AUTOMATED VEHICLES TACTICAL PLAN

TORONTO

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ACKNOWLEDGMENTS

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Expert Review Panel Members

Emiko Atherton
Director National Complete Streets Coalition, Smart Growth America (Washington, DC)

Ann Cavoukian
Distinguished Expert-in-Residence, Privacy by Design Centre of Excellence, Ryerson University (Toronto, ON)

Rita Excell
Executive Director, Australia and New Zealand Driverless Vehicle Initiative (ADVI) Centre of Excellence (Adelaide, Australia)

Raed Kadri
Director, Automotive Technology and Mobility Innovation, Ontario Centres of Excellences (Toronto, ON)

Brooks Rainwater
Senior Executive and Director, Centre for City Solutions, National League of Cities (Washington, DC)

Anthony Townsend
Principal Consultant and Author, Bits and Atoms LLC (New York City, NY)

Dr. Tom Vöge
Policy Analyst Intelligent Transport Systems, Organization for Economic Cooperation and Development – International Transport Forum (Paris, France)

Bryant Walker Smith
Assistant Professor School of Law and School of Engineering, University of South Carolina (Columbia, South Carolina)

Ismail Zohdy
Expert/ Program Manager of Self-Driving Transport, Roads and Transport Authority (RTA) Government of Dubia (Dubai, UAE)

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MESSAGE FROM THE MAYOR

Toronto is a City facing unprecedented growth. Not only is it one of North America's leading technological hubs, buts its businesses, culture, and values are constantly attracting more people to the City. With this growth comes challenges, one of them being our City's transportation system which is in need of consistent investment to try and keep up with the pace of change.

In the past, we have seen how significant shifts in transportation – such as the introduction of the car, ride-hailing services, expanded transit, and the like – have changed Torontonians' experience of the City, and their ability to access opportunities. The next major shift we expect to see in this industry includes automated and driverless vehicles.

The City is continuously adapting to the way our citizens prefer to move around while balancing the impacts on our transportation system. Automated vehicles (AVs) are no different. The federal and provincial governments have put forward investment, regulation, and policy documents to shape how AVs will arrive on a national and regional scale. The City of Toronto must do the same to not only respond to these changes, but to get ahead of them and the potential unintended consequences of AVs, so that we can ensure our community goals remain at the forefront when AVs are introduced. The cost of inaction in this transition will likely be much greater than upfront preparation. It is always better for us to be proactive when we think of new technologies being introduced into our society.

Toronto is currently in a unique position to get ahead of this change, and to help shape the introduction of AVs, rather than respond to it. Thanks to the collaboration of 30 City divisions and agencies in developing this plan, we have examined this technology not only as a mode of transportation, but as a potential means of addressing some of the challenges we as a City are already working to solve within and beyond the transportation system. AVs will be significant in Toronto's progress towards improved road safety, mobility, resiliency and sustainability. By embracing this new technology, we will meet our goals and get people moving around the city.

Built from existing City documents, the vision for Toronto is to ensure that we are harnessing the full potential of AVs while effectively preparing for them. Through recognizing and mobilizing the division of roles and responsibilities between other orders of government, industry, academia and the community in this field – Toronto will be able to act as a model city for other municipalities in Ontario and beyond. If appropriately prepared for, AVs can be a tool to shift Toronto towards the 21st century transportation system we hope to see. The AV Tactical Plan allows Toronto to lead in North America and internationally, in progressing towards that system.

The City of Toronto also understands that the impacts of AVs could span across stakeholder groups and jurisdictional boundaries and is committed to building effective relationships with these actors to develop our proposals. Part of the way we aim to achieve this is by first, remaining a fair and honest broker amongst the various parties involved in the introduction of this technology; second, increasing the agility and resiliency of this document to ensure that it remains current and adaptable for the phases of AV development; and finally, by presenting a 2050 vision of what ideal AV integration could look like. By addressing this technology through the long term outcomes of our policy proposals, the City is able to keep in mind the vision for the next thirty years, while working day-to-day and remaining fluid in how we aim to achieve it.

The Automated Vehicles Tactical Plan is the first of many steps that Toronto will need to take to prepare for this major urban transportation shift, while moving toward our shared goal of an equitable, green, safe and connected City. I look forward to continuing to work together to address these complex changes, which will make Toronto an AV-ready city!

John Tory
Mayor
City of Toronto

MESSAGE FROM THE GENERAL MANAGER, TRANSPORTATION SERVICES

Automated vehicles are on our roads today, in more than one form. Although the opportunities and consequences of this technology are still uncertain; what we do know is that shaping rather than reacting to a shift like this is necessary for Toronto to harness its potential. In the wake of this disruptive and transformative technological change, we at the City are committed to serving the public, and considering their needs through the implementation of an Automated Vehicles (AV) Tactical Plan.

The City of Toronto's AV Tactical Plan is a strategy developed through collaboration with community, public, industry and government stakeholders. AVs have the potential to impact the way that City staff plan for, prepare, and deliver services to the public. The extent of the impact depends on how the technology develops, the changing economics of urban transportation, and public acceptance of the technology.

The Tactical Plan is the result of collaboration across 30 City divisions and agencies, through the Interdivisional Working Group (IDWG) on Automated Vehicles. The IDWG is a forum for learning, discussion, and coordination of the City's efforts to prepare for AVs. It allows for a consistent approach to the technology, preventing a duplication of efforts, and increased ownership of the process across the City's operations and services. This Plan has also been developed through extensive consultation with residents, community, and industry stakeholders, to ensure that automated vehicle deployment remains aligned with City goals and the needs of the community.

Automated vehicles could have transformative economic, social, environmental and land use impacts. That is why taking a multidisciplinary approach to planning the transportation system of the future is so important. The Tactical Plan not only addresses the mobility and infrastructural impacts of AVs; but firmly establishes equity, sustainability, privacy and safety as pillars of how City staff will approach automated vehicles.

As the future of AVs is highly uncertain; a key aspect of the Plan is flexibility. We are preparing for a range of future scenarios, to ensure that – regardless of when or how automated vehicles arrive on Toronto's streets staff will be prepared, and how we deliver services will keep pace.

Although the time horizon for the Automated Vehicles Tactical Plan is 30 years, the Plan will be reviewed every three years to incorporate technological advancements and changes in the industry. We recognize that assumptions and predictions will change as the Plan is implemented, and commit to learning from these changes, refining the document and iterating – but we won't wait when certain advances take place, we will be ready to adjust.

Barbara Gray
General Manager, Transportation Services
City of Toronto

INTERDIVISIONAL AUTOMATED VEHICLES WORKING GROUP

The Automated Vehicles Tactical Plan is the result of years of collaboration amongst staff at all levels from 30 divisions and agencies participating in the City of Toronto's Interdivisional Automated Vehicles Working Group.

Chris Murray
City Manager
City Manager's Office

Tracey Cook
Deputy City Manager
Infrastructure and Development Services

Ulli S. Watkiss
City Clerk
City Clerk's Office

Jeff Fielding
Chief of Staff
City Manager's Office

Gregg Lintern
Chief Planner & Executive Director
City Planning

Joe Farag
Executive Director
Corporate Finance

Mike Williams
General Manager
Economic Development & Culture

Michael D'Andrea
Chief Engineer & Executive Director
Engineering & Construction Services

Jim Baxter
Director
Environment & Energy

Don Boyle
Chief Executive Officer
Exhibition Place

Stephen Conforti
Executive Director
Financial Planning

Matthew Pegg
Fire Chief/ General Manager
Fire Services

Lloyd Brierley
General Manager
Fleet Services

Lawrence Eta
Chief Technology Officer
Information & Technology

Wendy Walberg
City Solicitor
Legal Services

Carleton Grant
Executive Director
Municipal Licensing & Standards

Omo Akintan
Chief People Officer
People & Equity

Casey Brendon
Director
Revenue Services

Chris Phibbs
Executive Director
Social Development, Finance & Administration

Matt Keliher
General Manager
Solid Waste Management Services

Will Johnston
Chief Building Official/ Executive Director
Toronto Building

Patricia Walcott
General Manager
Toronto Employment & Social Services

Gord McEachen
Chief
Toronto Paramedic Services

Robin Oliphant
President
Toronto Parking Authority

Mark Saunders
Chief of Police
Toronto Police Service

Dr. Eileen de Villa
Medical Officer of Health
Toronto Public Health

Richard J. Leary
Chief Executive Officer
Toronto Transit Commission

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EXECUTIVE SUMMARY

The Automated Vehicles (AV) Tactical Plan provides an actionable path forward to prepare the City of Toronto for the introduction of highly automated (or driverless) vehicles on city streets, in public transit, and in the delivery of municipal services. The Tactical Plan builds on existing policies and strategies approved by City Council, recognizing that automation should be a tool toward a future that has already been envisioned, rather than act as a force that pushes Toronto away from its existing goals. To that end, the Plan sets the foundation for a future transportation system that optimizes mobility with improved social equity and health, environmental and economic sustainability, protection of privacy, integrated transportation options centred on public transit, increased efficiency, and progress toward achieving Vision Zero.

The Tactical Plan is a layered document, prefaced with the City's current understanding of automated vehicle technology, expected timelines for deployment, and business models for AVs. The document also includes a scan of Toronto's automated vehicle ecosystem, which outlines the investment and initiatives being undertaken to prepare for and advance this technology.

The Tactical Plan then outlines the City's strategic vision for the ideal future transportation system through a set of seven high-level directions outlining how the City will encourage and support the adoption of automated vehicles. A series of 18 goals collectively illustrate a future based on these directions for the year 2050, painting a picture of what effective integration of AVs could look like. The actions required to achieve those goals are identified as tactics, with a proposed level of progress to be reached over the next three years. Tactics regarding the potential use of automated vehicles in City operations is also included.

The seven directions that outline the vision are as follows:

1. **Social Equity & Health:** ***The City of Toronto will encourage the adoption of driving automation systems in a manner that improves social equity and health.***
   This section of the Plan focuses on ensuring barrier-free access, increased mobility equity, and the promotion of health through tactics that look at marginalized groups, access to mobility and integrating health equity into automated vehicle policies.

2. **Environmental Sustainability:** ***The City of Toronto will encourage the adoption of driving automation systems in a manner that increases environmental sustainability across a vehicle's entire lifecycle.***
   Through incentivizing or promoting low or zero-carbon energy sources, and reducing the amount of waste produced across the lifecycle of AVs, this portion of the Tactical Plan will focus on reduced vehicle emissions and waste.

3. **Economic Sustainability:** ***The City of Toronto will support and enhance sectors related to automated vehicles, with a particular focus on attracting industries, investment, and employment, as well as on exporting products and services.***
   The Economic Sustainability aspect of the Plan will aim to expand AV sectors, employment opportunities, and Toronto's leadership position as it relates to AVs through attracting investment, local talent, and collaboration across industries.

4. **Privacy:** ***The City of Toronto will support and enhance data privacy as it relates to the collection and use of information generated by automated vehicles.***
   This direction will focus on protecting privacy through setting standards, providing oversight and evaluation, and incorporating privacy principles into any potential collection and use of information generated by AVs.

5. **Road Safety & Security:** ***The City of Toronto will encourage the adoption of driving automation systems that are proven to create a net benefit to road safety and security.***
   A net benefit to road safety and security will be achieved through tactics that focus on preventing collisions, updating infrastructure, updating emergency response, and protecting data confidentiality, integrity and availability. Tactics will address the knowns and unknowns of AVs, and look at the ideal policies, technology, standards, and training required to achieve improved safety overall.

6. **Integrated Mobility:** ***The City of Toronto will encourage the adoption of driving automation systems that further integrate space-efficient and active modes of travel, and better manage all traffic impacts from the movement of goods.***
   This section of the Plan will focus on ease and access of all travel modes. Tactics will address increased used of space efficient modes of travel such as walking and public transit; the design of smart streets that meet dynamic daily needs; as well as increasing the seamlessness of the transportation system. This will be achieved through prioritizing optimal modes, rethinking street design, and improving connections within the system.

7. **Transportation System Efficiency:** ***The City of Toronto will enhance its ability to manage traffic in real-time through driving automation systems for the purpose of increasing the efficiency of moving people and goods*****.**
   The City will aim to increase the capacity and manage the demand within our existing transportation system through the actions in this section. Tactics focused on active traffic management, pricing mechanisms, and increased transportation-related data will harness AVs to manage traffic in real-time and address congestion.

The Tactical Plan also presents a first phase of preparation that is intended to ensure that the City of Toronto is “AV Ready” by the end of 2022. This near-term strategy includes five individual projects that align with the 78 tactics in the Plan. These projects include: an automated shuttle trial, implementing zones for transportation innovation, developing AV testing response and incident preparedness (TRIP) protocols, undertaking public education initiatives, and furthering research and development.

The Tactical Plan was developed under the leadership of the City’s Interdivisional Working Group on Automated Vehicles, which is comprised of dozens of divisions and agencies, with substantial support from and consultation with academic institutions, community stakeholders and non-profits, automotive and technology industry members and associations, international experts, and members the public.

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INTRODUCTION

Technological innovation can be an exciting, advantageous, yet disruptive force. There are few areas in which this is more apparent than when looking to new transportation technologies and the possible ways in which they could impact and transform cities.

The Automated Vehicles (AV) Tactical Plan was created to bridge the gap between the emerging technological development of AVs and the City of Toronto's existing long-term vision to become a more healthy, equitable, livable and sustainable City. The AV Tactical Plan outlines how the City should prepare for AVs and how it can influence the local introduction of the technology in these early stages. The overall goal is to be proactive, ensuring that Toronto is well-placed to both maximize opportunities and mitigate impacts arising from the arrival of AVs in Toronto.

In 2016, City Council requested staff to report on potential implications, preparations, and public acceptance of AVs. Following that report and in recognition of the opportunity to plan ahead, City Council further requested that staff develop a full and comprehensive tactical plan. This document is the articulation of a means of preparing for opportunities and challenges arising from automated vehicle technology – with assurance that all tactics included in the Plan support existing policies, plans, strategies, and directives approved by City Council.

It is important to note that the scope of this Tactical Plan only addresses vehicles operating on public roads and streets; it is not intended to address automation systems controlling the movement of trains, aircraft, off-road vehicles, and uncrewed aerial vehicles (UAVs – commonly known as drones).

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PART I
BACKGROUND

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PART I: BACKGROUND

Part I of the Tactical Plan provides the background and context for the City of Toronto's automated vehicle preparations.

This section outlines the technologies, business models, timelines and key players in the automated vehicle space, specific to Toronto.

The first section, entitled "***What are Automated Vehicles?"*** provides a description of automated, connected and electric vehicle technologies, and how they relate to one another.

"When Will Automated Vehicles Arrive?" outlines the four major categories of AVs that are currently being developed, and their predicted timelines for launch, and adoption – including their expected automation levels. These four categories are:

- Passenger vehicles
- Transit vehicles
- Goods movement and freight vehicles
- Public service vehicles

The last section, ***"Toronto's Automated Vehicle Ecosystem"*** describes the key players in this sector, and their involvement, responsibilities, and/or interest in AVs. The *industry* subsection speaks to major AV investments in and around Toronto; the *government* subsection outlines the responsibilities for each order of government and initiatives that have been implemented to ease AV adoption; the *academic, research and civil society organizations* subsection describes projects that are underway, and organizations that are in place for research and/ or development of AV technology; and the *residents* subsection outlines public opinion on AVs, specifically as it relates to the Greater Toronto and Hamilton Area.

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What Are Automated Vehicles?

Automated vehicles (AVs) use computers and sensors to understand the driving environment and operate with little or no human input. Throughout this report, the term "automated vehicle" is used to refer to vehicles designed to travel in public rights-of-way without a fixed guideway (i.e., rail, water, and air vehicles are excluded) in which at least some aspects of a safety-critical operation such as steering, acceleration and braking occur without direct driver input.

Automation Technologies

All vehicles exist on a scale of automation, however, as auto manufacturers release new models with different feature packages, it can be hard to know where precisely a vehicle falls along the spectrum.

The Society of Automotive Engineers (SAE) Levels of Driving Automation[1] (Figure 1) are a widely used set of definitions for indicating the level of driving automation. There are six levels – the higher the level, the more the vehicle is capable of handling all aspects of driving without human intervention.[2]

Assisted driving features

- **Level 0:** The human driver is operating and controlling the vehicle when these features are turned on, and must constantly supervise steering, braking and acceleration to maintain safety. Other vehicle systems may provide warnings or support, such as automatic emergency braking or lane departure warnings.
- **Level 1:** The human driver is operating and controlling the vehicle when these features are turned on, but is assisted with either steering or braking/acceleration (e.g., lane centering OR adaptive cruise control).
- **Level 2:** The human driver is operating and controlling the vehicle when these features are turned on, but is assisted with both steering and braking/acceleration (e.g., lane centering AND adaptive cruise control).

Automated driving features

- **Level 3:** The human driver is not operating or controlling the vehicle when these features are turned on (e.g., traffic jam chauffeur), but must drive if prompted in order to maintain safety.
- **Level 4:** The human driver is not operating or controlling the vehicle when these features are turned on, but will either:
  - need to drive if prompted in order to reach the destination (in a vehicle that can be driven) or
  - not be able to reach every destination (in a vehicle that does not have a steering wheel or pedals)
- **Level 5:** The human driver is not operating or controlling the vehicle when these features are turned on, and can reach any destination.

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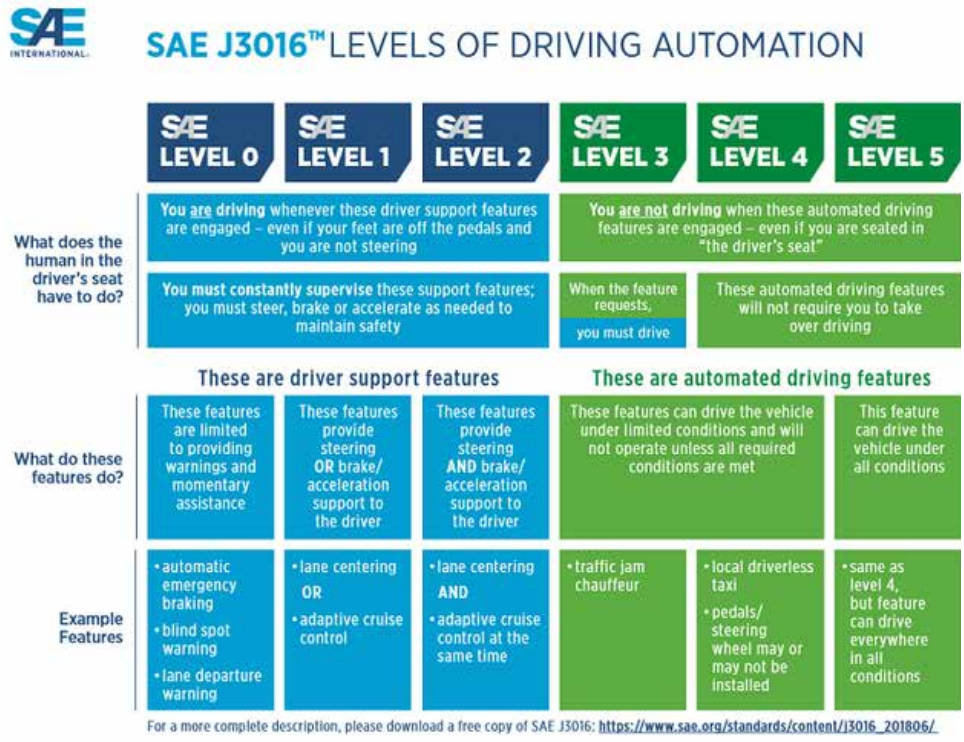

Figure 1: Visual chart showing the J3016 Levels of Driving Automation. (Originally visualized by: SAE International)[3]

Driving automation systems are made possible through a number of sensors that model and respond to the driving environment. Automakers, suppliers, technology developers, and other players in the industry have developed systems using one or more of the following sensor technologies:

- Cameras (monocular, stereo, infrared, or a mix of these)
- Radar (short range, long range, or both)
- Ultrasonics (i.e. Sonar)
- Lidar

Most automated vehicle developers utilize a mix of these technologies to ensure that these systems are aware of their surroundings. For SAE Level 4 and 5 driving automation systems, the industry has not yet created a standard understanding of what mix of sensors will be required, and currently develop their technology based on performance of these sensors (i.e. speed detection, sensitivity to colour, robust to weather and time of day, resolution, range), cost, market segment, and visual appeal.[4]

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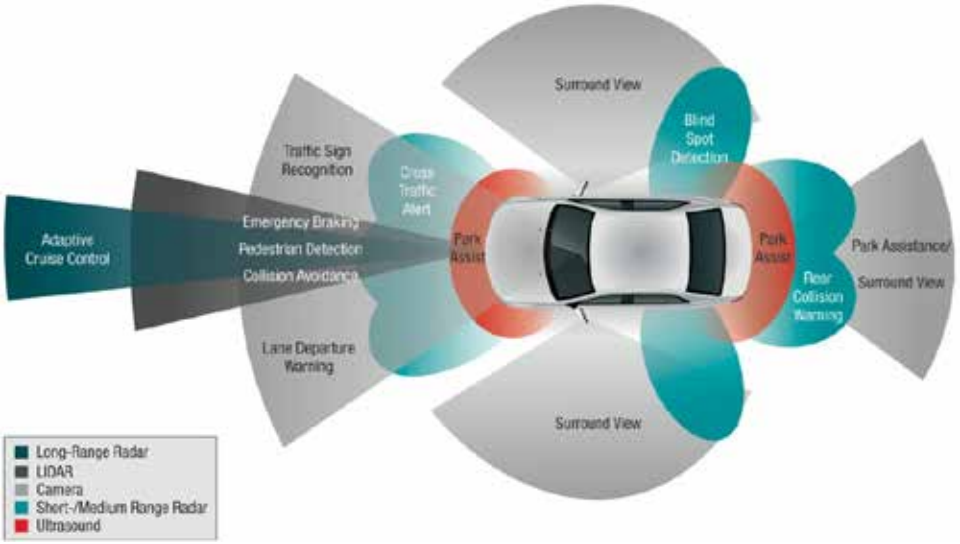

Figure 2: Sensors for Vehicle Computer Vision Systems. (Originally visualized by: Michigan Tech Research Institute)[4]

Connected Technologies

Torontonians already live with some intelligent transportation technology: high-occupancy vehicle lane enforcement and red light cameras are two examples. Wireless, connected technologies could further unlock the transformative potential of driving automation by enabling individual AVs to communicate both amongst each other and with transportation infrastructure.

Data Collection & Analysis

A vehicle equipped with sensors, communication technology, and computing power is a mobile "big data" collecting machine. Big data has three main characteristics: 1) volume – there are vast numbers of individual data points; 2) velocity – data comes into the system in real-time or near-real-time, and; 3) variety – data about many different objects, individuals and conditions in numerous formats. These are collectively known as the "3 Vs".

In the case of AVs, this data is generated from inputs that are both inside and outside the vehicle. Outside the vehicle involves: data on congestion, road safety, street and curbside usage, travel demand, air quality, noise and more. Inside, the vehicle collects data about its own performance, as well as its passengers' movements and activities – which raises new and unique considerations about data privacy and usage.

This data is mobilized in a variety of ways, such as through data analysis, modelling, visualization, and mapping. For example, instead of a simple count of on-street parking space inventory, location data broadcast by AVs (in conjunction with embedded curb sensors) could allow for the visualization of real-time, historical, and anticipated pick-up and drop-off patterns throughout the day, week-to-week, and seasonally, and for all points on a network. Better predicting demand could allow for more efficient management of transportation infrastructure.

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As driving automation technology becomes more common on new vehicles, the large amounts of data generated could be valuable not only for improving the vehicle's operation, but also for gaining more profound insights into urban conditions and helping decision-makers develop evidence-based policy.[5] With the advent of machine learning, algorithmically governed systems will be able to continually tweak and optimize themselves without any human intervention. However, this automation creates both opportunities and risks. On the one hand, it can reduce human error, reduce costs, increase productivity, and create openings for new services and products. On the other hand, depending on the quality of data and assumptions used to train the algorithms, automation can increase human error and bias in data outputs.

Telematics

Telematics refers to telecommunications, sensors and instruments technology which allow for the sending, receiving and storing of information to control vehicles on the move. Vehicle-to-Vehicle (V2V) technology allows for the wireless exchange of information about a vehicles' speed and position with surrounding vehicles, helping to avoid crashes and manage traffic congestion.[6] Vehicle-to-Infrastructure (V2I) and Vehicle-to-Everything (V2X) technology uses wireless technology to broadcast and receive information and messages about upcoming road conditions, construction zones, traffic lights, weather, emergency alerts and more. There are currently two major communication technologies that make this possible:[7]

- Dedicated short-range communications (DSRC) is a wireless communication technology – similar to Wi-Fi – enabling vehicles to communicate with each other and other road users directly, without involving cellular or other infrastructure. Every vehicle broadcasts its location, heading and speed securely and anonymously ten times per second. All surrounding vehicles receive the message, and each estimates the risk imposed by the transmitting vehicle.[8]
- Cellular V2X technology uses mobile networks provided by private carriers just like mobile phones. While cellular communications do not consistently provide high enough transmission speeds required for critical safety applications, they can carry longer-range communications for data transfers to support some mobility and environmental applications, along with supporting data collected and disseminated by transportation agencies, such as traffic and pavement data. The next iteration of cellular V2X technology is 5G communication – which brings promise of greater interoperability, wider bandwidth, increased cybersecurity and a decentralized network that runs on private cell towers.[9]

There is still uncertainty around precisely which wireless communication protocols will be widely adopted, but the vision of AVs connected using both V2V and V2I technologies that maximize the safety and efficiency of trips is powerful. Together, telematics technologies could make urban transportation systems more connected and responsive than ever.

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Electric Vehicle (EV) Technologies

Vehicle automation could be a lever for transitioning away from fossil fuels, as some AVs are being designed to run on small, light and quick-charging electric batteries. Technologies are being developed for AVs to travel to charging stations, and even charge while in motion via electromagnetic plates embedded in the pavement.

Transitioning to these zero-emission vehicles is important because internal combustion engine vehicles produce a major proportion of global greenhouse gas (GHG) emissions that contribute to climate change. Conventional vehicles also create air pollution which combined with other sources leads to 1,300 premature deaths and 3,550 hospitalizations in the City each year.[10]

However, the marriage of transportation automation with electrification in the passenger vehicle sector is not guaranteed. Automation technologies do not depend on electrification to function; in fact, some approaches to automation involve retrofitting conventional vehicles. Many prominent emerging AV services, both from conventional automakers and recently introduced ridehailing companies, use hybrid or conventional vehicles rather than fully electric ones.[11] The energy required to support the computing power required makes current automation technologies very energy-intensive, adding to the overall energy demands of the vehicle and making it more difficult to rely on batteries alone at the current state of technology.[12]

The extent to which AVs are zero-emissions will in part depend on the extent to which AVs are shared. Ride-hailing and transit vehicles typically drive many more kilometres per year than the average vehicle. For this reason, converting fleets of gas-powered vehicles to low or zero-carbon technologies is essential for maximizing the economic and environmental returns on investment.[13,14] Because they drive longer distances, these fleets can more quickly reap the benefits of fuel savings; furthermore, fleet owners can more easily invest in centralized charging infrastructure. Passenger and freight AVs – if powered by low or zero-carbon technologies such as hybrid electric, plug-in hybrid electric, or battery-electric – could significantly reduce GHG emissions and critical air pollutants associated with transportation.[5]

In spite of this, electric vehicles come with challenges, including a higher upfront cost for consumers and a lack of available charging infrastructure in the public and private domain. Beyond a certain point, the additional draw on the power grid could have further upstream impacts, depending upon how the electricity is generated and how innovation in electricity storage proceeds. Furthermore, AVs may increase commuter tolerance for longer commutes – as they could watch entertainment or even sleep while the vehicle drives itself. This could lead to energy-intensive urban sprawl, offsetting potential environmental benefits from the vehicles themselves.[5] Additionally, waste streams arising from the disposal of rare-earth minerals used in electric motors and especially lithium-ion batteries may pose new waste management challenges.[15]

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WHEN WILL AUTOMATED VEHICLES ARRIVE?

Despite all the activity around AVs, there is still uncertainty around how and when AV technology at higher levels will be launched, and if AVs will live up to the hype. Uncertainty enters into the picture from several sources: technology, policy, economic and human factors. Technological factors may include vehicle performance, security, and infrastructure requirements. Policy factors may consist of infrastructure investments, liability, allocation of right-of-way, and incentive programs. Economic factors may include scalability of commercial deployment, changes in the cost of materials and energy, and business case impacts from new regulations and competing innovators. Human factors may consist of personal comfort levels with riding in an AV, willingness to share rides with other passengers, ability to adapt driving skills when both conventional vehicles and AVs share the road, and individual willingness to share data.

The interactions between these and other factors will affect when highly automated vehicles are launched in the market, how much of the driving task the AV will perform, the rate of AV adoption, cost of AV technology, and the split between different transportation modes.[16] According to Gartner's Emerging Technology Hype Cycle, while automakers are actively developing automated driving systems (ADS), advanced AV technologies are still in their infancy, offering limited functionality within defined situations.[17]

By 2022
On-demand, fleet-based AV services currently deployed through private transportation companies may be scaled up and be introduced in major urban markets.

Automakers are actively developing automated driving systems, but they are not yet ready for mass commercialization. Some luxury model vehicles may offer Level 3 features, but these features will likely be uncommon until their cost significantly decreases. Level 2-3 feature packages – such as traffic jam and highway pilots – will become standard on new consumer vehicle models

Driving automation technology exists today in the form of advanced driver assistance systems (ADAS) including blind spot monitoring, forward collision warning, and lane assist.[18] By 2022, it appears likely that Level 2-3 features – such as traffic jam and highway pilots – will become more widely available in premium segment cars and later in volume models.

