Modal Optimization as a Contributor to Reducing GHG Emissions in Canada

July 2020

Pollution Probe
Clean Air. Clean Water.

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About

The Delphi Group

The Delphi Group is a Canadian strategic consultancy providing innovative solutions in the areas of climate change and corporate sustainability. As a pioneer in sustainability and environmental risk management, The Delphi Group has more than 25 years of experience in helping some of Canada's best-known companies improve the sustainability of their organizations – as well as the local and global communities in which they operate.

Pollution Probe

Pollution Probe is a national, not-for-profit, charitable organization that exists to improve the health and well-being of Canadians by advancing policy that achieves positive, tangible environmental change. Pollution Probe has a proven track record of working in successful partnership with industry and government to develop practical solutions for shared environmental challenges.

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Natural Resources Canada (NRCan) seeks to enhance the responsible development and use of Canada's natural resources and the competitiveness of Canada's natural resource products. We are an established leader in science and technology in the fields of energy, forests, and minerals and metals, and use our expertise in earth sciences to build and maintain an up-to-date knowledge base of our landmass. NRCan develops policies and programs that enhance the contribution of the natural resources sector to the economy and improve the quality of life for all Canadians. We conduct innovative science in facilities across Canada to generate ideas and transfer technologies. We also represent Canada at the international level to meet the country's global commitments related to the sustainable development of natural resources.

Acknowledgements

The Delphi Group and Pollution Probe would like to acknowledge that this study was made possible through funding support from Natural Resources Canada.

The Delphi Group and Pollution Probe would like to thank the Transportation and Air Quality Research Group at the University of Toronto for contributing the passenger modal shift scenario development for this study. In particular, we would like to thank the following individuals:

Marianne Hatzopoulou, Associate Professor, Department of Civil Engineering, and Canada Research Chair in Transportation and Air Quality, University of Toronto

Junshi Xu, PhD, Postdoctoral Researcher, Department of Civil Engineering, University of Toronto

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Executive Summary

In 2017, 24% of Canada's GHG emissions came from the transportation sector. This project seeks to identify modal optimization solutions that can be implemented by a variety of stakeholders and that will contribute to Canada's climate targets, including net zero by 2050, by improving energy efficiency across the transportation sector and determining the optimal way to move people, goods and services.

Movement of People

An analysis of the data around the movement of people in Canada in recent decades reveal some notable trends, including:

- Declines in annual kilometres driven in passenger vehicles
- Air travel is increasing significantly
- Intercity bus lines are dwindling
- Passenger light trucks (SUVs, pickups and minivans) have rapidly grown in popularity

Transportation infrastructure throughout Canada was built with passenger vehicles in mind. Today, 87% of all travel in the country is undertaken with passenger vehicles, which are responsible for 90% of passenger transport GHG emissions. A significant portion of Canadians use passenger vehicles by default, even for trips as short as several hundred metres.

The modal choice and modal cost data presented in this report suggest that convenience and reliability are likely more important than costs when it comes to the personal mobility of Canadians. The significant price differential between personal vehicle ownership and shared mobility options in urban settings indicates that Canadians are willing to pay more for a mode that will be at their disposal 24/7. In order for other modes to cut into the user share of personal vehicles, they have to be made more convenient, reliable and available.

Rural Canadians are very limited in terms of modal choice. They are likely to remain car-captive for the foreseeable future, and GHG reductions from their personal mobility will likely be derived from fuel-switching and vehicle rightsizing. Most modal shift opportunities should therefore be focused on cities, where over 80% of Canadians reside and where an even greater proportion find employment.

Modal shift will require concerted actions from multiple stakeholders. Key stakeholders and the types of actions they can be involved in are shown in the following table.

<table>
<tr><th>Stakeholder</th><th>Passenger vehicles to urban transit</th><th>Passenger vehicle or urban transit to active transportation</th><th>Aviation to intercity bus or passenger rail</th></tr>
<tr><td>Federal and Provincial Government</td><td colspan="3">• Infrastructure development
• Financial mechanisms (e.g. funding/incentive programs)
• Education and awareness
• Procurement best practice</td></tr>
<tr><td>Municipal Government</td><td>• Education and awareness
• Procurement best practice</td><td>• Education and awareness
• Infrastructure development
• Modal shift strategy
• Financial mechanisms (e.g. funding/incentive programs)</td><td>• Education and awareness
• Procurement best practice
• Modal shift strategy</td></tr>
<tr><td>Transit Authorities</td><td>• Infrastructure development
• Modal shift strategy
• Education and awareness</td><td>• Infrastructure development
• Modal shift strategy</td><td></td></tr>
<tr><td>Intercity bus and rail operators</td><td></td><td></td><td>• Infrastructure development
• Modal shift strategy
• Education and awareness
• Procurement best practice</td></tr>
<tr><td>Developers</td><td>• Infrastructure (access to transit)</td><td>• Infrastructure development</td><td></td></tr>
<tr><td>Electric Utilities</td><td>• Infrastructure (power for transit)</td><td></td><td>• Infrastructure development</td></tr>
<tr><td>Civil society, academia, research organizations, NGOs, associations</td><td>• Education and awareness</td><td>• Modal shift strategy
• Education and awareness</td><td>• Education and awareness</td></tr>
</table>

While car-to-transit shifts would significantly reduce passenger transport emissions in all Canadian cities, emissions reduction assessments and transit expansion should be prioritized in car-oriented cities such as Calgary, Ottawa-Gatineau, Edmonton, Québec and Winnipeg. Shifting people from passenger cars to transit would also reduce congestion and thereby reduce the carbon intensity of on-road freight transport.

Movement of Services

The movement of services is accomplished through so-called vocational trucks, which includes both specialty trucks (such as garbage trucks, salt trucks, etc.) and trucks used to haul equipment or materials (such as those used for service calls, utility trucks, etc.). There are limited modal shift options for the movement of services: vehicles tend to be highly specialized and the functional requirements preclude other modal options. In Canada, emissions reductions from the movement of services is more likely to come from fuel efficiency and fuel switching rather than modal shift.

Movement of Goods

An analysis of the data around the movement of goods in Canada in recent decades reveal some notable trends, including:

- The quantity of freight is increasing
- The distance that freight travels is increasing
- Delivery timelines are getting shorter

On a tonne-km basis, rail (44%) and heavy truck (33%) are the most prevalent methods of transporting freight domestically, while marine is primarily used for overseas exports and imports. Air is used significantly less than the other three modes. Trucks represent the greatest source of transportation emissions in the movement of goods and GHG emissions from the movement of freight trucks has more than doubled in the past three decades.

Based on the high proportion of goods shipped by truck and rail in Canada, and on the significant discrepancy in GHG emissions intensity between the two, the main opportunity to optimize freight transportation for GHG reductions is to transition truck freight to rail. There is some opportunity to shift freight onto ships in the Great Lakes/St. Lawrence inland waterway system, but given the limitations imposed by both the geography and seasonality of this option, it represents a very limited opportunity. There is no evidence that a shift away from air transportation of freight is possible given the specialized nature of this mode.

The potential for shifting road to rail will likely be specific to commodities, and shipments to/from specific locations. Key stakeholders and activities are shown below.

Stakeholder	Activities
Federal and Provincial Government	• Infrastructure development • Financial mechanisms (e.g. funding/ incentive programs, freight pricing initiatives) • Education and awareness • Procurement best practice
Municipal Government	• Education and awareness • Procurement best practice
Digital Logistics Companies	• Infrastructure • Modal shift strategy • Logistics-based solutions
Rail Companies	• Infrastructure development • Modal shift strategy • Education and awareness
Shippers	• Infrastructure (access to rail) • Logistics-based solutions • Procurement best practice
Civil society, academia, research organizations, NGOs, associations	• Education and awareness

An analysis of long-distance rail and truck shipments (greater than 1000km) originating in Canada indicated the following potential areas to explore for modal shift:

- Shipments originating in Calgary are more likely to travel by truck than other areas in Alberta
- Ontario has a higher reliance on trucks, especially for cross border shipments. 62% of freight that will be transported over 1000 km leaves the GTHA by truck
    - "Base metals and Articles of Base metals" are shipped from Hamilton all over Canada and to the US/ Mexico. There is a small quantity that goes by rail (mostly to the United States), but it is dwarfed by the overall tonnage and number of shipments that go by truck
    - "Miscellaneous Products" and "Other Manufactured Goods" move from the GTHA all over Canada and into the United States. Vancouver and the U.S. are the two biggest destinations

- The ratio of freight leaving Quebec City by truck vs. by rail is 65%, as compared with only 46% in the rest of the province and 33% in Montréal. Forest products represent the largest single share of this freight. Of the forest products leaving Quebec City by truck, 64% are bound for the U.S.
- Building intermodal or reloading terminals in strategic location(s) may accommodate the shift of freight shipments onto rail in the Atlantic provinces where rail lines do not currently extend. In general, intermodal freight represents a growth opportunity for rail.
- Changes in the natural resource sector, such as more northerly forestry operations in BC and the growing bioeconomy should be explored to ensure that new movements of goods are optimized for lower GHG emissions.

Abbreviations and Acronyms

CAC	Criteria Air Contaminant (synonymous with “air pollutant”)
CAD	Canadian Dollars
CN	Canadian National Railway
CO	Carbon Monoxide
CO_{2eq}	Carbon Dioxide Equivalent (in terms of climate forcing intensity)
CP	Canadian Pacific Railway
DCFC	Direct Current Fast Charger
ECCC	Environment and Climate Change Canada
EF	Emission Factor
EPA	United States Environmental Protection Agency
GHG	Greenhouse Gas
HDV	Heavy-Duty Vehicle
ICE	Internal Combustion Engine
LEZ	Low-Emission Zone
MDV	Medium-Duty Vehicle
MOVES	MOtor Vehicle Emission Simulator

Mt	Megatonne (one million tonnes)
MURB	Multi-Unit Residential Building
NOx	Nitrogen Oxides
NRCan	Natural Resources Canada
PCF	Pan-Canadian Framework on Clean Growth and Climate Change
PKT	Passenger Kilometre Travelled
PM	Particulate Matter
$PM_{0.1}$	Ultrafine Particulate Matter
$PM_{2.5}$	Particulate Matter with a diameter of less than or equal to 2.5 micrometres
PM_{10}	Particulate Matter with a diameter of less than or equal to 10 micrometres
RTK	Revenue Tonne Kilometre (generated when 1 tonne of freight is transported 1 km)
TCO	Total Cost of Ownership
TRAP	Traffic-Related Air Pollution
ULEZ	Ultra-Low Emission Zone
VOC	Volatile Organic Compound
ZEV	Zero Emission Vehicle (includes battery and plug-in hybrid electric vehicles, as well as hydrogen fuel cell vehicles)
ZEZ	Zero Emission Zone

1. Introduction

1.1 Objectives

This project seeks to assess modal optimization for the reduction for GHG emissions for the urban setting as well as intercity movement. The ultimate goal is to identify modal optimization solutions that can be implemented by a variety of stakeholders and that will contribute to Canada's climate targets, including net zero by 2050, by improving energy efficiency across the transportation sector and determining the optimal way to move people, goods and services.

1.2 Methodology

The methodology included a combination of approaches to create as clear, accurate and vivid a picture as possible of both the current state of transportation in Canada, and recommendations to drive modal shift that will be impactful and economical.

- Analysis of available data and statistics, including datasets prepared by Statistics Canada, NRCan and ECCC, many of which extend over multiple years, allowing for commentary on trends;
- Research, including interviews, to identify and develop modal shift activities;
- Literature review to address gaps in available statistics, inform the application of case study findings to other jurisdictions, and to identify best practices both within Canada and in comparable international jurisdictions.

1.3 Movement of Services

Within the stated objectives, the report focuses heavily on the movement of people and the movement of goods. There is very little information available to support a modal shift for the movement of services. Limitations include vehicle specificity, equipment required to provide services, and logistics that include often irregular scheduling and variation in locations.

The movement of services is accomplished through so-called vocational trucks, which includes both specialty trucks (such as garbage trucks, salt trucks, etc.) and trucks used to haul equipment or materials (such as those used for service calls, utility trucks, etc.). These are owned and operated by municipalities, utilities, and service providers such as HVAC, landscaping and maintenance companies, among others. There is a lack of data to characterize this sector in Canada. It was previously tracked through Statistics Canada's annual Canadian Vehicle Survey, however this product was discontinued.

There are limited modal shift options for the movement of services: vehicles tend to be highly specialized and the functional requirements preclude other modal options. Nonetheless, operational circumstances have inspired at least one company to identify an alternative to the business-as-usual scenario. Verizon is a telecommunication services provider that operates a fleet of over 42,000 vocational vehicles in the United States. Faced with traffic and parking challenges in New York City, the company deployed 25 specially designed buses that can each transport 14 technicians and their equipment to job sites in and around the city. The buses run specific routes, delivering technicians to job sites at high rise apartments or condo complexes, and picking them up at the end of the day or when they are ready to move to the next work area.[1]

In Canada, emissions reductions from the movement of services is more likely to come from fuel efficiency and fuel switching rather than modal shift. For example, the City of Vancouver considered the movement of services in it's Transportation 2040 Plan, noting that "As the number of people living and working in the city continues to grow, volumes of goods and services moving about will also increase." The proposed approach focuses on designating a network of truck routes and ensuring access to loading zones and parking in order to increase the efficiency of service delivery vehicles, along with supporting incentives and regulations to ensure right-sizing of service delivery vehicles.[2]

1.4. Impact of Alternative Fuels and Alternative Propulsion

In assessing modal optimization for GHG reductions, it is important to consider technology trends. For example, as cars transition to ZEVs, the GHG benefit of shifting passenger transportation from cars to public transportation will decrease and may even briefly reverse if ZEVs are adopted for personal vehicles before public transportation. This means that any modal shift strategy should continue to look at technology development and deployment through implementation. For the purposes of this report, the following guiding principles were used:

- Modal shift is a GHG reduction solution that can be deployed now, and hence actions should consider the current mix of fuel consumption across modes. Fossil fuels are still the predominant sources of energy for transportation.
- Not all modes will adopt lower-emitting fuels and propulsion at the same time, but achieving net zero emissions by 2050 will require fuel switches across all modes. This means that reversals in GHG benefits are likely to be only temporary and should not inhibit the implementation of modal shifting actions and strategies
- Modal shift will continue to be important in a low carbon future as it drives energy efficiency

As a result of this approach, alternative fuels and propulsion are only discussed in specific contexts where modal shift is likely not feasible.

