Pathway Study on Transportation in Ottawa

Presented to:
The City of Ottawa
110 Laurier Ave W
Ottawa, ON K1P 1J1

In relation to:
The City of Ottawa's Energy Evolution Strategy (Phase 2)

By:
Sustainability Solutions Group
11 Alex Cox Rd
Tatamagouche, NS

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Executive Summary

This pathway paper estimates and models transportation energy use in Ottawa and the associated GHG emissions, using 2016 as a baseline year. Nine best practice transportation strategies and their ability to reduce transportation-related emissions are reviewed in three scenarios with increasing levels of ambition. The conservative scenario reflects a business-as-planned outlook, plus some acceleration of vehicle electrification. The moderate scenario reflects interventions on enhanced transit, increased commercial electric vehicles, and increases to car sharing and active transportation. The aggressive scenario includes electrification of personal and commercial transportation, car free areas, expanded transit, and greater car sharing and active transportation.

In the moderate scenario, greenhouse gas emissions are reduced to about 50% of their projected level in a “business as usual” future. In the aggressive scenario, Ottawa’s transportation sector would be essentially carbon free by 2050.

Vehicle electrification has the largest emissions reduction impact of any single transportation measure, but given the interdepencies and synergies between the various strategies and measures, the scenario results are best regarded as the integrated results of all the emission reduction actions included.

Section 1: Present Assessment of Transportation

Pathway description

This pathway examines transportation technologies and strategies in the City of Ottawa that will help the sector meet emissions reduction goals in Ottawa's Energy Evolution Strategy.

Phase 1 of the Energy Evolution Strategy explored a pathway to encourage personal electric vehicles in the city and modelled how city-wide emissions may be affected. This pathway study expands upon the initial Phase 1 analysis by identifying and evaluating nine additional strategies that support energy reductions or fuel switching in the transportation sector, including greater active transportation, enhanced transit, car sharing, and road pricing. The work in the Energy Evolution Strategy and this pathway will complement the goals set out in the City's Transportation Master Plan.

Pathway Boundaries

Several transportation emission reduction strategies are researched, modelled, and evaluated in this paper. The table below details the strategies and their key considerations that the modelling tool (CityInSight) takes into account in projecting energy use and emissions to 2050.

Table 1: Study parameters for transportation.

Strategy	Summary	Key Considerations
Impact of land-use change	Model the emissions effects of creating compact communities.	• VKT reduction • Increase in walking, cycling, and transit usage
Electrification of commercial vehicles	Model incentives or regulations that increase the number of commercial electric vehicles.	• Increased market share of electric vehicles and reduction of traditional fossil-fuel based vehicles
Transportation Demand Management (TDM)/ behaviour change policies	Model various TDM policies to identify effective methods in changing behaviours to encourage transit use or active transport.	• Reduction of VKT • Increase in walking, cycling, and transit use
Parking management	Model parking management, as a particular dimension of TDM, to assess how changes to access of parking can change transportation behaviours.	• VKT reduction • Increase in walking, cycling and transit use

Car-free areas	Model how car-free areas can encourage active transportation rather than personal vehicles in different areas of a city.	• The location of car-free areas near retail or mixed-use neighbourhoods • Number of people who previously accessed the areas by personal vehicle • VKT reduction where car-free areas are introduced
Congestion charge	Estimate assumed transportation behaviour response to price signals (e.g. a mode share shift for specific OD pairs) in order to model the impact on energy use and emissions.	• The extent to which traffic is diverted to other roads, thereby increasing congestion in other locations • The response to the increase in the price of driving, which will vary based on the existing traffic levels and the availability of alternatives • The scope and timing of pricing, which may encourage shifts in travel by time of day, rather than a reduction in driving • Whether drivers take shorter trips rather than eliminating them completely • Implications to AV deployment
Enhanced transit	Following the lead of the Confederation Line in Ottawa, model the impact of increased transit routes, increased frequency, and different modes.	• The number of additional buses in operation and their type • The extent to which the new service causes an increase in transit ridership • The extent to which new transit riders previously drove alone • Length of vehicle trips reduced
Autonomous vehicles (shared)	Model the effects of autonomous vehicles and their rates of penetration within the community. Using previous studies, possible emission reduction strategies will be identified.	• Market share within a community • Impact on car mode share • Load factor, utilization and impact on size of vehicle stock • Rate of electrification for AVs • Impacts of reduced need for parking
Car share/ride share/car co-ops	Uptake projections in car share companies and trips.	• Reduction in personal vehicle ownership • Reduced VKT • Mode shift
Enhanced Bicycle Infrastructure	Various policies and infrastructure investments are described and reviewed for their effectiveness to increase cycling.	• Shift vehicle travel toward active transportation

Methodology

The Business As Planned (BAP) scenario parallels the Conservative Scenario and incorporates current City practice and policy that may affect GHG emissions within the city towards 2050. The Moderate Scenario begins to scale up actions found in this pathway paper such as intensified land-use, decreased reliance on fossil fuels for transport and increased active transport. The Aggressive Scenario further electrifies commercial vehicles, maximizes opportunities for cycling infrastructure, adds more car share services, and increases the relative amount of infill vs. greenfield development. More information on these scenarios including summary tables can be found in the Current Pathway Analysis and Projected Pathway Analysis sections of the paper.

CityinSight modelling includes a spatially explicit passenger transportation sub-model that responds to or accounts for changes in land-use, transit infrastructure, vehicle technology, travel behavior and other factors. CityinSight incorporates transportation emissions modelling methodology from the Global Protocol for Community-Wide GHGs (GPC).

Trips are divided into four types (home-work, home-school, home-other, and non-home-based), each produced and attracted by different combinations of spatial drivers (e.g. population, employment, classrooms, non-residential floorspace). Trip volumes are specified for each zone by origin and zone of destination pairing. For each origin-destination pair, trips are shared over walk/bike (for trips within the walkable/bikeable distance thresholds), public transit (for trips whose origin and destination are serviced by transit), and automobile.

The energy use and emissions associated with personal vehicles are calculated by assigning VKT to a stock-turnover personal vehicle model. All internal and external passenger trips are accounted for and available for reporting according to various geographic conventions.

Emission Types and Units

Tabel 2 provides common vehicle emissions types and their respective Global Warming Potential.

Table 2: Vehicle emission types.

Name	Abbreviation	Global Warming Potential
Carbon Dioxide	CO_2	1
Methane	CH_4	28
Nitrous Oxide	N_2O	298
Air Conditioning Refrigerant	HFC-134a	1,430

The Global Warming Potential (GWP) determines the relative global warming impact of different greenhouse gases, on a per unit mass basis. Carbon dioxide has a GWP of unity, and other gases are measured relative to that benchmark. For example, methane's GWP is 28, which means that one tonne of methane has the same global impact as 28 tonnes of carbon dioxide and would be described as 28 tonnes of CO2e. Note that because carbon dioxide emissions are so much greater than emissions of the other greenhouse gases, it has by far the greatest impact, even though the other gases are more powerful on a per tonne basis.

Other Common Unit Types

Terajoule (TJ): a unit of energy generally used to express large quantities of energy used over a period of a year. In Phase 1 of Ottawa's Energy Transition Strategy, transportation accounted for 31,200 TJ of energy used out of 114,200 TJ total.

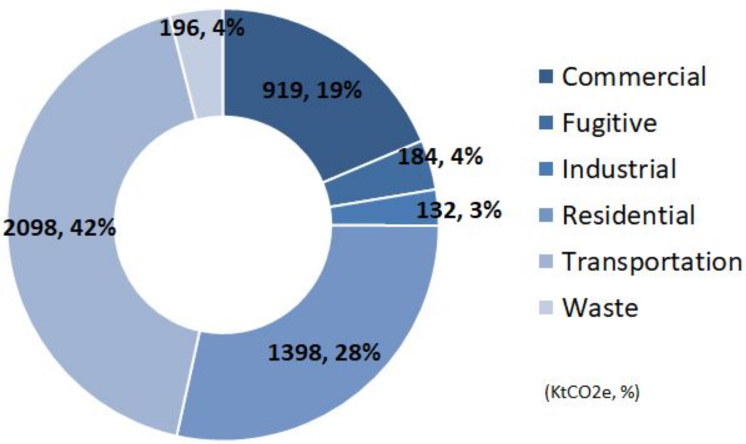
Tonnes/ kilotonnes/megatonnes Carbon Dioxide equivalent (tCO2e or ktCO2e or MtCO2e): a unit of measurement common in measuring the amount of total emissions over a period of year or years.

Background Information

Transportation Energy Use and Emissions Production

On-road community transportation activities generated 2,098 kilotonnes of CO2e in 2016, making it the second largest source of GHG emissions in the city, after buildings emissions (residential + industrial + commercial). Emissions from the transportation sector are growing more quickly than other sources and in the absence of new mitigation policies or programs, transportation emissions will become the largest GHG source in Ottawa.[1] Transportation accounted for 30,612 TJ of energy use, or 29% of total city-wide energy consumption in 2016.

Figure 1: Total Emissions by Sector in Ottawa, 2016.



There are really two transportation systems – one to provide personal mobility and one to support the movement of goods and services in the economy. They share the same infrastructure, but otherwise are quite different. There is an overlap with regard to light duty trucks, but personal and commercial transportation are generally provided by different types of vehicles with different technological possibilities. More important from a local government policy perspective, the personal mobility and commercial transportation systems are driven by different motivational dynamics (household decision making regarding trip-making and travel behaviour vs. business decisions to manage supply chains and meet customer expectations).

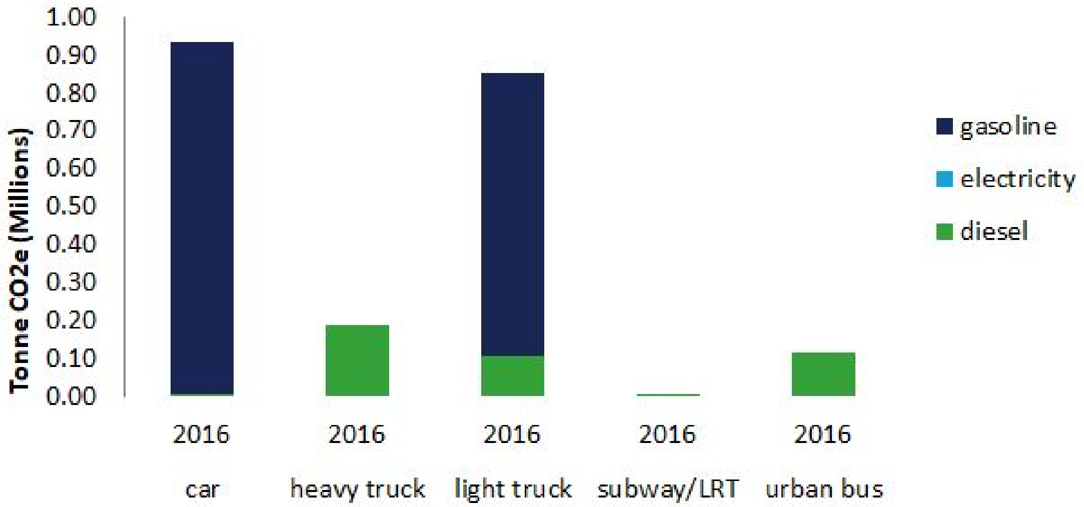
Commercial transportation energy use and emissions are comparable in size to personal transportation on a national or provincial scale, but in Ottawa, with its post-industrial, service oriented economy, personal transportation dominates both the energy consumption and the greenhouse gas emissions from transportation. In 2016, tailpipe emissions of greenhouse gases

[1] Energy and Emissions Plan for the CCP, 2012. http://www.ottawa.ca/calendar/ottawa/citycouncil/ec/2012/02-21/03-Document%204%20-%20CoF_Energy%20Plan_FINAL%5B1%5D.pdf

from gasoline-powered cars and light trucks, totalled 1,790 kilotonnes CO2e, fully 85.4% of total transportation-related emissions in the city, transit buses 5.6% and diesel powered heavy trucks the remaining 9%. If we assume light vehicle commercial traffic consumes the same amount of energy as heavy truck transportation in Ottawa[2], then 83% of transportation-related greenhouse gas emissions are due to personal mobility and 17% to commercial transportation.

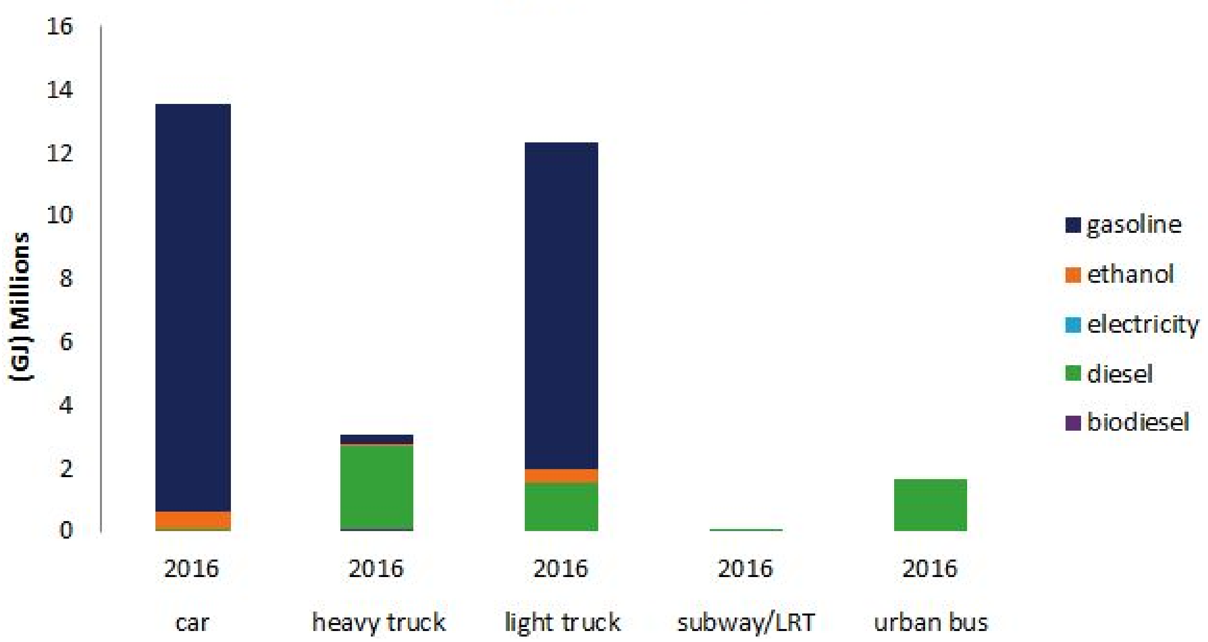
The figures below summarize energy consumed and emissions by vehicle type in 2016.

Figure 2. Transportation emissions in Ottawa by Vehicle Type and Fuel Ottawa, 2016.



[2] This assumes per capita light vehicle commercial traffic in Ottawa is 25% lower than in the GTHA, based on research done in the Greater Toronto-Hamilton area, a major hub for continental commercial transport. (McMaster Institute for Transportation and Logistics, "Estimating Urban Commercial Vehicle Movements in the Greater TorontoHamilton Area", prepared for Metrolinx, the share of light July 2010. http://mitl.mcmaster.ca/reports/MITL_Metrolinx_Report.pdf.)

Figure 3: Energy use by vehicle type and Fuel, 2016.



Transportation energy use and emissions are driven by the underlying demands for personal mobility and the delivery of goods and services, but are equally determined by the carbon intensity of the vehicles employed. Both of these emissions drivers—the demand for transportation services and the carbon intensity of the vehicles—are being affected by transformational technological, social and business model innovations. Vehicle electrification eliminates tailpipe emissions, and provided the electricity is sourced from carbon-free generation, could single-handedly bring about a carbon-free transportation sector, at least at the point of end use. The digital revolution is spawning a range of technologies and business models that could reverse the longstanding trend of growth in personal and commercial transportation demand, while at the same time increasing the vehicle utilization rate several-fold from its current average of about five percent. Similarly, trends in urban settlement patterns and infrastructure design that favour densification, mixed use zoning and active transportation are contributing further to a reduction in motorized vehicle traffic.

These trends are generally mutually reinforcing. Electrification of the vehicle fleet will be achieved sooner and at a lower cost in the context of a shift to mobility-as-a-service (Maas) business models. The mobility-as-a-service model reduces the size of the vehicle fleet and frees up vast amounts of parking land that can be repurposed to support the growth of more vibrant, mixed use neighbourhoods, which in turn improve the feasibility of mobility-as-a-service. The growth of artificial intelligence and telepresence technologies reduces the amount of personal mobility required for day-to-day access to employment, goods, services and amenities, and can facilitate growth in neighbourhood-level interactions and economic activity. Other innovations in mobility and digital technology improve the efficiency of logistics, and reduce the need for commercial transportation in both supply and demand chains.