While Level 2 and 3 driving automation systems may be able to handle certain driving tasks in limited circumstances, they carry the danger that drivers will overestimate the vehicle's abilities, leading to unsafe situations. Significant improvement will therefore be necessary before full operation of vehicles is passed from humans to computers.[18]

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Regulatory regimes at the federal and provincial/territorial levels may also require time to ensure the safety of AV technologies. Even if Level 4 and 5 AVs appear on the market as they are suggested to do in the 2020s (Table 1), it may still take decades before the majority of vehicles on the road are capable of automated driving.[18]

Level 4 and 5 AVs are predicted to have the most disruptive impact on urban mobility and associated services, not just in terms of moving people, but in many other applications as well, however, these technologies are currently at different stages in their development, and some may appear on City streets before others. Here are four major categories of AVs currently being developed:

- **Passenger vehicles:** Smaller-scale AVs could look like tiny 1-2 person pods, or familiar 4-6 person vehicles. These could be either personally owned or deployed in fleets as part of a ride-hailing service.
- **Transit vehicles:** Shuttles that can hold anywhere from eight to 25 people could complement our public transit network by providing first- and last-mile connections or conventional service in lower-demand areas.
- **Goods movement and freight vehicles**
    - **Semi-trucks:** Long-haul AV semi-trucks are being tested to follow one another in **platoons** (nearly bumper-to-bumper) in a line resembling a train. The close spacing reduces air-drag friction, lowers fuel consumption (and therefore lowers GHG emissions and air pollution), and allows goods to be transported more efficiently.
    - **Delivery robots:** Small vehicles could travel on sidewalks, campuses, or indoor commercial spaces, delivering everything from packages to restaurant take-out deliveries, right to customers' doors.
- **Public service vehicles:** Different levels of automation are being tested in public service vehicles such as waste collection trucks and snow plows to help improve their efficiency and safety. For example, fully automated snow clearing vehicles could plow stretches of sidewalk that are too narrow for current human-driven vehicles.

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Passenger Vehicles

In contrast to public transit and service vehicles – for which the timing of deployment is within the control of municipalities – the introduction of AVs to the general passenger vehicles fleet is subject to much more uncertainty (Table 1). Companies are setting targets for a "minimum viable product" which may include automated features, but could be limited to certain conditions such as well-maintained highways and fair weather. These products could be available for commercial sale, but will not have a significant impact on the overall transportation system.[19] Predictions are also changing from year to year based on the development of the technology.

Table 1:
Selected predictions of commercial availability of higher level AVs as of 2018. Adapted from the Eno Center for Transportation report Beyond Speculation 2.0: AVs and Public Policy (2019) by Paul Lewis and Alice Grossman.[19]

Sector	Organization	Predicted Launch Year	Automation Level
Vehicle manufacturer	BMW	2021	Levels 4 & 5
Vehicle manufacturer	Daimler	2020-2025	Levels 4 & 5
Vehicle manufacturer	Fiat-Chrysler	2023-2025	Level 4
Vehicle manufacturer	Ford	2021	Level 4 (ride-hailing)
Vehicle manufacturer	General Motors/ Cruise	2019	Unknown (ride-hailing)
Vehicle manufacturer	Tesla	2019	Level 4
Vehicle manufacturer	Toyota	2020	Level 4 (highway only)
Vehicle manufacturer	Volvo	2021	Level 4
Tech company	Zoox	2020	Levels 4 & 5
Tech company	Google/Waymo	2020	Level 4
Tech company	Uber	2021	Unknown (ride-hailing)
Market research firm	ABI Research	2021	Levels 4 & 5
Market research firm	IHS Markit	2019 (ride-hailing) 2021 (personal)	Levels 4 & 5

Depending upon the balance of AV ownership models – how many are personally owned and how many are shared – cities could experience a range of disruptive impacts to their infrastructure and built form.

PART I: BACKGROUND

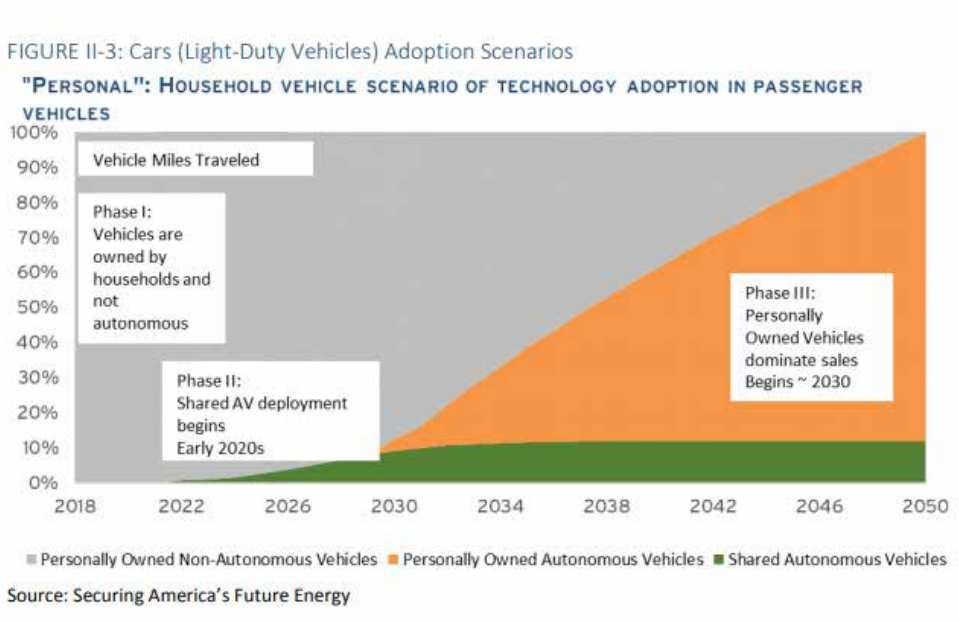
For the time being, Canadian consumers will likely continue to buy cars ¬– though at a reduced rate – as the millennial cohort opts for a more urban, less car-focused lifestyle (Fig. 3). This may lead to the emergence of two parallel vehicle markets: privately owned automobiles with an increasing array of automated features, and higher level AVs deployed under a shared on-demand model.[20]

Personally Owned Automated Vehicles

In the short term, vehicle manufacturers could begin to introduce Level 2-3 features – such as traffic jam chauffeur and highway pilots – into their premium models and later in volume models.

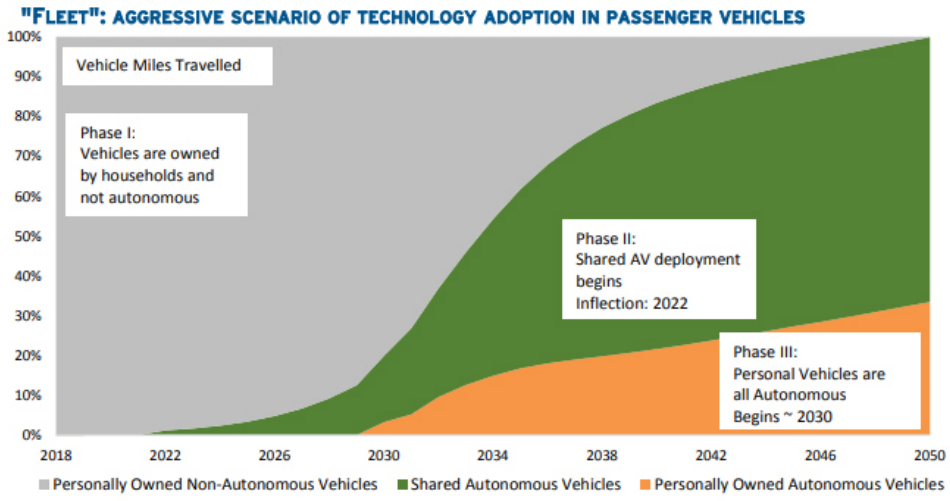
In this scenario, personally owned Level 2-3 AVs could enjoy market dominance for the foreseeable future until Level 4-5 AVs are developed, with sales expected to reach their peak in the mid-2030s.[20] Level 2-3 AVs could make driving more convenient and free up drivers to do other activities which could lead to longer and more frequent journeys. In this scenario, the status quo is extended – with continued urban sprawl and road congestion – and the positive transformative potential of AVs has not yet been fully realized.[20]

Figure 3: Household vehicle scenario of technology adoption in passenger vehicles. (Originally visualized by: Groshen et al.)[21]



PART I: BACKGROUND

Figure 4: Aggressive scenario of technology adoption in passenger vehicles. (Originally visualized by: Groshen et al.)[21]



Source: Securing America's Future Energy

PART I: BACKGROUND

Toronto, 2050

Snapshot #1: Sunjay's Exam

Sunjay, a twenty-three-year-old social work student, needs to get to school for a final exam. Living with his family in Scarborough, Sunjay makes the twenty-minute walk from his building to the nearest subway station most mornings if the weather isn't too bad. But this morning, he'd prefer to get to campus in less time so that he can squeeze in some last-minute studying for the exam.

Waking the personal virtual assistant on his phone, he quickly checks his options: Option 1) A shared AV (which picks up other riders along the way) – six minutes away, or; Option 2) A single-seat AV – two minutes away. Usually, he'd choose the shared option to save money, but this morning time is more important to him.

Sure enough, after a couple of minutes the single-seat AV pulls up to the curb and opens its door. Based on his user profile and trip history, the app already knows that Sunjay participates in an incentive program for customers using AVs to connect to transit, rather than for the whole journey. By travelling this way, Sunjay and others like him make the transportation system more efficient as a whole, and get a discounted rate after a certain number of trips.

The AV maneuvers easily along the streets, communicating between other vehicles, infrastructure and pedestrians to plan the most efficient route. Sunjay watches an interactive map on the interior screen, showing the trip progress.

Before long, the AV pulls up in front of the TTC station, in a designated fare-paid pick-up and drop-off zone. Three AVs ahead of Sunjay's each drop off their passengers and then quickly join the line to exit the area and merge back onto the road.

As Sunjay gathers his school bag and hurries into the station, he's grateful for being able to catch an earlier train and get in a few extra minutes of study time.

PART I: BACKGROUND

Shared Automated Vehicles

Ridehailing services (e.g., Uber and Lyft) are making up an ever-increasing share of trips in cities around the world. In Toronto, ridehailing trips have grown by 180% in 2.5 years. A recent study prepared by the City of Toronto's Big Data Innovation Team in partnership with the University of Toronto found that due to the substantial travel time savings for most trips, ridehailing services may compete with transit, but can also fill gaps in service.[22] **Shared AV (SAV) fleet companies** – Level 4+ vehicles providing either single trips back-to-back or pooled with other passengers – could continue this trend, beginning to provide on-demand service in some urban areas at the same time as Level 2-3 personally-owned vehicles become available in the consumer market. A study from the World Economic Forum and the Boston Consulting Group predicted that low-cost, convenient AV mobility-on-demand services could account for more than 40% of trips in urban areas by 2030, decreasing personal car and mass transit use by 14% each.[23]

Shared AV fleets could provide a significant return on investment as they can operate and generate revenue around the clock.[24] This business model could see substantial growth, as car ownership continues to decline and ride-hailing apps like Uber and Lyft continue to gain in popularity.

Shared AVs have the potential to provide an affordable and reasonably convenient commuting mode for Torontonians. One consulting firm has predicted travel cost savings of up to 60% (from $0.98 per km to $0.41 per km) if private vehicle trips were taken with a shared AV fleet instead.[25] By avoiding the high upfront purchase price, financing and other costs of car ownership, users can purchase as much (or little) mobility as they want.

Depending upon how quickly shared fleets are deployed and how comfortable people become using them, the popularity of human driven vehicles could decline.[20]

The first fleet-based AVs would likely be confined to geo-fenced areas or until they can operate in any condition they might encounter along their entire route. With appropriate policies, Level 4-5 shared AVs could potentially drive down congestion and parking demand, as well as increase mobility choices.[20]

In this scenario AVs contribute to the creation of new business and service delivery models, shifting job markets, transforming industries, altering energy consumption, and reshaping the urban form.[20]

"Mobility-as-a-Service aims to provide consumers with integrated, flexible, efficient and user-oriented mobility services. It implies a shift away from the personal ownership of individual motorized transportation modes, and non-integrated means of transportations towards the use of integrated multimodal mobility solutions consumed as services. This shift is enabled by combining transportation services from public- and private-transportation providers through an 'integrated mobility platform' that creates and manages the journey and integrates planning and payment on a one-stop-shop principle."[26]

Goods Movement and Freight Vehicles

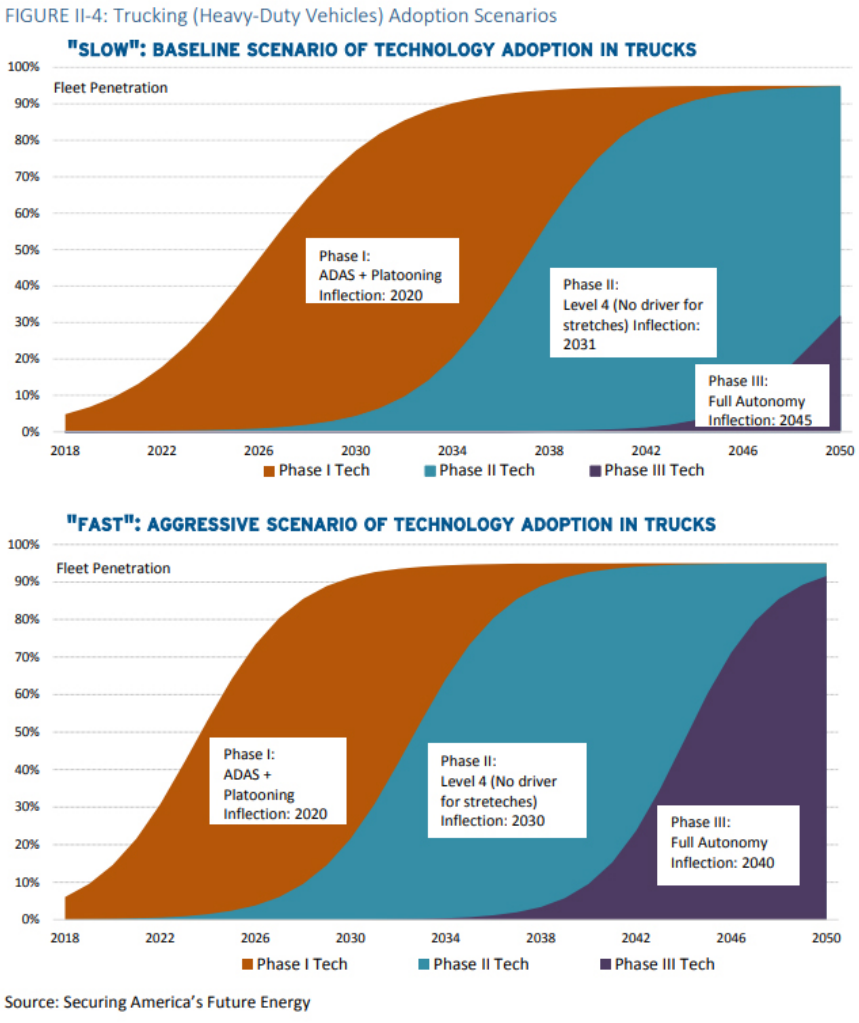
AVs could significantly change how good are moved between and within cities. AVs may be a tool for responding to overlapping trends in the goods movement sector that are presenting challenges for the industry: a driver labour shortage, particularly for long-haul operations; increasing congestion, particularly in dense urban environments; increasing volumes of goods to be shipped; and changing consumer behaviour, including a rapid shift to e-commerce and pressure for just-in-time deliveries.[27,28] Since fuel costs represent a significant portion of the cost to deliver goods, any opportunities to reduce fuel use will also be of interest to the industry.

PART I: BACKGROUND

Long-haul tractor-trailers are expected to be among the first vehicles to use AV technology on a large scale on public roads and are already being tested by various companies in the United States and Europe. Long-haul AV tractor-trailers would likely drive in platoons in dedicated lanes, resembling a train, with the driver acting as a "chaperone" rather than a dedicated driver and operator. Eventually, the platoons could travel without on-site human involvement. AV technology could enable freight services to increase productivity, from 13 hours per day of driving time (the current daily limit for a human driver in Ontario) to 20 hours with AVs.[29]

On a smaller scale, delivery robots are being designed to travel on sidewalks or in other public and private environments, delivering items such as packages and restaurant take-out deliveries right to customers' front doors. In the U.S., companies like Amazon, FedEx, Domino's, and others are actively piloting this technology as a way of reducing costs and increasing convenience for customers.[30]

Figure 5: Trucking (Heavy-Duty Vehicle) Adoption Scenarios (Originally visualized by: Groshen et al.)[21]



PART I: BACKGROUND

Transit Vehicles

Transit vehicles with driving assistance or automation technologies could help improve the safety and efficiency of public transit service. An SAE Level 1 or 2 transit bus with ADAS could provide: smooth acceleration and deceleration, automatic emergency braking and pedestrian collision avoidance, curb avoidance, precision docking, narrow lane/shoulder operations, and platooning. Higher level automation packages could be deployed in maintenance and yard operations, as well as shuttle, bus rapid transit and mobility-on-demand services (e.g., paratransit).[31]

AVs could both support and challenge existing public transit systems. On one hand, a technology that could strengthen transit networks is the low-speed automated shuttle.[32] These vehicles, capable of carrying eight to 25 people at speeds of around 25-30 km/h, could provide feeder service in neighbourhoods and employment areas where higher-order transit service is impractical and providing first-and-last mile connections to major transit routes or other important destinations is a challenge.[33] Automation and platooning of shuttles could lead to a new form of bus rapid transit (BRT), with AV buses operating on busways or high occupancy vehicle lanes.[34]

On the other hand, without proper planning, other AV services and vehicles could draw away riders from the transit system which would undermine its viability and create more congestion. This would be consistent with some studies that have shown that use of private transportation companies (PTCs) adds substantially to urban vehicle travel and occurs at the expense of transit ridership.[35]

Automated shuttles and other automated transit services could eventually provide more cost-effective alternatives to the current options for individuals with disabilities – especially if wheelchair securements and other assistance can be accomplished via advanced robotics.[36] To provide full accessibility in the absence of a driver, the automated vehicles would likely require robotics for this and related tasks for audiovisual information on vehicle location and stop announcements and for a fully accessible means of hailing, boarding and alighting from the vehicle, including any associated mobile applications and platforms. A video link (or similar) to an operations centre could also be used for passenger assistance and security.[31]

Vancouver-Surrey Driverless Shuttle Pilot

In February of 2019, a driverless shuttle transported passengers for free, short rides in Vancouver and Surrey as part of the two cities' bid for Infrastructure Canada's Smart City Challenge. The rides were in the ELA (electric automation) EZ10 Driverless Shuttle that has already been used in several cities around the world. This vehicle can hold 12 passengers, and can travel up to 40 kilometers per hour. This shuttle was a key component of the cities' attempt to create two collision-free multimodal transportation corridors. The Surrey corridor was a 3.4 kilometre route between Surrey Memorial Hospital and a major transit hub, and the Vancouver corridor was a two-kilometre route between Granville Island and Science World.[37]

PART I: BACKGROUND

Toronto, 2050

Snapshot #2: Carl's Morning Routine

Carl, 32 and his husband have a busy morning ahead of them - fixing breakfast, getting the kids ready, and making sure Carl gets to his job on time, where he works as a mechanic on a robotic assembly line. Carl usually takes their 6-year-old daughter to school while his husband stays at home with their 2-year-old son.

After finishing breakfast, Carl and his daughter leave the apartment and head downstairs out onto the street. It's a beautiful spring morning to walk the four blocks to his daughter's school. As they make their way down the sidewalk, an automated recycling collection truck approaches beside them, driving along its route and emptying bins left at the curbside. As Carl and his daughter step towards the crosswalk, the truck comes to a stop – signalling that it's seen them with a blink of its lights.

Carl remembers that when he was his daughter's age, apartment neighbourhoods like the one they live in used to be much different; they were isolated places, built around cars. But now fewer people own cars, and space once taken up by parking lots are now filled with mixed-use buildings that provide housing for families, community services, and spaces for local businesses. The number of people moving around the neighbourhood throughout the day has brought in lots of new transit customers, making it possible to offer more frequent service complemented by a network of automated shuttles.

After Carl drops his daughter off at her kindergarten class, it's time for him to head to work. "Take me to work," he says into his smartwatch. His personal virtual assistant knows his travel preferences and does the rest. It gives him directions to an optimal pickup location outside the school zone – calculated to minimize the detour the shuttle must take from its usual route. It lets him know it'll be a four-minute wait until the AV shuttle picks him up.

A few minutes later, the shuttle pulls up at the curb outside the school and opens its doors. It's almost full with commuters heading to similar destinations, but luckily there's a seat available. Even though mornings are always hectic, Carl is happy for the time he gets to spend with his family without the added hassle of worrying about how he'll get to work.

PART I: BACKGROUND

Service Delivery Vehicles

AV technologies are being developed not only for the passenger and freight sectors, but also for the delivery of services. Many companies are exploring how automation can contribute to improved traffic safety, worker conditions, efficiency, and a lower environmental impact. For example, self-driving street cleaning vehicles are being developed internationally that can automatically trace and pick up garbage, as well as trim roadside bushes, while sensing and monitoring the vehicle's vicinity to avoid obstacles in its path. These technologies can also be mass produced allowing for significant cost savings in service delivery.[38]

Automated features are being tested in numerous types of service vehicles to help improve their efficiency and safety. Waste collection trucks could automatically travel their routes, lifting and emptying bins, and reducing the risk of occupational injuries in workers.[39] Automated snow plows – already being tested at airports – could be deployed quickly after a major snowfall to clear streets and sidewalks.[40]

Since many services provided by the City occur along fixed routes (e.g., snow clearing, street cleaning, waste and recycling collection), there could be an opportunity to deploy non-passenger AVs (NPAVs) to supplement the existing suite of City services. Automating service vehicles to improve the safety and efficiency of public service delivery could consist of just automating certain driving functions or deploying fully automated vehicles.

PART I: BACKGROUND

Toronto, 2050

Snapshot #3: Jennifer's Appointment

Jennifer, a seventy-two-year-old downtown resident, needs to make her way to medical appointments a few times per month. Her apartment isn't far from the clinic, but between the limitations of her mobility device and the cold weather outside (snowstorms are still a reality in the Toronto of 2050!) it can be difficult for her to get far on her own.

Luckily, Jennifer can easily book one of the thousands of nearby automated shuttles using a smartphone app. In fact, since she's a regular customer, the app connects to her calendar and knows to send an accessible shuttle a few minutes earlier than usual to get her to the appointment on time.

Jennifer doesn't have to worry about her mobility device getting stuck in the snow as she makes her way to the curb since teams of automated plows have made short work of clearing snow and ice from both streets and sidewalks.

By the time she reaches the shuttle, it has already automatically lowered itself to align with the curb. The doors slide open and the shuttle's friendly attendant, Amena, greets Jennifer. Every accessible shuttle has an attendant, like Amena, who can help customers with special needs.

The shuttle drives itself more cautiously than usual, but that's a good thing – some other vehicles are having trouble braking in time due to weather. But because the shuttle can communicate with most of the other vehicles on the street, it can anticipate their movements and figure out the quickest, safest route to the clinic.

Once the shuttle pulls up to the curb outside the clinic, Amena helps Jennifer disembark. Watching the blizzard blow in off Lake Ontario, Jennifer is glad there's a safe, reliable, and accessible way for people like her to get where they need to go.

PART I: BACKGROUND

Learning from the Past

Throughout history, successive transportation innovations have enabled humans to reach more places faster. While AVs could represent the newest wave, it is worthwhile to look back at the lessons learned from the last time North American cities underwent such a transformation: the transition from horse-drawn carriage to the automobile.

The horse dominated nineteenth century urban and rural life in North America and Europe.[41] However, by the end of the nineteenth century new transportation options appeared on the scene and the transition away from the horse began.

Parallel developments in steam power, electricity, and the internal combustion engine led to a "widening up" of new mobility options – the bicycle, omnibus, horse-drawn streetcar, electric streetcar, cable car, railway, steam-powered car, electric car, and the internal-combustion engine car.[42]

Of course, not all of these options lasted. Public hygiene issues associated with horses, namely manure and carcasses (by the 1880s New York City removed the remains of about 40 horses from the streets each day), contributed to their decline. Electric streetcar systems were widespread across North America for a time – fostering tremendous growth in "streetcar suburbs" like the neighbourhoods of Riverdale, Parkdale, Mimico, Long Branch – before these lines were largely torn up in favour of new bus fleets. In spite of this Toronto continues to have the largest streetcar system in the Americas.[43]

Figure 6: A horse-drawn carriage moves along tree-lined Jarvis street circa 1885 to 1895, which has no visible curb and appears to be surfaced with either gravel or water-bound macadam (crushed limestone). In the background, a horse-drawn bus travels west along Carlton Street. (Source: City of Toronto Archives)[44]

City of Toronto Archives, Fonds 1478, f1478_it0012

PART I: BACKGROUND

Early automobiles were specialty items, used only by innovators, the wealthy, racers and hobbyists, as well as military applications. While the introduction of the Model T Ford made the automobile widely accessible, broader social and scientific developments over the span of about 100 years (1830s to 1930s) played roles in advancing and accelerating the transition to the automobile.

As the complex infrastructure that had developed around the horse-based economy began to decline, a new infrastructure emerged, enhancing the benefit of the automobile. Early barriers, such as buying fuel in cans from pharmacies and cars that required repair on route, were overcome with innovation and development of support networks. New professions and business models began to emerge: mechanics, traffic engineers, parking garages, gas stations, car washes, and taxi companies.[45]

Based on historical experience, here is what might be expected with regards to AVs:

- While there may be an initial explosion in new technologies, not all options in the current mobility marketplace will last.
- Early regulation will be focused on ensuring the safety and effectiveness of AVs, until the public is sufficiently comfortable with them.
- Later, the regulatory focus will shift to removing restrictions and supporting AVs in reaching their full potential - which could mean restricting older technologies.
- Infrastructure lasts for a long time so future-proofing it is essential to avoid a state of technological lock-in.
- The evolution of safety, standards, and formats will be a gradual, iterative process.
- There will be unanticipated uses of AVs, resulting in unintended consequences (e.g. the development of the drive-through for automobiles).
- The full potential of the technology will not be realized in a mixed environment. AVs, like automobiles, will require segregation and purpose-built infrastructure to maximize their benefit

Eventually, everything from what streets look like to how traffic is managed to the types of vehicles used for transporting people and goods may change dramatically.

PART I: BACKGROUND

TORONTO'S AUTOMATED VEHICLE ECOSYSTEM

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

Figure 7: Key players in the Ontario connected and automated vehicle sector. (Originally visualized by: WSP)[46]

Industry

The development of automated vehicle technology is generally occurring within three different groupings:

- Original Equipment Manufacturers (OEMs) – large automobile manufacturers and part suppliers
- New entrants/ Non-OEM companies developing their own suite of AV technology to design vehicles for deployment in a fleet context such as Lyft or Uber, and;
- Technology, telecommunications, and logistics companies such as Apple and Amazon.

These efforts by OEMs, non-OEMs and technology and logistics firms represent a shift within the automotive industry to a focus on software and services.

Although essential sensor hardware has decreased in cost, AV technology is still relatively costly for individual consumers and is unlikely to see mass commercialization in the short term. Many automobile manufacturers have predicted that the advent of driving automation technology will fundamentally reorient the industry, away from producing vehicles for personal ownership and towards deployment of shared AV fleets. Some companies have already begun to reposition themselves as mobility providers by making large investments and laying the groundwork for developing – and eventually deploying – their own AV fleets.

PART I: BACKGROUND

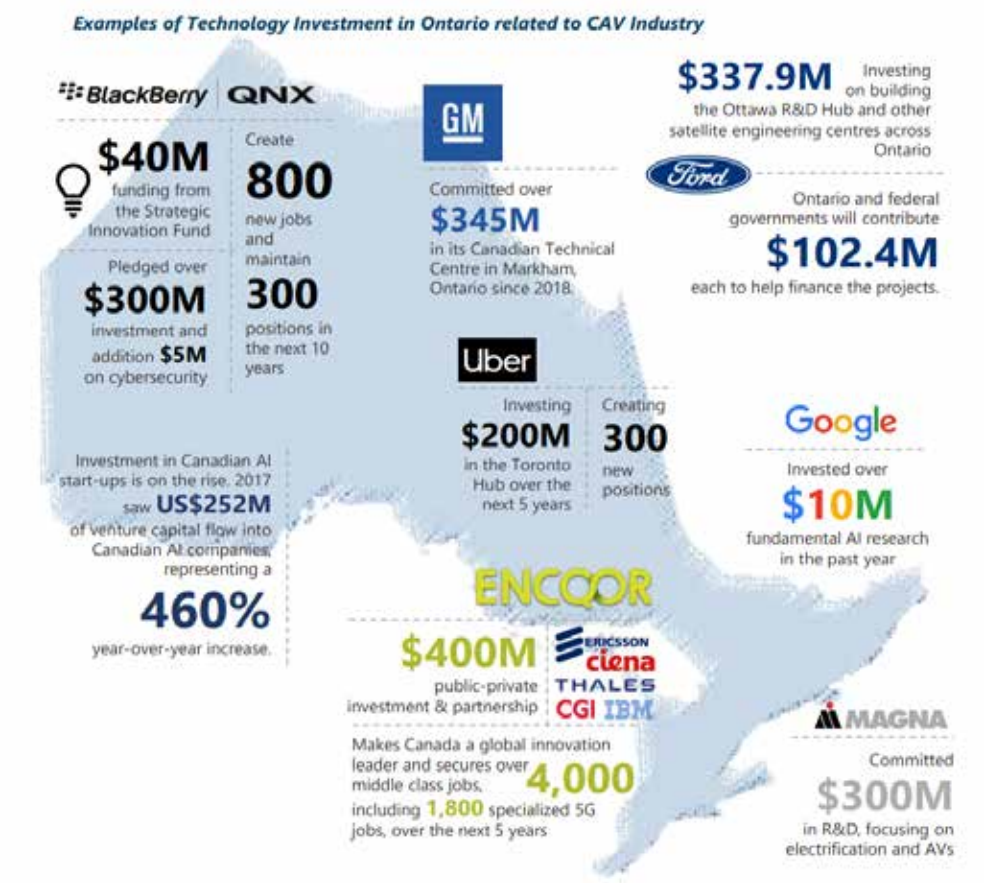


Figure 8: Examples of technology investment in Ontario related to the connected and automated vehicle industry. (Originally visualized by: WSP)[46]

In Ontario, industry members range from Small-Medium Enterprises (SMEs) to large Multi-National Enterprises (MNEs). The province has a well-established automotive and technology sector, and has welcomed connected and automated vehicle (CAV) development in a variety of forms.[46]

In 2019, BlackBerry QNX announced an investment of over $300 million in their Ottawa headquarters toward AV development, with an additional $40 million contributed by the federal government's Strategic Innovation Fund. BlackBerry QNX aims to develop new automated control systems, upgrade and secure communications in vehicles, improve vehicle safety by expanding its ADAS, and develop and use concept cars as labs for technology and software development with this funding. This investment will create 800 new jobs over ten years, and maintain an additional 300 more.[47]

In 2017 Ford Motor Co. announced an investment of $337.9 million in Ottawa for a Research and Engineering Centre that will focus on developing autonomous driving technology as part of Ford's mobile connectivity team.[48]

PART I: BACKGROUND

General Motors announced an investment of more than $345 million in 2018 for its Canadian Technical Centre in Markham; and has recently announced its repurposing of the Oshawa manufacturing plant to become a supplier of after-market parts for its existing models, and to provide 55 acres of the property as a test track for AVs and advanced technologies.