1 Vocational Truck Fleets Use Innovation to Get the Job Done, Work Truck, 2013 https://www.worktruckonline.com/152858/vocational-truck-fleets-use-innovation-to-get-the-job-done

2 Transportation 2040, Plan as Adopted by Vancouver City Council on October 31, 2012 https://vancouver.ca/files/cov/Transportation_2040_Plan_as_adopted_by_Council.pdf

2. Overview of Transportation in Canada

This section seeks to provide a broad overview of prevalent modes of transportation of people and goods at the national level, and to assist in defining the scale of key variables such as usage, cost and environmental impacts.

2.1. The Changing Policy Landscape

The transportation sector in Canada accounted for 24% of national greenhouse gas (GHG) emissions in 2017.[3] In 2016, the federal government introduced the Pan-Canadian Framework on Clean Growth and Climate Change (PCF), which articulates Canada's plan to meet its climate change commitments and grow the economy. Four key transportation areas were identified for concerted action with the Provinces and Territories:

1. Setting emissions standards and improving efficiency
2. Putting more zero-emission vehicles on the road
3. Shifting from higher- to lower-emitting modes and investing in infrastructure
4. Using cleaner fuels

In order to accelerate the adoption of zero-emission vehicles (ZEVs), the Government of Canada set ambitious targets of having 10% of all light-duty vehicle sales be ZEVs by 2025, 30% by 2030, and 100% by 2040. Canada is also working to enhance the deployment of medium- and heavy duty ZEVs, as demonstrated in the 2019 Mandate Letter to the Minister of Infrastructure and Communities. The letter states that, starting in 2023, new investments in public transit should support ZEV buses and rail systems, and that the Ministry should work with provinces and territories to deploy 5,000 ZEV transit and school buses within five years.[4]

Additional federal government measures to support a transition to low-carbon transportation include:

- Budget 2017 allocation of $182.4M to support EV charging infrastructure (through the Electric Vehicle and Alternative Fuel Infrastructure Deployment Initiative, or EVAFIDI)
- Budget 2019 allocation of $130M to support EV charging infrastructure at MURBs and workplaces, and to support the electrification of last mile deliveries and transit vehicles (through the Zero-Emission Vehicle Infrastructure Program, or ZEVIP)
- $300M is earmarked for the federal iZEV Program, which provides consumers with rebates of up to $5,000 for the purchase of an eligible ZEV
- $265M has been allocated to the Accelerated Capital Cost Allowance for ZEVs purchased by Canadian businesses
- Natural Resources Canada's Generation Energy Council, consisting of 14 experts from across the country with a mandate to advise on how Canada can transition to a reliable, affordable, low-carbon economy

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3 Environment and Climate Change Canada. 2019 National Inventory Report 1990 – 2017: Greenhouse Gas Sources and Sinks in Canada. Part 3.

4 Office of the Prime Minister. Minister of Infrastructure and Communities Mandate Letter. 2019. (https://pm.gc.ca/en/mandate-letters/2019/12/13/minister-infrastructure-and-communities-mandate-letter)

- The establishment of the Advisory Council on Climate Action, which will support Canada's commitments under the Paris Agreement by helping the Government identify further opportunities to reduce carbon pollution in the transportation and building sectors, using sustainable financial mechanisms
- In 2018 Canada endorsed CALSTART's Global Commercial Vehicle Drive to Zero Program, which is focused on catalyzing the deployment of zero and low emissions medium- and heavy-duty vehicles such as buses and delivery vehicles

2.2. Infrastructure

Canada's transportation network, pictured in Figure 1 consists of[5]:

- Over 38,000 km of primary highways ("core routes"), feeder routes (linking core routes and economic centres to key intermodal facilities and border crossings) and northern and remote routes (providing access to northern and remote areas, economic activities and resources)[6]
- Over 45,000 route-kilometres of track;
- Three key marine transportation corridors (Pacific, Atlantic and the Great Lakes/St. Lawrence inland waterway system), with over 550 port facilities. Seventeen of these are designated as Canada Port Authorities due to their strategic importance as 'critical to domestic and international trade'. These handle about 60% of all Canadian marine cargo[7,8] and
- Twenty six airports included in the National Airports System, defined as those that serve 200,000 passengers or more per year, and those serving the national, provincial and territorial capitals.[9]

Figure 1: National Transportation Infrastructure of Canada

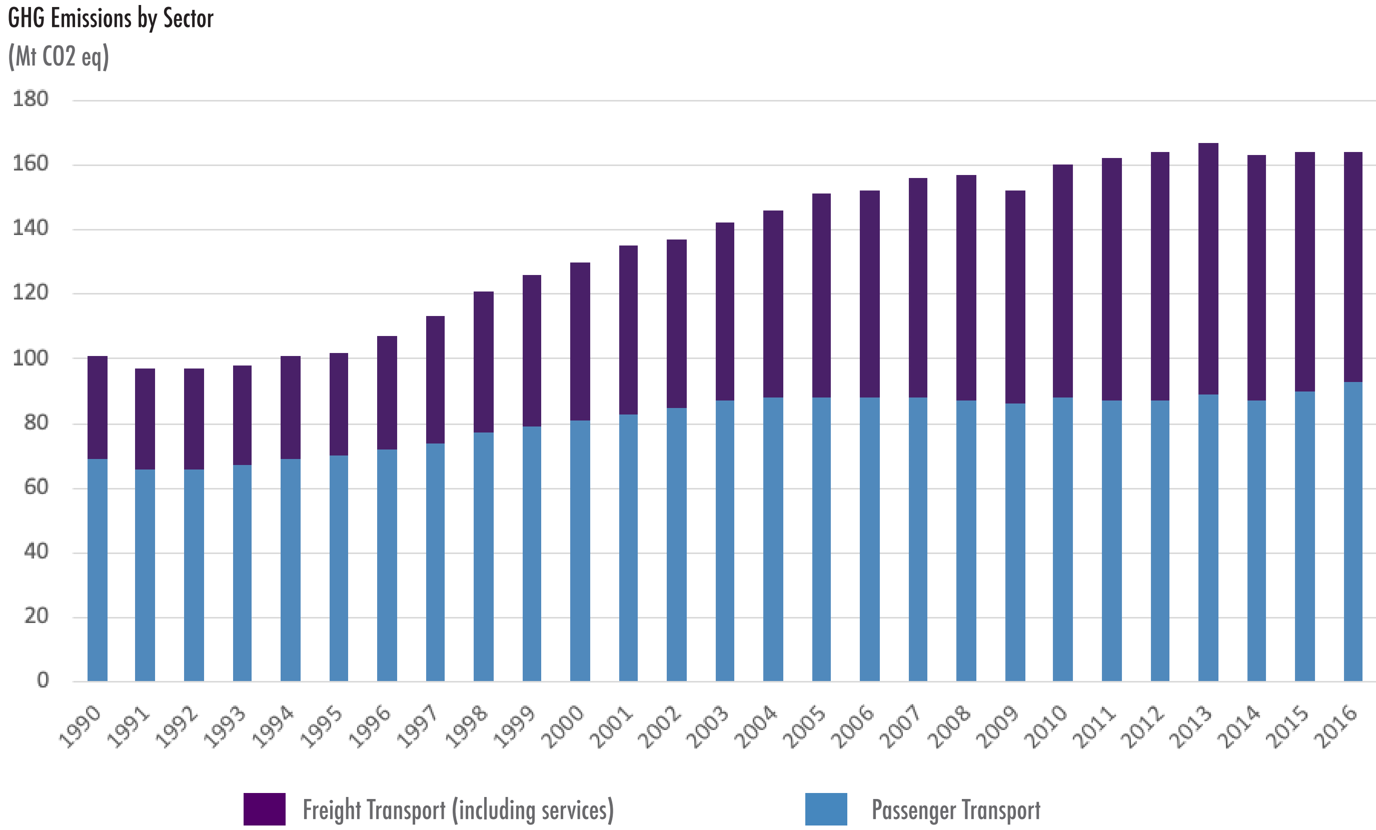
5 Transportation in Canada 2018, Transport Canada, https://www.tc.gc.ca/eng/policy/transportation-canada-2018.html
6 https://www.tc.gc.ca/eng/policy/acg-acgd-menu-highways-2149.htm
7 https://www.tc.gc.ca/eng/backgrounder-canada-port-system.html
8 http://acpa-ports.net/pr/facts.html
9 http://cyqm.ca/wp-content/uploads/2016/10/CAC-Canadas_National_Airports_A_Primer_FINAL_EN.pdf

As evidenced by the map, Canadian transportation infrastructure is primarily located in the southern portion of the country. Transportation-related emissions are consequently also concentrated in the south, primarily in urban centres.

2.3. GHG Emissions by Sector

In 2017, 24% of Canada's GHG emissions came from the transportation sector. This is up from 17% in 1990 – an increase that has come primarily from the freight sector.[10] Emissions from freight are projected to continue growing, exceeding those from passenger transportation by 2030 according to Canada's 2nd Biennial Report on Climate Change.[11]

Figure 2: Transportation GHG Emissions by Sector (Passenger/ Freight)

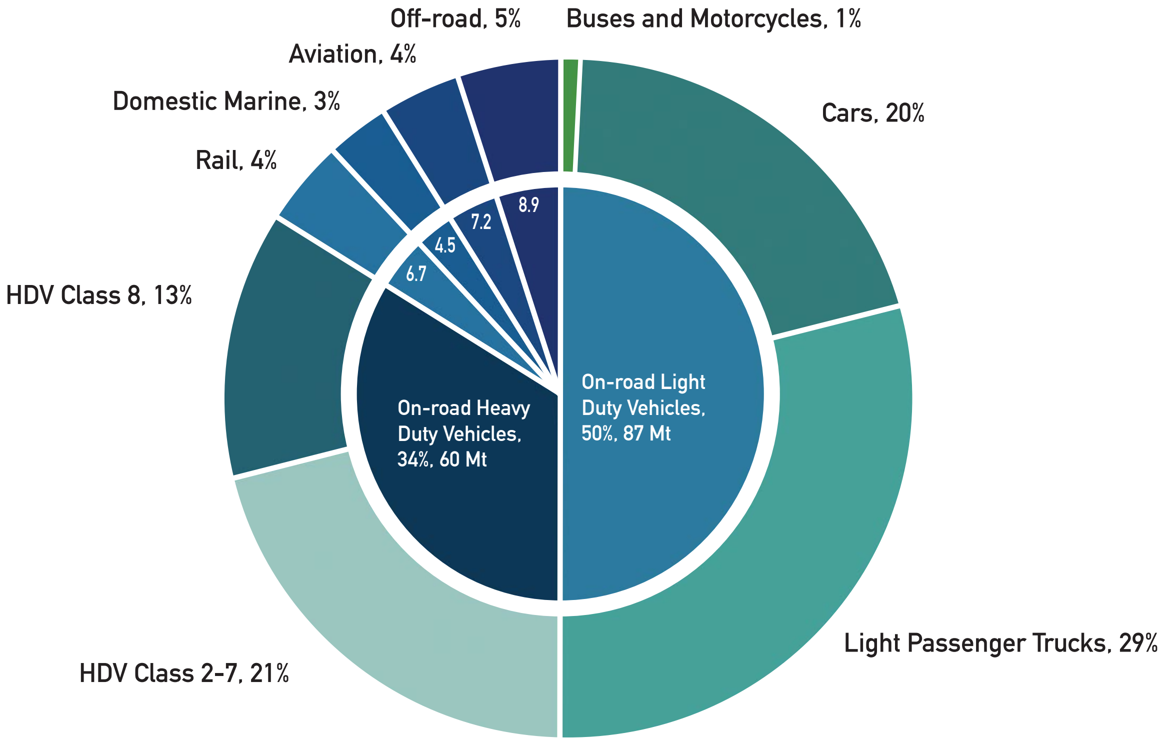


Breaking this down further, the majority of transportation-related emissions originate from on-road transportation.

10 National Inventory Report 1990-2017: Greenhouse Gas Sources and Sinks in Canada (Annex 10, Table 3), Environment and Climate Change Canada, http://www.publications.gc.ca/site/eng/9.506002/publication.html

11 The State of Freight: Understanding greenhouse gas emissions from goods movement in Canada, The Pembina Foundation, 2017. https://www.pembina.org/reports/state-of-freight-report.pdf

Figure 3: Transportation Emissions by Source, 2017[12]

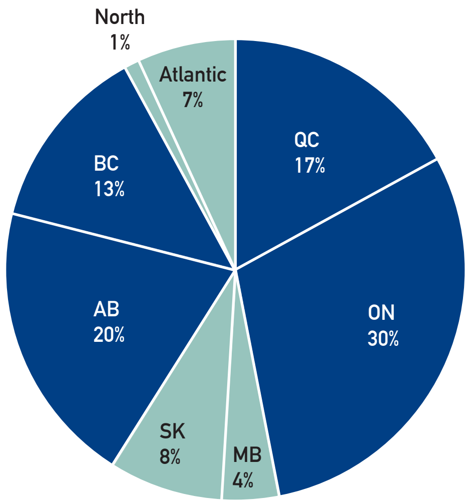


2.4. GHG Emissions by Region

From an emissions perspective, overall GHG emissions from transportation correspond to the provinces with the largest populations: Ontario, Quebec, Alberta and British Columbia. The total emissions from these four provinces consistently represent 80% or higher of the total emissions across Canada for every mode. (Figure 4)

Appendix A: Regional Overview of Transportation provides a summary of the economic, geographic and demographic factors that contribute to variations in transportation of both people and goods across Canada.

