Calgary

Future of Transportation in Calgary

Forward

Approximately 200 years ago, rail technology was first developed, and dramatically changed the way people moved within and between cities. 100 years ago, aviation started to transform the way people traveled between countries and continents. 50 years ago, spaceflight enabled humans to explore outside of our planet. Closer to home, transportation has evolved over the past centuries from horse and buggy to the automobile; this change has had a significant impact on the way cities have been designed and the way people live.

While it is difficult to imagine a future with a different form of personal transportation, it is more difficult to imagine that we have reached the apex of personal mobility during the period of some of the greatest technological change in human history. Cities will be at the forefront of this change, and planners, engineers and policy makers will have to make decisions on how to use the technology to better the quality of life for their current and future citizens.

The future is impossible to predict, but there are several trends that appear to be moving ahead with unwavering momentum. Automation, electrification and connected and shared mobility are predicted to improve into the foreseeable future.

This report gives a high-level overview of the key trends occurring in transportation and gives information on what local governments are responsible for, the benefits and risks of each technology, and the best way for The City of Calgary to move forward.

The City of Calgary Transportation Department undertook a review of societal trends and transformative transportation technologies at the direction of Calgary City Council.

May 2017

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Peer Review

The following internal and external stakeholders voluntarily reviewed the draft document and provided feedback. The City of Calgary would like to thank the following individuals and groups for their contribution to this document:

External

- Government of Alberta
- University of Calgary
- City of Winnipeg
- Alberta Centre for Advanced Micro Nanotechnology Products (ACAMP)
- Civil Maps
- Canadian Automated Vehicles Centre Of Excellence (CAVCOE)
- Canadian Highways Institute
- Manning Centre
- Stantec
- Urban Systems Ltd

Internal

- Calgary Police Services
- Calgary Parking Authority
- Law
- Calgary Transit
- Roads
- Transportation Planning
- Information Technology
- Corporate Analytics and Innovation
- Urban Strategy
- Calgary Community Standards
- Parks
- Environmental and Safety Management

Introduction

The City of Calgary Transportation department undertook a review of societal trends and transformative transportation technologies at the direction of Calgary City Council.

The future of mobility in Calgary

New transportation technology helps shape cities. For over 100 years, Calgary and cities across the globe have been shaped by the automobile. Planning transportation around the automobile has allowed people to live further away from their work and gave rise to most of the urban form in the modern world. New transportation technologies are expected to continue to change cities.

Over the past decade, increased computing power, smart phones and technological discoveries have enabled the development of technologies that were once in the realm of science fiction. While cities cannot predict the future, there are major technological and social trends occurring in transportation. Autonomy, electrification, connectivity and shared mobility are predicted to impact transportation over the upcoming decades.

As it relates to transportation:

- **Autonomy** refers to a vehicle's ability to perform tasks without a driver.
- **Electrification** refers to the increase in the production and uptake of vehicles using electric power as opposed to fossil fuels.
- **Connectivity and shared mobility**. Connectivity refers to an item's ability to be digitally connected to other items. Shared mobility is the trend of people using services to commute instead of owning a personal vehicle – shared mobility is enabled through connectivity.

Each of these trends is intertwined and supportive of one another. An electric autonomous car, that does not require a driver, can be shared by multiple commuters who are connected via a smart phone app.

Occurring concurrently to technological progress, cities are moving to be more liveable and human scale. Cities around the world are investing in public transit and cycling infrastructure that allows for mixed use development and lively pedestrian filled streetscapes. If planned accordingly, the development of new transportation technology does not have to be at odds with a liveable human scale city.

"If planned accordingly, the development of new transportation technology does not have to be at odds with a liveable human scale city."

Being proactive for an uncertain future

Cities do not want to be in the position where a transportation technology is beginning to be adopted by the public and there is uncertainty as to how/if it should be regulated, and how it fits into their strategic plans. Conversely, cities do not want to be in a position where they over-regulate a technology too early, potentially negating benefits of the technology, or invest prematurely in infrastructure for a technology that may not be adopted by Calgarians. For example, in 2001 it was predicted in Time Magazine that the Segway "will be to the car what the car was to the horse and buggy" (Time Magazine, 2001). Calgary would have made a poor investment if it had invested in a Segway network, especially if it meant transferring investment from a proven mode of transportation.

The City of Calgary has been proactively monitoring and planning for emerging technologies for decades through strategic planning and active participation in the Intelligent Transportation Systems (ITS) field. The technologies in the report are not new or surprising to The City. The Future of Transportation report's goal is to outline the next steps that will put The City of Calgary in a position where it can be proactive, but not restrictive or wasteful. The report aims to accomplish this goal by:

- Providing an understanding of emerging transportation trends and technologies so The City is not caught off guard when a new technology appears in Calgary.
- Providing information on what The City is in control of, what tools it has to influence the technology and what the responsibilities of other levels of government and industry are. This allows The City to understand what influence we have over the technology and its adoption in Calgary.
- Providing a scan of what other jurisdictions are doing in regards to regulating or promoting the technology, so Calgary can understand where it fits in relation to other cities and what innovative policies and practices it could utilize to influence the technology.
- Providing an analysis of how future technologies could impact the long term vision for Calgary as articulated in the Municipal Development Plan (MDP), Calgary Transportation Plan (CTP) and other City policy documents.
- Creating an understanding of how future technologies may impact The City's finances and steps that The City can take to be financially resilient.
- Detailing what the potential impacts are of the various technologies.

A large portion of the technologies in the report are in the testing phase and/or are not easily accessible to the general public. It may take years after the technology is adopted by the general public to understand the holistic implications to society and the built form. Being on the cutting edge of testing can brand The City as being progressive, offer new services that other cities do not yet have and sometimes foster job creation. This also comes with an increased risk of failure as new technologies are trialed and implemented. Alternately, Calgary can monitor what other municipalities are doing globally and learn from their successes and failures. The best approach for Calgary is to be a leader in fields of existing strength while monitoring developments in other cities.

The outcome we are seeking is to be ready to keep Calgary at the forefront of new transportation technology while balancing the cost to the public with the benefits and risks.

For a number of technologies in the report, Administration offers a number of next steps that can put Calgary in a leading role nationwide when it comes to policy and exploration of new transportation technologies. In the near term these include:

- Participate in field trials for a low-speed autonomous vehicle pilot project.
- Continuing development of an Electric Vehicle Strategy for Calgary.
- Create a scenario using the Calgary Regional Transportation Model (RTM) that accounts for new technologies and trends.
- Continue the nationwide municipal working group on autonomous vehicles.
- Collaborating with universities, private industry and all levels of government on various initiatives and pilot projects.
- Updating the MDP/CTP to reflect new technologies and societal trends.
- Updating bylaws to reflect technological changes in the near future.
- Incorporate an Autonomous Vehicle assessment into business cases for new transportation capital projects.
- Make City assets and information available (e.g. open data) for use to facilitate technological development.
- Build knowledge through staff attendance at key meetings and conferences.
- Explore opportunities for participation in the Government of Canada's Smart Cities challenge.

For other technologies in the report, it is recommended that the City monitor cities nationwide and globally before taking action.


1
2
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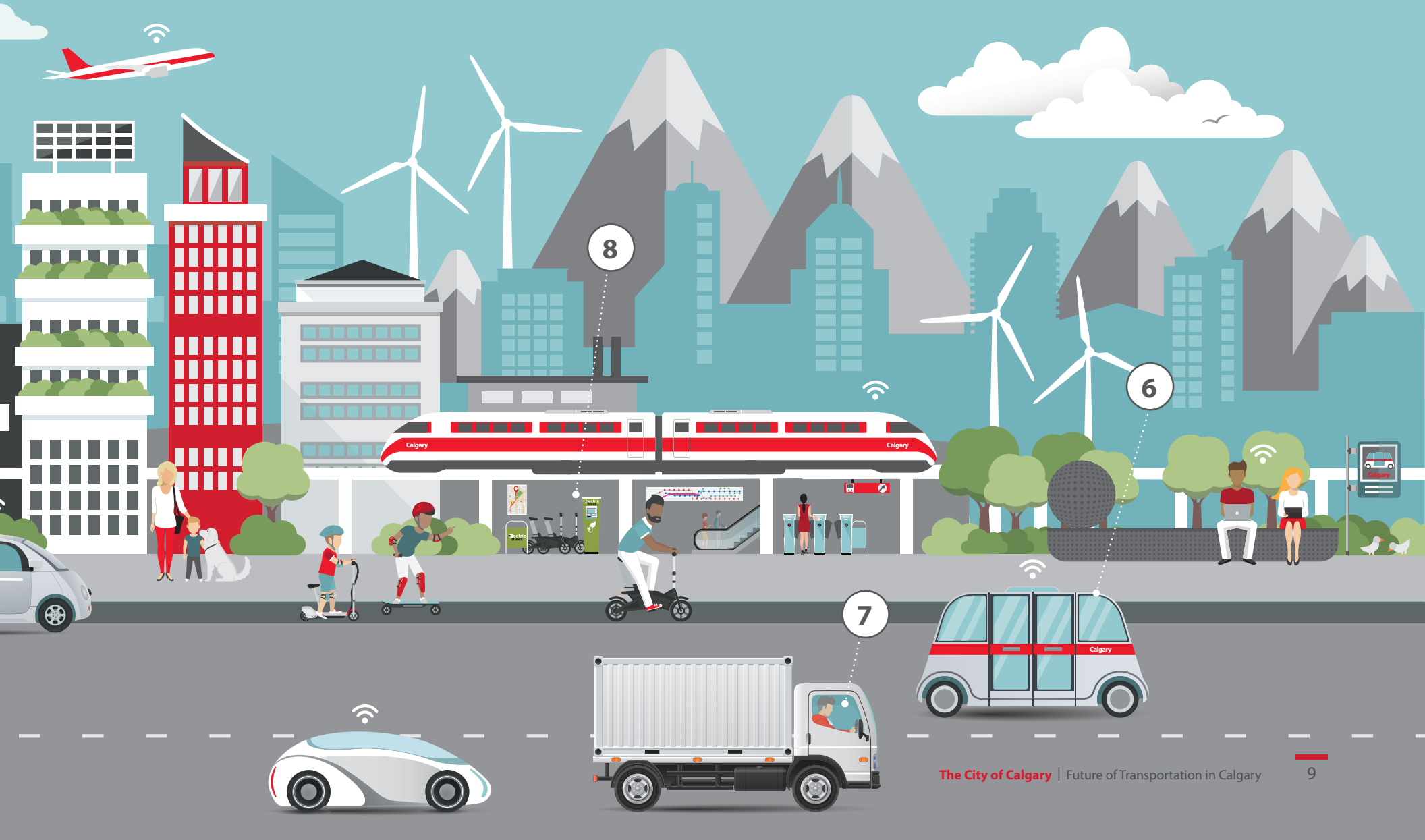
Calgary

Calgary in the 2040's – the interaction between technology and society

This section paints a picture of what Calgary may look like in the 2040's and a few of the technological and societal factors that may shape it.



In 25 years, Calgary will not only look different technologically, but different socially, environmentally and economically. A person commuting 25 years from now might not have the same family structure, job or concerns as we have today.

These social, environmental and economic factors are both influenced by and have influence on technology. Technology does not operate in a bubble, and even if an invention or innovation is technically feasible, it does not mean it will be adopted and have an influence on transportation and society as a whole.

Future Calgarians will still desire the goals of the Municipal Development Plan/Calgary Transportation Plan (MDP/CTP) of having high quality safe communities, a strong resilient economy, clean air and water, and being able to move around the city with multiple mobility options. The core goals of the MDP/CTP will remain, but the means to achieve those goals may change as society and technology change.

This section paints a picture of what Calgary may look like in the 2040's and a few of the technological and societal factors that may shape it.

1

Changing nature of work and the economy

Future predictions about commuting to work may be unreliable because many of today's existing jobs could be eliminated due to automation. University of Oxford researchers estimated that 47% of American jobs are at risk of being automated (Frey & Osborne, 2017). There will be also new jobs created. High skilled, non-routine creative jobs are expected to be safe, while routine jobs are expected to be automated. It is uncertain if job creation will outpace job loss. There is also an uncertainty as to if jobs will start and end at the same time as today's jobs e.g. 9 a.m. - 5 p.m.

With work trips composing the majority of peak trips in the network, a change to the amount and type of work could lead to changes in travel demand regardless of new transportation technology. The change will be dependent on how economically resilient and prosperous Calgary is. Calgary will have to compete to get new jobs and attract new industry in this new economy.

2

Human and cultural factors

Human and cultural factors will influence future technologies. A technology that is not viewed as 'cool', socially unacceptable or does not work with human needs and desires will likely only be adopted by a small segment of society.

For example: an autonomous vehicle that can pick up numerous different passengers along a route might be the most efficient way to run a shared autonomous vehicle network; however some people might not be comfortable with sharing a ride in a small vehicle with strangers and without an operator.

3

Market forces

The development of new technologies is being driven by the private sector and individuals purchasing goods. For transportation this means that some people may purchase technologies that benefit the individual, but not the network as a whole. For example: While it might be more efficient for the transportation network as a whole if people operated in smaller pod like vehicles that drove close together, the market demand might be for larger vehicles like trucks. This is more likely to happen in North America as the best selling vehicle for the past 30 years has been the Ford F-Series truck (Business Insider, 2017).

4

Government influence

Federal, Provincial and Municipal governments are not passive observers of transportation technology and will play an integral role in the adoption of future transportation technologies and how they are used on the transportation network. Governments do this by setting the rules on where and how technologies can operate and by funding infrastructure and research.

For example: The Federal Government regulates aerial drone technology and can limit where aerial drones can operate. For promoting technologies, Governments can promote electric vehicles by putting in policy or programs that encourage or fund the development of electric vehicle charging stations.

5

Demographics

As Calgary moves towards the future the age profile of the population will change over time. The population as a whole for the Calgary Region is expected to grow from roughly 1.6 million people today to 2.4 million in 2046 and just under 3.0 million in 2076. Over this period, the greatest population increases will occur with children under 14 and adults between 55 and 74 (Urban Futures, 2008).

Currently children and seniors make less automobile trips than adults. Children, because they are not legally allowed to drive and seniors due to declining health impact, especially those over the age of 80. With no "driver" required, Autonomous Vehicles (AVs) could be used by some seniors, children, disabled persons and other groups who cannot currently use conventional automobiles. This would increase the mobility of these groups, but add traffic onto the roadway network.

6

Licensing

Since 1983, there is a steady decline of young adults (16-44) obtaining drivers licences. According to a University of Michigan study, the key reasons stated for not getting a licence are: "too busy or not enough time to get a driver's license" and "owning and maintaining a vehicle is too expensive". In Calgary, the top reasons people stated for taking transit is that it is convenient for them, less expensive, they don't drive, and to avoid parking.

With the advent of shared autonomous vehicles, some of the top reasons why people do not drive may become less of a barrier and the top reasons to take transit may become less advantageous. AVs and other technologies could take riders from other modes.

7

Security and privacy concerns

The hacking of an autonomous or connected vehicle, a major data privacy breach or the use of an aerial drone for a terrorist attack could change public opinion, reduce adoption rates and change policy for a particular technology. Increasing technological complexity and system inter-dependence can result in greater vulnerability.

8

The sharing economy

The sharing economy, which is described as using peer-to-peer technology to facilitate the consumption of goods and services, is on a significant upswing both in Canada and globally. In transportation the main application is the sharing of vehicles or vehicle-for-hire services, but the technology also affects transportation through sharing of space, deliveries and information.

The global sharing economy is expected to grow from $15 billion in 2013 to $335 billion in 2025 (USD) (PwC, 2014). In Canada, roughly 29% of the population reports use of sharing services as of 2014 (DMCPI+, 2015). Response by cities has ranged from facilitation to increased regulation. The high rate of change and embrace of the sharing economy is likely to continue to disrupt traditional transportation methods in a number of ways.

Alignment with federal and provincial strategies

Changes in mobility choice and advancements in transportation technology are part of municipal, provincial and national conversations and are embedded in several plans and policies at various levels of government. This section highlights the key elements of what the provincial and federal plans are for new transportation technology and how these policies align with municipal policy.

Long Term Provincial Transportation Strategy -

The Government of Alberta is developing a long term, multi-modal transportation strategy that will guide decisions on transportation investments, policies and programs (Government of Alberta, 2016). The Province has identified six draft goals as part of its strategy:

1. Connected and Active Communities
2. Competitiveness, Market Access and Economic Growth
3. Safety and Security
4. Innovation and Technology Integration
5. Environmental Stewardship
6. Long-term Sustainability and Affordability

The Government of Alberta has emphasized the importance of working with stakeholders and partners including other governments, industry and post secondary institutions in order to successfully implement the transportation strategy.

As it relates to new transportation technologies and innovations, this transportation strategy will recognize the importance of being prepared for advancements, such as autonomous vehicles, which will impact how people, products and services are moved.

Alberta Transportation has also initiated a Zero Emissions Vehicle Impact Study to determine what role the Province should play in this emerging technology. Preliminary results from the study are anticipated in Q2 2017.

The City of Calgary is in ongoing conversations with Alberta Transportation on how to best utilize new transportation technologies. Alberta Transportation has shown interest in collaborating on a low speed AV pilot. **Details of the pilot are discussed in Attachment 2 of the Council report.**

"The City of Calgary is in ongoing conversations with Alberta Transportation on how to best utilize new transportation technologies."

Federal Transportation Strategy– (Transportation 2030) A Strategic Plan for the Future of Transportation in Canada

On November 2016, Marc Garneau, Minister of Transport released Transportation 2030, the federal strategy for the future of Transportation in Canada.

The five areas of focus are:

1. **Safer transportation –**
   Build a safer, more secure transportation system that Canadians trust.
2. **Trade corridors to global markets –**
   Improve the performance of our transportation system to get products to markets and grow Canada's economy.
3. **Green and innovative transportation –**
   Reduce air pollution and embrace new technologies to improve Canadians' lives.
4. **The traveller –**
   Provide greater choice, better service, lower costs and new rights for consumers.
5. **Waterways, coasts and the North –**
   Build world-leading marine corridors that are competitive, safe and environmentally sustainable, and enhance northern transportation infrastructure.

As it relates to new transportation technologies, actions for the goals include:

- Ensure government regulations enable, not suppress, innovation.
- Reduce carbon pollution by 30% from 2005 levels by 2030.
- Ensure that drones (unmanned air vehicles) are subject to simple, clear and enforceable regulations.
- Invest in areas such as smart grids, electricity transmission, renewable power and Smart Cities Plans that will lead to cleaner transportation technology.
- Support the safe and rapid deployment of connected and automated vehicles on our public roads to improve road safety; reduce congestion; increase mobility; protect the environment; and support economic opportunities for Canadian businesses.
- Invest $10.1 billion in transportation infrastructure to help eliminate bottlenecks and building more robust trade corridors.

The Federal Government also plans to launch a Smart Cities Challenge in 2017. Modelled on a similar competition in the U.S., cities across Canada would be invited to develop Smart Cities Plans together with local government, citizens, businesses and civil society. Participants will create ambitious plans to improve the quality of life for urban residents, through better city planning and implementation of clean, digitally connected technology including greener buildings, smart roads and energy systems, and advanced digital connectivity for homes and businesses. Further details will be announced by the Federal Government in 2017 (Government of Canada, 2016).

The City of Calgary plans on participating in the Smart Cities Challenge.

Transportation Association of Canada's Intelligent Transportation Systems (ITS) Architecture for Canada version 2

At the municipal level, much of the concerns regarding new technologies revolves around the compatibility of existing infrastructure with future technology. In 2010, Transport Canada released the ITS Architecture for Canada version 2.

The national architecture provides a common framework for planning and integrating with physical components of future transportation technologies. It establishes communication systems requirements and standards for travellers, vehicles, roadside devices, and control centres. The established protocols are closely aligned with the United States National ITS Architecture, and is the foundation for ongoing ITS work in Canada.

A new ITS Architecture for Canada is currently being developed by the Transportation Association of Canada. The City of Calgary is on the project steering committee for the new architecture.

Impacts on City policies, operations and finances

Municipal Development Plan (MDP) and the Calgary Transportation Plan (CTP)

Objectives of the Municipal Development Plan (MDP) and the Calgary Transportation Plan (CTP) are to identify the land use and transportation framework for the future development of Calgary. The plans were developed around 11 sustainability principles and 8 key directions, rooted in supporting the 100-year community-developed vision, imagineCALGARY.

These directions were developed to create the policies necessary to support the development of Calgary over the next 60 years while anticipating a future total population of 2.3 million.

When the MDP/CTP were produced (2006-2009), many of the technologies identified in this report were only at the 'concept' stage of development. There is only minimal consideration of these technologies in the actual plans. While the principles and key directions are for the most part still valid (e.g. Calgarians still want affordable and accessible travel options) the technologies are likely to have some major impacts to the transportation system.

Appendix 1 contains a full overview on how new technologies may impact the core principals of the MDP/CTP. As shown in the table, there are many potential impacts to the plan, both supportive and detractive. The extent to which each of these impacts manifests themselves will only be known in time. Technology is just one of many factors that affect the ability of The City to achieve the plans' vision.

While the key principles in the plans are still relevant and supported, there are some portions of the plans that will change as these technologies evolve. The next review of the plans should pay particular attention to the following aspects with respect to emerging technologies:

- Growth strategies
- Regional strategies
- City-wide mode split goals
- Parking policies
- Infrastructure investment strategies
- Regulatory and user-pay policy framework
- Transit Service Delivery

"Technology will put significant downward pressure on several revenue sources The City currently has in place."

Supporting transportation plans

Most of Calgary's long term plans touch briefly on future technologies and societal trends. Future technologies are not always emphasized as part of the planning process due to the uncertainty of if and when the technology will come to fruition, and how it will impact the transportation network. However the focus of the Future of Transportation report is on understanding longer term technologies that may be more fundamentally transformative and are most impactful to The City's MDP and CTP.

Highlights of each plan are as follows:

Smarter Mobility Plan – this Roads document focused on identifying new and emerging technologies, and the infrastructure gaps needed to prepare for those technologies.

Route Ahead – The Transit plan discusses new technologies including new fare payment systems, real time information systems and alternative fuels. The plan also anticipates that new transportation technology could be available to service projects like the West Campus.

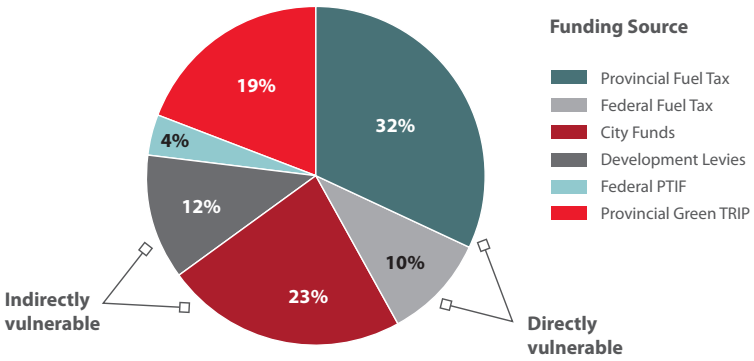
Step Forward – The pedestrian strategy discusses the societal transformation of creating walkable pedestrian oriented environments, which steps away from the car oriented paradigm of much of the 20th century. The use of new pedestrian safety technologies like rectangular rapid flashing beacons (RRFB) is also discussed. At the end of Step Forward, there is mention of how new technologies like wearable devices and autonomous vehicles will likely have to be accommodated in future revisions.

Cycling Strategy – The strategy recommends social innovations such as bike sharing and intelligent transportation solutions such as bike detection at signals. The strategy also calls for further investigation of electric bikes and utilizing new technology for enhanced data collection.

City finances

The arrival of future technologies has a mix of implications with respect to The City's fiscal future. The City will need to proactively plan for changes in revenue streams and new costs that might arise. At the same time, technology has the potential to significantly reduce some costs for The City. Appendix 2 provides a detailed assessment of the opportunities and impacts that technology will have on The City's finances.

10-Year Share of Capital Funding | 2015-2024



Technology will put significant downward pressure on several revenue sources The City currently has in place. Services that rely on these funds will need to find alternate sources if they are to continue. Significant impacts are expected to:

- Fuel and carbon taxes (both provincially and federally) – if electrification occurs as expected, these funding sources will decline over time as more and more vehicles do not require gas or diesel.
- Calgary Transit – shared autonomous vehicles and other private sector mobility innovations could reduce ridership and fare box revenue from Calgary Transit.
- Calgary Parking Authority revenue returns to The City – if parking options are more abundant for AVs, the price of parking will drop significantly. Vehicles will intelligently seek the lowest cost parking; this will tend to push down prices if a vehicle can park automatically.
- Traffic and Parking Fines – assuming AVs are law abiding, there would likely be minimal infractions to generate these revenues. In this scenario, there could be a reduced need for traffic officers.
- More dispersed tax base – if AVs increase development further out of Calgary, this could increase the use of City infrastructure without corresponding increases to the property tax base. If AVs enable the redevelopment of inner city parking lots, this could increase the property tax base.