In May 2018, Ontario-based Magna announced $300 million committed to research and development focusing on electrification and AVs.[46]

Uber Technologies Inc. has announced an investment of $200 million in Toronto to support AV research over five years, including the opening of an engineering hub in the city, and expanding its Advanced Technologies Group. Uber's Chief Executive Officer Dara Khosrowshahi has stated that Uber "recognizes Canada's commitment to innovation and the vibrancy of Toronto's tech ecosystem" and that the company would like to "support the innovation coming out of this great, diverse region."[49]

With the Autonomous Vehicle Innovation Network in Ontario, the start-up space has seen strong growth in recent years as well, with companies developing technologies in every aspect of the automated vehicle sector. Some examples include Ecopia, Invision AI, Pantonium, Pitstop, Weather Telematics, X-matik, and more.[50]

Government

In Canada, the regulation of vehicles and road safety is a shared responsibility among all levels of government (Table 2). Transport Canada establishes safety regulations for the manufacturing, importation and shipment of motor vehicles and motor vehicle equipment through the Motor Vehicle Safety Act (MVSA). Provinces and Territories are responsible for the licensing of drivers, vehicle registration and insurance, and regulation for the safe operation of vehicles on public roads. For the Province of Ontario, these regulations fall under the Highway Traffic Act.

Municipal governments are responsible for: the creation and enforcement of by-laws on vehicle movement; the use and development of local infrastructure; and regulation or delivery of passenger transportation in the form of transit, taxis and ride hailing services. Transport Canada's Guidelines for Trial Organizations encourages those who are testing AVs in Canada to engage with municipal and provincial authorities regarding local traffic laws, infrastructure and safety considerations, and preparations for local emergency services.[51]

Despite the distinct roles and responsibilities of each level of government, all jurisdictions are encouraged to work together to ensure that there is continued learning and knowledge transfer throughout the development of this technology, for its safe testing and deployment.

PART I: BACKGROUND

Table 2:
Levels of Government and their Responsibilities (adapted from Automated and Connected Vehicles Policy Framework for Canada: Report of the PPSC Working Group on Connected and AVs)[52]

Federal	Provincial/Territorial	Municipal
Setting and enforcing motor vehicle safety standards for new or imported motor vehicles and motor vehicle equipment Investigating and managing the recall and remedy of non-compliances and safety-related motor vehicle defects nationwide Public education on motor vehicle safety issues Monitoring and developing rules on privacy and cybersecurity Setting and enforcing compliance with technical standards related to wireless technologies integrated into vehicles and roadside infrastructure Relevant legislation: Motor Vehicle Safety Act	Testing and licensing human drivers and registering motor vehicles in their jurisdictions Enacting and enforcing traffic laws and regulations (including trials) Conducting safety inspections Regulating motor vehicle insurance and liability Public education on motor vehicle safety Adapting provincially-owned infrastructure to support CAV deployment Planning for future transportation projects (e.g., highway management, transit) Relevant legislation: Highway Traffic Act	Enacting and enforcing bylaws Enforcing traffic laws and regulations Adapting infrastructure to support CAV deployment Managing passenger transportation (including public transit, taxis and ride-hailing services) Managing and creating new logistics for traffic control and parking enforcement Public education on motor vehicle safety Relevant legislation: Municipal Code

Toronto is well-placed in the AV ecosystem thanks to the investment and best practices provided by both the provincial and federal governments.

PART I: BACKGROUND

AV Testing in Ontario

In 2016, Ontario was the first province in Canada to launch a pilot program to allow the testing of automated vehicles on its roads. This ten-year program allowed for eligible participants (i.e. auto manufacturers, technology companies, academic and research institutions, and parts manufacturers) to apply for a permit to test SAE Level 3, 4 and 5 automated vehicles under strict requirements outlined in Regulation 306/15: Pilot Project – Automated Vehicles of the *Highway Traffic Act*.[53] On January 1, 2018, the program was updated with three important changes:

1. Automated vehicles equipped with SAE Level 3 technology are available for public purchase in Canada, and can be driven on Ontario roads. These vehicles are no longer restricted to registered pilot participants.
2. The testing of driverless AVs is now permitted on Ontario roads, under strict conditions.
3. Cooperative truck platoon testing is now permitted on Ontario roads, under strict conditions.

Some of the requirements for participants under the pilot program include:

- Only vehicles manufactured and/ or equipped by approved applicants are permitted
- The driver must remain in the driver's seat of the vehicle at all times and monitor the vehicle's operation unless approved for driverless testing. For driverless testing, full human oversight of the vehicle's functionality is required while operating on a public roadway.
- All current Highway Traffic Act rules of the road and penalties apply.
- Pilot applicants accept liability in an at-fault collision caused by the technology, if driverless.
- Pilot participants must alert local authorities prior to testing, and indicate where and when testing will occur.[54]

Additional Provincial Supports

Ontario has invested $80 million over five years in the Autonomous Vehicle Innovation Network (AVIN), $40 million over three years in a new auto plan to increase innovation and training, and has committed to increasing the number of post-secondary students graduating in science, technology, engineering, and mathematics (STEM) disciplines by 25% over the next five years, to 50,000 per year.[55]

The Ministry of Transportation of Ontario is also leading a **CAV Readiness Initiative** with funding from Transport Canada. This initiative brings together government and other stakeholders to facilitate capacity building within the Greater Toronto and Hamilton Area (GTHA) and Kitchener-Waterloo corridor and to establish a common and consistent planning horizon and framework for CAVs in this region. Metrolinx, the Region of Peel, the City of Toronto, and WSP are partners in this initiative. Following the release of a CAV Readiness Report in 2019, the group will establish a CAV Liaison Committee for the region, whose mandate will be to continue efforts to prepare transportation and transit agencies from the GTHA & surrounding areas for a future that includes CAV.

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Federal Supports

The federal government has made some significant investments of its own, including $2.9 million in funding from Transport Canada under the Program to Advance Connectivity and Automation in the Transportation System (ACATS). The Program aims to prepare the country for wider use of connected and automated vehicles on roads through the following:

- Research, studies and technology evaluations
- The development of codes, standards and guidance materials
- Capacity-building and knowledge-sharing activities[56]

Provinces and territories, municipalities, Indigenous peoples, academia, and not-for-profit organizations were eligible to submit proposals for grants and contributions through this program from September – November 2017.[57] Fifteen projects were funded from a variety of partners through ACATS, including: the City of Toronto, the Canadian Automobile Association, the Canadian National Institute for the Blind, the City of Calgary, the City of Vancouver, the Intelligent Transportation System Society of Canada and the Ministry of Transportation of Ontario amongst others.[58]

In addition to the funding provided by the federal government, Innovation, Science and Economic Development Canada (ISED) and Transport Canada (TC) have established five Vehicle of the Future Advisory Groups to engage experts on issues associated with CAVs, and inform a whole-of-government approach for this technology. These advisory groups address topics such as safety, innovation and competitiveness, and data privacy and security, amongst others. Transport Canada, the Standing Senate Committee on Transport and Communications, and the Canadian Council of Motor Transport Administrators have also released a series of guidelines and policy documents for the safe testing and deployment of automated vehicles in Canada.

- *Driving Change: Technology and the future of the automated vehicle* that outlines the regulatory and technical issues related to the deployment of automated and connected vehicles.[59]
- *Canadian Jurisdictional Guidelines for the Safe Testing and Deployment of Highly Automated Vehicles* that provides a series of considerations and recommendations that support Canadian jurisdictions in their planning and roll-out of automated vehicles.[60]
- *Testing Highly Automated Vehicles in Canada: Guidelines for Trial Organizations* that highlights Canada as a destination for research and development, clarifies the role of each level of government for AV trials, and establishes minimum safety requirements for trial organizations operating in Canada.[51]
- *Safety Assessment for Automated Driving Systems in Canada* that is a voluntary tool to help AV developers review safety of vehicles equipped with SAE level 3-5 features which they intend to manufacture, import, operate, and/ or sell in Canada.[61]
- *Canada's Safety Framework for Automated and Connected Vehicles* that informs stakeholders of Transport Canada's safety-focused approach to AV/CVs and sets a stable policy direction for safe deployment on Canada's roads.[62]

Academic, Research and Civil Society Organizations

Southern Ontario is home to a wide range of developments in the AV technology space. Networks among industry, local governments, academic institutions and research organizations have created an environment in which to learn from one another and grow the next generation of advanced vehicle technologies and services. This network provides an opportunity for the City of Toronto to support, and help foster an area that can contribute to the successful deployment of AV technology.

The **Ontario Centres of Excellence (OCE)** brings together industry, academic, and government stakeholders across Southern Ontario to capitalize on the economic opportunities of AVs while supporting the province's transportation systems and infrastructure to adapt to these emerging technologies.[63] Specifically, OCE supports the commercialization of academic intellectual property, industry-academic collaborations and the development of emerging technologies. This includes overseeing the execution of advanced technology platforms, as well as supporting and investing in early-stage projects with a probability for commercial success and return on investment.[64]

The **Autonomous Vehicle Innovation Network (AVIN)** is a Government of Ontario initiative, delivered through the Ontario Centres of Excellence. A key aspect of Ontario's auto plan, AVIN works to support subject matter experts, post-secondary institutions and other industry stakeholders to commercialize new products and services in the automotive and transportation sector, and support Ontario's readiness for the adoption and deployment of these technologies.[46]

AVIN is comprised of a research and development partnership fund, a WinterTech AV development fund, talent development, six regional technology development sites, and a technology demonstration zone in Stratford, Ontario where CAV companies can test, validate and showcase their products. These sites enable small- and medium-sized enterprises (SMEs) to develop, prototype, and validate new technologies, access specialized equipment (hardware and software), and obtain business and technical advice. The **Toronto Region** site of AVIN focuses on artificial intelligence for connected and autonomous vehicles, with partners including the MaRS Discovery District, University of Toronto, Ryerson University and York University. The five other AVIN sites in Ontario support the development of new technologies in their own unique focus area:

- **Durham Region:** Human Machine Interface (HMI) and User Experience
- **Hamilton Region:** Multimodal and Integrated Mobility
- **Ottawa Region:** Vehicle-to-Everything (V2X) Communications
- **Waterloo Region:** High- Definition (HD) 3D Mapping and Localization
- **Windsor-Essex Region:** Cross-Border Technologies and Cybersecurity[65]

In late 2016, the **Ontario Good Roads Association (OGRA)** established the **Municipal Alliance for Connected and Autonomous Vehicles in Ontario (MACAVO)**. The purpose of MACAVO is to provide a forum for municipal and regional staff to collaborate on research, facilitate vehicle testing with industry and academics, and share resources and knowledge on integrating connected, automated and autonomous vehicles into municipal operations. Participating governments include the Cities of Toronto, Barrie, Brampton, Hamilton, and Stratford, the Regions of Durham and York, and more.

PART I: BACKGROUND

MACAVO is working with municipalities to identify and create a seamless, coordinated Preferred AV Testing Corridor from Windsor to Ottawa.[66] The objective of this initiative – the first municipal coordination of its kind in the world – is to attract and retain talent within Ontario while working in partnership with private corporations, testing critical infrastructure technologies along the preferred corridor and working directly with CAV stakeholder groups to find innovative solutions to problems.

The **Canadian Automated Vehicles Centre of Excellence (CAVCOE)** provides consulting services, analyses and recommendations to all stakeholders who are involved in the deployment of automated vehicles, or who will be impacted by their arrival. Stakeholders served include government, public sector agencies, private sectors companies, and industry associations. CAVCOE's expertise is on how AVs will impact operational, business and revenue models, allowing the organization to assist in the development of policies, strategies and plans for AVs as well as identify potential business models or strategies that can maximize benefits and mitigate consequences from AV deployment.[67]

The **Canadian Urban Transit Research & Innovation Consortium (CUTRIC)** supports projects that develop the next-generation of mobility and transportation technologies for Canadians. These technologies help advance Canada's low-carbon and "smart" technology sectors, supporting job growth and economic development over the long-term. CUTRIC's National Smart Vehicle Demonstration & Integration Trial plans to integrate semi-autonomous and (eventually) fully autonomous, connected, and electric vehicle shuttles/pods and buses across up to 12 Canadian municipal jurisdictions as first-mile/last-mile applications. The primary project objectives are the development of standards for V2V and V2I communication protocols, electric low-speed autonomous shuttle (e-LSA) manufacturer equipment and cybersecurity protocols.[68]

The **MaRS Discovery District** provides a range of services from connections to talent, capital, and customers, to advisory services, and more. MaRS supports over 1,200 Canadian science and tech companies by providing them with tailored resources at every stage of their growth. The MaRS Solutions Lab works with Canadian cities to develop solutions for a range of complex challenges. This is done through three main service offerings: innovation labs, innovation procurement, and learning by doing. MaRS has produced a number of reports and provided support for the development of the future of cities – including involvement in AVIN, and research on automated vehicles, data interoperability, and the sharing economy.[69]

Ryerson University's Transportation and Land Use Planning Laboratory (TransForm Lab) conducts research on how existing and novel means of transportation influence urban systems in the Greater Toronto and Hamilton Area (GTHA), and how regional and local factors shape travel behaviour and human movement. Through consumer surveys and focus groups, TransForm Lab researchers have explored GTHA residents' interest and expected behavioral responses to AVs.

PART I: BACKGROUND

The **University of Toronto's iCity Centre for Automated and Transformative Transportation Systems (iCity-CATTS)** has a mandate to study how 'smart' transportation technologies (including AVs and e-sharing) will affect people's transportation choices, how businesses provide transportation as a service, and how cities should plan for these changes to achieve the best results for society.

Also based at the University of Toronto, the **aUToronto** team is developing a fully autonomous passenger vehicle as part of the the AutoDrive competition – created in 2017 in a partnership between GM and SAE International. Eight universities from across North America were challenged to make an electric Chevy Bolt self-driving by 2020.[70] The team received its Chevy Bolt in October 2017 and dubbed it Zeus. The team won first place in the first year of the competition focused on architecture definition, sensor and computing platform selection, paper study, and leverage simulation; and won again in May of 2019 navigating an urban driving course at the University of Michigan's Mcity facility.[71]

Residents

Public opinion on the arrival of a new, disruptive technology is challenging to understand and measure. In the case of disruptive innovations, individuals have no previous experience on which to base their expectations and opinions can be greatly influenced by marketing and advertising (especially during the early stages of adoption) as well as word-of-mouth among peers and broader social networks.

A 2018 study from the University of Memphis found that, in general, the more barriers a person perceives around AVs, the farther into the future they are likely to estimate both the availability of the technology and their willingness to adopt it.[72] Perceived negative impacts of AV adoption include practicalities (inadequate infrastructure, perceived low value-to-cost ratio, safety concerns) and psychological barriers (disruption of routines and norms, perceptions and beliefs associated with the product). Perceived benefits include travel time and cost, social image among peers, environmental impacts, and greater mobility for those with mobility challenges. Taken together, these factors mean that public opinion regarding AVs can be difficult to accurately measure at this time.

A study from the World Economic Forum and the Boston Consulting Group shows that willingness to adopt AV technology varies depending on demographic factors and built environment factors (e.g., neighbourhood type, traffic, and density of mass transit). Residents of countries with a strong, established car culture had the lowest level of acceptance of AV adoption, while residents of countries with rapidly developing economies with higher levels of congestion were most likely to accept AVs.[23]

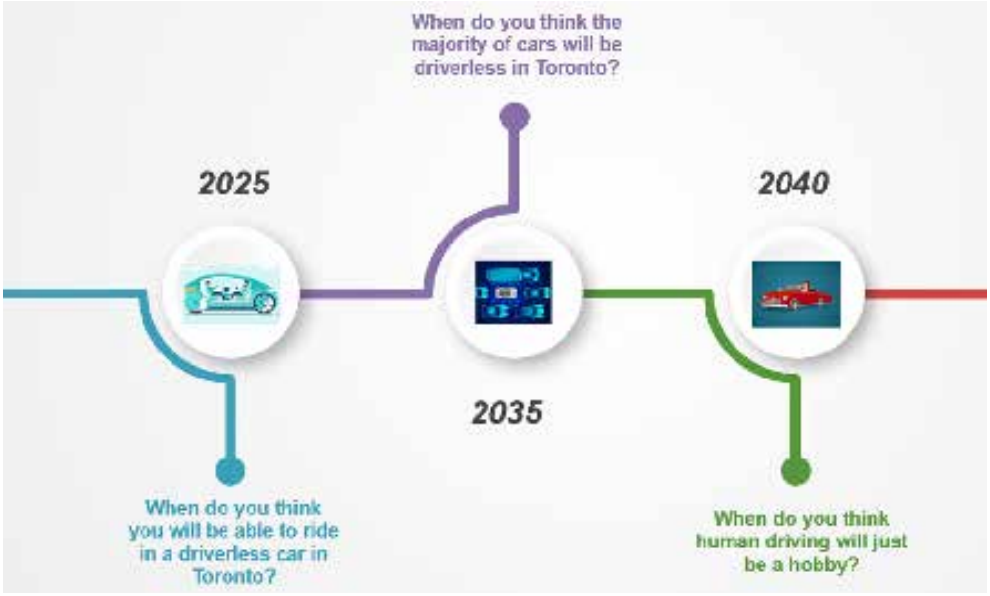
PART I: BACKGROUND

In 2016 the City of Toronto partnered with Metrolinx to support a public opinion survey conducted by Ryerson University's School of Urban and Regional Planning.[73] The survey was intended to provide a base level of understanding around public support for vehicle automation and potential behaviour change associated with the adoption of AVs. Ryerson re-administered this survey in 2018 with 3,200 residents of the GTHA and added questions to reflect an updated context. Respondents were asked to predict when certain AV milestones would take place (Figure 9). Respondents were asked the following:

> *Do you expect driverless cars to ever be available for use or purchase in Toronto at any time in the future?*

Approximately one-third of respondents (31.7%) answered "no." The remaining two-thirds (68.3%) who answered "yes" were asked three further questions and to select what year they expected it to become a reality. The median year for each question is outlined in Figure 9 below.

Figure 9: AV Predictions by Residents of the Greater Toronto and Hamilton (Median Year)



There is a high degree of alignment between public expectations and expert predictions, especially in the short term horizon. On average, GTHA residents' predicted they might be able to ride in a driverless car by 2025 – a reasonable estimate based on the forecasts detailed in the previous section. Estimates for events occurring farther in the future are bound to be subject to a higher margin of error. With that in mind, looking to the market saturation of AVs, where the majority of vehicles in Toronto would be automated, the public was slightly more optimistic in projecting 2035 compared to many experts, who predict this may occur by the 2050s. Based on expert forecasts, it may take longer for human driving to be relegated to a hobby than 2040, as the public predicted.

Other key findings from the 2018 survey include:

What benefits and consequences do respondents expect from AVs?

- Respondents (63.9%) expected distracted and impaired driving would be reduced as a result of AVs.
- Of the potential impacts of AVs, respondents were most unsure or neutral (49.4%) regarding the impacts on hacking and cybersecurity.
- Data privacy was cited by almost a third (31.8%) of respondents as being the most negatively impacted.

How might respondents' travel behaviour change, should AVs be available?

- There is significant variation in AV interest amongst consumers.
    - While interest in AVs remained largely the same between 2016 and 2018 (48% vs. 52%), more respondents indicated they would be willing to pay more for a fully driverless vehicle in 2018 (48%) than in 2016 (25%).
- Younger respondents were significantly more interested (63%) in using AVs than older respondents (aged 35-55: 47%; aged 55 and over: 35%)
- Many respondents did consider changes in their travel behaviour if AVs became commercially available
    - In 2018, approximately one-third of respondents indicated interest in extending their commutes if they didn't have to drive, down from two-thirds in 2016.
    - When asked if respondents were willing to ride different forms of public transit (including small shuttle bus, regular-sized or articulated bus, streetcar, light rail train, subway train, commuter train) should they be driverless, willingness ranged from 50.4% for light rail and subway trains, to 37.9% for regular-sized buses, and 44.1% for shuttles
    - Although not specific to AVs, 20% more respondents had indicated that they had used ride-hailing services in 2018 (44.3%) compared to 2016 (24.9%)

How do AVs relate to respondents' public policy priorities?

- Similar to 2016, half of all respondents (50%) indicated that the government should monitor the implementation of AVs
- A quarter of respondents reported that they were aware of provincial and municipal AV planning initiatives.
- Road safety was most the most highly supported policy objective (81.3%) followed by unobstructed movement of emergency vehicles and better traffic management

Overall, Ryerson University researchers summarized their findings as the following:

- Most consumers are still learning about AV technology and ongoing AV planning initiatives.
- Largely due to an uncertain value proposition and evolving understanding about the technology, most consumers are reluctant to commit to using AVs.

PART I: BACKGROUND

Toronto, 2050

Snapshot #4: Michelle's Commute

Michelle, a 30-year-old data scientist living in Toronto's West End, is not a morning person. Sipping her second cup of coffee and half-listening as her personal virtual assistant reads her emails out loud to her, an urgent message from her supervisor comes in: *More glitches are in need of debugging*. "It's only 8 a.m. Can't it wait?" she thinks, as she grabs her keys and backpack and heads out the door.

Out on the street, Michelle makes her way to the Toronto Bike Share station at the end of the block. Through facial recognition technology, the Bike Share station knows she's a daily user and debits her mobility service account at the discounted rate. With the bike released from its dock, Michelle stows her backpack, dons her helmet and – after waiting for the bike lane sweeper bot to pass – steps out into the protected bike lane.

Beyond the buffer of parked spots and pick-up/drop-off zones, Michelle can see cars, shuttles and trucks – both with and without humans in the driver's seat – rolling down the street at a steady pace, but she doesn't feel unsafe at all.

As she approaches the intersection, Michelle pulls into the right hand side of the green painted box on the asphalt. An automated delivery truck blinks to acknowledge that it sees her. Sensing a cyclist in the box, the smart traffic signal triggers a cyclist priority light, giving her a chance to make her right turn safely and easily.

Arriving downtown, Michelle drops off her bike at a nearby station. With her third cup of coffee in hand, she makes her way to the office. As she watches a convoy of delivery bots whirr by down the sidewalk, alerting pedestrians with their cheerful electronic chirping, Michelle rolls her eyes and thinks to herself, "Ugh…morning people."

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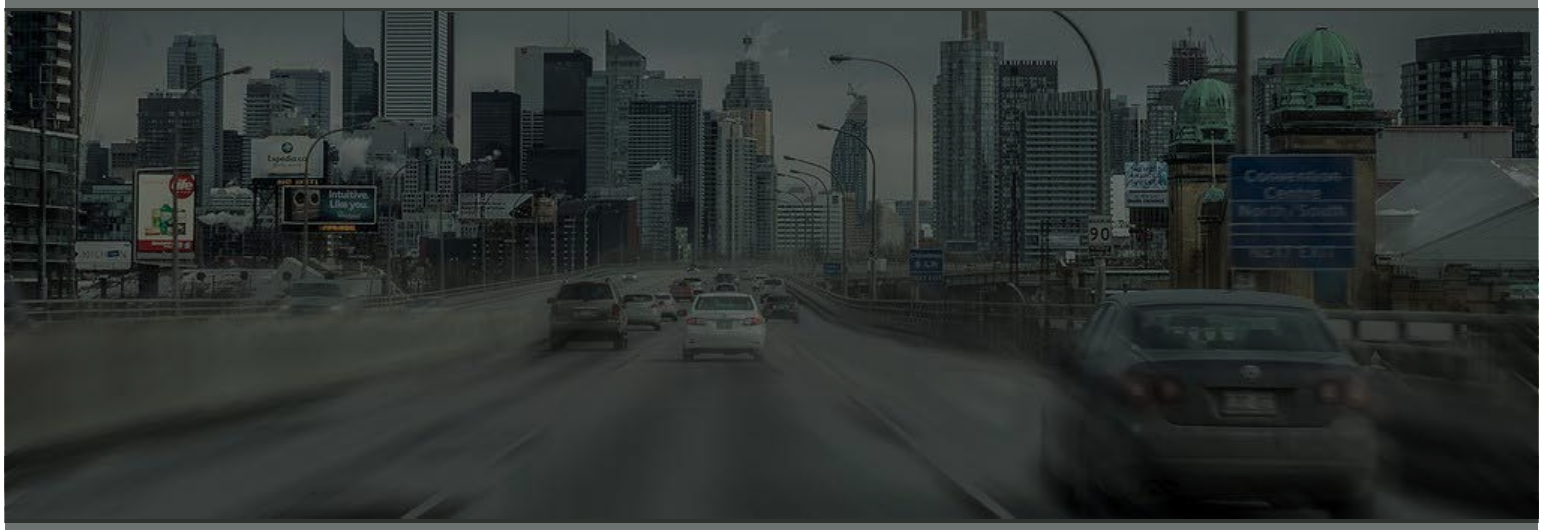

PART II

TACTICAL PLAN

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PART II: TACTICAL PLAN

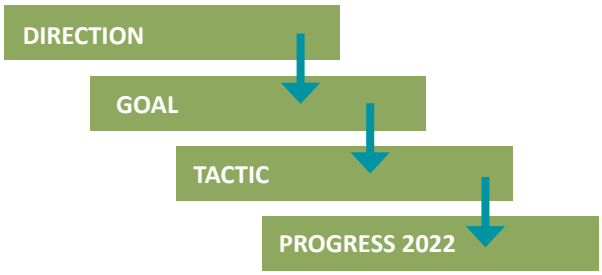
The Automated Vehicles Tactical Plan consists of seven broad Directions that reflect the City of Toronto's strategic vision for the future of its transportation system. Each Direction statement is built on a foundation comprised of existing City policies, plans and strategies. The seven Directions are:

1. Social Equity & Health
2. Environmental Sustainability
3. Economic Sustainability
4. Privacy
5. Road Safety & Security
6. Integrated Mobility
7. Transportation System Efficiency

This Plan is organized according to each Direction, and includes a brief description of its purpose, followed by guiding policies and strategies. After the introduction for each Direction, there are key performance indicators (KPIs) included for monitoring the progress of the AV Tactical Plan. These KPIs are connected to a 2050 Goal.

Goals paint a mental image of what life in the City of Toronto could be like in 2050 if the City has successfully harnessed the potential of automated vehicles to achieve its broader vision. Goals are a long-term outcome, meant to be achieved any time between tomorrow and 2050; they are not specific targets to be met over a 30-year time period. Goals in this Plan form subsections for each Direction. Underlying actions or "tactics" contribute to the success of these Goals.

Tactics and their explanations form the bulk of this Plan. Each section will list the 2050 goals, followed by the underlying tactics that should be taken to achieve it. Tactics can be completed sometime between tomorrow and before 2050 – and vary in their timelines. Most Goals have more than one Tactic to support them and outline the associated automated vehicle impact that the City can address. The Plan will include the stated Tactic, a brief explanation of its intent, followed by proposed progress for the City to achieve by the end of 2022.



The City acknowledges that not all Tactics are equally urgent. Some impacts from automated vehicles will need to be addressed in the long term, while some actions can be taken today to begin proactively preparing for this technology. As such, the proposed progress for 2022 outlines the specific initiative the City will undertake in order to contribute to or implement the Tactic in the next three years.

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SOCIAL EQUITY & HEALTH

1. SOCIAL EQUITY & HEALTH

The City of Toronto will encourage the adoption of driving automation systems in a manner that improves social equity and health.

The City of Toronto will apply a social equity and health lens to the introduction of AVs, to unlock new mobility options in a way that will benefit a broad cross-section of Toronto's population.[75] Populations that are currently unable to drive a vehicle due to accessibility restrictions or age limitations could experience a higher degree of personal freedom to travel on their own. Also, Torontonians underserved by the existing transportation system may have access to new, more affordable and faster ways of getting around, connecting them to opportunities across the City.

An intentional focus on equity is required to ensure that this disruption to the City's transportation system does not introduce new forms of discrimination.New mobility business models may not account for everyone's needs, and may subject certain individuals to unfair pricing, reduced choice and poorer service quality. In addition, the potential health benefits of AVs (e.g. improved safety, reduced noise) may not be distributed across all neighbourhoods equitably.

This Direction for the Tactical Plan aims to alleviate some of these concerns, building from City strategies focused on accessibility and socioeconomic equity. The Social Equity section will focus on ensuring barrier-free access for all transportation system users, as well as providing equitable service levels to all neighbourhoods for all trip types.

GUIDING POLICIES AND STRATEGIES:

Toronto Official Plan (2015):[76]
This Plan will create a better urban environment, a competitive local economy and a more socially cohesive and equitable city through the integration and coordination of transportation planning and land use planning

The transportation system will be developed to be inclusive of the needs of people with disabilities and seniors

TO Prosperity: Toronto Poverty Reduction Strategy (2015-2035):[77]
Transit Equity:
- *6. Make transit more affordable for low-income residents.*
- *7. Improve transit services in the inner suburbs.*

Toronto Public Health: Strategic Plan (2015-2019):[78]
Priority Direction #2: Champion healthy public policy - Collaborate with city divisions and community stakeholders to advance municipal policy for healthy social, built and natural environments

Toronto Seniors Strategy (2013):[79]
Equity: Older adults should have equitable access to services and programs

Toronto Strong Neighbourhoods Strategy 2020:[80]
Improve transit access in our neighbourhoods:
- *Apply Neighbourhood Equity Scores when planning transit routes and transit services levels.*

1. SOCIAL EQUITY & HEALTH

Summary of Goals and Tactics

Goals	Key Performance Indicators	Tactics
1.1 Ensure Barrier-Free Access: In 2050, the City will have harnessed the widespread adoption of automated vehicles to ensure all users have barrier-free access to personal mobility services.	Percentage of AV services that are barrier-free for each group	1.1.1 Access for Individuals with Disabilities 1.1.2 Access to Transit for Individuals with Disabilities 1.1.3 Access for Unbanked Individuals 1.1.4 Access for Low-Income Individuals 1.1.5 Access for Non-Anglophones
1.2 Increase Mobility Equity: In 2050, the City will have harnessed the widespread adoption of automated vehicles to ensure reasonably equitable service levels to all neighbourhoods regardless of trip type, vehicle class or ownership.	Median wait time for barrier-free AVs versus standard AVs by geographic area (neighbourhood)	1.2.1 Equitable Service Coverage 1.2.2 Equitable Performance Standards 1.2.3 Mobility Neutrality
1.3 Promote Health: In 2050, the City will have harnessed the widespread adoption of automated vehicles to promote equitable health outcomes.	The City of Toronto will be determining the required key performance indicators from 2019-2022	1.3.1 Healthy Mobility

1. SOCIAL EQUITY & HEALTH

1.1 ENSURE BARRIER-FREE ACCESS

In 2050, the City will have harnessed the widespread adoption of automated vehicles to ensure all users have barrier-free access to personal mobility services.