With all these interacting moving parts, it is particularly challenging to model low-carbon transition pathways or to assign emission reduction potentials to individual measures. The nine strategies for reducing transportation emissions considered in the scenarios presented below should be viewed in this context. For example, vehicle electrification plays a larger role in these scenarios than other strategies, and there is no question it is an effective way to reduce emissions provided that the carbon intensity of the electricity can be kept to zero or very low levels. Calculating the emission reductions from vehicle electrification is quite straightforward, unlike some other measures whose impacts are less direct (e.g. land-use changes), where there is still much uncertainty with regard to their net impact on emissions (e.g. autonomous vehicles), or where their successful implementation depends on the success of other measures (e.g. the potential for active transportation increases as urban form and spatial structure allow more goods and services to be obtained with shorter trips). This does not mean they have low potential for reducing emissions, only that more assumptions are required in their quantitative analysis, assumptions which tend to err on the side of underestimating their potential impacts.

Finally, it should be noted that the electrification of transportation is itself a transition of enormous magnitude that will be occurring simultaneously with efforts to eliminate carbon emissions from other sectors, efforts that will also put new demands on the electricity supply. The transition to a low-carbon future generally and the electrification of the vehicle fleet specifically will be greatly assisted by strategies that reduce the demand for vehicle kilometres of travel or the size of the vehicle stock.

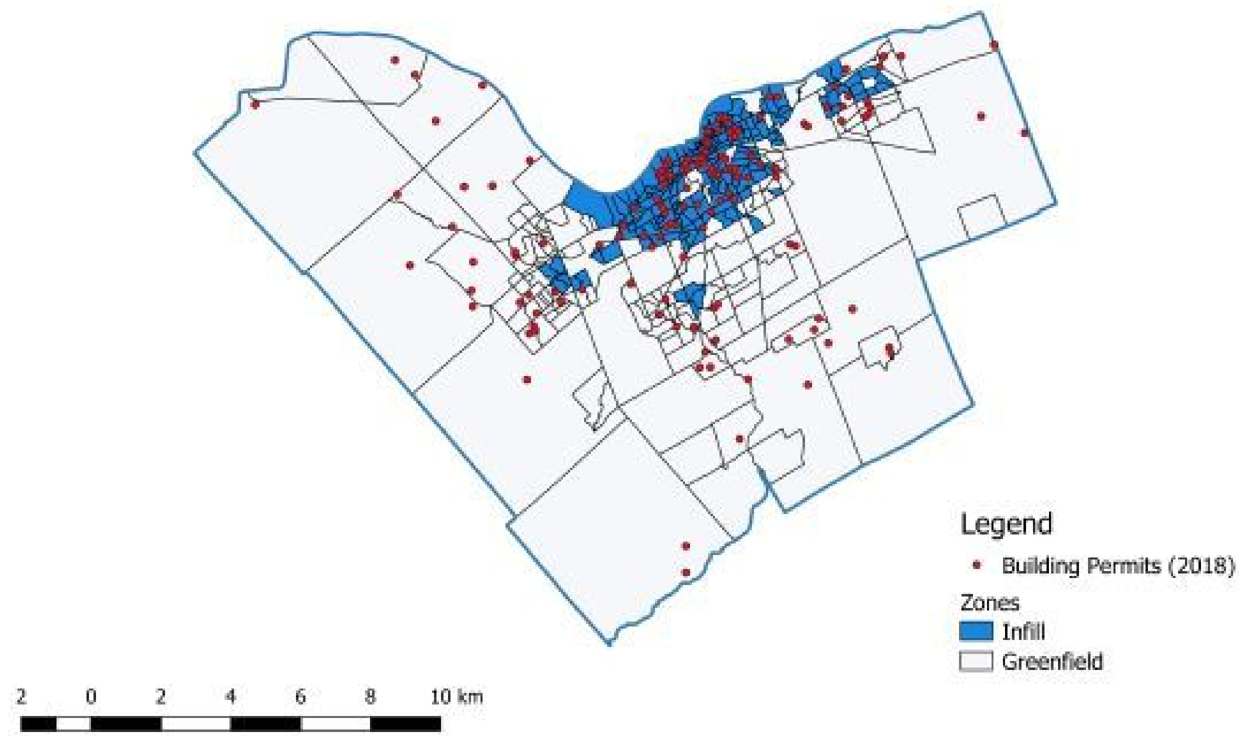
Strategies Assessment

This section discusses several strategies and technologies to reduce energy use and the resulting emissions from the transportation sector. The sub-sections provide background summaries, and policy and action discussions.

Land-use Change

Mixed land-use allows citizens to live near employment centres, commercial centres, or recreation, thereby reducing trip lengths. For trips that can be made short enough to facilitate walking and cycling, emissions can be eliminated altogether. There is currently a mix of infill and greenfield development in Ottawa. Towards 2050, this mix continues with an assumption that 50% of new development will be greenfield, and 50% as infill. In the integrated, low-carbon scenario, a shift towards greater infill development will occur and reduce the VKT correspondingly. The figure below shows construction of new units occurring as of 2018.

Figure 4: Comparing Infill to Greenfield Development in Ottawa, 2018.



Making cities more compact with mixed land-uses at the neighbourhood level results in reduced car ownership, increased active transportation, makes public transport more attractive, and can reduce VKT by as much as 15-30%.[3,4] Travel surveys of communities can help set benchmarks and show behavioural and emissions differences between compact and non-compact communities. An example is shown in Table 3.

Table 3: Travel decisions made by citizens depending on their location and land use.[5]

	Urban	Inner Suburb	Outer Suburb
Cars Per Household	1.3	1.8	2.2
Number of destinations within 1km	44.3	26.2	12.9
Mean distance to closest retail (km)	0.6	1.5	2.1
Non-auto modes used in a typical week			
• Walk to work	33%	4%	2%
• Walk to do errands	47%	20%	12%
• Cycle	44%	24%	24%
• Use Transit	45%	12%	5%

When considering land-use and transportation energy and emissions, the greatest impact that cities can make over the long run is prioritizing infill and brownfield development, and creating a transit-oriented development (TOD) strategy. Infill and brownfield development will prioritize development opportunities on lands that are underutilized, abandoned, or were previously zoned for one use such as office-commercial. Infill and brownfield development take development pressure off of the urban periphery and greenfield land. TOD can be implemented in densifying neighbourhoods, offering transit nodes where frequent service is present.

Sample modelling by the Centre for Clean Air Policy shows the impact of land-use decisions that prioritize infill development and implement a TOD strategy. Each policy had the potential to dramatically increase transportation use, reduce trip distance, and cut emissions. A summary table of this modelling is provided below.

Table 4: Transportation impacts of land use and emissions change.[6]

	VKT (%)	Emissions (Mt CO2e)
TOD	-21	-717
Infill / Brownfield Prioritization	-39	-1375

[3] Dierkers, G., Silsbe, E., Stott, S., Winkelman, S., and Wubbem, M. "CCAP Transportation Emissions Guidebook- Part One: Land-Use, Transit & Travel Demand Management." Center for Clean Air Policy, 2008. http://www.ccap.org/guidebook/CCAP%20Transportation%20Guidebook%20(1).pdf.

[4] *Transport Energy and CO2*. 2009. Paris, France: International Energy Agency / OECD. https://www.iea.org/publications/freepublications/publication/transport2009.pdf.

[5] Horning, Jessica, Ahmed El-Geneidy, and Kevin Krizek. 2007. "Perceptions of Walking Distance to Neighborhood Retail and Other Public Services." Montreal: Mcgill University. http://tram.mcgill.ca/Research/Publications/distance_perception.pdf.

[6] CCAP Transportation Emissions Guidebook- Part One: Land-Use, Transit & Travel Demand Management.

Through Ottawa's Official Plan, policies have already been identified to make the city more compact and multi-modal. Ottawa identifies these goals under Section 1.6 of the Official Plan: A City of Distinct Livable Communities:[7]

- A mix of land uses, housing types, compact and inclusive development, clustering of neighbourhood facilities and services and excellent pedestrian connections make communities more complete as well as walkable. Their attractiveness and pedestrian functions are increased by proactive urban design that improves the relationships between public and private land uses, built forms and the surrounding landscape.

- Liveability is addressed by accommodating new growth and development in a more sustainable manner utilizing compact, mixed-use built form principles, including a moderate increase in density.

- In underdeveloped areas, density is increased by adding more buildings in appropriate locations.

The Ottawa Pedestrian Plan (2013) identifies the goal to increase walking and walkability in the city. Along with better infrastructure, changes in land-use can help Ottawa reach 2031 targets, as shown below:

Figure 5. Ottawa goals for walking as indicated in the Ottawa Pedestrian Plan.

Exhibit 1.6 Walking Mode Shares for Internal Trips: 2011 Observations and 2031 Targets Established in TMP (morning peak period)

		Modal shares for 2011 and 2031					
		Inner Area	Inner Suburbs	Orléans	Riverside South/ Leitrim	Barrhaven	Kanata/ Stittsville
Walking	2011	51%	14%	19%	18%	23%	22%
	2031	52%	16%	20%	21%	24%	23%

Transportation decisions interrelate with the above policies and impact the urban environment. Decisions and policies that favour decentralized land-use (sprawl) will generally favour personal automobile use and result in the greatest amount of emissions. Contrarily, decisions that favour compact and mixed use communities served by transit will favour walking, cycling, or transit and result in fewer emissions.[8]

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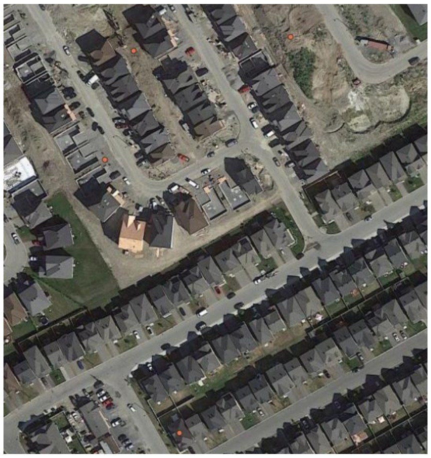
[7] "Ottawa Official Plan - Volume 1." Government. Ottawa, May 2003. https://ottawa.ca/en/city-hall/planning-and-development/official-plan-and-master-plans/official-plan/volume-1-official-plan.
[8] Litman, Todd. "Evaluating Transportation Land Use Impacts Considering the Impacts, Benefits and Costs of Different Land Use Development Patterns." Victoria Transportation Policy Institute, July 2017. http://www.vtpi.org/landuse.pdf.

Uptake Scenarios

Ottawa currently has a mix of infill and greenfield development. Greenfield development has tended to be low-density, favouring single-detached housing and taking place in areas such as Orleans, Barrhaven, or Kanata. Ottawa has also pursued infill initiatives such as the Richmond/Midway/Hartleigh development (Figure 5). The City has also pursued initiatives for TOD near the Confederation Line Stations. Infill initiatives are projected in the Integrated Scenario.

Figure 6. Sample new developments in Ottawa.

BAP/Conservative Scenarios



Bridlewood, West Ottawa
Units/ha: 16-20
Development Type: Single family detached. Front/back yards and attached/detached garages.

Orleans, East Ottawa
Units/ha: 10-17
Development Type: Single family detached. Front/back yards and attached/detached garages.

Moderate / Aggressive Scenarios

Richmond/Midway/Hartleigh
Units/ha: 50-70
Development Type: 3-Storey infill, multi-family rowhouses, and plex, at-grade parking.

Metcalf & Argyle, Centretown
Units/ha: 300-500
Development Type: High Density, 5-15 Storeys, underground parking, mixed-use.

Table 5: Uptake scenarios for land-use.

Action	Conservative	Moderate	Aggressive
Land-use	Official plan until 2031	70% of new development is in urban centres or adjacent to existing or new LRT, BRT by 2025.	90% of new development is in urban centres or adjacent to existing or new LRT, BRT by 2025.
Walking	No change in city-wide modeshift	For 2km trips, Mode shift to 20% of the walking and cycling potential away from vehicles and driving.	For 2km trips, Mode shift to 50% of the walking and cycling potential away from vehicles and driving.

Electrification of Commercial Vehicles

Commercial vehicles account for a significant proportion of transportation emissions. Without significant intervention, emissions from commercial vehicles will likely increase as Ottawa's population continues to grow.

Roughly all emissions in the commercial vehicle sector could be avoided through electrification of commercial fleets. Diesel is the major source of fuel as of 2016 for commercial vehicles in Ottawa, accounting for 60% of energy use, followed by gas at 37%. An insignificant amount of commercial vehicles were electric in 2016.

The major technologies for electrifying transportation include: fuel cell technology— which can be charged from multiple energy sources—and battery-electric. Battery-electric vehicles are better suited to vehicles making short trips within the city, while fuel-cell technology can be more effective for longer-range trips. Each technology has advantages and disadvantages, but both may be needed to successfully electrify the majority of commercial vehicles. A summary graphic of tradeoffs is provided in Figure 7.

Figure 6. Commercial vehicles by energy use, 2016.

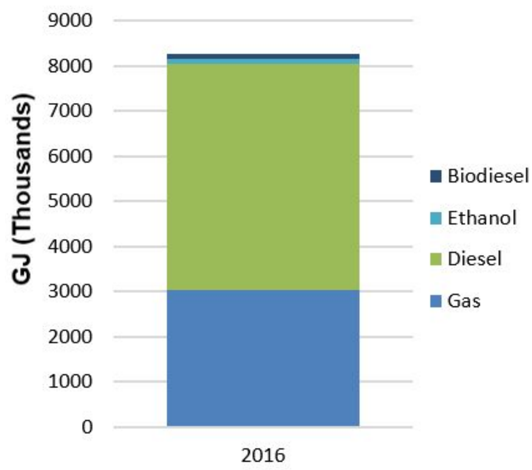
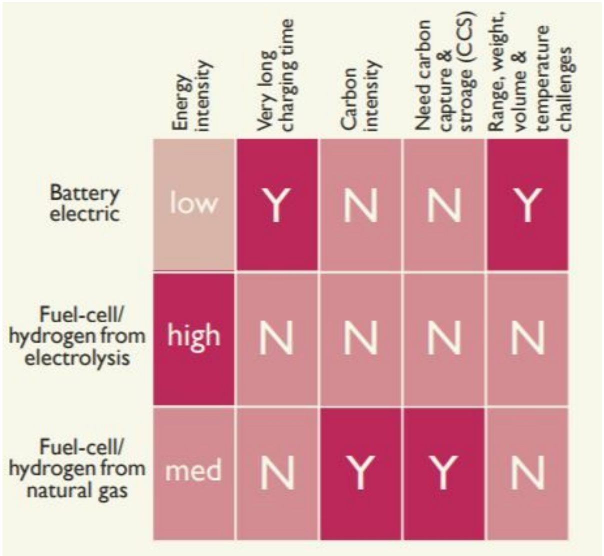


Figure 7. Comparison of large vehicle electrification options in BC.[9]



[9] Talebian, Hoda, Omar Herrera, Tran Martino, and Walter Merida. 2018. "Electrification of Road Freight Transport: Policy Implications in British Columbia." Energy Policy. Vancouver, BC: UBC. https://pics.uvic.ca/transportation-futures-british-columbia.

Infrastructure Options

1. Electric road systems (ERS): This infrastructure works with commercial vehicles that can receive electricity from installed power stations along the road. Inductive charging places power stations within the road and vehicles drive over them to charge. This technology is still being piloted but has shown to be less efficient than overhead lines, and higher costs per kilometre.[10]

2. Overhead catenary lines: This technology has already been established in urban areas as it connects transit lines, including the upcoming Confederation Line. This technology will require a connection on the trucks themselves, along with regulation stating that trucks must use them. To date, pilot programs are being run in Sweden, Germany, and the US.[11]

3. Charging stations: Charging stations might be required for commercial vehicles that are battery powered and making multiple deliveries in various areas of the city. Demand may vary depending on the location of warehouses and how companies organize their routes.

Other Actions and Bylaws

Table 6: Policies and actions for electrification of commercial vehicles.

Policy or Strategy	Description	Level of Difficulty to Implement
Carbon tax	Adding charges for use of carbon-emitting fuels can incentivize business to become more efficient and choose carbon-free technology.	Difficult: This must be led and implemented by the Province of Ontario or the Federal Government.
Fuel station regulations	A bylaw can require new or redeveloped stations to provide alternative fuel. The City of Surrey (BC) has adopted such a regulation.	Low: Normal city process to create new bylaws.
Off-street parking requirements	Cities can require commercial businesses to be equipped with electric vehicle charging stations as a first step toward creating the infrastructure needed for electric vehicles.	Low: Many cities are adopting new parking bylaws to encourage personal and commercial electric vehicles.
Street design	Cities can design streets to be narrower to decrease vehicle accessibility or add car-free areas. These design measures direct companies to choose smaller delivery vehicles such as bicycle courier or small electric cargo vehicles. Enforcing parking regulations to prohibit double parking can also signal companies to choose other vehicles.	Medium-Difficult: Cities can begin designing new streets and retrofitting existing streets to be more narrow and decrease vehicle access. Street retrofits require strategy for consultation and diverting traffic flows.
Transforming City Fleets	City fleets perform several core functions such as garbage pickup, roads and water servicing and maintenance. Other vehicles that may fall in city purview are ambulance, fire, and police. Transforming city fleets can be a model for commercial vehicle electrification	Medium: Adding electric vehicles will require a larger budget but may lower life cycle costs.

