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.[61]

If in the future higher level AVs become widely adopted, there may be significant reductions in the number of collisions on Canadian roads.[49] 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.[62]

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.[63] 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.

Guiding Policies and Strategies:

Vision Zero Road Safety Plan (2017-2021):[61]

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.

Summary of Goals and Tactics

Goals	Tactics	Key performance indicators
5.1 Prevent Collisions	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	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)
5.2 Update Infrastructure	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	Number of infrastructural barriers to AV use eliminated
5.3 Update Emergency Response	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	Average response speed (specifically driving time)
5.4 Protect Data Confidentiality, Integrity & Availability	5.4.1 Data Standards	Month-over-month percentage +/- (increase/decrease) of security breaches that result in unauthorized data discovery, and leakage, of personal information.

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.

5.1.1 Transition to AVs

Proposed 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.[64] 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.[65] 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.[49]

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

Proposed 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.

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.[10]

These technologies may 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.[10] 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.[66]

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

Proposed 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.[61] 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.[49]

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.

5.1.4 Vehicle Collisions - Environmental Conditions

Proposed 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.[67] 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.[68]

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 – Traffic Control Redundancy

Proposed Tactic: Develop and implement a practice of triple redundancy of traffic controls to reduce injuries and deaths from vehicle collisions resulting from an automated driving system failure to detect any one particular traffic control data source.

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.[69]

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.

5.1.6 Vulnerable Road Users

Proposed 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.[61]

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.[70] 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

Proposed 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.[71]

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.[72]

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

Proposed 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.[73] 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.[74] 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.

5.2.1 AV Integration

Proposed 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.

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

Proposed 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.[75] Gradual deployment around automated transit, wherein "AV-based service networks are installed and managed for constrained public applications."[76] 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. This is one method for municipalities to deal with the integration of automation into 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

Proposed 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.[77] 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.[78] 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

Proposed 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.[79]. 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.[79]

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.

5.3.1 Emergencies – Vehicle Priority

Proposed 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.[80]

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

Proposed 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

Proposed 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.[81] 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 an accident.[82]

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.[83]

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 a detailed training note, online modules, and other materials designed from industry content, and will assess the opportunity for hands-on training in an AV.

5.3.4 Enforcement

Proposed 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.[84]

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

Proposed Tactic: Develop and implement approaches for shared AV fleet companies to manage vehicle malfunctions and 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.[85]

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 driving automation systems 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.

5.4.1 Data Standards

Proposed 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.[50]

One of many potential data access models is the data trust – a legal structure in which trustees provides 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).[86] 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.[87]

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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