Key Performance Indicator:

- Percentage of AV services that are barrier-free for each group

1.1.1 Access for Individuals with Disabilities

Tactic: Develop and implement a policy to ensure that shared automated vehicle fleet companies provide an appropriate level of barrier-free access and ensure that unnecessary limitations (e.g. visual, auditory) are avoided. Approaches should consider the safety needs of individuals who require the assistance of an attendant or service animal, and boarding needs of seniors, families with children, and individuals with mobility impairments.

Individuals living with disabilities often experience lesser access to mobility services than non-disabled individuals.[81] While human-driven taxicabs and private transportation company vehicles have human operators available to assist passengers in and out of the vehicle, shared AV fleet vehicles without a human on board may be inaccessible to many individuals who require extra assistance and do not have a dedicated support person.[82] Onboard attendants could provide assistance tailored to the specific needs of customers, including loading and unloading mobility aides and parcels and helping individuals get from door-to-door.

- *Proposed progress to 2022: Research, learn and identify challenges that individuals with disabilities may face in accessing barrier-free services likely to be provided by shared AV fleet companies.*

1.1.2 Access to Transit for Individuals with Disabilities

Tactic: Develop and implement a mechanism to provide an appropriate level of barrier-free access and ensure that unnecessary limitations (e.g. visual, auditory) are avoided in automated transit vehicles.

TTC's accessible travel network provides customers with disabilities with the freedom and flexibility to travel throughout the City of Toronto. All conventional bus services are low-floor and accessible, all streetcar services will be accessible by 2020, and all subway stations by 2025. Operator assistance with mobility device securement is available on all buses.

TTC's Wheel-Trans paratransit service currently provides a safe and reliable transit option for persons with disabilities to travel with freedom and dignity. This is an on-demand service where riders can make reservations for vehicles that are wheelchair-accessible, and driven by trained operators who can assist those with any disability to board, find seats, and efficiently reach their destination.[36]

1. SOCIAL EQUITY & HEALTH

As part of the Wheel-Trans 10-Year Strategy, many Wheel-Trans customers can now take advantage of TTC's Family of Services, where Wheel-Trans can serve as a first-mile, last-mile feeder to conventional transit for customers with conditions that permit travel on the fixed route system. Automated shuttles and other automated transit services may eventually provide more cost-effective alternatives to the current options for individuals with disabilities.[36] To provide full accessibility in the absence of a driver, the automated vehicles would likely require advanced robotics for ramp deployment, mobility device securement and related tasks, passenger communications and a video link (or similar) to an operations centre for passenger assistance and security.[31]

- *Proposed progress to 2022: Use lessons learned from automated transit shuttle pilot to inform further research into accessible automated transit vehicles.*

1.1.3 Access for Unbanked Individuals

Tactic: Develop and implement a policy that enables shared automated vehicle fleet companies to accept payment through mechanisms that are available to unbanked populations.

With the rise of ride-hailing, smartphones, and a cashless society – service providers have moved away from accepting cash payment in favour of electronic payment platforms: apps that are connected directly to users' credit cards and bank accounts. For some users, this provides convenience; for others, it can be a source of exclusion. Unbanked – or financially excluded – individuals (those without access to some or all mainstream banking services) are estimated to comprise between one and five percent of Canada's population (306,000 to 1.53 million people.[83]

As new mobility services – including AVs – begin to roll out, unbanked individuals could find their access to mobility options restricted unless their needs are specifically accounted for in designing these services.[31] By continuing to accept cash as payment as well as offering prepaid debit cards and other options, unbanked individuals will be able to share in the benefits of electronic payment without the need for a bank account or credit card.[84]

- *Proposed progress to 2022: Engage stakeholders with regard to barriers that unbanked individuals may face in accessing services provided by shared AV fleet companies.*

1. SOCIAL EQUITY & HEALTH

1.1.4 Access for Low-Income Individuals

Tactic: Develop and implement a mechanism to subsidize or support low-income residents to allow for equitable access to mobility services regardless of trip type, location, time of day, and technical requirements.

According to the 2016 Census, individuals with low-income comprised 20.2% of Toronto's population (using the low-income measure, after tax).[85] Low-income individuals may have few options when it comes to when and how they get to their workplaces, relying on the stable pricing currently provided by public transit and taxicabs or the convenience of a personal vehicle. In addition, low-income individuals are most likely to find themselves on the wrong side of the 'digital divide' – lacking access to Internet and mobile technology as our lives increasingly move online.

Most app-enabled shared mobility services require access to a digital device and cellular connectivity. Ride-hailing companies are not subject to a fare structure (apart from a $3.25 minimum fare) leaving them free to use 'dynamic pricing'[86] (also known as 'surge pricing') – increasing their prices during peak hours, special events, or inclement weather to both entice more drivers to pick up fares and manage demand from ride-hailing customers.

By contrast, TTC services and taxicabs have regulated fare structures to make sure they are affordably and consistently priced.[87] The City of Toronto's Fair Pass Discount Program allows individuals receiving Ontario Disability Support Program (ODSP) and Ontario Works (OW) assistance to pay a reduced fare. Both modes require little technology to use – simply wait at a transit stop or hail a taxicab by lifting your arm up and signal the taxi to stop.

If automated mobility services – whether as public transit vehicles or shared fleet vehicles – are offered only at a price premium and require cellular connectivity, it may disproportionately impact low-income individuals who may not have access to a smartphone.

For automated transit and shared AV fleet mobility services to successfully serve everyone, they must ensure that technology is not a barrier to access and that they are affordably and predictably priced to serve Toronto's low-income population.[88]

- *Proposed progress to 2022: Research and document the potential impacts to low-income residents from the introduction of automated vehicles.*

1.1.5 Access for Non-Anglophones

Tactic: Develop and implement a policy that enables shared automated vehicle fleet companies to provide services to non-Anglophone populations.

Toronto is home to a linguistically diverse population – in fact, one in twenty Torontonians (over 130,000 individuals) do not speak English.[89] These individuals may experience significant barriers to participating in community and civic life, accessing public and community services, finding employment, and achieving a decent standard of living.[89]

1. SOCIAL EQUITY & HEALTH

It is essential that these populations have the same level of access as English-speaking populations. This could include ensuring that mobile applications used for booking services are multilingual, and onboard announcements are in plain language, with clear enunciation and spoken slowly enough to be easily understood.

- *Proposed progress to 2022: Research and document the potential impacts to non-Anglophone populations from the introduction of automated vehicles.*

1.2 INCREASE MOBILITY EQUITY

In 2050, the City will have harnessed the widespread adoption of automated vehicles to ensure reasonably equitable service levels to all neighbourhoods regardless of trip type, vehicle class or ownership.

Key Performance Indicator:

- Median wait time for barrier-free AVs versus standard AVs by geographic area (neighbourhood)

1.2.1 Equitable Service Coverage

Tactic: Develop and implement a mechanism to coordinate mobility services to provide equitable service in terms of frequency, hours of service per day, and proximity across all neighbourhoods for all trip types.

Torontonians live and work differently than they did when much of the transportation system was built. Changes in employment and land use patterns mean that work days and commutes are very different than they were in the past.[90] For this reason, the City and TTC have invested millions of dollars in various initiatives such as the All-Day-Every-Day Network, Overnight Network, Express Bus Network, Service Reliability etc.

An affordable, accessible and reliable transportation system connects people to jobs, services and civic life.[77] AVs – whether operated by public transit agencies or ride-hailing companies – will be able to enhance the transportation network.

- *Proposed progress to 2022: Identify areas in Toronto with lower mobility service coverage and research the potential impacts to frequency, hours of service, and proximity across neighbourhoods from AVs.*

1. SOCIAL EQUITY & HEALTH

1.2.2. Equitable Performance Standards

Tactic: Develop and implement a mechanism for shared AV fleet companies to report against equitable performance standards, and monitor data (e.g. wait time and declined rides) as a way to identify and respond to potentially discriminatory practices.

Automated decision-making through mobility platforms may introduce alternate forms of discrimination– both intentionally and unintentionally. While this discrimination may not be illegal, unfair outcomes will result if certain groups consistently experience differential pricing, reduced choice and poorer service quality when using mobility services.[91] Therefore, it will be essential to develop and implement a mechanism to identify, track and mitigate against potentially inequitable outcomes as quickly as possible and hold mobility service providers accountable.

- *Proposed progress to 2022: Research, learn and identify potential equity issues related to services provided by shared AV fleet companies.*

1.2.3. Mobility Neutrality

Tactic: Develop and implement a policy to prevent low-occupancy private passenger automated vehicles from receiving unregulated priority within the transportation system.

It is expected that private passenger AVs will be governed by privately owned algorithms, leaving open the possibility that AV fleet operators could program their vehicles to give certain classes of passengers unregulated priority in traffic – for example, sending a message to surrounding vehicles to make way and let them jump ahead. This could give select users privileged treatment relative to other users on the road network through mechanisms like paid services or loyalty rewards, while others who cannot afford or access premium services would be left stuck in traffic.[92]

Net neutrality is the idea that Internet service providers (ISPs) should treat all data that travels over their networks fairly, without improper discrimination in favor of particular apps, sites or services. Similarly, “mobility neutrality” is the concept that our transportation network should not provide preferential treatment for certain classes of users based on their ability to pay for or otherwise access a premium service or membership.

A “mobility neutral” approach would not, however, prevent the City from providing preferential treatment to certain modes or occupancy types if they achieve certain policy objectives (e.g. reducing congestion or pollution or protecting vulnerable road users), as it already does. Today, for example, transit and emergency response vehicles receive regulated (i.e. policy-supportive) priority on the road network and will continue to do so.[93]

- *Proposed progress to 2022: Produce a white paper exploring the impacts of tiered product or service offerings involving AVs and generate policy options on how to prevent select vehicles from receiving unregulated priority within Toronto’s transportation system.*

1. SOCIAL EQUITY & HEALTH

1.3 PROMOTE HEALTH

In 2050, the City will have harnessed the widespread adoption of automated vehicles to promote equitable health outcomes.

Key Performance Indicator:

- The City of Toronto will be determining the required key performance indicators from 2019-2022

1.3.1 Healthy Mobility

Tactic: Develop and implement a mechanism to integrate health and health equity into automated vehicles policies through use of evidence on population health impacts related to injury prevention, physical activity, network connectivity, greenspace, noise, and air pollution.

Health Equity is the principle that all people should be given the opportunity to reach their full health potential and not be disadvantaged from doing so based on race, ethnicity, religion, gender, age, social class, socioeconomic status or other socially determined circumstances.[94]

In achieving this aim, municipalities should provide equitable distribution of resources needed for health, access to opportunities available, and support offered to people negatively impacted.

The City will promote equitable health outcomes resulting from automated mobility, including encouraging: increased safety and injury prevention, active transportation and physical activity, shared travel modes, network connectivity and greenspace, as well as reduced noise, air pollution, and traffic congestion. This will be achieved through incorporating a health equity lens into all automated vehicles policy in the City.

- *Proposed progress to 2022: Consult with internal stakeholders to review and summarize available City data that is relevant to applying a health equity lens to the AV Tactical Plan. Identify gaps in available information and determine options to address those gaps. Engage external consultant to recommend healthy mobility key performance indicators, and to begin collecting and analyzing baseline data to apply a health lens to AVs.*

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ENVIRONMENTAL SUSTAINABILITY

2. ENVIRONMENTAL SUSTAINABILITY

The City of Toronto will encourage the adoption of driving automation systems in a manner that increases environmental sustainability across a vehicle's entire lifecycle.

In July 2017, City Council approved an ambitious climate action strategy, TransformTO, with the objective of reducing local greenhouse gas emissions by 30 percent by 2020, 65 percent by 2030, and 80 percent by 2050.[95] Transportation makes up approximately 35 percent of all GHG emissions in Toronto, with 80 percent of that source attributed to personally-owned vehicles.[95]

AVs – particularly electrically-powered AVs – could help the City to advance the TransformTO goals. Beyond reducing GHG emissions and improving air quality, shared AV fleet vehicles which are built-to-last could transform the cradle-to-grave cycle of the current auto industry – reducing waste and contributing to a new circular economy.[96]

GUIDING POLICIES AND STRATEGIES:

TransformTO Climate Action Strategy (2017):[97]

The Chief Corporate Officer recommends that:

1. City Council approve the following long-term goals and pursue necessary measures to realize a low-carbon Toronto in 2050 that achieves an 80% reduction in greenhouse gas (GHG) emissions against 1990 levels:

f) 100% of transportation options - including public transit and personal vehicles - use low or zero-carbon energy sources, and active transportation accounts for 75% of trips under 5 km city-wide by 2050; and

g) 95% of waste is diverted in all sectors – residential, institutional, commercial and industrial - by 2050

6. City Council direct the Chief Corporate Officer to initiate three TransformTO Acceleration Campaigns, as described in this report, to maximize the community benefit potential of low-carbon action, namely:

c) Exploring the Implications and Opportunities of Electric Mobility.

Circular Economy Procurement Implementation Plan and Framework (2018):[99]

1. Mitigate climate change and achieve a resilient low-carbon future, considering both operational and lifecycle emissions, and advancing community resilience in alignment with TransformTO.

2. Minimize both the full lifecycle impacts and maximize the full utility of goods and services.

3. Achieve aspirational goals of zero waste, and to treat any remaining waste produced that cannot be reused or recycled as resource that has value.

4. Align with the City's Supply Chain Transformation and be strategic, transparent, and encourage innovation while adhering to all City purchasing legislation and By-laws.

5. Align with City Council approved strategies aimed at improving environmental (i.e. reduction in greenhouse gas emissions), social (i.e. community health, wellbeing, employment) and economic (i.e. fiscal sustainability) outcomes.

6. Collaborate with relevant partners and sectors, including relevant local industry associations, to help drive innovation towards more circular services, products, and mutually beneficial solutions.

2. ENVIRONMENTAL SUSTAINABILITY

Summary of Goals and Tactics

Goals	Key Performance Indicators	Tactics
2.1 Reduce Vehicle Emissions: In 2050, the City will have harnessed the widespread adoption of automated vehicles to ensure that all vehicles use low- or zero-carbon energy sources.	City-wide GHG emissions Percentage of vehicles licensed through the City that use low- or zero-carbon energy sources Percentage of City fleet that use low- or zero-carbon energy sources	2.1.1 Low or Zero-Carbon Energy Sources 2.1.2 Low or Zero-Carbon Energy Sources for Shared AV Fleets
2.2 Reduce Vehicle Waste: In 2050, the City will have harnessed the widespread adoption of automated vehicles to minimize waste generated from vehicle upgrades and automated fleets.	Average fleet lifecycle Waste diversion rate	2.2.1 Vehicle Waste Reduction 2.2.2 Vehicle Waste Reduction for Automated Transit Vehicles 2.2.3 Vehicle Waste Reduction for Shared AV Fleets

2. ENVIRONMENTAL SUSTAINABILITY

2.1 REDUCE VEHICLE EMISSIONS

In 2050, the City will have harnessed the widespread adoption of automated vehicles to ensure that all vehicles use low- or zero-carbon energy sources.

Key Performance Indicators:

- City-wide GHG emissions
- Percentage of vehicles licensed through the City that use low- or zero-carbon energy sources
- Percentage of City fleet that use low- or zero-carbon energy sources

2.1.1 Low or Zero-Carbon Energy Sources

Tactic: Develop and implement a policy to incentivize the adoption of low or zero-carbon energy sources, particularly electric-powered AVs.

Internal combustion engine vehicles comprise a large proportion of greenhouse gas (GHG) emissions in Toronto. Passenger, freight and transit AVs – if powered by low or zero-carbon technologies such as hybrid electric, plug-in hybrid electric, or battery-electric – could significantly reduce greenhouse gas emissions and critical air pollutants associated with transportation.[5] This would help Toronto meet its targets under its TransformTO climate action strategy.[95]

▶ *Proposed progress to 2022: Coordinate the incentivization of low or zero-carbon AVs with the City's work on electric mobility. Design and develop an AV-specific strategy for these vehicles that is consistent with TransformTO.*

2.1.2 Low or Zero-Carbon Energy Sources for Shared AV Fleets

Tactic: Develop and implement a policy for shared AVs to use low- or zero-carbon energy sources.

Ride-hailing vehicles typically drive many more kilometres – and contribute more GHG emissions – per year than the average vehicle. For this reason, converting fleets of gas-powered vehicles to low or zero-carbon technologies is essential to maximize the economic and environmental returns on investment.[13,14]

Early electric and low carbon vehicle market growth is often concentrated in jurisdictions where governments are breaking down the barriers to adoption through supportive regulations, consumer incentives, charging infrastructure and local action to promote awareness of these vehicles.[13]

▶ *Proposed progress to 2022: Research, learn and identify potential issues surrounding the use of low- or zero-carbon vehicles by shared AV fleet companies*

2. ENVIRONMENTAL SUSTAINABILITY

2.2 REDUCE VEHICLE WASTE

In 2050, the City will have harnessed the widespread adoption of automated vehicles to minimize waste generated from vehicle upgrades and automated fleets.

Key Performance Indicators:

- Average fleet lifecycle
- Waste diversion rate

2.2.1 Vehicle Waste Reduction

Tactic: Develop and implement a policy to reduce the amount of waste produced across the lifecycle of automated vehicles.

The amount of waste that AVs could generate over their lifecycles is unknown. Safer operations may mean fewer vehicles discarded due to damage from collisions.[98] However, waste streams arising from the disposal of rare-earth minerals used in electric motors and especially lithium-ion batteries may pose new waste management challenges.[15]

A Circular Economy approach aims to reduce waste and maximize resources by moving away from a linear take-make-and-dispose approach – to an innovative system that focuses on product longevity, renewability, reuse, and repair. Potential lifecycle impacts of AVs should be mitigated where possible and advance the City of Toronto's goals of achieving a circular economy and zero waste.[99][100]

▶ *Proposed progress to 2022: Research, learn and identify the environmental and waste impacts associated with the lifecycle of automated vehicles.*

2.2.2 Vehicle Waste Reduction for Automated Transit Vehicles

Tactic: Develop and implement a policy to reduce the amount of waste produced across the lifecycle of automated transit vehicles.

In July of 2008, the TTC committed itself to purchasing environmentally preferable products and services in all of its operations where appropriate through its Green Procurement Policy.[101]

Environmentally Preferable Products have a number of beneficial characteristics such as compliance with the latest environmental, health and safety legislation; reducing waste and making efficient use of resources; reducing polluting by-products and safety hazards during manufacture, use and disposal; being reusable or containing reusable parts; being recyclable in whole or in part; containing recycled materials; a long service-life; ability to be economically and effectively repaired, refurbished or upgraded; and promoting the responsible use and conservation of fuels and electricity.

The TTC Green Procurement Policy provides a solid foundation to which AV-specific standards could be added in the future as they are identified.

▶ *Proposed progress to 2022: Research, learn and identify the environmental and waste impacts associated with the lifecycle of automated transit vehicles.*

2. ENVIRONMENTAL SUSTAINABILITY

2.2.3 Vehicle Waste Reduction for Shared AV Fleets

Tactic: Develop and implement a policy to reduce the amount of waste produced across the lifecycle of shared automated vehicles.

The circular economy and the sharing economy are complementary to one another. The circular economy aims to eliminate unnecessary, excess production of items, while sharing platforms tap into idle assets and allow them to generate income for their owners – squeezing more value out of the products, and impacting the lifecycle of these items.[102,103]

According to a study conducted among 10,000 car-sharing users in 2013, approximately 7-10% had decided to drop plans to buy a car and opted into renting instead.[104] This contributes to an overall reduction in waste from shared fleet companies, which will only be amplified with the introduction of AVs. Shared AV fleet companies will be able to get more time and use out of their vehicles due to efficient movement and fuel usage – however this could result in shorter vehicle lifespans, increased obsolescence, and unintended consequences to the environmental waste impacts of AVs.

- *Proposed progress to 2022: Research, learn and identify the environmental and waste impacts associated with the lifecycle of vehicles used by shared AV fleet companies.*

ECONOMIC SUSTAINABILITY

3. ECONOMIC SUSTAINABILITY

The City of Toronto will support and enhance sectors related to automated vehicles, with a particular focus on attracting industries, investment, and employment, as well as on exporting products and services.

Toronto is well-positioned in the automated vehicle industry due in large part to the organizations at the provincial level that are leading the way in economic development.

The Autonomous Vehicle Innovation Network (AVIN) referenced in the background section, has built upon Ontario's leadership in the automotive manufacturing and supply jurisdiction, as well as its information and technology sector, to position itself as an economic development leader around automated and connected vehicle technology. AVIN provides resources such as "research and development funding, talent development, technology acceleration, business and technical supports, and demonstration grounds" to position Ontario-based connected and automated vehicle companies as North American leaders in this sector.[63]

This is only one area of the vast amount of expansion, growth and leadership occurring in Toronto within the AV industry.

GUIDING POLICIES AND STRATEGIES:

Economic Development and Culture Divisional Strategy (2018-2022):[105]

Combat economic and cultural disparities across Toronto through impactful programs and services for equity-seeking communities and underserved areas of the city.

Improve industry competitiveness for emerging and established business and cultural sectors.

Enable the workforce to respond to new and future opportunities and challenges.

Increase access to City-owned space to provide stakeholders with places to interact.

3. ECONOMIC SUSTAINABILITY

Summary of Goals and Tactics

Goals	Key Performance Indicators	Tactics
3.1 Expand Sectors: In 2050, the City will have harnessed the widespread adoption of automated vehicles to have retained and attracted additional investment in sectors closely related to automated vehicles.	Total economic output of sectors related to AVs	3.1.1 Expand Investment and Employment 3.1.2 Testing 'Sandbox'
3.2 Expand Employment Opportunities: In 2050, the City will have harnessed the widespread adoption of automated vehicles to ensure a smooth transition in the workforce to meet the needs of tomorrow.	Number of jobs created in AV-related sectors per 1000 jobs Percentage of workers who have transitioned into a new role	3.2.1 Talent Development 3.2.2 Workforce Reskilling 3.2.3 Community Benefits
3.3 Demonstrate Sector Leadership: In 2050, the City will have harnessed the widespread adoption of automated vehicles to be recognized as a leading automated vehicles cluster, particularly in ways that support this tactical plan.	Number of times Toronto achieves top 50 in global AV rankings	3.3.1 Global Competitiveness 3.3.2 Cross-Sector Collaboration

3. ECONOMIC SUSTAINABILITY

3.1 EXPAND SECTORS

In 2050, the City will have harnessed the widespread adoption of automated vehicles to have retained and attracted additional investment in sectors closely related to automated vehicles.

Key Performance Indicator:

- Total economic output of sectors related to AVs

3.1.1 Expand Investment and Employment

Tactic: Develop and implement a policy and mechanism to expand investment and employment in local sectors related to automated vehicles.

Ontario is poised to be one of the leaders in intelligent transportation, with expertise in connected and autonomous vehicle technology, machine learning, connectivity, cybersecurity, and quantum computing. According to the Province, more than 170 companies in Ontario are involved in the connected and automated vehicle sector.[106]

These investments can be attributed to Ontario's large automotive and IT clusters, a high-quality workforce, access to the North American market, a thriving research and development (R&D) environment, and its award winning manufacturing. The City will leverage these regional strengths and continue to develop its local automated vehicle sector.

▶ *Proposed progress to 2022: Partner with Toronto Global – the regional investment attraction agency – to research and learn about opportunities to expand sectors related to AVs.*

3.1.2 Testing 'Sandbox'

Tactic: Develop and implement a testing 'sandbox' to allow industry to play, cluster, and innovate quickly.

Although better known in the agile software development field, an emerging best practice for testing disruptive technologies is to create a 'sandbox.'[107] A sandbox is a technical environment with a well-defined scope, which allows for isolated execution of software or programs for independent evaluation, monitoring or testing. This controlled environment allows for players to reduce the risk of technical errors prior to wide distribution of their product.[108]

Developing a testing sandbox within Toronto's boundaries could be beneficial –not only in terms of adapting AV technologies to local conditions – but also in terms of contributing to the economic development of the AV industry.

▶ *Proposed progress to 2022: Develop and implement an innovation corridor and innovation zones to accelerate proof-of-concept pilots.*

3. ECONOMIC SUSTAINABILITY

3.2 EXPAND EMPLOYMENT OPPORTUNITIES

In 2050, the City will have harnessed the widespread adoption of automated vehicles to ensure a smooth transition in the workforce to meet the needs of tomorrow.

Key Performance Indicators:

- Number of jobs created in AV-related sectors per 1000 jobs
- Percentage of workers who have transitioned into a new role

3.2.1 Talent Development

Tactic: Develop and implement a mechanism to increase the local talent base in sectors related to automated vehicles.

Toronto is already the largest centre of education, research and innovation in Canada. The success of its educational institutions plays a large part in why some of the best businesses and brightest minds are attracted to this City.[109] Toronto is home to innovative programs like OCAD University's Strategic Innovation Lab and the University of Toronto's Institute of Aerospace & Engineering's aUToronto team which built a self-driving car. The City was ranked as the "best economy for young people" in 2015[110] and hosts one of the most diverse and highly educated talent pools within Canada. Talent has always been the driving force behind Toronto's economic prosperity and innovation, and will remain so with the introduction of AVs.

▶ *Proposed progress to 2022: Evaluate effectiveness of mechanisms for increasing the talent pool supporting the automated vehicle cluster.*

3.2.2 Workforce Reskilling

Tactic: Develop and implement a policy to address the anticipated need for workforce reskilling as a result of AVs.

The adoption of vehicle automation technologies has the potential to both create employment opportunities and render some existing jobs obsolete.[111] As noted by the Brookfield Institute for Innovation and Entrepreneurship, this potential varies by industry and is the result of a number of factors, "including the fit between changing skills demand and the skills of workers within local labour markets, the ability and willingness of workers to upskill or retrain, and the availability of training programs tailored to the needs of local firms and workers."[111] For example, driving jobs could see a decline while information technology-focused occupations such as software developers, web designers, and user support technicians could experience growth.[112]

With these conditions comes several challenges. First, individuals occupying in-demand roles need to possess the right skill sets. Second, individuals in impacted roles need to receive the right amount of upskilling and retraining to remain employable as the technology changes. Finally, individuals in roles that will be phased out need to be retrained now to transition effectively prior to mass integration of AVs.[112]

▶ *Proposed progress to 2022: Monitor workforce and social assistance impacts and work with partners – in government, postsecondary, labour unions and private sectors – to connect Toronto residents to training and reskilling opportunities.*

3. ECONOMIC SUSTAINABILITY

3.2.3 Community Benefits

Tactic: Develop and implement a mechanism to ensure that large-scale infrastructure projects related to automated vehicles identify ways to achieve inclusive economic development through community benefits opportunities.

The City of Toronto's Poverty Reduction Strategy acknowledges significant potential to reduce poverty in Toronto through City policies and programs aimed at leveraging the City's economic powers to drive inclusive economic development. For example, the City's Social Procurement Program focuses on leveraging an institution's purchasing power to create social impact and inclusive economic growth, hence achieving a double bottom line through City procurement.

With the integration of automated vehicles and the potential impact to both infrastructure developments, as well as Toronto's labour force, the City of Toronto is aiming to incorporate community benefits initiatives and opportunities into its upcoming projects to ensure that equity-seeking groups and impacted labour sectors are able to benefit from this technology.

- *Proposed progress to 2022: Use the City's Community Benefits Framework (forthcoming) to guide how to leverage community benefits through large transit projects, and infrastructure developments.*

3.3 DEMONSTRATE SECTOR LEADERSHIP

In 2050, the City will have harnessed the widespread adoption of automated vehicles to be recognized as a leading automated vehicles cluster, particularly in ways that support this Tactical Plan.

Key Performance Indicator:

- Number of times Toronto achieves top 50 in global AV rankings

3.3.1 Global Competitiveness

Tactic: Develop and implement a mechanism to increase Toronto's recognition and competitiveness in sectors related to automated vehicles.

Toronto has a natural competitive advantage when it comes to attracting investment in AV related sectors, which can be attributed to several factors: its location at the centre of the 4th largest metropolitan area in North America; its thriving economy with a GDP of over $172 billion in 2017 – about 10% of Canada's total GDP; a highly skilled, multilingual workforce of 1.52 million people, almost 64% of whom have a post-secondary education; and major transportation hubs like Pearson International Airport, the Port of Toronto, and many major highways and multi-modal railway facilities within the area.[113]

3. ECONOMIC SUSTAINABILITY

Currently, Southern Ontario is the fourth largest exporter of vehicles in the world, with manufacturing facilities for GM, Fiat-Chrysler, Ford, Toyota, Honda and their supply chains. The Toronto-Waterloo Region Corridor includes research universities and technology companies, attracting Uber and General Motors and creating jobs in the region.[114] With so much technological innovation and entrepreneurship already taking place in Toronto, the City will ensure that it leverages this competitive advantage in order to create a hub for automated transit technology, and improve its global recognition.

- *Proposed progress to 2022: Develop an economic development strategy to make Toronto a hub for automated transit vehicle technology.*

3.3.2 Cross-Sector Collaboration

Tactic: Develop and implement a mechanism to facilitate cross-sector collaboration between sectors related to automated vehicles and Toronto's other economic sectors.

Toronto is Canada's business and financial capital. It is competitive in an array of major business sectors, including technology, green energy, food and beverage, film and television, digital media and more. This industrial diversity drives cross-sectoral interactions and knowledge sharing that has led to leading-edge hybrid sectors like med-tech, green-tech, and food-tech, which are currently thriving within the City.[115]

Toronto is well-placed to facilitate collaboration between industries involved in developing AV technology – including the service industry, safety & security industry, in-car intelligence and assistance, autonomy, infrastructure & connected cars, intelligent manufacturing, onboard sensors, and the specialty vehicle industry.[116] The City aims to facilitate this collaboration amongst AV industries, and between AV and other thriving sectors in Toronto, to ensure the continued development of an economically competitive municipality.