While immediate action is not critical, continual monitoring of these funding sources and potential alternatives is important to protect The City's fiscal position. Initiatives such as the City Charter are important as they may provide options to cities to address some of these impacts.

Analyzing transformative technological trends

There are arguably more technological innovations occurring at this time than any other point in history. Administration narrowed down the list of technologies in this report through research, analysis, conversations with subject matter experts, and conversations with Councillors.

Scope

The report looks at technologies that may be fundamentally transformative of the system, and are most impactful to The City's Municipal Development Plan (MDP) and Calgary Transportation Plan (CTP). The technologies discussed in this report differ from 'business as usual' and are expected to result in changes to The City's transportation and land use patterns.

Today's rapidly changing transportation technologies can be categorized into three major trends Autonomy, Electrification, and Connectivity and Shared Mobility.

Autonomy - Computational power is increasing with artificial intelligence and machine learning improving every year. For transportation this means there will be an increase in the amount of automation into the foreseeable future. Vehicles are likely to become increasingly automated to the point a human driver is no longer required.

Electrification - The price of batteries is dropping rapidly and storage capacity is increasing. This convergence of price and capacity is allowing manufacturers to build practical and cost-effective electric vehicles for the first time. Combined with the technological and economic feasibility of renewable energy sources, this offers an effective and increasingly convenient approach to reduce transportation emissions.

Connectivity and shared mobility - Computers used to be the only devices connected to the internet. In the past few years, watches, cars, traffic signals and a multitude of other devices are now connected to the internet. In the near future, there are expected to be more and more devices connected to the Internet of Things (IoT) allowing for interaction between devices and a greater amount of information for the user, companies and governments. This connectivity allows for the sharing of transportation resources. In Calgary we currently see the beginning of this trend with people being able to search their area for a car-sharing service or book a Transportation Network company service on their smart-phone and track their ride in real time.

Status of technology

Five categories were developed to define each technology's current status/level of adoption or use globally.

Concept – The technology may exist as a drawing, video, idea or other form but no physical model has been created to date. This report does not focus on these technologies but they will be monitored to see if they are progressing to a higher state of readiness.

Prototype – A prototype model has been created to demonstrate that the technology is possible, but testing of the technology is very preliminary or unclear.

Testing – Several prototype models have been created and are currently undergoing significant testing. The technology is not yet available to the public.

Limited Availability – The technology is just completing testing, or is moving from testing to availability for purchase.

The technology is in use in some jurisdictions but has only been in place for a short period of time.

Widespread – The technology is available to Calgarians currently who have the means, and is available in multiple jurisdictions worldwide. For this report, these technologies are no longer considered 'future' technologies.

Level of Impact

An impact level of high, medium or low was given to each technology based on how it will impact The City of Calgary and the citizens of Calgary.

Low – Business as usual technology. This does not have significant impacts on how Calgarians move around the city. This is not the main focus of this report.

Medium – The technology will likely have some impact to some parts of the population, but does not result in a large change to transportation networks or the travel behavior of commuters.

High – Not business as usual technology. The technology has the potential to strongly influence how people commute in the city. This is the main focus of this report.

Matrix of transportation technologies

The matrix (Figure 1) provides an analysis on their impact to The City along with their state of readiness. Technologies with a higher level of impact on the transportation network that are further along in their technological development were given a more thorough analysis. Technologies with a lower impact or that are at the conceptual/early prototype stage of technological development were identified, but not explored in as much detail.

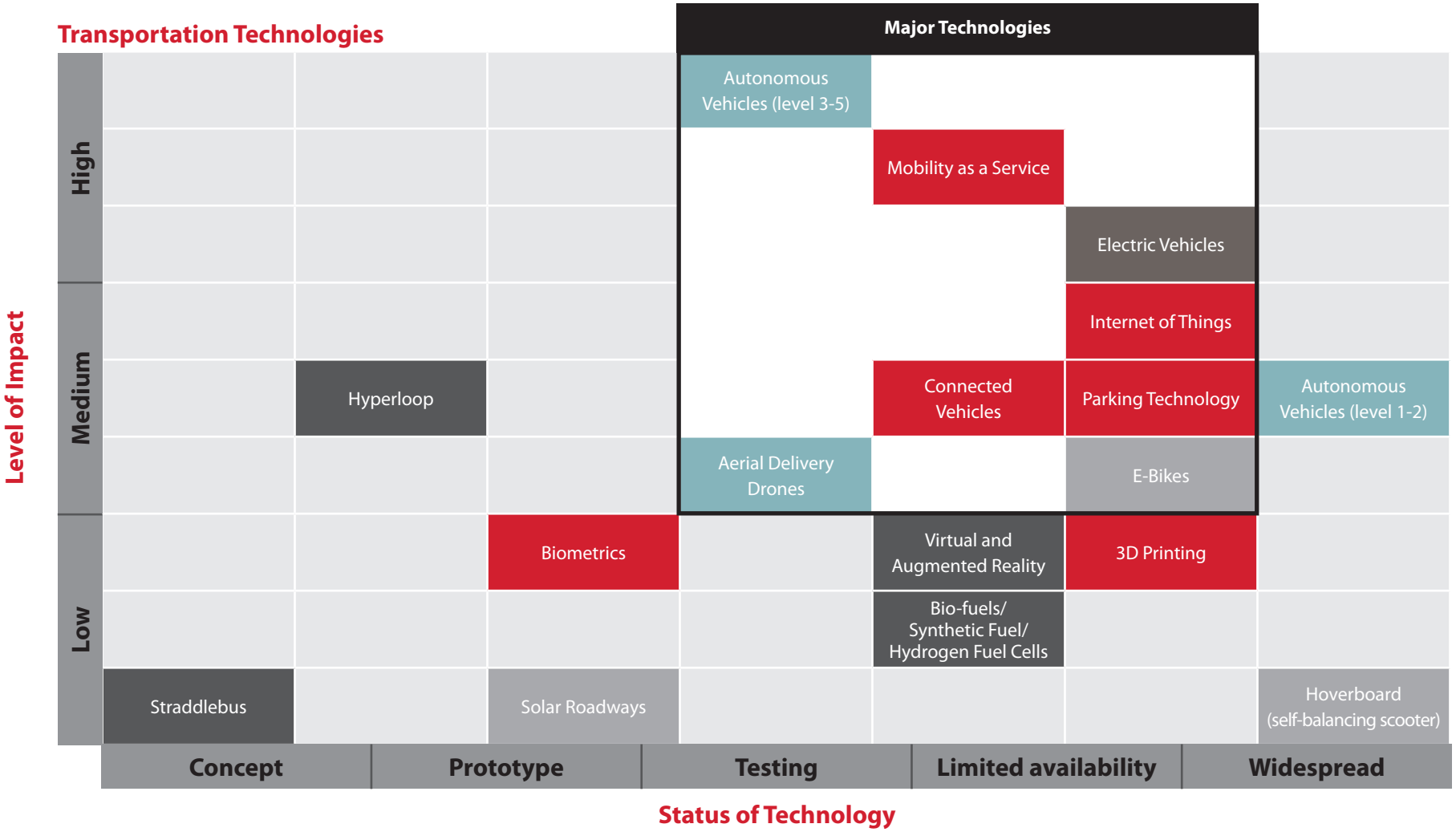


Figure 1 - Matrix of transportation technologies

Major technologies

Autonomy

This chapter explores autonomous vehicles (AVs) and aerial delivery drone technology, how they could shape the physical and social landscape of Calgary and what The City of Calgary can do to influence their adoption and implementation.

Automated systems developed over the past decades have allowed commercially available cars to parallel park themselves and planes and other aerial vehicles to reach their destinations using autopilot. In the upcoming decades it is predicted that a car's computer will be able to perform all aspects of driving, and unmanned aerial drones will be able to complete tasks without human intervention.

Car companies are forecasting that a switch to autonomous vehicles (AVs) means a potential switch from the current ownership model of a dealership selling consumers a vehicle, to one where the car company owns and operates a fleet of vehicles and the consumer pays a fare to use the service, also known as Mobility as a Service (MaaS).

For the consumer, a fully autonomous car could provide a different experience of commuting and may influence how much they commute and where they choose to work and live. For freight, AVs will impact how goods get to market.

For cities there is a great deal of uncertainty of how AVs will impact quality of life, traffic congestion, safety, land use patterns and the finances of cities. For governments, the best course of action for dealing with uncertainty, the growing number of technological advancements, and company announcements is to explore various scenarios of what could occur and put processes in place in order to deal with new issues when they arise.

Aerial drones are posed to have less of an impact on transportation. Technologically, most aerial delivery drones are only able to carry small packages and all aerial drones are heavily regulated by federal legislation to the point where no one can legally deliver a package in an urban environment in Canada. However, technological advancements and changes to federal legislation could change the viability of aerial deliveries in Calgary.

Autonomous vehicles

- The dominant form of transportation in Calgary is the personal automobile. A major change to the operation of the dominant mode of transportation will have the most significant implications on the transportation network.
- AVs are currently designed to operate on the existing roadway network mixed with human drivers. No special infrastructure is required for AVs to function on Calgary roadways.
- There is a great deal of debate and uncertainty regarding AV impact on traffic congestion, vehicle ownership, parking, public transit and urban form.
- Once a human driver is not required, the broader set of impacts from autonomous vehicles will be most significant.
- Fully autonomous vehicles may begin to appear on Calgary roads in the 2020s.

What is autonomous vehicle technology?

Autonomous Vehicle (AV) technology is an umbrella term encompassing different types of technology that hand over some or all functionality of driving from the human driver to the vehicle's computer. As defined by SAE International Inc., there are six different levels of automation, (Figure 2) from a vehicle where all features are controlled by the human driver (Level 0), to technology that helps drivers keep in their lane (level 1-2) to vehicles that can drive by themselves with human supervision (level 3) to vehicles that can operate without human intervention or presence (level 4-5). As time progresses, new AV technologies will likely be developed and refined.

Six different levels of automation

Level	Name	Description	Execution of Steering and Acceleration/ Deceleration	Monitoring of Driving Environment	Fallback Performance of Dynamic Driving Task	System Capability (Driving Modes)
Human driver monitors the driving environment						
0	No Automation	the full-time performance by the human driver of all aspects of the dynamic driving task, even when enhanced by warning or intervention systems	Human driver	Human driver	Human driver	n/a
1	Driver Assistance	the driving mode-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the human driver perform all remaining aspects of the dynamic driving task	Human driver and system	Human driver	Human driver	Some driving modes
2	Partial Automation	the driving mode-specific execution by one or more driver assistance systems of both steering and acceleration/ deceleration using information about the driving environment and with the expectation that the human driver perform all remaining aspects of the dynamic driving task	System	Human driver	Human driver	Some driving modes
Automated driving system ("system") monitors the driving environment						
3	Conditional Automation	the driving mode-specific performance by an automated driving system of all aspects of the dynamic driving task with the expectation that the human driver will respond appropriately to a request to intervene	System	System	Human driver	Some driving modes
4	High Automation	the driving mode-specific performance by an automated driving system of all aspects of the dynamic driving task, even if a human driver does not respond appropriately to a request to intervene	System	System	System	Some driving modes
5	Full Automation	the full-time performance by an automated driving system of all aspects of the dynamic driving task under all roadway and environmental conditions that can be managed by a human driver	System	System	System	All driving modes

Figure 2 - Society of Automotive Engineers Definitions of Autonomous Vehicle Levels (SAE, 2016)

Status of technology:
Level 1-2 Widespread availability
Level 3-5 Testing

Level 1 (Driver Assistance) and 2 (Partial Automation) vehicles can currently be purchased and are currently operating on Calgary's roads. For example Mercedes-Benz offers a number of vehicle models with DISTRONIC PLUS with Steer Assist technology, which keeps the vehicle in its lane while being able to follow the vehicle ahead at a safe distance (Mercedes-Benz, 2017).

Level 3 (Conditional Automation) technologies are being tested on public roadways throughout North America, Europe and Asia. Notably, in 2016 Transportation Network Company (TNC) UBER has level 3 vehicles in Pittsburgh, Pennsylvania; the vehicles still have a driver/engineer in them to take over when the vehicle's computer encounters a circumstance it is unable to handle (UBER, 2016). Level 4 (High Automation) and 5 (Full Automation) technologies are currently being tested in North America, Europe and Asia.

There are a variety of estimates as to when level 4-5 AVs will begin to operate on public roadways ranging from the early/mid-2020s to mid-2030s. It is predicted that by 2050, level 4-5 AVs will compose approximately 50% of the vehicle fleet (VTPI, 2017) and that trucking and company vehicle fleets would be the first to adopt the technology due to high driver costs and the higher turnover rate of commercial vehicles (The Guardian, 2015). For example, car company Ford is projected to own and operate fleets of shared AVs (Ford, 2016).

Stage	Decade	Vehicle sales	Vehicle fleet	Vehicle travel
Available with large price premium	2020s	2-5%	1-2%	1-4%
Available with moderate price premium	2030s	20-40%	10-20%	10-30%
Available with minimal price premium	2040s	40-60%	20-40%	30-50%
Standard feature included on most new vehicles	2050s	80-100%	40-60%	50-80%
Saturation (everybody who wants it has it)	2060s	?	?	?
Required for all new and operating vehicles	?	100%	100%	100%

Figure 3 - Victoria Transport Policy Institute AV implementation projections

"Autonomous vehicle fleets will quickly become widespread and will account for the majority of Lyft rides within five years."

John Zimmer, co-founder and president of Lyft Inc. September 2016

Industry

Most major car and many technology companies are working on AV technology. There are new announcements weekly for new developments with AVs. The list below provides a snapshot of some of the recent AV announcements and developments.

- In 2016, Ford announced that it intends to have a high-volume, fully autonomous SAE level 4-capable vehicle in commercial operation and mass production in 2021 in a ride-hailing or ride-sharing service (Ford, 2016).
- In 2016, BMW reported that it will launch a self-driving electric vehicle, the BMW iNext, in 2021 (BMW, 2016).
- In 2016, General Motors invested $500 million with Transportation Network Company (TNC) Lyft and bought AV company Cruise Automation for $1 billion to help develop fully autonomous car share services (Fortune, 2016).
- Volvo has started a pilot project in Gothenburg, Sweden to put 100 level 3 vehicles in the hands of residents (Volvo, 2017).
- Honda is working on developing AVs and has patented an augmented reality application that allows drivers to see people behind trees and columns (The New York Times, 2016).
- Alphabet (Google's parent company) has created a new company called Waymo, signalling that it is past the research phase and is beginning to commercialize the technology (The New York Times, 2016). Waymo is partnered with Fiat-Chrysler and Honda.
- Daimler is developing fully autonomous cars and freight trucks. It has constructed the "Mercedes-Benz F 015 Luxury in Motion" concept car that has a modified interior that allows for people to sit face to face and interact. From the Daimler AV website: "We are convinced that the car can be more than just a means of transport: we see it as a private retreat that offers more freedom" (Daimler, 2017).
- Tesla Motors announced in October 2016 that its cars would come equipped with hardware to allow them to eventually be fully autonomous with future software upgrades (The New York Times, 2016). Tesla CEO Elon Musk has pledged that he will have a Tesla that can drive itself from Los Angles to New York by the end of 2017 (Wired Magazine, 2016). In January 2017, Elon Musk tweeted that Tesla will transition from 'Enhanced Autopilot' to 'Fully Self-Driving' as soon as '3 to 6 months'.
- At the 2015 Frankfurt Auto show, the former US Secretary of Transportation (Anthony Foxx) stated he expects driverless cars to be in use all over the world in 10 years (BBC News, 2015).
- Uber CEO has indicated that he expects Uber's fleet to be completely autonomous by 2030 (Mobility Lab, 2015).
- John Zimmer of Lyft predicts that by 2021, "a majority" of rides on its network will be in autonomous vehicles, and by 2025 personal car ownership in US cities will be a thing of the past (The Verge, 2016).

Mercedes-Benz F 015 Luxury in Motion" concept car that has a modified interior that allows for people to sit face to face and interact. (Photo credit: Driving.ca)

Today in Calgary, Tesla Model S and Model X vehicles have autonomous features including Autosteer, Auto Lane Change, Autopark and Summon.

Barriers to adoption

While there is a substantial amount of progress being made in regards to the technology, there are still a number of hurdles that level 3-5 AVs will have to overcome before they are ubiquitous on Canada's roads. Most of the items are able to be overcome, however it may delay the technology's implementation by a number of years.

Technological

Fully autonomous vehicles still have difficulty operating in adverse weather conditions such as fog and heavy snow. It is predicted that the technology will become available to resolve these technical issues and handle adverse weather conditions better than a human driver.

Ethical issues

There are moral and ethical dilemmas that need to be overcome. If a vehicle runs into a situation where it cannot avoid a collision and is faced with a decision of who to collide with, who does it favour? For example, if a pedestrian steps out onto the roadway without the car having ample time to stop, does the vehicle hit the pedestrian or veer into another vehicle to avoid hitting the pedestrian but potentially harming the "driver". Mercedes-Benz has taken the stance that it will save the car's driver and passengers, even if that means sacrificing the lives of pedestrians, in a situation where those are the only two options (Car and Driver Magazine, 2016).

Societal acceptance

Canadians are currently divided on how they view fully autonomous vehicles. A 2016 survey found that one in four Canadians said they were looking forward to AVs, while around half of Canadians stated it would depend on the technology and how well it works, and the remaining quarter had a negative view of the technology (Kanetix, 2016).

While AVs are hypothetically safer because they remove the human from the driving equation, as driver error is the source of the vast majority of collisions in Alberta (Alberta Transportation, 2012), a single AV accident or a hacking incident may cause discomfort and delay the adoption of the technology. Education on the limitation of the technologies will play a major role in social acceptance and proper use of the technology.

Society may have a growing discomfort with automation as it will likely take over jobs in some fields.

Cost

IHS Automotive forecasts that the price for the self-driving technology will add between $7,000 and $10,000 to a car's sticker price in 2025, a figure that will drop to around $5,000 in 2030 and about $3,000 in 2035 (IHS Automotive, 2014).

Legislative items

Current provincial and municipal legislation do not contemplate the regulation of AVs. A review of City bylaws with AVs in mind has not yet been conducted. There is nothing in provincial legislation or municipal bylaws that explicitly block the operation of AVs. Rather, the operation of an AV would likely be indirectly barred by various requirements in the legislation with respect to vehicle legislation, distracted driving legislation and operator licensing. City bylaws that could be impacted include Calgary Traffic Bylaw 26M96 and Livery Transport Bylaw 6M2007. The Provincial Traffic Safety Act and associated regulations will also need to be updated.

Risk compensation - partial automation

The theory of risk compensation states that people adjust their behaviours to suit the perceived level of risk (Speck 2012). Risk compensation may be evident in levels of autonomy up to level 3 in which a user's perception of safety results in less attention to monitoring the vehicle, even though the capacity of the vehicle's autonomy does not warrant that level of control. This is pushing some automakers to transition to Level 4/5 autonomy as quickly as possible to reduce the impact of risk compensation. (Davis, 2017)

Responsibilities

Unlike past transportation improvements that were implemented by the public sector like light rail transit (LRT) and the roadway network, the push for AV technology is coming from the private sector. The private sector is working towards and is responsible for creating a safe, robust vehicle that can follow local traffic laws and operate in various environments such as roads covered in snow and ice and different traffic conditions. Provincial and federal levels of government are actively working to resolve issues related to the legislative status of automated vehicles; the regulation and licensing of related services; and the public interest issues of data privacy and safety. The City of Calgary would be responsible for the following items:

Municipal Responsibility	Description and Action
Building and maintaining infrastructure	The City is responsible for building and maintaining the transportation network for all transportation modes. The City chooses how to allocate resources to various modes such as bicycle lanes, interchanges or transit infrastructure to create a multimodal transportation network.
Traffic Congestion Management	The City is responsible for managing traffic flow through Intelligent Transportation Systems (ITS) and traffic demand through Transportation Demand Management (TDM).
Land Use Bylaw and Planning	The City can set bylaw requirements for development, which may change with a new transportation technology. For example, if autonomous car share is more popular in the future, then The City can relax the parking requirements for developments, but may need more space for pick up/drop off zones.
City Bylaws	AV technology will need to be operated in accordance with the Street Bylaw 20M88 and the Calgary Traffic Bylaw 26M96. A review of City bylaws will have to be conducted in order to understand which bylaws need to be amended - Bylaw amendments need to be in alignment with the Provincial Traffic Safety Act.
Parking	The City is responsible for ~ 20% of parking lots in Calgary's downtown. The presence of level 4-5 AVs may cause less usage of some lots, and may allow The City and/or private sector to redevelop underutilized lots.
City Vehicle Fleet	The City could purchase different levels of AV technology for its public transit or vehicle fleet. For example, buses could be equipped with level 2 AV technology that keeps them in their lane in a narrow right of way, or Parks could purchase an autonomous mower for park maintenance.
Licensing Taxis	Assuming the Province does not regulate driverless taxis/shared AVs, The City would have jurisdiction to do so, but is not required to do so – that is, Council may decide that regulating driverless taxis/ shared AVs is unnecessary.
Social	The City has a social mandate to provide the citizens safe and affordable transportation options.

Figure 4 - Examples of what The City of Calgary would be responsible for with the advent of autonomous vehicles

Past work conducted by The City of Calgary on technology:

At the Transportation Department, Roads has been actively monitoring and planning for future autonomous and connected vehicles for the past several years, particularly through active participation with the ITS Canada conferences and special interest sessions to monitor the current state of technology, and through continuing research. Industry and stakeholder surveys, such as the 2014 Smarter Mobility Plan, allow for more detailed monitoring of the state of connected vehicle and autonomous vehicle technology.

What if someone were to operate the technology today in the city?

Level 1-2 vehicles operate legally on Calgary's roadways currently. Drivers of Level 1-2 vehicles are still legally required to adhere to the distracted legislation and cannot use cell phones and other handheld devices while driving.

There is nothing in provincial legislation or municipal bylaws that explicitly blocks the operation of level 3-5 AVs. Rather, the operation of an AV would likely be indirectly barred by various requirements in the legislation with respect to vehicle legislation, distracted driving legislation and operator licensing.

What other countries/parts of the world are doing

USA

Each year, the number of states considering legislation related to AVs has gradually increased. As of 2016, at least 34 states and D.C. have considered legislation related to AVs (National Conference of State Legislatures, 2016). Much of the testing for all levels of AVs has occurred in the USA.

In 2016, The U.S. Department of Transportation published the "Federal Automated Vehicles Policy" to establish a foundation and a framework upon which future Agency action will occur. The document includes Vehicle Performance Guidance for Automated Vehicles, Model State Policy, NHTSA's Current Regulatory Tools and New Tools and Authorities (US DOT, 2016).

Prime Minister Justin Trudeau visits the Blackberry QNX facility in Ottawa in December 2016 as the company announces its Autonomous Vehicle Innovation Centre (AVIC). (Photo credit: Sean Kilpatrick/The Canadian Press)

Canada

On Jan. 1, 2016, Ontario became the first province in Canada to create a pilot regulatory framework to test automated vehicles on its roads. The pilot intends to help attract and enable research and development in Ontario in this emerging industry, positioning the province as a global leader in the AV market. In November 2016, Ontario launched the first automated vehicle (AV) pilot program in Canada, led by The University of Waterloo, the Erwin Hymer Group and BlackBerry QNX (Government of Ontario, 2016).

In February 2016, Federal Transportation Minister Marc Garneau requested the Senate's Transportation and Communications Committee to report on the regulatory, policy and technical issues for smooth introduction of automated vehicles. The 2016 Federal Budget approved $7.3 million over two years to support the development of a regulatory framework for emerging vehicle technologies including automated vehicles (Government of Canada, 2016).

Asia

In 2016, Shanghai, China created a 100-square-kilometer closed course for testing of autonomous vehicles.

Japan is working to outfit Tokyo with a self-driving vehicle fleet for the 2020 Summer Olympic Games.

Singapore has had driverless low speed shuttles since 2015 and was the first country to trial self driving taxis. Singapore is currently testing full size driverless buses that are expected to be on public roadways by 2020.

United Kingdom

The UK has created a regulatory and legislative framework to support the development and mass production of automated vehicle technologies. In November 2016, the UK Government announced 390 million pounds of funding to boost the development of low emission vehicles and AVs (Reuters, 2016).

Fully autonomous vehicles can legally be tested on public roads in the United Kingdom today as long as a test driver is present and can take responsibility for the safe operation of the vehicle (UK Department for Transport, 2015).

European Union

The European Union and its Member States participate in international working groups which are revising the regulations as prerequisites for the deployment of automated vehicles. Furthermore the European Union is funding research on automated road transport as a priority in the Horizon 2020 Transport Research programme (European Parliment, 2016).