Figure 4: Transportation GHG Emissions by Province/ Region



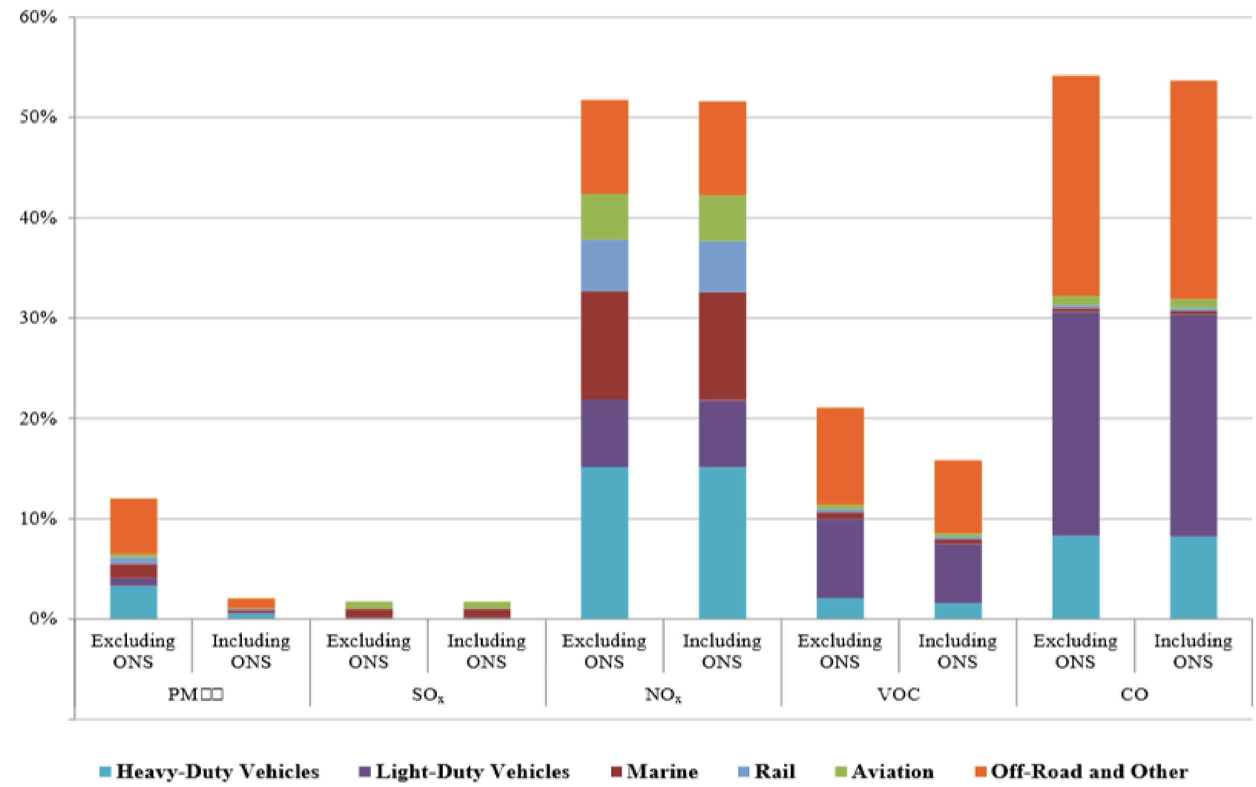
12 Transport Canada

2.5. CAC Emissions

While the focus of this study is on reducing emissions of GHGs, transportation activities that burn fossil fuels are also responsible for the emission of criteria air contaminants (CACs). These include nitrogen oxides (NOx), particulate matter (PM), volatile organic carbons (VOCs) and carbon monoxide (CO). Collectively, CACs have negative impacts on the environment, including smog and acid rain, and on human health, including on the respiratory and cardiovascular systems.

These impacts are most pronounced in highly trafficked areas such as dense urban cores or busy highway corridors. Freight transport and off-road vehicles tend to be the biggest sources of CACs. However, diesel buses, locomotives and marine vessels, as well as jet fuel powered aircraft are all significant sources of CACs.

Figure 5: CAC Emissions by Transportation Source[13]



Notes: ONS= Open and Natural Sources. SO_X= Sulphur oxide. NO_X= Nitrogen oxide. VOC= Volatile organic compounds. CO= Carbon monoxide. $PM_{2.5}$= Particulate matter less than or equal to 2.5 microns.

13 Transport Canada. 2019. Transportation in Canada 2018: Statistical Addendum. Accessible by emailing: TCAnnualReport-RapportannuelTC@tc.gc.ca

3. Analysis of Transportation in Canada

3.1. Movement of People

Canadians spend an average of 1.2 hours, or 5% of their day traveling between activities. For nearly 16 million people, this includes commuting to work. Eighty five percent of households own at least one vehicle – 39% own two or more.[14] In rural areas, 95% of households own a passenger vehicle, while in cities with over 1 million residents, household vehicle ownership stands at 79%.[15] While people under 30 are embracing public transit, those over 50 remain attached to their cars.[16]

Aside from active transportation (walking and cycling), the movement of people in Canada is predominantly undertaken through the use of six modes: urban transit, intercity bus, intercity rail, domestic aviation, cars, and passenger light trucks (pickups, SUVs and minivans). While passenger cars and light trucks are often categorized together, they are treated as separate modes by this study to a) illustrate trends in private vehicle usage, and b) illustrate the potential benefits of a shift from passenger light trucks to cars. Emissions and ridership data for passenger travel via watercraft are not available and are not included in this study.

An analysis of the data around the movement of people in Canada in recent decades reveal some notable trends.

- **Declines in annual kilometres driven in passenger vehicles.** For passenger light trucks, average distances driven peaked in the decade spanning 1995-2005. Between 2005 and 2016, annual distances driven by light trucks decreased by 15% (from 18,200 to 15,500 km). A similar trend holds true for passenger cars, with annual average distances driven decreasing by 19% between 2005 and 2016 (from 18,200 to 14,700 km). In both cases, 2016 (the most recent year in the dataset) saw the lowest average distances driven in the entire dataset (which goes back to 1990).
- **Air travel is increasing significantly.** Annual passenger travel by air has been steadily increasing since 2003. In fact, total passenger kilometres via air more than doubled between 2003 and 2016, and only experienced year-over-year declines twice in that timeframe. Each year seems to bring a new historic peak in total passenger air transport distance, with an average annual increase of 5% between 2006 and 2016.
- **Intercity bus lines are dwindling.** Canada's intercity bus industry has been struggling in recent years, and providers have been forced to engage in many service reductions and route cancellations to remain in operation. The industry has experienced annual net losses since 2012, and the total number of intercity bus operators has decreased from 22 to 13.[17]
- **The rise of the passenger light truck.** One of the most notable trends in passenger transport has been the rapid rise of light trucks, which include pickups, SUVs and minivans.

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14 Transport Canada. 2019. Transportation in Canada 2018. (https://www.tc.gc.ca/eng/policy/transportation-canada-2018.html)

15 Statistics Canada. 2018. Survey of Household Spending, 2017. (https://www150.statcan.gc.ca/n1/daily-quotidien/181212/dq181212a-eng.htm)

16 Transport Canada. 2019. Transportation in Canada 2018. (https://www.tc.gc.ca/eng/policy/transportation-canada-2018.html)

17 Statistics Canada. 2018. Passenger bus and urban transit, 2016. (https://www150.statcan.gc.ca/n1/daily-quotidien/180719/dq180719f-eng.htm)

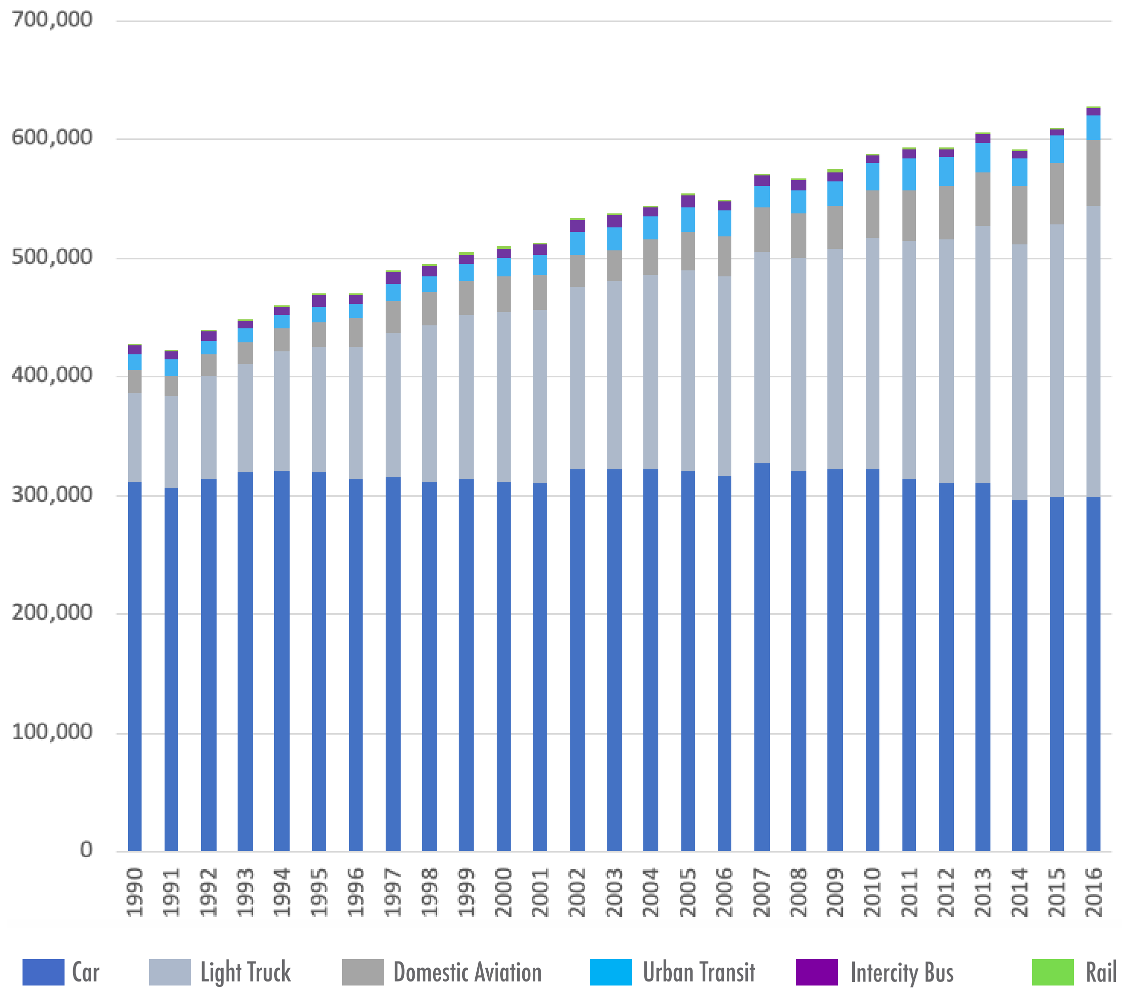
> In 1990, light truck sales represented just under 20% of all light-duty vehicle sales in Canada. By 2016, this share of sales stood at roughly 42%. In the decade spanning 2006 to 2016, light truck sales increased by an average of 5% per year. In the same timeframe, passenger car sales increased by an average of 1.3% per year, with net sales declines in several of those years.

These trends will inform the roles of different stakeholder groups and the overarching decision-making process surrounding modal shift actions in Canada going forward.

3.2. Usage

To gain a sense of how Canadians choose to get around, the most fundamental metric is total annual passenger kilometres travelled by mode.

Figure 6: Canadian Annual Passenger km Travelled, by Mode (millions km)[18,19]



18 Data amalgamated from: Statistics Canada. Transportation: Key Indicators. (2020). (https://www150.statcan.gc.ca/n1/en/subjects/Transportation?count=50#data)

19 Passenger km data for domestic aviation are only available as a discrete dataset from 2015 onwards. Domestic aviation data used in this figure and elsewhere in the report took the portion of domestic travel from total Canadian aviation passenger km from 2015 and 2016 (28.96%), and proportionately allocated this to total aviation passenger km back to 1990. Passenger km data from domestic aviation prior to 2015 are thus used for illustrative purposes only.

As can be seen in Figure 6, a large majority (87%) of all vehicular travel within Canada is undertaken by passenger cars and trucks. Domestic aviation facilitates roughly 9% of all travel, while urban transit covers 3%. Intercity bus and passenger rail have minor shares, accounting for 1% and 0.2%, respectively.