- *Proposed progress to 2022: Implement an initiative to foster collaboration among the AV cluster.*

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PRIVACY

4. PRIVACY

The City of Toronto will support and enhance data privacy as it relates to the generation, collection and use of information by automated vehicles.

Privacy plays a key role in a free, democratic society and is an essential element in maintaining public trust in government. The City of Toronto is committed to protecting the privacy of individuals and will ensure that privacy protection continues to play a key role in an open, accessible and transparent government.

With the introduction of AVs, the volume and variety of data generated and transmitted between vehicles, infrastructure, connected devices, and third party data repositories will increase substantially.[59] However, realizing some of the potential benefits to traffic management, traveller information, safety, enforcement and more – is dependent on establishing stringent standards and clear guidelines around the privacy of these vehicles.[117]

The City of Toronto is subject to the Province of Ontario's *Municipal Freedom of Information and Protection of Privacy Act,* which provides a right of access to City information while at the same time protecting the privacy of individuals.[118] However, contemporary issues of data governance still need to be resolved and standards must be in place to protect the data of individuals using AVs and the general public outside the vehicle.

In addition to legislative requirements to ensure privacy, Privacy by Design guidelines provide a strong foundation to lead AV technology developers to take proactive steps to ensure users' privacy is minimally invaded.[119]

The future of urban, data-driven mobility depends on government, private mobility companies, and the public having confidence that their data is being used in the way it is intended.

GUIDING POLICIES AND STRATEGIES:

The City of Toronto's Protection of Privacy Policy:
The City of Toronto will:

a. Ensure all employees share responsibility for the protection of personal information privacy and compliance with the roles and responsibilities identified in this Policy;

b. Plan for and ensure that privacy protection requirements are embedded in the design of all City programs, processes, projects and technology architecture.

c. Establish and communicate a set of privacy standards and guidelines to improve the protection of personal information by identifying, investigating, assessing, monitoring and mitigating personal information privacy risks in City programs and activities involving the collection, use, disclosure and disposal of personal information.

d. Apply this policy and related policies and practices in the collection, use, disclosure, and disposal of personal information;

e. Clearly communicate to the public how personal information is collected, used, disclosed and disposed.

4. PRIVACY

Summary of Goals and Tactics

Goals	Key Performance Indicators	Tactics
4.1 Protect Public Privacy: In 2050, the City will have ensured that a robust mechanism for the governance of data generated by driving automation systems is in place prior to the widespread adoption of automated vehicles. This is to protect the privacy of transportation system users and their data.	Month-over-month percentage +/- (increase/decrease) of privacy breaches that result in unauthorized data discovery, and leakage, of personal information.	4.1.1 Data Privacy Standards 4.1.2 Privacy Standards: Automated Transit Vehicles 4.1.3 Privacy Standards: Shared AV Fleets 4.1.4 Privacy Governance and Oversight 4.1.5 Privacy Principles: Privacy by Default 4.1.6 Privacy Attestation Services

4. PRIVACY

4.1 PROTECT PUBLIC PRIVACY

In 2050, the City will have ensured that a robust mechanism for the governance of data generated by driving automation systems is in place prior to the widespread adoption of automated vehicles. This is to protect the privacy of transportation system users and their data.

Key Performance Indicator:

- Month-over-month percentage +/- (increase/decrease) of privacy breaches that result in unauthorized data discovery, and leakage, of personal information.

4.1.1 Data Privacy Standards

Tactic: Develop and implement a policy and mechanisms consistent with Privacy by Design principles, to address ownership, custody, usage, and safeguarding of data associated with a natural person, that is either managed by the City proper, or an authorized third party operating under agreement with the City.

AVs will create new real-time data connections between vehicles, infrastructure, connected devices, and third-party data repositories. In order for a data-driven mobility system to work, government, private transportation companies, and the public need to be confident that their privacy is being protected and their data is being used in a way to which they have they have given their informed consent.

Additionally, Toronto's residents should be able to quickly understand how these technologies work and the purposes they serve. One way this could be accomplished is through signage that highlights what type of data is being collected in and around the vehicle and how it will be used.[120]

To the greatest possible extent, the City will advocate for the adoption of Privacy by Design principles in the automated vehicle environment prior to the widespread introduction of AVs. This means addressing privacy at the initial design stages and throughout the complete development process of new products, processes or services that involve processing personal data by practicing the following seven Foundational Principles:[119]

Principle 1 - Proactive not reactive: preventative not remedial
Principle 2 - Privacy as the default setting
Principle 3 - Privacy embedded into design
Principle 4 - Full functionality: positive-sum, not zero-sum
Principle 5 - End-to-end security: full lifecycle protection
Principle 6 - Visibility and transparency: Keep it open
Principle 7 - Respect for user privacy: Keep it user centric

Furthermore, the City will participate in the development of federal privacy standards and, where required, create policies and standards that address AVs.

- *Proposed progress to 2022: The City will develop a policy framework, and corporate procurement standards, to address privacy aspects associated with the ownership, custody, and use, of personally identifiable information captured from AVs.*

4. PRIVACY

4.1.2 Privacy Standards: Automated Transit Vehicles

Tactic: Develop and implement policies to ensure automated transit vehicle riders understand what personal data is accessed and collected from them.

TTC vehicles today are equipped with video cameras to ensure the safety and security of employees, customers and property. Smart fare collection systems record the time and location of trips and are often linked to customer profiles.

Recognizing the need to minimize privacy intrusion, TTC currently does not allow any unauthorized copies of data/images in any format (hardcopy, electronic, etc.) to be taken from the video recording system.

TTC will take all possible measures to ensure that if connected technologies (e.g., V2X) are introduced into transit vehicles, personally identifiable information is not accessible to malicious agents over the air.

- *Proposed progress to 2022: Research and learn more about the privacy impacts for automated transit vehicles.*

4.1.3 Privacy Standards: Shared AV Fleets

Tactic: Develop and implement policies to ensure shared AV fleet service consumers are educated about what personal data is accessed and collected from them.

The primary method of matching ride hailers to ride providers for shared fleet companies currently is through the collection, retention and processing of personal and public data on their users. This information includes home address, contact information, payment details, device locations, trip histories, and more.[121,122]

As automation increases the amount of data that can be collected, privacy concerns also increase.[123] Data will permeate most aspects of the AV experience and companies are likely to want to monetize this data as an additional revenue stream. The City of Toronto has a responsibility to ensure that, to the greatest extent possible, any personally identifiable information is de-identified at the source, and the public is aware of what data is being gathered and used when they take a ride in a shared fleet AV.

- *Proposed progress to 2022: Research and learn more about the privacy impacts for shared AV fleet consumers.*

4. PRIVACY

4.1.4 Privacy Governance and Oversight

Tactic: Develop and implement an enterprise automated vehicle assurance framework that reflects the City's authority over, and oversight of, data privacy protection across multiple dimensions/domains.

An enterprise AV assurance framework will ensure that the data privacy, and protection, aspects of this technology, including threats to the enterprise itself are addressed through an overarching, programmatic approach.

An enterprise consists of the people, processes, environment and automated information systems associated with AVs and to have a successful assurance framework for this, the capability to withstand attack should be true across all components.[124]

▶ *Proposed progress to 2022: Develop an AV enterprise assurance framework for the City to implement as it relates to their authority over, and oversight of data privacy protection.*

4.1.5 Privacy Principles: Privacy by Default

Tactic: Support the development and adoption of automated vehicle technology consistent with Privacy by Default principles.

Individuals signing up for online and connected services (e.g., social media) may unknowingly be sharing personally identifiable information, without having explicitly opting to do so. As more vehicles become connected through navigation apps, infotainment systems and other software, the risk of users unknowingly broadcasting their personally-identifiable information could increase significantly.

The Privacy by Default principle – one of the seven Privacy by Design foundational principles – states that when a system or service includes choices for the individual on how much personal data they share with others, the default settings should be the most privacy-friendly ones.[125] This consists of several components:[126]

- Privacy controls should default to the protected state rather than having to be activated or selected (i.e. controls are built in and automatically switched on).
- The collection of personal information is limited to that necessary for the primary purpose identified in the notice
- Personal information is used only for the primary purpose(s) identified and only if the individual has provided implicit or explicit consent, unless a law or regulation specifically requires otherwise.

▶ *Proposed progress to 2022: Design and develop a mechanism that will determine if and how Privacy by Default principles are embedded into AV technology.*

4. PRIVACY

4.1.6 Privacy Attestation Services

Tactic: Develop and implement a standard for the City through which the sufficiency of automated vehicle data privacy protections can be verified.

AVs along with their supporting technologies, bring with them increased capabilities and demand for interconnectedness, data analytics and sharing of information to deliver a better customer experience as well as increased use of cloud computing and mobile devices.[127]

However, this brings risks: privacy breaches are becoming more common, whether due to human error, employee indiscretion or cyber-attacks. This has led to heightened compliance obligations, increased regulatory enforcement, and increased privacy awareness and expectations from the public.

To address these challenges, the City will adopt a Privacy by Design certification and accreditation process which would assess AV products, services, processes or systems against the privacy by design principles and related privacy control framework (e.g., through a risk scorecard technique). By doing so, it would ensure privacy and security through every phase of the data lifecycle (e.g. collection, use, retention, storage, disposal or destruction), and foster greater public trust by demonstrating that residents' data is secure, and that privacy is being well managed and continuously updated.

- *Proposed progress to 2022: Develop a minimum data privacy protection standard for the City to undertake.*

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ROAD SAFETY & SECURITY

5. ROAD SAFETY & SECURITY

The City of Toronto will encourage the adoption of driving automation systems that are proven to create a net benefit to road safety and security.

Most fatalities and serious injuries on our roads are preventable, with approximately 94 percent of serious crashes due at least in part to human error, such as paying insufficient attention to road conditions. In light of this, Toronto has committed to a bold vision of reducing all traffic-related deaths and injuries to zero.[128]

If in the future higher level AVs become widely adopted, there may be significant reductions in the number of collisions on Canadian roads.[59] Longer term, when AVs make up three-quarters of vehicles on the road, we could see an end to virtually all traffic injuries and fatalities.[129]

In the near term, newer base model vehicles have begun to include features such as lane-keeping, automatic braking, and blind spot detection which help identify safety risks that can assist drivers in avoiding a crash.[130] Other vehicles have (Level 2-3) highway pilot features which allow the driver to give up control of steering and braking under certain conditions while the driver supervises, ready to take over when needed; however, there is the risk that drivers will become distracted when they need to pay attention and overestimate the abilities of technologies which are very much still under development.

Improved road safety and security will be highly dependant on these technological advancements and the way in which drivers choose to use them.

GUIDING POLICIES AND STRATEGIES:

Vision Zero Road Safety Plan (2017-2021):[128]

VISION STATEMENT:

The City of Toronto, with the commitment of all partners, aims to eliminate fatalities and serious injuries on city streets to create a safe and healthy city.

HOW WILL WE ACHIEVE VISION ZERO?

Vision Zero is a long-term strategy. Making changes to infrastructure and traffic-safety culture takes time. However, we will get there through improvements to Engineering, Education, Technology and Enforcement.

Engineering Safety Measures target the design and operation of city streets to prevent collisions from occurring while also minimizing the impact that human error can have in causing collisions.

Education Safety Measures will raise awareness and improve the understanding of issues we face and include targeted interventions.

Technological Safety Measures will employ technical solutions to improve road safety. Initiatives such as passive detection, automated enforcement and enhanced data analysis will be utilized.

Enforcement Activities will be done in collaboration with Toronto Police Service and the Ontario Provincial Police. These initiatives will continue to build on the most efficient and effective uses of our limited enforcement resources to improve road safety.

5. ROAD SAFETY & SECURITY

Summary of Goals and Tactics

Goals	Key Performance Indicators	Tactics
5.1 Prevent Collisions: In 2050, the City will have harnessed the widespread adoption of automated vehicles to ensure that traffic-related injuries and deaths from automated vehicles are zero.	Number of killed/ seriously injured involving AVs per VKT (vs. non-automated vehicles) Number of non-KSI collisions involving AVs per VKT (vs. non-automated vehicles)	5.1.1 Transition to AVs 5.1.2 Transition to AVs - Transit 5.1.3 Vehicle Collisions - Human Factors 5.1.4 Vehicle Collisions - Environmental Conditions 5.1.5 Vehicle Collisions - Data Redundancy 5.1.6 Vulnerable Road Users 5.1.7 Reducing Traffic Infiltration 5.1.8 Shared AV Fleet Safety Standards
5.2 Update Infrastructure: In 2050, the City will have harnessed the widespread adoption of automated vehicles to ensure that all appropriate transportation infrastructure facilitates their use.	Number of infrastructural barriers to AV use eliminated	5.2.1 AV Integration 5.2.2 AV Integration – Transit 5.2.3 AV Integration – Connected Vehicles 5.2.4 New and Revised Standards
5.3 Update Emergency Response: In 2050, the City will have ensured that a robust mechanism for the governance of data generated by AVs is in place prior to the widespread adoption of automated vehicles. This is to safeguard the data confidentiality, integrity, and availability of transportation system users.	Average response speed (specifically driving time)	5.3.1 Emergencies – Vehicle Priority 5.3.2 Emergency Response Policies 5.3.3 Emergency Response Protocols & Training 5.3.4 Enforcement 5.3.5 Emergencies – Shared AV Fleets
5.4 Protect Data Confidentiality, Integrity & Availability In 2050, the City will have ensured that a robust mechanism for the governance of data generated by AVs is in place prior to the widespread adoption of automated vehicles. This is to safeguard the data confidentiality, integrity, and availability of transportation system users.	Month-over-month percentage +/- (increase/decrease) of security breaches that result in unauthorized data discovery, and leakage, of personally identifiable information.	5.4.1 Data Standards

5. ROAD SAFETY & SECURITY

5.1 PREVENT COLLISIONS

In 2050, the City will have harnessed the widespread adoption of automated vehicles to ensure that traffic-related injuries and deaths from automated vehicles are zero.

Key Performance Indicators

- Number of killed/ seriously injured involving AVs per VKT (vs. non-automated vehicles)
- Number of non-KSI collisions involving AVs per VKT (vs. non-automated vehicles)

5.1.1 Transition to AVs

Tactic: Manage the transition to automated vehicles by educating the public on how to appropriately use and interact with automated vehicles and by updating regulatory and enforcement mechanisms to address vehicles without human drivers.

Current opinion research in the GTHA indicates that the public's perception surrounding automated vehicles is mixed.[74] During the transition period when roads will be shared by both manual and automated vehicles, public education campaigns will play a key role in shaping positive outcomes.

The City has a role to play in educating the public on what they can expect from AVs on the road and be made fully aware of the privacy implications of using AVs.[131] It will be particularly important to educate the public on the need to be attentive in partially-automated vehicles. Safety concerns may arise from overreliance by drivers on low levels of automated technology, as well as an increased likelihood of drivers, pedestrians, cyclists and other road users of taking risks that they would regularly avoid.[59]

In addition, the City will need to update enforcement protocols for regulating interactions between AVs and non-AVs. By taking a proactive approach toward tackling anticipated challenges, the City will ensure road safety and security are the first priority during this transition period.

- *Proposed progress to 2022: Develop materials, and host sessions to educate the public on automated vehicles and how to interact safely with them. Engage with relevant stakeholders to update regulatory and enforcement processes as it relates to AVs and begin implementation of these changes.*

5.1.2 Transition to AVs – Transit

Tactic: Manage the transition to automated vehicles by educating operators and riders on how to appropriately use and interact with these vehicles, and by updating vehicle specifications to include partial automation that is proven to increase safety.

Transit agencies around the world are currently determining how to integrate low levels of automation into their operations.

5. ROAD SAFETY & SECURITY

Partial automation technologies that can be added to a typical 40-foot bus, cutaway bus, or articulated bus include smooth acceleration and deceleration to improve fuel economy, automated emergency braking (AEB) and pedestrian warnings for collision avoidance, precision docking at bus stops, curb avoidance during bus stop approaches and turns, operations in narrow lanes or road shoulders (e.g., for Bus-on-Shoulder or BRT guideway), and bus platooning to enhance throughput in constrained corridors.[31]

These technologies will increase the safety of operations, provide a better and more accessible service to customers, or improve driving performance in terms of fuel economy, network efficiency, or other metrics.[31] The City supports updating vehicle specifications to include this technology as a means of improving safety.

However, these technologies come with risks. Other road users' initial experiences with automated transit could also cause them to misjudge or overestimate vehicle collision avoidance capabilities. This could lead to risk-taking behaviors, such as turning in front of a bus, which could result in a crash in cases in which the automated system is not capable of responding. Proactive education for operators and riders on how to appropriately interact with and use these vehicles will be essential during this transition period.[132]

- *Proposed progress to 2022: Use learning from the testing of Driver Safety Assistance Technology, and the AV transit shuttle pilot to conduct research, and identify policy options for educating operators and riders on how to use and interact with these vehicles.*

5.1.3 Vehicle Collisions - Human Factors

Tactic: Support the development and adoption of automated vehicle technology that is proven to positively contribute to realizing the City's Vision Zero Action Plan.

The ***Vision Zero Action Plan*** for the City of Toronto includes safety measures that vary from enhanced data collection, to automated enforcement strategies, education and awareness initiatives, automated pedestrian detection, safety corridors and more.[128] With the creation of this *Tactical Plan* as a supplement to strategies like Vision Zero, AVs will provide the opportunity to contribute to many of the goals and safety measures set out within ***Vision Zero***.

Some manufacturers have made bold statements about the potential safety gains that can be made from these vehicles – for example, Nissan has announced a target of "virtually zero" fatalities and serious injuries from collisions involving new Nissan vehicles.[59]

The City of Toronto aims to realize some of these promises, by incorporating the adoption of AV technology into the City's Vision Zero initiatives.

- *Proposed progress to 2022: Develop and test a mechanism that will determine if and how safety is improved with AVs as it relates to Vision Zero.*

5. ROAD SAFETY & SECURITY

5.1.4 Vehicle Collisions - Environmental Conditions

Tactic: Support the development and adoption of automated vehicle technology that is proven to reduce injuries and deaths from vehicle collisions resulting from Toronto's unique environmental conditions.

Toronto experiences four distinct seasons, including winters with heavy snowfall; however, environmental conditions remain a major challenge for deployment of AVs. This problem is a well-known concern within the field, as AVs rely on a number of sensors – including GPS, traditional cameras, radar, and LIDAR technology to detect other vehicles and pedestrians.[133] Inclement weather impacts at least two, if not more of these applications - with cameras rendered useless in fog or heavy snow and LIDAR sensors unable to function properly with precipitation.

Many manufacturers are creating new ways to address these environmental problems – such as high-definition maps to more easily navigate in the snow even when road markings are not visible, redundant cameras and sensors to continue running even if they are covered in dust or road salt particles, protective coatings to keep some sensors free from cover and more.[134]

The City of Toronto will address concerns around the environment by encouraging AV technology that is proven to contribute to road safety improvements in these conditions.

- *Proposed progress to 2022: Develop and test a mechanism that will determine if and how safety is improved with AVs as it relates to Toronto's environmental conditions.*

5.1.5 Vehicle Collisions – Data Redundancy

Tactic: Develop and implement a policy of providing real-time and up-to-date data on traffic controls to support the triple redundancy of traffic control device detection.

AVs are equipped with vital safety technologies such as LIDAR that can draw a real-time 3D image of its surroundings, radar sensors that can measure the size and speed of moving objects and high-definition cameras that are able to read signs and signals in order to establish their location.[135]

The City of Toronto will seek to improve these capabilities by promoting a practice of triple redundancy in the data that governs the movement of AVs. In other words, AVs should have at least three sources of information on traffic regulations - in-field control devices that are detected in real-time by the vehicle (signage, markings, signals, etc.), open data on in-field devices (pavement marking plans, signal timing, etc.), and high-definition mapping conducted by mobility service providers and original equipment manufacturers prior to deployment. This will better inform the movement of AVs and potentially contribute to increased safety of Toronto's residents.

- *Proposed progress to 2022: Design a process to provide all traffic regulations, in real-time where possible, through the City's Open Data Portal to assist in the fault-free operation of automated driving systems.*

5. ROAD SAFETY & SECURITY

5.1.6 Vulnerable Road Users

Tactic: Support the development and adoption of automated vehicle technology that is proven to increase detection of vulnerable road users and the ability to communicate with them.

The City of Toronto's Vision Zero strategy employs four safety improvements in: engineering, education, technology, and enforcement – to address six emphasis areas that are a concern. These areas include: vulnerable road users such as pedestrians, school children, older adults, cyclists, and motorcyclists, and behavioural factors such as aggressive driving and distracted driving.[128]

In the absence of an active human driver, there needs to be a method to easily convey a driverless car's behaviour and intentions in various traffic conditions.[136] Until this is achieved, AVs will likely contribute to confusing and inconsistent interactions between various users on the road – especially in a mixed traffic setting.

- *Proposed progress to 2022: Research and identify preferred AV technologies that are proven to increase detection and communication with vulnerable road users.*

5.1.7 Reducing Traffic Infiltration

Tactic: Develop and implement a policy and mechanism to manage automated vehicle traffic infiltration on local streets and in residential areas.

With the proliferation of smartphone apps, and increased use of GPS-navigation, more commuters are turning to local streets to ease their travel time during peak hours. These apps use real-time traffic data to re-route drivers around long delays, often taking vehicles through relatively unknown bypasses or residential streets.[137]

The City of Toronto actively aims to address some of these impacts by incorporating traffic calming measures on its local streets to build and maintain a safe and efficient road system for all its road users. When applied appropriately, these measures can have a positive impact on travel speeds, traffic volumes, and road safety generally.[138]

However, traffic calming measures can only go so far while AV technology develops even further, essentially integrating these GPS routes into their everyday navigation systems. The City will reduce traffic infiltration on Toronto's local streets and residential areas by developing a policy or mechanism to manage AV traffic.

- *Proposed progress to 2022: Collaborate with stakeholders and assess potential solutions to manage AV traffic infiltration on local streets.*

5.1.8 Shared AV Fleet Safety Standards

Tactic: Develop and implement a policy regarding safety provisions for shared AV fleet companies.

Shared AV fleets may increase road safety in terms of avoiding collisions; however, AV manufacturers and shared AV fleet companies will need to consider ways to make people feel safe and secure with a driver no longer present.[139] Remote monitoring could alert emergency assistants when potentially hostile or dangerous situations are detected. Passengers may feel safer if there are discreet "exit strategies" for uncomfortable situations, for example by allowing passengers to choose to be dropped off in a 'safe space' near their destination instead of directly in front of their home.

Overall it will be important to recognize that a person's sense of safety depends upon social contexts, for example lone travellers compared to groups, male or female, and young or old. By combining these user profiles with location and time-based data, the safest route for a given passenger could be determined.[140] Establishing personal safety standards for shared AV fleets will be essential to promoting their use across all segments of Toronto's population.

▶ *Proposed progress to 2022: Conduct research to better understand potential safety issues associated with shared AV fleet services.*

5.2 UPDATE INFRASTRUCTURE

In 2050, the City will have harnessed the widespread adoption of automated vehicles to ensure that all appropriate transportation infrastructure facilitates their use.

Key Performance Indicator:

- Number of infrastructural barriers to AV use eliminated

5.2.1 AV Integration

Tactic: Manage the transition to automated vehicles by identifying and focusing investment on corridors or areas for early integration of and potential exclusive use by AVs.

Many companies are developing AV technologies with the intention that they use existing (as opposed to purpose-built) transportation infrastructure; however, achieving the maximum potential benefits of AVs will likely require upgraded infrastructure at some point in the future.

5. ROAD SAFETY & SECURITY

During early stages of deployment of AVs, their interactions with human-driven vehicles and pedestrians may need to be monitored to ensure safety. Identifying and focusing investment on corridors or areas is one way to support early integration of AVs, including the potential creation of dedicated lanes or other types of user separation once AVs constitute a significant proportion of the vehicle fleet. This could introduce a greater level of safety during the transition to widespread adoption of AVs as well as provide an opportunity to learn about different potential infrastructure upgrades.

- *Proposed progress to 2022: Work with the Ontario Good Roads Association (MACAVO) and neighbouring municipalities to identify and implement a corridor within Toronto that can be used for early integration of AVs - that will promote innovation in transportation and standardization across municipalities.*

5.2.2 AV Integration – Transit

Tactic: Manage the transition to automated vehicles by identifying and focusing investment on corridors or areas for early integration of automated transit vehicles.

One possibility for safely integrating automated transit into mixed traffic is through operating in dedicated corridors or areas.[141] Gradual deployment around automated transit could include the installation and management of AV-based service networks for constrained public applications.[142] There are five levels of this deployment – beginning with short, closed-loop applications, moving to more flexible, constrained areas, building to a rich inter-connection with rail and ending at a limitless reach of anywhere, anytime at any distance. Methods such as these will need to be considered by municipalities to address the integration of automation intro transit.

- *Proposed progress to 2022: Review incident data, conduct industry research, and evaluate Driver Safety Assistance Technology to determine procurement needs. Host a vendor day to learn more about the products and develop a business case for procurement. Install, implement and test success of equipment, while evaluating if or when rollout should be extended to the entire fleet.*

5.2.3 AV Integration – Connected Vehicles

Tactic: Develop and implement a policy and mechanism to securely integrate connected vehicles into the transportation system, including options to finance or supply connected and automated vehicle infrastructure and coordination.

Connected vehicle (CV) technologies may be able to reduce travel-time delays caused by congestion by more than a third.[143] As connected vehicles and infrastructure exchange data with one another about traffic conditions, potential safety hazards and construction zones, the flow of traffic can be improved and people can get where they need to go faster.

However, these connections may also create increased cybersecurity risks.[144] Infrastructure serves as an access point and can allow for external agents, either physically or through connections, to penetrate firewalls and gain access to the City's V2I network. Therefore, integration of connected vehicle technologies must be done in a secure manner to mitigate this potential vulnerability.

- *Proposed progress to 2022: Coordinate the secure integration of connected vehicles into Toronto's transportation system, with the Congestion Management Plan. Design and develop an AV-specific strategy for these vehicles that is consistent with the Plan.*

5.2.4 New and Revised Standards

Tactic: Develop and implement maintenance and design standards that integrate the use of automated vehicles while increasing the safety of the transportation system for all users.

A future in which AVs are widespread will require rethinking basic assumptions of traffic operations and engineering as well as our built infrastructure.[34] For example, this could include consistent pavement markings and signage that are visible to humans and AVs in any road condition and increased snow clearing in winter.[34]

The City of Toronto will proactively reexamine design standards for AVs while maintaining safety as the top priority.

- *Proposed progress to 2022: Produce a white paper exploring potential updates to maintenance and design standards with the introduction of AVs - and generate policy options for changes to Toronto's existing standards.*

5.3 UPDATE EMERGENCY RESPONSE

In 2050, the City will have harnessed the widespread adoption of automated vehicles to ensure that all emergency services are equipped to address the unique needs of situations involving these vehicles, and that emergency vehicles receive priority in traffic for faster emergency response.

Key Performance Indicator:

- Average response speed (specifically driving time)

5.3.1 Emergencies – Vehicle Priority

Tactic: Develop and implement a mechanism to improve the yielding of automated vehicles to emergency vehicles.

Yielding to emergency vehicles often leads to confusion as vehicles attempt to move out of the way with limited space and little coordination between drivers.

AVs may one day provide a solution to this problem, as the sharing of information between vehicles could allow them to become aware of an approaching emergency vehicle sooner and coordinate with each other to move out of its path. As of 2017, Waymo had begun training its AVs to be able to recognize what ambulances and other emergency vehicles look and sound like in real-life situations, noting that this training is key to detecting and responding in emergency situations that these vehicles do not come across regularly.[145]

The City will harness this capability to improve the navigation of emergency vehicles alongside other vehicles.

- *Proposed progress to 2022: Collaborate with industry and study the potential opportunities for AV yielding to emergency vehicles. Generate policy options for the City's emergency service divisions to take advantage of any potential opportunities - to be included in a white paper for 2022.*

5.3.2 Emergency Response Policies

Tactic: Integrate consideration for automated vehicles into existing policies for responding to emergencies.

The City of Toronto is responsible for a variety of emergency services – including fire response, paramedics, and police enforcement. To coordinate emergency response and recovery efforts regardless of the situation, across all of these services and the remaining City divisions – emergency plans, protocols, and policies are needed as a reference point.

AVs are a new technology that is not yet considered amongst the City's existing Emergency Plans and policies – and as such, require an individual look into how to integrate consideration for these technologies, into the City's everyday standards.

- *Proposed progress to 2022: Consider the City's existing Emergency Response Policies, and study potential updates that will need to be incorporated with the introduction of AVs. Incorporate policy options and Standard Operating Guidelines into a white paper for 2022.*

5.3.3 Emergency Response Protocols and Training

Tactic: Develop and implement protocols and training addressing emergency response in an automated vehicle environment.

When hybrid vehicles were introduced, they posed a new challenges for emergency responders due to the high-voltage battery packs they carry.[146] As such, numerous safeguards were designed by vehicle manufacturers to help ensure that this high-voltage battery pack was kept isolated from contact with anything other than the hybrid propulsion system in any situation in which this vehicle could find itself.

To assist emergency responders in dealing with this new technology, the majority of vehicle manufacturers provided 'Emergency Response Guides,' which give instructions on the safe handling of hybrid vehicles when approached at the scene of a collision.[147]

Similarly, AVs will be equipped with many new components that manually driven cars did not previously have, and will require protocols and associated training to address this.[148]

- *Proposed progress to 2022: Develop a Standard Operating Guideline for emergency response dealing with protocols and training for incidents involving AVs. This guideline will include appropriate training methods/ materials such as: detailed training notes, online modules, or other materials designed from industry content, and will assess the opportunity for hands-on training in an AV.*

5.3.4 Enforcement

Tactic: Develop and implement operating procedures addressing AVs when responding to infractions.

Current driving infractions are entirely dependent on actions that the driver does or does not take. AVs introduce a new element to driving responsibility with the introduction of driverless vehicles, and cars with passive trip-takers.

AVs are expected to be capable of compliance with all traffic laws and control devices, however liability in the event of a traffic infraction has yet to be determined by legislators due to these new elements.[149]

The City will get ahead of this uncertainty by developing operating procedures to respond to such infractions.