Testing of AVs is currently being conducted in France, Germany, Sweden and numerous other countries in the EU.

What are Canadian cities doing?

As part of the project, The City of Calgary reached out to municipalities across the country to establish a nationwide working group on AVs. The group currently serves as an informational coalition and shares information between cities.

Municipality area	Municipal work on AVs
Edmonton	The City of Edmonton presented their annual report to Urban Planning Committee on Automated and Connected Vehicle Technology on October 19, 2016. Administration was directed to provide a report outlining what it has been doing and what it could be doing differently as a cross-departmental team in advance of future plans in order to address the Autonomous and Connected Vehicle Technology. At the March 15, 2017 Urban Planning Committee Administration was directed to return to June 7, 2017 committee with: details of additional City of Edmonton resourcing required to support the Automated Vehicle Test Track and Pilot; a work plan and framework for addressing automated vehicle technology as a cross-departmental team; and a report with resource options focused on integrating a new mobility paradigm (such as Automated Vehicles, car-sharing, and ride-sharing) into city strategies.
Mississauga	Mississauga is developing their first formal Transportation Master Plan and a Parking Master Plan with AV technology in mind. They are working with University of Toronto Masters' students to research the impacts of AVs on parking.
Montreal	On May 16th, 2016 the municipal Council mandated the Transportation and public work Commission to study the issues and challenges of the future arrival of AVs in Montreal. In addition, in its Transportation Electrification Strategy 2016-2020, Montreal sets out the creation of an Institute for Electrification and Intelligent Transportation. This Institute will have the mandate to develop, experiment and promote innovations and new concepts in electric and intelligent transport. Among other things, a test corridor will be created which will allow real-world tests to be carried out and will thus serve as a commercial showcase for new technologies.
Ottawa	Ottawa is preparing a white paper on the impacts of disruptive technologies and behaviour/demographic changes on the urban form and infrastructure investments.
Toronto	The City of Toronto is involved in a number of actions in regards to AV technology including: the completion of a 3 year AV work plan; reporting to their Public Works Infrastructure Committee and City Council on how to best prepare for the introduction of automated and AVs; hosting AV workshops with CAVCOE; working with departments throughout their City and; working with the University of Ryerson on public surveys and transportation modelling work.
Greater Toronto Area (Metrolinx)	Metrolinx in conjunction with consulting firm WSP has produced a background paper on AVs and shared mobility and is looking to integrate the concepts into their regional planning.
Vancouver	TransLink has completed its Future of Driving report that has been endorsed by their Board and directed staff to implement recommended actions. In April 2016, City of Vancouver staff provided a memo to City Council on the implications of automated vehicles on the City's transportation, land use, economic and sustainability plans, as well as the steps necessary to update those plans (to maximize benefits and mitigate negative impacts). On December 14th, 2016 the City of Vancouver presented a brief update to Council with some additional information and a near term work plan.
Winnipeg	On September 20th, 2016 City Administration was directed by City Council to conduct a cross-jurisdictional analysis on self-driving vehicle planning and report back in 2017.

Figure 5 - Municipal government work across Canada on autonomous vehicles

Level of impact: **Level 1-2 Medium / Level 3-5 High**

Figure 6 illustrates the benefits and potential issues arising from AVs. The higher the level of vehicle automation, the higher the level of impact e.g. a vehicle with cruise control (level 1) makes a long drive a bit easier for some, where a vehicle that can pick a commuter up and drop them off (level 4-5) has a more profound impact.

Opportunities	Risks
Increased safety – human error is the leading cause of collisions, removing humans from driving tasks could improve safety.	Increased vulnerability – system failures and hacking might be more frequent.
Increased mobility options – autonomous car share services could provide more choice for commuters in terms of cost, schedule and mode.	Risk compensation - people adjust their behaviours to suit the perceived level of risk. For level 1-3 vehicles, people could become worse drivers offsetting potential safety benefits.
Less congestion – AVs can drive more efficiently than human drivers. This attribute has the potential to decrease congestion, however if the supply of roadway increases, there will likely be induced demand which could reduce the initial benefits. Once AVs start to be used by the public, planners and engineers will have a better idea of how they impact congestion.	Increased travel and more congestion – if driving is easier and less expensive, people may take more trips which may lead to higher rates of congestion. Once AVs start to be used by the public, planners and engineers will have a better idea of how they impact congestion.
Reduced cost for citizens – the shared AV business model may reduce the need for households to purchase a vehicle, people could forgo parking costs.	Increased costs for citizens - additional vehicle equipment, services and maintenance may be required.
Increased mobility for non drivers – independent mobility for those who cannot currently drive due to mental or physical restrictions. Increased fuel efficiency – an AV can drive more efficiently than a human driver.	Increased sprawl and development outside the city - people may be comfortable with commuting for longer distances. This could negatively impact The City's tax base and The City's planning efforts.
Reduced parking requirements – shared AVs may decrease the need for car ownership and parking. This could also result in the redevelopment of inner city parking lots.	Reduced cycling, walking and transit usage - people may shift away from other modes towards AVs. Reduced usage in active modes could lead to higher obesity rates. Job reduction – will reduce the number of driving and other related transport sector jobs.
Increased comfort and productivity during commuting – vehicle occupants could partake in other activities while commuting.	Reduced revenue from parking – vehicles that drive themselves do not have to park in the downtown, thus decrease parking revenue.
Potential for an AV transit fleet that could provide more frequent, dynamic services.	Privacy – AVs constantly scan the environment with cameras and LiDar and will likely track the origin destination patterns of each trip.
Potential for first mile and last mile transit services to be integrated and feed into public mass transit services.	Vehicle failure - How AVs stop (either parked in the middle of a lane or on the side of the road) as a default fallback response to system failure (e.g. sensor failure), could cause saftey or traffic flow issues.
Increased amount of data that can be used to make better planning and operating decisions.	
An increase in AVs could lead to an increase in electric and shared vehicles. For example, an autonomous vehicle is more easily shared as it can be relocated without a driver and the higher upfront cost of an electric car is spread between multiple people in a shared system.	

Figure 6 - Opportunities and risks of autonomous vehicles

Infrastructure

AVs, at all levels, are being designed to operate on existing roadway infrastructure. For local governments this means no additional or specialized infrastructure will be required for vehicles to operate on the roadway network.

In a Texas A&M Study looking at public sector questions and Original Equipment Manufacturers (OEMs) answers to questions about AVs, state and local governments asked how they could build infrastructure to better support the technology. OEMs replied that they are designing AVs to function on existing roadways and do not want or require customized infrastructure stating that "if they were to design vehicles that relied on infrastructure changes or specific actions by the public sector, their vehicles would never function" (Wagner, Baker, Goodin, & Maddox, 2014).

In a number of years, if the vast majority of the vehicle fleet is fully autonomous, the City could conceivably narrow roadways and explore other infrastructure improvements.

Impacts to automobile ownership – shared vehicles

The impact of AVs on Calgary largely depends on the business model of how they operate – either being individually owned or operated as shared vehicles.

There are two main models of shared AVs:

a) A large company, like Ford, or a TNC/taxi company, owns and operates a fleet of fully autonomous vehicles.

b) Citizens rent out their own fully autonomous vehicles via an application.

Benefits of higher shared usage of fully autonomous cars in comparison to individual ownership may include:

- Less private vehicle ownership, lower probability of 2+ vehicle households, which could lead to additional cost savings per household.
- Reduced car ownership could lead to less vehicle kilometres travelled in the transportation network and less traffic congestion.
- Less parking requirements.
- Accessibility – disabled and other users who cannot drive conventional automobiles have extra options.
- Private vehicles are parked for 90-95% of the time (Shoup, 1997), shared vehicles are a more efficient way to use vehicles.

Risk of higher shared usage of fully autonomous cars in comparison to individual ownership may include:

- Lowers the economic entry for vehicle usage which could increase the amount of auto users and congestion.
- Shared fully autonomous fleets could take away ridership from transit, walking and cycling.
- Traditional taxi companies, TNCs and car rental agencies will face more intense competition.
- Fully autonomous car shares still produce zero occupancy vehicle trips, increasing congestion and emissions.
- An excess of shared vehicles may result in increased curbside congestion.

The price and adoption rate of shared AVs will be partially dependent on if and/or how The City of Calgary licences the fleet. If shared AVs require Taxi Plate Licences (TPLs) and The City limits the number of shared AVs, then the cost of a fare would likely increase and usage would likely decrease. If The City limits regulations, there is a higher likelihood of usage. The City will be facing the decision of how or if to regulate and licence fully autonomous shared vehicles in the upcoming 5-10 years.

Impacts to parking

Level 4 and 5 AVs would be able to drop off their passengers and drive away. After the vehicle has dropped the passenger off, it hypothetically could act in a number of different ways.

Options	Scenario	Potential Impacts on the Transportation Network	Future mitigation measures
Find parking	Vehicle owners would likely want to minimize their costs. This may mean that the vehicle could avoid parking charges in the downtown, or other paid areas, instead parking in the nearest available free location.	The City loses revenue from both parking charges, parking fines and the loss of transit ridership. Vehicles choose to park in nearby communities without restrictions until they are called upon which may upset some community members. There could be local area traffic congestion as vehicles find parking.	The City could charge a cordon fee for entering the downtown or a road use (per km) charge instead of parking fees to discourage 'deadhead' travel*. However, this may discourage people from going downtown. The City could set up geo-fences which would only allow fully autonomous vehicles to park in certain areas e.g. a designated lot outside the downtown. There are a number of logistical items that would need to be implemented for this approach to be successful.
Commute back to the residence of the driver	If operating costs are inexpensive, private vehicle owners could send their vehicles back to their residence.	Sending a vehicle back home would double the amount of vehicle kilometers travelled on the network and may cause traffic congestion in non-peak directions while increasing pollution and greenhouse gas emissions (emissions may be less of an issue if the vehicles are electric).	If operating costs are high (fuel costs), then it would not be economical to double the amount of vehicle kilometres travelled on a daily basis. If operating costs are not high, then a per km toll could be implemented to deter sending empty vehicles long distances and also may discourage long commutes*.
Drive around Calgary until being summoned	If operating costs are inexpensive, zero occupancy vehicles could drive around the streets until they are summoned by the owner or another commuter.	Since a zero occupancy vehicle has little to no value of time, aside from operating cost and opportunity cost (only with shared vehicles), a vehicle may drive around the streets adding to congestion and road wear.	If operating costs are not high, then a per km toll could be implemented or incentives to return power to the electrical grid could be provided (for electric vehicles)* . The actions could deter sending empty vehicles long distances and also may discourage long commutes.
Pick up other passengers	Both vehicles from a private fleet (owned by a company such as Ford) or shared vehicles (rented via app to individuals) can pick up other passengers, much like a taxi service today.	While having the vehicle actively picking up other customers is a more optimal vehicle behaviour for the efficiency of the transportation network, there will likely still be vehicles that do not have an active fare (much like taxis today) and have to either park or drive around until they are summoned.	There will likely be a spatial distribution pattern that is ideal for shared vehicles to maximize the amount of trips taken. In the future, The City should work with their TNC and taxi company trip data to better understand how to maximize mobility for citizens while minimizing the amount of driving and parking required.

Figure 7 - Parking/drop off scenarios for autonomous vehicles

*** Currently, the Traffic Safety Act expressly prohibits a municipality from imposing any tax, fee, licence or permit respecting the use of highways by pedestrians or vehicles (section 16). The ability for Alberta cities to charge usage fees could change under the new City Charter.**

Impacts to traffic congestion

The Secured by Design (SBD) automotive report "How Autonomous Vehicles could relieve or worsen traffic congestion" reports that AVs are unlikely to solve traffic congestion in the next 20 years and may actually make traffic congestion worse. It is not until a high percentage of the fleet are autonomous that there is expected to be a positive impact on congestion levels due to AVs being able to drive more efficiently in higher concentrations (SBD, 2016).

There is a great deal of uncertainty of AVs impact on congestion due to multiple intertwined technical, social, political and economic factors. With a high risk of uncertainty as to how AVs will impact traffic congestion, The City of Calgary, along with the Canadian Nationwide Municipal AV group recommend that Canadian cities continue with Transportation Demand Management (TDM) Strategies and investments in a multimodal transportation network including BRT and LRT. LRT serves as the backbone of the transportation network, alleviates congestion, increases mobility, is necessary infrastructure in transit oriented development (TOD) and transports people in a density that AVs cannot replicate. BRT infrastructure is valuable for the same reasons as LRT and can be adaptable to new forms of transit such as micro transit services.

Moving forward, the Transportation Forecasting Division is developing a scenario using the Regional Transportation Model (RTM) to estimate the potential impacts on congestion and other travel metrics of AVs. The City is also planning to work through the Urban Alliance to model AV loading and unloading in the downtown.

Decreased congestion	Increased congestion
Less traffic collisions.	Users who are currently unable to take personal vehicle trips including Seniors, Youth and the disabled could be able to use level 4-5 AVs, adding to the total traffic demand.
Tighter spacing and coordination between vehicles (platooning) – efficiency increases with higher level of AV adoption.	The appearance of Zero Occupancy Vehicles.
Shared Vehicle Fleets.	Adhering to the driving rules. While The City discourages people exceeding the speed limit for safety reasons, people driving over the speed limit increase the vehicle flow.
Better and more consistent driving behaviours.	Larger vehicles. There is a potential that people may want more space to work, rest or play in if the vehicle can drive itself.
Less time looking for parking spaces with vehicles talking to each other.	Loading and unloading has the potential to cause delays in the downtown.
Smaller vehicles. Shared AV companies may offer smaller vehicles to customers, or vehicles that are the right size for the trip.	People making more trips.
Note: Capacity increases to the roadway may be negated by induced /latent demand; when the supply of a roadway increases, the demand also increases. For example: if AVs free up road space, some of that additional capacity is likely to be taken by people making more auto trips.	People using AVs instead of Transit.
	People commuting longer distances.
	Appearance of autonomous delivery services.

Figure 8 - The factors that influence autonomous vehicles impact on traffic congestion

Impact on urban planning

Risks to urban planning

People commuting in an AV may have a higher tolerance for longer commutes since they can spend time in the vehicle working, resting or recreating. This may lead to people choosing to live further away from the city increasing the potential for exurban development that increases congestion and financial impacts on City infrastructure. The City of Calgary needs to work closely with our regional partners to monitor and understand the potential demand for regional commuting once AVs become a reality.

People may be comfortable with commuting longer distances, which may entice people to move outside city boundaries. Picture of Canmore, Alberta.

Opportunities for urban planning

The advent of shared fully autonomous vehicles may minimize the need for parking and vehicle infrastructure within a development or community. This could lead to the ability to relax parking requirements in the Land Use Bylaw; the redevelopment or redesign of parking lots and the ability to develop and redevelop communities to have less space dedicated to parking and other vehicle amenities, allowing that space to be allocated to higher value land uses or amenities. Planning and the development community should be engaged to understand what opportunities exist for AVs and other future technologies. A next step is to bring together planning and the development community to understand how new technologies could impact the design of communities. This engagement can be done as part of the Smart Cities Challenge.

Lower automobile ownership and having vehicles adhere to low speed limits, could produce communities that are pedestrian friendly. Picture of Vauban in Freiburg, Germany where roads are too narrow for on street parking and speed limits in the community are 5 km/h.

Smart Cities Challenge

To encourage cities to adopt new and innovative approaches to city-building, the federal government proposed at the 2017, March 22 federal budget to provide Infrastructure Canada with $300 million over 11 years to launch a Smart Cities Challenge Fund. Modelled on a similar competition in the U.S., the Smart Cities Challenge would invite cities across Canada to develop Smart Cities Plans, together with local government, citizens, businesses and civil society. Participants will create ambitious plans to improve the quality of life for urban residents, through better city planning and implementation of clean, digitally connected technology including greener buildings, smart roads and energy systems, and advanced digital connections for homes and businesses.

The City of Calgary plans on working with internal and external stakeholders to participate in the Smart Cities Challenge. The challenge should highlight how AVs and other technologies can be best integrated into the urban realm.

Impact to Transit

Autonomous technologies have the potential to impact both the operations and competitiveness of transit.

Operational impacts

Bus: AV technology has the potential to eliminate the drivers from transit services, which are one of the main operating costs for transit agencies. The automation of buses could allow for different service types, such as micro transit and bus platoons, and could allow for the reallocation of staff to different positions in customer service and other fields.

Dedicated transit only lanes with only autonomous transit services would produce a near 100% concentration of AVs in a dedicated lane which could lead to higher roadway capacity efficiencies.

The Netherlands is currently trialing fully autonomous buses (Photo credit: Mercedez-Benz)

Last mile shuttle services: Last mile services connect users or goods from a transportation hub or activity centre to a final destination. A number of municipalities across the world are studying the impacts of low speed AVs to provide a last mile service option. Low speed AVs are further discussed in Attachment 2 of this report.

Low Speed Autonomous Shuttle in Switzerland (Photo credit: swissinfo.ch)

Rail: There are currently a number of driverless rail systems in operation including Vancouver's SkyTrain which has been operating without a driver since the 1980s. What makes these services able to operate without a driver is that they do not have any crossings that intersect with roadways or pedestrians.

Completely grade separating the current and future LRT lines in Calgary was determined to be cost prohibitive.

In the future, it is feasible that there will be technology that allows autonomous trains to operate without grade separated intersections.

Vancouver's Sky Train

Competitiveness of Transit

Transit could be negatively or positively impacted by AV technology.

Negative:

If transit service stayed the same, there is a potential that driverless vehicles could take ridership from transit. According to the Calgary Transit customer satisfaction survey, the main reasons people take public transit in Calgary are that it is convenient for them, less expensive, they don't drive, and to avoid parking. AVs largely address these issues. This could lead to a snowball effect of less people taking transit, which leads to transit having to cut resources, which further decreases the attractiveness of transit.

Positive:

Mass transit will be cost and time competitive whenever travel demand to/from major trip generators outstrips the ability of other modes to serve that demand (e.g. downtown, special events, major activity centres, high-intensity development areas, main corridors). Transit services like LRT, BRT and mainline routes are envisioned to be competitive and required into the foreseeable future. Low frequency feeder services could be out competed if an AV service offers a lower cost, better service alternative.

Future transit vehicles can also utilize autonomous technologies to make the service more competitive. A fully autonomous level 4 bus could reduce operational costs and allow transit to offer a variety of different services and vehicle types. AVs could also feed into higher order transit services (e.g. LRT).

Transit is currently monitoring new technologies that would improve the safety of their bus fleet.

Impacts to freight and delivery

AVs are likely to be adopted more quickly in the freight sector. High driver wages, labour shortages and limited operating hours have created an incentive for trucking companies to switch to fully autonomous services (a driver would likely still be required for the transportation of dangerous goods). This offers increased flexibility for scheduling and delivery. The ability to drive multiple trucks in linked platoons (essentially a road train) can also reduce fuel consumption and therefore operating costs for trucking companies.

The Central North America Trade Corridor Association (CNATCA) is working on an autonomous friendly corridor concept to facilitate regional goods movement. AV technology could allow for more trucks on Calgary's roadways and smaller vehicles that could allow for more local deliveries. The City will monitor future developments.

In 2016 Budweiser teamed up with autonomous vehicle company OTTO to complete the first driverless freight delivery of beer. (Photo credit: Budweiser)

Several companies are also experimenting with smaller, AV delivery vehicles that could potentially travel on the sidewalk network rather than using the road. Domino's Pizza is working with the government of New Zealand to test the DRU (Domino's Robotic Unit), which is a small robot that can deliver pizzas to customers (CBC News, 2016). Food-delivery robots are also currently being piloted in Washington, D.C., where Starship Technologies has partnered with local restaurants to provide food delivery. The services alert customers that a robot will be delivering their meal, provides them real-time tracking of the delivery and a link that allows the customer to open the machine to retrieve the contents (NBC News, 2017). The vehicles weigh 18 kilograms and go up to 6.5 km/hr.

Virginia has just recently enacted legislation that will enable the robots to use sidewalks and crosswalks as of July 1, 2017. Bots will be limited to a speed of 10 miles per hour and cannot weigh over 50 pounds. The bots are free to be completely autonomous so long as they are monitored remotely (Regan, 2017). As Calgary becomes a more accessible city for mobility purposes, this could also facilitate the potential for wheeled delivery vehicles as this would reduce the number of obstacles for them to overcome.

Legged robots are also being explored for potential delivery purposes. The advantage of legged technology is it would allow the robots to travel on a greater variety of terrain than just by using wheels alone. Google-backed Boston Dynamics is working on improving their current prototypes so that they may be potentially used for delivery in the future (Knight, 2016).

Impact on other City Departments

On July 19th 2016, the Transportation Department worked with the Office of Sustainability and the innovation lab to conduct an internal workshop with business units across The City. The purpose of the workshop was to understand how they saw AV technology impacting their business unit. The workshop was attended by approximately 20 City staff and 5 University of Calgary researchers; the University of Calgary was looking to understand the main items of debate at The City.

The workshop presented City staff with a number of different scenarios; a discussion took place about how the scenario would impact each business unit and what items would need to be further explored.

City of Calgary internal staff autonomous vehicle workshop

For example, one of the scenarios was, "AVs are available for both commercial and private use." For this scenario some of the debate was around how The City could use AVs for different vehicles in our fleet: Roads (e.g., snow removal) Waste and Recycling Services, Transit, Fleet Services, Parks (e.g., lawn maintenance). They also looked at how Human Resource strategy and policy could require review e.g., personnel requirements change as a result of adopting the technology.

Some of the questions and themes brought up from The City workshop participants included:

- If The City starts adopting AV fleets, what are the impacts for safety, security, budgets, and labour relations? There is a big concern about job losses or job role changes for City of Calgary staff.
- More information is needed on how the technology will inform policy development.
- How do we ensure commercial activities using AV technologies are safe and efficient? Who will regulate the safety of the technology?
- How can Transit maximize the new technology to improve its service?

The major recommendation from the working group was to create a group that involves relevant internal and external stakeholders that will be affected by AV technology so that City Departments can keep up to date on relevant information and have a flexible approach to the technology.

Next steps

Several recommendations were developed to guide The City's next steps in regards to AVs.

Recommendations

1. **Establish an Internal Working Group to monitor, share information and develop strategies and actions for AVs.**

   The largest lesson learned from the internal workshop was that multiple departments and business units will be impacted by the new technology; not just Transportation. AV technology is changing at a rapid rate and The City should have a formalized process on how to deal with risks and opportunities as they arise.

   The City will form an internal working group in order to: monitor, share information and develop strategies and actions for AVs. It is envisioned that the working group would also invite the private sector and the surrounding regional municipalities to take part in the conversation in how to best address issues and explore opportunities presented by AV technology.

The working group would have a representative that would liaise with the larger country wide working group, the provincial and federal government. Transportation will coordinate and organize the working group meetings with input from other business units. This strategy falls in line with what Toronto, Edmonton and Vancouver are doing.

2. Participate in an AV pilot project.

In collaboration with the University of Alberta, Government of Alberta, the City of Edmonton and other stakeholders, The City is looking to move forward with a low speed, autonomous transit vehicle pilot between the Zoo LRT station and the TELUS Spark Science Centre. Attachment 2 of the report provides more details onthe benefits of this initiative.

3. Develop an Autonomous Vehicle Future Scenario.

The Transportation Forecasting Division is developing an AV scenario using the Regional Transportation Model (RTM) to better represent the regional implications of AV technology. This scenario may be used for analysis on a variety of AV scenarios and will help assess the impact of different policy levers.

4. Collaboration with the University of Calgary.

City staff met with numerous faculty members from various departments at the University of Calgary. The City plans on releasing a number of projects through the Urban Alliance in order to better understand and prepare for AVs. For example, the Department of Civil Engineering would work with City staff to simulate optimal loading and unloading configurations in the downtown core for AVs.

5. Collaboration with the private sector.

In the process of creating this report, companies and organization emerged that were very knowledgeable. It will be beneficial to collaborate with the private sector on new transportation technology initiatives.

6. Update the MDP/CTP with new technology in mind.

When the MDP/CTP was developed in 2009, AV technology was in its infancy and was not seen as a transformative technology. Over the past few years AVs have become a realistic technology that are envisioned to impact Calgary's transportation network and land use decisions in the upcoming decades. AV and other technologies will be integrated into the MDP/CTP update expected for 2019.

7. Add an Autonomous Vehicle assessment into capital business cases.

While the development of transportation infrastructure options may consider the potential impacts from autonomous vehicles, this type of analysis is not explicitly identified as part of the business case process for capital projects. This action would see the transportation capital business case template being modified as to indicate the usefulness or adaptability of the infrastructure in a fully-AV environment. The resulting information would then be considered as part of the funding prioritization process, identifying whether exposure to risk exists and qualitatively describing the severity of impact to the proposed investment.

