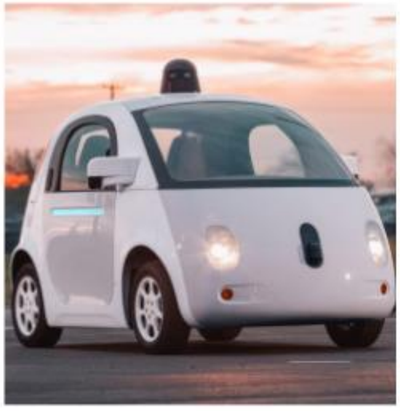

Appendix A

Connected and Autonomous Vehicles:

Technical Background

Prepared for the
Corporation of the City of London

Civic Works Committee Meeting

May 28, 2018

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1 INTRODUCTION

Autonomous vehicles (AVs) are driverless or self-driving vehicles that are capable of detecting the surrounding environment using artificial intelligence (AI), a variety of sensors, and a global positioning system (GPS) coordinates among other means to successfully and safely navigate a transportation system.

AVs have the potential to deliver the following if properly managed:

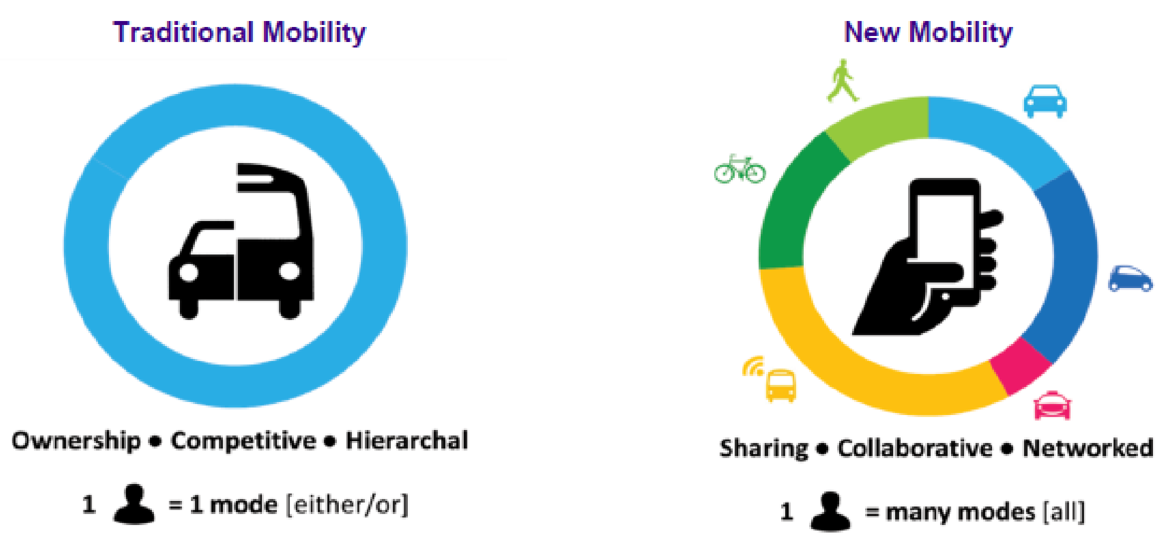
- Environmental benefits;
- Economic prosperity;
- Societal betterment;
- Safety improvements;
- Traffic congestion management; and
- Improved flow of goods and services.

One of the major improvements to road safety is the elimination of human driver error and distraction, due to the AV technology taking over the driving operation. However, this expectation needs to be tempered with early levels of vehicle autonomy where the attention of the human driver to maintain safe vehicle operations remains critical.

It is anticipated that AVs will be widely available and market-ready anywhere between now and 2040[1] with some lower level automation vehicles already on the market and in use today.

The emergence of new app-based transportation services, such as Uber and Lyft, has expanded the market for ride-hailing services by offering lower prices, improved convenience and rider amenities, and stronger brand recognition compared to traditional taxis. These services include new features such as a split-fare and shared-ride / carpool functions, enabling two or more people to share rides and split the cost.

The impending arrival of AV technology is expected to have a significant impact, by changing the personal economics of transportation choice, and likely resulting in a shift in the current transportation paradigm.



There are two primary ownership models anticipated for AVs as they emerge, the individual ownership model and the shared ownership model.

The individual ownership model is similar to the current, widespread car ownership model. If the AV technology advances with emphasis on individual ownership, this will likely decrease public transit use, promote more travel, and result in more cars on the road.

The shared ownership model which is similar to car sharing, ridesharing, or Mobility-as-a-Service (MaaS) programs that may likely see a communal fleet of vehicles to service transportation needs and will reflect the trend that new generations are not as interested in vehicle ownership as previous generations[2].

In practice, it is more likely that a mixed ownership model consisting of both individual and shared ownership will emerge. However, the proportion of individual vs. shared ownership is uncertain as the direction of AV technology is unclear at this time.

Policymakers should work with transportation professionals, telecommunication providers, vehicle companies, and software technology companies to assess the impacts, develop short and long-term implementation policies, and prepare investment strategies to facilitate and mitigate the impacts of this technology.