Figure 7: Number of Registered Vehicles in Canada, by Mode (2005-2016)[20,21]

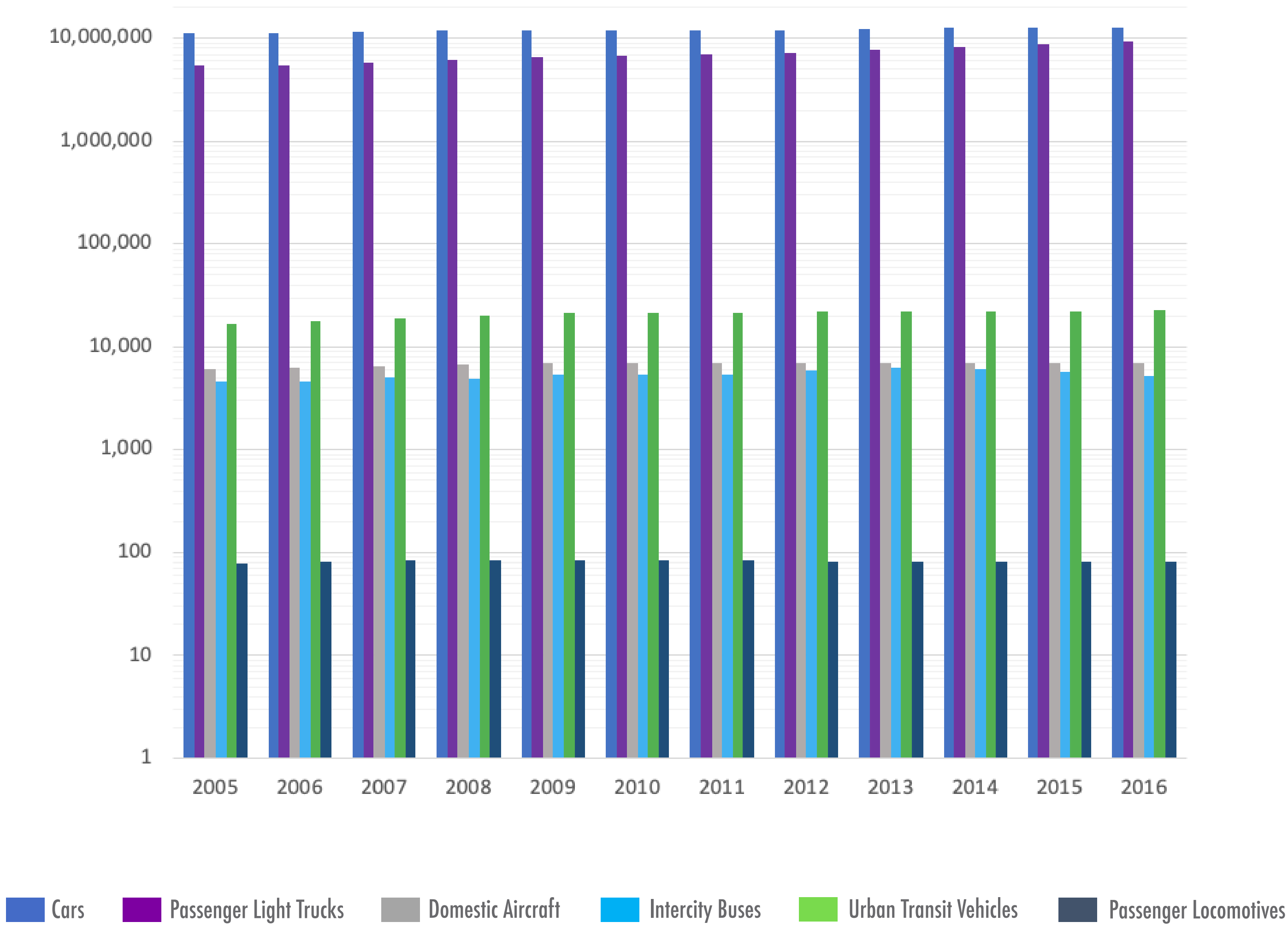


Figure 7 shows that vehicle numbers within all six passenger modes increased between 2005 and 2016. These increases range from marginal in the case of passenger locomotives (2%) to highly significant in the case of passenger light trucks (41%). Growth in the rolling stock of cars, passenger aircraft and intercity buses was significant, ranging from 10 to 13%, while urban transit experienced a very significant gain of 27%.

20 Data amalgamated from: Statistics Canada. Transportation: Key Indicators. (2020). (https://www150.statcan.gc.ca/n1/en/subjects/Transportation?count=50#data)

21 Data for three of the five modes were unavailable for years prior to 2005.

Figure 8: Canadian Urban Transit Vehicles by Type (2016)[22]

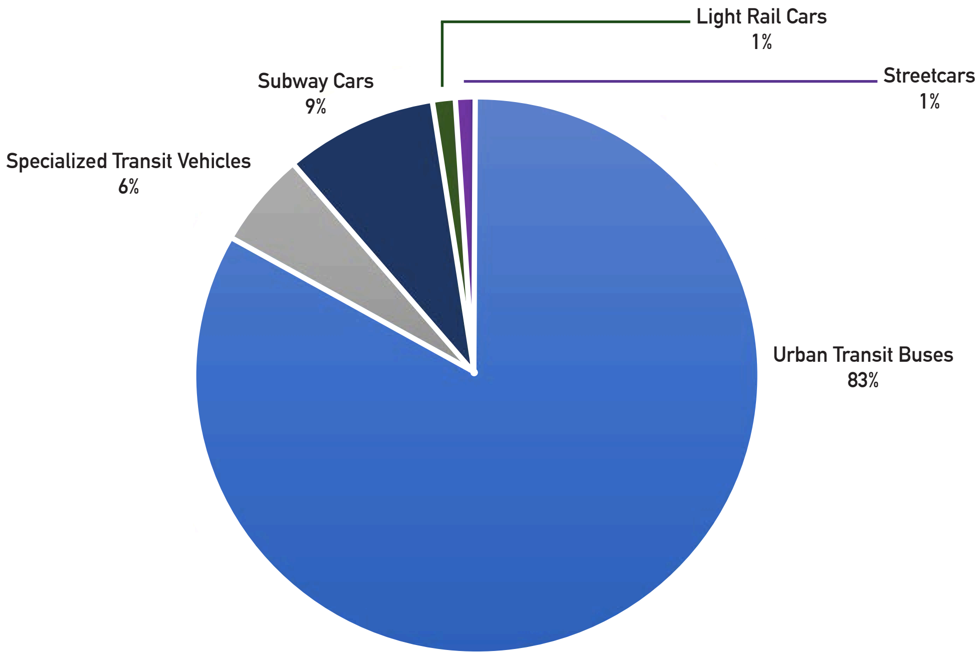


Figure 8 illustrates the fact that a large majority of urban transit continues to be comprised of diesel buses. In terms of energy use in urban transit, diesel provides 82% of total energy, while electricity (subways and light rail) provides 9% and natural gas provides 8%. The use of natural gas in transit buses has been on the rise since 2013, as cities have sought to procure lower-carbon alternatives to diesel. More recently, an increasing number of ZEV buses have been put into service or ordered by municipalities in Canada, with a significant rise in numbers expected , in part as a result of the Government of Canada target of getting 5,000 ZEV buses into service by 2024.

3.3. Cost

Proportionately, Canadian spending on transportation is second only to shelter. While shelter accounts for an average of 29% of total household spending, transportation accounts for 20%, and food for 13%. In 2017 the average Canadian household spent $11,400 on vehicle purchasing and maintenance and $2,100 on transport fuels – a cost increase of 6.7% from the previous year. This is in contrast to the average household spend of $1,274 on all forms of shared transport, including public transit, aviation, intercity bus and rail.[23] On average, Canadians spend roughly seven times as much on passenger vehicles every year than on all other modes of travel combined. In total, the average household spends over $14,300 per year on transportation. A detailed breakdown of total annual transportation costs in Canada is provided below.

22 Data amalgamated from two sources: Statistics Canada. 2020. Transportation: Key Indicators. (https://www150.statcan.gc.ca/n1/en/subjects/Transportation?count=50#data); and Statistics Canada. 2020. Table 34-10-0248-01 Inventory of publicly owned public transit assets, Infrastructure Canada. (https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=3410024801)

23 Statistics Canada. 2018. Survey of Household Spending, 2017. (https://www150.statcan.gc.ca/n1/daily-quotidien/181212/dq181212a-eng.htm)

Table 1: Total Annual Household Expenditures on Transportation in Canada (2018) [24]

Expenditure	Total Cost (millions)
New and Used Vehicle Purchases	$84,438
Fuels and Lubricants	$46,668
Repair and Maintenance (including spare parts)	$29,568
Passenger Vehicle Insurance	$7,678
Parking	$3,270
Other Passenger Vehicle Operation Costs	$2,623
Passenger Vehicle Rentals	$1,315
Taxi and Limousine Fares	$1,340
Passenger Vehicle Sub-total	$176,920
Urban Transit Fares	$4,751
Passenger Rail Fares	$326
Intercity Bus Fares	$1,174
Aviation Fares	$15,666
Water Transport Fares	$498
Other Transport Service Fares	$3,013
Shared Mobility Sub-total	$25,428
Total Household Expenditures on Transportation	$202,348

Annualized vehicle ownership costs in Canada, which include purchase costs, depreciation, fuel, maintenance, insurance, etc., typically range from $9,000 to $13,000, depending on factors such as type of vehicle and mileage.[25] Adult public transit passes, on the other hand, range in costs from roughly $1,750 (in Toronto) to $960 (in Fredericton) per year.[26] It is difficult to estimate the cost of the combination of transit passes, car rentals or vehicle sharing that would create a degree of functional equivalency between a family that owns a car and a family that does not in urban settings across the country, but the large difference in costs suggests that vehicle ownership is likely more expensive for a certain portion of the urban population.

To further inform a discussion on costs related to modal shift options, it is important to determine the average fuel costs per passenger km for each mode of passenger transport in Canada. To do this, the project team gathered data from Statistics Canada and Natural Resources Canada related to the following metrics:

- Total Canada-wide kilometres travelled by mode, by year
- Total passenger kilometres, by mode and year

24 Transport Canada. 2019. Transportation in Canada 2018: Statistical Addendum. Accessible by emailing: TCAnnualReport-RapportannuelTC@tc.gc.ca

25 Canadian Automobile Association (CAA). 2020. Driving Costs Calculator. (https://carcosts.caa.ca/)

26 Cadieux, M. 2019. What a Public Transit Pass Costs in Every Major Canadian City. MTL Blog. (https://www.mtlblog.com/news/what-a-public-transit-pass-costs-in-every-canadian-city)

- Allocation of total kilometres travelled for each fuel, by mode and year
- Total litres of each of each type of fuel used, by mode and year
- Average fuel economy of each type of mode, by fuel and year
- Average cost per litre (or equivalent) of fuel, by year
- Total fuel costs, by mode and year

In the case of passenger cars and light trucks, these metrics were amalgamated to determine the average cost of fuel per passenger kilometre for the year 2016. In the case of intercity bus, passenger rail and domestic aviation transport, the total amount of fuel used in 2016 was available, so the average cost of fuel was multiplied by total fuel used, and then divided by total passenger kilometres.

Figure 9: Cost of Fuel per Passenger km, by Mode (2016)

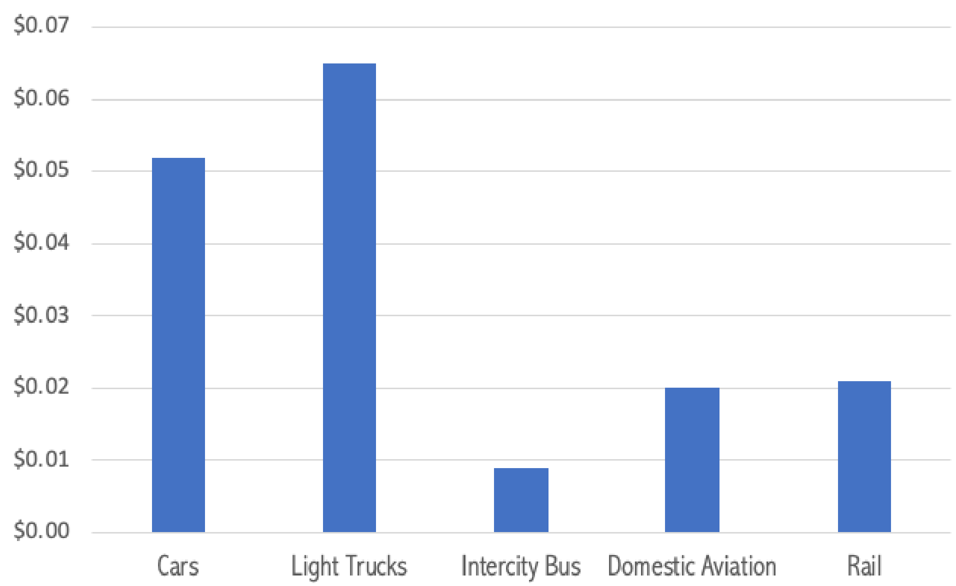


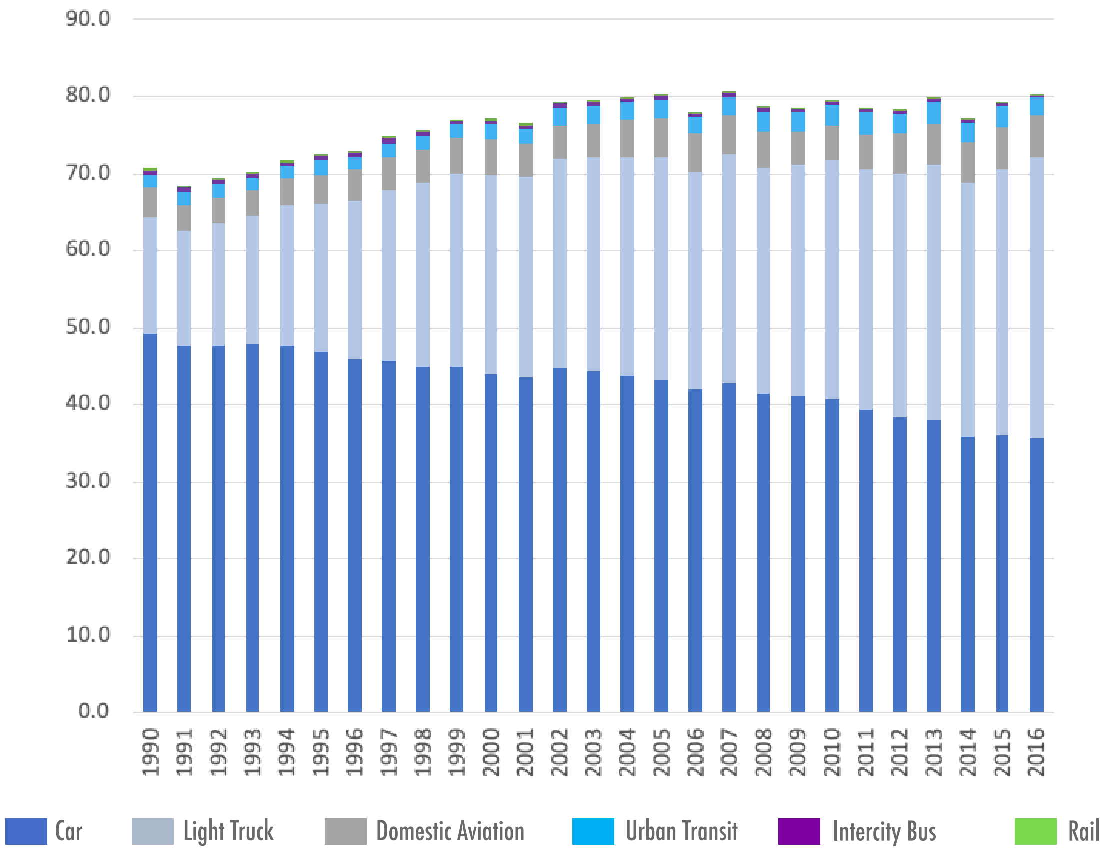
Figure 9 does not include data for urban transit fuel costs per passenger kilometre as data on the fuel economy and ridership of various urban transit vehicle types are unavailable. It should be noted that cost of fuel per passenger km can be highly variable – see Section 4.2.3.