[10] "The Future of Trucks: Implications for Energy and the Environment." International Energy Agency, 2017. www.iea.org/publications/freepublications/publication/TheFutureofTrucksImplicationsforEnergyandtheEnvironment.pdf.
[11] Ibid.

Figure 8. An electric bike makes a delivery during winter in Stockholm, Sweden[12]

Figure 9. Shift Delivery Co-op uses electric bikes in Downtown Vancouver.[13]

<u>Boundaries and Barriers of Strategy</u>

Barriers to this strategy are noted below, with additional boundaries and barriers provided near the end of the paper.

Jurisdiction
If strong actions or policies need to be taken, Ottawa must work with Provincial and Federal governments to establish regulations to electrify a greater proportion of commercial vehicles. There will also be upfront costs of new infrastructure that may be difficult for Ottawa to finance alone.

Further study is needed to understand capacity issues in providing enough electricity to electrify 50% to 100% of commercial vehicles in Ontario. In British Columbia's case, 64% of commercial vehicles will be required to be electric in order to meet climate goals in the transportation sector.[14] This will be completed with a combination of fuel-cell and battery-electric technologies. Modelling for BC projects reports an energy shortfall to reach the 64% target; for every 1% of reduced GHG emission from commercial trucks, an additional 1.5 to 3.8% of additional hydroelectric, or renewable, energy is required.[15] This amounts to approximately 33 Terawatt hours (TWh) of additional electricity over 2015 levels.[16] In Ontario, the IESO anticipates the ability to meet increasing electrical demands stemming from electrified transport, but will require continued growth from low-carbon sources as well as nuclear energy and natural gas to do so.[17]

Market Barriers and Technology
Commercial vehicles and providers of service have an interest in reducing their costs—including the cost of gasoline—and should be motivated to make the transition to electricity where feasible. However, if there is no financial cost to continue operations as usual, there is less incentive to

[12] The life of cargo bike delivery heroes during winter in Sweden https://www.youtube.com/watch?v=1UzNI3kgSO4
[13] "Women in Urbanism." Modacity, 12. 20, 2016. http://www.modacitylife.com/blog/women-in-urbanism-robyn-ashwell
[14] "Electrification of Road Freight Transport: Policy Implications in British Columbia." Energy Policy. Vancouver, BC: UBC.
[15] Ibid.
[16] Ibid.
[17] "Preliminary Outlook and Discussion: Ontario Supply/Demand Balance to 2035." 2016. IESO, March 23. http://www.ieso.ca/-/media/Files/IESO/Document-Library/sac/2016/SAC-20160323-Ontario-Planning-Outlook.pdf?la=en

change to electric vehicles. Cities can add road pricing measures with reduced costs for electric vehicles, or a carbon tax can change business cases but will require policy from senior levels of government.

Electrictrifying commercial vehicles presents a larger technological challenge than personal vehicles due to truck and cargo weights, the distance of daily travel, and the absence of widely-distributed vehicle charging stations. Commercial vehicles that operate solely within urban areas face lower barriers due to shorter trips and greater availability of charging stations. The more intensive use of commercial vehicles (high annual distances travelled) can work in favour of the economics of electrification. There is promise for new technologies as major companies, such as Daimler and Tesla, announce the launch of electric semis able to operate over similar distances to most long distance freight trucks operating today.[18]

The full network of energy supply must be accounted for when considering electrifying commercial vehicles. Ottawa and Ontario have the advantage of plentiful hydroelectric energy and other low-carbon electricity sources, such as nuclear power, which would result in near zero emissions for electric commercial vehicles.

Scope Limitations
In this strategy, there will be some travel that is out of scope for Ottawa. Trips that originate from outside the city, and trips that have origins inside the city but destinations outside the city are difficult to account for and regulate and therefore are not modelled.

Uptake Scenarios

Table 7: Uptake scenarios for commercial vehicles.

Action	Conservative	Moderate	Aggressive
Commercial Vehicles	10% of heavy trucks are zero emissions by 2030; 40% by 2040.	20% of heavy trucks are zero emissions by 2030; 60% by 2040.	40% of heavy trucks are zero emissions by 2030; 100% by 2040.
City Fleet	Municipal fleet is 20% electric by 2020; 40% by 2040.	Municipal fleet is 40% electric by 2020; 60% by 2040.	Municipal fleet is 60% electric by 2020; 100% by 2040.

[18]Lambert, Fred. "Daimler Unveils Electric E-Cascadia Semi Truck to Compete with Tesla Semi, Launches Electric Truck Group." Electrick, June 9, 2018. https://electrek.co/2018/06/07/daimler-electric-semi-truck-ecascadia-tesla-semi.

Transportation Behaviour Change/TDM Program

Changing behaviours around transportation is the goal of Transportation Demand Management (TDM) programs. TDM can be targeted to only reduce peak-hour traffic, or can be part of a city-wide traffic management program. TDM makes walking or taking transit as appealing as driving. It originates from the idea that citizens make multiple trips daily and base their travel decisions on factors including convenience, time, and safety. If driving to meet friends nearby, to get a coffee, to exercise, or run an errand is accompanied by free and plentiful parking, plentiful travel lanes, and direct door-to-door access, then a vehicle trip is chosen. The externalities of traffic, congestion, pollution, and sprawl occur as people choose the vehicle trip. TDM can help alter this mode choice.

A TDM program has the ability to move a city towards a low-carbon future by reducing VKT, reducing demand for travel, and increasing alternative modes of transportation. Not all actions are equal, but cities are recommended to take a holistic approach. A list of researched TDM actions is shown in the table below.

Table 8: Impact of TDM strategies.[19]

Strategy	Details	Vehicle Trip Reduction Impact (for commuting to work)
Parking Charges	Paying for parking	20-30%
Information Alone	Information on alternatives to driving alone	1.4%
Services Alone	Ridematching, shuttles, guaranteed rIde home (for emergency)	8.5%
Monetary Incentives Alone	Subsidies for carpool or transit	8-18%
Service & Monetary Incentives	Transit voucher and guaranteed ride home	24.5%
Cash Benefit	Cash benefit offered in lieu of accepting free parking	17%

Ottawa has already recognized TDM as a strategy to change travel behaviour, and notably has a program for TD Place at Lansdowne Park. With the goal of having vehicle trips account for less than 50% of travel. TD place offers a shuttle service, additional bike parking, and off-street parking away from the site. Further, since 2010 Ottawa has implemented several city-wide TDM strategies that include more and safer bicycle infrastructure, advertising programs for cycling, transit passes for the University of Ottawa, connecting car share service to transit with one pass, ridesharing, and other actions.[20] Ottawa also has TDM guidelines where new development applications for commercial or mixed-use building must comply. Having a TDM coordinator for the operations of a building is a notable strategy in Ottawa's guidelines.[21]

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[19] Table Adapted from Nelson/Nygaard, "TDM: State of the Practice" 2013.
[20] "Transportation Demand Management Strategy (Draft)." 2012. Noxon Associates Limited: City of Ottawa. http://ottawa.ca/calendar/ottawa/citycouncil/trc/2012/05-02/02%20-%20Doc%201.pdf.
[21] Ibid.

TDM Policies and Strategies

Many of the policies described in the Transportation Pathway are included in typical TDM programs, including congestion charging, car-free areas, and parking management.

1. Fees and Charges: Charging users to use roads and parking is a major way to shift the balance from personal vehicle trips, especially single occupant trips. Fees such as fuel taxes or carbon taxes can also be applied to realize full costs of driving.

2. Greater Information: The use of newer technologies, particularly smartphones and transportation apps, can greatly encourage alternatives to personal automobiles. Transit riders can get real-time transit data through smartphone applications, create a more accurate picture of the length of time required to reach a destination, and make travel decisions accordingly.[22]

3. Enhanced Bicycle/Pedestrian Infrastructure: Many design considerations can be made to ensure walking or cycling is comfortable and attractive, including proper, well-maintained sidewalks and street lighting, attractive landscaping or art, seating, bicycle accommodation in parkades, secure bicycle storage, and employee shower and changing facilities.[23]

4. Transit Passes: Employee and student transit passes can be provided by employers and institutions to encourage transit use. Furthermore, housing developers can provide passes to new housing developments in lieu of providing parking.

5. Parking Management: This method of TDM removes the convenience of abundant and free parking, and is analyzed further in the following section.

Uptake Scenarios

The TDM strategy has strong relationships with land-use, road/congestion charging, and parking management and will be modelled under those strategies.

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[22] Nelson/Nygaard Consulting. 2013. "Transportation Demand Management: State of the Practice." Michigan: Smart Growth America. https://smartgrowthamerica.org/app/legacy/documents/state-of-the-practice-tdm.pdf.
[23] Ibid.

Parking Management

Parking requirements are within City control and are implemented during the development of new buildings, homes, temporary structures, events, and transit stations. Cars are parked 95% of the time, and can use numerous parking spaces within a week. Plentiful and accessible parking encourages vehicle ownership and operation. Firm policies paired with strict enforcement of parking regulations can encourage citizens to reduce personal automobile use and ownership. Trip-making decisions and modal choices are sensitive to both the availability of parking and its costs, making parking management strategies particularly effective in changing behaviour.

When considering transportation emissions, parking policies have been shown to reduce demand for personal vehicles trips and reduce community VKT. The table summarizes a study that shows how different parking policies reduced VKT over different periods of time.

Table 9: Parking policies and measures, and VKT reductions.[24]

Measure	Reduction of VKT Potential	Time for Implementation
Resident (priced) parking permits for on-street	0-10%	1-2 Years
Park and Ride systems	10-25%	2-5 Years
Parking Cash Out for workplaces	10-25%	1-2 Years
Reduce Off-street parking requirements for new construction	10-25%	5+ years
Double Parking charges in busy areas	10-25%	1-2 Years
Car-Free Zones	25%+	2-5 Years
Compact Communities	25%+	5+ Years

The parking strategies below can encourage citizens to reconsider trips taken by vehicle, share rides, or decide against owning a vehicle at all.

1. On-street parking fees: a strong pricing program that is regularly reviewed and studied can encourage citizens to choose other methods of travel, while improving parking availability in cities.

2. Implement maximum off-street parking requirements for new developments: reducing or eliminating parking requirements for residential developments, workplaces and shopping areas can change norms and encourage behaviours and development patterns that reduce automobile dependence.

[24] *Transport Energy and CO2*. 2009. Paris, France: International Energy Agency / OECD. https://www.iea.org/publications/freepublications/publication/transport2009.pdf.

3. Zero off-street parking requirements near destinations served by transit: developments near transit, under TOD strategies, can encourage modal shifts from personal vehicles to transit..

4. Parking cash out: employees are offered a cash equivalent to the cost of a free parking spot at their workplace if they choose not to drive to work.

5. Increase enforcement for illegal parking: within city centres or dense areas, citizens may attempt to double park in a travel lane beside a parked car, or park in undesignated areas. This can be a safety concern as emergency vehicles may have trouble getting to their destination, or other cars may need to maneuver around them.

6. Eliminate or redevelop surface parking lots: surface parking can act as an agent for sprawl, act as a cue to incentivize driving, and delay more dense developments within a community.

7. Compact communities: parking has a connection to land use. As more destinations and activities are closer together there is an increase towards walking, cycling, and transit.

Uptake Scenarios

No major change is anticipated in the BAP scenario. An action was developed to increase parking rates by a factor of 1.5 in City-owned lots and on-street parking using the City's transportation model as part of an integrated scenario; the action works in unison with a suite of land use changes. As a result, the parking management aggressive scenario is modelled as an action under the aggressive Land-use Actions (Table 10). Further actions to increase walking and cycling and increased development near transit stations are combined in the Aggressive Land-use Scenario, thereby reducing the need for personal vehicle trips.

Table 10: Uptake Scenarios for parking management.

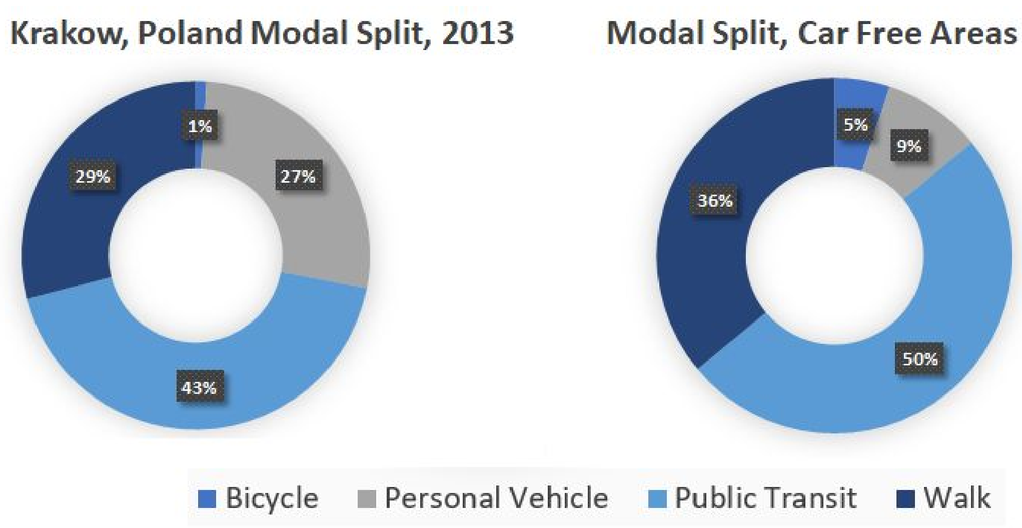
Action	Conservative	Moderate	Aggressive
Parking Management	No change	No change	Increase on-street parking fares during peak hours by a factor of 1.5 by 2050.

Car-free Areas

A car-free zone/area or pedestrian area/corridor is an area vehicles cannot access. They typically use barriers or a change in streetscape treatment to indicate restricted vehicle access. Car-free areas support the goals of sustainable transportation planning by increasing the proportion of citizens who will walk or cycle to their destination. One such example is Sparks Street in Ottawa, which plays a role within the community as a cultural and event centre, and where residents can meet for lunch or dinner, to take in a festival, to relax in the public space, or to walk home.

Car-free areas can often create a sense of place in a neighbourhood. Studies conducted in Krakow, Poland showed that citizens accessed new public squares and car-free areas increasingly by foot, bicycle, or transit when compared to non car-free areas. In three car-free areas, approximately 50% of citizens walked to the areas, 10% cycled, 35% of citizens used public transit , and car use was below 5% on average.[25] This is contrasted against a normal modal split of 43% transit, 29% walking, 27% personal vehicle, and 1% bicycle.[26] When surveyed on the reason that people chose to visit the car-free areas, the most common reason was a lack of vehicles.[27]

Figure 10. Normal modal split vs. car-free areas, Krakow, Poland.



Another benefit of car-free areas is the creation of more opportunities for planting and landscaping, therefore reducing urban temperatures resulting from overly paved areas—the "urban heat island effect". When landscaped, car-free areas can act as natural air conditioners. Exceptional cases such as Seoul, South Korea exist where an urban freeway was removed and a naturally occuring river was uncovered resulting in 3-4 degrees Celsius lower temperatures than nearby areas.[28]

[25] Szarata, Andrej, Katarzyna Nosal, Urszala Duda-Wiertel, and Lukzak Franek. 2017. "The Impact of the Car Restrictions Implemented in the City Centre on the Public Space Quality." *20th EURO Working Group on Transportation Meeting*, September. https://ac.els-cdn.com/S2352146517309158/1-s2.0-S2352146517309158-main.pdf?_tid=718b0618-fb06-4f0c-9177-5fbb685812ee&acdnat=1533133189_9b3bd0d41a650e2da38869272ec17316.

[26] Szarata, Andrej. 2013. "Accessibility of Public in Krakow." Powerpoint, Krakow. http://www.accessibilityplanning.eu/wp-content/uploads/2014/02/Krakow-presentation_Szarata_23May13.pdf.

[27] Ibid

[28] Meinhold, Bridgette. 2010. "Seoul Transforms a Freeway Into A River and Public Park." Inhabitat. 2010. https://inhabitat.com/seoul-recovers-a-lost-stream-transforms-it-into-an-urban-park.

Car-free Policies and Strategies

The City has a vision to make a pedestrian area in Kanata. Kanata has a commercial centre which favours pedestrian movement in the shopping streets. Future development can densify and mix uses to include residential development. Future planning can permit full pedestrian infrastructure that is car-free.

Creating car-free areas in neighbourhoods, recreational or commercial areas that already have active streetscapes can encourage a shift away from car travel. Indicators can be low-parking vacancies, full bicycle racks, new shops or restaurants opening frequently, or a high-density of restaurants or bars.