Interrelated with autonomous vehicles is connected vehicle (CV) technology[3], which is integral to providing up-to-date information to AVs through a variety of communications channels, including:

- **Vehicle-to-Vehicle (V2V):** Enhance the situational predictability and operation of AVs in close proximity such as through platooning (i.e. AVs travelling together in close formation), intent (e.g. lane changes, braking, etc.), and hazards (e.g. flat tire, roadway debris, etc.).

- **Vehicle-to-Infrastructure (V2I):** Directly communicate the status and condition of nearby infrastructure (i.e. infrastructure-to-vehicle) and presence/intent of the vehicle-to-infrastructure. Examples of this include Smart Traffic Signals that better manage transportation demands and congestion; and, Smart Parking that efficiently directs AVs to available parking spaces.

- **Vehicle-to-Everything (V2X):** A more general term for communications with an AV's surroundings in addition to V2V and V2I that may include vehicle-to-pedestrian/bicycle communication (e.g. location information to reduce conflict and improve safety) or vehicle-to-network communication (e.g. Google's Waze or similar real-time application).

Some elements of CV technologies are already being implemented in other cities and are being considered for the City's current Transportation Intelligent Mobility Management System (TIMMS) project.

2 TAXONOMY AND DEFINITIONS

Many automated features, ranging from cruise control to self-parking and lane assist, have been available on vehicles for a number of years. To answer the question of when a vehicle crosses over from being high-tech to self-driving, the Society of Automotive Engineers (SAE) has established a new international standard (J3016)[4] that provides a classification system for vehicle automated driving systems. There are six levels of driving automation which span from no automation (Level 0) to full automation (Level 5).

A brief overview of the SAE levels of automation is provided below:

- **Level 0:** Human driver monitors the driving environment and performs full driving tasks.
- **Level 1:** Human driver monitors the driving environment while the driver assistance system executes either the steering or acceleration/deceleration tasks for a specific driving scenario.
- **Level 2:** Human driver monitors the driving environment while the driver assistance system executes both the steering and acceleration/deceleration task for a specific driving scenario.
- **Level 3:** Automated driving system monitors the driving environment and executes all aspects of the driving tasks for a specific driving scenario, with the expectation that the human driver will respond appropriately to a request to intervene.
- **Level 4:** Automated driving system monitors the driving environment and executes all aspects of the driving tasks for a specific driving scenario, even if the human driver does not respond appropriately to a request to intervene.
- **Level 5:** Automated driving system monitors the driving environment and executes all aspects of the driving tasks for all driving scenarios.

The key distinction is between Level 2, where the human driver monitors the driving environment and performs part of the dynamic driving task, and Level 3, where the automated driving system monitors the driving environment and performs the entire dynamic driving task. That distinction is important as it leads to the potential for two different AV ownership models (described above), individual or shared. Both ownership models (and the proportions of each) will provide different new opportunities and challenges for transportation networks.

3 KEY PRIVATE AND PUBLIC PLAYERS

There are many players who play a role in shaping the autonomous vehicle scene[5]. Google, Uber, most major automakers, and other organizations are investing significantly in the advancement of driverless technology. Additionally, many research institutions are partnering with automakers to provide research support, validation, and testing sites. Several universities are also studying the ethical questions associated with driverless cars (e.g. how to determine who gets harmed versus saved in an unavoidable collision).

Some of the key players involved in the autonomous vehicle industry include:

- **Automakers** – Nissan, Mercedes, Tesla, Daimler, Ford, Volvo, Audi;
- **Technology Providers** – Google, Uber, Apple, Alibaba, Baidu, Easy Mile, Navya;
- **Research Institutions** – Multiple engineering colleges in Canada and the US;
- **Manufacturing** – A range of hardware systems providers;
- **Insurance Agencies** – Establishing ramifications of fault;
- **Legal Advisors** – Crafting the laws surrounding autonomous vehicle use;
- **Federal Government** – Supports research on safety and policies around CAVs;
- **State and Provincial Governments** – Jurisdictional legislation enabling testing and use and any need for special licensing; and
- **Local and Regional Governments** – Mostly looking to understand the implications of the technology on bylaws, enforcement, and infrastructure. Also, provide testing locations.

Automakers and technology providers are pushing the technology into uncharted territory, from a legal and technological standpoint. Audi has announced the new A8 sedan, its luxury flagship, which is anticipated to be the first Level 3 autonomous vehicle in Canada and may be released as early as 2018. Some companies don't see a way to make Level 3 vehicles safe, due in large part to the issue of the handoff between automated system and driver. As a result, companies like Volvo, Ford, and Google are opting to target Level 4 production. Experimental programs and permits in Ontario current require vehicles with an automated system of at least Level 3.

4 OVERVIEW OF CURRENT LEGISLATION AND PROGRAMS

The introduction of a more integrated transportation mobility environment raises questions about what this disruption will mean for the transportation industry. Base engineering assumptions such as lane widths, roadway cross sections, and merge lane lengths may need to be reconsidered. How streets are designed may need to be changed, taking into account the possibility of reduced demand, changes to parking requirements, and AV demands for enhanced information technology (IT) infrastructure.