- *Proposed progress to 2022: Scope a framework to capture desired enforcement analytics. Collaborate with the provincial government to distinguish types of AV vehicles on the road, and potential issues that will arise for enforcement of these vehicles.*

5.3.5 Emergencies – Shared AV Fleets

Tactic: Develop and implement approaches for shared AV fleet companies to manage vehicle malfunctions and react to major city emergencies.

During emergencies, danger and panic can result from dense crowding, traffic disturbances, and slow human reaction times which limit the movement of people attempting to reach safety. To this end, the US Department of Transportation has been investigating how vehicle-to-vehicle communications could allow vehicles to move closer, at higher speeds, to improve evacuation outcomes.[150]

However, this effect can only occur once the number of CAVs on the road reaches a critical mass. Therefore, large shared AV fleet companies are the natural starting point to scale up this capacity quickly. Regardless of their role in major city emergencies or risks around vehicle malfunctions – the vehicle-to-vehicle communications amongst large fleets could allow AVs the ability to respond to these situations in a coordinated fashion.

▶ *Proposed progress to 2022: Conduct research to better understand potential safety issues and emergency response needs and opportunities associated with shared AV fleet services.*

5.4 PROTECT DATA CONFIDENTIALITY, INTEGRITY & AVAILABILITY

In 2050, the City will have ensured that a robust mechanism for the governance of data generated by AVs is in place prior to the widespread adoption of automated vehicles. This is to safeguard the data confidentiality, integrity, and availability of transportation system users.

Key Performance Indicator:

- Month-over-month percentage +/- (increase/decrease) of security breaches that result in unauthorized data discovery, and leakage, of personally identifiable information.

5.4.1 Data Standards

Tactic: Develop and implement a policy and mechanisms to address ownership, custody, usage, and safeguarding of data that is confidential, but not personally identifiable.

With the introduction of AVs, the amount of data generated and transmitted will increase substantially. This data can be extremely beneficial from a transportation planning perspective. However, realizing some of the potential benefits to traffic management, traveller information, safety, enforcement and more – is dependent on establishing robust standards and clear guidelines around data ownership, custody, usage, and safeguarding.[117]

One of many potential data access models is the data trust – a legal structure in which trustees provide independent stewardship of data and makes decisions about its use for the beneficiaries of the data (i.e., the public to whom the data belongs).[151] Whichever form this mechanism takes, the City will establish a robust and trustworthy data infrastructure in order to maximize positive uses of data generated and used by AVs as well as minimize risks to individual and collective privacy.[152]

▶ *Proposed progress to 2022: Develop a policy framework to address security considerations regarding the ownership, custody and usage of data captured and collected from AVs. Participate in the development of an overarching AV cloud policy framework.*

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INTEGRATED MOBILITY

6. INTEGRATED MOBILITY

The City of Toronto will encourage the adoption of driving automation systems that further integrate space-efficient and active modes of travel, and better manage all traffic impacts from the movement of goods.

When human transportation technology changed over a century ago, our streets and infrastructure changed with it. Urban planning and transportation engineering reoriented our cities almost exclusively toward the automobile. With the legacy – and consequences – of those planning choices now apparent, planners have been developing a new vision for our streets – integrated mobility. Integrated mobility is the ability for people to move easily from place to place according to their own needs. This means taking a transit-centric approach which connects all modes of travel including active transportation and automobile travel, enabling door-to-door and seamless mobility throughout the city, that is accessible to everyone.[153]

Even in an automated future, high-capacity transit will remain the most efficient use of urban space and the most affordable and sustainable method of transportation for users.[154] A single travel lane can carry at most 1,600 people per hour in a private vehicles, while an on-street bus lane can carry up to 8,000 people per hour, and an on-street transit way (bus or rail) can carry up to 25,000 people per hour.[155] To serve the City of Toronto's mobility goals, transit, alongside space-efficient and active modes, must remain a top priority in the City's approach to this emerging technology.

GUIDING POLICIES AND STRATEGIES:

Toronto Complete Streets Guidelines (2017):

Streets for People - Safe, Accessible, Choices, Transportation, Networks, Connectivity, Healthy, Resilient

- *Streets should enhance human and environmental health by providing a range of safe, inviting and attractive choices for mobility and integrate all modes into a seamless network.*

Streets for Prosperity - Economic Vitality, Social Equity, Flexible, Cost Effective

- *Streets should also be flexible and have the ability to change over time, adapting to needs, preferences and technologies. Streets are not static, and should be cost effective to build, operate and maintain in all seasons.*

Toronto Official Plan (2015):[76]

City streets are significant public open spaces which connect people and places and support the development of sustainable, economically vibrant and complete communities.

- *balance the needs and priorities of the various users and uses within the right-of-way*
- *improve the quality and convenience of active transportation options within all communities by giving full consideration to the needs of pedestrians, cyclists, and public transit users*
- *increase transit priority throughout the City by giving buses and streetcars priority at signalized intersections and by introducing other priority measures*

Toronto Transit Commission's 5-Year Corporate Plan:[156]

Mission: To provide a reliable, efficient and integrated bus, streetcar and subway network that draws its high standards of customer care from our rich traditions of safety, service and courtesy.

6. INTEGRATED MOBILITY

Summary of Goals and Tactics

Goals	Key Performance Indicators	Tactics
6.1 Increase Space Efficiency: In 2050, the City will have harnessed the widespread adoption of automated vehicles to ensure a greater proportion of intraurban travel will be by more space-efficient and active modes of travel.	Throughput in persons per hour per unit area of public right-of-way Percentage change in mode share for: • Active transportation • Transit • 2+ occupant vehicles • Combined-purpose vehicles Urban Goods Movement KPI TBD based on completion of Goods Movement Strategy	6.1.1 Transit Priority 6.1.2 Active Transportation Priority 6.1.3 High-Occupancy AV Priority 6.1.4 Urban Goods Movement
6.2 Design Smart Streets: In 2050, the City will have harnessed the widespread adoption of automated vehicles to ensure the design of city streets is optimized to meet dynamic daily needs.	Number of flexible curbside hours per 100m	6.2.1 Street Design 6.2.2 Road Classification & Use 6.2.3 Flexible Curbs
6.3 Increase System Seamlessness: In 2050, the City will have harnessed the widespread adoption of automated vehicles to ensure that Toronto's transportation system is seamless to the user.	Percentage of ridership satisfied with system seamlessness	6.3.1 Transit-Centric Mobility-as-a-Service (MaaS) 6.3.2 Microtransit

6. INTEGRATED MOBILITY

6.1 INCREASE SPACE EFFICIENCY

In 2050, the City will have harnessed the widespread adoption of automated vehicles to ensure a greater proportion of intraurban travel will be by more space-efficient and active modes of travel.

Key Performance Indicators:

- Throughput in persons per hour per unit area of public right-of-way
- Percentage change in mode share for: active transportation, transit, 2+ occupant vehicles, combined-purpose vehicles
- Urban Goods Movement KPI TBD based on completion of Goods Movement Strategy

6.1.1 Transit Priority

Tactic: Develop and implement a mechanism to increase the ability to provide transit priority with AVs.

Transit priority provides municipalities with a cost-efficient way to reduce transit delay, improve service reliability, and prioritize the use of transit vehicles.[157] Automated and connected vehicles provide an added benefit to this solution by allowing vehicle-to-vehicle and vehicle-to-infrastructure communication that can:

- Reduce the likelihood of collisions at intersections;
- Increase the reliability of transit movements and schedules; and
- Increase the availability of information for performance measurement.

In promoting a transit-centric approach at the City of Toronto, improving transit priority through technology will not only increase the reliability of the service, but it will incentivize the use of automated transit that receives priority in traffic, as opposed to private AVs.

▶ *Proposed progress to 2022: Research and learn about AV technology potential to provide transit priority and isolate corridors for potential integration. Coordinate with the Toronto Transit Commission to ensure that work on transit priority for Toronto's surface transit network is considered in the development of this Tactic. Incorporate policy options based on stakeholder input into a white paper for 2022.*

6. INTEGRATED MOBILITY

6.1.2 Active Transportation Priority

Tactic: Develop and implement corridors and zones dedicated to walking and biking in conjunction with AV infrastructure upgrades.

Municipalities and transit agencies have the opportunity to leverage the emergence of AVs to improve the lives of urban residents; however, this requires proactive urban policy, with a focus on reducing the amount of motor vehicle travel, supporting high occupancy trips via transit, and making safe spaces for walking and cycling. NACTO's Blueprint for Autonomous Urbanism supports rebalancing the right-of-way through AVs, by moving more people in fewer vehicles on less-congested streets. This way, space can be used more efficiently towards active, sustainable modes, and technology can help manage the public realm dynamically.[34]

- *Proposed progress to 2022: Study the potential impacts to active transportation with the introduction of private and public automated vehicles. Generate policy options to be included in a white paper for 2022 that will address how walking and biking will remain a priority alongside AV infrastructure upgrades.*

6.1.3 High-Occupancy AV Priority

Tactic: Develop and implement policies to give high-occupant vehicles priority in planning and infrastructure for AVs.

High occupancy vehicle (HOV) lanes are lanes reserved for vehicles carrying at least two people, with the goal of moving a higher number of people with fewer vehicles. However, effectively enforcing occupancy requirements in HOV lanes presents a challenge in that it is difficult to consistently count the number of passengers in a vehicle.

While automatic passenger counting infrastructure could mitigate this problem for the vehicle fleet at large, AVs could provide another avenue through which to ensure that HOV lanes are used only by vehicles with two or more occupants. By sharing onboard passenger count data obtained through sensors embedded in the AV, these vehicles could automatically be granted or denied access to HOV lanes based on how many people they are carrying.[34]

- *Proposed progress to 2022: Coordinate the development of HOV priority for AVs with the City's existing work on high-occupant vehicles. Explore options to implement policies for planning and infrastructure that consider AVs, and isolate a preferred solution based on the City's intended HOV goals.*

6. INTEGRATED MOBILITY

6.1.4 Urban Goods Movement

Tactic: Develop and implement a policy and mechanism to manage urban goods movement in automated vehicles, including non-passenger AVs.

AV technologies could have a large impact on both public and private urban goods movement.[158] The use of automation to deliver directly to a customer's door could increase the reliability of the delivery, lessen traffic congestion, reduce the costs associated with parking, labour, and fuel, reduce emissions, and increase productivity substantially with the opportunity for uninterrupted operations.[159] Non-passenger AVs such as sidewalk delivery robots are one example of an urban 'last-mile' logistics solution for e-commerce. Companies such as Amazon, FedEx, and Domino's, are looking to sidewalk bots as a method of last-mile delivery, to reduce costs and improve efficiency.[30]

In addition to the benefits outlined above, automated urban goods movement may place more demands on curb space, cause difficulty managing truck movements, and impact other modes of transportation. Sidewalk delivery robots in particular, would need to be capable of navigating encounters with pedestrians and deal with crosswalks and streets with the added difficulty of moving through public spaces like sidewalks, footpaths, and bicycle lanes.[160]

▶ *Proposed progress to 2022: Coordinate the management of urban goods movement in AVs with the City's Goods Movement Strategy. Consult with relevant stakeholders on potential issues, priority concerns and opportunities, and the City's role in its development.*

6.2 DESIGN SMART STREETS

In 2050, the City will have harnessed the widespread adoption of automated vehicles to ensure the design of city streets is optimized to meet dynamic daily needs.

Key Performance Indicator:

- Number of flexible curbside hours per 100m

6.2.1 Street Design

Tactic: Develop and implement a new standard for street design that addresses the unique needs and challenges of AVs.

The introduction of AVs creates opportunities to rethink how we design our streets. With proper planning, cities can leverage AVs as a means of enhancing the public realm and transportation system, to achieve broader goals of equity, environmental sustainability, safety, and a multimodal environment.[34] New street design measures could include reducing speed limits, reducing lane widths, and planning for dynamic street and curbside management from the start.[34]

The City of Toronto recognizes the need to develop a new standard for street design that addresses the unique needs and challenges of AVs.

▶ *Proposed progress to 2022: Study the unique needs and challenges of AVs on Toronto's street design. Consult with stakeholders on potential issues and opportunities.*

6. INTEGRATED MOBILITY

6.2.2 Road Classification & Use

Tactic: Develop and implement a policy to increase the role of local streets as facilitators of vehicular access to adjacent buildings.

The City of Toronto's Road Classification System ensures that the street network performs most efficiently and safely from both a traffic operations and road safety perspective. This system divides Toronto's streets into local roads, collector roads, minor arterial roads, major arterial roads, and expressways based on their use and characteristics.[161]

Local roads provide access to property, with low traffic speeds, generally no bus routes, less than 2,500 vehicles per day, and dedicated sections for both cyclists and pedestrians. As AVs bring a risk of increased vehicular and curb use, the City will look into developing a policy to increase the role of these streets as facilitators of vehicular access to large buildings, particularly in high-density urban areas.[161] Access lanes could provide space for pick-ups, drop-offs, and deliveries – and could be "fully traversable" with restricted access at other times of day.[34]

- *Proposed progress to 2022: Study potential opportunities and issues with using local streets as a facilitator for vehicular access to buildings.*

6.2.3 Flexible Curbs

Tactic: Develop and implement a mechanism to optimize the use of curbside space by automated vehicles over the course of a day.

In the future, the curb may be able to be more responsive and flexible – rather than fixed – as AV technologies are introduced. Curbside space has the potential to host a variety of different programs and activities that can vary throughout the day or the time of year. NACTO's Blueprint outlines several curb elements that can be layered atop one another: vendors, public seating, digital infrastructure, freight loading, green infrastructure, delivery lockers, market, pick-up/drop-off zones, and transit stops.[34]

In addition to incorporating flexible curbside uses, the City can also "code the curb" to monitor the amount of time a vehicle uses it, and account for and broadcast any availability of curb space to connected AVs. Through coded incentives and deterrents, the City could better manage the use and availability of its curbside space.[34]

- *Proposed progress to 2022: Create policy options to optimize the use of the curb for AVs over the course of a day - to be included in a white paper for 2022.*

6. INTEGRATED MOBILITY

6.3 INCREASE SYSTEM SEAMLESSNESS

In 2050, the City will have harnessed the widespread adoption of automated vehicles to ensure that Toronto's transportation system is seamless to the user.

Key Performance Indicator:

- Percentage of ridership satisfied with system seamlessness

6.3.1 Transit-Centric Mobility-as-a-Service (MaaS)

Tactic: Develop and implement a policy to support a coordinated transportation system to achieve seamless mobility centered on public transit.

AVs and MaaS are often referenced in connection with one another, as highly automated vehicles allow for the flexibility and integration required of MaaS. As cars gain the ability to "drive for themselves," ride-hailing and journey-planning through a mobility platform becomes much more convenient.[162] The City will aim to be ahead of this revolution, and begin thinking about how to support a coordinated transportation system to achieve seamless mobility centred specifically on public transit. If there is ease of access to the City's transit services, this option will become more attractive, and can draw users to the transit system.

- *Proposed progress to 2022: Coordinate the development of Mobility-as-a-Service in relation to AVs with the City's existing work on MaaS, and fare integration in general. Consult with relevant stakeholders on potential issues, priority concerns and opportunities, and the City's role in its development.*

6.3.2 Microtransit

Tactic: Develop and implement a policy regarding the integration of automated microtransit into the transit system.

Microtransit consists of shared public or private sector transportation operating either as fixed routes or on-demand via mobile apps.[163] By using 'right-sized' vehicles – either small commuter shuttles or shared fleet vehicles – the microtransit model could address the challenge of first and last-mile connections to transit hubs, while improving mobility to areas that conventional transit cannot serve efficiently.

In 2018, the City of Toronto – in partnership with the TTC and Metrolinx – submitted a successful funding proposal to Transport Canada to operate a time-limited trial project with an automated transit shuttle. The purpose of the project is to test the shuttle technology's ability to meet an existing unmet need in public transit, such as filling the lower-demand "last mile" gap. This trial represents a first step in evaluating the viability of integrating microtransit into the transit system. While there are still many technical limitations to this technology, automated shuttles and shared AV fleets could significantly improve the viability of the microtransit model by making it more cost-effective to offer service to more people.

- *Proposed progress to 2022: Evaluate the success of the Minding the Gap automated shuttle trial, which will run from 2020-2021.*

TRANSPORTATION SYSTEM EFFICIENCY

7. TRANSPORTATION SYSTEM EFFICIENCY

The City of Toronto will enhance its ability to manage traffic in real-time through driving automation systems for the purpose of increasing the efficiency of moving people and goods.

Driving automation systems, at varying levels of automation, offer quantifiable benefits in terms of improving traffic efficiency. Low levels – including adaptive cruise control, automatic emergency braking, and lane departure warnings – contribute to fewer incidents, which in turn provides a positive effect on overall traffic congestion. Studies have also shown that with a higher adoption rate of these low-level systems, roads can operate at higher vehicle densities and flow rates.[164]

In the long-term, as centralized management of all vehicle movement becomes more feasible with connected vehicle technology and higher adoption rates of AVs – increased capacity and reduced delays from incidents will become much more likely. Advanced sensors in AVs will be able to collect and distribute information at a faster and more accurate rate, contributing to the overall effect of traffic information as an indispensable tool for informing drivers of traffic conditions and incidents along their route.[164]

The City will continue to use tools to manage traffic, which will only be further improved as AVs emerge. Current strategies, such as: deterring the use of low-occupancy private vehicles through regulation, pricing mechanisms, and policies; encouraging transit use; exploring potential partnerships; and keeping drivers informed in real-time through increased amounts of data; will continue to play a vital role in traffic management.

GUIDING POLICIES AND STRATEGIES:

Congestion Management Plan (2016-2020):[165]

- *Intelligent Transportation Systems - increasing the amount and quality of traffic information for improved planning, prioritizing and performance evaluation;*
- *Congestion & Engineering Studies - Identifying practical solutions to key expressway congestion and safety concerns, through advanced technologies/ systems or applying current solutions in innovative ways;*
- *Curbside Management - Using innovative solutions to improve the balance of parking demand with traffic operational requirements;*
- *Support of All Modes of Transportation*
    - *Improving the effectiveness and coordination of traffic management activities involving public transit vehicles and active transportation modes; and*
    - *Exploring the most creative and effective use of typical street design standards and traffic engineering techniques to provide a more balanced use of the road right-of-way*
- *Traveller Information - Strengthening data sources and networks to ensure information on current traffic conditions, incidents and events is accurate and reliable.*

7. TRANSPORTATION SYSTEM EFFICIENCY

Summary of Goals and Tactics

Goals	Key Performance Indicators	Tactics
7.1 Increase System Capacity: In 2050, the City will have harnessed the widespread adoption of automated vehicles to better manage all vehicular traffic in real-time conditions, and to increase the capacity of existing transportation infrastructure.	Annual average daily curbside access events per 100m Number of open datasets on City of Toronto Open Data portal Throughput in persons per hour per unit area of public right-of-way	7.1.1 Transition to AVs - Traffic Flow 7.1.2 Active Traffic Management & Coordination 7.1.3 Designated Loading Areas 7.1.4 Open Data
7.2 Manage System Demand: In 2050, the City will have harnessed the widespread adoption of automated vehicles to ensure less acute demand across the transportation system.	Proportion of daily traffic outside AM/ PM peaks	7.2.1 Curbside Fee 7.2.2 Transit Incentives and Pricing 7.2.3 Manage On-Street Parking Demand 7.2.4 Manage Off-Street Parking Demand 7.2.5 Manage the Peak 7.2.6 Manage Travel Demand

7. TRANSPORTATION SYSTEM EFFICIENCY

7.1 INCREASE SYSTEM CAPACITY

In 2050, the City will have harnessed the widespread adoption of automated vehicles to better manage all vehicular traffic in real-time conditions, and to increase the capacity of existing transportation infrastructure.

Key Performance Indicators:

- Annual average daily curbside access events per 100m
- Number of open datasets on City of Toronto Open Data portal
- Throughput in persons per hour per unit area of public right-of-way

7.1.1 Transition to AVs – Traffic Flow

Tactic: Develop and implement a mechanism to improve traffic flow in real-time by managing the mix of non-automated, partially automated, and highly automated vehicles travelling together on city streets and highways.

Managing the flow of traffic can be a challenge for transportation authorities. One solution in use in several neighbourhoods and cities across North America to reduce traffic speeds, encourage safe driving, and improve traffic flow is the Pace Car. Pace Car Programs work like this: residents signing up for the program agree to drive courteously, at or below the speed limit, and follow other traffic laws – essentially acting as a 'mobile speed bump' which models safe driving and results in calmer traffic.[166] Through advanced computer modelling and machine learning, an automated Pace Car could analyze traffic conditions, such as bottlenecks, gridlock, and on-ramp merges, adjusting its speed and position in a way that improves traffic flow for other vehicles on the road.[167]

The City will explore tools and techniques such as Pace Cars to manage the mix of non-automated, partially automated, and highly automated vehicles in real-time. Other options to manage the flow of traffic include traffic calming mechanisms such as traffic circles, choker/chicane/pinch point devices, and speed humps.

▶ *Proposed progress to 2022: Identify potential options to manage the mix of varying levels of automation on Toronto's streets. Identify the optimal solution for Toronto based on research.*

7.1.2 Active Traffic Management & Coordination

Tactic: Develop and implement a mechanism for increasing the average annual daily AV traffic per lane kilometre of arterial roads and expressways.

AV and connected infrastructure technologies could help the City move more vehicles through a given segment of road, thereby increasing the efficiency of existing transportation infrastructure.

First, vehicle-to-vehicle (V2V) communications enabled by connected technology allow cars to communicate and coordinate with each other in real-time.

Second, vehicle-to-infrastructure (V2I) technologies, including smart signals can use cameras and sensors to detect how many cars are waiting in each lane and, how much time it takes to clear up this traffic and it can also communicate with other nearby smart signals to connect to the grid as a network of signals that will work in tandem to maximize traffic efficiency. [168]

Finally, vehicle-to-network (V2N) or vehicle-to-everything (V2X) systems, allow connected vehicles to communicate with cellular devices and the cloud so that drivers can take advantage of in-vehicle services that assist with traffic updates. Transmission of connected vehicle data to traffic management centres allows for real-time active traffic management, relaying information that can enhance the level of predictability for AVs, improving overall travel time and increasing vehicle densities and flow rates.[168]

- *Proposed progress to 2022: Coordinate the development of a mechanism to increase throughput with the development of the 2021-25 Congestion Management Plan.*

7.1.3 Designated Loading Areas

Tactic: Develop and implement a standard for designating automated vehicle loading and unloading areas in high-demand places.

With the increased demand on the curb from the introduction of AVs, designated hubs for pick-up and drop-off zones become vital. Cities need to incorporate structure and incentives around access to the curb to influence its impact on the mobility system, and assist productive use of street place, while ensuring public life and the urban economy flourish.[34]

Aside from designated zones by geography, the City of Toronto can also consider time of day designations that can address peak congestion periods, peak delivery periods, and free-flow timing.

- *Proposed progress to 2022: Research, identify and assess potential options to designate AV loading and unloading areas in Toronto. Select a preferred solution to be designed in the next phase of this Plan.*

7.1.4 Open Data

Tactic: Coordinate the provision of transportation-related regulatory and traffic data through the City's Open Data Portal.

Four principles of Open Data guide the City of Toronto's information sharing: transparency, participation, accountability and accessibility.[169] The City's Open Data Portal exemplifies these principles, as an easy-to-use tool that allows both technical and non-technical users to interact with and use City data in a visual way. The Portal currently includes the City's entire catalogue of open datasets, as a means of improving service delivery, and supporting public trust in government.[170]

7. TRANSPORTATION SYSTEM EFFICIENCY

There are currently 64 datasets included in the Transportation Data Catalogue shared via Open Data.[171] The City will coordinate the addition of more transportation-related regulatory and traffic data into the Open Data portal to improve active traffic management with the introduction of AVs.

- *Proposed progress to 2022: Continue adding transportation-related regulatory and traffic data sets to the City's Open Data Portal.*

7.2 MANAGE SYSTEM DEMAND

In 2050, the City will have harnessed the widespread adoption of AVs to ensure less acute demand across the transportation system.

Key Performance Indicator:

- Proportion of daily traffic outside AM/ PM peaks

7.2.1 Curbside Fee

Tactic: Develop and implement a pricing mechanism or permit system to manage curbside demand from AVs.

Whether as storage space for vehicles, space of commerce, or space for people, curbs have increasingly become contested spaces.[172] Pick-up and drop-offs from ride-hailing services are already placing increased demands on limited curbside space – a condition expected to worsen if shared AV fleets become widespread.[173]

Pricing the curb would allow for efficient allocation of limited curbside space, ensuring faster turnover of vehicles, increasing access to delivery zones and pick-up/drop-off areas while minimizing the fight for the curb across modes.[174]

- *Proposed progress to 2022: Coordinate the development of curb management for AVs with the City's Curbside Management Strategy. Explore variable pricing options to manage demand from AVs (both personally owned and commercial), and isolate a preferred solution based on success from short-term curb management initiatives, and the City's intended focus for the medium-long term.*

7.2.2 Transit Incentives and Pricing

Tactic: Develop and implement a pricing mechanism or value proposition that ensures transit is more attractive to riders than AV alternatives.

In many cities across North America, transit ridership is increasingly challenged by factors beyond the control of transit agencies, including the rise of ride-hailing services and decline in employment.[175] Due to these declines, some municipalities have had to form alternative partnerships with private companies, or cede some of its ridership to competitors.[176]

7. TRANSPORTATION SYSTEM EFFICIENCY

In 2016, TTC ridership declined slightly (a growth rate of -0.1%) – a trend attributed mainly to stagnation in full-time employment growth (and corresponding growth in part-time and temporary employment), rendering the purchase of an Adult Regular Metropass unviable for many people.[177] In response to this trend, the TTC's Ridership Growth Strategy was developed as an extension of the TTC's Corporate Plan 2018-2022 with three main strategic objectives:[178]

1. Retain current customers;
2. Increase transit rides per current customer, and;
3. Attract new customers to the system.

With AVs presenting a new, and convenient method of transportation at potentially lower prices, the City will need to ensure that there are transit incentives, value propositions, and pricing mechanisms in place that preserve transit as the more attractive choice for riders.

- *Proposed progress to 2022: Use lessons learned from automated transit shuttle pilot to inform further research into the value proposition of automated transit, and research and identify other options.*

7.2.3 Manage On-Street Parking Demand

Tactic: Develop and implement a pricing mechanism to ensure that the cost of on-street parking to the user of an automated vehicle reflects economic, social, and environmental impacts.

Many people have predicted that, with the onset of AVs, users will no longer have the need to park because these vehicles will be able to – through rideshare format – pick up the next customer, or, if personally owned, these vehicles will be able to return home and park themselves. However, current parking revenue trends and expert predictions indicate that parking will remain an important source of revenue for the City of Toronto well into the future.[179]

Drivers' continuous search for parking spaces creates negative externalities: an IBM survey even recognized that parking searches amongst these spots – taking between 13-32 minutes –account for about 30% of traffic and circling vehicles produce harmful emissions.[180] Additionally, on-street parking occupies a large portion of the right-of-way, cutting into public realm space.

Connected curbside sensors may allow for real-time updates of parking availability to be communicated to AVs. Furthermore, demand-based pricing policies have been shown to increase turnover in parking spaces, allowing more people to access parking where and when they need it.[181]

- *Proposed progress to 2022: Monitor technological and policy developments in other jurisdictions which could inform the management of on-street parking in Toronto.*

7. TRANSPORTATION SYSTEM EFFICIENCY

7.2.4 Manage Off-Street Parking Demand

Tactic: Develop and implement a regulatory framework or pricing mechanism to ensure that the cost of off-street parking to the user of an automated vehicle reflects economic, social, and environmental impacts.

Studies have been conducted on the impact AVs will have to parking structure designs in the future. According to a study from the University of Toronto, future parking designed especially for AVs could have multiple rows of vehicles stacked behind each other as opposed to two rows for current parking structures, decreasing the need for parking space by an average of 60 percent to a maximum of 90 percent.[182]

Re-imagining car-park designs is only one of the impacts to off-street parking in an automated future. As commercial parking business models change, the City will need to ensure that there is a policy framework in place to make the most of this newly freed-up space.

- *Proposed progress to 2022: Research, learn and identify externalized costs associated with off-street parking.*

7.2.5 Manage the Peak

Tactic: Develop and implement a mechanism to improve travel time reliability and system efficiency by maintaining or reducing the number of automated vehicle trips during peak congestion periods.

According to the TomTom Traffic Index, Toronto commuters spent 30% more time travelling during peak congestion periods. This translates to an average daily delay of about 34 minutes, a total of 130 hours per year.[183]

Automated and connected vehicles could reduce these statistics, by improving travel time reliability and system efficiency through synchronization, communication, and ideal speed and signal adjustments.[143] In addition to these measures, The City could encourage the implementation of pricing mechanisms and time-based access restrictions on geofenced areas.

- *Proposed progress to 2022: Research and identify potential congestion issues during peak hours, arising from AVs.*

7. TRANSPORTATION SYSTEM EFFICIENCY

7.2.6 Manage Travel Demand

Tactic: Develop and implement a pricing mechanism to ensure that the cost of travel to the user of an automated vehicle reflects economic, social, and environmental impacts.