Modal options that are not only low-carbon but that have low fueling costs should be prioritized for action by governments and other transportation stakeholders. This will help to ensure that these options are feasible for as many Canadians as possible, including those with constrained travel budgets.

3.4. Environmental Impacts

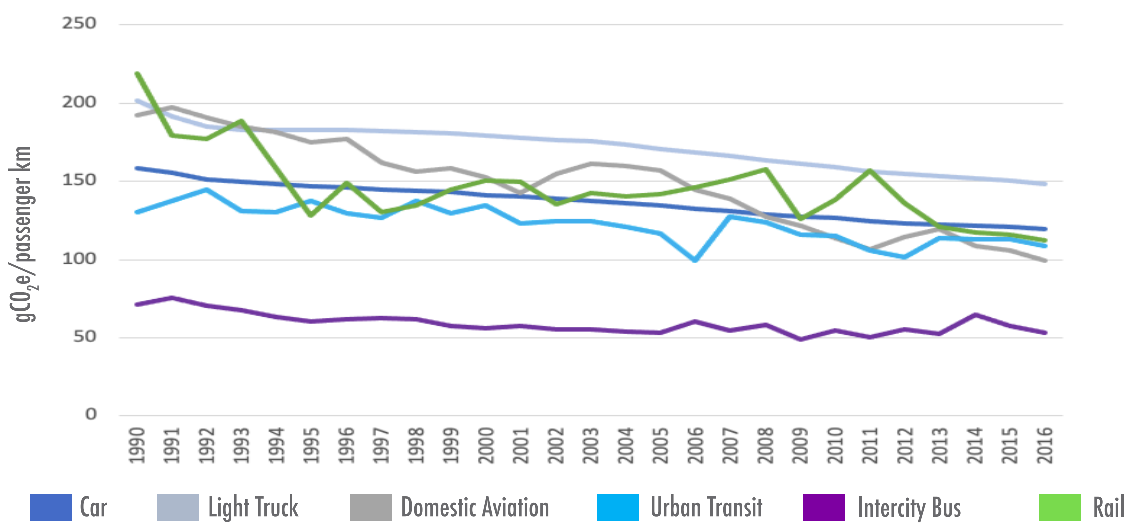
Transportation is responsible for roughly one quarter of all GHG emissions in Canada, and the share of emissions from passenger transport continues to be higher than that of freight, but by a narrowing margin. Recent trends indicate that national emissions from freight transport will surpass those from passenger transport by 2030.

Figure 10: Total GHG Emissions by Passenger Mode in Canada [27,28]



Consistent with the trend seen in total passenger kilometres by mode, 90% of all passenger transportation GHG emissions in Canada result from the use of light duty cars and trucks. It is interesting to note that in 2016, emissions from light trucks (pickups, SUVs and minivans) surpassed those from cars for the first time. Domestic aviation was responsible for approximately 7% of emissions in 2016, while urban transit accounted for 3%. Intercity bus and passenger rail each accounted for less than 0.5%.

Figure 11: GHG Emissions per Passenger km in Canada (1990-2016)



27 Data amalgamated from: Statistics Canada. Transportation: Key Indicators. (2020). (https://www150.statcan.gc.ca/n1/en/subjects/Transportation?count=50#data)

28 Note that GHG emissions for urban transit vehicles exclude emissions from electricity generation.

Data for Figure 11 reflect the nationally-averaged numbers from Statistics Canada and Natural Resources Canada, (supported by comparable datasets from other jurisdictions[29]), however average numbers require further insight to be informative to a modal shift discussion. Modal GHG intensities can be highly variable for the following reasons

Car and light truck: impacted by vehicle speed and road congestion
Urban transit: impacted by occupancy and capacity
Aviation, intercity bus and passenger rail: also impacted by occupancy

Urban Transit

Theoretical energy efficiency would dictate that emissions per passenger kilometre should be significantly, rather than marginally, below that of personal vehicles. That logic holds true during morning and evening peaks in commuter travel and during normal weekday business hours. On evenings and weekends, however, transit vehicles tend to have far lower occupancy rates, and as a result emissions intensity per passenger kilometre can spike to levels well above those of personal vehicles.[30] In smaller, less dense communities, these numbers are further exacerbated due to low average vehicle occupancy rates. In general, diesel transit buses emit approximately 2,500 g CO_2e per kilometre. With a high occupancy rate of 50 passengers per trip, this would yield an emissions intensity of 50 g CO_2e per passenger kilometre (comparable to numbers for intercity buses). However, at an occupancy rate of 5 passengers, the emissions intensity of the same bus would be approximately 500 g CO_2e per passenger kilometre.[31] Average bus speed is also a key determinant of GHG intensity. For example, a bus that travels at an average speed of 10 km/h is likely to have a GHG intensity approximately twice that of a bus travelling at 30 km/h, all other factors being equal (see Figure 12 below). These numbers speak to the need to "right-size" vehicles, plan service schedules, and optimize routes and transit infrastructure to efficiently handle typical passenger loads at specific times.

Air Travel

Air travel is another outlier in the average emissions per passenger kilometre data. At first glance, the data might lead one to assume that air travel is a more efficient option than personal vehicle or public transit use in most travel scenarios. However, airlines must ensure that occupancy rates on flights are high in order to remain profitable. They must also ensure that distances travelled by regularly scheduled flights are sufficient to encourage a minimum threshold of travellers to choose air over ground-based transport. If airlines did offer flights that spanned the relatively short distances typically covered using passenger vehicles, the net emissions intensity of air travel would be significantly higher than it is. This is largely due to the fact that aircraft use a disproportionately high amount of fuel on takeoff, which means that longer distance flights tend to be far more fuel efficient than short haul flights.

29 Federal Aviation Administration, Office of Environment and Energy. 2015. Aviation Emissions, Impacts and Mitigation: A Primer. See Figure 1: Comparison of Vehicle Fuel Efficiency. (https://www.faa.gov/regulations_policies/policy_guidance/envir_policy/media/Primer_Jan2015.pdf)

30 Wang, A, et al. 2018. Automated, electric, or both? Investigating the effects of transportation and technology scenarios on metropolitan greenhouse gas emissions. Sustainable Cities and Society. Vol 40. (https://www.sciencedirect.com/science/article/abs/pii/S2210670718302026)

31 Alam, A, and M. Hatzopoulou. 2016. Deriving Local Operating Distributions to Estimate Transit Bus Emissions Across an Urban Network. Transportation Research Record: Journal of the Transportation Research Board. (https://journals.sagepub.com/doi/10.3141/2570-07)

Cars and Light Trucks

National data on car and light truck emissions intensity reveal numbers that are far lower than those which would be expected for passenger vehicles in cities. In major cities such as Toronto, Montréal, and Vancouver, congestion and idling increase emissions intensity significantly, up to a range of 250 to 300 g CO2e per kilometre for each vehicle. And because the average passenger vehicle occupancy in Canada is only about 1.15, emissions per passenger kilometre remain very high in cities.[32] Indeed, emissions intensity numbers for major cities differ greatly from the nationally-averaged numbers presented in Figure 12, which speaks to the need for different transportation decarbonization solutions in different parts of the country. While passenger vehicles have become far more fuel efficient on a per-vehicle basis since 2005, the number of these vehicles on Canada's roads has increased significantly in that timeframe – by over 13% in the case of passenger cars, and over 40% in the case of passenger trucks.[33]

32 Wang, A, et al. 2018. Automated, electric, or both? Investigating the effects of transportation and technology scenarios on metropolitan greenhouse gas emissions. Sustainable Cities and Society. Vol 40. (https://www.sciencedirect.com/science/article/abs/pii/S2210670718302026)

33 Natural Resources Canada, Office of Energy Efficiency. Transportation Sector: Canada. Table 32: Car Explanatory Variables. 2019. (http://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/showTable.cfm?type=CP&sector=tran&juris=ca&rn=32&page=0) Natural Resources Canada, Office of Energy Efficiency. Transportation Sector: Canada. Table 60: Truck Explanatory Variables. 2019. (http://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/showTable.cfm?type=CP&sector=tran&juris=ca&rn=60&page=0)

Due to the above-mentioned variability in passenger GHG intensity, which depends on factors such as local conditions, trip length and vehicle occupancy levels, it is more effective to inform this study by exploring ranges of GHG intensity by mode which account for these factors. Such ranges are captured in Figure 12, below, which draws from a global database compiled by the IPCC.

Figure 12: Global Average GHG Emissions Range per km for Passenger and Freight Modes[34]

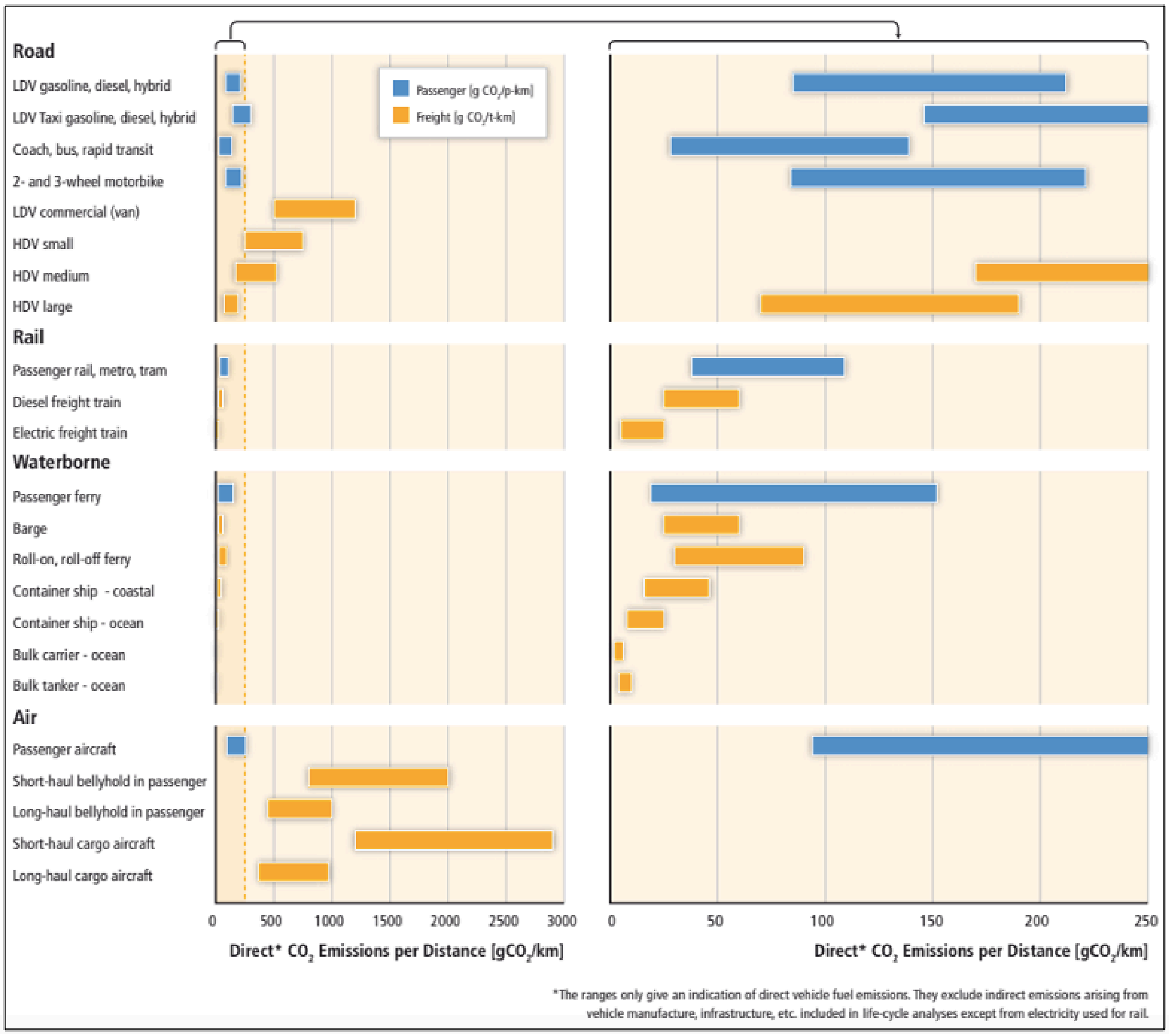


Figure 12 captures the fact that under optimal circumstances, modes which tend to be carbon intensive such as aircraft or passenger vehicles can actually be less carbon intensive than modes that tend to be low-carbon (e.g., urban transit, intercity bus and rail) when low-carbon modes are used in less-than optimal circumstances. This speaks to the need to engage in modal optimization assessment on a case-by-case, area-specific basis rather than at a broad systems level.

34 Sims R et al. 2014. Chapter 8: Transport. In: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Edenhofer, O. et al (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. (https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_chapter8.pdf)

3.5. Movement of Goods

Canada's freight transportation system consists of three corridors: Western, Continental (Windsor to Quebec City), and Atlantic Corridor. Each is unique and driven by different trends.

Western Corridor

The Asia-Pacific Gateway Strategies launched both federally and provincially by British Columbia in the mid-2000's were very effective in facilitating trade between Canada and the Asia-Pacific region by enhancing the capacity and efficiency of the Asia-Pacific Gateway and Corridor. Canada's western ports have seen a dramatic rise in traffic as a result. Exports to Asia consist primarily of resources: agricultural products (food), wood and metallic ores; while imports are mostly manufactured goods including machinery and electrical equipment, automobiles and other transportation equipment. The rise in shipping to Asia from British Columbia has led to a similar increase in rail and truck traffic between the ports and other areas of the country. Canada's road and rail infrastructure feed both of BC's major ports: Vancouver and Prince Rupert.

Continental Corridor

This corridor includes the Great Lakes/St. Lawrence inland waterway system, which connects the industrial heartland of central North America with international shipping destinations. It includes the Port of Montréal, the second largest port in Canada and the shortest direct route to European markets.[35]

From a surface transportation perspective, this corridor (Windsor to Quebec City) is the busiest in terms of truck traffic and is a gateway to the U.S. mid-west and northeast. About half of Canadian exports by truck are exported through border crossings in this corridor.[36]

Atlantic Corridor

The Atlantic ports have seen consistent traffic over the past decade, primarily exports of petroleum and seafood products and imports of container-based shipments through the Port of Halifax. From a surface perspective, this is the least busy of the three corridors.