In order to proactively prepare for these changes, policies and programs are currently being initiated federally and provincially to prepare for CAV technology. Policymakers have identified that Ontario provides an excellent opportunity to lead in the development and application of CAV technology because of its strength in the information, communication, technology, and automotive industries, together with its extensive transportation infrastructure.

4.1 Province of Ontario Legislation

On January 1st, 2016, Ontario became the first province in Canada to pilot an on-road test program for automated vehicles and related technology. This pilot was initiated to facilitate investment and development in Ontario. The pilot applies to vehicles of SAE levels 3, 4, or 5 and outlines requirements for monitoring by a driver, insurance, and reporting to Ministry of Transportation, Ontario (MTO)[6].

Highlights of the Ontario's current (2016) AV pilot regulations include:

- Vehicles are restricted to testing purposes only;
- A 10-year duration for the pilot, including interim evaluations;
- Only vehicles manufactured and 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;
- The driver must hold a full class licence for the type of vehicle being operated;
- Eligible participants must have insurance of at least $5,000,000;
- All current Highway Traffic Act rules of the road and penalties will apply to the driver/vehicle owner; and
- Vehicles must comply with SAE Standard J3016 and any requirements of the Motor Vehicle Safety Act (Canada) that apply to automated driving systems for the vehicle's year of manufacture.

On December 21st, 2017, the MTO engaged stakeholders via Ontario's Regulatory Registry[7] and proposed amendments to the AV pilot regulation[8]. These proposed enhancements to the AV pilot program are to:

- **Permit driverless testing of AVs.** The testing of AVs as part of the pilot through additional application requirements, such as a law enforcement and work zone interaction plan and alerting local municipalities of AV testing.
- **Expanded data reporting requirements.** Pilot participants would need to indicate the SAE level of the AV tested, annual reports on unplanned or non-scheduled disengagements, in-vehicle telematics (e.g. hours tested, distanced travelled, speed, harsh braking, etc.), weather conditions, and road types.
- **Permit public registration of SAE Level 3 AVs.** This would include Original Equipment Manufacturer (OEM) AV technology eligible for sale in Canada, not aftermarket and/or AV conversion products. The MTO expects SAE Level 3 AVs to be commercially available in the near future. MTO communications will include updated beginner driver education handbooks and outreach to auto industry stakeholders to leverage the availability of safety information to consumers.
- **Permit cooperative truck platoon testing.** A new pilot (within the existing AV pilot) that allows the testing of cooperative truck platooning with a driver present in each vehicle, under strict conditions and along specified routes. Cooperative truck platoons utilize a form of adaptive cruise control with V2V communication that allows for closer following distances and improved efficiencies.

The effective date of the above-proposed amendments described above is unclear at the time of writing.

4.2 Ontario Centre of Excellence

Encouraging development partnerships has been recognized as an important step in preparing for AVs. The Ontario Centre of Excellence (OCE) has rolled out a Connected Vehicle / Automated Vehicle Program that encourages partnerships between companies, and/or partnerships between companies and academic research teams to develop and commercialize innovations in CAV technologies that focus on projects demonstrating strong potential for commercialization. With this phase of the program, OCE will allocate $2,000,000 leveraged by matching contributions from small, medium and large companies[9].

4.3 Autonomous Vehicle Innovation Network

In November 2017, the Province of Ontario launched the Autonomous Vehicle Innovation Network (AVIN), investing over $80 million over 5 years[10]. The AVIN programs focus on supporting the development and demonstration of CAV technologies, transportation infrastructure, intelligent transportation systems (i.e. the City's current TIMMS project), and transit-supportive systems and vehicles in Ontario.

The AVIN has five main objectives[11]:

- Commercialize C/AV and transportation and infrastructure system technologies;
- Build awareness, educate and promote Ontario as a leader;
- Encourage innovation and collaboration;
- Leverage Ontario talent; and
- Support regional auto brain belt clusters.

4.4 Ontario Good Roads Association

In November 2016, the Ontario Good Roads Association spearheaded the creation of the Municipal Alliance for Connected and Autonomous Vehicles in Ontario (MACAVO). This alliance between municipalities across Ontario actively promotes the testing and integration of CAVs within our communities in an effort to have all jurisdictions work together. This provides MACAVO members with the opportunity to learn from each other and develop a synchronized set of logistics, policies, and communication channels to help the CAV industry move forward in Ontario while integrating with municipal services[12].

Presently (as of March 2018)[13], MACAVO is actively engaging Ontario municipalities to develop a preliminary transportation network that is supportive of the preferred use of SAE Level 4 and 5 CAVs. The vision is to develop a province-wide CAV corridor between Windsor and Ottawa with seamless transitions between municipalities. Once achieved, this would be the first and largest CAV corridor developed in the world with anticipated socio-economic and Vision Zero benefits.