8. Make City assets and information available for use to facilitate technological development.

The City has a variety of assets, from physical infrastructure such as roads and buildings, to data and information on the transportation system. Efforts should be made to make these available on a case-by-case basis to support technological development in the private sector that is of mutual benefit. This could involve making infrastructure available (in kind or otherwise), supporting open data initiatives or other cooperative efforts.

9. Explore opportunities for participation in the Government of Canada's Smart Cities challenge.

The City of Calgary plans on working with internal and external stakeholders to participate in the Smart Cities Challenge. The challenge should highlight how AVs and other technologies can be best integrated into the urban realm.

10. Explore a High Tech Logistics Hub.

Real Estate & Development Services (RE&DS) is working with Calgary Economic Development to examine the potential of promoting Dufferin North as a leading edge technology center for goods distribution. It is envisioned that Dufferin North could utilize autonomous vehicles, drones and other new transportation technology to improve the distribution of goods and attract businesses.

Aerial delivery drones

- The federal government has exclusive jurisdiction over aeronautics. Aerial delivery drones would not be able to operate in urban areas under current federal regulations.
- If aerial delivery drone federal regulations are relaxed to allow for urban deliveries, it is expected to have only a moderate impact on the transportation network as a whole.
- Aerial drones have a higher potential for recreation and survey uses than product delivery.
- All aerial drones have security, privacy and safety issues.

What is aerial delivery drone technology?

Aerial delivery drones are unmanned aerial vehicles that can be used to transport packages, medical supplies, food and other goods under a certain weight. For cities, it helps to solve the last mile problem for commercial goods; taking them from a warehouse or store to an individual customer within the same area of the city. For rural or remote areas, it helps transport goods such as medicine to hard to reach places. This section focuses primarily on aerial delivery drone Technology and does not cover recreational or survey drones.

Status of the technology: **Testing**

While recreational and survey drones are currently available to the public for purchase, drones that are able to deliver packages in urban environments are in their testing phase. The main application to date has focused on delivering medical and emergency supplies in remote areas of the world (UPS, 2016).

Industry

Companies testing drone delivery prototypes include Amazon Prime Air, Google, UPS, and DHL. In December 2016, Amazon Air Prime completed its first delivery to a customer in Cambridge, England (The Guardian, 2016).

Canadian Company Drone Delivery Canada hopes to develop an unmanned aerial delivery system that will "eventually allow corporate and government clients to deliver packages across Canada via drone" (Calgary Herald, 2017).

December 2016 Amazon Prime Air delivery of TV streaming stick and bag of popcorn directly to the garden of a nearby customer in Cambridge, England. (Photo credit: Amazon)

Barriers to adoption

Technologically aerial drone delivery of small goods is feasible, however, severe weather, collisions with birds and short battery lives put the drones at risk of falling out of the sky and injuring people or damaging buildings in populated areas. The main barrier to the adoption of aerial delivery drones is federal regulation.

"Companies testing drone delivery prototypes include Amazon Prime Air, Google, UPS, and DHL."

Who is responsible for what?

Federal

The federal government has exclusive jurisdiction of aeronautics. Delivery drones are considered unmanned air vehicles (UAVs) that are guided by section 602.41 of the Aeronautics Act. A Special Flight Operations Certificate (SFOC) is required for some UAV operations in Canada. Even recreational drones are subject to several requirements prior to use. Figure 9 provides an overview of some of the regulatory requirements for operating drones in Canada. Failure to comply with the regulations can result in a fine ranging from $3,000 for recreational drone operation to $25,000 (and/or jail time) for corporations operating non-compliant UAVs.

Transport Canada is currently developing new regulations to address the safety requirements, growing popularity, and economic importance of aerial drones. Proposed changes include:

- new flight rules
- aircraft marking and registration requirements
- knowledge testing
- minimum age limits
- pilot permits for certain aerial drone operations

The updated regulations are expected to be made available for comment later in 2017.

Transport Canada –
Aerial drone flight permission process

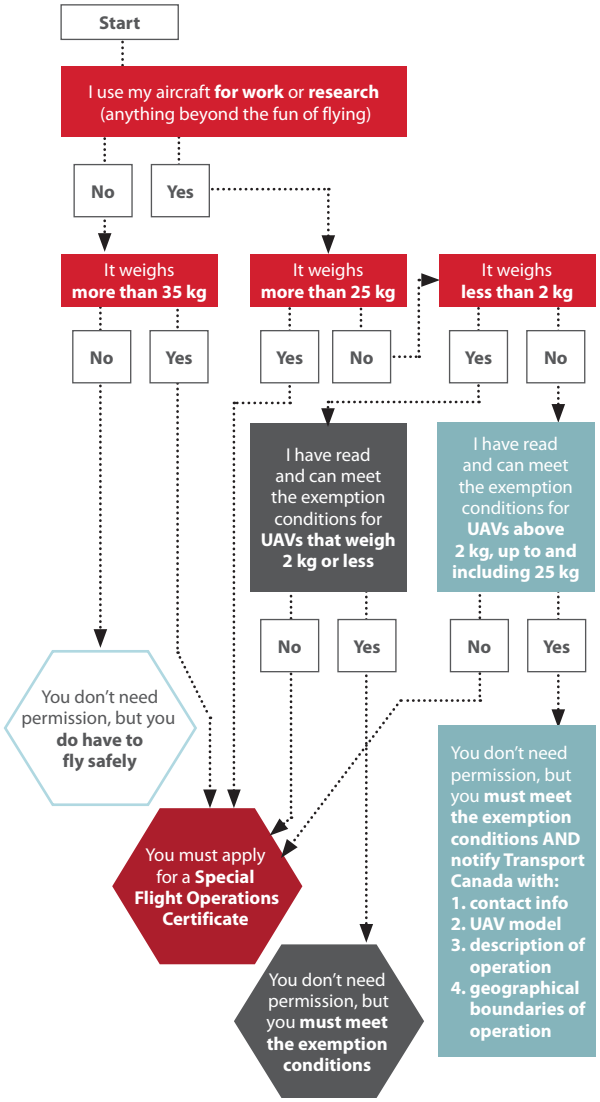


Figure 9 - Transport Canada flow chart on drone rules

Municipal

The City of Calgary can restrict the operation of drones on City Land.

For example:

The Parks and Pathways Bylaw 20M2003 states
"No Person shall set off, launch or operate, while in a Park: any remote control device including boats, planes, helicopters or cars; except where such activity is specifically allowed by the Director." (Bylaw 20M2003 sec 24(c)).

The Street Bylaw 20M88 states
"No person in control of a model airplane of any nature shall use any portion of a Street for the purpose of flying or testing such a model airplane." (Bylaw 20M88 sec 12).

In some, but not all instances, the use of a drone within City boundaries requires City consent, depending on the area in which the drone is being operated.

What work has The City of Calgary undertaken?

The City of Calgary has not worked on drone delivery technology directly, but Corporate Analytics and Innovation (CAI) sent a memo to Council in 2015 regarding aerial drone usage. Some City departments and business units use aerial drones for surveying and emergency work, including: Calgary Parks, Corporate Analytics and Innovation, the Calgary Fire Department, Calgary Emergency Management Agency (CEMA) and the Calgary Police Service.

What if someone were to operate a drone delivery service today in the city?

Aerial delivery drone services would not be allowed to legally operate in Calgary due to Transport Canada regulations. Only Calgary Police can enforce Criminal Code or other federal legislation relating to aerial drone operation. Bylaw Enforcement Officers can only enforce bylaw offences, of which only a few would apply to drone operation.

Aerial delivery drone services in rural/remote areas are more feasible under current federal regulations.

What are other countries and cities doing?

- The village of Foremost, Alberta has a 2,400 square kilometre drone testing area. The Foremost test site is the first location in Canada where drones can legally operate beyond visual line of sight (CBC News, 2017).
- In July 2016, Amazon partnered with the British Government, to trial drone delivery. This trial will potentially pave the way for commercial air deliveries for UK residents (BBC News, 2016).
- Google's partnered with the US Government in 2016 to trial delivery drones as part of its Project Wing program (Bloomberg, 2016).

Level of impact: Medium/Low

In the unlikely scenario Aerial Delivery Drones are legalized in urban areas at a federal level, the impacts to the transportation network are low due to most delivery drones ability to carry only small packages.

This may allow for some emergency deliveries in the city e.g. delivering medical supplies to a person in distress. For legislative, technical and safety reasons, it is not expected that delivery drones will carry heavy packages or people anytime in the near future.

Aerial Delivery Drones are expected to be useful in delivering medical equipment and supplies in remote areas outside the city boundary.

Next steps

We are still many years away from aerial delivery drones in urban environments; there are many of obstacles to overcome before the technology becomes available for aerial deliveries in Canadian cities largely due to federal regulations. The City of Calgary will continue to monitor advancements in drone delivery technology, municipal enforcement and new revisions to federal regulations.

Major technologies

Electrification

This chapter explores electrification of the transportation system, the resulting demand for new types of vehicles including E-bikes and electric vehicles, and what role The City of Calgary can have in this new technology.

The transition to electric passenger cars is already beginning. New vehicles are able to drive about 350 kilometres on a single charge, roughly the round-trip distance between Calgary and Lake Louise. These vehicles are already less expensive to operate and maintain today than a comparable gasoline-powered car. Initial purchase prices are also expected to be the same or less than gasoline-powered cars by the mid-2020s, at which point adoption of electric vehicles is projected to increase exponentially.

Electric vehicles also reduce local air pollution, noise and greenhouse gas emissions from transportation (Axsen et al, 2015). As a result, some national and regional governments offer financial incentives to purchase electric vehicles, and several (including Germany) are actively considering banning the sale of gasoline-powered vehicles by 2030 (Road and Track, 2016), (Green Car Reports, 2016).

Electrification is not limited to passenger vehicles. Electric buses are already in use in some cities, along with electric or hybrid-electric delivery trucks and waste and recycling vehicles. Electrification has not been adopted yet for long haul trucking due to the cost and weight of current batteries. Electric bikes are increasing in popularity to assist cyclists in difficult terrain.

Most charging for electric vehicles will occur at home or business garages, but there is also demand for publicly-accessible charging stations along intercity highways and at major destinations.

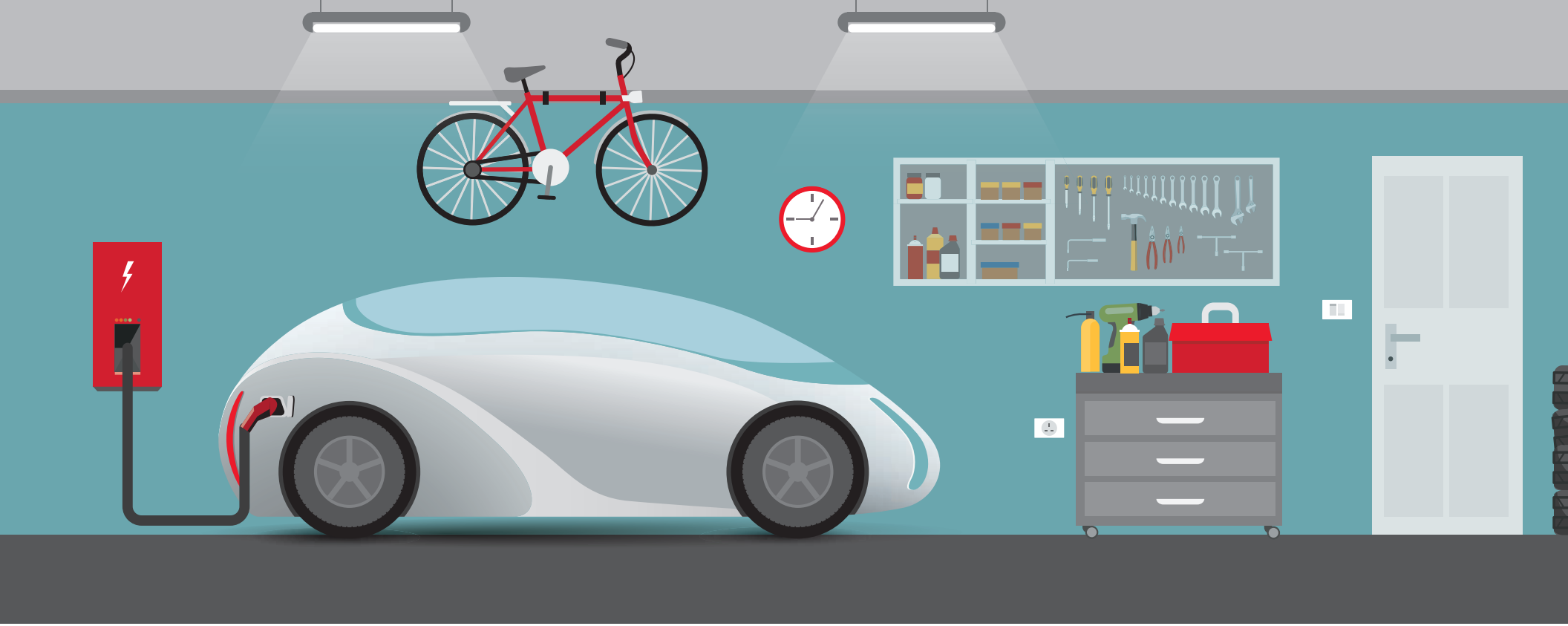
Recharging times for electric vehicles are longer than fueling times for gasoline-powered cars however, making it more desirable to install charging stations near services and amenities.

Increased demand for electricity to charge these vehicles will increase demand on the electrical distribution system. This may require upgrades to the system in some locations, but could in part be managed through pricing signals to influence the time of day that charging occurs. In the future, idle electric vehicles may help balance electricity demand in cities by storing and/or releasing excess electricity.

Increasing use of electric vehicles will reduce the amount of gasoline and diesel used in transportation. This in turn will reduce the amount of infrastructure funding received from provincial and federal gas taxes, requiring alternative funding to meet infrastructure needs.

Electric vehicles

- The performance and affordability of electric vehicles has improved dramatically over past decade. Electric vehicles are expected to make up a higher percentage of the vehicle fleet in the near future.
- Electric vehicles are expected to do most of their charging at a persons' place of residence and at off-street parking locations e.g. parkades.
- Even with Alberta's current electrical power supply originating from coal, there are still environmental benefits from electric vehicles. As Alberta's power supply moves away from coal, the environmental benefits of electric vehicles will increase.
- Electric vehicles may trigger broader upgrades to electrical infrastructure.
- A large portion of City of Calgary's transportation infrastructure funding comes from provincial and federal fuel tax revenues. As fewer vehicles use gasoline and diesel, a replacement funding source will be needed to fund infrastructure projects.



What are electric vehicles?

Electric vehicles are vehicles that are fueled by electricty. Emerging technologies in this category include hybrid-electric vehicles, fully electric vehicles (EVs) and hydrogen fuel cell vehicles. These are being applied to passenger vehicles, buses, urban delivery vehicles and service vehicles. Due to the weight and capacity of existing batteries, electrification of heavy duty long-haul trucking is only in the experimental phase at this time. Alternative fueling infrastructure (e.g. EV charging stations) is a necessary part of all alternative fuel systems.

Status of technology: **Limited availability/Widespread**

EVs currently represent about 1% of car sales globally, and less than 1% in Calgary and Alberta. However, the rapid decline in battery costs, and increasing range of newer EVs is making this technology increasingly attractive to the public. The new Chevy Bolt and Tesla Model 3 offer ranges of about 350km, with a sale price around $35,000 US. Most major car manufactures intend to offer similar options over the next five years.

Although EVs are more expensive to purchase than the equivalent gasoline powered car today, they are already cheaper to operate and maintain. This is due to lower costs to 'refuel' with electricity versus gasoline, and few moving parts in the drivetrain that require regular maintenance. EVs are projected to cost the same or less than the equivalent gasoline powered vehicle starting in the mid-2020s (Bloomberg, 2016). This will result in a rapid increase in EV sales, with various projections of EVs accounting for anywhere from 25% to 50% of all new car sales globally by 2040. Although Bloomberg New Energy Finance (Bloomberg New Energy Finance, 2016) has already revised their adoption estimate higher (to 47% of all new sales by 2040) the chart shown below, (Figure 10) from their early 2016 analysis, an indication of the rate of growth expected for EV sales.

Synergies with autonomous vehicle technology and ridesharing initiatives may result in even faster adoption of EVs. This is because the computers used in autonomous vehicles are also well suited to optimize the electric drivetrain.

For rideshare companies, such as Uber and Lyft, EVs can reduce lifecycle costs to own and operate their vehicle fleets. In Calgary, cost savings are already being realized by local taxi companies as hybrid-electric vehicles comprised 30% of all taxis in 2016. For the near future, hybrid-electric vehicles (which generate electricity from braking and a gasoline motor, instead of plugging in) will likely be the more common technology used by manufactures such as Ford in reducing fuel consumption and associated emissions for popular SUVs and pick-up trucks (Green Car Reports, 2015).

Development of fully electric pickup trucks and SUVs is currently behind fully electric cars. Changes to fuel consumption regulations in the United States may also slow North American efforts to develop fully electric pickup trucks and SUVs, except in states with stricter emission rules such as California. Trucks make up about half of vehicle sales in Alberta currently.

Providing the infrastructure for charging EVs is more cost competitive than other fuel options. For example, hydrogen fueling stations can cost between $500,000 to $5 million to install (Qin, N. and P. Brooker, 2014), (Car and Driver, 2008). By comparison, it costs approximately $100,000 for a DC Fast Charging station, or $1,000 to $10,000 for a slower Level 2 charging station for EVs.

Figure 10 - Annual projected increase of electric vehicles (Data compiled by Bloomberg New Energy Finance)

What work has The City of Calgary undertaken?

The City's Climate Change Program, in coordination with the Transportation department, is currently developing an Electric Vehicle Strategy for Calgary.

Electric vehicles offer the greatest opportunity of any alternative fuel technology to reduce greenhouse gas emissions from private and fleet automobiles – between 10% to 40% reduction in emissions by 2040 in Calgary, depending on the rate of public adoption (Layzell, D. and B. Straatman, 2016). Public adoption of electric vehicles is just beginning in Calgary. As of June 2015, there were 125 electric vehicles in Calgary, along with 19 public charging stations. The Calgary Parking Authority installed an additional six public charging stations as of December 2016, while private businesses installed an additional 28 stations between mid 2015 and December 2016.

As part of the strategy development, The City is coordinating with regional partners in southwest Alberta on the development of a regional 'fast charging' network to connect with the Kootenays, Montana and potentially central Alberta.

This network will allow electric vehicles to charge in under 30 minutes, much faster than the current public charging stations located in Calgary. Tesla is also installing a bank of fast charging stations for Tesla vehicles just north of Calgary.

"Electric vehicles offer the greatest opportunity of any alternative fuel technology to reduce greenhouse gas emissions from private and fleet automobiles."

Barriers to adoption

- Hybrid-electric, fully electric and hydrogen fuel cell vehicles all have higher up-front purchase costs compared to an equivalent gasoline-powered vehicle at this time. EV passenger vehicles are projected to cost the same or less than equivalent gasoline powered cars in the early to mid-2020s as battery prices continue to fall.
- Public charging infrastructure for EVs is currently limited in Calgary, and non-existent for hydrogen fuel cell vehicles.
- Retrofitting condos and apartment buildings for home charging is more involved than new construction. Retrofitting single family homes for home charging is technically straight-forward, but requires an up-front investment of about $2,200 (Cantech Letter, 2016).
- For long distance trips, EVs take longer to recharge (30 minutes for an 80% charge at a DC Fast Charging Station) than gasoline or hydrogen fuel cell vehicles take to refuel.
- Range limitations and driver range anxiety.

What are other countries and cities doing?

Government policies in other jurisdictions are already driving faster local adoption of EVs in order to reduce both local air pollution and greenhouse gas emissions. Germany is actively considering introducing requirements for all new car sales to be zero emissions (such as EVs) by 2030, while Norway and the Netherlands are considering similar requirements that would start in 2025. India has a goal to have 100% of vehicles on the road (not just new sales) to be zero emissions by 2030, although this will likely be difficult to achieve (The Financial Express, 2016).

The Provinces of British Columbia, Ontario and Quebec (along with many US jurisdictions) offer financial incentive programs that reduce the cost of buying EVs and home charging stations, which have directly increased sales of EVs in those jurisdictions. It is unclear what US Federal regulations regarding fuel efficiency and greenhouse gas emissions will look like going forward, but numerous US states (most notably California) are expected to continue implementing their incentive and regulation programs.

Many North American cities are installing public charging stations and/or engaging in promotional activities to support public adoption of EVs. The most successful examples include San Francisco, Atlanta, Los Angeles, San Diego, Portland and Seattle (Lutsey, N. et all, 2015). Various jurisdictions in Canada, such as Vancouver, are also actively installing EV charging stations. Private organizations, such as Sun Country Highway and Tesla, are actively installing public charging stations across Canada, often in collaboration with other businesses such as hotels.

Several North American jurisdictions have introduced building code changes that require new houses or condos to be pre-wired for home EV charging stations. For single family dwellings, this is estimated to reduce the installation cost for home charging stations from at least $400 to $1,500 (Cantech Letter, 2016) (in addition to approximately $700 for the charging station itself). As of 2019, the European Union will require all new or refurbished housing to be equipped with a complete Level 2 charging station, not just pre-wiring (CleanTechnica, 2016).

In response to government regulations, technology advances and broadening customer demand, numerous automotive manufacturers are developing new hybrid-electric and electric vehicles (Vox, 2016).

Electric charging station in the municipal parkade

Who is responsible for what?

Federal

The Federal government's Pan-Canadian Framework on Clean Growth and Climate Change (Government of Canada, 2017) includes a commitment to work with provincial governments and industry to develop a Canada-wide strategy for zero-emissions vehicles by 2018. The strategy will expand on early Federal programs to install public charging stations across Canada. Several grant programs, including ones from NRCAN, already include public charging infrastructure as eligible programs.

Grant funding to support the transition of municipal buses and fleet vehicles to electric or zero-emissions technologies would be another approach available to support adoption of this technology.

Provincial

The Provincial government is currently studying what role(s) it should take regarding electric and other zero-emissions vehicle technologies. The provincial decision to achieve complete phase out of coal power plants by 2030 will further improve the greenhouse gas and air pollution benefits of electric cars operating in Alberta going forward.

Some provinces and states already offer financial incentives or rebates on the purchase of an electric vehicle or home charging station. Direct investments in public charging infrastructure, changes to building code requirements for pre-wiring to support charging stations, and educational programs are also areas that could be addressed by the Province.

Grant funding to support the transition of municipal buses and fleet vehicles to electric or zero-emissions technologies would be another approach available to provincial governments to support adoption of this technology.

The province could also consider modifications to annual registration fees to reflect lower carbon emissions, impacts on fuel tax revenue and other impacts such as battery recycling.

Municipal

The City of Calgary is taking a leadership role in developing an EV Strategy for Calgary. Depending on the recommendations of the EV Strategy, The City may choose to set development requirements (voluntary or regulatory) around pre-wiring for home charging stations in new single-family dwellings and condos. The City could also be a contributor, in collaboration with utilities, private businesses and other regional governments in the installation of some public charging stations.

The City and regional partners across southern Alberta are applying for national grants to enable the installation 15 to 20 fast charging stations to support long-distance EV travel across and beyond Alberta.

Enmax is responsible for planning to accommodate changes in electricity demand due to EV charging activity.

The CPA currently has a role in owning and operating several public charging stations in Calgary, and may expand the number of stations in CPA parking facilities in the future. The CPA may also play a role in the potential provision of curbside EV charging.

Private Sector

The Private Sector has a significant role to play in providing public and private charging infrastructure to Calgarians. The majority of the 47 public charging stations in Calgary have been installed by private businesses in order to serve customers. These are the more affordable but slower Level 2 charging stations, which are suitable for 'topping up' an EVs battery charge while travelling within Calgary (as opposed to the fast charging stations that enable regional travel).

Automotive retailers in Calgary also have a key role to play by selling an increasing variety of electric vehicles, and providing educational and maintenance support to EV buyers.

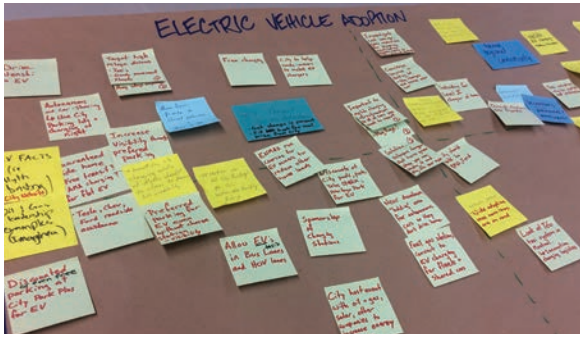
What if electric vehicles began operating today in Calgary?