Air Transportation

Freight transported by air is distinct from that transported by land or sea both in nature and routes travelled. Air transport is independent of transportation corridors and focused on high value, low weight goods.

35 www.portofmontreal.com
36 https://www.tc.gc.ca/eng/policy/transportation-canada-2016.html#western-corridor

Key Trends in the Movement of Freight

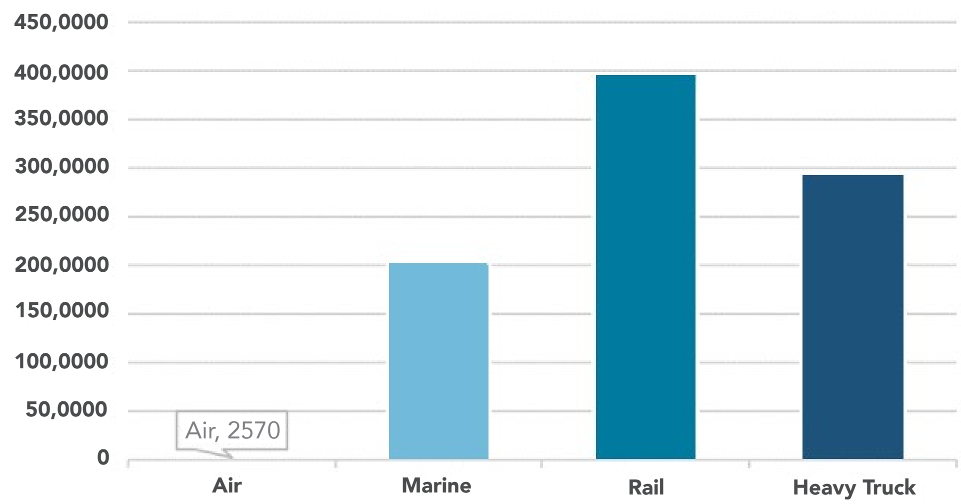
An analysis of the data around the movement of goods in Canada in recent decades reveal some notable trends.

- The quantity of freight is increasing. The Canadian population and economy are growing, leading to increased retail spending. Simultaneously, online shopping has exploded in popularity in recent years: from 1997 to 2017, e-commerce sales increased by an astounding 3,000%.[37] This has driven a significant increase in freight.
- The distance that freight travels is increasing. The globalization of supply chains has increased the average distances that both base materials and finished goods are traveling.
- Delivery timelines are getting shorter. E-commerce shoppers have grown to expect faster delivery times. Further, inventory management has increasingly shifted to just-in-time delivery (JIT), forcing suppliers to ensure delivery within tight timelines while continuing to maintain low pricing. This has not just increased the rate of flow of freight, it has altered the landscape of freight transport and delivery. There has been an increase in regional distribution hubs such as in Mississauga, Cornwall and Calgary. These regional hubs offer convenient access to transportation infrastructure, along with the space to develop large scale facilities.

3.6. Usage

On a tonne-km basis, rail (44%) and heavy truck (33%) are the most prevalent methods of transporting freight domestically, while marine is primarily used for overseas exports and imports. Air is used significantly less than the other three modes.

Figure 13: Movement of freight by mode, 2016



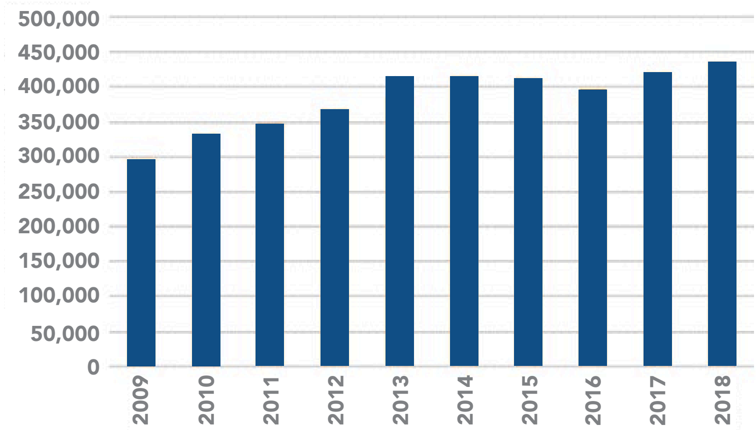
37 *"How is the Growth of E-Commerce Affecting Trucking?"*, 2019 https://www.truckinginfo.com/324451/how-is-the-growth-of-e-commerce-affecting-trucking

Rail

Rail is predominantly used to transport freight: 98% of GHG emissions reported in the National Inventory Report for rail are as a result of transportation of freight, and 2% from the transportation of passengers.[38] Over two thirds of the freight transported by rail travels within Canada, largely interprovincially (this includes freight travelling to and from ports for export). The remaining 32% is primarily bound for the United States, with a small proportion of exports continuing to Mexico.

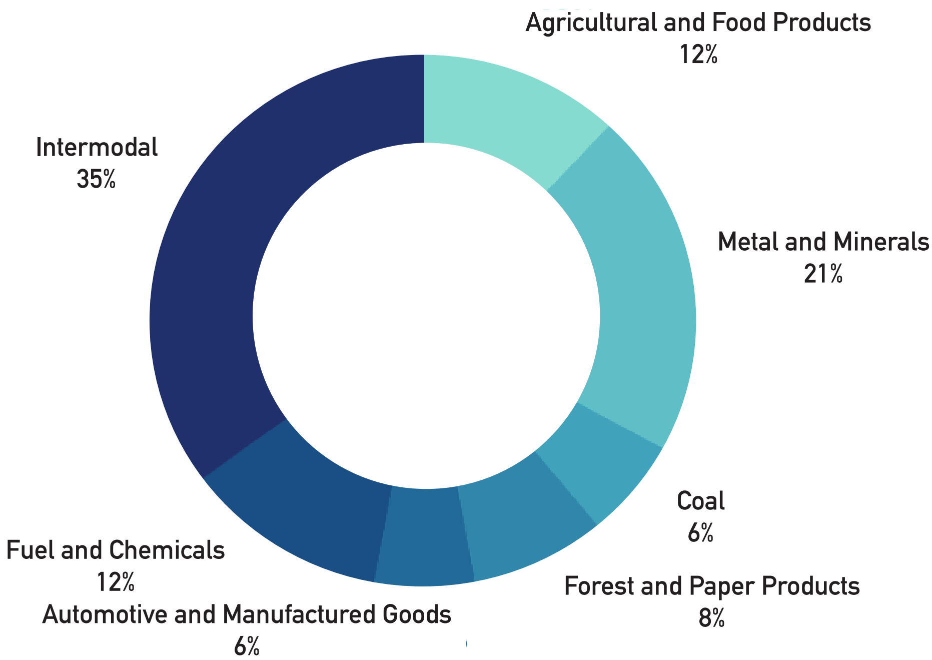
Freight shipments by rail are increasing year over year.

Figure 14: Rail Freight, million tonne-kilometres 2009-2018[39]



Freight moved by rail is primarily comprised of bulk commodities and an increasing share of shipping containers (intermodal freight).

Figure 15: 2016 Rail Freight Profile, based on carloads[40]



38 National Inventory Report 1990-2016: Greenhouse Gas Sources and Sinks in Canada
39 Based on data from Statistical Addendum 2018.
40 https://www.railcan.ca/101/delivering-canadas-amazing-products-to-the-world/

The sector is dominated by two freight rail companies: Canadian National and Canadian Pacific. Rail is used most in Ontario and Alberta, and very little in the Atlantic provinces. There is no rail service in Newfoundland or Prince Edward Island, and very limited rail service in the North.[41]

Despite the increase in tonne-kilometres reflected in Figure 9, the number of freight cars and the length of track operated have both decreased. Conversely, the number of locomotives has increased over the same period (Table 2), as has the tonnage shipped and distance travelled (Table 3).[42] This is as a result of Precision Scheduled Railroading, a strategy developed to transport freight using a more simplified, direct line of transport using trains that operate on fixed schedules rather than based on a minimum number of loaded cars.

Table 3: Changes to rail infrastructure and equipment

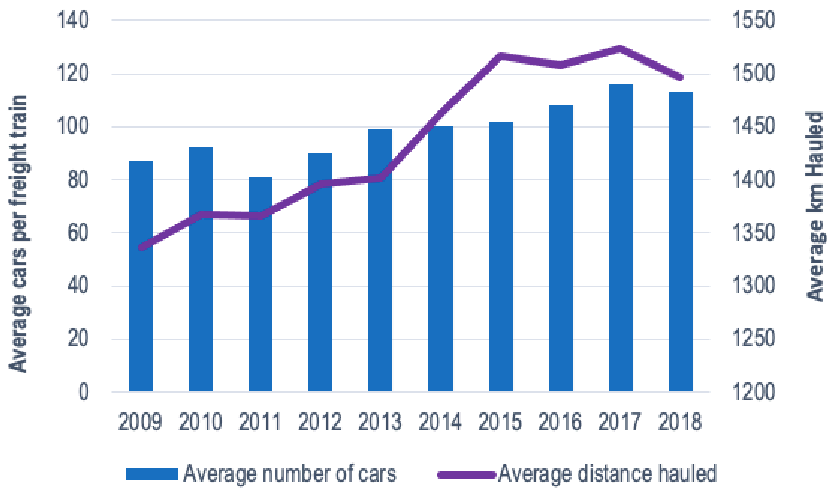
Year	2009	2017	2018
Total km of track operated	45,323	45,572	41,757
Freight cars	76,000	55,000	59,000
Locomotives	2,742	3,177	3,764

Table 4: Tonnage and total km of freight shipped by rail

Year	2009	2017	2018
Freight train km (thousands)	95,877	104,660	110,354
Tonnes originated (thousands)	244,062	358,998	341,674

Consistent with the overall growth in rail, the average number of cars per train is increasing, as is the average distance hauled.

Figure 16: Average number of cars and distance hauled for freight shipped by rail, 2009-2018



41 Note that the shares for freight rail by province in Figure 12 are based on fuel use. This approach may overrepresent the share for British Columbia and Alberta, as the mountainous terrain results in additional fuel consumption per km.

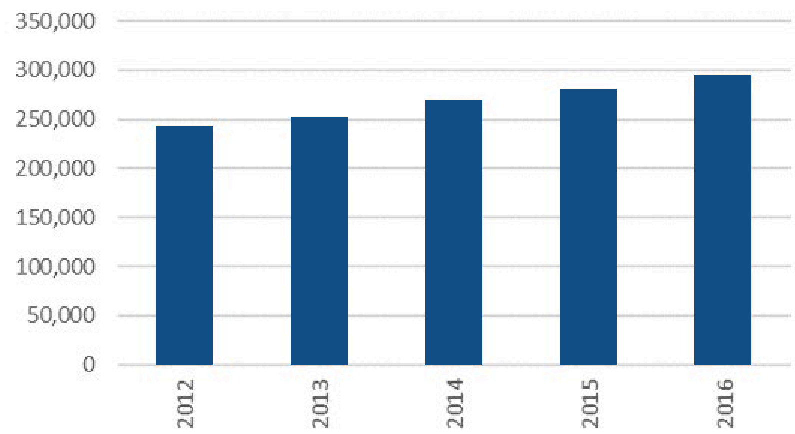
42 Rail statistics from Railway Association of Canada, Rail Trends 2019

Freight Trucks

While rail transports more freight on a tonne-km basis, for-hire trucking accounts for over 90% of the total shipments made in Canada.[43] Canadian for-hire trucking companies are concentrated in Ontario (42.5%), Québec (18.2%), Alberta (14.4%), and British Columbia (13.5%). Within the trucking industry, there is significant variation between freight service providers in terms of size, operational scope, distances traveled (long-haul, drayage or last mile delivery) and type of goods moved. There are large, vertically integrated companies, mid-size firms private fleets and independent owner-operators. In December 2018, there were approximately 208,000 trucking businesses registered in Canada, 67% of which consisted of a single owner-operator.

As for rail, freight shipped by truck also continues to increase year over year (Figure 17).

Figure 17: Truck Freight, million tonne-kilometres, 2012-2016



Over three quarters of the total tonnage of freight transported by truck is moved within provinces (Table 3), which speaks to the fact that nearly all freight, regardless of the primary shipping mode, will travel by truck for a portion of the journey.

Table 4: Volume of Freight Transported by Canadian For-Hire Carriers, millions of metric tonnes[44]

	2012	2013	2014	2015	2016
Domestic					
Intraprovincial	494.4	518.3	550.2	545.3	579.0
Interprovincial	78.5	74.6	78.0	81.9	74.0
Total Domestic	**572.9**	**592.9**	**628.3**	**627.2**	**653.0**
International					
Exports	45.6	53.0	55.8	55.3	68.2
Imports	43.4	44.8	46.5	46.7	34.3
Total International	**89.0**	**97.8**	**102.3**	**102.0**	**102.5**
TOTAL	**661.9**	**690.8**	**730.6**	**729.2**	**755.5**

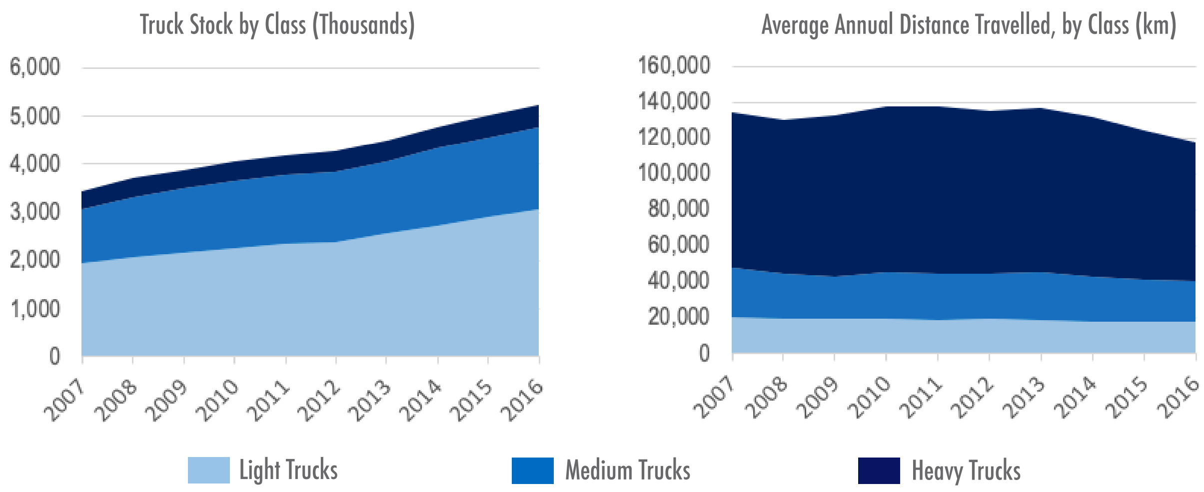
43 Commodity flows by mode in Canada: Canadian Freight Analysis Framework, 2016. Statistics Canada, 2019. https://www150.statcan.gc.ca/n1/en/daily-quotidien/190315/dq190315c-eng.pdf?st=6ZLUN4dF

44 Statistical Addendum 20189, Table RO8

Freight trucks are categorized by gross vehicle weight as heavy (more than or equal to 14,970 kg) medium (3,856 to 14,969 kg) or light duty (up to 3,855 kg). Heavy trucks are widely used to move freight long distances, while medium and light duty trucks are often used for shorter distances. including within and between interurban areas. Medium- and light -duty truck fleets are also commonly used in the movement of services.