Following the establishment of a designated Windsor-Ottawa CAV corridor and network supportive of fully autonomous vehicles, next steps facilitated by MACAVO in preparation for CAVs may include:

- Engaging automobile and original equipment manufacturers (OEMs);
- Engaging the Ontario Provincial Police (OPP) and other municipal authorities;
- Engage the OCE, AVIN, universities and other development networks;
- Identify special transportation network features required for CAVs; and
- Identify data sharing and security.

4.5 Institute of Transportation Engineers

In April 2018, the Institute of Transportation Engineers (ITE) released a Position Statement on CAVs in light of recent safety concerns that highlights the current state of the technology with the understanding that these positions should evolve over time[14].

A summarized version of these key tenets include:

- The support that zero fatalities and serious injuries (i.e. Vision Zero objectives) can only be achieved through CAV technology;
- Caution that loosely regulated deployment of CAVs risks innocent lives;
- The support for the rapid adoption of safety assist (SAE Level 1) technologies;
- Caution that current SAE Level 2 and 3 technologies requiring driver monitoring have not yet been proven safe for general use in all environments;
- SAE Level 4 systems are the most appropriate as an objective for “driverless vehicles”; and
- Cooperative systems achieved through communication between vehicles, infrastructure, and other users will provide an enhanced layer of safety and must be pursued.

4.6 Canadian Urban Transit Association

The Canadian Urban Transit Association (CUTA) published *Transit Vision 2040* to provide guidelines for optimizing mobility and transit in Canadian society. One of the strategic directions presented in the publication advised cities to prepare for connected and automated vehicles[15]. The City of London has the opportunity, as a municipality, to create policies and pilots that prepare for CAVs, including V2I, V2V, V2X, and “Internet of Things” (IoT) technologies.

4.7 Canadian Urban Transit Research and Innovation Consortium

The Canadian Urban Transit Research and Innovation Consortium (CUTRIC) is currently leading projects with CAV components, the most notable of which is the National Smart Vehicle Demonstration and Integration Trail[16]. This project 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 of the National Smart Vehicle Demonstration and Integration Trail are the development of:

- Standardized V2V and V2I communication protocols;
- Interoperability standards for electric low-speed autonomous shuttle (e-LSA) manufacturer equipment; and
- Standardized cybersecurity protocols.

Another related report developed by CUTRIC for Industry Canada in 2015 entitled “Automotive and Transportation Innovation Across Canada and Regional Transportation Needs and Capacities as Targeted Research, Development, and Demonstration Projects”[17]. This report included a high-level examination of CAV systems such as sensors, signalling, controls, and communications security.

4.8 National Operations Center of Excellence

Under the banner of the National Operations Center of Excellence (NOCoE), the American Association of State Highway Transportation Officials (AASHTO), the Institute of Traffic Engineers (ITE), and ITS America (ITSA) are working together through the Vehicle to Infrastructure Deployment Coalition (V2I DC) have challenged municipalities to work together to achieve deployment of roadside radio infrastructure to broadcast signal phase and timing (SPaT) in real-time at signalized intersections on at least one road corridor or street network in each of the 50 states by January 2020[18].

As of April 2018, nearly 40 municipalities had engaged the SPaT Challenge with 10 corridors operational, including Detroit, Pittsburgh, San Francisco, Phoenix, and Las Vegas.

5 CAV PROJECTS IN SIMILAR MUNICIPALITIES

The City of London can look at what steps other municipalities have taken towards preparing for autonomous vehicles on city streets. Several examples of municipalities who are investigating and pursuing steps that would take them towards policy and pilot projects that would provide long-term CAV benefits to their communities.

5.1 ACTIVE-AURORA

Launched in 2014, ACTIVE-AURORA is the first network of test beds for CVs in Canada, with ACTIVE based in Edmonton, Alberta, and AURORA based in Vancouver, British Columbia. This testbed implements CV technology enabling vehicles to wirelessly “talk” to other vehicles and roadside infrastructure in real time, communicating information such as location, speed, following distance, inclement weather, adverse road conditions, and more.

This project provides real-world test zones, combined with laboratory settings, where conditions can be customized to simulate various situations. These facilities offer cutting-edge learning opportunities and hands-on experience for the next generation of transportation experts.

5.2 City of Calgary

At the June 26, 2017 meeting of the Standing Policy Committee (SPC) on Transportation & Transit, City of Calgary Council resolved that Administration in collaboration with regional stakeholders prepare a business case and risk assessment to evaluate the merits of testing autonomous vehicles on Calgary's roadways and region.

At a follow up SPC meeting on December 8, 2017, Administration responded with a Business Case and Risk Assessment and recommendations were carried to direct the report to the Province of Alberta to enact legislation allowing the testing of AVs; and, direct Administration to establish an intake process for using City-owned assets that support the economic development of the autonomous systems industry in Calgary.