Electric vehicles are already operating in Calgary today. If consumer uptake of electric vehicles occurs at the rates predicted, Calgary and the surrounding region will require more public charging infrastructure to meet the demand for recharging on the go. Calgary already has just over 50 Level 2 public charging stations provided by a variety of private companies as well as the Calgary Parking Authority. These Level 2 stations can provide a valuable but modest 'top up' charge over several hours. In order to recharge an EV battery to enable long distance trips (e.g. Calgary to Banff), more powerful fast charging stations will be required. There are currently no fast charging stations in Calgary or most of southern Alberta, so this gap is being addressed through the EV Strategy being developed by The City of Calgary in collaboration with our regional partners. The City currently has some EVs in normal fleet operations. The City can, over time, adopt EVs into a broader cross-section of the fleet to better understand the realities of this type of vehicle. For example: The City is exploring conducting an electric bus pilot in collaboration with the Province of Alberta.

Electric vehicles represent one of the greatest opportunities to reduce GHG emissions from the transportation sector, which accounts for 36% of all emissions in Calgary.

Through the upcoming EV Strategy for Calgary, The City is engaging stakeholders to consider what public charging infrastructure is appropriate to support the adoption of this technology, and any requirements (voluntary or regulated) for pre-wiring of electrical conduits in new homes and condos to allow for home charging stations. The City can also explore ways to encourage provision of workplace charging stations.

At the same time, Enmax must evaluate impacts and opportunities to the electrical distribution network as a result of increasing EV charging activity, and whether (in time) the battery storage capacity of EVs can be leveraged to reduce impacts on the electrical network. In addition, EV battery storage may offer opportunities to support the roll out of renewable energy by providing temporary storage of excess wind or solar power for use during peak load times.



Stakeholder feedback on EV Stategy

"EVs represent one of the greatest opportunities to reduce GHG emissions from the transportation sector, which accounts for 36% of all emissions in Calgary."

Level of impact: **Medium/High**

Increased adoption of electric vehicles may have several impacts on Calgary's transportation and land use network.

Opportunities	Risks
Installation of public charging stations for EVs is possible in new locations that did not previously provide 'fueling' services. In many jurisdictions these charging stations are installed off-street in existing parkades, parking areas for businesses, or in homes. They can be a great compliment in a mixed-used development, allowing drivers to shop or rest in the area while charging their vehicle. In some cities public charging stations have been installed on-street (where on-street parking is already allowed). Additionally, when the stations are no longer needed, there are no lingering environmental impacts (compared to gas stations).	Increased adoption of EVs would reduce the amount of gas taxes collected by the Provincial and Federal governments, which in turn could reduce the amount of grant funding available to The City of Calgary for investments in transportation network infrastructure.
Reduced noise and local air pollution from either EVs or hydrogen fuel cell vehicles may help make Main Streets more desirable locations for shopping and recreation. As of September 1, 2019, US Federal regulations will require these vehicles to make a modest amount of noise when moving at low speeds to guard against pedestrian collisions. Canadian regulations may follow suit.	The technology is quickly evolving and there could be some elements of the electrical charging infrastructure e.g. a certain standard of plug, that could become quickly outdated.
The number of gas stations may decline over time as gasoline-powered vehicles make up a smaller percentage of cars and fuel efficiency increases in Calgary. Some service station providers are considering providing some fast charging infrastructure for EVs, (The Guardian, 2016) but the majority of EV charging in cities (as opposed to regional highways) will likely occur at home or workplaces. A reduction in the number of public service stations may create opportunities for redevelopment of these lands to new urban uses, but may also require remediation due to ground contamination.	

Figure 11 - Opportunities and risks of electric vehicles

Next steps

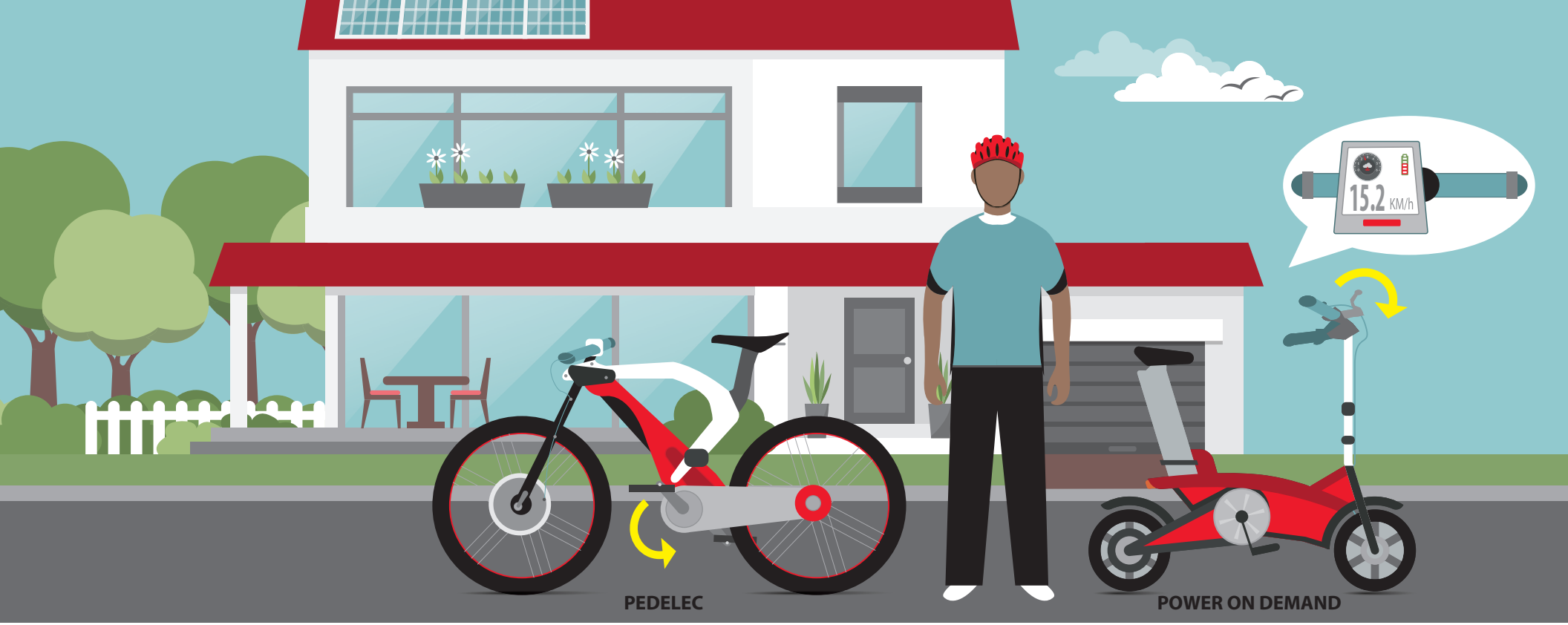
The City should complete development of the Electric Vehicle Strategy for Calgary in collaboration with Enmax, the CPA and stakeholders.

The strategy will include recommendations regarding public charging infrastructure, policy and bylaw changes related to potential on-street charging activity, enabling private development readiness for EVs, and educational programs. The City should seek to align its actions and investments with regional partners, private-sector businesses and other orders of government.

The City should also continue discussions around the likely decline in gas taxes (as the adoption of hybrids and EVs increases) with the Provincial and Federal governments to ensure stable or alternate funding for high priority transportation network investments in the future.

Electric bikes (E-Bikes)

- E-Bikes have been around for over 100 years. What has changed dramatically over the past decade is the decline in cost and weight of the bikes, and improvements in battery technology.
- Current models can be very similar or identical to regular bicycles in appearance and operation.
- E-Bikes are becoming very popular globally with E-Bikes composing 25% of new bicycle sales in the Netherlands. E-Bikes are not yet as popular in North America.
- Studies have shown that people purchase E-Bikes for convenience, not speed. E-Bikes open up cycling for seniors, those with disabilities and those with longer or hilly commutes.
- A review of City bylaws is needed to facilitate E-Bike usage across the pathway network.



Pedelec E-Bikes have an internal motor that helps users pedal.

Power on Demand E-Bikes use a throttle and/or pedaling to propel the user.

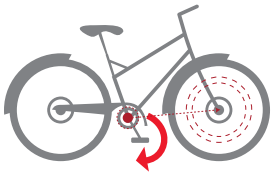
What is an electric bike?

An electric bicycle (E-Bike) is a pedal bicycle with an integrated electric motor which can be used to propel the rider forward. There are a large variety of E-Bikes available, from ones that only have a small motor to assist the rider, to somewhat more powerful ones which tend to be closer to a moped in terms of functionality. All E-Bikes retain the ability to be pedaled by the rider and this is the main reason why they are not considered electric motorcycles or mopeds.

E-bikes are classified into two main categories

Power on Demand:

On a power on demand E-bike, the motor and the pedals are independent of each other, making pedaling optional. Riders can either cruise along without pedaling (riding only with the motor) or pedal while using the motor (using hybrid motor and pedal power). Riders activate the throttle via a twist grip, a thumb press, or a simple on/off switch.



Pedal Electric Cycles (Pedelec) or Pedal Assist cycles:

Pedelecs are only designed to assist the rider with extra power while they are pedaling, not to replace it. Motorized power on a pedelec is only provided when the cyclist is pedaling, making the use of a pedelec almost identical to riding a regular bicycle—only making it a bit easier for long rides, up tough stretches, or for individuals who have difficulties riding regular bicycles.

Provincial Power Bicycle Definition	Operating requirements
• Electric motor with a maximum power of 500 watts • Top speed of 32 km/h • No weight restriction • Includes power assisted bicycles • Must maintain its pedals, or the vehicle will be considered as a moped which require registration and insurance	• No driver's licence required • Minimum driving age is 12 • No insurance or registration required • Motorcycle helmet required

Figure 12 - E-Bikes are categorized as Power Bicycles under provincial legislation.

"E-bikes are now popular among consumers and are the highest selling electric vehicle on the planet with forecasted sales of 35 million in 2016."

Navigant Research, 2016

Status of technology:
Limited availability/Widespread

E-bikes are an old technology with the first patents being filed in 1890s. With technological advances in battery and materials, E-bikes are now popular among consumers and are the highest selling electric vehicle on the planet with forecasted sales of 35 million in 2016 (Navigant Research, 2016).

- In the Netherlands, The Dutch Industry-Association reported that the number of E-bikes sold in the Netherlands increased by about 52 per cent to 276,000 between 2011 and 2015, while the number of manually powered bicycles fell by 33 per cent in the same period. One in four bikes bought in the Netherlands is an E-bike (Bike Europe, 2016).
- The global market for E-bikes is dominated by China, with an estimated 85 per cent of worldwide E-bike sales; 32 million bikes were sold in China in 2013. It is predicted that there are more E-bikes than cars on the road in China (INSG, 2014).
- E-bikes in North America have not had the same market growth as Europe and Asia. In the United States, an estimated 185,000 E-bikes were sold in 2013, according to the Electric Bikes Worldwide Report (EWBR). The EWBR highlights that there was an 80 per cent sales growth in 2013 over 2012 (INSG, 2014).

E-Bikes compose 25% of new bike sales in the Netherlands

Barriers to adoption

- E-Bikes are more expensive than traditional bicycles. Costs range from $1,500 to $5,000.
- There is somewhat of a bicycle culture stigma in North America that may prevent some users from adopting the technology.
- E-Bikes can be heavier than normal bikes.
- Government policies can restrict E-Bike usage.

Although E-Bikes look almost identical to other bicycles, they could face a cultural stigma in North America that could delay their adoption.

What work has The City of Calgary undertaken?

Transportation plans for all types of bicycles on roadways and cycle tracks. There has been no thorough analysis on E-Bikes done by Transportation, however, there have been very few complaints about E-Bikes.

What are other countries and cities doing?

Different countries have various laws governing E-Bike usage. Most western countries allow E-Bikes on pathways, however many countries have lower wattage and speed limits. In Canada it is federally mandated that an E-Bike be designed with a motor that will cut out when the speed of the bicycle reaches 32km/h.

Country	Watt limit	Speed limit (km/h)	Power on demand E-Bikes allowed on cycle paths	Pedelec's allowed on cycle paths
Australia	250	25	Yes	Yes
Canada	500	32	Depends on municipality	Depends on municipality
European Union	250	25	Yes	Yes
United Kingdom	250	27.5	Yes	Yes
United States	750	32	Depends on municipality	Depends on municipality

Figure 13 - Status of E-Bikes across the world (Wikipedia, 2017)

Who is responsible for what?

Federal

Under the Federal Motor Vehicle Safety Act, both power on demand and pedelecs are defined as power-assisted bicycles. As part of the Motor Vehicle Safety Act, the federal government sets the definition of a power-assisted bicycle. For example: The Motor Vehicle Safety Act states that a power-assisted bicycle must be capable of being propelled by muscular power.

Provincial

The provincial government uses the federal definition power-assisted bicycle, but has renamed it Power Bicycle. As part of the Traffic Safety Act, the provincial government legislates the operating requirements and restrictions of power bicycles. For example: a person who is under the age of 16 years and is operating a moped or power bicycle shall not carry any passengers on the moped or power bicycle. The provincial government also sets the need to license and insure vehicles.

Municipal

Through local bylaws, The City can designate where E-Bikes can operate.

Under The City of Calgary Traffic Bylaw, both power on demand and pedelec E-Bikes are defined as bicycles[2] and can use roadways, High Occupancy Vehicle (HOV) lanes and bike lanes.

In The City's Parks & Pathways Bylaw, pedelec E-Bikes are considered bicycles and are allowed on pathways and trails (except where bicycles are prohibited) whereas power on demand E-Bikes are not allowed on pathways and trails. It should be noted that a cyclist riding an E-Bike must abide by posted speed limits set in different areas of the city. For example, along pathways and trails, pedelec E-Bikes, like regular bicycles, are to go no faster than 20 km/h, regardless of whether or not the motor is still operating.

[2] If an E-Bike is over 35 kg; or over 750 watts; or has a hand or foot operated clutch or gearbox driven by the motor that transfers the power to the driven wheel, is not a "bicycle" for the purposes of the Calgary Traffic Bylaw.

What are Canadian cities doing?

In Ottawa, E-Bikes that physically resemble traditional bikes are permitted on City of Ottawa bike paths. Scooter type power assisted devices and bicycles with a non-conventional appearance are NOT permitted on the pathways because they tend to be heavier and therefore have an increased risk to health and safety in the event of a collision.

The City of Toronto modified their definition of bicycles in multiple municipal codes to read "Includes a bicycle, tricycle, unicycle, and a power-assisted bicycle which weighs less than 40 kg and requires pedaling for propulsion ("pedelec"), or other similar vehicle, but does not include any vehicle or bicycle capable of being propelled or driven solely by any power other than muscular power." They also modified the municipal code for footpaths, pedestrian ways, bicycle paths, bicycle lanes and cycle tracks to permit the use of power-assisted bicycles (E-Bikes).

The City of Vancouver has defined a power assisted bicycle as part of their Motor Vehicle Act, as a Motor Assisted Cycle Regulation, and have also included a section in their bylaw prohibiting the use on the seawall. "No person shall drive, operate, or propel despite section 63A.(1), on any path adjacent to a seawall or on any seawall, any motor vehicle, assisted or not, except for a motorized wheelchair, and for the purpose of this by-law, a "seawall" is a way normally open to the use of the public that is adjacent or close to a body of water."

What if someone were to operate an E-Bike today in Calgary?

Figure 14 displays where different types of bicycles are allowed to operate in Calgary as per The City's Traffic Bylaw and the Parks & Pathways bylaw.

Operation	Electric motorcycle/moped	Bicycle	Pedelec	Power on Demand (E-bike with throttle)
Regulated under the Calgary Traffic Bylaw				
Roadway	✓	✓	✓	✓
Bicycle Lane	✗	✓	✓	✓
HOV Lane	✗	✓	✓	✓
Sidewalk	✗	Not allowed unless: a) You are a newspaper carrier delivering newspapers b) It is a child's bicycle operated by an individual under the age of Fourteen (14) years c) The Traffic Engineer has designated that the riding of bicycles is permitted		
Regulated under the Parks and Pathways Bylaw				
Pathway	✗	✓	✓	✗
Trail	✗	✓	✓	✗

✓ Allowed
✗ Not allowed

Figure 14 - Legal status of vehicle operations

Level of impact: **Medium/Low**

If Calgary follows the trend of European and Asian cities, then there are likely to be many more E-bikes in Calgary over the next few years.

Opportunities	Risks
Bike Europe reports that one of the main reasons for the growing popularity of E-Bikes throughout Europe is that they can be used by the elderly, people with disabilities and people that need to travel long distances to school or work (Bike Europe, 2016). Research from Portland University supports this claim with a 2014 study revealing that approximately 45 per cent of North American E-Bike users are 45 or older and about 30 per cent indicated some kind of limited mobility. 70 per cent of the people surveyed in the study said they purchased E-Bikes to replace some of their car trips (Anderson, 2014). E-Bikes in Calgary could support a wider demographic of people cycling and replace some vehicle trips.	There is a concern that E-Bikes could be used for speeding, which could cause safety concerns, particularly on pathways. However research indicates that people use E-Bikes primarily for convenience and not for speed (Bike Europe, 2015).
Research has indicated that pedelec E-Bikes provide an effective workout while improving some aspects of cardiovascular health, especially for riders who previously had been sedentary (Peterman, Morris, Kram, & Byrnes, 2016). The adoption of E-Bikes in Calgary could likely lead to higher rates of cycling and many health benefits for Calgarians.	

Figure 15 - Opportunities and Risks of E-Bikes

Next steps

The Calgary Parks business unit will conduct a further investigation into E-Bike usage on Calgary's pathways and trails as part of the comprehensive review of The City's Parks & Pathway Bylaw. Transportation has volunteered staff to help with the E-Bike review. One of the goals would be to create a uniform definition of a bicycle for all City documents for greater rule legibility.

Connectivity and shared mobility

This chapter explores the connected technologies of: The Internet of Things, Mobility as a Service, Connected Vehicles and Parking Technologies.

In 1992 there were 1 million computers connected to the internet. As of 2015 there are 15 billion devices including computers, watches, cell phones and vehicles connected to the internet. Intel projects this number to grow to 200 billion by 2020 (Intel, 2017). The move from a desktop computer being the main user of the internet to everyday objects being connected is dubbed the "Internet of Things" (IoT).

The abundance and inexpensiveness of connectivity has led to a variety of societal and technological innovations. Connectivity has made its way into personal automobiles. Connected vehicles are expected to be a pillar of a smart society and to revolutionize the way people move. Connected vehicles have the potential to transform the way we travel through the creation of a safe, interoperable wireless communications network—a system that includes cars, buses, trucks, trains, traffic signals, cell phones, and other devices.

Connected vehicle applications will provide connectivity allowing for vehicle-to-vehicle (V2V) communication, vehicle-to-infrastructure (V2I) communication, collectively referred to as vehicle to everything (V2X) communication to:

- Enable crash prevention
- Enable safety, mobility and environmental benefits
- Provide continuous real-time connectivity to all systems

With the advent of AVs it is projected that car and technology companies will place more emphasis on providing services rather than products.

An example of services vs. products from other sectors include switching from buying physical copies of movies to instead watching movies via a streaming service like Netflix, or instead of buying music albums, using a service streaming like Spotify to listen to music. Transportation Network Companies (TNC) like Uber, Lyft, Car2Go and Bridj are using a similar approach to connect with customers via smart phone e.g. instead of purchasing a car, you use the service of a TNC to reach your destination. This shift away from personally owned modes of transportation, towards mobility services is called *Mobility as a Service* (MaaS).

Services such as parking and fare payments are also benefitting from the increase in connectivity. In Calgary, the ParkPlus system already allows users to pay by phone, text, or even automatically with PayBySky. Smart phone apps are available that allow people to rent out their own parking space, similar to AirBnB.

Connected vehicles

- Connected vehicles allow vehicles to talk with other vehicles and infrastructure.
- Low latency communication is required in order for safety benefits. Dedicated Short Range Communications (DSRC) in the 5.9 GHz spectrum band is emerging to be the standard for vehicle safety (though no standard has been officially set).
- New vehicles such as the 2017 Cadillac CTS are equipped with DSRC that are intended to increase safety.
- Connected vehicles are complementary with autonomous vehicles and the term Connected Autonomous Vehicles (CAV) is now being used by some industry experts.
- The City can choose to invest in connected infrastructure such as connected traffic signals. The City's current standard traffic controller hardware specifications follow nationwide advanced controller standards and keeps The City Future Ready for new connected infrastructure.
- Security and privacy are major concerns.

What is connected vehicle technology?

Connected vehicle technology allows for vehicle-to-vehicle (V2V) communication, and/or vehicle-to-infrastructure (V2I) communications, such as a vehicle communicating with a traffic signal. For the purposes of this report, connectivity is primarily focused on the operation of the vehicle, rather than the communication of entertainment and media to the vehicle.

Vehicles would generally communicate over the Dedicated Short Range Communications (DSRC) protocol set aside for vehicle connectivity (though other communication protocols could play a role).

The DSRC protocol is being designed to ensure communication latency is small enough that it can be used for safety applications (existing cellular networks have too much lag, limiting them to uses such as providing traveller information). Having vehicles that talk to each other, allows for better vehicle safety and roadway efficiency.

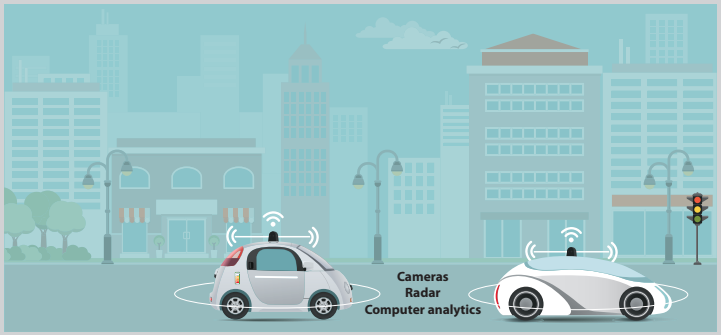
For example, if a car hits black ice, it can communicate this information to other vehicles approaching that icy section of roadway. If vehicles and traffic signals are equipped with V2I technology, signals would be able to alert a driver that the light is soon changing to red, or that a vehicle is approaching to hold the light green.

Calgary Transit and Calgary Fire currently use a simple version of this technology, known as Traffic Signal Priority (TSP) using the Opticom system.

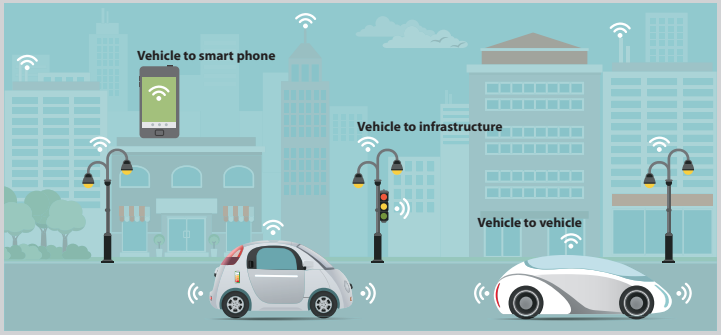
Autonomous vs. Connected vehicles

An AV can "sense" the vehicle ahead of it via camera, radar or LiDAR. A connected vehicle can "sense" the vehicle ahead of it via the vehicles communicating with each other. AV and connected vehicle technologies are largely complimentary; each system would help support the other in case of a failure. For example: if a vehicle's radar were to fail, the connected technology would inform the vehicles computer that there is a car ahead and vice versa. Connected vehicle technology does have additional benefits including having a greater range than on-board vehicle equipment and not depending on "line of sight" communications to be effective.

For example: while a radar system can see the preceding vehicle, connected vehicle technology can tell if the 5th car ahead is starting to brake. Car manufacturers are equipping their new vehicles with both connected and autonomous technologies. V2I technologies can be used to deploy and provide real time congestion info to vehicle navigation systems. The benefit of this approach (versus deployment via smart-phones) is that the information is integrated into the vehicle, and is less distracting for drivers.



Level 4-5 Autonomous vehicles | navigate without human input



Connected vehicles | share data to help navigate safely

Vehicles in the future are expected to have both connected and autonomous features. The term Connected Autonomous Vehicle (CAV) is used by some industry experts to talk about the confluence of the two technologies.

Status of technology:
Testing/Limited availability

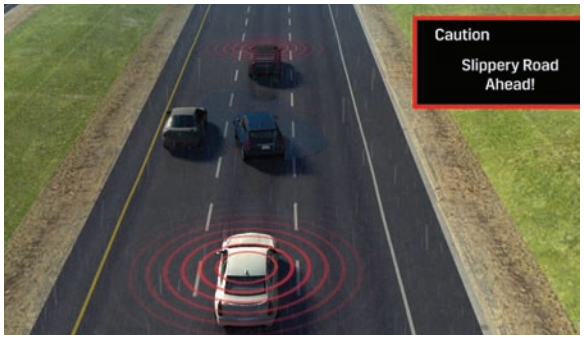
Connected vehicle technology predates AV technology. The US Department of Transportation has been testing connected vehicle technology since the mid 1990s, while the Defense Advanced Research Projects Agency (DARPA) started its AV Grand Challenges in the mid 2000's (US DOT, 2017).