The number of trucks in all classes has been steadily increasing, while the distance traveled per truck has decreased slightly.

Figure 18: Stock of trucks in annual distance travelled, by class



The American Transportation Research Institute attributes these trends to the rapid growth of e-commerce and the decentralization of distribution networks. While the number of truck trips is increasing, average trip lengths are decreasing.[45]

Marine

In 2018, 342.1 million tonnes of cargo were handled at the seventeen Canada Port Authorities, up 2% from the prior year.[46] The three largest ports (Vancouver, Montréal and Prince Rupert) account for two thirds of the Canada Port Authorities revenue.[47]

Marine transportation is largely geared toward international exports: in 2011, the last year for which data is available, international shipping represented 82% of the total tonnage shipped via marine vessel from Canadian ports. It is key to international trade, accounting for 20% of exports to the US and 95% of exports to other countries.

The three key marine transportation corridors (Pacific, Atlantic and the Great Lakes/St. Lawrence inland waterway system) all support both international and domestic shipping, however they have unique characteristics:

- The Pacific ports such as Vancouver and Prince Rupert are strategic hubs for international trade with the Asia Pacific Region. Tugs and barges service the islands and more remote coastal communities that are less easily accessible by road or rail.

45 "How is the Growth of E-Commerce Affecting Trucking?", 2019 https://www.truckinginfo.com/324451/how-is-the-growth-of-e-commerce-affecting-trucking

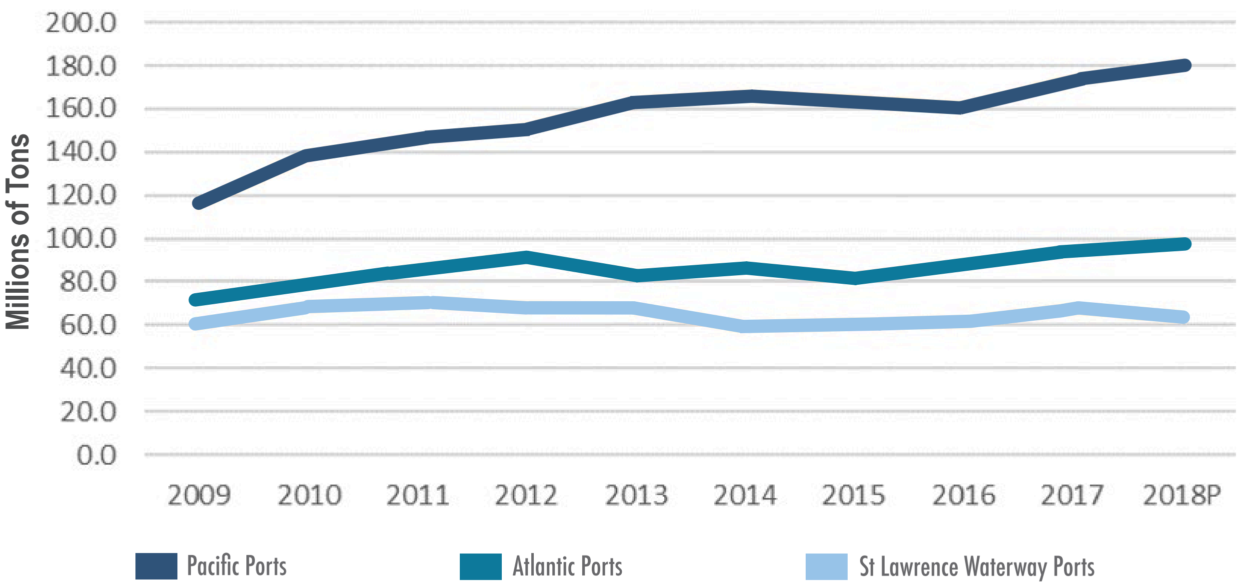
46 National Inventory Report 1990-2016: Greenhouse Gas Sources and Sinks in Canada

47 https://www.tc.gc.ca/eng/backgrounder-canada-port-system.html

- The Atlantic ports such as Halifax and Saint John also primarily support import and export traffic, with a smaller share of domestic shipping along the east coast.
- The Great Lakes/St. Lawrence inland waterway system connects Ontario and Quebec with several U.S. states as well as overseas markets via the Atlantic Ocean. This is an important trade corridor for both domestic and international shipping, with fifteen major international ports and over fifty regional ports on both sides of the Canada - U.S. border. Due to ice cover in many areas of the waterway the winter months, the corridor operates seasonally, typically from about late March to late December.

Since 2009, traffic at the pacific ports has increased significantly as trade with Asia has increased. The ports along the Great Lakes/St. Lawrence inland waterway system have seen a smaller increase, while Atlantic ports have remained consistent.

Figure 19: Canadian marine traffic (2009-2018)



The significance of the coastal corridors lies not in the opportunity for modal shift, but in the fact that the ports represent a key destination of road and rail freight traffic as they carry goods bound for export to the ports. The Great Lakes/St. Lawrence inland waterway system represents the best opportunity for shifting freight from road and rail to the more efficient marine vessels. It is described further below.

Great Lakes/St. Lawrence Waterway

In 2017, 185 million tonnes of freight were handled at Canadian ports on the Great Lakes/ St. Lawrence inland waterway system.[48] Two thirds of this freight was handled at Quebec ports, including the Port of Montréal, the second largest Canada Port Authority.

48 Economic Impacts of Maritime Shipping in the Great Lakes – St. Lawrence Region, Martin Associates, 2018. https://www.marinedelivers.com/wp-content/uploads/2019/01/EcoImp-e-Web-FullReport.pdf

Table 5: Freight handled at Canadian ports on the Great Lakes/St. Lawrence inland waterway system

Commodity	Tonnage Handled at Canadian Ports (1000 tonnes)
Containers	13,819
Steel	2,629
General cargo	3,334
Iron ore	52,872
Grain	26,275
Stone/ aggregate	13,633
Cement	3,205
Salt	10,803
Other dry bulk	15,528
Liquid bulk	37,586
Coal	5,549
TOTAL	**185,233**

Marine Fleet

There is little information to characterize historical changes in Canada's marine fleet. A recent snapshot of the fleet is provided in Table 6.[49]

Table 6: Canada's marine fleet, 2018

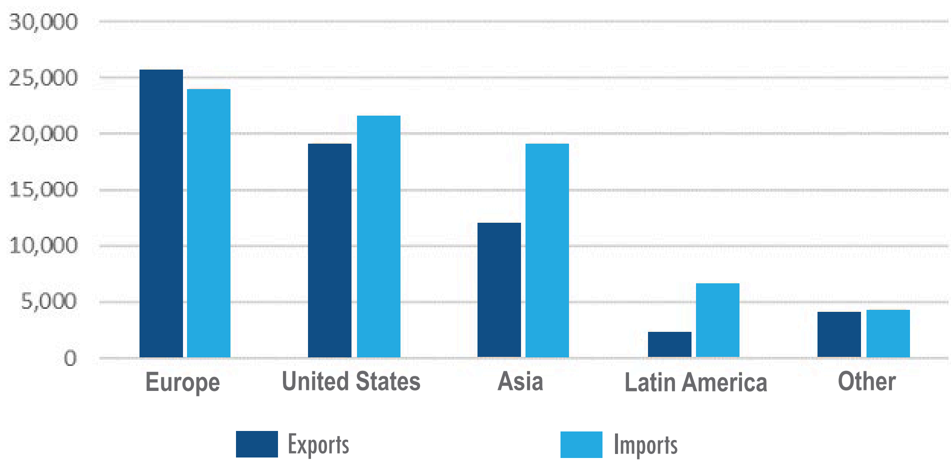
Type of Vessel	Count in 2018
Commercial fleet (1000 gross tonnage and over) • Dry Bulk Carriers • General cargo • Tanker	113
Barges (15 gross tonnage and over)	1,876
Tugs	484

49 Transportation in Canada 2018, https://www.tc.gc.ca/documents/Transportation_in_Canada_2018.pdf

Air

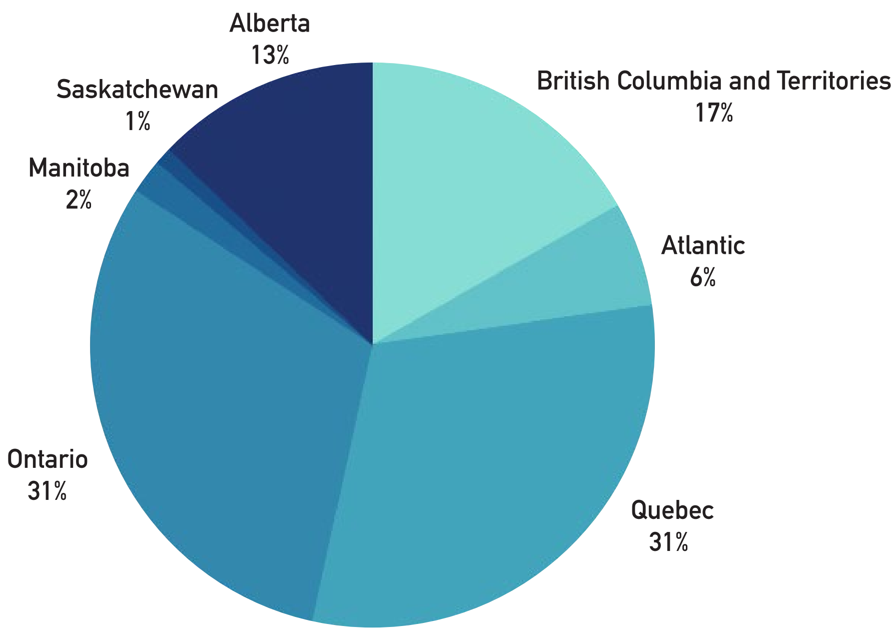
Due to it's high cost, freight shipment by air tends to be limited to low weight, high value freight. In 2018, less than one million tonnes of cargo were transported via this mode.[50] Thirty five percent represented domestic shipments, 15% was being shipped to or from the United States, and the remaining half was being shipped to or from other international destinations. Based on dollar value, international shipments by air comprise 45% exports and 55% imports, with the majority of goods being shipped to/from Europe and the United States.

Figure 20: Exports and Imports by Air (2018) in millions of dollars



Freight shipment by air is used most in Ontario and Quebec. Notable is the relatively high share in the Northern territories, where freight shipment by air is often the only choice due to minimal road and rail infrastructure in many areas, along with climate-related limitations of other modes.

Figure 21: Air Shipment of Freight: Shares by Province/Region



50 Statistical Addendum 2018, Table A16

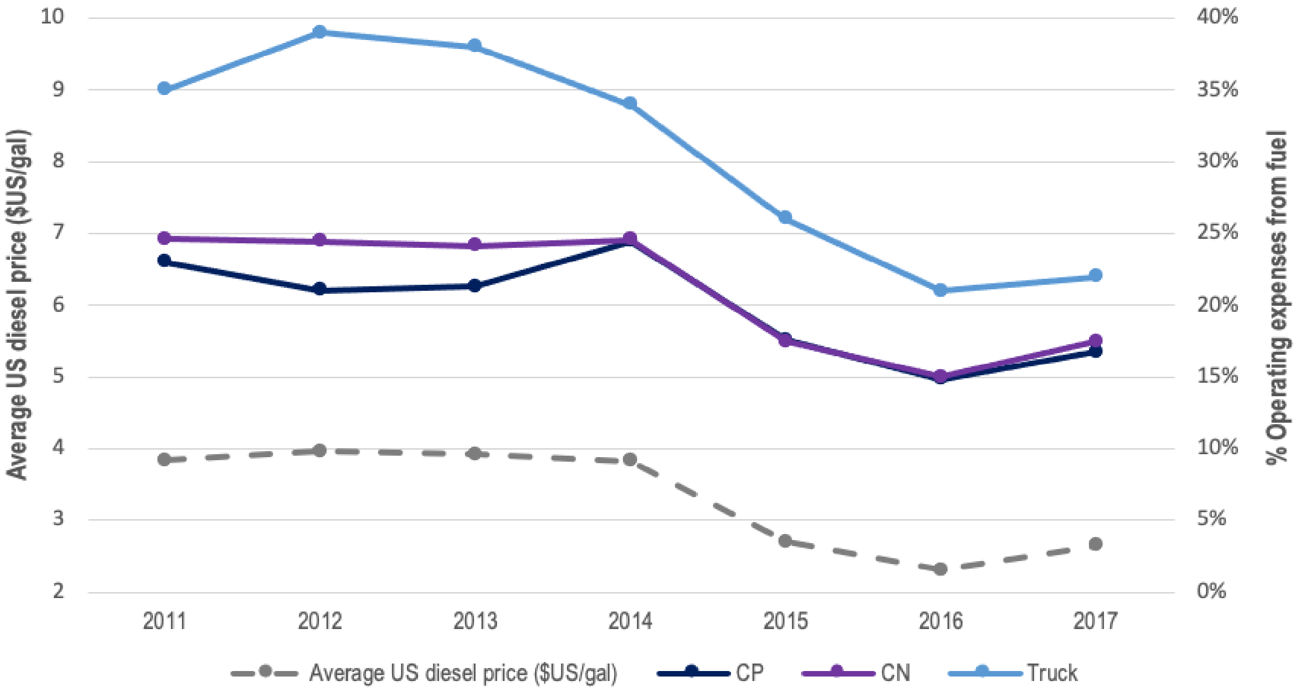
3.7. Cost

From a modal shift perspective, there are two important ways to view cost. The first is to consider cost from the perspective of the type of investment that would be required to increase modal share – e.g. infrastructure and equipment costs where new infrastructure and equipment would enable modal shift. The second is the cost from the perspective of the entity paying for shipment; the cost that factors into modal choice for entities paying for the transportation of freight. Publicly available data for each of these types of costs is extremely limited as it is generally considered proprietary due to competitiveness issues.