5.3 City of Edmonton

The City of Edmonton's Transportation Committee passed a motion on May 27, 2015, directing Administration to report on the steps that are being taken to stay informed and educated on autonomous vehicles and the potential impacts to the roadway and transit network. The Administration responded on September 16, 2015, with a report that outlined the City of Edmonton's position and Council directed Administration to follow up with Q4 Annual Reports each year. These were subsequently presented by Administration in 2016 and 2017.

The September 2015 report outlined that the City is a member of University of Alberta's Center for Smart Transportation Steering Committee which has created a connected vehicle test bed for testing real-time information exchange between vehicles and roadside equipment. The Center also conducted a survey to gauge Edmontonian's interest in connected vehicles. The City of Edmonton is also undertaking an assessment of the implications of automated vehicles on traditional road engineering principles such as capacity, demand, parking, and land use.

Under the ACTIVE-AURORA project, ACTIVE currently includes 30 advanced roadside equipment units in Edmonton along 3 corridors that will establish wireless connections with onboard equipment in passing test vehicles. These test beds will provide a harsh winter environment in which to test CV systems and their impact on the transportation system (e.g. safety, mobility, and the environment).

5.4 City of Pittsburgh

The City of Pittsburgh is the first City to have a self-driving ride-sharing service on their streets. Through a partnership with the City of Pittsburgh, Volvo, and Uber, residents of Pittsburgh can now hail a self-driving Uber. The vehicles will also come with a safety driver in the driver's seat to take over if necessary. This pilot project has been allowed to move forward because of support received from City Administration. The City of Pittsburgh helped Uber lease a large plot of land for a testing track and successfully fought against potential state regulation that would ban ride-sharing services.

As of writing, Uber has suspended its self-driving operations in Tempe, Pittsburgh, San Francisco, and Toronto following the recent fatality in Phoenix in March 2018.

5.5 City of Stratford

The City of Stratford (located less than 1 hour from the City of London) put forth a bit to become Ontario's first live test bed for driverless cars in 2016. In 2017, the AVIN launched a unique demonstration zone (among the first of its kind in Canada) that will allow researchers to hone the technology and test CAVs in a wide range of everyday, real-life transportation scenarios. The necessary CAV technologies for pilots will be developed at various locations across Ontario before arriving at Stratford for testing[19].

5.6 City of Toronto

The City of Toronto's Public Works and Infrastructure Committee gave direction on May 16, 2016, to the General Manager of Transportation services to report back to the Committee with recommendations on how the City of Toronto could prepare for the arrival and expansion of autonomous vehicle technology.

At the City's January 5, 2018, Public Works and Infrastructure Committee meeting, Administration provided a report for action to prepare the City of Toronto for AVs. The report outlines next steps proposed, including the development of a cross-divisional policy position to ensure preparedness amongst all City services; and, the deepening of partnerships, including formal membership in the Municipal Alliance for Connected and Autonomous Vehicles in Ontario (MACAVO) and support for the University of Toronto's proposed iCity Centre for Automated and Transformative Transportation Systems.

In 2018, the City's Transportation Services division will implement the final year of the "Preparing for Autonomous Vehicles" work plan, focusing on the relationships between infrastructure and automation. The City may be able to influence the areas where activities related to automation are more likely to occur through policies such as parking, traffic, and curbside management. Concurrently, the City will continue to look at the broader picture of how highly automated vehicles can help achieve broader social, environmental, and economic goals[20].

5.7 Waterloo Centre for Automotive Research

The Waterloo Centre for Automotive Research (WatCAR) is located within Stratford's Connected City. WatCAR hosts research competencies in five (5) main areas[21]:

- Connected and autonomous vehicles;
- Lightweight and fabrication;
- Powertrain and emissions;
- Software and data; and
- Structures and safety.

6 POSITIVE AND NEGATIVE IMPACTS

There are many unknowns and changes as CAV technology progresses and different manufacturers innovate. Questions with significant implications are being asked about the effects of this technology on society[22].

The potential impact of driverless vehicles is vast, with both positive and negative implications. The extent of these impacts will largely be driven by government policy. Potential positive impacts related to CAVs include:

- **Improved public safety.** This is the largest positive impact, with the potential elimination of 90% of automobile accidents that are caused by human error.
- **Improved mobility for the elderly, disabled and youth.** CAVs are a benefit to groups with difficulties getting regular access to transportation.
- **Improved traffic circulation.** Assuming a 90% market share of driverless vehicles, freeway congestion could reduce by as much as 60% due to shared-use daily commutes. Also, traffic circulating on public streets looking for available parking currently accounts for 30% of city traffic. That could potentially be eliminated with shared driverless vehicles.
- **Reduced need for parking.** Self-driving fleets will reduce the need for on-street parking due to ridesharing and vehicle sharing. It is further expected that curbside space in downtowns will need to be reconfigured to have more loading/unloading zones and shared vehicle parking.
- **Improved personal mobility options and reduced personal mobility costs.** Each new self-driving taxi added to the fleet eliminates the need for about 10 privately owned cars. Essentially, people's mobility options will be increased substantially, so the need to own a private vehicle will be less necessary. Among other opportunities, driverless cars could provide first mile/last mile transit solutions.
- **Reduced emissions.** A self-driving, electric taxi in 2030 would produce 90 percent lower greenhouse gas emissions (GHG) than a 2014 gasoline powered privately owned vehicle, and 63 to 82 percent fewer GHG emissions than a 2030 privately owned vehicle with a hybrid engine.
- **Increased road capacity and throughput.** The ability to constantly monitor surrounding traffic and respond with finely tuned braking and acceleration adjustments should enable CAVs to travel safely at higher speeds and with reduced headway (space) between each vehicle. Research indicates that the platooning of autonomous vehicles could increase lane capacity (vehicles per lane per hour) by up to 500 percent.