IHS Automotive predicted that approximately 20% of vehicles sold worldwide in 2015 had some form of connective features; however this is currently limited to travel information and media via cellular networks.

DSRC systems are expected to be introduced into vehicles in the next few years and have been recently demonstrated at the 2017 Consumer Electronics Show in Las Vegas (Hamblen, 2017).

IHS Automotive predict that by 2025 almost every new car sold will have connected features. With the projected widespread adoption of connectivity in vehicles, vehicles will become similar to smart-phones where users can download various entertainment applications.

General Motors announced in March 2017 that all of its new 2017 Cadillac CTS sedans would come equipped with DSRC V2V technology that will allow them to communicate with other similar models and detect potential upcoming hazards, like slippery roads or disabled vehicles. For example, when one CTS has a hard braking situation or swerves to avoid an object in the road, that information is communicated to other CTS sedans behind it to alert those drivers to those conditions via DSRC (The Verge, 2017).



All new 2017 Cadillac CTS sedans will come equipped with DSRC V2V technology. (Photo credit: Cadillac)

Barriers to adoption

- **Autonomous technologies –** while there are connected vehicle technologies that are complementary to AV technology, there are certain connected vehicle and infrastructure technologies that could be expensive and unnecessary. For example, a connected traffic camera that tells a vehicle that there is a pedestrian crossing the road could be unnecessary if an AV can detect the pedestrian without the camera.
- **Globally harmonized standard –** There is no global connected vehicle communication standard. However, most technology is being designed around the Dedicated Short Range Communications (DSRC) protocol, which is a 75 MHz spectrum in the 5.9 GHz communication band set aside for vehicle communications. A global standard would enable automakers, governments, and technology developers to, at a minimum, adopt analogous conceptual and technological frameworks across markets (Center for Automotive Research, 2016).
- **Data privacy issues –** Connected vehicles produce large amounts of data that could be accessed by private and public entities. People could be uncomfortable with this.
- **Cyber security –** There is a risk that connected infrastructure and vehicles have the potential to be hacked.

What are other cities doing?

Edmonton and Vancouver - ACTIVE-AURORA Project

The ACTIVE-AURORA Project is a connected vehicle collaboration between the University of Alberta, University of British Columbia, Province of Alberta and City of Edmonton and private stakeholders. The project launched in 2014 and has $3.6 million in financial support from all levels of government and private stakeholders.

The ACTIVE-AURORA project consists of four test-beds and two laboratory test environments, with ACTIVE representing the Edmonton component and AURORA representing the Vancouver component. Research on these test beds involves outfitting select infrastructure and vehicles with connected technology, and is designed to evaluate how connected vehicle technology can be applied to transportation safety, traffic demand management and increase peak capacity and smooth traffic flow on busy roads.

In May 2016, ACTIVE-AURORA released an app to the general public that gives the user audible information on traffic, collisions and speed zone changes.

As part of the project, The City of Edmonton outfitted one of its buses with connected vehicle technology. The bus can receive audible message warnings that it is speeding, approaching a high collision intersection and if it is following too close (if the vehicle ahead is equipped with connected vehicle technology).

Who is responsible for what?

Federal

Transport Canada and the US Department of Transportation are coordinating and collaborating on V2V and V2I communications technology and applications development and implementation for light- and heavy-duty vehicles, including architecture and standards to support interoperable deployment. The main focus at this point is refining the communications spectrum and protocols. This will include, where appropriate, joint planning and priority-setting, collaborative research projects, as well as information exchanges to support analyses as well as architecture and standards development. For example, working together on cyber security and developing standards for V2I infrastructure.

Transport Canada recently completed a truck platooning trial in Quebec of which V2V technology is a main component (McCormick, 2016). Findings from the trial should be made available in 2017.

Municipal

Cities do not have to take any active role in order for connected vehicles to function with other connected vehicles. The City does have the choice to invest in connected infrastructure that can talk with vehicles and other infrastructure and collect data. The Roads ITS section is actively monitoring to see if future V2I technologies are appropriate for future lifecycle upgrades. The City needs to evaluate the cost of V2I infrastructure and determine the potential value derived before making any investments. The City may also need to determine if it is necessary to supplement communication technology in dense areas (such as the downtown) to ensure vehicle connectivity is not interrupted.

What work has The City of Calgary undertaken?

In preparation for potential communication needs of future technologies, The City's current standard traffic controller hardware specifications follows closely to the Institute of Transportation Engineer's Advanced Transportation Controller specifications, and Application Programming Interface.

This keeps The City's traffic signal control technology as 'future-ready' as currently possible for connected vehicle and autonomous vehicles.

The City does not have any V2I infrastructure in place for personal vehicles but the Opticom system that is used for transit and emergency priority would be a form of V2I infrastructure.

V2V technology would be provided by vehicle manufacturers, so The City is not involved in this aspect. However, V2V infrastructure could be purchased or integrated into City fleet vehicles (such as buses) or be made a vehicle-for-hire equipment requirement if there are service and safety benefits.

What if someone were to operate a connected vehicle in Calgary today?

Until The City has V2I infrastructure in place, there would be little benefit to vehicles with V2I capabilities. However as more vehicles have connected technology, likely V2V coordination would increase. Once fleet penetration of vehicles with V2I is high enough and if the City installs V2I infrastructure, V2I applications may become beneficial. This should be reviewed over the 2020s, particularly as the fleet becomes more fully connected.

"V2V infrastructure could be purchased or integrated into City fleet vehicles (such as buses)".

Level of impact: **Medium**

The increase in vehicle connectivity will have several impacts on the transportation and land use system.

Opportunities	Risks
Vehicle-to-vehicle (V2V) communication can help avoid vehicle collisions. A NHTSA study of connected vehicles has shown that 80% of non-alcohol related crashes could have been prevented using the technology (NHTSA, 2016).	V2V and V2I benefits are only maximized if other vehicles and infrastructure are able to send and receive signals. The technology may not achieve its full potential until it is widespread.
Research has shown that by having vehicles talk with each other there is the ability to increase highway capacity via platooning (vehicles operating close together) and improved string stability (vehicles reacting faster and more efficiently to other vehicles). The level of impact on capacity is dependent on the level of connected vehicle adoption in the network (Shladover, Su and Lu 2012).	V2I infrastructure is quickly changing and becoming less expensive. Current infrastructure may be quickly obsolete if The City was to deploy infrastructure today. There would also be associated installation and maintenance costs that would impact the operating budget.
Vehicle-to-infrastructure (V2I) applications can also improve safety. For example, the ACTIVE-AURORA project is currently exploring how alerting drivers of dangerous situations can improve safety.	The source of the data between vehicles and transportation infrastructure needs to be trusted and the system needs to be protected against hacking and interference. This is to maintain both safety and user privacy. The USDOT is working with industry to develop strict controls to prevent tampering with connected vehicle software and hardware (US DOT, 2017). Cyber security and telecoms standards will need to be created and defined.
Data generated and collected from connected vehicles can be analyzed and used for planning, traffic monitoring, dynamic parking management, transit operation and to manage traffic in real time. Research from the USDOT indicates that connected vehicles applications can reduce travel time delays caused by congestion by one third (US DOT, 2017).	Continuous alerts and notifications can be distracting to drivers. The amount of info shared with drivers will need to be managed as to not be overwhelming.
Applications for connected vehicles include variable speed limits, incident management, ramp metering, dynamic congestion pricing, advanced traveller information, transit operation, priority for transit vehicles, and real time adjustment of traffic signals.	For V2I applications, The City will want to be cautious regarding the use of information provided. For example, The City may share that a traffic light is currently red, but allow the vehicle to decide how to use this information (versus telling the vehicle to stop). This could reduce liability risks on the part of The City.

Figure 16 - Opportunities and risks of connected vehicles

Next steps

The City will monitor the ACTIVE-AURORA project to understand what benefits can come from V2I communications.

Investments in V2I infrastructure currently would be premature as V2I standards have not yet been set and AVs and other technologies may make some investments in infrastructure unnecessary.

The City will continue to monitor connected vehicle technology.

Mobility as a Service (MaaS)

- MaaS is a societal change enabled by technological development.
- MaaS can include multiple modal sharing services including bike share, transit, taxi, transportation network companies (TNCs) and other services.
- Many popular MaaS options exist in Calgary today (Uber, Car2Go, Calgary Transit etc).
- MaaS applications combine multiple travel options into a smart phone interface.
- MaaS could augment or compete with some Calgary Transit services, especially if autonomous MaaS options become available for a competitive cost.

What is Mobility as a Service?

MaaS is a shift away from personally owned modes of transportation and towards mobility solutions that are consumed as a service. MaaS can be enabled by integrating services offered by multiple independent providers (e.g. transit, taxi, bike share, car share) into one mobile application, allowing travellers to plan and pay for their mobility needs using one or multiple transportation providers through a single portal. The goal of MaaS is to increase mobility, provide on-demand service and be more attractive than car ownership. MaaS usage is expected to expand in popularity as new transportation modes and initiatives become available. For example: one may be picked up by an autonomous car share vehicle, be dropped off at a transit station and then use a bike share program at lunch to meet a friend, all ordered/paid through a single app.

Status of technology: **Limited availability**

New technologies such as smart phones have enabled resource sharing, instead of owning, between people and business in many sectors. For example the world's most used "hotel" service is AirBnB which allows users to rent other users homes or rooms instead of using a typical hotel service.

This same technology is being applied more widely in transportation. This connectivity has allowed for new models of transportation services like free floating car share models (Car2Go), ride sourcing (Uber), micro transit services (Bridj) and some bike share programs. Coordination of these options as part of an overall solution describes the MaaS approach.

Growth in shared-use services is rapid. Between 2014 and 2015 the number of carsharing memberships in Calgary grew by 50%, while fleets grew by 26%. Car2Go's launch into Calgary was extremely successful, with over 4 million trips provided since launch and over 100,000 members as of November 2016. Uber already has about 700 drivers in Calgary since returning in December 2016 to meet growing demand.

It is expected that MaaS will continue to expand. The Conference Board of Canada estimates up to half of private vehicles may be replaced by on-demand vehicles with the proliferation of AVs. In the shorter term, transportation ridesharing options are estimated to grow by 6-12% annually (eMarketer, 2016). This could have a significant impact on reducing the average number of vehicles per household, particularly for the second (and third) vehicle. This would result in reduced parking requirements for homes and could decrease their cost.

In November 2016, Car2Go surpassed 100,000 members in Calgary, making Calgary the fastest growing car2go city in North America (Car2Go, 2016)

"Between 2014 and 2015 the number of carsharing memberships in Calgary grew by 50%."

Car2Go, 2016

What work has The City of Calgary undertaken?

Calgary does not have a service that integrates trips of different modes. For example, there is no service which allows you to transfer from a car share vehicle to LRT under a seamless system.

However, Calgary does offer a number of components that typically make up a MaaS suite of options. These include car sharing services provided by Car2Go and on-demand mobility services, including taxi companies and Transportation Network Companies (TNCs).

Transportation network companies

Community Services has done extensive work and has produced regulations on Transportation Network Companies. Uber recently relaunched operations in Calgary as of December 2016. TappCar also operates a shared ride service in Calgary.

Bike share

Calgary does not currently have a bike share program. Implementing a public bike share system in Calgary's Centre City is Action #11 of the 50 action items in the Council-approved Cycling Strategy. The goal of a bike share system is to provide Calgarians and visitors with a quick and convenient mobility option throughout the Centre City.

Transit

Calgary Transit is currently researching how MaaS can be integrated into its fare strategy enhancing payment options, as well as using MaaS services to provide service on low ridership bus routes. MaaS has potential to be a "last mile" solution, which would be a significant shift from current transit provisions. It also could have potential to provide services for Calgary Transit Access.

Car share

Transportation has been working with Car2Go since their launch in 2012 to facilitate car share services on Calgary streets. A comprehensive parking policy was developed in 2015 to help manage parking locations and vehicle congestion that has resulted from the success of the service.

Who is responsible for what?

Depending on the mode and services, different levels of government and private companies have different responsibilities and powers.

- The City has the authority to set bylaws around the operations of taxi and ridesharing services through the Livery Transport Services unit and the Livery Transport Advisory Committee (LTAC). This includes regulations around safety and fares.
- The Province has jurisdiction for establishing drivers' licences and insurance requirements for TNCs.
- Private operators are responsible for the dispatch and coordination of rides with drivers.
- Insurance companies are responsible for providing insurance solutions for MaaS providers.
- Smart phone apps which coordinate MaaS options may be developed either by local governments or private entities.
- The City operates public transit and para-transit services.

Barriers to adoption

There is nothing restricting the coordination of services under a MaaS approach.

Challenges primarily occur on two fronts. The first is the coordination efforts required between individual service providers to partner in a comprehensive solution of travel services e.g. alignment with fare payment systems. Second, the individual services themselves are subject to appropriate and comparable regulations in their respective industry e.g. Transportation Network Companies. These can be the biggest barriers for a successful MaaS solution.

What are other countries and cities doing?

- Helsinki, Finland has been developing comprehensive MaaS services, first with the Kutsuplus, an on-demand minibus service run by the public transit authority. This was concluded in 2015 and replaced with Whim, an app that provides access to a variety of transportation options, coordinated by MaaS Global.
- Dallas Area Rapid Transit (DART) has partnered with local TNC companies to allow their mobile ticketing app to incorporate rides to and from transit stops.
- St. Petersburg, Florida, Pinellas Suncoast Transit Authority (PSTA) have partnered with Uber and local taxi service to augment transit service in two underserved locations. PSTA subsidizes half of the fare (up to $3) for trips within these zones.
- Boston is piloting UberACCESS, which connects customers using wheelchairs with accessible vehicles.
- In 2016, Uber launched Level 3 autonomous pilot programs in Pittsburgh. A subset of each city has been mapped in high-definition and an engineer is in the vehicle to takeover if the car becomes confused.

What if MaaS started operating in Calgary today?

Coordination of multiple transportation services under one platform could be done through smart phone apps or websites. This currently does not exist in Calgary on a large scale but could change quickly depending on the utility of the MaaS service. TNCs are already operating in Calgary but it is possible that new services could be offered through a MaaS platform that may require regulatory review or adjustment. There are also opportunities for existing service provides (for example, taxi companies or Calgary Transit) that could augment their existing services and partner with others as part of a MaaS product.

Citibike is a popular bike share system in New York

Level of impact: **High/Medium**

Opportunities	Risks
A wider array of transportation options can augment existing travel and potentially reduce car ownership and parking requirements.	Rideshare services could take ridership from existing, profitable transit services, particularly as the vehicles become automated and costs come down. This would likely impact Transit's revenue-generating capabilities.
Vehicles are used more efficiently.	Service providers could enter and/or leave the city on very short notice or increase service costs, which could reduce the resiliency of the transportation system if alternatives are not available. A well working MaaS platform could be crippled by the withdrawal of a major service provider.
The shared approach of services can reduce barriers to travel.	Heavy rideshare usage could create curbside congestion in areas where there is heavy drop off/pick up demand.
More transportation options improves affordability.	Fleets of rideshare and on-demand vehicles will need storage locations during non-peak times. Car2Go currently stores their fleet on city streets. While this can cause some parking congestion challenges it also provides revenue opportunities for The City.
More cost-effective solutions can be tailored for different areas that may not be cost-effective under traditional public transit models.	
Areas without existing services may have new services available.	
Vehicle fleets may turn over more often due to increased usage, which would decrease the average age of the vehicle fleet. This can lead to improved safety outcomes.	

Figure 17 - Opportunities and risks of Mobility as a Service (MaaS)

Next steps

The City should continue to monitor developments with various service providers and look for opportunity for a MaaS solution to supplement current mobility options, where it can meet safety and reliability requirements and provide value for customers.

Particular areas of consideration include:

- Para-transit options (on-demand trip planning).
- Late night transit services.
- Park and ride/station design with respect to drop off and pick-up locations.
- Trip-planning and fare integration.
- Parking stalls for car share vehicles.
- First/last mile service from LRT stations.
- New community services.
- Privately operated or sponsored bike sharing service.
- Regulation to address equity issues (e.g. curbside clustering, impacts to viability of publicly-funded accessible transit, congestion).

The City should continue to strive for equity in facilitating MaaS services so that no one particular service has a distinct advantage. The resulting competition should result in increased service levels and decreased costs.

Internet of Things (IoT)

- IoT technology is becoming very affordable and available in a wide variety of applications and products.
- IoT in transportation can improve customer service by giving customers access to information, and data generated can improve planning and decision making at The City of Calgary.
- City working on a dedicated communication network (LPWAN) to help facilitate a City IoT network.
- Security and privacy issues are top concern.

What is the Internet of Things?

The Internet of Things (IoT) is the trend towards providing network connectivity to everyday objects, allowing them to send and receive data. This can be achieved in a number of ways, such as including connective abilities on existing objects or by deploying sensors that can report a variety of information about an object, which can then be used in decision making.

Status of technology:
Limited availability/Widespread

There are estimated to be 15 billion connected devices as of 2015. This is expected to be 200 billion by 2020 (Intel, 2017). Currently, most IoT applications are in business, manufacturing and health care.

The significant increase in the availability of broadband Internet, coupled with Wi-Fi capabilities of numerous devices is the major driver behind IoT. IoT applications can be people-people, people-things, and things-things (Morgan, 2014). Devices will generally include connectivity by default over time rather than this being an exception.

IoT is a major driver behind "smart cities". The driving forces behind smart cities are to "help reduce waste and improve efficiency" (Morgan, 2014). Sensors can be used in numerous applications to tailor services to citizens, improve responsiveness and provide monitoring of assets. In transportation, sensors can facilitate travel and parking information, road conditions, signal coordination and data collection. Generated data can also add huge value to system planning and operations.

IoT in vehicles enables the introduction of road pricing that could be a replacement for fuel tax.

Key points about IoT include:

- IoT devices are becoming smarter 'out of the box' rather than needing programming.
- Costs are continually dropping.
- Wireless connectivity protocols are continuing to evolve, such as 5G LTE-M.
- IoT industry standards are continually evolving.
- More types of information available.

"The Internet of Things is exploding. It's made up of billions of 'smart' devices – from miniscule chips to mammoth machines." (Intel, 2017)

What work has The City of Calgary undertaken?

Since the IoT covers a wide variety of applications, there are many activities already in place that are taking advantage of connective technology. Examples include:

- Calgary Transit's Computer-Aided Dispatch (CAD)/ Automated Vehicle Location (AVL) system, which provides information on the location of all transit vehicles in real time. This allows Calgary Transit to provide real time bus arrival information to customers and also use the location information to improve bus scheduling and operations. Several vehicles are also fitted with automated passenger counters to collect ridership data for planning and designing bus service.
- Roads uses Bluetooth information and INRIX data to provide real time traffic information and monitoring via the Traffic Management Centre.

The Calgary Transit app provides real-time transit updates.

- The City of Calgary has developed the Common Fleet Operating System (CFOS) for more than 2,500 City fleet vehicles. With cellular and WiFi connectivity this system captures vehicle telematics data for asset tracking and proactive vehicle maintenance. Snow removal status are also collected and displayed on calgary.ca.
- Information Technology is evaluating provisioning a Low Power Wide Area Network (LPWAN) which would provide a communication platform for City IoT assets.
- Information Technology is evaluating developing an IoT software platform called Calgary Network of Things (CNOT) which would provide a secure and open source platform to collect and share sensor data based on The City of Calgary infrastructure.

Barriers to adoption

There are no major regulatory barriers to increased use of IoT technologies.

Cost barriers are likely to be overcome as costs continue to drop for sensor products. In some cases, current carrier networks may need to evolve to provide the capacity for IoT data. The City needs to be comfortable that appropriate security protocols are in place around data from IoT systems.

Smartwatch contractless payment.

Who is responsible for what?

The City is responsible for provisioning IoT technologies where it makes fiscal sense to support maintenance and enhance customer service.

- The City also is responsible for maintaining security of The City's information technology network. A balance is needed between ensuring The City can leverage IoT technologies without compromising network security. The City also has a fibre network that can potentially provide support for IoT communications.
- IoT standards are generally set by industry consortiums, in consultation with federal governments.
- Crowd sourcing and private entities will play a large role in collecting some types of data (for example, traffic activity).
- The federal government sets communications protocols.
- Private companies install the communication networks.

What are other countries and cities doing?

- Cities such as London, Chicago, Amsterdam, Barcelona and Sydney have deployed LPWAN networks to facilitate IoT technologies.
- Barcelona is considered a leader in IoT, using IoT to improve connectivity of traffic lights, parking and waste management systems through a central platform to improve infrastructure management (Clark, 2015).
- Amsterdam has partnered with Cisco and Philips to deploy a smart street lighting network to improve area ambiance and be varied to save energy and deter undesirable activities.

What if IoT operated in Calgary today?

- IoT will incrementally be used where value is added. Development of a City owned IoT platform would provide The City with a secure, controlled platform to collect, store and share IoT information. If an IoT platform is not developed, The City of Calgary will have to rely on different vendor locked-in IoT solutions and data silos.

  This also introduces some risks with respect to data security, ownership and privacy, and could potentially increase development and support cost to maintain the IoT solutions.

What are the implications of sensor technology at The City?

The main issues that The City would need to address are:

- **Digital Security –** Are City IoT assets and the corresponding information secure and is privacy maintained?
- **Interoperability –** Are IoT solutions developed using open source/open standard APIs that facilitate communication between systems?
- **Sensor network –** How can The City of Calgary build a reliable infrastructure with city-wide coverage to support hybrid sensor networks that can be used to communicate and collect sensor data from the field?
- **Return on Investment –** Can adding sensors be used to enhance service without budgetary impacts? Can savings be found?
- **Procurement Strategy –** IoT practice demands liberal access to IoT components. An effective procurement strategy is required to allow The City to test out new IoT innovations based on The City infrastructure.

Level of impact: **Medium/High**

Sensors could be deployed in a number of applications to improve customer service. Potential examples include:

- Low cost wide deployment of traffic sensors for improved signal coordination.
- Identifying waste and recycling containers that are full at transit stations.
- Identifying when bus shelter glass is broken.
- Identifying which parking spaces are available, both on and off-street.
- Identifying if street lights are not working or signs have been knocked down.
- Identifying how icy the roads are and if they have been plowed.
- Identifying if street trees and plants need water.
- Improving movement of emergency vehicles through traffic.
- Identifying potholes.
- Toll collection on roadways and bridges.

It is unlikely that sensors themselves will have much impact to the land use network. However future penetration of sensor networks will require The City of Calgary to look into using infrastructure such as street light poles as sensor installation nodes.

Opportunities	Risks
Improved customer service for citizens using the transportation system.	IoT components will be mix-and-match in fashions that are innovative, creative, experimental and have no current market ready solutions. Industry standards for IoT are also emerging, evolving, diverging and converging. The City needs to avoid deploying IoT solutions that will soon be replaced by newer standards.
More responsive, targeted maintenance of transportation assets. Data collected from sensors has the potential to improve decision making, both at operational and strategic levels.	Although the technology is improving, it is possible that sensors have a higher than expected rate of failure due to Calgary's winter weather, reducing their usefulness.
Sensors within vehicles will be a key component to enable AVs. Sensors will improve the tracking of goods and deliveries which will improve the efficiency and safety of commercial fleets.	Cyber security of the sensor, communication network and data is a risk. What are the consequences if the sensor device is hacked or the data is leaked? The City needs to ensure compliance with FOIP legislation.
Enables the introduction of road pricing to phase out fuel taxes.	Operating costs to The City will increase if the main objective is to increase customer service.

Figure 18 - Opportunities and risks of the Internet of Things (IoT)

Next steps

The City will continue to monitor the technology and experiences in other Canadian cities.

Opportunities for using sensors will be explored on a case-by-case basis where it enhances customer service and makes fiscal sense.

Parking Technology

- Calgary is a nationwide leader in this parking technology field.
- Technology is facilitating a seamless experience (e.g. PayBySky, License plate recognition).
- Downtown parking strategy will need to change to address vehicle congestion.
- AVs will significantly change parking demand due to the vehicles ability to park itself, or drop off a passenger and drive away. When AVs become more popular, there will have to be a greater focus on vehicle loading than parking.

What are parking and curbside management technologies?

Parking and curbside management technologies are technologies that help ensure parking space is well used, be it through making it easier to find parking space, pay for a parking space, encouraging turnover of existing parking spaces, development of automated parkades, or guiding people to underused parking spaces.

Status of technology:
Limited availability/Widespread

There are a number of technological changes that are occurring, or will likely occur to parking in Calgary.