It is uncertain exactly how AVs will impact travel demand; however, one possibility is that vehicular travel could increase due to several factors: enhanced driver experience, more reliable travel times, improved safety, reduced costs associated with vehicle ownership or car-sharing, zero-occupant vehicle standing and circulating, dispersed land use patterns, and increased mobility for non-drivers.[18]

One New York-focused study found that private transportation companies added 5.7 billion miles of driving in America's nine largest metro areas at the same time that car ownership grew more rapidly than the population.[35] This will likely only be exacerbated with AVs unless fees such as road tolls are implemented to control usage, and balance the impacts.[184]

- *Proposed progress to 2022: Study potential issues associated with zero-occupant vehicles. Engage stakeholders to identify potential solutions and begin generating options for the City of Toronto to implement if and when zero-occupant vehicles become prevalent.*

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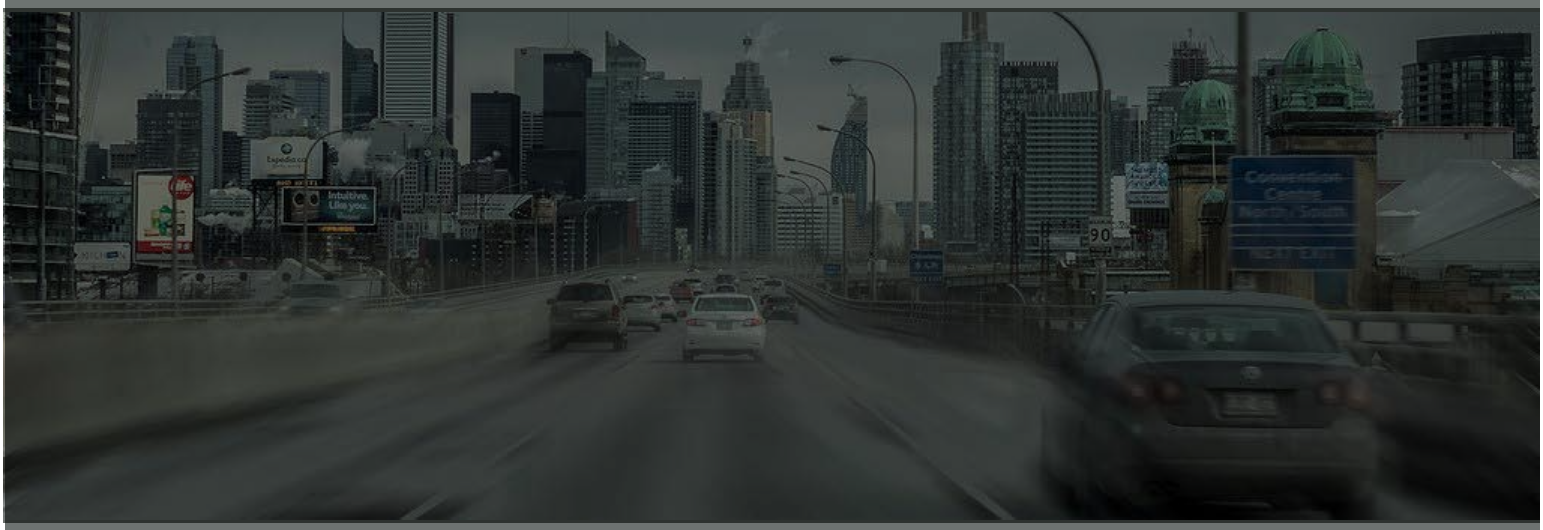


PART III

CITY OPERATIONS

PART III: CITY OPERATIONS

In addition to the seven directions putlined in Part II that outline the strategic vision for automated vehicles, there are three additional sections in this Tactical Plan that prepare the City's internal operations for AVs. These sections are also built on a foundation of existing City policies, plans and strategies.

The sections are:

- *Public Service Vehicles*
- *Future-Proofing*
- *Tactical Plan Data Governance*

The first section of Part III addresses the City's fleet of vehicles, and proposes progress over the next three years on how to learn and assess the impact from AVs. This section outlines aspects such as the safety, security and fueling of fleet vehicles that range from contracted services, to new potential non-passenger business models, to the transit fleet more broadly.

The second section, Future-Proofing looks at ways in which the City can ensure that current and short-term initiatives do not become obsolete in the long-run. These tactics address travel demand, building standards, and infrastructure investment decisions.

Finally, the Tactical Plan Data Governance section recognizes that the City will be dealing with many new and unfamiliar streams of data with the introduction of AVs, and includes Tactics to develop tools and mechanisms to address these changes.

PUBLIC SERVICE VEHICLES

PUBLIC SERVICE VEHICLES

Automated vehicle technologies are being developed not only for the passenger and freight sectors, but also for the delivery of public services. Many companies are exploring how automation can contribute to improved traffic safety, worker conditions, system efficiency, and a lower environmental impact. For example, self-driving street cleaning vehicles are being developed internationally that can automatically trace and pick up garbage, as well as trim roadside bushes, while sensing and monitoring the vehicle's vicinity to avoid obstacles in its path.[38] This Tactical Plan proposes to make the most of developments such as these to improve road and worker safety relating to municipal fleet vehicles, and more effective public service delivery.

GUIDING POLICIES AND STRATEGIES:

Congestion Management Plan (2016-2020):[165]
Incident & Event Response – Strengthen relationships among key agencies – e.g., Transportation Operation Centre (TOC), emergency services, towing industry, road maintenance, etc. to improve coordination, reduce response and clearance times, and improve safety of field personnel

Consolidated Green Fleet Plan 2014-2018:[185]
The goal of the Consolidated Plan is to choose vehicles, equipment, fuels, and practices that consume less fuel and emit less GHG and air pollution, meet the City Fleets' operational requirements, are sustainable, and are economically viable.

Fleet Services Review - Strategy for the Fleet Services Division:[186]
Improve data collection and performance indicator based reporting

Develop a long-term plan to improve aging infrastructure and space adequacy

Continue to address environmental needs at all City-operated fuel sites

PUBLIC SERVICE VEHICLES

PSV.1 Road Safety

Tactic: Develop and implement policies that address potential safety issues and benefits from the use of automated fleet vehicles.

The City of Toronto's Driver/Operator Fleet Safety Policy on Safety & Compliance includes the following policy statement: "As employees of the City of Toronto, it is our duty to protect the interests of the residents of Toronto by carrying out our work in a safe and efficient manner, and to maintain good public relations with those who use the City roadways."[187]

Automated vehicles provide a new opportunity to update vehicles and equipment to contribute to improved road safety.

- *Proposed progress to 2022: Research and learn about the safety impacts of integrating automation into City of Toronto fleet vehicles, and engage with relevant stakeholders to assess potential solutions – including availability of options, cost, liability and viability.*

PSV.2 Vehicle Effectiveness

Tactic: Develop and implement a mechanism to review and enhance the cost and operational effectiveness of automated fleet vehicles.

A Fleet Services Review conducted from 2014- 2015, included an in-depth analysis of a few major fleet management functions, and provided recommendations for improvement.[186] A five-year business plan was developed to address certain aspects of Fleet Services' organizational and operational practices and procedures.

The City of Toronto's Fleet Services Division is actively pursuing enhanced cost and operational effectiveness in all of its initiatives as articulated in the Guiding Policies and Strategies section. This plan will support the introduction of AV technology that contributes to the achievement of these goals.

- *Proposed progress to 2022: Engage and consult with industry stakeholders to assess the options available for procuring automated fleet vehicles. Assess the cost and operational effectiveness of these vehicles through stakeholder consultation.*

PUBLIC SERVICE VEHICLES

PSV.3 Vehicle Security

Tactic: Develop and implement policies and mechanisms to safeguard the operation and data security of automated fleet vehicles.

AVs may be vulnerable to exploitation from a cybersecurity perspective by malicious actors. The third-party and cloud service providers through which vehicle-to-vehicle communications (V2V), vehicle-to-infrastructure communications (V2I), and vehicle-to everything (V2X) communications could take place provide a multitude of entry points for a person or entity attempting to gain access.[188] For this reason, the City will ensure that, similar to other vehicle types, public sector fleet vehicles will be protected from cybersecurity threats as automated and connected features are integrated into their operations.

- *Proposed progress to 2022: Research and learn about potential security issues associated with automated fleet vehicles. Engage and consult with stakeholders on safeguarding the operation and data security of these fleets, including coordinating with Provincial and Federal levels of government for direction on options, cost, liability and viability of vehicle security.*

PSV.4 Vehicle Fueling

Tactic: Develop and implement a mechanism to provide fueling services for automated fleet vehicles.

The City of Toronto's Fleet Services Division is responsible for oversight of any fuel sites managed by the City's Divisions.[185] Regardless of the method of fuel for future AV fleet vehicles –whether they are green or fossil fuels – the City will need to manage the fueling services required to power these fleets.

In the past, the City's efforts under the Consolidated Green Fleet Plan (2014-2018) have proven successful – unless there was a cost or lack of infrastructure that they City could not manage. Alternative fuels that were tested to improve the environmental impacts of City Fleets were occasionally unsustainable due to a need for additional funding or facilities to accommodate it.[185]

However, alternative fueling options are becoming increasingly affordable and viable. o Moving forward, the goal is to choose vehicles, equipment, fuels, and practices that consume less fuel and emit less GHG and air pollution, while meeting the City's operational requirements, and remaining sustainable and economically viable.[185] As AVs begin to meet and address some of these needs the City will need to ensure that it is considering fueling services to contribute to them.

- *Proposed progress to 2022: Analyze the existing fuel options available for public service vehicles. Research and learn about additional needs resulting from AVs and engage and consult with stakeholders on how to address this.*

PUBLIC SERVICE VEHICLES

PSV.5 AV Fleet - Transit

Tactic: Integrate automated vehicle technologies into the Toronto Transit Commission's vehicle fleet.

Multiple use cases have been envisioned for incorporating various technology packages into automated transit. For example, an SAE Level 1 or 2 automated transit bus could assist with: smooth acceleration and deceleration, automatic emergency braking and pedestrian collision avoidance, curb avoidance, precision docking, narrow lane/shoulder operations, and platooning. Higher level automation packages could be deployed in maintenance and yard operations, as well as shuttle, bus rapid transit and mobility-on-demand services (e.g., paratransit).[31]

- *Proposed progress to 2022: Research and learn about add-on safety features available for bus and streetcar fleets. Assess available options and select a solution that can be tested in the short-term. Continue to study automated vehicle technology that improves safety in Toronto's TTC vehicle fleet.*

PSV.6 Non-Passenger AVs for City Services

Tactic: Support the research and development of non-passenger AVs that can provide municipal services.

Since many services provided by the City occur along fixed routes (e.g., snow clearing, street cleaning, solid waste collection), there could be an opportunity to deploy non-passenger automated vehicles (NPAVs) to supplement the existing suite of City services. Using NPAV service vehicles to improve the safety and efficiency of public service delivery, could consist of automating certain driving functions or deploying fully automated vehicles.

Toronto recently hosted the Institute of Navigation's (ION) 9th Annual Autonomous Snowplow Competition, in which teams of university and college students used high-performance automated vehicle guidance, navigation, and control technologies to design a snowplow vehicle capable of removing snow from predefined paths.[189] Such a technology could provide snow clearing services where current vehicles cannot reach, such as narrow sidewalks.

Building from the potential of this emerging technology and others, the City will support the research and development of non-passenger AVs that can provide new and improved City services.

- *Proposed progress to 2022: Assess potential non-passenger AV options available for City Services. Scope its viability, including an analysis of cost and operational effectiveness; and implement a solution for immediate City needs within the next three years. Test the success of an NPAV snowplow pilot.*

PUBLIC SERVICE VEHICLES

PSV.7 Contracted Service Vehicles

Tactic: Manage the transition to automated vehicles by ensuring long-term contracted services account for the ability to upgrade technology over the contract term. Develop and implement standards for the integration of partial automation into contracted services.

The City of Toronto's Fleet Services Review/ Strategy recommends subletting contracts for maintenance and repair, as well as better managing supplier contracts for improved performance standards.[186]

Recognizing that many of the City's services are provided via long-term contracts – the City will ensure that the transition to AVs is captured in these partnerships as well, by maintaining its ability to upgrade technology over the contract term, as well as developing and implementing standards for the integration of partial automation that will improve the delivery of contracted services.

- *Proposed progress to 2022: Research and learn about the potential options to integrate AV technology into contracted vehicles during the contract term. Identify any potential issues that may arise in integrated this technology into a new term, and engage and consult with relevant stakeholders to discuss barriers and opportunities.*

PSV.8 Data Collection

Tactic: Develop and implement a mechanism to collect urban environmental data from automated fleet vehicles. This data collection should support improved road safety, traffic management, transportation planning, asset management and transportation network security, consistent with Privacy by Design principles.

Data can be collected from public service vehicles for increased integrity and accountability, including: collision reporting, accuracy data, data on the role of the vehicle and the driver, fuel data, and more.

This data will be used for the overall improvement of service delivery through aspects of vehicle safety, traffic management, and asset management.

- *Proposed progress to 2022: Research and learn about the potential safety, traffic management, transportation planning, asset management, and network security improvements that could arise from AV fleet data collection. Engage and consult with stakeholders, including the Provincial and Federal governments, to assess how to integrate a data collection mechanism that is cost effective, and secure.*

FUTURE-PROOFING

FUTURE-PROOFING

There are many uncertainties around the long term impacts of driving automation systems that may need to be considered and addressed by the City over the next three years. Studies and modelling exercises can be undertaken to anticipate the future of this technology as it relates to travel demand, planning and investment. This will help proactively generate policy options and solutions to be implemented in the short term, based on the foreseeable future.

GUIDING POLICIES AND STRATEGIES:

Congestion Management Plan (2016-2020):[190]

Action B2.1: Develop a Resilience Lens and apply it to City investments, with a focus on infrastructure.

Action B2.2: Integrate resilience into development and land use planning processes.

Action C4.1: Embed resilience as a practice across the City and partners.

FUTURE-PROOFING

FP.1 Travel Demand Modelling

Tactic: Research and develop tools to test emerging practices in updating travel demand models to accommodate automated vehicles.

Travel Demand Models are computer programs which predict how people use transportation systems. They are used to test the implications of infrastructure (e.g. the addition of a new road or higher-order transit line), policy (e.g. changes to transit service levels or fare policies) or technology (e.g. AVs) changes on future travel patterns.

These predictions of future travel patterns are based on projected land use, demographics, and the region's existing travel patterns, through variables such as population, employment, households, current travel behaviour, and more. Outputs can include traffic volumes for various roadway segments, ridership on transit routes, and travel times.

A variety of modelling tools can be used to understand the impacts of automated and autonomous vehicles. A few potential changes that could be considered to expand AV modelling capabilities include changes to: vehicle ownership and availability, coordinated activity patterns, location choice and land use, mode share and network supply.[191]

The University of Toronto is actively researching in this space with the GTAModel, an advanced regional travel demand modelling system used by municipalities in the Greater Toronto Area (GTA).[192] The City continues to consult with this academic partner as research progresses.

The travel demand modelling tactic will improve the City's capability to predict travel behavior changes associated with the introduction of AVs and the implications of possible AV-related policies.

FUTURE-PROOFING

FP.2 Building Standards

Tactic: Research and consider development of new or improved building standards that allow for flexibility in retrofitting buildings for future needs associated with automated vehicles.

Land use and transportation patterns are inherently linked together, and AVs could radically change both of these. Some potential impacts to the future of building design with the introduction of AVs, include:[193]

- *'Smart' buildings that can communicate with vehicles*
- *Increased pick-up and drop-off at buildings that could impact building design*
- *Changes to utility infrastructure, including charging stations*
- *Minimized parking or flexible parking infrastructure for other uses. Design considerations could also include reducing sloped surfaces, ducting for future utilities, outside light for beautification, and designing for lower loads*
- *Consideration for CAV vehicle access*
- *Building exits and fire safety considerations*

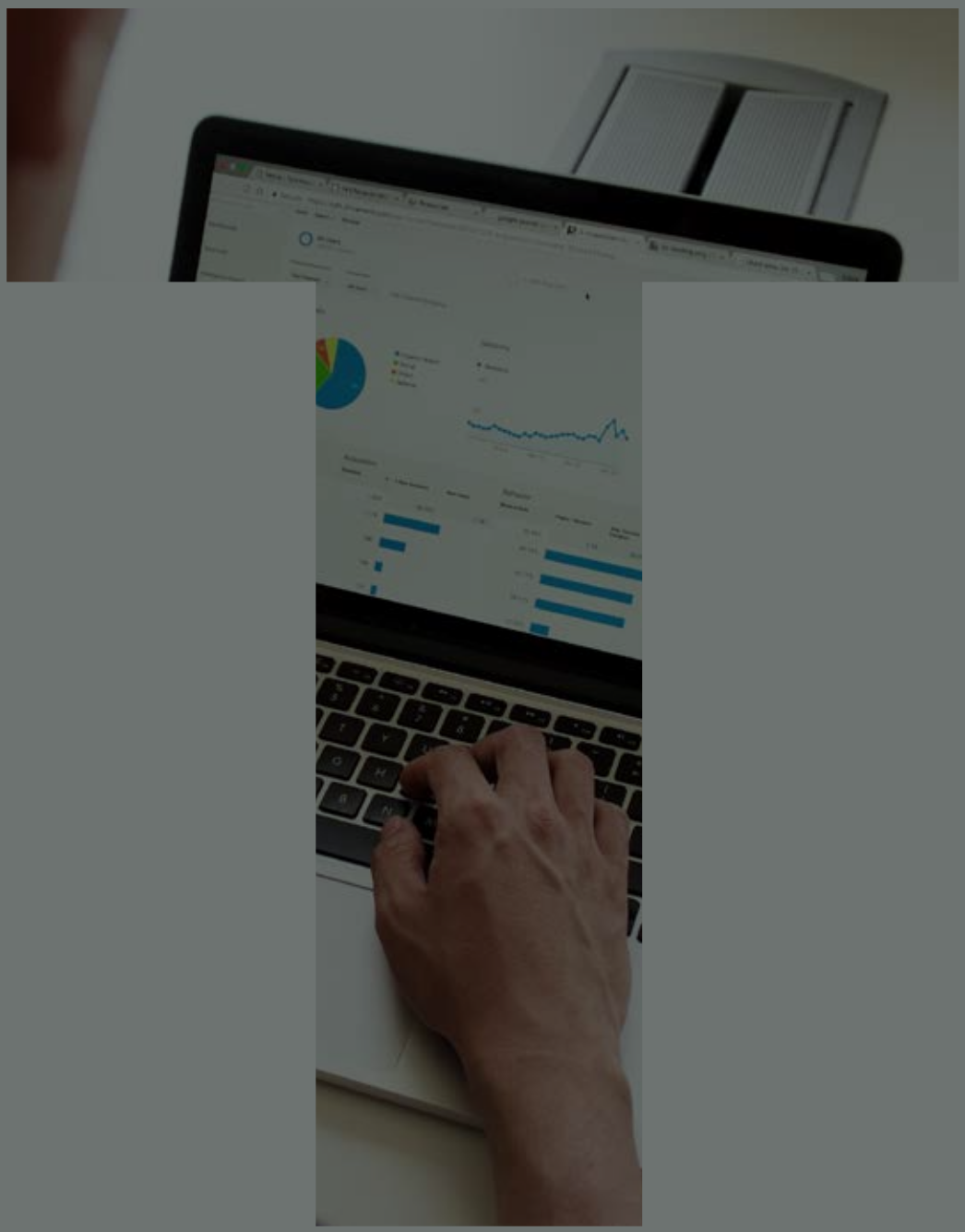
FP.3 Planning and Investment

Tactic: Research emerging practices in updating forecasts and infrastructure investment decisions to accommodate future needs associated with automated vehicles.

AVs will challenge the existing business models of transportation providers and infrastructure developers. This model includes public authorities incorporating fixed, physical infrastructure with no smart capabilities that can only be used by human-operated vehicles. This system limits the parameters of vehicle advancements, including traffic management improvements.[194]

Transportation-infrastructure providers will need to consider changes to infrastructure investment based on consumer attitudes related to AVs. With an uptake in AV use, highway authorities will need to understand how these vehicles see – whether that includes updating the maintenance of infrastructure, or incorporating connected vehicle technology altogether. For Toronto, this is especially important as it pertains to inclement weather like snow or fog. Assisting these vehicles in "seeing" better by customizing infrastructure to improve its visibility for AVs, could be a priority in the future. There is also an opportunity for infrastructure providers to share information through infrastructure to improve travel for all road users.

The City will research emerging practices in updating forecasts and infrastructure investment decisions to ensure that any future needs of AVs are addressed in the correct timeframe.



TACTICAL PLAN DATA GOVERNANCE

TACTICAL PLAN DATA GOVERNANCE

Open government requires well-managed and accessible information in order to function. With vast new data streams, emerging from both AVs and the infrastructure that supports them, developing tools to manage this new information pipeline and extract useful performance indicators will move the City towards successful execution of this Tactical Plan. Ultimately, a robust data governance framework can improve service delivery, build public trust and confidence in government, and enhance civic engagement through transparency, participation, accountability and accessibility.

GUIDING POLICIES AND STRATEGIES:

Congestion Management Plan (2016-2020):[169]

To enable rapid, comprehensive, and high-value open dataset releases, the City of Toronto needs to focus on establishing an automated data release pipeline that enables internal partners to seamlessly identify, access, and push data to the Open Data catalogue. Decreasing the manual effort required to publish and update open datasets is essential for modernizing and scaling up the City's Open Data program. Real-time access to data in its original, unmodified, and disaggregated form with full transparency on its progress through the publication pipeline is the goal.

WHAT WE NEED TO DO

- *Develop an automated publication pipeline that includes privacy and security considerations*
- *Make the publication pipeline public for progress tracking*
- *Publish real-time open data streams from primary record repositories*

Strategic Actions, 2013-2018:[195]

- *Enhance Performance Measurement*
- *Develop and implement a "best in class" performance measurement and indicators system across the organization by the end of 2015 by:*
- *Developing a Corporate Measurement and Indicators Framework with common language, standardized categories of performance measures and indicators, metadata standards, and processes to maintain and regularly update results.*
- *Implementing regular web-based reporting to the public, staff and Council on how Toronto is progressing including related to quality of life.*
- *Improving the City's capacity to compare its results over time, in relation to established targets, benchmarked to other cities, in Ontario, Canada and internationally and by neighbourhood.*

TACTICAL PLAN DATA GOVERNANCE

GOV.1 Collection of Data from Third Parties

Tactic: Develop and implement a policy and mechanism to collect data from automated vehicles using the transportation system. This data should support improved road safety, traffic management, transportation planning, asset management and transportation network security, consistent with Privacy by Design principles.

Connected and automated vehicles will be a rich source of data due to their high-quality sensors, fast processing capabilities, and extensive travel. These vehicles will be able to collect everything from hyper-local weather data, to the quality of road-side lighting, that can be shared with the appropriate parties in the network to assist in their day-to-day activities.[196]

The City of Toronto could potentially be informed when signage and infrastructure needs to be fixed, providing savings, faster response times, and greater public benefit. Regardless of how fast these vehicles are introduced however – data optimization will be needed to shape how this data is shared, impacted in large-part by operational and regulatory requirements from each level of government.

GOV.2 Data Tools

Tactic: Develop and implement robust tools to support new data streams from automated and connected vehicles.

AVs generate an immense amount of data – potentially several terabytes of data in eight hours of operation.[197] With such a large amount of data that can be shared, these networks will demand faster and more flexible infrastructure and tools in place to adapt to unexpected problems.

Governments will need to invest in robust tools that can help reduce data delays, and minimize the reliance on network data centres, while maintaining the privacy and security of the public with communication through them.

GOV.3 Monitoring Indicators

Tactic: Develop and implement robust indicators to monitor the transition from human-driven vehicles to automated vehicles as well as their associated impacts on the transportation system and delivery of City of Toronto services.

The Tactical Plan is based on available products, and predictions around when highly automated vehicles will be introduced on Toronto's streets. It has been built with the understanding that there is still a lot of uncertainty within this industry – and that the City of Toronto should focus on taking action on items that are relevant in the short-term.

As this technology develops, impacts to the transportation system and delivery of City of Toronto services will emerge, and the City's predictions around what those may be, could change. As such, monitoring indicators are an important aspect of measuring the on-going validity of this Plan. City staff will develop and implement indicators to monitor the transition from human-driven vehicles to automated vehicles, as well as their associated impacts on our organization, to ensure that the Tactical Plan continues to develop with these changes.

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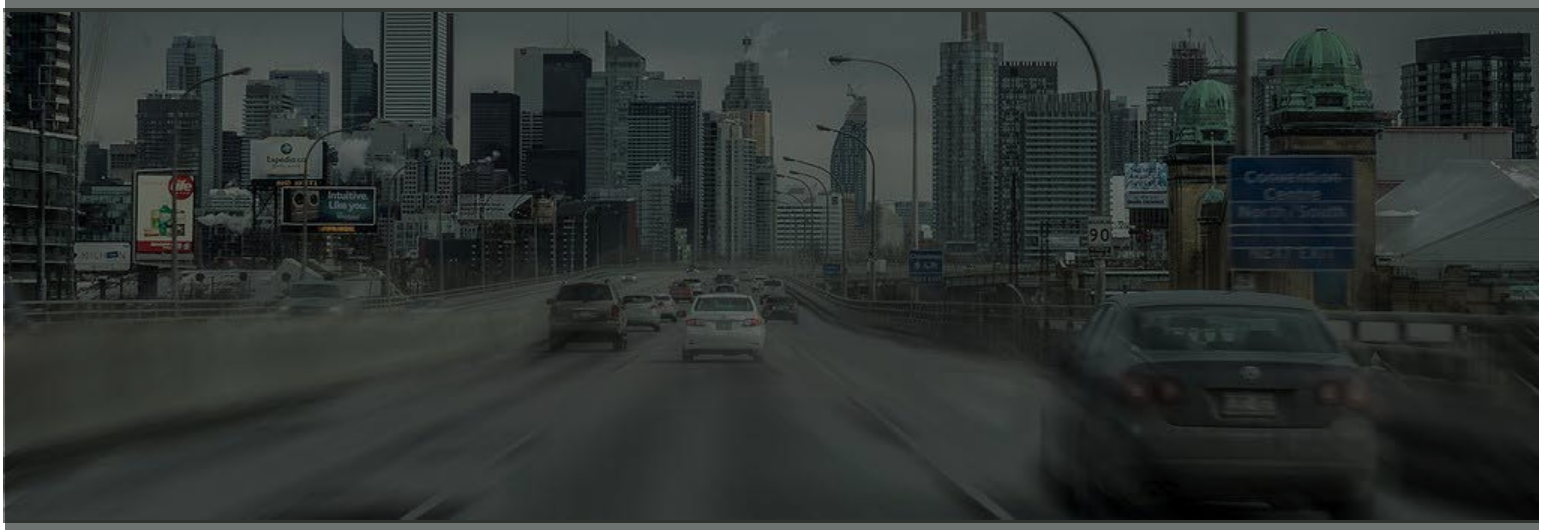

PART IV

AV READINESS 2022

PART IV: AV READINESS 2022

The Automated Vehicles Tactical Plan aims to prepare the City of Toronto for a massive shift in the transportation system as we know it over a span of three to thirty years. However, action needs to be taken today to ensure that Toronto remains ahead of this technology, and at pace with international development.

The City is taking a proactive, transit-centric approach to automation that recognizes the significant AV investments within the region, as well as the regulatory guidelines and changes at both the provincial and federal levels. The Province of Ontario recently updated its automated vehicle pilot program to allow for driverless vehicle testing (as opposed to requiring a human to provide oversight within the vehicle), and commercial sale of SAE Level 3 automated vehicles. The City needs to be ready to respond to impacts and related events from this technology being introduced to Toronto's streets.

This is just one of many examples of AV development already underway. Part IV: AV Readiness 2022, is Toronto's opportunity to be prepared for this transformation. The five projects outlined in this section describe what we will do immediately to ensure that the City is able to keep up with other municipalities; to catalyze the synergies between enhanced public services and new private innovations; and to stay ahead of further developments and long-term potential impacts from automated vehicles (i.e. land use, parking, etc.).

This section sets the foundation for Toronto to ensure that any significant changes related to this technology, will not come as a surprise to City government, or Torontonians.

AV Readiness 2022 is defined by the following five projects:

- *Automated Shuttle Trial*
- *Transportation Innovation Zones*
- *Testing Response & Incident Preparedness (TRIP)*
- *Information Hub*
- *Research & Development Program*

PART IV: AV READINESS 2022

Automated Shuttle Trial

Undertake and complete an automated shuttle trial project.

The AV Tactical Plan outlines the City of Toronto's strategic direction for automation, including equity, sustainability, mobility, and more. One important aspect of this strategy, is taking a transit-centric approach to automation.

Automated technologies should not move the City away from its intended policy objectives, but rather, be harnessed to help advance them. Automation in transit can contribute to the goals of this Tactical Plan, by ensuring a more space-efficient mode of travel, a more seamless system for the user, less acute demand across the transportation system, and improved safety.

For a fixed period of time, the Automated Shuttle Trial will test the ability of automated shuttle technologies to fill gaps in the current transit system, particularly first-mile/last-mile connections to rapid transit stations. The City of Toronto is partnering with the Toronto Transit Commission and Metrolinx with funding support from Transport Canada, to deliver this project and learn about some of the opportunities and challenges associated with integrating automated transit shuttles into the transit network.

The objectives of this project are to:

- Increase understanding and knowledge of the technical and administrative requirements to operate an automated shuttle
- Increase understanding and knowledge of the interaction and value of an automated shuttle in the transit and transportation system;
- Increase understanding and knowledge of the human response to an automated shuttle, including public support for innovation in the public transit system
- Provide leadership in automated vehicle preparedness at the municipal level through knowledge transfer and exchange with neighbouring municipalities
- Develop a plan to increase the attractiveness of Toronto for investment in the development and export of automated transit vehicle technology

This project will address and provide learning for the following tactics:

1.2.1 Equitable Service Coverage
3.1.1 Expand Investment and Employment
3.3.1 Global Competitiveness
3.3.2 Cross-Sector Collaboration
4.1.2 Privacy Standards: Automated Transit Vehicles
4.1.6 Privacy Attestation Services
5.1.2 Transition to AVs – Transit
6.3.2 Microtransit

PART IV: AV READINESS 2022

Transportation Innovation Zones

Establish a process and locations for "transportation innovation zones" in the City of Toronto.

Disruptive transportation technologies provide exciting opportunities for better public and private services. The City of Toronto is increasingly approached by private sector actors with requests to test new technologies on City infrastructure. Although these requests present unique prospects for Toronto, they also provide new challenges: the City does not currently have a framework for systematically assessing requests or obtaining approval for proposed trials, nor an area to dedicate towards potential testing – leaving some opportunities unseized.

A Transportation Innovation Zone framework will set the course for facilitating private-sector led transportation technology trials that are both supported by the public and have the potential to support existing City priorities. Specifically, the Framework will propose a fair and transparent process for receiving and assessing requests from the private sector, and an approach to obtain proactive expressions of interest from the public and stakeholders in potential Innovation Zones, as well as a process to streamline approvals for select testing activities in Innovation Zones.

A Transportation Innovation Zone will be a dedicated place to learn about automated vehicle technology and its relationship to the transportation system; allowing for quick trials and demonstration projects.