Potential negative impacts related to autonomous vehicles include:

- **Increased vehicle kilometres travelled (VKT).** Additional VKT increases may be realized from induced demand as travel costs fall and greater access to travel options occurs. A latent demand for travel also exists that will be realized with the availability of CAV fleets.
- **Increased urban sprawl.** Regardless of the mode of available travel, people tend to live an average of 25-30 minutes from where they work. It is predicted that driverless vehicles could travel up to 190 km/h on major highways. For this reason, and the ability of people to engage in activities in their vehicles other than driving, it is likely that people will be willing to live even farther from where they work, which could result in reduced access to public services, increased infrastructure requirements, and reduced farmland/natural land.
- **Job loss.** Almost 1 million people are employed in motor vehicle and parts manufacturing. Additionally, truck, bus, delivery, and taxi drivers account for nearly 6 million jobs in Canada and the U.S. These jobs, and others could potentially be impacted by vehicles that do not need drivers. However, this would likely happen gradually and it is anticipated that many new jobs would also be created with the introduction of CAVs.

7 RECOMMENDATION: STRATEGIC PLAN

With the introduction of CAVs onto our streets, an autonomous vehicle strategy, as well as a framework for pilot projects, should be developed for the City of London. A policy based approach should be introduced to guide collaboration among transportation professionals, telecommunication providers, vehicle companies, and software technology companies in order to encourage innovation and incentivize development.

The development and introduction of a CAV Strategic Plan will encourage research and development to take place in London. The plan will create the basis and an environment that will allow for expanded employment opportunities through a local CAV supply chain and cultivate advances in the academic and the research and development sectors.

The City of London should consider potential policy implications and develop a CAV Strategic Plan that balances the many interests and issues at play. A number of the considerations that will be reviewed during the strategic plan development are presented below.

7.1 Infrastructure

The implications of autonomous vehicles on the infrastructure requirements should be considered by the strategic plan. There is a wide variety of CAVs being developed, some of which require no communication with infrastructure and could operate within the existing system while others would rely on significant communication with surrounding infrastructure[23]. This potentially means a policy would be required to guide the replacement of existing systems with costly smart infrastructure (physical and digital) that can communicate with these vehicles. With the additional infrastructure technology, the life cycle renewal of the infrastructure could be changed.

7.2 Land Use

The widespread adoption of autonomous vehicles could result in a change to the current land use practices. There is the potential for CAVs to make driving more desirable and may create a willingness to commute longer distances. Potential narrowing of right-of-way requirements and a reduced need for parking infrastructure could create the opportunity to repurpose land and reconsider zoning policies. The CAV Strategic Plan should review current land use policies and recommend changes to adapt to how transportation services are delivered and utilized.

CAVs are expected to create demand for drop-off areas that are as close as possible to the entrances of destinations. These drop-off areas will impact site-level design and affect access management in the form, location, design of curb cuts, and drop-off/loading areas.

Reducing parking and narrowed right-of-ways will yield substantial redevelopment opportunities in urban areas dominated by surface parking and wide roadways.

7.3 Transit

One of its greatest advantages of transit is its adaptability. Service is adaptable in terms of network scope and ridership demands. Transit is a major component of mobility. Electric vehicles, autonomous technology, and driverless shuttles could all combine to create a new vision of what transit service looks like.

City travel is dominated by the private car, traffic congestion is now widely recognized as a major and growing urban transportation problem. The fundamental need to move people rather than vehicles will remain. Traffic congestion is likely to remain fairly constant, where the demand to move people will meet or exceed the physical capacity of the road network.