- The parking industry, including the Calgary Parking Authority, is moving towards an approach where the vehicle's license plate serves as a parking pass or 'token'. The licence plate info would be recorded by cameras in a given parking area (either at entry/exit, or through enforcement, a component of the ParkPlus technology). The licence plate approach allows for a more catered approach for a wider variety of parking privileges for customers. This can include parking passes for different types of users (residents, visitors), and different payment products or options. Florida International University is an example where the entire campus parking system is operated under a virtual permit approach using licence plate recognition technologies. The Calgary Parking Authority will be rolling out an enhancement to the ParkPlus system that will move components of the Residential Parking Program to a virtual permit approach in Q2 2017. This work will be done in conjunction with the Residential Parking Program review in 2017.
- Automated parking facilities are not new and are beginning to be constructed in Canada. The first facility was constructed in 2012 in downtown Vancouver and there are 22 facilities in the US. Calgary had an application for a similar facility that has not yet been constructed. These facilities may become more common in constrained environments and increase the availability of parking in these locations.
- Ultimately, as part of self-driving cars, a range of possible options open up with respect to parking. Volvo is working on a self-parking/automated valet system that would let drivers drop off their vehicle at the entrance of a parking facility. The car would then navigate itself to an available parking space. In the longer term, it is expected that vehicles will have a wider variety of parking options. This could range from parking on-site to returning home to park.
- Calgary Parking Authority has partnered with PayBySky, a technology that lets users pay for parking simply by installing a meter into the vehicle which then automatically starts and stops paid parking sessions without needing any interaction from the driver.
- Further opportunities for automating parking sessions include working with auto manufacturers to obtain real time GPS information, enabling real time data streams from car sharing and taxi companies, and using Licence Plate Recognition software to automatically start and stop sessions when a vehicle is detected entering and leaving a location.
- Opportunities to integrate parking payment systems across public and private facilities.
- Connected infrastructure and vehicles can measure and broadcast the availability of parking spaces to other vehicles looking for parking.

"With more parking options available in a self-parking environment, alternative mechanisms will be needed to manage congestion into and within the downtown."

What if self-parking technologies began operating in Calgary today?

The main issues that The City would need to address are:

- **Loading:** Passengers need to be loaded and unloaded in a safe manner. This may necessitate changing the design of buildings to accommodate on-site loading (in existing or future parkades), or changes to how the on-street space is allocated, such as adding more loading spaces. The goal would be to ensure safety and manage resulting congestion.
- **Periphery parking:** Areas surrounding the periphery of downtown may become more attractive places for vehicles to park, since parking is cheaper (or free) in these locations and the vehicle could easily go park in these locations. On-street policies (such as the residential parking permit program) and land-use policies (such as allowing new surface parking lots) will need to be in place or implemented as to manage the amount of parking in these areas to limit congestion and maintain quality of life and area character.
- **Downtown parking:** With more parking options available in a self-parking environment, this will increase the accessible parking supply, which would likely bring parking prices down significantly. Congestion could increase as a result of increased loading activity. Congestion would not be able to be mitigated by managing total parking supply at this point. Rather, alternative mechanisms will be needed to manage congestion into and within the downtown. Improved utilization would also decrease the need to construct as much new space.
- **Revenue:** The parking contributions from the Calgary Parking Authority will likely have significant downward pressure. The City would need to find alternate sources of revenue for programs and services that are funded through these dividends.

Barriers to adoption

Some of the parking solutions (such as self-parking) share the same barriers as AVs as they are dependent on having the same regulations in place.

That said, activities like self parallel parking already exist in vehicles today, so increased automation in parking will likely take place on the path to full self-valet service. Other parking technology solutions can be done under existing regulations.

The ParkPlus system allows people to pay for parking by using machines, cell phone, or the Virtual Pay Machine.

Who is responsible for what?

The City is responsible for managing the on-street parking supply and setting rules and regulations around the off-street parking supply in new developments.

- The Calgary Parking Authority is responsible for delivering and managing The City's off-street parking supply (roughly 20% of overall supply), particularly in the downtown.
- The Calgary Parking Authority and Roads are responsible for managing the on-street parking supply.
- Vehicle manufacturers are responsible for development of vehicle technologies that let cars self-park or interpret information on parking availability within the vehicle.
- Communication of the available parking supply is currently done via individual parking operators (including the CPA). This could be done on an individual or coordinated effort in the future, and could include integration with vehicles via V2I technology.

What are other countries and cities doing?

- In July 2016, The United Kingdom put forward potential legislative amendments to facilitate remote parking technologies and laneway assistance as these features are felt to be realized sooner than full AVs (Jee & Mercer, 2016).
- Columbus, Ohio was the winning city in the US Department of Transportation Smart Cities challenge in 2016. Part of the pilot will be to deploy a parking management system that can provide real time occupancy info to users, although it remains to be seen what (if any) value this has as by the time a vehicle becomes aware of a potentially available parking space, other vehicles may have taken the space.
- San Francisco has recently completed its dynamic pricing trial and is looking to roll out citywide in 2017 (Downing, 2016.)

What work has The City of Calgary undertaken?

Calgary adopted a dynamic pricing approach to commercial on-street parking in 2013 setting prices using occupancy data.

This is facilitated with the ParkPlus technology and is seen as a leading method in North America for managing on-street parking (Barter, 2016).

This policy approach is quite similar to the dynamic pricing approach used in San Francisco SFPark Program that was launched in conjunction with the US Federal Highway Administration in 2010.

Level of impact: **Medium**

Adoption of a virtual licence plate system has the potential to increase the flexibility and efficiency of managing on and off-street parking.

- Improved information on parking availability would reduce cruising for parking, which would reduce emissions and traffic in busy areas.
- Self-parking vehicles could increase traffic congestion if vehicles are dropping off passengers and then looking for places further out to park.
- Demand for parking lots may increase in periphery parking areas (fringe of downtown) so that vehicles can park cheaply and are not too far away if called upon.
- There may also be increased demand for parking shared fleet vehicles either on-street throughout The City or at large storage lots in locations where land is less expensive, such as outside of the city, when the vehicles are not in use (such as overnight).
- Parking lot operators may move towards app-based systems, rather than physical lot operations. Operators may not be located in Calgary at all.
- Connected infrastructure and vehicles could improve the utilization of available parking spaces and decrease the need to build new stalls.

Opportunities	Risks
It is likely that less land will be needed for parking facilities, particularly in the downtown. The recent decision to conclude the downtown cash-in-lieu parkade program is a reflection of this anticipated impact.	Traffic could be increased from empty vehicles on their way to/from parking spots.
Infrastructure funding that may have been dedicated to parkades provided by The City could be redirected to other priorities.	Periphery areas around major generators (such as downtown) may be subjected to increased parking congestion and regulation.
Local congestion could be reduced from reduced cruising for parking.	Increased availability of parking may deter people from using other travel options.
The customer experience for parking would likely be improved by making it easier to find and pay for parking.	Shared mobility fleets may seek to store vehicles on city streets when not in use, such as overnight.
Compliance with parking rules would likely be increased if AVs are obedient to following parking regulations and signage.	Revenues from parking facilities and parking enforcement are likely to decrease.

Figure 19 - Opportunities and risks of parking technology

Next steps

The City, in conjunction with the Calgary Parking Authority, should continue to monitor technologies and look for opportunities to implement technological improvements to augment current parking operations and policies.

Particular opportunities include applying plate-based systems for registration, payment and enforcement in more areas such as in neighbourhoods.

The Residential Parking Program review, scheduled for 2017, should consider the potential impacts from self-parking vehicles in producing any recommended changes.

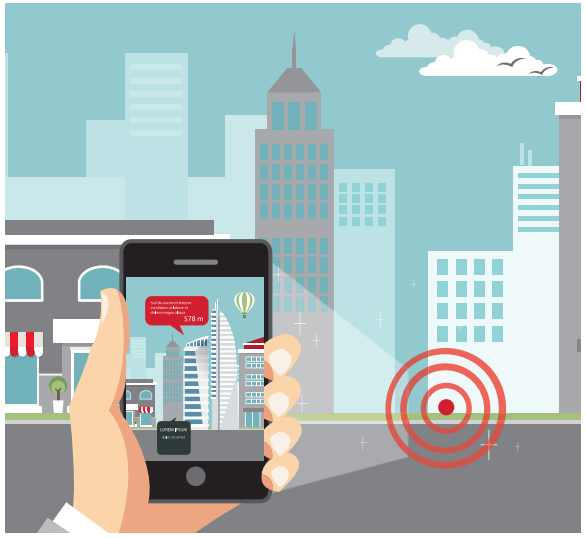
Land use planning in areas peripheral to the downtown should be cognizant of the potential pressure to develop satellite commuter parking facilities.

Other technologies

This chapter explores the technologies of: Virtual Reality, Augmented Reality, 3D Printing, Biometric Technologies, Hoverboards, Straddle bus, Solar roadways, Hyperloop and Biofuels.

Virtual Reality and Augmented Reality

What is it? Virtual Reality (VR) is a three-dimensional, computer generated environment which can be explored and interacted with by a person. Augmented Reality (AR) is a technology that superimposes a computer-generated image on a user's view of the real world, thus providing a composite view.



The current VR systems are goggle based and include hardware such as Facebook's owned Oculus Rift and Google's Google Cardboard. When designing the new Westbrook operations centre, The City of Calgary teamed up with local company DIRTT to produce a virtual reality landscape of the new Westbrook facility that could be walked through by operations staff. The virtual mock up allowed staff to see the facility and review functionality of the design prior to being constructed.

AR systems can be smart phone based or google/ glasses based. The popular 2016 game Pokémon Go uses augmented reality technology to show characters augmented in the real world.

How does this impact transportation?

Much like a smart phone, there will likely be many applications created by users for VR and AR systems. Both virtual and augmented reality could be used in the future to help with the planning process, much like the Westbrook facility, and with public consultation.

For example, instead of attending an open house and seeing the design of a building on paper, the public could use VR technology to have a 3D walkthrough of the planned infrastructure or development. Using AR, the public could see a superimposed image in the field of what infrastructure, art or a development may look like and provide feedback on the design of the project before it is constructed.

Actions for The City of Calgary

- Monitor impacts on transportation and land use.
- Explore on a situational basis if the technology can be used to benefit City projects.
- Investigate VR and AR as an affordable tool for use on upcoming project plans to improve public engagement.

3D printing

What is it? 3D printing or additive manufacturing is a process of making three dimensional solid objects from a digital file. For example one can print anything from small plastic figurines to an entire building. The process is currently expensive to print everyday goods; however prices are expected to decline over the next few years.

How does this impact transportation?

Being able to print various goods in ones own home may reduce the amount of trips one makes. For example: if you lost or broke a coffee cup, instead of going to a store to buy a new one, you could print one from your own home.

There are expected to be advancements in 3D printing technology that allow for more diverse materials that will be able to produce a wider variety of goods. The impact of this technology from a transportation and land use perspective is less clear and longer term.

Actions for The City of Calgary

- Monitor impacts on travel behaviour and land use.
- Explore on a situational basis if the technology can be used to benefit City projects.

Biometric technologies

What is it? Biometrics are distinct measurable physiological characteristics of an individual. New technologies are making it easier to understand biometric indicators of individuals.

How does this impact transportation?

Academics are starting to use biometric tools in order to gauge people's reaction to different urban environments. For example, the MIT developed MindRider is a bicycle helmet that tracks the cyclists brain activity on different roadways. Researchers are then able to map where cyclists feel the most and least comfortable. In the future these tools can be used to better plan streets and urban spaces.

Actions for The City of Calgary

- Monitor impacts on transportation and land use.
- Explore on a situational basis if the technology can be used to benefit City projects.

In New York, the MindRider helmet was used to map out areas where cyclists were relaxed and areas where they required more concentration.

Hoverboards (self-balancing scooter)

What is it? A hoverboard is self-balancing motorized scooter without handles. Top speeds of hoverboards range from 6-12 km/h depending on the model. They are among a growing trend of personal mobility devices that allow the user to commute in a relitively fast low effort manner.

How does this impact transportation?

Much like the Segway, hoverboards are expected to have a minimal impact on the transportation network due to the relatively low adoption rate of the technology amongst the general population. There is a general consensus that the hoverboard is less efficient than cycling and is more of a recreational device rather than a mode of commuting for most.

Actions for The City of Calgary

Hoverboards and other transportation technologies that use pathways will be reviewed as part of the comprehensive review of the Parks & Pathway Bylaw.

"There is a general consensus that the hoverboard is less efficient than cycling and is more of a recreational device rather than a mode of commuting for most."

Straddle Bus or Transit Elevated Bus

What is it? A transportation concept introduced at the High-Tech Beijing Expo in May 2016. The idea is to elevate buses above traffic so they are not slowed by traffic congestion, and they do not add to traffic congestion.

How does this impact transportation?

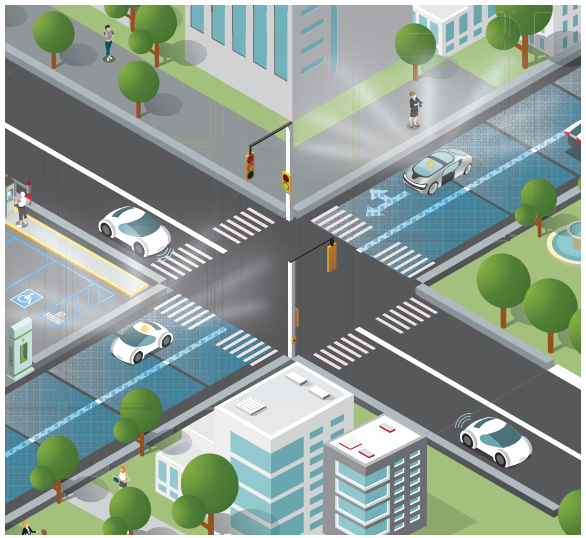
In August 2016 a prototype was built and underwent a 300m test run in Qinhuangdao, China. However, reports at the end of 2016 indicate that the prototype has been abandoned and it is unclear if the company is still active (Shetti, 2016).

There are many logistical and safety items that need to be sorted out before the elevated bus can be a viable transportation option. Issues include being able to accommodate larger vehicles under it (ground clearance is just 7 feet), being able to operate under bridges and traffic lights, vehicle turning and roadway design/laning. Currently if viable, it would be very limited in which roadways it could operate on.

Actions for The City of Calgary

The project did serve to highlight the potential use of the vertical space associated with our road right of ways.

Solar Roadways and Pathways



What is it? Building pathways and roadways with photovoltaic panels in order to heat the roadway surface to melt snow and provide energy.

How does this impact transportation?

The technology could take advantage of roadway space for solar energy generation. USA company, Solar Roadways is undertaking a trial in Sandpoint, Idaho in a public square. However, the trial has been very expensive and has not yet produced any solar electricity (Varinsky, 2016). French engineering firm Wattway has recently partnered with a local construction company in Calgary to conduct testing on private property.

The City of Calgary is aware of the trial but not directly involved. The main objective of the trial is to test the technology in Calgary's climate. The information from the trial will be made available to The City.

Actions for The City of Calgary

The City of Calgary will review the results of the Wattway trial and monitor and new developments with the technology.

"French engineering firm Wattway has recently partnered with a local construction company in Calgary to conduct testing on private property."

Hyperloop

What is it? Hyperloop is a proposed mode of freight and passenger transportation that uses a vacuum tube system to propel pods at high speeds over long distances.

How does this impact transportation?

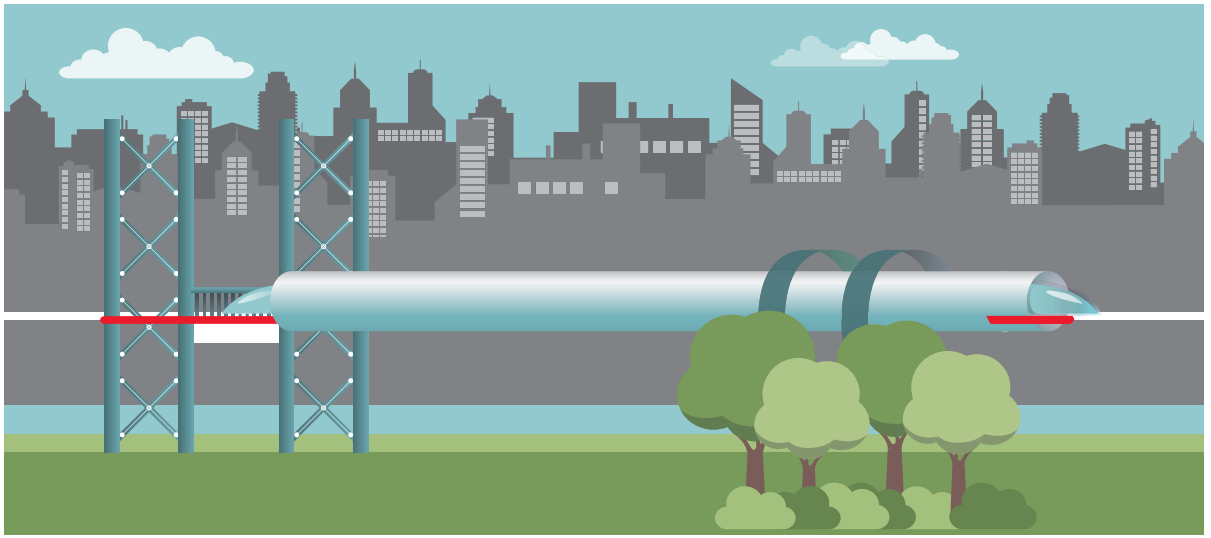
The technology could allow for passenger and freight travel at a regional scale, it theoretically could compete with high speed rail. The technology is at a conceptual phase with a few companies and universities exploring its feasibility.

Theoretically, operating at a projected speed of 1,200 km/h, a hyperloop between Calgary and Edmonton could move goods and people between cities in a 15 minute one way trip.

Actions for The City of Calgary

The technology is not proven and regional plans should not be modified because of the hyperloop concept. The City of Calgary will continue to monitor developments with the technology.

The City of Calgary is in ongoing conversations with the Toronto Company TransPod about their potential plans of developing a Hyperloop test track in the Calgary area.



Biofuels/Synthetic Fuel

What is it? Biofuels are fuels produced using organic material. Some biofuels are blended into regular gasoline and diesel supplies. Waste can also be a component of biofuels. Synthetic fuels are highly pure and do not need to be blended.

How does this impact transportation?

The use of biofuels offers several benefits such as reduced GHG emissions and providing a use for existing waste streams. From 2005 to 2012 The City conducted a pilot of different forms of Renewable and Bio diesel within their heavy fleet equipment. Over the length of this initiative, GHG emission reductions cumulated in over 6,100 tonnes of savings. The leadership that The City provided played a major role in the advancement of this technology within the province and allowed industry to refine the blending process in advance of the provincial regulation.

Actions for The City of Calgary

On April 2017, City Council directed Calgary Transit Administration to bring a scoping report outlining a potential pilot project to field test synthetic diesel fuel in Calgary Transit buses. The report was directed to go to Council no later than September 2017.

"The use of biofuels offers several benefits such as reduced GHG emissions and providing a use for existing waste streams."

Hydrogen Fuel Cells

What is it? Hydrogen is the use of hydrogen fuel cells to generate electricity to power vehicles. The hydrogen is produced through a variety of means including the electrolysis of water, methane, natural gas or other compounds.

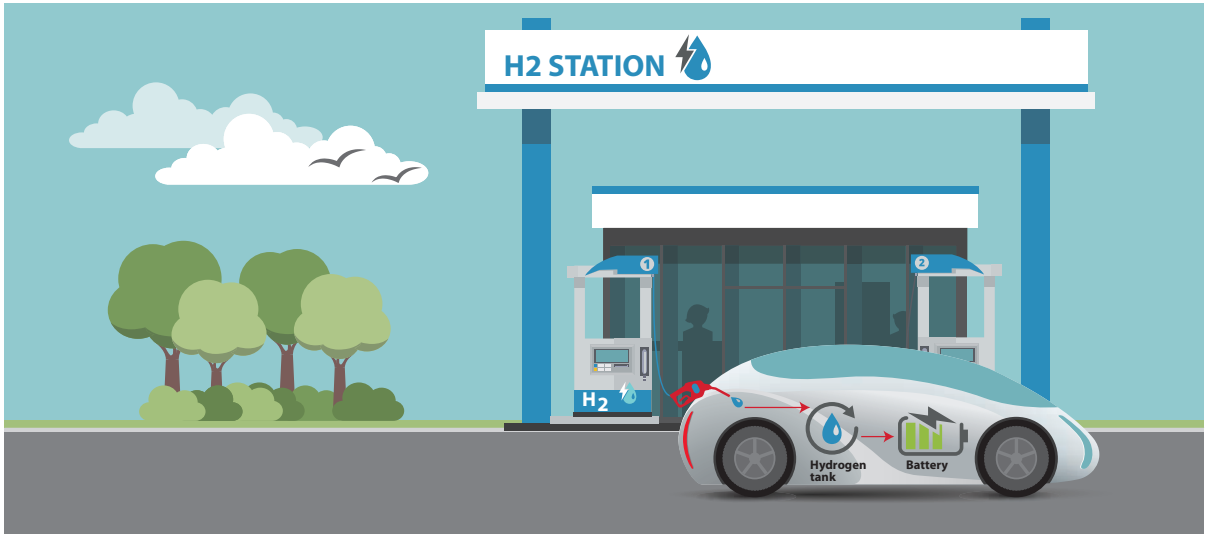
How does this impact transportation?

Hydrogen fuelled vehicles completely eliminate tail pipe emissions and drastically reduce vehicle noise from the environment. However, due to the energy required to produce hydrogen, and emissions caused by the extraction, compression and distribution of natural gas to produce hydrogen, in most cases this technology does not provide any total (well to wheel) greenhouse gas emission reductions when compared to conventional diesel vehicles (it typically does offer a modest reduction compared to gasoline-powered vehicles).

It is unlikely that any hydrogen fuel cell vehicles are currently in use in Calgary. The three primary markets for hydrogen passenger cars are California, Japan and Germany, since these are the three regions where most of the hydrogen fuelling infrastructure has been installed to date. British Columbia also has some hydrogen fueling infrastructure. Consequently, sales of private and commercial hydrogen fuel cell vehicles are largely restricted to these markets.

Actions for The City of Calgary

The City will continue to monitor the development of this technology, and whether the market will grow outside existing core markets. This would guide any future support for a fuelling infrastructure network.



Retrospective and next steps

This report ultimately captures a moment in time with respect to the ongoing development of future technologies and their potential impact on Calgary.

Retrospective

In 1994, The City of Calgary published the GO Plan which outlined Calgary's Transportation Plan for the next 30 years. Much of the document is still relevant today, with much of the plan's proposed transportation network coming to fruition. Within the Go Plan there are appendices that explore future transportation technologies. Below are some of the predictions the Go Plan made about technology in the 2010s-2020s.

Automation –
Quotes from the Go Plan Appendices

- "Can you imagine a car with no steering wheel that can make its own decisions? It may not be on the market for some time yet, but research is currently being done in the US, Europe and Japan on a system that may provide hands off driving"
- "Traffic Technology extends beyond the mechanics of tomorrow's vehicle. Research is being done with the goal of making highways intelligent too"
- "Advanced Traffic Management Systems (ATMS) will mean a driver will be in touch with all sorts of valuable commuting information while in the automobile. Instead of tuning into the radio for traffic updates, future drivers could use ATMS to provide a communication link between driver, vehicle and roadway. This will keep traffic flowing smoother, causing fewer delays and frustrations"
- "Advanced Traveller Information Systems (ATIS) can provide drivers with road and traffic information: to the home via television or computer terminal to help with pre-trip planning, to the driver via changeable message signs, to the driver via on board display and voice systems."

Predictions vs. today – The general predictions that vehicles and roadways would get smarter through computer technology are coming into fruition. However, one of the items that the Go Plan did not account for is the rapid development of the smartphone and applications like Google maps that provide a user traveller information to their pocket – instead of their television or computer terminal.

Alternative Fuels -
Quotes from the Go Plan Appendices

- "It's possible that when motorists go to "fill 'er up" in coming years, they could be taking on fuel from sugar beets, made from coal or even derived from water. Propane, Compressed Natural Gas, Ethanol, Methanol and Hydrogen are all potential fuels of the future"
- "Propane and compressed natural gas (CNG) are the most likely substitute for gasoline in the near future"

Predictions vs. today – Vehicles today are starting to shift away from gasoline and diesel, but not to propane and natural gas as the Go Plan predicted. Developments in battery technology, the use of existing electrical infrastructure and electric vehicle companies like Tesla have made electric cars the preferred alternative fuel choice for the foreseeable future.