The development of this Zone and framework will begin with the following tasks:

- Research best practices for piloting/testing zones
- Assess and scope available and existing assets within the City that can be considered when developing the Innovation Zone (rights-of-way, works yards, etc.).
- Conduct stakeholder engagement to assess the impact of this Zone on municipal operations, and to identify the needs and concerns of community and industry stakeholders
- Develop a policy for streamlining requests for new technologies and testing

This project will address and provide learning for the following tactics:

3.1.2 Testing 'Sandbox'
5.1.5 Vehicle Collisions – Data Redundancy
5.2.1 AV Integration
5.2.2 AV Integration – Transit
5.2.3 AV integration – Connected Vehicles
5.2.4 New and Revised Standards
5.3.1 Emergencies – Vehicle Priority
6.1.1 Transit Priority
6.1.2 Active Transportation Priority
6.1.4 Urban Goods Movement
6.2.1 Street Design
6.2.2 Road Classification & Use
6.2.3 Flexible Curbs
7.1.3 Designated Loading Areas

PART IV: AV READINESS 2022

Testing Response & Incident Preparedness (TRIP)

Develop a "Testing Response & Incident Preparedness" system, including the submission of AV TRIP Plans by testers.

On January 1, 2018, the *Highway Traffic Act's* Ontario Regulation 306/15: Pilot Project – Automated Vehicles was updated by the Province of Ontario to reflect three important changes:

1. Automated vehicles equipped with SAE Level 3 technology are available for public purchase in Canada, and can be driven on Ontario roads. These vehicles are no longer restricted to registered pilot participants.
2. The testing of driverless AVs is now permitted on Ontario roads, under strict conditions.
3. Cooperative truck platoon testing is now permitted on Ontario roads, under strict conditions.

With these changes, came new application requirements for anyone requesting a permit to test on Ontario's roads.

1. The applicant must alert the impacted municipality and/or regional municipality in writing prior to testing to advise where the testing will take place. The Ministry recommends contacting the Municipal Clerk's Office.

2. In supplement to the application, the applicant must provide to MTO, municipalities (City Clerk) and relevant authorities such as law enforcement and first responders a work zone and law enforcement interaction plan, in writing and prior to testing, explaining how the vehicle will interact with police and emergency vehicles, how the vehicle will react to construction zones and how the vehicle will interact with police and construction personnel on public roads.[54]

Both changes will be addressed directly by municipalities, and the City of Toronto is working to ensure that it is prepared to receive location notifications and work zone/ law enforcement interaction plans while also addressing the impact of these notifications on City services.

The City of Toronto will establish an administrative system and response protocols to better respond to automated vehicle testing that occurs on Toronto streets, and to ensure that first responders and law enforcement are prepared for this technology for the continued safe piloting of AV technologies on our streets.

This project will address and provide learning for the following tactics:

5.3.2 Emergency Response Policies
5.3.3 Emergency Response Protocols and Training
5.3.4 Enforcement
5.3.5 Emergencies – Shared AV Fleets

PART IV: AV READINESS 2022

Human Learning

Initiate a collaborative effort to provide opportunities for human discovery and learning on safe use of and interaction with automated vehicles.

Toronto's Automated Vehicles Ecosystem section in Part I of this Plan outlines the various partners across industry, government, academic, research, civil society organizations, and residents in this space. With multiple players in our region there are numerous forms of messaging for the public on what automated vehicles are, how to interact with them safely, and what they could potentially mean for Toronto.

This project will ensure that the public knows how to interact with automated vehicles both as direct users and as individuals that share road space with AVs. A third-party group that can broker funding and messaging across government and industry is the proposed mechanism for the development of this project.

This project will address and provide learning for the following tactics:

4.1.3 Privacy Standards: Shared AV Fleets
5.1.1 Transition to AVs

PART IV: AV READINESS 2022

Research & Development Program

Foster research and development to solve current transportation-related challenges.

The City of Toronto recognizes that timelines, business models and impacts of driving automation systems are still uncertain. In the current and near-term, the City can harness the potential of automated vehicles through technological development in low-risk situations.

For long-term uncertainty, research can be undertaken to explore a range of scenarios, increase the knowledge of City staff, and begin to generate policy options in areas where changes could quickly shift.

Over the next three years, the City's AV Research & Development Program will focus on winter maintenance, particularly sidewalk snow clearing in the Toronto & East York district; as well as the studies outlined below.

PART IV: AV READINESS 2022

This project will address and provide learning for the following tactics:

1.1.1 Access for Individuals with Disabilities

1.1.2 Access to Transit for Individuals with Disabilities

1.1.3 Access for Unbanked Individuals

1.1.4 Access for Low-Income Individuals

1.1.5 Access for Non-Anglophones

1.2.2 Equitable Performance Standards

1.2.3 Mobility Neutrality

1.3.1 Healthy Mobility

2.1.1 Low or Zero-Carbon Energy Sources

2.1.2 Low or Zero-Carbon Energy Sources for Shared AV Fleets

2.2.1 Vehicle Waste Reduction

2.2.2 Vehicle Waste Reduction for Automated Transit Vehicles

2.2.3 Vehicle Waste Reduction for Shared AV Fleets

3.2.1 Talent Development

3.2.2 Workforce Reskilling

3.2.3 Community Benefits

4.1.1 Data Privacy Standards

4.1.4 Privacy Governance and Oversight

4.1.5 Privacy by Default

4.1.6 Privacy Attestation Services

5.1.3 Vehicle Collisions – Human Factors

5.1.4 Vehicle Collisions – Environmental Conditions

5.1.6 Vulnerable Road Users

5.1.7 Reducing Traffic Infiltration

5.1.8 Shared AV Fleet Safety Standards

5.4.1 Data Standards

6.1.3 High Occupancy AV Priority

6.1.4 Urban Goods Movement

6.3.1 Transit-Centric Mobility-as-a-Service (MaaS)

7.1.1 Transition to Automated Vehicles – Traffic Flow

7.1.2 Active Traffic Management & Coordination

7.1.4 Open Data

7.2.1 Curbside Fee

7.2.2 Transit Incentives and Pricing

7.2.3 Manage On-Street Parking Demand

7.2.4 Manage Off-Street Parking Demand

7.2.5 Manage the Peak

7.2.6 Manage Travel Demand

PSV.1 (Fleet Vehicle) Road Safety

PSV.2 (Fleet) Vehicle Effectiveness

PSV.3 (Fleet) Vehicle Safety

PSV.4 (Fleet) Vehicle Fueling

PSV.5 AV Fleet - Transit

PSV.6 Non-Passenger AVs for City Services

PSV.7 Contracted Service Vehicles

PSV.8 Data Collection

FP.1 Travel Demand Modelling

FP.2 Building Standards

FP.3 Planning and Investment

AR.1 Multimodal Level of Service

AR.2 Land Use Planning

AR.3 Parking Demand

AR.4 Strategic Foresight

AR.5 Mobile Production

AR.6 Mobility Marketplace

PART IV: AV READINESS 2022

Studies

Multimodal Level of Service

Develop and implement a mechanism to establish performance measures that ensure efficient movement of people and goods in an automated vehicle environment.

Measuring the performance of a given street or network for all users can pose challenges for transportation planners. Traditionally, a level of service (LOS) has been one of many tools employed to assess traffic conditions in cities, measuring the delay experienced by motorists at a given intersection. As cities increasingly embrace a multimodal future, new performance measures are needed to assess conditions for all users – pedestrians, cyclists, transit, and vehicles (passenger and freight). These measures should capture potential benefits as well as risks.[198]

Pedestrian measures might include walkability ratings, minimal delay at crossings, foot traffic volumes and public life surveys. Cyclist measures could include travel time and delay, bicycle counts and the Bicycle Environmental Quality Index. Transit measures could include on-time performance, ridership per revenue hour, and average speed. Vehicle performance measures could focus on safety (i.e., rate of crashes, injuries, and fatalities) travel time, freight delivered by hour and time spent loading and unloading.[198] AVs provide an opportunity to reimagine how we assess the performance of city streets.

Land Use Planning

Research potential impacts of automated vehicles on land use planning regulations, standards, and guidelines.

AVs will change more than just transportation – having an impact on the structure of our streets, cities, towns and neighbourhoods. On the one hand, this technology could increase the use of personal vehicles, which would exacerbate sprawl, congestion and pollution. On the other hand, if used predominantly through shared modes, there may be a reduction in the need for parking and expansion of roads, and increased potential to repurpose public space for uses such as businesses, green space, and walking/ cycling infrastructure.[199]

Regardless of the direction this technology may take, what remains true is that the City of Toronto must prepare for these impacts by researching how land use planning regulations, standards, and guidelines may need to change in line with AVs.

PART IV: AV READINESS 2022

Parking Demand

Research potential impacts of automated vehicles and emerging practices in updating parking demand forecasts and capacity requirements, as well as local parking authority services.

Research regarding the impact from AVs on parking often refers to predictions around more fleet-based shared travel, narrower vehicle sizes, and ultra-precise navigation technology - which would drastically reduce the need for parking.[200] A McKinsey & Company report predicted that by the middle of this century, driverless cars could cut the need for parking in the US by more than 61 billion square feet.[201]

Developers of projects being planned today already see parking garages as a changing investment, as more people are driven to places and events through private transportation network companies like Uber or Lyft. These companies have increasingly shifted the priority for planners from parking, to managing the competition for curb space. Designers have begun envisioning parking garages and lots as flexible structures that can be adapted for other commercial and residential uses.

By researching impacts from AVs on parking demand and capacity requirements, the City of Toronto will be able to make the investments needed ahead of time – saving future costs of converting this infrastructure. This study will allow Toronto to prepare, regardless of the outcomes of AV integration.

Strategic Foresight

Research and forecast broader societal changes that could impact the transportation system.

Macro-level trends – demographic, immigration, political and consumer trends – have historically had a widespread effect on transportation systems. For example, the City's current transportation network emerged and evolved largely as a product of the post-World War II baby boom. The infrastructural legacy of that era had considerable influence on transportation technology and policy which followed.

The effects of these macro-level societal trends tend to manifest over decades, not months or years. As new generational cohorts continue to influence broader society, it will be important to consider their potential effects or influence in the context of an emerging new mobility system including AVs.

PART IV: AV READINESS 2022

Mobile Production

Research potential impacts of AVs and mobile food preparation and manufacturing (e.g. 3D printing) and the City's ability to regulate these activities while taking place on moving vehicles.

Modern zoning, which separates land based on its use, emerged partly in response to the heavy industrial activities of the 19th- and 20th-century, where large industrial plants brought noise, pollution, smoke, odours and freight traffic to the city. The City of Toronto's current Zoning By-law 569-2013, for example, restricts all manufacturing and processing activities to Employment Industrial zones.[202]

However, emerging models of small-scale, light manufacturing and food-processing activities bear little resemblance to the production activities of the past. Multipurpose AVs are being developed, which can not only move people and goods, but also serve as mobile spaces for businesses such as delivery vehicles where food is prepared on route, or 3D printing workshops.[203]

While this model could open up new business opportunities for residents, it will need to be carefully monitored to ensure that commercial or light industrial uses do not pose a nuisance or hazard. The City of Toronto will explore the potential impacts of mobile production, and its role in regulating business activities which produce food, beverages, or other goods in limited quantities.

Mobility Marketplace

Research potential impacts of domination of the mobility marketplace by a small number of global providers and the City's ability to regulate or influence an appropriate level of competition and support for local companies.

The shift towards a mobility marketplace in which new platforms enable consumers to make choices that offer them the greatest value and convenience at the lowest price point is underway. Both the auto industry and newer entrants to the mobility field like Waymo, Uber and Lyft are investing heavily in developing their own mobility products and services.[204]

Accordingly, technology in the form of algorithms and machine learning now plays a significant role in many companies' business models. These technological advances which help to enable greater mobility choices could also lead to collusion between competitors and the formation of cartels among mobility service providers.[92]

As this marketplace changes, it will be essential to ensure Torontonians continue to have a wide range of mobility options. The City of Toronto aims to research how this will impact local businesses and residents especially if there is limited competition within the mobility marketplace.

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GLOSSARY

GLOSSARY

Advanced driver assistance systems (ADAS)
The precursors of AV technology offered by OEMs today in the form of advanced driver assistance systems (ADAS) such as blind spot monitoring, forward collision warning, lane assist among others.

Alighting
To descent from a train, bus, or other form of transport.

Algorithm
A sequence of instructions, rules, and calculations executed by a computer in a particular order to yield a result, typically an answer to a specified problem. Algorithms can be used in combination with other algorithms to solve complex problems.[205]

Artificial intelligence
1. *(discipline)* Artificial intelligence (AI) is an area of computer science that emphasizes the creation of intelligent machines that work and react like humans.
2. *(tool)* The term "artificial intelligence" is used to describe machines that mimic "cognitive" functions that humans associate with other human minds, such as "learning" and "problem solving".[205]

AV/AVs
Automated vehicle

Connected vehicle
A vehicle that is capable of safe, interoperable networked wireless communications among vehicles (V2V – Vehicle to Vehicle), the infrastructure (V2I – Vehicle to Infrastructure), (V2X – Vehicle to Other) or passengers' personal communications devices. Examples of communication modes can include Dynamic Short Range Communications (DSRC), Wi-Fi or 5G networks.

Driving automation system
The hardware and software that are collectively capable of performing part or all of the driving task on a sustained basis; this term is used generically to describe any system capable of level 1-5 driving automation.[1]

First mile
First mile is a term used to describe the movement of people and goods from a starting point in a home or business to a transportation hub. See also *Last mile*.

Last mile
Last mile is a term used to describe the movement of people and goods from a transportation hub to a final destination in the home. See also *First mile.*

LiDAR
A detection system which works on the principle of radar but uses light from a laser to measure distances to objects.

GLOSSARY

Low-income measure, after tax (LIM-AT)
The Low-income measure, after tax, refers to a fixed percentage (50%) of median adjusted after-tax income of private households. The household after-tax income is adjusted by an equivalence scale to take economies of scale into account. This adjustment for different household sizes reflects the fact that a household's needs increase, but at a decreasing rate, as the number of members increases.[206]

Low or Zero-Carbon Energy Sources
Low-carbon or zero-carbon energy sources reduce or eliminate carbon emissions associated with conventional petroleum fuels, such as gasoline and diesel. The most common low-carbon fuels are alternative fuels and cleaner fossil fuels, such as natural gas (CNG and LPG). The main purpose of a low-carbon fuel standard is to decrease carbon dioxide emissions associated with vehicles powered by various types of internal combustion engines while also considering the entire life cycle ("well to wheels"), in order to reduce the carbon footprint of transportation. Zero-emissions vehicles emit no exhaust gas from the onboard source of power, including harmful pollutants such as particulates (soot), hydrocarbons, carbon monoxide, ozone, lead, and various oxides of nitrogen.

Machine learning
Machine learning is the scientific study of algorithms and statistical models that computer systems use to effectively perform a specific task without using explicit instructions, relying on patterns and inference instead. It is seen as a subset of artificial intelligence. Machine learning algorithms build a mathematical model based on sample data, known as "training data", in order to make predictions or decisions without being explicitly programmed to perform the task.[205]

Mobility-as-a-Service (MaaS)
Mobility as a Service or Transportation as a Service, describes a shift away from personally owned modes of transportation and towards mobility solutions that are consumed as a service. This is enabled by combining transportation services from public and private transportation providers through a unified gateway that creates and manages the trip, which users can pay for with a single account.

Non-OEM companies
Companies which do not manufacture their own vehicles, but may – for example – modify an existing vehicle by "integrating systems from multiple suppliers and coupling that with their own AV technology stack".

Original Equipment Manufacturer (OEM)
Any company that manufactures parts for use in new vehicles, but often used to describe automobile manufacturers that assemble and market vehicles under their own brand.

GLOSSARY

Private Transportation Company (PTC)
A Private Transportation Company (PTC), sometimes known as a transportation network company (TNC), mobility service provider (MSP) or ride-hailing service, is a company that matches passengers with drivers (or eventually AVs) via websites and mobile apps. A PTC is defined in the Toronto Municipal Code Chapter 546, Licensing of Vehicles-For-Hire § 546-1.

Radar
A device or system consisting usually of a synchronized radio transmitter and receiver that emits radio waves and processes their reflections for display and is used especially for detecting and locating objects or surface features.[207]

Ride-hailing
The act of hailing a private vehicle for the purposes of securing a transportation service. Usually paid for by a time and/or distance based fee. Excludes: traditional taxis, limousines and public transportation.
See Private Transportation Company (PTC)

Ride-sharing
The act of sharing a private vehicle with another known or unknown passenger and sharing the cost of operating the vehicle (such as carpooling).

Shared automated vehicle (AV) fleet
Driverless vehicles (SAE Level 4 or 5) operated as part of an on-demand ride-hailing service

SAE Levels of Driving Automation
The current global standard for indicating the level of driving automation. There are six levels, from zero to five. The higher the level, the more the vehicle is capable of handling the full driving task without human intervention, including monitoring the environment, navigating between destinations, and avoiding collisions.

Travel Demand Model (TDM)
Travel Demand Models (TDM) are computer programs which predict how people use transportation systems. They are used to test the implications of infrastructure (e.g. the addition of a new road or higher-order transit line), policy (e.g. changes to transit service levels or fare policies) or technology (e.g. AVs) changes on future travel patterns. These predictions of future travel patterns are based on projected land use, demographics, and the region's existing travel patterns, through variables such as population, employment, households, current travel behaviour, and more. Outputs can include traffic volumes for various roadway segments, ridership on transit routes, and travel times.

GLOSSARY

Transportation Network Company (TNC)
See Private Transportation Company (PTC)
Ultrasound
Vibrations of the same physical nature as sound but with frequencies above the range of human hearing. Used to detect objects by emitting pulses or vibrations, and detecting or measuring their return after being reflected.[208]

Unbanked
Unbanked (or financially excluded) refers to those individuals who lack access to some or all mainstream banking services.

Vehicle-to-infrastructure (V2I) communication
In V2I, the infrastructure plays a coordination role by gathering global or local information on traffic and road conditions and then suggesting or imposing certain behaviors on a group of vehicles. One example is ramp metering, already widely used, which requires limited sensors and actuators (measurements of traffic density on a highway and traffic lights on ramps).

Vehicle-to-vehicle (V2V) communication
Vehicle-to-vehicle (V2V) is an automobile technology designed to allow automobiles to "talk" to each other. The systems will use a region of the 5.9 GHz band set aside by the United States Congress in 1999, the unlicensed frequency also used by Wi-Fi. The US V2V standard, commonly known as WAVE ("Wireless Access for Vehicular Environments"), builds upon the lower-level IEEE 802.11p standard.

Vehicle-to-everything (V2X) communication
V2X communication is the passing of information from a vehicle to any entity that may affect the vehicle, and vice versa. It is a vehicular communication system that incorporates other more specific types of communication as V2I (Vehicle-to-Infrastructure), V2V (Vehicle-to-vehicle), V2P (Vehicle-to-Pedestrian), V2D (Vehicle-to-device) and V2G (Vehicle-to-grid).

VKT
Vehicle Kilometres Travelled

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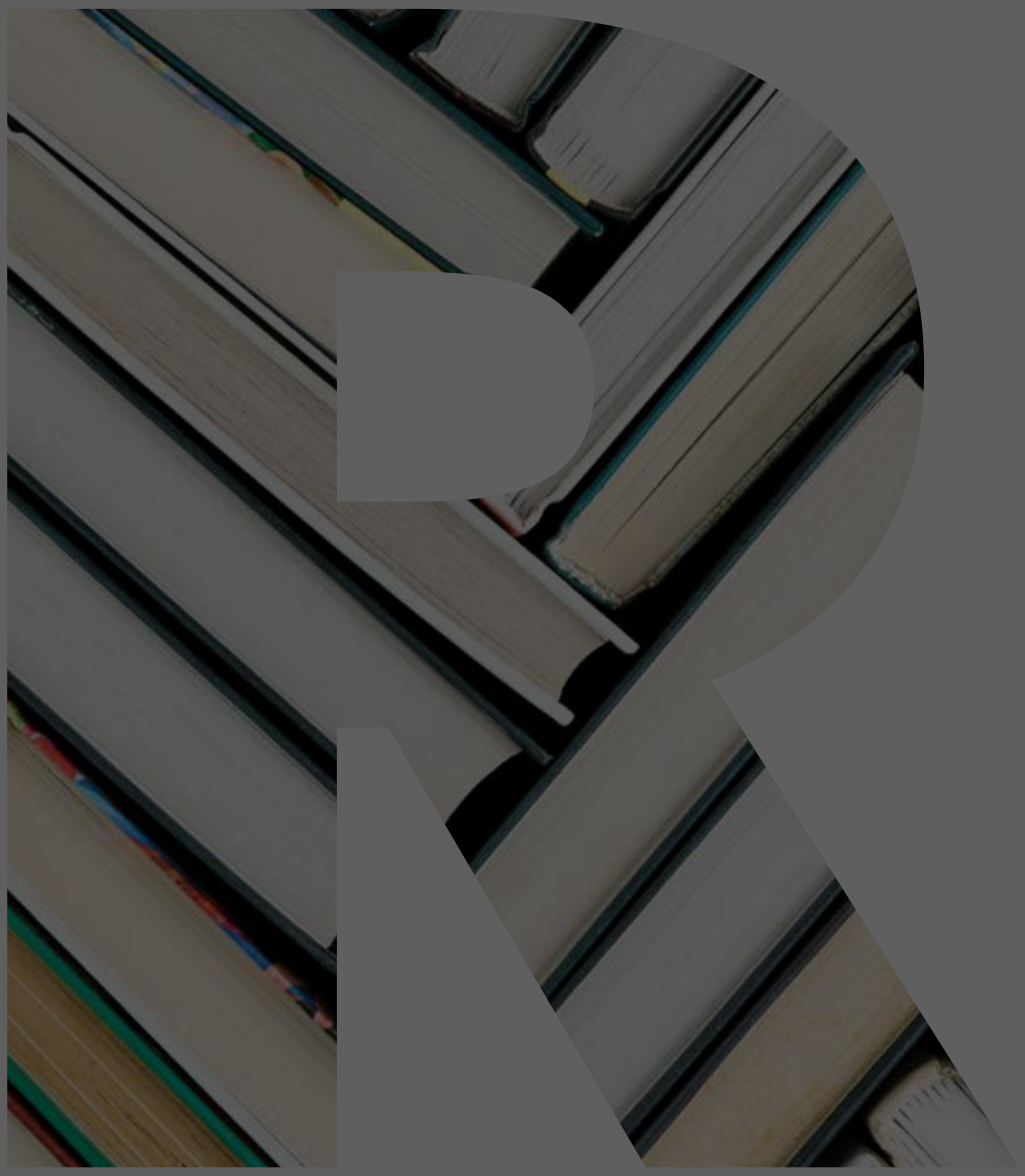

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APPENDICES

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APPENDIX A: JURISDICTIONAL POLICY SCAN

When it comes to envisioning a future with automated vehicles, Toronto is not alone. Cities around the world having been paying close attention to automated vehicle technology and developing policy to both mitigate threats and maximize opportunities that this shift may bring. In developing the Tactical Plan, the Automated Vehicles team conducted a broad environmental scan of automated vehicle and new mobility policies to learn best practices from peer cities.

Review of Policies
Adelaide, AU • **Supporting policy:** The 30-Year Plan for Greater Adelaide[209] South Australia is the first region in Australia to provide laws allowing for the on-road trials of driverless vehicles. In June 2016, the South Australian Parliament enacted the *Motor Vehicles (Trials of Automotive Technologies) Amendment Bill 2016.* This new legislation provides guidelines to facilitate on-road testing and development of driverless vehicles and other advanced automotive technology on South Australian roads. There have been at least nine trials approved by the Department of Planning Transport and Infrastructure since this legislation came in place. The South Australian Government has also provided $10 million over three years to projects that contribute to the applied research of Future Mobility technologies that provide real benefits to its communities. This investment named the Future Mobility Lab Fund aims to foster development in the connected and autonomous vehicle field.[210] There is also an industry advisory body known as the Australia and New Zealand Driverless Vehicle Initiative (ADVI) that supports the safe and successful introduction of driverless vehicles in Australia. This Initiative is supported by over 120 partners from across the automotive, insurance, transport, motoring, parking, communications, banking, logistics, defense, technology and research sectors, as well as all levels of government.[211] There are a number of strategic documents that guide the ADVI's work, including: • Secure Your Seat[212] • Strategic Goals[213]
Austin, TX • **Supporting policy:** Smart Mobility Roadmap[214] Encompasses five areas: • Shared-Use Mobility • Electric Vehicles and Infrastructure • Autonomous Vehicles • Data and Technology, and • Land Use and Infrastructure The first section provides insight into each of these areas as well as the convergence of technology. It also discusses national efforts related to shared, electric and autonomous mobility. The second section looks at how this technology may affect Austin's equity, affordability, safety and workforce. The final section discusses the current Council and Board resolutions and initiatives, and describes how executing a plan like this may impact projects and operational resources.

APPENDICES

Boston, MA

- **AV policy:** Executive Order on Autonomous Vehicles in the City of Boston[215]
- **Supporting policy:** Go Boston 2030[174]

Automated vehicle policies exist within the context of a broader mobility strategy

Issued by the Mayor's Office on October 20, 2016, the Executive Order established a city-wide policy for autonomous vehicles in the City of Boston and required that the Boston Transportation Department:

- Publish testing guidelines for AVs which limit the time, place and manner of testing operations as well as establish a reporting requirement
- Develop policy recommendations regarding AV technology, business models, and street regulation and design which ensure sustainability, accessibility and equity goals are achieved.

Columbia, SC

- **Supporting policy:** The Columbia Compass[216]

The Columbia Compass is the comprehensive plan for how Columbia, South Carolina will grow over the next ten years. The City of Columbia is currently in the process of researching and developing this plan.

The Transportation section of the Columbia Compass outlines its vision, stating that transportation is about mobility and accessibility for all – not just cars, but pedestrians, bikes, transit, freight and passenger rail.

The guiding principles include:

- Transportation safety for all users
- Equitable access to opportunities
- Respecting neighborhood identities and promoting community investment
- Improving network resilience through increased connectivity, green infrastructure and enhanced multimodal connections
- Exploring innovative ways to meet the current and future needs of the City including transportation technology, shared mobility, and alternative funding mechanisms
- Creating a connected multimodal network that improves travel choice, and increases the share of citizens who bike, walk, or use transit for daily travel

The draft recommendations include preparing for future technology – specifically, planning for impacts from alternative fuels, advances in freight delivery logistics, alternative mobility modes, and autonomous/ self-driving vehicles.[217]

Dubai, UAE

- **AV policy:** Dubai Autonomous Transportation Strategy

The Dubai Future Foundation, in conjunction with Dubai's Roads and Transport Authority produced the Dubai Autonomous Transportation Strategy that aims to transform 25% of total transportation in Dubai to autonomous vehicles by 2030. The strategy includes the launch of the Dubai World Autonomous Transportation Challenge as a global request for procurement to encourage the world's most innovative and cutting-edge companies, academic institutions, and research and development centers to test advances in this technology that are tailored to the streets of Dubai.[218]

Dubai's vision includes three key areas of focus:

1. Comprehensive and integrated multimodal self-driving transport services.
2. Self-driving transport operations policies and legislation.
3. The worldwide self-driving transport competition.[219]

APPENDICES

Los Angeles, CA

- **Supporting policy:** Urban Mobility in a Digital Age[220]

Transportation Technology Strategy
This transportation technology strategy proposes several policy considerations, near-term actions and pilot projects for LADOT to consider as it prepares for better urban mobility in the future.

1. Build a solid data foundation
2. Leverage tech + design for a better transportation experience
3. Create partnerships for more shared services
4. Establish feedback loops for services + infrastructure
5. Prepare for an automated future

Urban Mobility in a Digital Age - Pilots

Data-as-a-Service

- Analyze crowdsourced data for roadway design impacts on congestion
- Test customer feedback tools on public services
- Develop an online project dashboard for this strategy
- Deploy connected infrastructure in the Promise Zones
- Experiment with parking inventory technologies

Mobility-as-a-Service

- Launch mobility hubs to integrate and connect modes
- Pilot on-demand transit
- Expand shared services to low-income neighbourhoods citywide
- Test smart fares

Infrastructure-as-a-Service

- Deploy temporary car-free zones across the city
- Test assumptions around roadway capacity and utilization
- Identify new infrastructure assessment tools
- Launch an AV pilot
- Pilot an AV network on city streets and incentivize sharing

APPENDICES

Portland, OR

- AV policy: Connected and Automated Vehicles Policies221
- Suppo**rting policy:** 2035 Comprehensive Plan[222]

The City of Portland, Oregon has been developing AV policies since 2017 when the Mayor signed the Smart Automated Vehicles Initiative (SAVI) and directed the Portland Bureau of Transportation to propose interim policies that "ensure connected and autonomous vehicles will serve Portland's safety, equity, climate change, and economic goals."

Connected and Automated Vehicles Policies

Priorities and outcomes:

- Prioritize connected and automated vehicles that are fleet/shared ownership, fully automated, electric and, for passenger vehicles, shared by multiple passengers (known by the acronym FAVES).
- Develop and implement strategies for each topic.

Tools:

- Use a full range of tools to ensure that connected and automated vehicles and private data communications devices installed in the City right of way contribute to achieving Comprehensive Plan and Transportation System Plan goals and policies.

Seattle, WA

- **AV policy**: Preliminary Automated Mobility Policy Framework[13]
- **Supporting policy:** New Mobility Playbook[223]

1. Continue prioritizing the needs of people walking, biking, and taking transit and leveraging the growth of our robust transit network.
2. Support the development and testing of automated mobility technology, learning from the pilots and partnerships with local and national technology and operating equipment manufacturers (OEMs).
3. Establish clear policy parameters that ensure AVs help achieve the Mayor's five core values and the shared and emerging mobility principles —not counteract them.
    - Put people first
    - Design for customer dignity and happiness
    - Advance race and social justice
    - Forge a clean mobility future
    - Keep an even playing field

APPENDICES

Washington, DC

- **AV policy:** Autonomous Vehicles Principles Statement

The City of Washington established an Interagency Working Group on Autonomous Vehicles in February of 2018. The District engaged in peer-to-peer learning with other cities to explore the implications of this technology.[224] In 2017 the Working Group established a set of principles that are more specific to the needs and opportunities of Washington; stating that if AVs are deployed and integrated into the transportation system adhering to these principles, Washington will be able to maximize benefits and proactively address challenges.

The principles for AV deployment in the District are as follows:

1. Safety - reduce driver, passenger, and pedestrian injuries and fatalities, and protect consumer data
2. Equity - improve access across geographies and populations, improve accessibility
3. Efficiency - reduce the inefficiencies and negative externalities of congestion, reduce costs, reduce pollution, improve movement
4. Sustainability - improve environmental impacts, be financially sustainable, adapt to changes

To achieve these principles, the Working Group recommends that the DC Government embody the following attributes:

1. Adaptability
2. Transparency and Privacy
3. Comprehensiveness
4. Alignment[225]

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