The Gehl Institute developed 12 Criteria for evaluating public spaces, which can be used as a strategy to evaluate public spaces or develop them further to make them car-free. The 12 criteria are listed in Appendix 1 and are based on making pedestrians feel safe, welcome, and protected from harsh climates and the noise, pollution, and high speeds of vehicles.

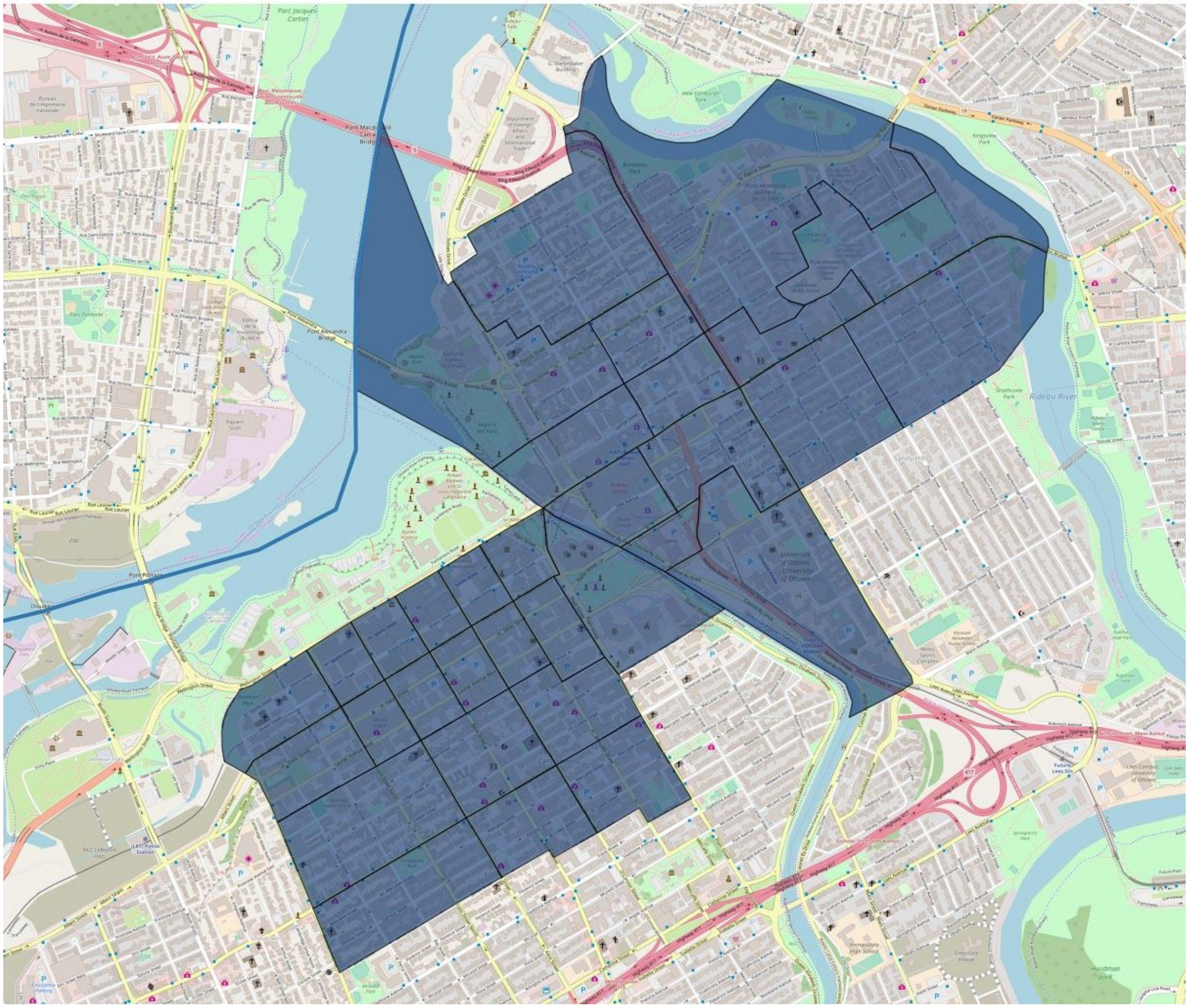
Uptake Scenarios

The Integrated Scenario identifies areas in Ottawa with high concentrations of commercial resources and housing density. Two notable indicators for placement of a car free area include areas where the population densities exceed 5000 people per square kilometre, and areas where 70% of residents commute to work by walking or cycling. The map below shows an aggregation of these indicators to include Byward market and downtown Ottawa, Wellington-Rideau, Sparks and Bank streets, and the University of Ottawa campus. Appendix 2 provides background maps for population densities and active transportation.

Table 11: Uptake scenarios for car-free areas.

Action	Conservative	Moderate	Aggressive
Car Free Areas	None	None	Care-free areas in: Byward Market Downtown Wellington-Rideau Sparks Bank Street Ottawa-U campus

Figure 11. Car-free areas in Ottawa



Congestion Charges

Congestion charges are fees for entering a specific area by car, and are a method of reducing peak time traffic in a city that is considered a form of Transportation Demand Management (TDM). Traffic congestion has a cost to motorists because their trip duration increases. Traffic congestion also has several external costs that should be noted:

- Other road users such as cyclists or transit users may have to bear similar costs of traffic congestion that are not directly caused by them.
- Pollution and climate impacts caused by traffic congestion are costs borne by an entire community, not just drivers;
- Busy streets with traffic hinder walking or cycling as there may be perceived danger, poor air quality, or poor ambience/environmental factors; and
- Economic Costs that are borne by entire cities occur due to congestion. In a previous report, Transport Canada modelled the economic cost of non-recurrent congestion, where congestion is caused by irregular events, and found the Ottawa-Gatineau region loses between $100 and $250 million yearly depending on congestion levels in 2006 dollars.[29] A study of recurring congestion, a result of road capacity and driving behaviour, costs the region between $39 and $89 million in 2002 dollars.[30]

Vehicles operate most efficiently when travelling at a constant speed (and that efficiency is highest around 60 km/hour). Congestion increases greenhouse gas emissions due to vehicle idling, low speeds and stop-and-go acceleration cycles. A study produced in California modelled emissions from traffic and various speeds, and is shown in the table below.

Table 12: Climate emissions related to traffic rates.[31]

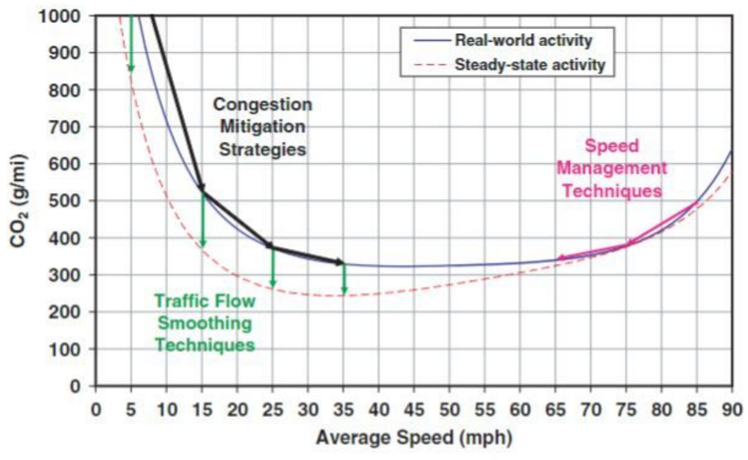
Speed Range	8-24 kph (congestion)	32-100 kph	100-130 kph (speeding)
Emissions Rate in Grams of CO2/km	500-800	200-500	300-500

The same study modelled emissions from traffic and found a possible 7-12% reduction in each of the three following methods:

[29] "Costs of Non-Recurrent Congestion in Canada Report." 2006. Technical. Transport Canada Economic Analysis. Canada: Transport Canada. http://www.bv.transports.gouv.qc.ca/mono/0964770/01_Report.pdf.
[30] "The Cost of Urban Congestion in Canada." 2006. Transport Canada. https://pdfs.semanticscholar.org/ae2c/c8a3231b62525af11e01f2d7e2a4a7c13a80.pdf.
[31] Barth, Matthew, and Kanok Boriboonsomsin. 2010. "Real-World Carbon Dioxide Impacts of Traffic Congestion," May. https://escholarship.org/uc/item/07n946vd.

1. Congestion mitigation strategies (Congestion Charging) that reduce severe congestion so higher average speeds are achieved and maintained;
2. Speed management techniques that can bring down excessive speeds to more moderate speeds of approximately 85 kph (e.g., by enforcement, road design to limit speeding); and
3. Traffic flow smoothing techniques that can suppress shock waves and thus reduce the number of acceleration and deceleration events (e.g., variable speed limits, autonomous vehicles).

Figure 12. Strategies to reduce traffic related emissions and the modelled effect.[32]



Stockholm, Singapore, London, and Milan provide notable examples of cities implementing congestion charges and changing travel behaviour. Each city experimented with different methods of implementing congestion charges such as charging flat or variable rates, targeting specific roads (road-pricing) or entire urban areas (cordon pricing), and charging all day or only peak hours. The experience of these cities is summarized in Appendix 3. Congestion charges require tailoring to specific city cultures and environments. There are continuous research efforts on how congestion pricing may affect businesses and what effect it has for people of different incomes.

Each case city described above is different than Ottawa as the populations are generally larger and there are more people per square kilometre, however congestion charging was successful in reducing traffic counts by 14% in Stockholm and Milan, and 45% in Singapore.[33] The transit mode share increase ranged from 5% in Stockholm to 13% in Singapore (Table 13).[34]

[32] Ibid
[33] Jarl, Valfrid. "Congestion Pricing in Urban Areas - Theory and Case Studies." Thesis. Lund University: Department of Technology and Society, 2009. http://www.tft.lth.se/fileadmin/tft/dok/publ/5000/Thesis183_VJ_scr.pdf.
[34] Ibid

Table 13: Transportation and traffic changes after congestion charges in major cities.[35]

	Singapore	London	Stockholm	Milan
Target Reduction	-25-30%	-10-15%	-10-15% in AM & PM	-10%
Actual Reduction: Traffic-Overall Traffic - AM Peak Cars-Overall	 -45% -45% -75%	 -14% No Data -36%	 -22% -16% -22%	 -14% No Data No Data
Mode-share - AM Peak Transit / Car Before (AM) Transit / Car After (AM)	 37/63 50/50	 87.5/12.5 89/11	 70/30 75/25	 No Data No Data

Congestion Charge Policies and Strategies

The following tools, suggested by the Victoria Transport Policy Institute, could be implemented in Ottawa.

Table 14: Policy tools for traffic congestion and other road pricing systems. (Adapted from Littman).[36]

Name	Description	Objectives
Road toll	A fixed fee for driving on a particular road.	To raise revenues for transit and discourage single-passenger trips
Congestion pricing (time-variable)	A fee that is higher under congested conditions than uncongested conditions, intended to shift some vehicle traffic to other routes, times and modes.	To raise revenues and reduce traffic congestion.
Cordon fees	Fees charged for driving in a bounded area of a city such as City Centre	To reduce congestion in major urban centers.
HOV lanes	A high-occupancy-vehicle lane that accommodates a limited number of lower-occupant vehicles for a fee.	To favour HOVs compared with a general-purpose lane, and to raise revenues compared with an HOV lane.
Distance-based fees	A vehicle use fee based on how many kilometres a vehicle is driven.	To raise revenues and reduce various traffic problems.
Pay-As-You-Drive insurance	Pro-rates premiums by mileage so vehicle insurance becomes a variable cost.	To reduce various traffic problems, particularly accidents.

[35] Ibid.

[36] Littman, Todd. n.d. "Road Pricing: Congestion Pricing, Value Pricing, Toll Roads and HOV Lanes." Victoria Transport Policy Institute. http://www.vtpi.org/tdm/tdm35.htm.

Uptake Scenarios

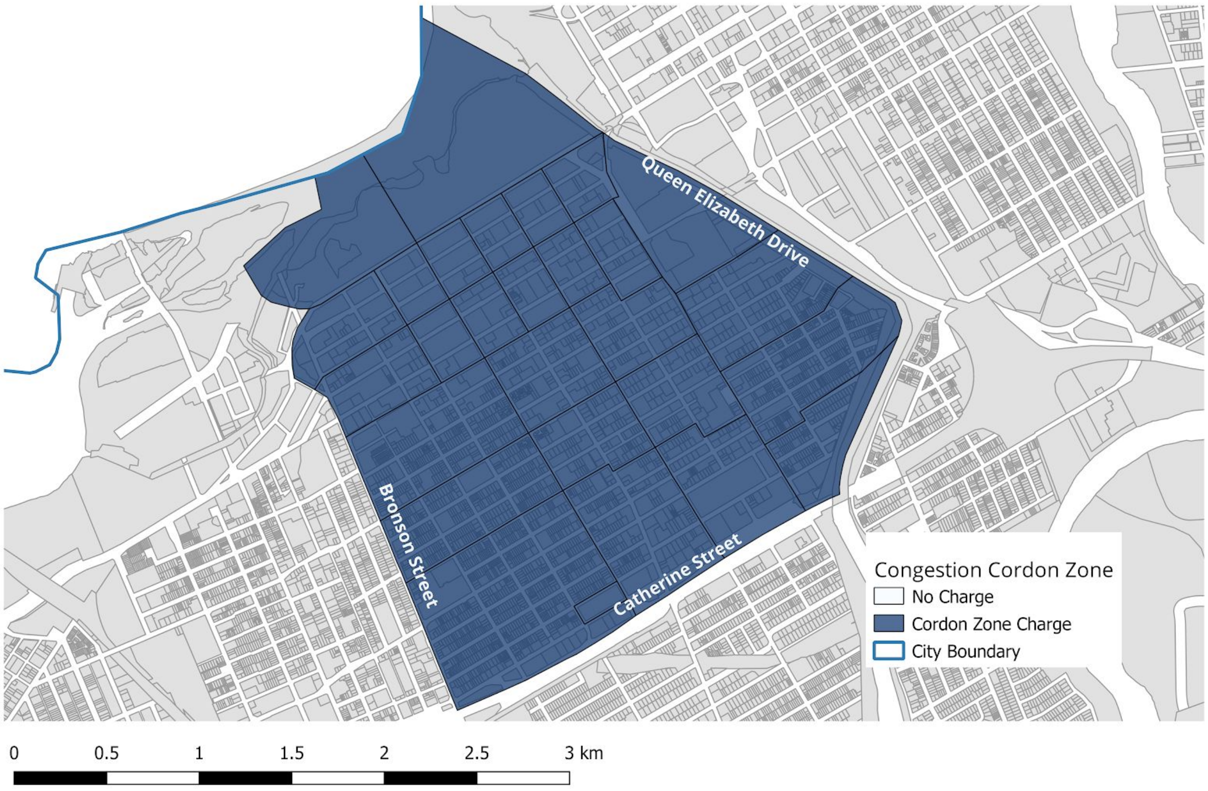
In the Aggressive Scenario, a Cordon Congestion Charge is applied in Ottawa's downtown core, with bounding streets: Bronson (West), Catherine (South), and Queen Elizabeth Drive (East), the north boundary extends to the Ottawa River (Figure 13). A congestion charge of $20 (higher than London, UK in order to test the policy)[37] is assumed between 6:00 am and 10:00 am on weekdays.

This action was developed using Ottawa's transportation model in an Integrated Scenario and responds to a suite of land-use changes.

Table 15: Uptake scenarios for congestion charges.

Action	Conservative	Moderate	Aggressive
Congestion Charges	None	None	$20 congestion charge applied to the downtown core between 6:00 am and 10:00 am on weekdays.

Figure 13. Modelled congestion charge zone for Ottawa.



[37] "Congestion Charge" Transport for London. https://tfl.gov.uk/modes/driving/congestion-charge

Enhanced Transit

Quality transit is the backbone of any sustainable transportation plan and will often impact land-use decisions, requiring a more dense urban form and mix of land-uses. Quality transit service is a significant strategy to reduce GHG emissions and keep them low; the Confederation Line as a transit enhancement in Ottawa will reduce an estimated 94,000 tonnes of GHG emissions by 2031.[38] A shift away from personal vehicle use towards transit usage can reduce household emissions up to 2,177 kg of CO2 per year according to the American Public Transit Institute.[39]

In addition to reducing greenhouse gas emissions, enhanced transit can have many other important benefits to a community, including greater public space, a less noisy environment, greater accessibility for persons with different physical abilities, and less urban space dedicated to roads. Higher ridership of transit can result in reduced energy use within a community, greater options for walking and cycling, and reduced VKT.

Well designed transit systems work best in compact and mixed use communities, which implies a relation to land-use. When transit and land-use work well together, further gains in walking and cycling use can be realized and community emissions from transportation are further reduced.