Connected Mobility -
Quotes from the Go Plan Appendices

- "Will telecommuting change travel patterns much? There is clearly a major potential for travel changes. If people are working at home, then they will not be travelling to/from work during peak periods, at least on some days of the week. At the same time, if telecommuters are working at local telecommuting business centres near their neighbourhood, then the trip to their 'normal' centralized workplace will simply be replaced by a trip to this local centre... An even more significant effect, on which one can currently only speculate, is the possibility of a highly decentralized economy focused on the home or the neighbourhood. In such a context, the relocation possibilities for jobs, together with a significant degree do shopping by telephone (teleshopping), could greatly alter current patterns of travel demand."
- "...we estimate that 50-55% of total employment in the city in 2023 will be in jobs with a potential for telecommuting".
- Naturally, there is a cost, in terms of the information and communications technology required to support telecommuting. If telecommuting is allowed to happen through trends in the workforce, these costs would presumably be borne by the private sector.

However, should telecommuting be supported or 'forced' by public policy initiatives such as subsidizing communications infrastructure and/or in-home computers for telecommuters, these costs would at least partially be borne by the taxpayer. The savings on new/improved road and transit facilities might be replaced by these new costs for computing and communications infrastructure.

Predictions vs. today – Telecommuting was expected to have a significant impact on transportation. It was thought that a large percentage of Calgarians would telecommute, that it would cause a decentralized workplace, and that people would now live outside the city in places like Canmore. The reality today is that the technology exists for people to telecommute, but only a small percentage of Calgarians do (0.5% according to the 2016 Civic Census Place of Work Survey). This is largely due to human factors and workplace culture – most people want to work with other people and be in a social environment. Other predictions about local telecommuting business centres and teleshopping (buying items off television infomercials) never took off largely because they were superseded by other technologies like laptops, high speed internet, smart phones and the advent of shopping over the internet.

Most Canadian did not rely on telecommuting to fix their transportation problems and continued to invest in transit and roadway improvements. In the USA in the 1990s, Marin County and in Honolulu plans for rail projects were stopped when a key policy board was convinced that it would have been more cost effective to purchase every household a person computer that could be used for dynamic ridesharing. Both rail lines are finally under construction 20 years later at much higher costs; the computers were never purchased and there are now apps that enable dynamic ridesharing.

Shared Mobility -
Quotes from the Go Plan Appendices

- "Ridesharing can be implemented by individual companies/institutions (either as an isolated program or as part of a more comprehensive trip education program), or it may be sponsored by municipal/Provincial governments, as has been done in Toronto and Vancouver. A major Issue in ridesharing is 'matching up' the participants with each other."

A prediction vs. today – The power of the internet and smart phones to connect people was not anticipated in decades prior. It may have been difficult to imagine that almost every person in Calgary would be carrying a GPS unit and a mobile device that could link them up to a privately owned transportation network company. The advent of smart phones has made it possible to connect people and offer services that were unforeseeable a number of years ago.

We are trying to predict the future much like Go Plan did in the 1990s, and we will likely overestimate the impact of some technologies and cultural changes, underestimate others, and not foresee a game changing technological product or application (much like the Go Plan didn't not account for the impact of smart phones). However, the themes of the Go Plans predictions still largely hold today. Vehicles and roadways will become smarter, vehicle fuels will be diversified, and communications technology will improve which will allow for the greater utilization and sharing of resources.

Next Steps

In order for The City of Calgary to be resilient and future-ready, continual and ongoing monitoring and adjustment of plans and strategies will be critical.

Ongoing Monitoring of Future Technologies

The City should continue to monitor developments in technologies that are expected to significantly change travel and land use patterns in the future. A brief assessment should be included in future monitoring reports on the Calgary Transportation Plan and Municipal Development Plan. As more information is known about technologies, this should be used to inform or initiate any future updates to these plans.

Additionally, for staff to keep up-to-date on developments, active information exchange at technical events is highly valuable. These venues typically provide the most current information and allow staff to establish and maintain a network of contacts across industry, government and academia. The City should place increased support on having staff attend key meetings and conferences. This can be done within existing operational budgets. The City should also look for opportunities to participate in planning and pilot projects as appropriate (such as the low-speed autonomous shuttle pilot).

Collaboration with other jurisdictions

Through this report The City of Calgary has made contact with several different municipalities across Canada. Many cities are working to prepare for future technologies similar to Calgary. The City should continue working with other municipalities to share the costs of trials and facilitate gaining broader knowledge more quickly than could be done on our own. This includes continued exchanges of information with other cities and regularly conducting discussions through various channels and associations.

Collaboration with academia

The University of Calgary definitely sees the opportunities and challenges that future transportation technologies pose to cities and society in general. The Urban Alliance is an excellent vehicle for continuing to explore and research these technologies that The City should leverage for this work. Other institutes, such as SAIT and the University of Alberta, are also actively studying and preparing for these technologies, and The City should continue to look for mutually beneficial opportunities to work with these groups.

Collaboration with industry

The City can play a facilitating role with industry members to support the development of future technologies. This can be through partnerships, making City assets and information available for use, and facilitative policies and practices that encourage business and innovation. Working with industry can benefit Calgary through employment opportunities. At The City level, industry can also provide a healthy perspective on the upcoming technologies and how to best prepare for them. The City should continue to collaborate with industry on an opportunity basis.

Undertake Pilot Projects

The City should look for opportunities to participate in pilot projects as appropriate. The proposed pilot of the low-speed autonomous shuttle offers an opportunity for The City to introduce autonomous transit technologies to the public. This has several benefits, of which are outlined in detail in Attachment 2 of the Council report. Pilot projects are generally a good way for The City to learn more about a given technology without requiring a significant investment. This approach can generally be accomplished within existing budgets. Budget may be required to sustain successful pilot projects beyond the pilot period, or to expand pilot projects to a city-wide scale. These impacts will be brought to Council as appropriate.

Updating of Strategies and Bylaws

A review of the Municipal Development Plan and the Calgary Transportation Plan is anticipated over the next few years. These policies should build on the work in this report to identify opportunities to maintain a flexible and resilient transportation system given the significant uncertainty that exists. As the uptake and certainty of technologies becomes more apparent, it may be necessary to revisit aspects of the two plans on an ongoing basis.

Several bylaws and strategies are indentified for updating throughout the report. While there are some certainties with respect to bylaw changes (for example, e-bikes, electric vehicle strategy), it will be necessary to continually monitor relevant bylaws and introduce amendments on an incremental, ongoing basis as technologies mature and become more common. The transportation capital business case template will be refined to consider the impact of technologies on the longevity of proposed investments. Generally, when legislation from a higher order of government (Provincial, Federal) is needed to facilitate technology, the City will wait for the higher order of government to make changes before changing City bylaws.

Participate in the Smart Cities Challenge

The federal government proposed at the 2017, March 22 federal budget to provide Infrastructure Canada with $300 million over 11 years to launch a Smart Cities Challenge Fund. Similar initiatives in the United States and United Kingdom have been highly successful at spurring innovative solutions for cities and awarding funding to help implement new solutions. Smart city plans typically address a wide range of issues, from transportation and built form to energy use and environment. There are a number of areas with respect to future technologies where Calgary is in a leadership position. Work on this report has facilitated relationships between numerous stakeholders and City staff. This puts The City is in a good position to partner with industry and academia to put forward solutions that can improve the quality of life of Calgarians.

Appendices

Appendix 1 - Potential Impacts from Future Transportation Technologies to the MDP/CTP Sustainability Principles

As shown in the below table, there are many potential impacts to the plans, both supportive and detractive. The extent to which each of these impacts manifests themselves will only be known in time. Technology is also just one of many factors that affect the ability of The City to achieve the plans' vision.

	Potential Impacts from Future Transportation Technologies	
MDP/CTP Sustainability Principle	**Supportive**	**Detractive**
1. Create a range of housing opportunities and choices	• AVs may reduce some housing costs, such as parking costs, depending on the uptake of on-demand mobility-as-a-services (Maas). This may make a broader mix of housing projects more viable.	• AVs may facilitate exurban development (e.g. sprawl) by reducing commuting costs (operating and congestion) and improving the commuting experience. This could increase auto usage. This may reduce the viability of other housing options from a cost-competitiveness perspective. It is likely much of this development could occur well outside of Calgary. This could reduce the future tax base for The City.
2. Create walkable environments	• AVs will be safer for pedestrians. • Electric vehicles will be quieter and reduce noise pollution. • On-demand services could see people being dropped off at the perimeter of highly walkable nodes and corridors.	• AVs could increase traffic and require more auto-oriented infrastructure, which could detract from pedestrian environments. • Anticipated efficiency gains from a fully autonomous fleet may increase speeds and make walking less desirable.
3. Foster distinctive, attractive communities with a strong sense of place	• Cities may focus more on passenger drop-off locations, allowing for more walking and interaction with character areas (i.e. autos on the perimeter of an area). • Increased use of mobility-as-a-service and AVs may reduce the need for parking, allowing redevelopment of some surface parking into mixed use developments. • The role of roads could be minimized in communities, with a focus on repurposing the space for more human-level uses. New areas would be more intimate in scale. • An increase in mobility for people with mobility issues results in more community engagement and participation as well as visibility to them.	• If permitted, drones could be a distraction or nuisance in these areas. • Dense areas, such as the downtown, may be over-congested if there is too much auto activity (empty cars entering/leaving the downtown, or cars looking to pick up/drop off passengers).
4. Provide a variety of transportation options	• There will likely be a wider variety of travel options, from on demand services to intermediate transit options (i.e. van pools, shuttles, e-bikes etc.). • The cost to operate auto and transit services should decrease from autonomous technology and electric drivetrains. • AVs will provide increased access for user groups who cannot currently drive (seniors, children and teenagers, persons with disabilities).	• AVs may take away from transit ridership on some corridors. • On demand services may take ridership from high-demand transit routes, which will make remaining routes more expensive to provide. • Increased traffic (and speeds) may make walking and cycling less desirable. • Increased traffic from new driving trips from user groups who had not previously travelled on their own.

5. Preserve open space, agricultural land, natural beauty and critical environmental areas	• Electric vehicles will help mitigate the air quality impacts from travel in and around these locations.	• If AVs facilitate more sprawl, this may detract from the amount of natural greenfield area that is preserved.
6. Mix land uses	• AVs may be able to take better advantage of shared parking strategies, which would facilitate a better mix of land use types. • On-demand services (MaaS) could facilitate dropping off people at mixed-land use nodes to complete daily needs.	• High traffic demands (in areas such as downtown) could lead to congestion that could detract from mixed-use nodes.
7. Strategically direct and manage redevelopment opportunities within existing areas	• The improved usage of area parking may reduce parking as a barrier to redevelopment. • If less parking is required in new developments, this will reduce their cost and make them more competitive.	• There might be increased requirements to handle passenger loading demand, which could increase development costs.
8. Support compact development	• Reduced parking requirements from AVs could help facilitate compact development.	• If AVs cause sprawl, it is likely that the compactness of development may be reduced overall, as some people may choose to live and work further away from the city.
9. Connect people, goods and services locally, regionally and globally	• Drones could augment current shipping options and increase efficiency of goods movement. • 3D printing could reduce the need to ship some goods and services, which may change associated traffic patterns. • Truck traffic may be redistributed to less congested periods (such as overnight). Use of platoons and alternative fuels to increase cost efficiency is likely. • Autonomous electric vehicles may become more convenient for short-haul personal trips. • AV fleet size could be increased or decreased as required, increasing robustness and flexibility of transportation network during major events such as Stampede or Olympics.	• The demand for industrial and logistics areas may be changed or reduced depending on the impact and use of autonomous fleet technology. • There may be reduced demand for short-haul flights and coach trips due to the attractiveness of using AVs.
10. Provide transportation services in a safe, effective, affordable and efficient manner that ensures reasonable accessibility to all areas of the city for all citizens	• AVs are expected to significantly improve the safety of the network. • Increased capacity from a fully AV fleet could result in reduced congestion. • Transportation is likely to become more affordable due to reduced costs for ownership, operation and maintenance.	• Efficiency gains from AVs may be offset by increased trips, causing congestion.
11. Utilize green infrastructure and buildings	• Electrification of the vehicle fleet is expected to reduce greenhouse gas emissions and local air pollutants. • Buildings will likely need to incorporate infrastructure to facilitate electric vehicle charging, which may create new business and employment opportunities. • Batteries in electric vehicles may be able to help balance load demands on the electrical system, increasing the effectiveness of renewable energy. • Redevelopment of service stations lands to rapid charging is an opportunity for redevelopment, new commercial services and mitigating the environmental liability.	• Increased charging activity for vehicles will increase demand on the electrical system, potentially requiring some upgrades to the generation system. • The power distribution network will need to be updated to reflect the new distribution and storage requirements for EVs. This an opportunity as well though for improving the resiliency of the system with local nodal storage.

Appendix 2 - Potential Fiscal Implications

The arrival of future technologies has a mix of implications with respect to The City's fiscal future. The City will need to proactively plan for changes in revenue streams and new costs that might arise. At the same time, technology has the potential to significantly reduce some costs for The City. The following table provides an overview of some of the potential impacts. Note that many of the impacts will materialize once full adoption of the technology is in place.

Technology	Opportunities	Impacts
AVs – Personal (Private) and shared Vehicles	• May reduce the need for capital investments if capacity increases are realized once system fully autonomous. • May be an opportunity to move towards a fuller user-pay system on the road network. • Decreased collisions should reduce demands on fire and police resources. • There might be an increase in roundabouts or traffic circles and reduction in signalling once AVs have a high market saturation.	• Will require improved maintenance of some assets (such as lane markings) and services such as snow clearing depending on technology that prevails. • May require The City to invest more in GIS mapping of certain assets and provide real time data on any network disruption such as lane closures for construction or maintenance. • May reduce revenues from traffic infractions. • May reduce revenues from the sale of parking and parking infractions.
AVs – Public Transit	• Will reduce labour costs, depending on the technology and its ability to meet the broader customer service objectives. • Some jobs could be reallocated from drivers to customer service agents.	• Reduced labour needs could result in negative impacts on job availability.
AVs – Goods and Freight	• Platooning and further automation of goods movement may reduce overall network congestion and reduce capital investment needs.	• Reduced labour needs could result in negative impacts on driving jobs.
Connected Vehicles	• In longer term, some infrastructure such as signs and signals may only be provisioned virtually.	May require infrastructure investment at signals and other control devices if V2I becomes common.
Drones	• If proliferate for deliveries, may move some traffic off of the road system, which could reduce congestion and infrastructure investment.	• If proliferate, there may be new costs for drone enforcement.
Electric Vehicles	• May increase electricity sales and revenues for utilities such as ENMAX. • Once tested in local conditions, may reduce operating and maintenance costs for City fleet vehicles and buses. • Required changes to the distribution and local storage network is an opportunity to improve the resiliency of the electrical network. • Noise attenuation may no longer be necessary.	• Will reduce revenues from existing fuel taxes that currently fund infrastructure. • City may want to provide funding for charging stations in some circumstances. • May incur costs to ENMAX to upgrade elements of the electrical distribution system. • The City may need to deal with the disposal of used batteries.
E-Bikes	• More people cycling could reduce the need for extra roadway and transit infrastructure.	

Internet of Things	• In some circumstances, sensors may replace manual monitoring and improve service efficiency. • Energy saving for street lights. • Air health monitoring.	• Provision and maintenance of sensors would be a new cost. • Data security for City owned devices will be a new cost.
Mobility as a Service	• May offer a more cost effective method for providing some current transit and Calgary Transit Access services or allow for new, additional services that were not previously cost effective. • Various MaaS services could feed into the transit network. • May need to consider charges for loading activities in congested areas.	• Will put significant downwards pressure on parking revenues. • May reduce revenues for Calgary Transit, particularly if profitable routes have more competition. This could impact the fare-to-subsidy ratio.
Parking Technologies	• There could be opportunities for further marketing of ParkPlus with respect to AV integration, and some electric vehicle charging. • The technology may facilitate additional parking transactions, which could increase revenue. • Existing parking facilities may be more efficiently used if cars can become packed more densely due to automation. • Less expenditure on land for parking.	• Existing parking structures may not have the structural capacity to handle additional vehicle weight from more dense parking. • Challenge to integrate various parking providers into a common and seamless payment technology.

Appendix 3 – Triple Bottom Line Implications

The arrival of future technologies has a mix of implications with respect to social, environmental and external economic impacts to Calgarians and society in general. There will be significant benefits in terms of health, environment and costs of travel. The trade-off is a likely negative impact on many existing employment fields, reduced physical activity, and increased social isolation. The following table provides an overview of some of the potential impacts. Again, many of the impacts will materialize once full adoption of the technology is in place.

Social Implications		
Technology	**Opportunities**	**Impacts**
AVs – Personal (Private) and shared Vehicles	• Personal AVs provide significant opportunities to augment current travel options for those who are not able to drive, such as seniors, children and those with disabilities. • AVs should dramatically reduce injuries and deaths from auto accidents, which would have significant health benefits. • Impaired driving unlikely to be a future concern with level 4-5 AVs.	• Increased use of AVs at the expense of more active travel modes could result in negative health impacts on the population. • Viable organ donors could be reduced, as many organ donations are obtained from victims of automobile accidents.
AVs – Public Transit	• There could potentially be increased customer service if resources previously directed to drivers are redirected to this area. • The greater mix of transit options (such as different vehicle types) can help people with unique travel needs. • Safety of the system would be further increased through automation.	• If there is less public transit service as a result of travelers shifting to other travel options, there may be reduced social activity that results from the use of public transit (e.g. increased isolation).
AVs – Goods and Freight	• The ease of obtaining goods should be increased.	• There could be increased social isolation due to a reduced need to go to stores (e.g. robot delivery units).
Connected Vehicles	• The enhanced safety resulting from CVs would have positive health benefits.	• No significant negative social impacts have been identified.
Drones	• The ease of obtaining goods should be increased.	• There could be increased social isolation due to a reduced need to go to stores (e.g. robot delivery units).
Electric Vehicles	• No significant social opportunities identified.	• No significant negative social impacts have been identified.

E-Bikes	• E-bikes should increase the mobility of groups such as seniors, providing an additional travel option.	• No significant negative social impacts have been identified.
Internet of Things	• People are more connected digitally. • May allow for more targeted marketing and provision of transportation services. • Ability to obtain more information to inform travel decisions.	• Increased connectivity will increase privacy and security concerns for the public. • Increased targeted marketing may become a nuisance.
Mobility as a Service	• People have more mobility options and reduces travel as a barrier. • Impaired driving less likely with more mobility options e.g. people can use a TNC for a ride home from the bar.	• No significant negative social impacts have been identified.
Parking Technologies	• No significant social opportunities identified.	• No significant negative social impacts have been identified.

Environmental Implications		
Technology	**Opportunities**	**Impacts**
AVs – Personal (Private) and shared Vehicles	• AVs will likely have less energy consumption relative to traditional vehicles, through improved driver behavior and lighter vehicle design. • AVs may be designed to be more easily recycled. • The reduction in collisions would reduce waste from damaged vehicles and property.	• Mass adoption of AVs would accelerate the replacement of the existing vehicle fleet, which would need to be disposed of or recycled. • Increased travel may have some environmental impacts. • The potential for sprawl generated from the flexibility of AVs could have significant environmental impacts.
AVs – Public Transit	• The public transit fleet may be more 'right-sized' to the demand, which could reduce environmental impacts.	• Reduced public transit usage could have environmental impacts if the public switches to personal vehicles.
AVs – Goods and Freight	• Fewer collisions may result in less damage to property, including damage from spilled goods.	• The lack of a driver could result in response challenges if an environmental incident were to occur (e.g. spill).
Connected Vehicles	• CVs will increase the efficiency of travel, which can have positive benefits.	• No significant negative environmental impacts have been identified.
Drones	• Drones may be able to identify more quickly conditions on the transportation system.	• Drones may cause increased noise and visual pollution.
Electric Vehicles	• The use of electric vehicles will have a positive impact on emissions reduction. This result is further improved if the power grid fuel sources are changed to reduce GHG at the point of generation. • Noise pollution is likely to be reduced.	• If traditional fuel stations are abandoned, there will be an increase in sites requiring environmental reclamation before being repurposed. • Where vehicles are stored (ie home locations), there may be an increase in land dedicated to parking as to facilitate vehicle charging if it is not done on-street. • There could be a significant increase in battery waste products.

E-Bikes	• E-bikes would increase the attractiveness of cycling, which would have environmental benefits for those who switch from traditional automobiles.	• There would be a resulting battery waste stream produced.
Internet of Things	• The use of sensors in certain applications may help reduce waste (e.g. plants that have died, assets that are damaged, etc) by better directing resources.	• More products may have electric components attached to them in the waste stream.
Mobility as a Service	• Better matching vehicles with services will result in a better usage of existing vehicles, which would reduce the total vehicle fleet (and resources used to produce the fleet).	• No significant negative environmental impacts have been identified.
Parking Technologies	• Better parking information systems will help reduce unnecessary travel resulting from searching for parking.	• Parking structures that are no longer useful may end up being demolished. Underground parking may struggle to be repurposed in some cases.

Societal Economic Implications		
Technology	**Opportunities**	**Impacts**
AVs – Personal (Private) and shared Vehicles	• Travel costs are likely to be reduced for citizens and businesses. • Businesses may find opportunities to incorporate advertising into the vehicles. • There may be increases in tourism and productivity as people could travel further in their vehicles without driving and could incorporate sleeping and other activities in the vehicle as it takes them to their destination.	• Reduced labour needs could result in negative impacts on job availability, particularly in for-hire vehicles and fleet vehicles. • If tolls are introduced to help fund infrastructure, this would be a new fee for travelers. However, this may be somewhat offset by the disuse of fuel tax as a revenue tool if the fleet electrifies.
AVs – Public Transit	• It is possible that increased automation could reduce transit fares.	• Reduced labour needs could result in negative impacts on job availability.
AVs – Goods and Freight	• Platooning and further automation of goods movement may help bring down the costs of goods. • Faster delivery of goods could lead to higher efficiency for businesses. • A broader range of goods may be available to the public. • Assuming improved compliance with vehicle weight restrictions, the rate of pavement deterioration would be reduced.	• Reduced labour needs could result in negative impacts on driving jobs.
Connected Vehicles	• If vehicles are able to move more efficiently through connectivity, this may result in reduced travel times for the public. • Connectivity may help reduce collisions which would reduce the associated costs with collisions.	• Initially, there may be a cost premium for these features.
Drones	• Drones may increase economic activity by providing a new delivery solution that may be more cost effective in some cases.	• It is unclear if there may be an increase in issues related to damage from drones (e.g. dropped cargo, drone collisions, etc).
Electric Vehicles	• In the long term, it is expected that electric vehicles will cost less to own and operate than gas or diesel fuelled vehicles, which will result in savings for the general public.	• Jobs in the traditional vehicle field would need to transition to the electric vehicle field. This could include more focus on computer systems and less on mechanical ones. The nature of vehicle maintenance may change.

E-Bikes	• E-Bikes increase the attractiveness of cycling trips, which can be more cost effective relative to driving.	• No significant negative economic impacts have been identified.
Internet of Things	• The availability and use of sensors may help reduce labour costs for activities that currently require manual checking. • The collection of data could lead to new economic opportunities for business and improved marketing.	• No significant negative economic impacts have been identified.
Mobility as a Service	• The provision of on-demand services should reduce car ownership, which would result in savings to individuals who forego potential vehicle purchases.	• The nature of employment may change, from full-time drivers to more casual drivers or automation.
Parking Technologies	• PayBySky solutions will help reduce spending on parking by only charging for actual parking use. • Parking fees in high-demand areas are expected to drop since vehicles may park outside of these areas.	• Some parking solutions may enable for additional abilities for paid parking.

Appendix 4 - Economic Diversification

Many technologies that Calgary will be facing in the future present opportunities for economic diversification. This is especially pressing given the current economic reality.

Calgary is fortunate to offer a number of advantages which can potentially attract technology and manufacturing firms to the city. These include:

- A highly-educated workforce, with skills that could be transitioned to support future technology industries.
- A relatively young population.
- High levels of labour force productivity and participation.
- A competitive tax environment.
- A highly ranked quality of life.
- A unique environment for testing technology (from a weather and terrain perspective).

As part of Canada's Innovation Agenda, The Government of Canada is focusing on identifying and supporting business innovation 'super clusters'.

Clusters are areas that share a number of attributes (successful entrepreneurs, excellent universities, a pool of top talent, and access to financing) to create a self-propelling economic area. Clusters need to be focused and purposeful. The Government of Canada is working with national stakeholders to determine the right model for selecting and supporting world-leading clusters in Canadian industry. Calgary has an opportunity for future technologies to position itself as a possible candidate for a transportation technology cluster.

The City has been working with industry groups, such as ACAMP (the Alberta Centre for Advanced MNT Products) to better understand how The City can support economic development of future technologies.

The City can help facilitate these activities by:

- Making City assets available for technology testing purposes.
- Providing supportive policies and land use.
- Facilitating trials of technology.
- Working in conjunction with local academic institutes and the private sector on partnerships that can support industry activity.

These activities can help support an AV development cluster in Calgary.

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For more information please visit calgary.ca/transportation