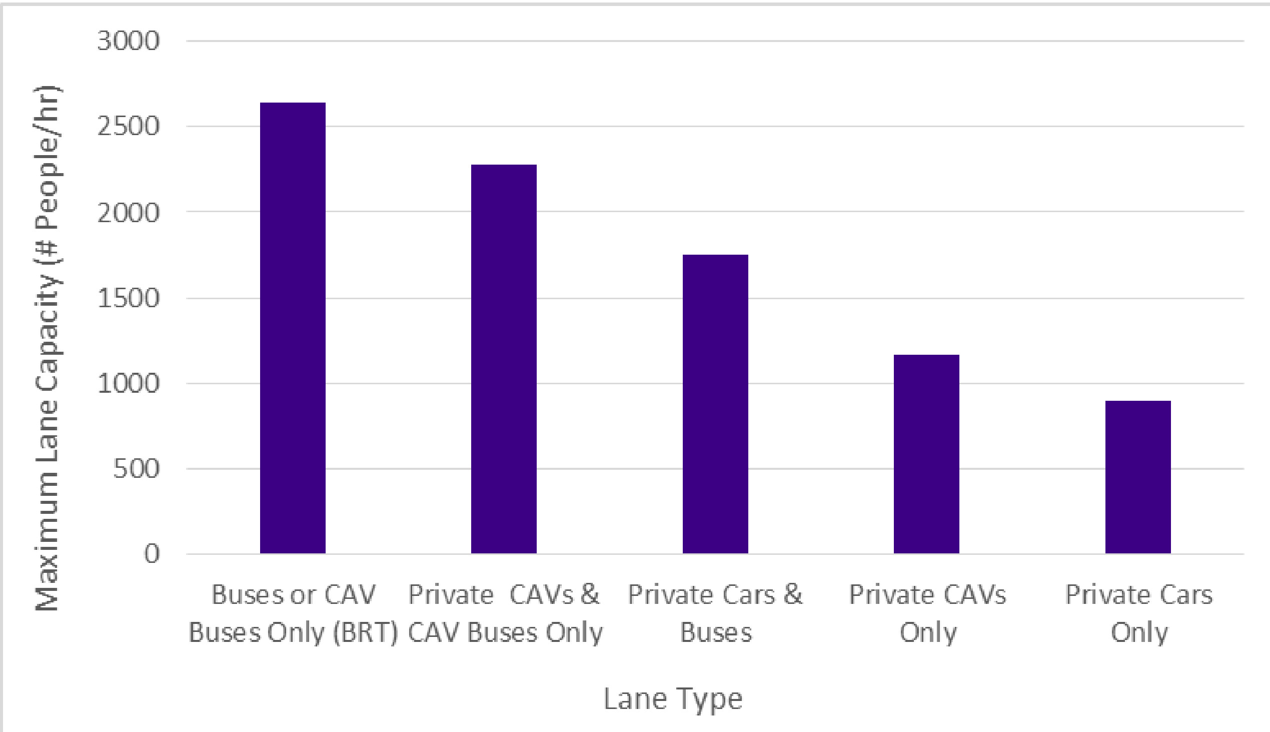
Declining vehicle occupancy and the fact that AVs can run empty suggest there is potential for AV traffic to increase, not decrease, congestion in cities of the future. Given the limitation in roadway space, integrated mobility with mass transit at its core will be fundamental in moving people, since it has the highest vehicle occupancy and the largest capacity to carry large volumes of people efficiently in growing busy cities.

The adaptation of CAV technology may lead to changes in the designation of space in public rights of way.

Large-scale rapid transit systems (i.e. BRT or LRT) in dedicated lanes have the flexibility to control what types of vehicles can use the dedicated lanes, and when, and to leverage the infrastructure to optimize operations as technology evolves.

As CAV technology evolves, it is reasonable to consider a future where driverless vehicles connect to rapid transit stops, or public transit vehicles have the ability to be dynamically routed to pick up passengers without necessarily following the same route every time.