Transit Policies and Strategies

Many strategies exist to enhance transit within a community, including:

- Improving system performance through additional routes, coverage area, frequency of service and hours of operation;
- Increasing efficiency through the introduction bus only lanes during peak times;
- Using Bus-Rapid Transit systems with permanent dedicated bus lanes to increase travel speed and rider convenience;
- Increasing the share of transit vehicles that are electric;
- Reducing fares for weekends and holidays;
- Keeping fares low;
- Enhancing design of transit stations and stops to provide safety and comfort for riders. Making efforts for placemaking (see Car-Free Areas);
- Developing phone apps for more rider information, use one-tap cards for transit and other services; and
- Allowing flexibility in the system for the "last-mile" by introducing better pedestrian design and bicycle facilities. Partnering with car-share operators to provide parking near transit stations or use transit tap cards (see car share options).

[38] *Transforming our Nation's Capital: The Benefits of Light Rail.* City of Ottawa. 2012. http://www.ligneconfederationline.ca/media/pdf/The%20Benefits%20of%20Light%20Rail%20-%20Web.pdf
[39] "Public Transportation Greenhouse Gases and Conserves Energy." n.d. American Public Transport Association. https://www.apta.com/resources/reportsandpublications/Documents/greenhouse_brochure.pdf.

Fuel Types in Transit

Low-carbon transit also requires a shift in fuels. Transit fleets today rely heavily on diesel buses, but a shift towards electric vehicles will reduce emissions. Other options can be considered in the mid-term such as compressed natural gas (CNG), hydrogen, biodiesel, or hybrid buses.

Ottawa currently has 936 buses in its fleet not including Para Transpo, as recorded by OC Transpo.[40] Fuel costs are a significant operating cost for bus operations and therefore there is an incentive to be as efficient as possible. Hybrid buses can be a step towards reducing fuel use and emissions (Ottawa currently runs 177 hybrid buses), but the final step is moving towards full electrification of a transit fleet. Hybrid and electric bus technologies can have a capital cost that is 50% or greater than a diesel bus.[41] Previous studies have quantified different fuel types on regular transit runs and found that hybrid buses emit roughly 40% less GHG emissions (CO2, NOx) than diesel, and electric can emit zero emissions depending on how electricity is generated. A summary table is provided below.

Table 16: Bus fleet GHG emissions by fuel source for a New York transit run (adapted from Translink Hybrid Bus Showcase Study).[42]

Transit Route	Diesel	CNG	Hybrid	Electric*
New York Bus Cycle	7,076	5,685-6,602	4,251	0
Central Business District Cycle	2,779	2,360-2,809	2,262	0
Manhattan Cycle	4,268	3,457	2,841	0
% Reduction from Diesel		0-20%	18-40%	100%*

*When using/charging with Hydro Power in New York State

[40] "OC Transpo Bus Fleet." Government. OC Transpo, n.d. http://www.octranspo.com/about-octranspo/bus_fleet.
[41] *Transport Energy and CO2*. Paris, France: International Energy Agency / OECD, 2009.
[42] Rees, Stephen, Christine DeMarco, Tamim Raad, and Joanna Brownwell. 2003. "Sustainable Region Showcase for Metro Vancouver." Vancouver: Translink.
https://www.translink.ca/~/media/Documents/plans_and_projects/urban_showcase/general/urban_showcase_proposal.ashx.

Uptake Scenarios

The City's affordable transit network[43] and ultimate transit network[44] as shown in the Transportation Master plan are used as templates for the moderate and aggressive scenarios respectively, to identify high density neighbourhoods lacking frequent transit, and increase speeds and frequency of transit.

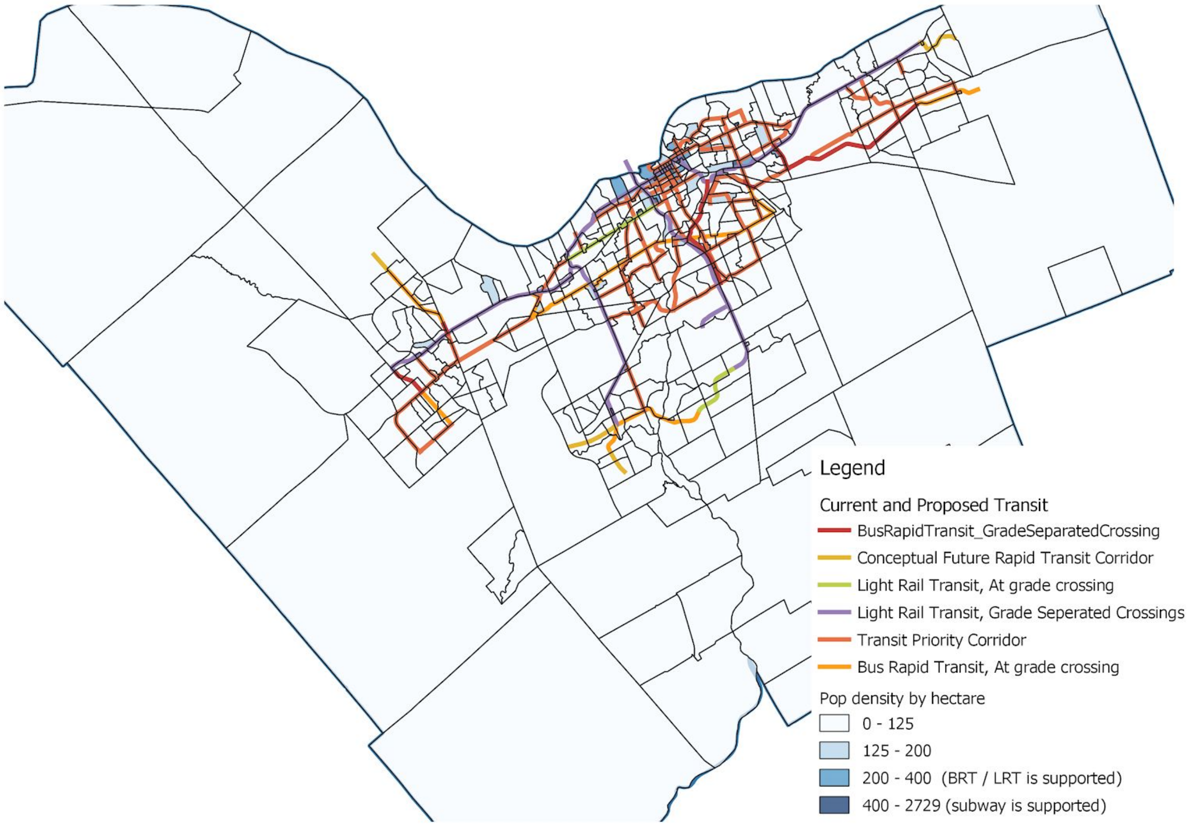
Table 17: Uptake scenarios for enhanced transit.

Action	Conservative	Moderate	Aggressive
Enhanced Transit	Completion of the Confederation Line- Phase 1 and 2	The Affordable Network is completed, and accompanied by a 10% transit modal increase. 100% of Transit vehicles are electric by 2050	Identify high density neighbourhoods without sufficient transit and increase transit share by 25% in these neighbourhoods The frequency of LRT is increased to every 90 seconds in downtown areas, and outer areas are increased to match. BRT speed is increased by 20% through prioritized lanes and stop lights where separated infrastructure is available. 100% of Transit vehicles are electric by 2050 Complete "Ultimate Transit" Network as shown in Transportation Master Plan

As part of Enhanced transit pathway, analysis of the future transit system proposed under the Ottawa Transportation Master Plan was undertaken with the aim of identifying zones that were underserved by the transit system, articulated in Figure 14. Zones would be considered underserved if they contained sufficient density for a higher level of transit than what is currently provided to the zone, using best practice thresholds for the Greater Toronto Area.[45] To commence this analysis, a GIS layer of all of the proposed transit lines was prepared and overlaid on a spatial analysis of density in the City. This analysis, illustrated in Figure 14, indicated that the proposed 2050 transit system provides generally appropriate coverage for the City and that no additional rapid transit beyond existing city plans was modelled.

[43] Ottawa Transportation Master Plan, Affordable Network: https://documents.ottawa.ca/sites/default/files/documents/tmp_map5_afford_network_en.pdf
[44] Ottawa Transportation Master Plan, Ultimate Network: https://documents.ottawa.ca/sites/default/files/documents/tmp_map_3_en.pdf
[45] Higgins, C. D. (2016). Benchmarking, planning, and promoting transit-oriented intensification in rapid transit station areas. Retrieved from https://macsphere.mcmaster.ca/handle/11375/20228

FIgure 14. Transit expansion possibilities in the Ottawa region.



Autonomous Vehicles (Shared)

Autonomous vehicles (AVs), or driverless vehicles, represent a newer technology that has the potential to radically transform urban mobility. Depending on how they are adopted, whether they are privately owned or shared, and the regulatory and other infrastructure that is built to support them, they have the potential to reduce vehicle ownership rates, VKT and related greenhouse gas emissions. The Province of Ontario has been a leader in Canada in testing the technology. Cities today are considering policy or are piloting programs to review whether autonomous vehicles can operate safely and effectively in their respective urban environments.

Many transportation planners and urban thinkers are skeptical about the potential benefits of autonomous vehicles.[46,47] Autonomous vehicles may cost less to operate and own, so this may have a rebound effect of more vehicles being on the road or encouraging people to live further away from city centres.

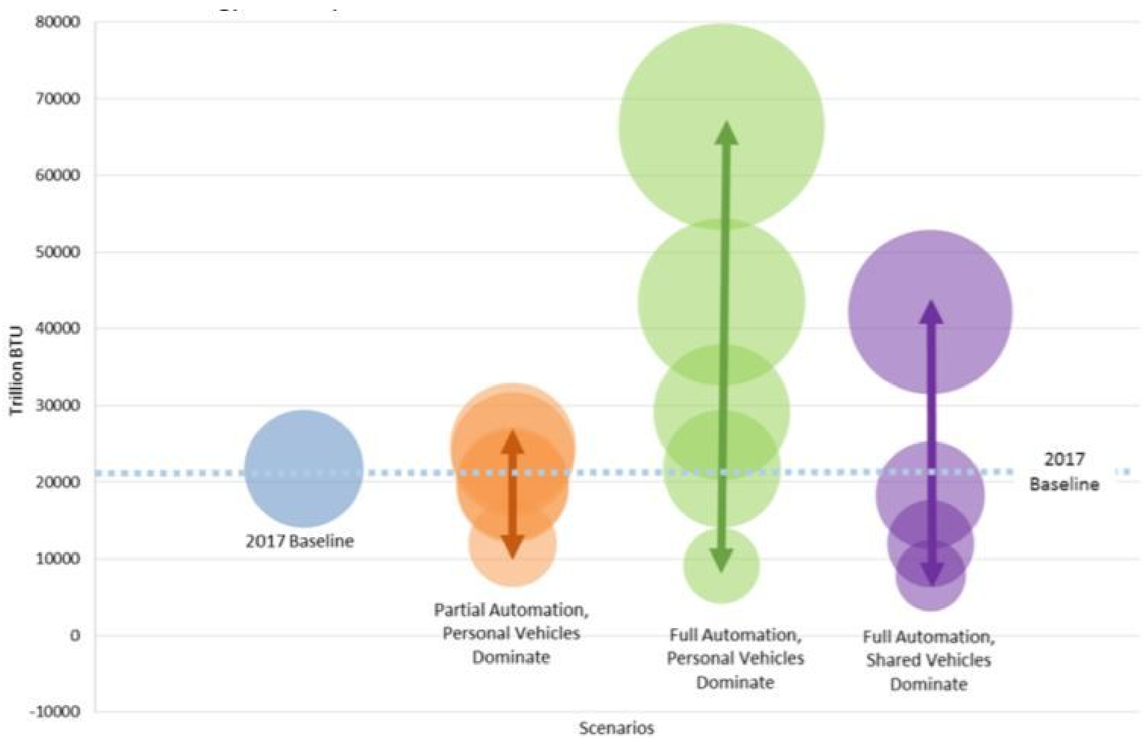
[46] Littman, Todd. 2018. "Autonomous Vehicle Implementation Predictions: Implications for Transport Planning." Victoria, BC: Victoria Transportation Policy Institute. https://www.vtpi.org/avip.pdf.

[47] Speck, Jeff. 2017. "Jeff Speck: Autonomous Vehicles & the Good City." Lecture presented at the Congress for New Urbanism, Savannah, Georgia, July 6. https://www.youtube.com/watch?v=utnPEbDNbrE.

Based on a scenario developed by the Rocky Mountain Institute, the action assumes that personal vehicle ownership declines by 50% by 2050 but personal VKT increases by 20%.[48] The increase in VKT results as new cohorts of the population (young and elderly, for example) have access to vehicles, and the convenience of private vehicles increases, with the cost of travel decreasing.[49]

Benefits to the climate can be achieved through the use of autonomous vehicles, although it is not guaranteed without regulation from a public entity. Any benefits will come from a combination of emission free or light vehicles, the ability for the moving vehicles to reduce distances from one another (platooning), and policy requirements or incentives for sharing vehicles. Emissions projections can vary considerably because there is no prediction of technology take-up (full vs. partial), and whether the majority of AVs will be shared in a carpooling or taxi method, or be personal vehicles. In some scenarios, AV's will induce more demand, attract new user groups (perhaps at the expense of transit), and increase VKT and energy demand.[50] A sample trendline is shown below showing a range of energy consumption rates under different scenarios.

Figure 14. Energy consumption comparisons of different AV scenarios in the US.[51]



[48] Johnson, C., & Walker, J. (2016). Peak car ownership: The market opportunity of electricity automated mobility services. Rocky Mountain Institute. https://rmi.org/Content/Files/CWRRMI_POVdefection_FullReport_L12.pdf
[49] Ticoll, D. (2015). Driving changes: Automated vehicles in Toronto. https://www1.toronto.ca/City%20Of%20Toronto/Transportation%20Services/TS%20Publications/Reports/Driving%20Changes%20(Ticoll%202015).pdf
[50] Ross, Catherine, and Subhrajit Guhathakurta. 2017. "Autonomous Vehicles and Energy Impacts: A Scenario Analysis." Energy Procedia. Georgia Institute of Technology. https://www.sciencedirect.com/science/article/pii/S187661021736410X.
[51] Ibid.

AV Policies and Strategies

In order to make autonomous vehicles work for cities such as Ottawa, the current best practices include:

1. Maintaining goals for compact communities that prioritize walking, cycling, and transit usage;
2. Finding opportunities to redesign infrastructure for cars such as parking lots, on-street parking, alleys/lanes;
3. Making autonomous vehicles internalize their own costs through congestion charges;
4. Ensuring that autonomous vehicles emit less or do not emit at all through better efficiency or electrification;
5. Ensuring that a local government can access data and reports on vehicles usage in order to adjust community and development goals; and
6. Being conscious of risks that come from collisions and mass system failures common to any technology.

Uptake Scenarios

As suggested by Rocky Mountain Institute's research, increased availability of AVs can greatly reduce personal vehicle ownership. However, the attractiveness and convenience of AVs can attract new cohorts (young and elderly) to automobiles, and reduce other forms of transport such as transit, walking, or cycling, while increasing automobile VKT. In response to the pathway stakeholder meetings, the VKT increase was increased to 150% from 2016 levels to reflect a rapid uptake of AVs, rather than 20% indicated by the RMI research paper. The aggressive scenario is the only uptake scenario that will model AVs where the City has permitted them and regulated them to be 100% electric.

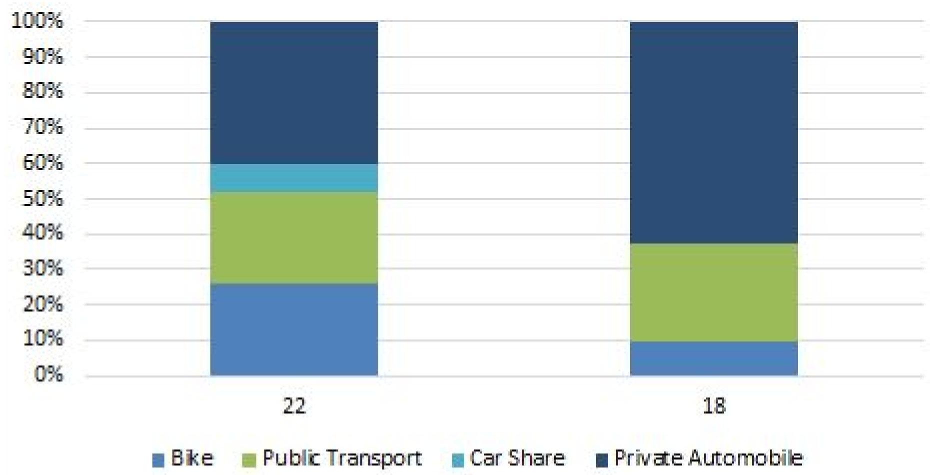
Table 18: Uptake scenarios for AVs.

Action	Conservative	Moderate	Aggressive
Autonomous Vehicles	No AVs	No AVs	Personal vehicle ownership declines by 50% by 2050; Per Capita VKT increases by 150%; AVs are electric only.

