 58 (almost 80%) of those Guidelines are addressed by at least one or more of the five proposed Programs or CAV Liaison Committee.

Guidelines	Programs						TOTAL
	Program 1 CAV Development Streams	Program 2 Development of CAV Modelling Tools	Program 3 Pilot Projects Management Program	Program 4 Data Needs and Management	Program 5 Development of a Regional Mobility Platform Strategy	Regional Collaboration CAV Liaison Committee	
Technology (T)							
T-01							**0**
T-02	✓			✓	✓		**3**
T-03							**0**
T-04							**0**
T-05							**0**
T-06	✓						**1**
T-07							**0**
T-08	✓						**1**
Physical Infrastructure (PI)							
PI-01	✓		✓				**2**
PI-02	✓		✓				**2**
PI-03	✓						**1**
Communications, Privacy and Cybersecurity (CPC)							
CPC-01	✓			✓	✓		**3**
CPC-02	✓		✓	✓			**3**
Data Needs and Management (DN)							
DN-01			✓	✓	✓		**3**
DN-02				✓			**1**
DN-03				✓			**1**
DN-04				✓			**1**
Inter-Regional Goods Movement (IEG)							
IEG-01	✓		✓	✓			**3**
IEG-02							**0**
IEG-03	✓						**1**
Intra-Regional Goods Movement (IAG)							
IAG-01			✓	✓			**2**
IAG-02			✓				**1**
IAG-03							**0**
IAG-04				✓			**1**
Mobility Services (MS)							
MS-01					✓		**1**
MS-02					✓		**1**

Guidelines	Program 1 CAV Development Streams	Program 2 Development of CAV Modelling Tools	Program 3 Pilot Projects Management Program	Program 4 Data Needs and Management	Program 5 Development of a Regional Mobility Platform Strategy	Regional Collaboration CAV Liaison Committee	TOTAL
MS-03	✓			✓	✓		3
MS-04					✓		1
MS-05					✓		1
Network Management Operations (NMO)							
NMO-01	✓			✓			2
NMO-02	✓			✓			2
NMO-03	✓			✓			2
NMO-04	✓			✓			2
Public Fleet Management and Operations (PF)							
PF-01			✓				1
PF-02							0
PF-03							0
PF-04							0
Transit Management and Operations (TMO)							
TMO-01							0
TMO-02			✓				1
TMO-03							0
Freight Safety & Regulations (FSR)							
FSR-01	✓						1
FSR-02							0
Regional Collaboration (RC)							
RC-01						✓	1
RC-02			✓	✓	✓	✓	4
RC-03				✓	✓	✓	3
Safety (SY)							
SY-01	✓						1
SY-02	✓						1
SY-03	✓						1
SY-04	✓						1
Standards (STD)							
STD-01	✓			✓			2
STD-02	✓						1
STD-03	✓						1
STD-04	✓			✓			2
Transit Service Planning (TSP)							
TSP-01	✓				✓		2

CROSS REFERENCE TABLE OF PROGRAMS TO GUIDELINES

Guidelines	Programs						TOTAL
	Program 1 CAV Development Streams	Program 2 Development of CAV Modelling Tools	Program 3 Pilot Projects Management Program	Program 4 Data Needs and Management	Program 5 Development of a Regional Mobility Platform Strategy	Regional Collaboration CAV Liaison Committee	
TSP-02	✓						1
Transportation Planning (TPP)							
TPP-01		✓					1
TPP-02		✓			✓		2
TPP-03		✓					1
TPP-04		✓					1
Bonus/Malus Policy (BMP)							
BMP-01					✓		1
BMP-02					✓		1
BMP-03							0
BMP-04							0
Traffic Laws and Regulations (TLR)							
TLR-01							0
TLR-02			✓				1
TLR-03			✓				1
Infrastructure Policies and Regulations (IPR)							
IPR-01	✓						1
IPR-02	✓						1
Pilot Programs (PP)							
PP-01	✓		✓		✓		3
PP-02	✓		✓				2
PP-03	✓		✓				2
PP-04	✓		✓		✓		3
PP-05	✓		✓				2
PP-06	✓		✓		✓		3
TOTAL	**34**	**4**	**18**	**19**	**17**	**3**	