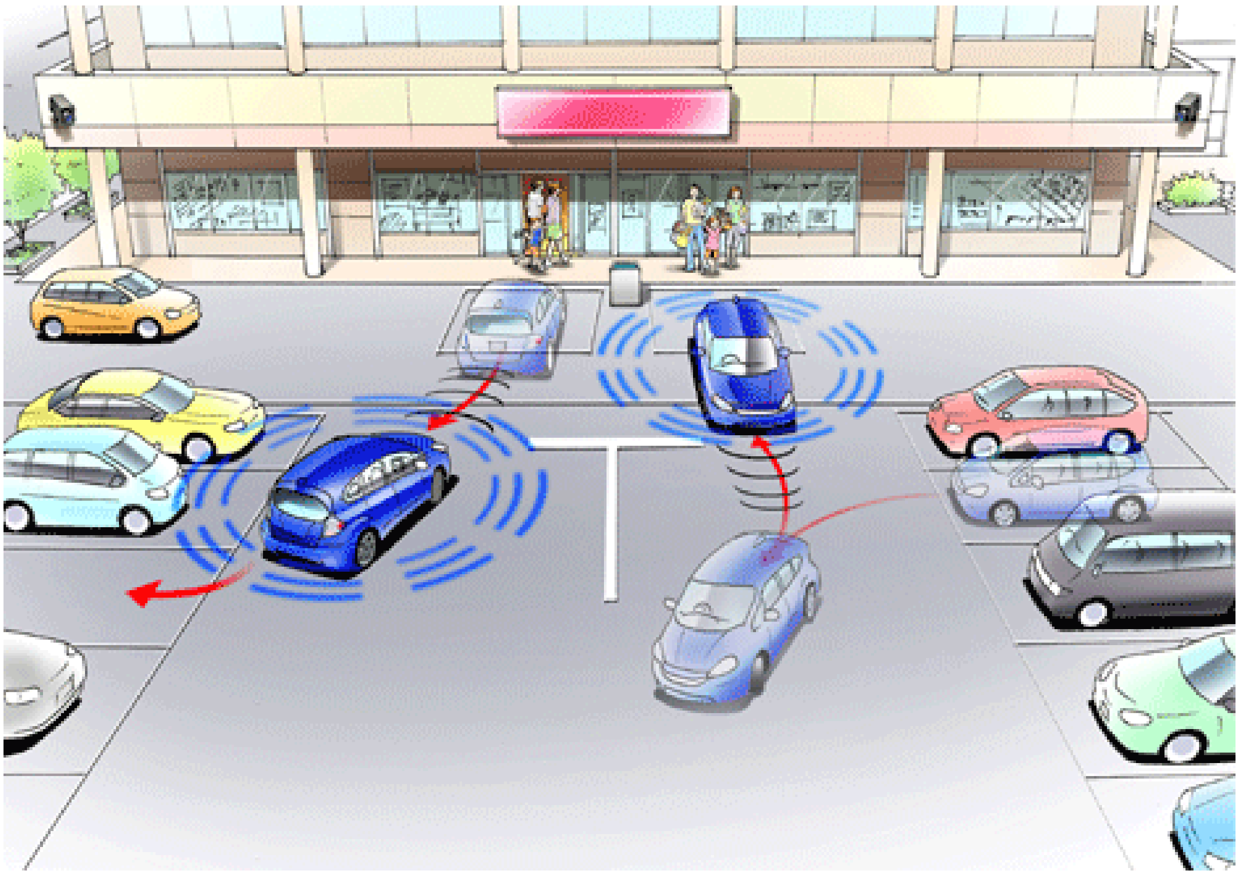
The following graphic shows the maximum person-carrying capacity of a lane for various vehicle types, including CAV technologies. Dedicated lanes for transit or other high-occupancy vehicles will continue to be a solution that enables a higher person movement capacity, and a more rapid flow of people along corridors where travel demand is high.



At the present time, the majority of larger on-street AVs being developed and tested are shuttles that can hold 10-12 people on average, and operate at average speeds of 20-25 km/h. These shuttles are almost exclusively electrically-powered with lithium batteries. Testing occurs mostly in low-traffic areas like business parks or university campuses, on fixed routes of only a few kilometres.

Coordination of the interaction between mass transit and CAV mobility providers to ensure that an integrated mobility model, which moves the largest amount of people, will be the key to ensuring congestion is managed in the future.

7.4 Parking



The implementation of CAV technology may affect conventional parking strategies. The technology may increase deadhead parking trips and parking in undesirable areas. This may also result in a loss of on and off street parking revenue. The CAV Strategic Plan should consider how the shifts of costs and revenues can be rebalanced given the effect CAVs may have on the parking framework.

Municipalities need to recognize and plan for changes in parking demand by identifying long-run opportunities for AV parking structures or large surface lots away from city centres, revising codes for parking requirements, and incorporating parking areas into comprehensive plans and other planning documents.

7.5 Accessibility

CAVs could expand accessibility for people who cannot drive due to disability, age, or other barriers. If CAV ownership follows the shared use model, a proactive policy may be required to ensure accessibility, especially for those who might need additional accommodation (such as wheelchair ramps or lifts). Without some proactive policy responses, automation of transportation could risk widening rather than shrinking the mobility gap for some persons with disabilities.

7.6 Safety

CAV technology has the potential to improve safety for all road users. SAE Level 1 vehicles today have features such as lane departure warnings, dynamic cruise control, etc. to assist drivers. Additional research, development, and testing should improve CAVs to detect and respond accordingly to all types of emergency situations.

The MTO pilot project requires that a human driver be able to take over the driving operations. This is an important first step on the road to SAE Level 5 CAVs until the technology has been tested and proven. In order to fully achieve the safety features of CAVs, there will need to be a critical mass of SAE Level 5 CAVs versus traditional vehicles.

7.7 Privacy and Security

Privacy and data security issues will always be a concern for consumers. The CAV Strategic Plan should consider how these concerns can be addressed while still delivering a safe and reliable product. In addition to the general public's concerns, the integration of CAVs into existing municipal systems (e.g. traffic signal systems, physical roadway infrastructure, etc.) raises other privacy and security issues. The CAV Strategic Plan should specify how municipal data is shared with third-party CAV original equipment manufacturers (OEMs) and mobility service providers so that it is done in a secure manner. It should be noted that privacy and security issues will be an on-going component and the CAV Strategic Plan needs to able to adapt to these evolving systems as they emerge.

7.8 Public Awareness and Education

Lastly, public awareness and education is an important element in the adoption of CAVs in our community. Public outreach can easily target all positive and negative impacts of CAVs depending on the educational message. Public education about the safety, congestion, mobility, privacy safeguards, and environmental implications of CAVs could affect technology adoption and market acceptance. Consumer awareness could lead to the use of a shared ownership model for CAVs rather than an individual ownership model, which could have congestion, mobility, and environmental advantages[24].

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