Ride Sharing, Car Co-ops

A recent technology to change the realm of transportation in urban environments has been car sharing. Car-sharing promotes a car-free or car-light lifestyle by allowing citizens of a city to reach destinations that are not accessible by transit or are inconvenient. People who do not own a car but may need to run errands may also find car sharing convenient. Generally, the vehicles are shared by a private company for profit and so more efficient vehicles are chosen resulting in less emissions. When paired with behaviour change options (i.e. TDM) car sharing can reduce personal vehicle ownership and vehicle kilometres travelled (VKT). A study conducted on a popular car-share provider, Car2Go, found that membership contributed to a reduction of vehicle ownership, members were more multimodal (taking more than one transportation method) than car owners, and the distance travelled was lower for members than non-members.[52] The mode share for car share users compared to non car share users is shown in Figure 15.

Figure 15. Modal split of car share users (left column) and non car share users (right column).



The two common methods for implementation of car sharing are: one-way trips (free-floating) or two-way trips. One-way trips allow a user to book a vehicle then drop it off at their destination with no further action needed (i.e. Car2Go). The one-way vehicles may be found in designated areas or in any area of a city where parking is permitted. The two-way vehicle requires the user to book the car and pick it up at designated area then return the vehicle to that designated area to complete the transaction (i.e. Zipcar). Ottawa currently features the following:

Table 19: Car-share providers operating in Ottawa.

Provider	Implementation Method	Fleet Size
Zipcar	Two-Way	13-15 Vehicles
Vrtucar	Two-Way	170 Vehicles (20 in Gatineau)

52 Kopp, J., Gerike, R., & Axhausen, K. (2015). Do sharing people behave differently? An empirical evaluation of the distinctive mobility patterns of free-floating car-sharing members. Transportation.

Car sharing is an important factor in TDM measures because it can reduce VKT. Previous studies suggest that the reduction of personal car use along with a reduction in VKT can result in reduced personal emissions of 146 to 312 kg CO_2/year.[53] In its analysis of car share systems, Metro Vancouver estimates that 1 car share vehicle can take 3 personal vehicles off of the road.[54]

Car-Share Policies and Strategies

Car sharing is in a growth stage in Ottawa as there is no one-way service currently available, and major providers such as Car2Go have not yet entered the city. car share providers generally look for the following options in order to launch their service in a community:[55]

1. Visibility & Availability: car share organizations need to be visible in residential, commercial, and mixed-use neighbourhoods to be seens as a available and reliable option for residents. This is often a matter of permission from local governments and issue of parking permits. In commercial areas, parking lots dedicated to car share services that are visible encourage citizens to use the service.

2. Access to Transit/Walkable neighbourhoods: car share services can integrate with a transit network by providing a short journey from a rapid transit station to home or a destination. This is often called the "last mile."

3. Affordability of Service: Car sharing needs to be as or more affordable than owning a private vehicle. The affordability often comes intrinsically as parking is often free for users, and paid for by the car share company.

Actions a city can take to promote car sharing often mirror what a car share service needs to thrive. Most commonly a city can:

1. Permit Car Share Services to buy parking spaces in neighbourhoods - Having available car sharing within your neighbourhood adds convenience and accessibility for those who do not own a car. Prioritizing parking in commercial centres allows car share users to feel secure that they can park easily and conveniently at their destination, and another user can take that car away;

2. Integrate with Transit Service - Ottawa currently works with Vrtucar to allow citizens to integrate their transit pass with the car share service. This feature is convenient for users and can help Ottawa gain ridership for their transit service;

3. Require Parking Reductions in new Developments - Local governments can reduce parking requirements for new multi-family housing developments when a developer provides a car

[53] Do sharing people behave differently?
[54] "Metro Vancouver Car Share Study: Technical Report." 2014. Technical Report. Vancouver: Metro Vancouver Regional District. http://www.metrovancouver.org/services/regional-planning/PlanningPublications/MetroVancouverCarShareStudyTechnicalReport.pdf. pg 22
[55] Metro Vancouver Car Share Study. http://www.metrovancouver.org/services/regional-planning/PlanningPublications/MetroVancouverCarShareStudyTechnicalReport.pdf

share service. This is considered a Transportation Demand Management (TDM) option and described in the Behaviour Change Program; and

4. Set goals to create walkable neighbourhoods: The addition of car share services can incentivize households to remain car-free knowing that they have the option of renting a vehicle rapidly. This would follow the roll-out of the Ottawa Pedestrian Plan.

Uptake Scenarios

The car sharing uptake scenarios work in tandem with land use, transit, and autonomous vehicles uptake scenarios. As shown below, there will be greater uptake of car sharing in zones with frequent transit and greater density currently and in the future as land use becomes more compact and transit is increased. Further, the Aggressive Scenario of AVs will replace car sharing as the service becomes the norm.

Table 20: Uptake scenarios for car-share users.

Action	Conservative	Moderate	Aggressive
Increased Car Share	Car share increase in Centretown and LRT stations; car ownership declines by 5% in these zones and mode share by 10%.	Car share increase in Centretown and LRT stations; car ownership declines by 10% in these zones and mode share by 25%.	Replaced by Autonomous Vehicles

Bicycle Infrastructure

Prioritizing bicycle use has been an initiative many North American cities have been pursuing in recent transportation strategies. Bicycle infrastructure is a very broad term, but can be summarized as any item or initiative that encourages or supports citizens who choose cycling as a mode of transport. This can include separated lanes, prioritized signaling, intersection design, location of bike racks, or calmed streets. All partners and sectors can play a role by providing end-of-use facilities like secure bike racks, shower/changing rooms, bike-share systems, and electric bikes to suit different ages/abilities of riders.

Ottawa's Transportation Master Plan identifies a goal of building a great cycling city. It will commence designing more infrastructure such as greenways, separated lanes, and other infrastructure. The following policies and goals are currently in place:

- Increase cycling lanes, of different standards, across the city-region;
- Increase peak time/morning mode share of cyclists from 2.7% to 5% in the city as a whole, and 8% within the Ottawa Greenbelt;
- Update the Zoning by-law to ensure cycling facilities in new developments are designed to a high standard; and
- Promote cycling facilities in the city and increase safety year-round.

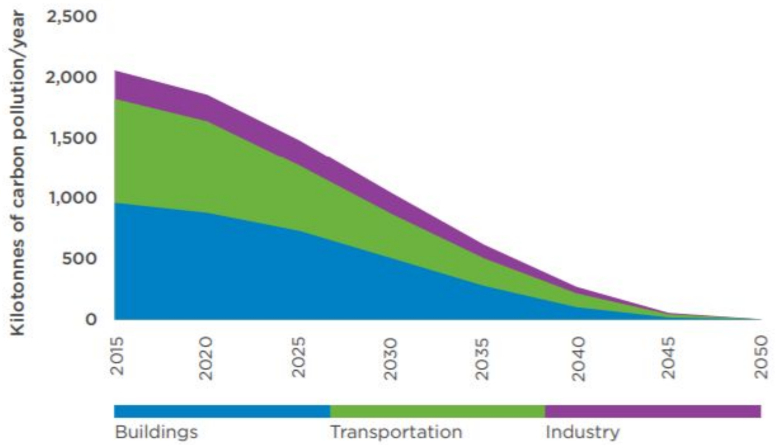
As a winter city, Ottawa will tend to see a decline in cycling during the colder months , however regular snow removal along major cycle corridors can encourage winter cycling.

New strategies and theories regarding bicycle infrastructure are being discovered at an increasing rate. However, the consensus of city practice is that quality infrastructure can make a city more livable, environmentally sustainable, and boost the local economy.[56]

The City of Vancouver targets 50% or more of all trips to be taken by cycling, walking, or transit, with 12% by bicycle. In response to the target, the city has modelled emissions reductions and found a potential emission reductions from 1500 kt CO_2e to below 500 kt CO_2e.[57] This includes the use of a greater number of electric bicycles.

With increased walking and cycling, Vancouver has already achieved an emissions reduction of 36% from the 2007 baseline year, and 10% cycling mode share.[58]

Figure 16. City of Vancouver emissions modelling, 2015-2050.

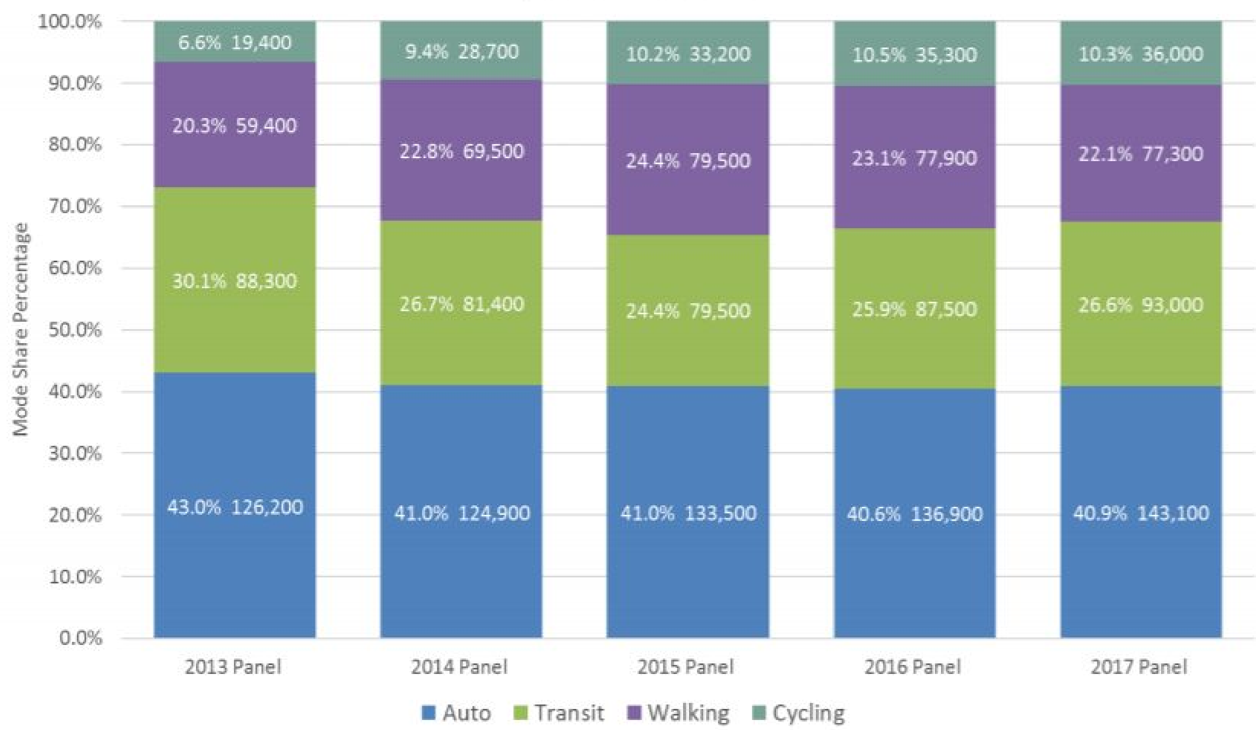


Bicycle Infrastructure Policy and Strategies

Cycling ridership within cities is highly correlated with greater cycling infrastructure investment. Many cycling studies also show that ridership has less correlation to weather patterns than one would think.[59] Canadian cities such as Vancouver and Montreal are often considered leaders in implementing new bike infrastructure and have begun to see record increases in riding and bicycle commuting. Vancouver has added several protected lanes in key areas of the city, including the downtown island, and currently features greater than 300 km of bike lanes.[60] These initiatives have made cycling the fastest growing form of transportation within the city, capturing 10% of the mode share to work as of 2017.[61]

[56] "Protected Bike Lane Statistics." 2018. People For Bikes. 2018. http://peopleforbikes.org/our-work/statistics/statistics-category/?cat=protected-bike-lane-statistics.
[57] "Renewable City Action Plan." 2016. Greenest City. Vancouver. https://vancouver.ca/files/cov/energy-and-emissions-forecast-final-report.pdf.
[58] Ibid.
[59] Dill, Jennifer, and Theresa Carr. 2014. "Bicycle Commuting and Facilities in Major U.S. Cities: If You Build Them, Commuters Will Use Them." *Transportation Research Record*. https://doi.org/10.3141/1828-14.
[60] "Walking + Cycling in Vancouver Report Card." 2017. Greenest City. Vancouver. https://vancouver.ca/files/cov/walking-cycling-in-vancouver-2016-report-card.pdf.
[61] "2017 Vancouver Panel Study: Transportation." 2018. Greenest City Action Plan. City of Vancouver. https://vancouver.ca/files/cov/2017-transportation-panel-survey-final-draft-20180516.pdf.

Figure 17. Vancouver's increasing cycling mode share.



Bicycle Lanes

A city can choose many different types of bicycle lanes depending on road conditions, nearby land uses, levels of traffic, and road speeds. The National Association of City Transportation Officials (NACTO) provides relevant guidance for implementing and designing bicycle lanes in North American Cities. As determined by NACTO, the separated lane or "cycle track" provides the most comfortable and accessible lane for bicycle travel and can encourage cyclists of all ages and abilities to cycle for their needs.[62] A description of lane types and respective benefits, and recommended areas of implementation is included in Appendix 4.

Ottawa currently has a bicycle network with greater than 200km of lanes during summer periods. The goal of the city is to increase separated lanes, or cycle tracks, and maintain them year round in an effort to keep ridership in the winter months. The city is targeting spending $70 million by 2031 to increase the network, as shown in the table below.

[62] "NACTO: Urban Bikeway Design Guide." Cycle Tracks. 2011. NACTO. http://www.ocpcrpa.org/docs/projects/bikeped/NACTO_Urban_Bikeway_Design_Guide.pdf.

Table 21: Cycling expenditures in Ottawa.[63]

Exhibit 5.1 2031 Cycling Network projects – Capital Costs by Facility Type ($ millions)

Facility type	Phase 1: 2014-2019	Phase 2: 2020-2025	Phase 3: 2026-2031	*Total*
Cross-town bikeways	7.8	11.7	2.0	***21.5***
Transit-oriented development links	1.8	1.5	2.3	***5.6***
Institutional and employment links (outside downtown)	1.9	2.5	0.0	***4.4***
Community links (neighbourhood bikeways, missing links)	9.7	7.5	17.0	***34.2***
Bicycle parking and city-wide enhancements	0.4	0.8	2.8	***4.0***
Recreational links	0.3	0.0	0.0	***0.3***
Total	***22.0***	***24.0***	***24.0***	***70.0***

Note: All costs are in 2013 dollars.

Bicycle Parking

Cities are increasingly requiring new developments to have both short-term and long-term cycling parking facilities. These requirements can be for residential or nonresidential buildings. Short-term bicycle racks are generally outside and racks for longer term parking are provided for users of a building who intend to stay 2 or more hours.

Table 21: Criteria for short-term and long-term bike parking.[64]

Criteria	Short-term	Long-Term
Parking Duration	2 hours or less	2 hours or more
Fixture Types	Standard outdoor racks	Lockers, racks in secured areas
Weather Protection	Unsheltered	Sheltered or enclosed
Security	Unsecured, passive, surveillance (eyes on the street)	**Unsupervised**
		Individual-secure such as lockers
		Shared-secure such as bicycle room or cage
		Supervised
		Valet bicycle parking
		Paid area of transit station
Typical Land Uses	Commercial or retail, medical/healthcare, parks and rec. areas, community centres	Residential, workplace, transit

Many cities are offering guidance on bicycle parking design for on-street and off-street parking spaces. In the case of on-street bicycle parking, this can be a local initiative where racks can also

[63] Ottawa Transportation Master Plan.
[64] Adapted from Association of Pedestrian and Bicycle Professionals.

serve as source of public art and local pride. Off-street bicycle parking should be designed to be functional and secure; off-street parking rates vary from city to city but can be based on dwelling units or an amount of commercial space. Cities can also require shower and changing facilities based on similar criteria. Ottawa currently has zoning requirements for off-street spaces in different building types. This can range from .50 spaces per dwelling unit or 1 per 250m^2 for commercial buildings.[65]

Other Policies:

1. Complete Streets Framework - In newly developing urban areas ensure cycling infrastructure is included in street design to promote cycling for new residents. This can be paired with parking reductions for new developments

2. Street Retrofits in busy cycling areas - The City can observe streets that already have high number of cyclists without infrastructure, and retrofit the street with appropriate infrastructure.

3. Bicycle Share - Many cities, including Ottawa, are adding a public bicycle share in urban areas to add convenience for citizens to choose a bike if they don't own one, replace vehicles for low-distance trips, or augment transit trips.

4. Wayfinding, Signalling, and Street Signs - Cities can help encourage cycling by adding clear signals for where a cyclist can go and be away from high traffic areas. Cyclists can also be given priority in busy intersections to ensure they can establish their path before traffic.

5. Traffic Calming in neighbourhoods - Additions of roundabouts, or closing direct paths through streets with exceptions for cyclists can reduce traffic levels and encourage citizens to cycle within their own neighbourhood.

Uptake Scenarios

Increased cycling uptake will occur as Ottawa's Cycling Master Plan continues to be built out, and uptake scenarios will also work in tandem with the Land Use uptake scenario. Areas that densify, are more compact and mixed-use, and have greater public transit will be identified as areas with higher rates of cycling.

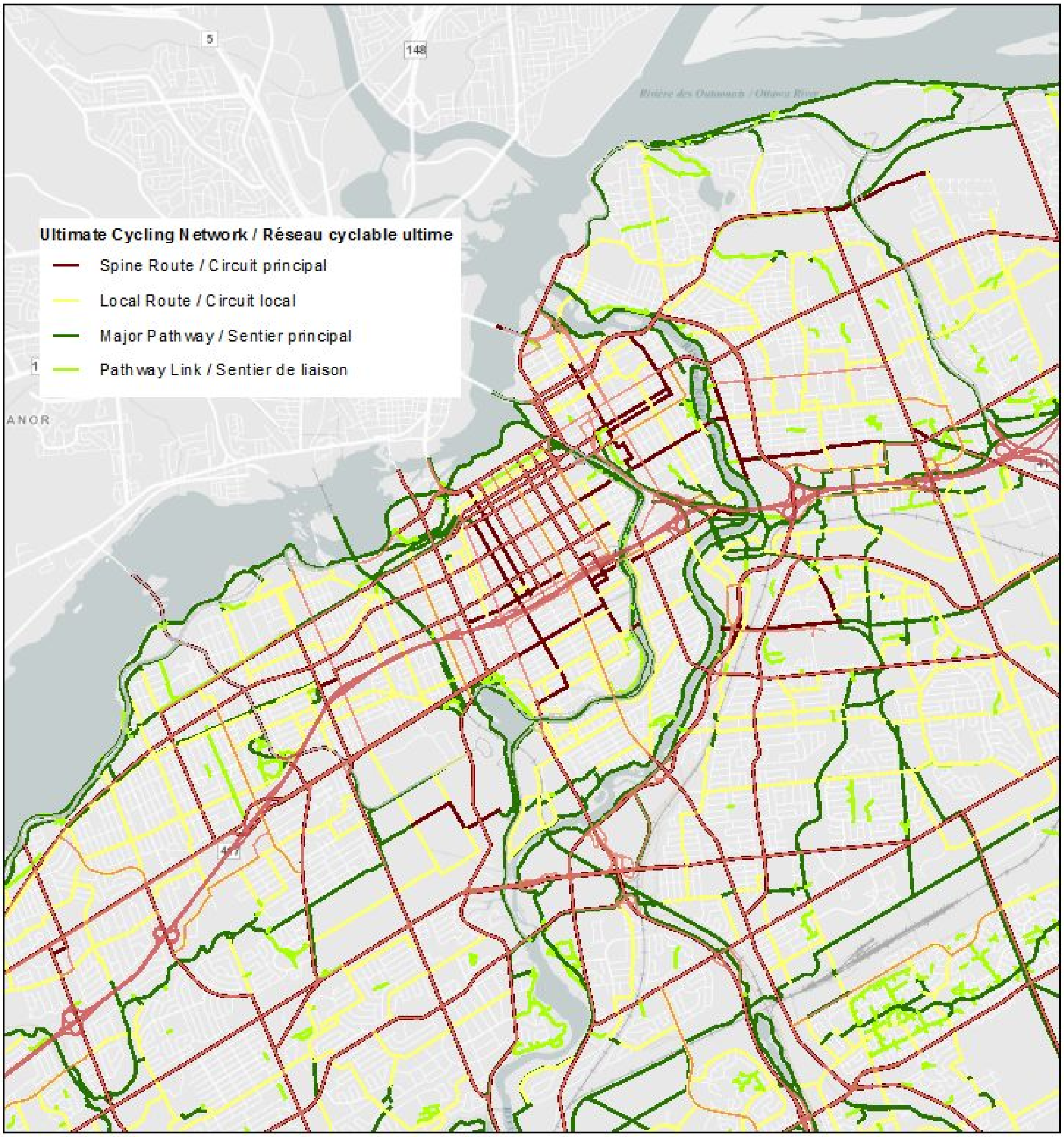
Table 22: Uptake scenarios for increased bicycle infrastructure.

Scenario	Conservative	Moderate	Aggressive
Enhanced Bicycle Infrastructure	None	Mode shift to 20% of the cycling away from vehicles and driving for trips up to 5km	Mode shift to 50% of the cycling away from vehicles and driving for trips up to 5 km.

[65] "Part 4 - Parking, Queuing and Loading Provisions (Sections 100-114)." City of Ottawa, n.d. https://ottawa.ca/en/part-4-parking-queuing-and-loading-provisions-sections-100-114.

Ottawa's ultimate cycling plan is shown in the figure below.

Figure 18. Ottawa's ultimate cycling network.[66]

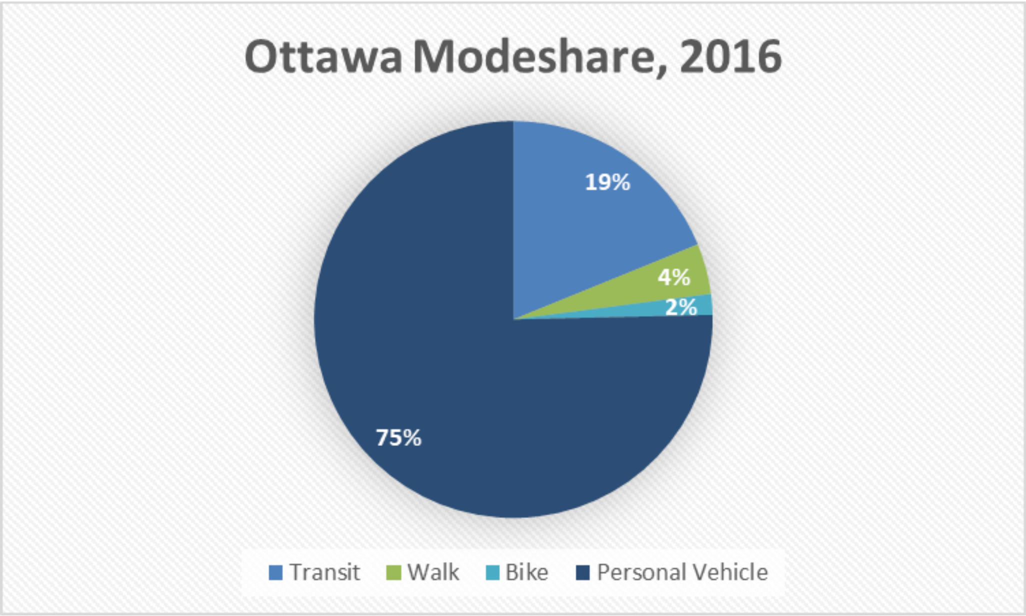


66 "Ottawa Cycling Master Plan." geoOttawa, 2018. http://maps.ottawa.ca/geoOttawa/.

Current Pathway Assessment

Through policies like the Transportation Master Plan and Cycling master plan, Ottawa has already begun to build the pathway toward a more sustainable transportation future. Ottawa continues to add options to increase the share of walking, cycling, and transit use, however the community still favours the use of the personal automobile. Mode share analysis completed for the year 2016 shows 75% of personal trips are made by personal vehicle.

Figure 19. Ottawa mode share, 2016.



With notable additions to public transit through the Confederation Line and cycling network, Ottawa is poised to reduce the amount of energy and emissions used in the transportation within the community.

A comparison of Ottawa's transportation policy and the transportation pathways presented in this paper is shown below.

Table 24: Comparing pathway strategies to Ottawa's transportation policy.

Transportation Pathway	Ottawa's Existing Policy
Impact of land-use change	Official Plan: • The City will manage growth by directing it to the urban area where services already exist or where they can be provided efficiently. • Growth in the existing designated urban areas will be directed to areas where it can be accommodated in compact and mixed-use development, and served with quality transit, walking and cycling facilities. • The central area, designated mainstreets, mixed use centres and town centres will be compact, liveable, and pedestrian-oriented with a vibrant mix of residential uses, and social, cultural and economic activity. • Infill and redevelopment will be compatible with the existing context or planned function of the area and contribute to the diversity of housing, employment, or services in the area.
Electrification of Commercial Vehicles	No policy currently
Transportation Demand Management (TDM) / Behaviour Change Policies	Ottawa Transportation Plan
Parking Management	Ottawa Municipal Parking Management Strategy • Set off-street and on-street parking rates based on local parking studies and stakeholder consultation
Car Free Areas	Ottawa Pedestrian Plan
Congestion Charge	No policy currently
Enhanced Transit	Ottawa Transportation Master Plan, OC Transpo Confederation Line Extensions
Autonomous Vehicles (AVs) (Shared)	No policy currently
Car Share / Ride Share/ Car Co-ops	No policy currently
Enhanced Bicycle Infrastructure	Ottawa Cycling Master Plan • Invest $70 Million in cycling infrastructure by 2031

Section 2: Projected Pathway Assessment

The projected pathway will accelerate policies and actions in the current pathway, or Business as Planned (BAP) Model. The conservative scenario will mirror the BAP, and the moderate scenario will accelerate policy and actions taken in the BAP, notably in enhanced transit, electric commercial vehicles and bicycle mode share. The aggressive scenario will further electrify commercial vehicles, maximize opportunities for cycle infrastructure, add more car share services, and model scenarios where the majority of development is infill rather than greenfield.

Table 25: Low carbon pathway and assumptions.

Action	Conservative Scenario	Moderate Scenario	Aggressive Scenario
Impact of land-use change	No Change (Official plan until 2031)	50% of new development is in urban centres or adjacent to existing or new LRT, BRT by 2025, under affordable transit network.	90% of new development is in urban centres or adjacent to existing or new LRT, BRT by 2025, under ultimate transit network.
Walking as impacted by Land-Use change	No change	For 2km trips, Mode shift to 20% of the walking and cycling potential away from vehicles and driving.	For 2km trips, Mode shift to 50% of the walking and cycling potential away from vehicles and driving.
Electrification of Commercial Vehicles	10% of heavy trucks are zero emissions by 2030; 40% by 2040	20% of heavy trucks are zero emissions by 2030; 60% by 2040.	40% of heavy trucks are zero emissions by 2030; 100% by 2040.
TDM)/Behaviour Change Policies	Modelled under parking management and road pricing	Modelled under parking management and road pricing.	Modelled under parking management and road pricing.
Parking Management	No change	No change	Increase parking fees for on-street and city-owned lots by a factor of 1.5 by 2050.
Car Free Areas	None	None	Byward market and downtown Ottawa are car free; Wellington-Rideau, Sparks, Bank, Ottawa-U campus.
Congestion Charge	None	None	Congestion charge of $20 applied to the downtown core between 6:00 am and 10:00 am on weekdays.

Enhanced Transit	Completion of the Confederation Line- Phase 1 and 2	The Affordable Network is completed, and accompanied by a 10% transit modal increase. 100% of Transit vehicles are electric by 2050	Identify high density neighbourhoods without sufficient transit and increase transit share by 25% in these neighbourhoods The frequency of LRT is increased to every 90 seconds in downtown areas, and outer areas are increased to match. BRT speed is increased by 20% through prioritized lanes and stop lights where separated infrastructure is available. 100% of Transit vehicles are electric by 2050 Complete "Ultimate Transit" Network as shown in Transportation Master Plan
Autonomous Vehicles (AVs) (Shared)	No AVs	Personal vehicle ownership declines by 50% by 2050; VKT increases by 20%; AVs are electric only	Personal vehicle ownership declines by 50% by 2050; VKT decreases by 10%; AVs are electric only
Car Share / Ride Share/ Car Co-ops	Car share increase in Centretown and LRT stations; car ownership declines by 5% in these zones and mode share by 10%. AVs may cancel this out.	Car share increase in Centretown and LRT stations; car ownership declines by 10% in these zones and mode share by 25%. AVs may cancel this out.	Car share increase in Centretown and LRT stations; car ownership declines by 15% in these zones and mode share by 50%. AVs may cancel this out.
Enhanced Bicycle Infrastructure	None	Mode shift to 20% of the walking and cycling away from vehicles and driving. Use 5km for cycling.	Mode shift to 50% of the walking and cycling away from vehicles and driving. Use 5km for cycling.

Uptake Projections

The following tables detail the energy use and emissions reductions based on the actions and assumptions described in this pathway paper.

Conservative

Table 26. Energy and GHG emissions results of the conservative transportation pathway.

Action	Description	Cumulative emissions reductions 2018-2050 (kt CO2e)	Emissions reductions 2050 (kt CO2e)	Cumulative energy reductions 2018-2050 (TJ)	Energy reductions 2050 (TJ)
Spatial Distribution	Official plan until 2031	No change	No change	No change	No change
Increase/improve cycling & walking infrastructure	No Change	N/A	N/A	N/A	N/A
Car Free Zone	None	N/A	N/A	N/A	N/A
Congestion Charge	None	N/A	N/A	N/A	N/A
Expand Transit	Completion of the Confederation Line- Phase 1 and 2	No change	No change	No change	No change
Electrify Transit	2016 fuel shares are held constant	N/A	N/A	N/A	N/A
Electrify Municipal Fleets	Municipal fleet is 20% electric by 2020 and 40% electric by 2040	149	7.25	1,328.32	66.63
Electrify personal vehicles	33% of new vehicle sales by 2050	2,619	302.34	22,723.84	2,786.95
Car Share	Car ownership declines 5% and car mode share declines 10% in Centretown and LRT stations car share zones	95	2.29	1,351.63	33.31
Autonomous vehicles	No Change	N/A	N/A	N/A	N/A
Parking management	No Change	N/A	N/A	N/A	N/A
Electrify commercial vehicles	10% of heavy trucks are zero emissions by 2030; 40% by 2040	2,726	161.39	27,940.02	1,752.61

Moderate

Table 27. Energy and GHG emissions results of the moderate transportation pathway.

Action	Description	Cumulative emissions reductions 2018-2050 (kt CO2e)	Emissions reductions 2050 (kt CO2e)	Cumulative energy reductions 2018-2050 (TJ)	Energy reductions 2050 (TJ)
Spatial Distribution	50% of new development is in urban centres or adjacent to existing or new LRT, BRT by 2025.	2,052	115	35,072	1,989
Increase/improve cycling & walking infrastructure	Mode shift to 20% of the walking and cycling potential away from vehicles and driving. Use 2 km for walking and 5km for cycling.	264	13.14	3,653.62	191.16
Car Free Zone	None	N/A	N/A	N/A	N/A
Congestion Charge	None	N/A	N/A	N/A	N/A
Expand Transit	Build out Affordable Transit Network by 2050	2,634	147	43,098	2,452
Electrify Transit	100% electric by 2050	2,986	150.44	31,913.47	1,691.20
Electrify Municipal Fleets	Municipal fleet is 40% electric by 2020 and 60% electric by 2040.	242	10.87	2,168.10	100.02
Electrify personal vehicles	40% of new vehicle sales by 2040; 50% by 2050	5,772	515.11	51,553.54	4,863.03
Car Share	Car ownership declines 10% and car mode share declines 25% in Centretown and LRT stations car share zones	151	5.78	2,106.23	84.1
Autonomous vehicles	None	N/A	N/A	N/A	N/A
Parking management	None	N/A	N/A	N/A	N/A
Electrify commercial vehicles	20% of heavy trucks are zero emissions by 2030; 60% by 2040	4,262	242.09	43,817.43	2,628.91

Aggressive

Table 28. Energy and GHG emissions results of the aggressive transportation pathway.

Action	Description	Cumulative emissions reductions 2018-2050 (kt CO2eq)	Emissions reductions 2050 (kt CO2eq)	Cumulative energy reductions 2018-2050 (TJ)	Energy reductions 2050 (TJ)
Spatial Distribution	90% of new development is in urban centres or adjacent to existing or new LRT, BRT by 2025. Congestion charge of $20 applied to the downtown core between 6:00 am and 10:00 am on weekdays. On-street parking fares increase by a factor of 1.5 during peak hours by 2050.	1,485	77	31,165	1,664
Increase/improve cycling & walking infrastructure	Mode shift to 50% of the walking and cycling potential away from vehicles and driving. Use 2 km for walking and 5 km for cycling.	1,878.26	34.69	9,809.11	504.83
Expand Transit (Transit Enhancement)	Complete "Ultimate Transit" Network as shown in Transportation Master Plan LRT frequency increased to 90 seconds in downtown areas, and outer areas are adjusted to match. BRT speed is increased by 20% in areas where separated infrastructure is available.	4,430	284	71,537	4,633

Electrify Transit	100% electric by 2030	3,588	150.45	40,350.62	1,691.22
Car Free Zone	Byward market and downtown Ottawa are car free; Wellington-Rideau, Sparks, B ank, Ottawa U. campus	7	0.19	102.52	2.77
Electrify Municipal Fleets	Municipal fleet is 60% electric by 2020 and 100% electric by 2040.	392	18.14	3,496.48	166.66
Electrify personal vehicles	88% of new vehicle sales by 2030; 90% by 2050	18,665	1,136.73	171,791.09	11,038.04
Car Share	None, replaced by autonomous vehicles	N/A	N/A	N/A	N/A
Autonomous vehicles	Personal vehicle ownership declines by 50% by 2050; VKT per capita increases by 150%; AVs are electric only	5,728	283.29	23,187.00	235.02
Electrify commercial vehicles	40% of heavy trucks are zero emissions by 2030; 100% by 2040	4,262	242.09	43,817.43	2,628.91

Constraints

Legal/Jurisdiction

A major driver to moving towards a sustainable transportation system is the use of taxation policy such as carbon pricing in order to shift economic norms away from fossil based energy. Carbon pricing requires a joint partnership between different levels of government, from set-up to implementation. The first step with this measure is for Ottawa to work with the province to bring in such a policy, however political climates may not be favourable for such measures at this time.

Road pricing is similar to carbon pricing but can be led by a municipality. However, other levels of government will need to participate and generally agree with the strategy.

Funding/Fees

Infrastructure requires large amounts of funding and may need coordination with higher levels of government or different methods of fee collection. Pathways towards autonomous vehicles and car sharing may lead to a reduction in the fees that are collected for transportation infrastructure (e.g. gas taxes). Long-term planning for low-carbon transportation needs to occur in order for the pathway to be successful.

Behavioural/Cultural

Changing travel behaviours and norms is difficult. Mode choices are personal and relate to individuals' core beliefs. For example, a driver may wish to drive to their destination because of a perceived lack of safety. Many design initiatives can change these fears, such as using CEPTD measures for new buildings, or improving street lighting.

Changing street design and patterns to include cycling infrastructure can include removing existing lanes, or on-street parking spaces. This can be a conflict for residents of a neighborhood and businesses who may not agree with the change or fear a reduction of business. Even with proper consultation, bike lanes can be rejected due to political pressure.

Furthermore, there is a cultural norm to live in a single detached home that is away from the noisiness of the city. Planners can underestimate the desire for low-density living, and the resistance encountered by planning initiatives to provide other housing options.

Technological

There can be technological constraints in the adoption of new infrastructure or new types of vehicles. For example, the full electrification of heavy-duty commercial trucks may be delayed by the lack of fast chargers that work with larger batteries for trucks travelling long distances. Cities may need to rapidly implement new and faster charging systems within their communities to encourage demand for electric light-duty vehicles, commercial fleets, or heavy duty trucks.

There are also gaps when considering autonomous vehicles. Implementation of AVs will need to be coordinated with different levels of government. This will require different types of infrastructure that support the safe operation of AV's in the urban environment.

Ways to advance this pathway

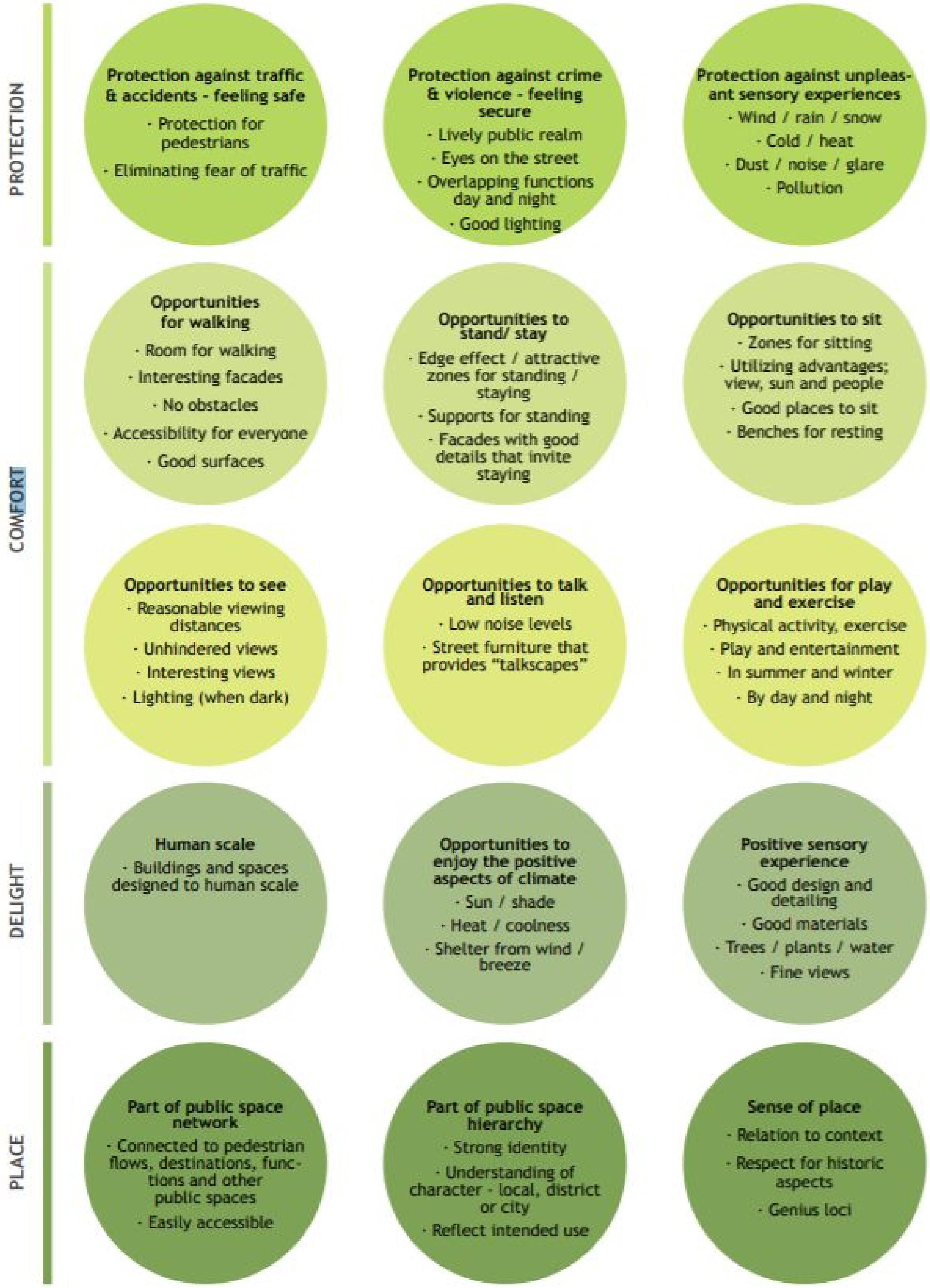
The following are considered “Quick-Start” approaches and are recommended to Ottawa and its partners to reduce transportation emissions, and are in addition to recommendations made in Phase 1.

1. Community consultation and analysis to add more car-free areas in the urban boundary and in Village Centres.
2. Continue to build cycling infrastructure and promote this form of active transportation.
3. Reduced or zero parking for new buildings near destinations served by transit stations.
4. Increased paid parking zones and increased rates near Village Centres.
5. Public EV charging keeps pace with demand.
6. Increased enforcement of bylaws prohibiting double parking beside a parked car
7. Greater effort to work with car share providers such as Car2go or Vrtucar to add to their fleet and move towards allowing one-way trips.
8. Work to ensure that autonomous vehicles in the city are electric.

Modelling by CityInSight will determine the most effective approach to ensure transportation related emissions will meet the goals of the ETS and reduce GHG emissions to 80% below 2012 levels.

Appendices

Appendix 1: 12 Quality Criteria for Public Spaces and Car Free Areas[67]



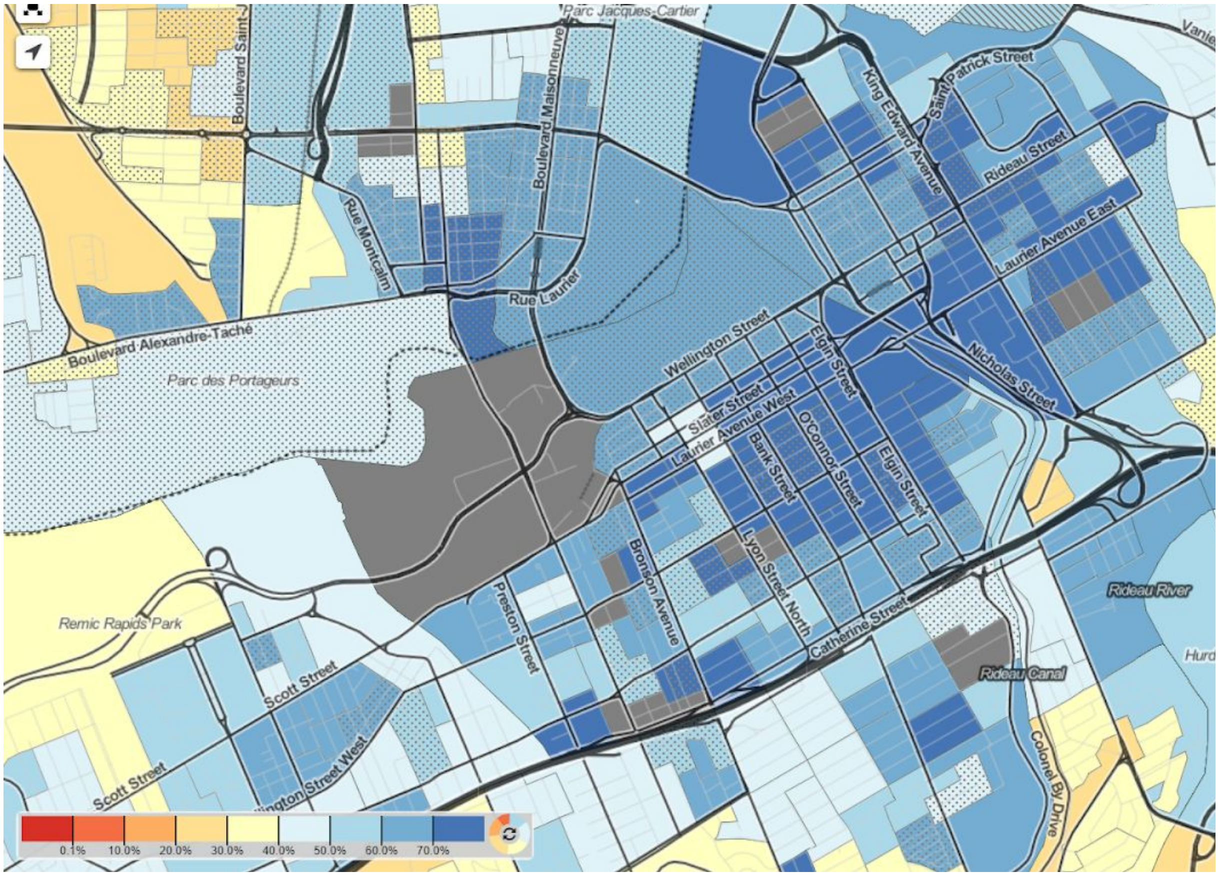
[67] "12 Quality Criteria" Gehl Institute. Adapted by Seattle Department of Transportation. 2009 https://www.seattle.gov/dpd/cs/groups/pan/@pan/documents/web_informational/s048430.pdf

Appendix 2: Car Free Indicators Map (Population Density and Active Transport)[68]

Population Density (Green identifies areas where population density exceeding 5000 km^2).

68 "Ottawa Active Transport." and "Population Density" Census Mapper. Mountain Math, n.d. https://censusmapper.ca.

Areas of Ottawa where 70% of residents use active transport to work, marked in dark blue.



Appendix 3: Congestion Charging Methods in International Cities

Table 26: Congestion Schemes in International Cities.[69]

	Singapore	London	Stockholm	Milan
Other Measures	Increased Transit, Park & Ride	Increased Transit	Increased Transit, Park & Ride	Increased Transit
Charge Varies by: Vehicle Type Time Place	 No No No	 No No No	 No Yes No	 No No No
Passage / Day Fee	One Fee	Day Fee	Passage	Day Fee
Principal Objectives	Congestion	Congestion	Congestion Environment	Environment Congestion
Times	M-Sat 7:30am - 10:15am	M-F &am-6:30pm	M-F 6:30am-6:30pm	M-F 7:30am-7:30pm
Exemptions: Residents Other	 No Carpools, Commercial Trucks	 90% No	 No No	 Annual Card Multiple Entrance Discounts
Affected Area	6-7km^2	22km^2	34.5Km^2	8km^2

[69] Table Adapted from: Jarl, Valfrid. "Congestion Pricing in Urban Areas - Theory and Case Studies." Thesis. Lund University: Department of Technology and Society, 2009. http://www.tft.lth.se/fileadmin/tft/dok/publ/5000/Thesis183_VJ_scr.pdf.

Appendix 4: Bicycle Lane Types

Table 26: Bicycle lane standards, areas of application, and benefits.[70]

Bicycle Lane Type	Criteria of Implementation	Benefits
Conventional Bike Lanes - Exclusive spaces that are created through pavement markings and signage only	• Roads with less than 3000 vehicles per day • Speeds less than 50km/h • High Transit Volume is present	• Increased cyclist comfort on busy streets • creates a visual separation from vehicles • Increases predictability of bicycle movement and interaction
Buffered Bike Lanes - Similar to conventional with a designated buffer space separating bicycles from traffic	• Similar to conventional bike lanes • On streets that have greater widths	• Provides a greater distance from vehicles • Provides space for cyclists to pass each other without entering traffic lane • Cyclists can be out of door-swing zone of parked vehicles • Cyclists can bike in pairs
Contra-Flow Bike Lanes - Lanes designed to allow cyclists to ride in opposite direction of motor vehicle traffic	• Observed areas of cyclists already travelling the wrong way • Corridors where alternate routes require excessive out-of-direction travel • Where alternative corridors subject cyclists to high volumes of traffic • Low-speed, low-volume streets	• Increased connectivity and access to cyclists in both directions • Reduces dangerous wrong-way riding • Decreases sidewalk riding • Decrease trip distances • Slow motor vehicle traffic down
Cycle Tracks / Separated Lanes - One-way or two-way protected bicycle lanes that are completely separate from motor vehicles	• Along higher speed streets with few driveways and cross streets • Streets with higher traffic rates • Curving streets where vehicles may encroach cycle lanes more frequently • Streets that are observed to have high bicycle volumes	• Provides the greatest comfort and safety for cyclists • Reduces risks and safety issues with parked cars or car attempting to park • Offers room for cyclists to pass or ride in pairs • Most attractive to riders of all ages and abilities • Reduced interference with transit / buses

[70] NACTO: Cycle Lane Types.

Appendix 5: Transportation Modelling Assumptions for Business as Planned

	Data/Assumption	Source	Summary approach/methodology
Transit			
Expansion of transit	Transit mode shares by O-D zones in 2011 and 2031 model data Hold mode shares constant after 2031 through 2051	Ottawa transportation model data for 2011 and 2031	It is assumed the modelled 2031 trips by mode reflects planned transit expansion
Electric vehicle transit fleet	No electrification of transit vehicle fleet assumed 2016-2050.		No electrification of transit vehicle fleet assumed 2016-2050.
Active			
Cycling & walking infrastructure	Active mode shares by O-D zones in 2011 and 2031 model data Hold mode shares constant after 2031 through 2051	Ottawa transportation model data for 2011 and 2031	It is assumed the modelled 2031 trips by mode reflects planned cycling and pedestrian infrastructure expansion
Private & commercial vehicles			
Vehicle KM travelled	No data from City or other transportation agencies. Derived by the model.		Vehicle kilometres travelled projections are driven by buildings projections. The number and location of dwellings and non-residential buildings over time in the BAP drive the total number of internal and external person trips. Person trips are converted to vehicle trips using the baseline vehicle occupancy. Vehicle kilometres travelled is calculated from vehicle trips using the baseline distances between zones and average external trip distances.

Vehicle fuel efficiencies	Vehicle fuel consumption rates reflect the implementation of the U.S. Corporate Average Fuel Economy (CAFE) Fuel Standard for Light-Duty Vehicles, and Phase 1 and Phase 2 of EPA HDV Fuel Standards for Medium- and Heavy-Duty Vehicles.	EPA. (2012). EPA and NHTSA set standards to reduce greenhouse gases and improve fuel economy for model years 2017-2025 cars and light trucks. Retrieved from https://www3.epa.gov/otaq/climate/documents/420f12050.pdf http://www.nhtsa.gov/fuel-economy	Fuel efficiency standards are applied to all new vehicle stocks starting in 2016.
Vehicle share	Personal vehicle stock share changes between 2016-2050. Commercial vehicle stock unchanged 2016-2050.	CANSIM and Natural Resources Canada's Demand and Policy Analysis Division.	The total number of personal use and corporate vehicles is proportional to the projected number of households in the BAP.
Electric vehicles	2-3% of Market Share in 2040	Canada's Electric Vehicle Policy Report Card 2016. Axsen, Goldberg, Melton (Simon Fraser University)	The Ontario Long-Term Energy Plan predicted 5% of new vehicles sold being electric by 202 however all incentive programs have been eliminated at this time. The BAP will use a similar market share to other provinces who lack distinct policy to support EV (Alberta, Saskatchewan, Manitoba) as established by the Canada's Electric Vehicle Policy Report Card 2016. Axsen, Goldberg, Melton (Simon Fraser University)

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