There is no data to inform a cost analysis of marine or air freight.

Some information may be inferred with regards to surface shipping. Both rail and truck operating costs are sensitive to fuel price but trucking more so. Figure 18 provides a comparison of the proportion of operating costs from fuel consumption for truck and rail based on US data published by the American Transportation Research Institute (APRI)[51] and CN and CP in their annual reports.[52]

Figure 22: Operating cost sensitivity to fuel price for truck and rail



This result is not surprising given that trucking consumes more fuel per tonne.km of freight shipped than rail. However, it may become an important consideration from a modal shift perspective with rising carbon prices in Canada. Most long-term contracts for freight shipping, either truck or rail, have a provision for fuel surcharges, meaning that the price of shipment is fixed to a benchmark fuel cost and then additional fuel costs are flowed through to the shipper. Again, details of these contracts are not publicly available, but the higher apparent volatility of trucking operating costs with respect to fuel price suggests that the shipping distance at which rail becomes cost competitive with truck will decrease. A more fulsome discussion of the relationship between shipping distance and cost can be found in Section 4.2.1.

51 American Transportation Research Institute, An Analysis of the Operational Costs of Trucking: 2018 Update. http://truckingresearch.org/wp-content/uploads/2018/10/ATRI-Operational-Costs-of-Trucking-2018.pdf

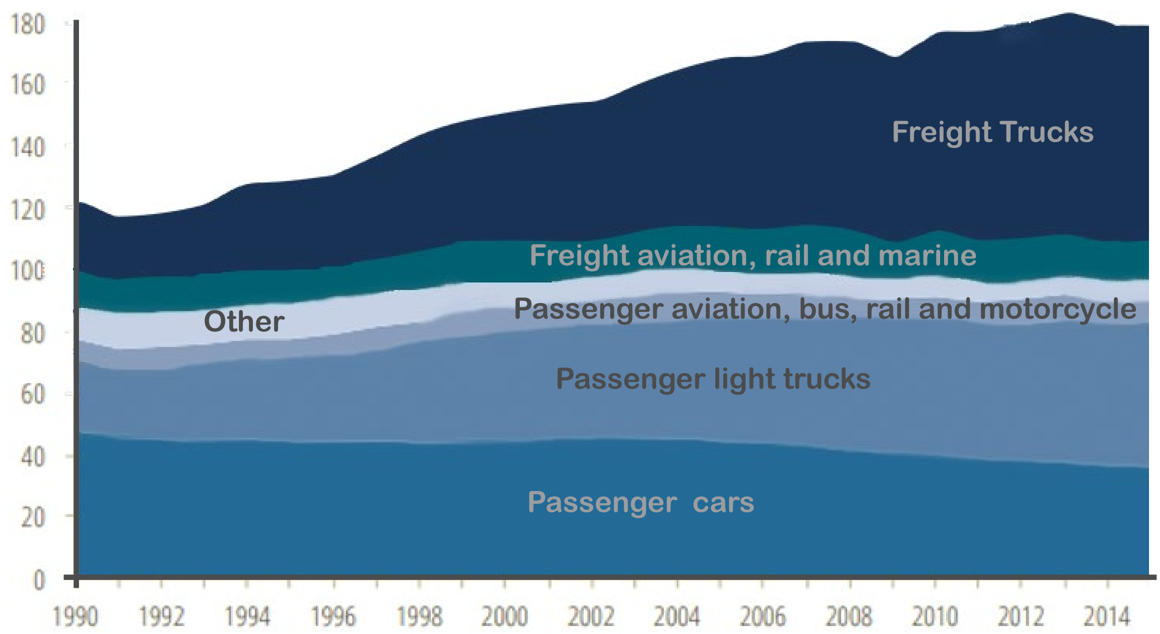
52 Accessible at https://www.cn.ca/en/investors/reports-and-archives/?Category=Annual%20Report and https://investor.cpr.ca/financials/default.aspx

3.8. Environmental Impacts

Total GHG Emissions

Trucks represent the greatest source of transportation emissions in the movement of goods (see Figure 19). GHG emissions from the movement of freight trucks has more than doubled in the past three decades.

Figure 23: Transportation GHG Emissions by Source



GHG Emissions Intensity

GHG emissions intensity for freight is reported per revenue tonne km (RTK). One RTK represents one tonne of freight moved one kilometre and is inclusive of GHG emissions incurred through the movement of empty freight vehicles.

Air has the highest GHG intensity followed by freight trucks rail and marine. Similarly to the GHG intensity discussion in the movement of people, GHG intensity in freight is multi-factoral and dependent on the type of goods shipped (low density goods tend to be more GHG intense as they require higher volumes of cargo space), cargo fullness, age and model of equipment etc. The following discussion looks at average GHG intensities, with data gaps in the Canadian context preventing a more detailed assessment of potential ranges.

Air

GHG emissions from the movement of freight by air have remained constant for the last several years, despite a slight rise in tonne-km of freight transported. This reflects a historical trend of increasing aircraft efficiency.[53]

53 Fuel Efficiency Trends for New Commercial Jet Aircraft: 1960 to 2014, ICCT 2015 https://theicct.org/sites/default/files/publications/ICCT_Aircraft-FE-Trends_20150902.pdf

Table 7: Air freight GHG intensity, 2007-2016

Year	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
GHG Intensity ($g\ CO_2e$/tonne-km)	200.3	165.8	184.3	191.8	180.8	175.2	176.0	168.4	175.1	155.6

Freight Trucks

Data in Canada on GHG intensity per RTK tends to be poor given the large number of companies and broad range in truck models and ages. Table 8 provides truck GHG intensities for heavy duty trucks from a variety of sources.

Table 8: Truck emission intensity factors (g CO2e/tonne-km)

Data Source	Value	Methodology
GHGenius v4.03a	107.23	Data on the energy intensity of road freight in Canada is published as part of NRCan's energy efficiency trends analysis tables. These are based on a survey of Canadian truck owners/operators in 2000. Respondents provided an estimate of km travelled and fuel consumption.
Transport Canada, Vehicle Use Study (2014 data)	125.12	Only study to perform electronic monitoring of fuel consumption, speed, distance travelled and other parameters in Canada (most others use self reported data). The average speed of the trucks monitored appears low for a truck going a long distance on the highway (35 km/h).
US EPA (2013 Data)	100.27	US DOE Transportation Energy book and Federal Highway Administration data.

Rail

While the usage of rail for transport of freight increased by 10% from 2007 to 2016, GHG emissions intensity per RTK decreased by 12%, as illustrated in Table 9.

Table 9: Freight rail GHG intensity, 2008-2017[54]

Year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
GHG Intensity ($g\ CO_2e$/RTK)	17.90	17.08	16.59	16.40	15.97	15.15	14.61	14.61	14.02	14.14

Marine

A 2013 study commissioned by The Great Lakes Seaway Partnership in 2013 estimated that the GHG intensity of vessels travelling through the Great Lakes/St. Lawrence inland waterway system[55] was 11.5 gCO_2e/tkm in 2010, and projected that this would decrease to an estimated 7.7 gCO_2e/tkm by 2025 based on renewal of the fleet.

54 Rail Trends 2019, Railway Association of Canada https://www.railcan.ca/resources/

55 Environmental and Social Impacts of Marine Transport in the Great Lakes- St. Lawrence Seaway Region, Research and Traffic Group 2013 https://www.marinedelivers.com/wp-content/uploads/2018/12/Environmental-Benefits-Study-Full-Report.pdf

4. Alternatives to Currently Prevalent Modes

4.1. Factors that Influence Modal Choice: Movement of People

Wide geographic expanses within and between cities in Canada mean that people tend to spend a lot of time travelling to access services and amenities for both work and leisure. This being the case, and due to an historic abundance of low cost, energy dense petroleum products, Canada's infrastructure was built to prioritize the use of privately-owned passenger vehicles. As such, Canadians overwhelmingly choose their personal vehicles over other modes of transportation. Changing this will require a fundamental shift in how cities and inter-city corridors are planned.[56]

As of 2016, 74% of Canadian workers commuted to and from work in single-occupancy cars or trucks.[57] Discouraging these types of travel patterns is important from human health and quality of life perspectives as well as for the mitigation of climate change. Strategies undertaken by urban and transportation planners in Canada to accomplish this tend to fall into two categories: land use strategies (e.g., walkable neighbourhoods, mixed-use development, and transit-oriented development) and low-carbon transportation strategies (e.g., complete streets, congestion pricing, low-emission zones, car-pooling and active transportation infrastructure, and public transit enhancements). At their core, these strategies are both aimed at facilitating shifts to less carbon-intensive modes of travel.[58]

It is integral to note that modal shifts which may be feasible in certain parts of the country may not be feasible everywhere. The differences between transportation options in rural and urban Canada are very stark. Rural areas are notable for having less congestion than cities, with fewer stops and starts, and higher average road speeds, which results in better fuel economy than urban driving. However, many rural areas have limited or no access to shared mobility options such as public transit and tend to have long distances between destinations. This turns many rural Canadians into "car captives" with no viable alternatives to a personal vehicle. Rural Canadians tend to log far more kilometres annually than their urban counterparts, and thus tend to pay more in transportation costs.

Urban Canadians have a unique set of transportation pros and cons. Pros tend to include easy access to a variety of shared mobility options, from public transit to aviation, intercity bus and rail, as well as short distances between destinations. These benefits provides urbanites with the option to use low-cost and low-carbon modes if they choose to. The cons around mobility in urban centres include congestion and slow road speeds (which causes fuel economy to spike), over-crowded or under-serviced shared mobility, high parking costs and limited parking availability, and high levels of near-road air pollutants.

Prioritizing modal shift activities where over 80% of Canadians live and where different mobility options are available is likely the most feasible approach to modal shift with the highest GHG reduction impact. For rural Canadians, reducing the carbon intensity of travel

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56 Impacts on Emissions, Air Quality, Population Exposure and Health Associated With Modal Shifts in Personal Travel Options – A Review, by Scott, D.M. for Health Canada, March 2018.

57 Statistics Canada. Census Profile, 2016 Census. 2018. (https://www12.statcan.gc.ca/census-recensement/2016/dp-pd/prof/index.cfm?Lang=E)

58 Impacts on Emissions, Air Quality, Population Exposure and Health Associated With Modal Shifts in Personal Travel Options – A Review, by Scott, D.M. for Health Canada, March 2018.

is more likely to be focused on switching to more fuel efficient vehicles (or even a ZEV), vehicle downsizing/right-sizing, and engaging in behavioural changes such as car-pooling or using active transportation wherever possible.

4.1.1. Observable Trends

Determining which factors have the biggest impact on Canadians' choice of mode of transport is a critical step when deciding which types of lower-carbon alternatives to support. These factors vary by location, age group, and income level, however there are common traits that generally hold true. The following are key considerations for modal shift within the movement of people, as they represent the major determinants of modal choice decision-making in Canada:

- **Cost:** Trips made by mode vary in cost, including visible costs (e.g., fares paid) and invisible costs (e.g., vehicle maintenance). Cost can be subject to perception where there is less of a direct connection between the cost of the individual trip and the amount being paid at the time of the trip.
- **Trip length and time:** For individuals, choosing optimal modes often comes down to a balancing act between trip length and total time required. Most people are willing to walk or bike relatively short distances, but once a certain distance and/or time threshold is reached, will tend to opt for a motorized mode such as passenger vehicles or urban transit. Understanding this balance is important when designing or retrofitting communities with low-carbon lifestyles in mind.
- **Availability:** Modal decisions are limited to available options in a given location.
- **Convenience:** This refers to the ease with which Canadians can utilize various modes, which includes considerations such as schedule, accessibility, comfort, familiarity and versatility.
- **Reliability:** The degree to which a mode can be trusted to ensure that a destination is reached at a required time or within a required timeframe.
- **Capacity:** The ability of infrastructure and associated vehicles to move a given number of people within a given length of time.

As illustrated in Figure 24 and Figure 25, which show significant similarities despite being based on data from two different continents and collected over twenty years apart, distance, or travel time, and convenience are the primary determinants of modal usage for the movement of people. These figures show that a significant portion of travellers will use passenger vehicles by default, even for trips as short as several hundred metres. A large majority of people will not walk or bike more than one kilometre at a stretch, and on average a majority of people require access to a motorized mode of transport for distances greater than 500 metres. This has major implications for how low-carbon transportation systems are planned, suggesting, for example, that in order to optimize usage rates for shared mobility, access points need to be as close as possible to residential areas. Figure 24 further suggests that the threshold at which a significant portion of travellers will begin to opt for air travel over passenger vehicles is in the 600 to 700 kilometre range. As passenger air has more than doubled in popularity since the year this dataset was developed (1995), it can be assumed that this air versus passenger vehicle threshold has decreased in recent years. This is problematic from a GHG perspective, as the per-kilometre carbon intensity of air travel increases as distances flown become shorter.[59]

59 Wihbey, J. 2015. Fly or drive? Parsing the evolving climate math. Yale Climate Connections. (https://www.yaleclimateconnections.org/2015/09/evolving-climate-math-of-flying-vs-driving/)

Figure 24: Modal Split by Passenger Travel Distance (based on data from the United States, 1995)[60]

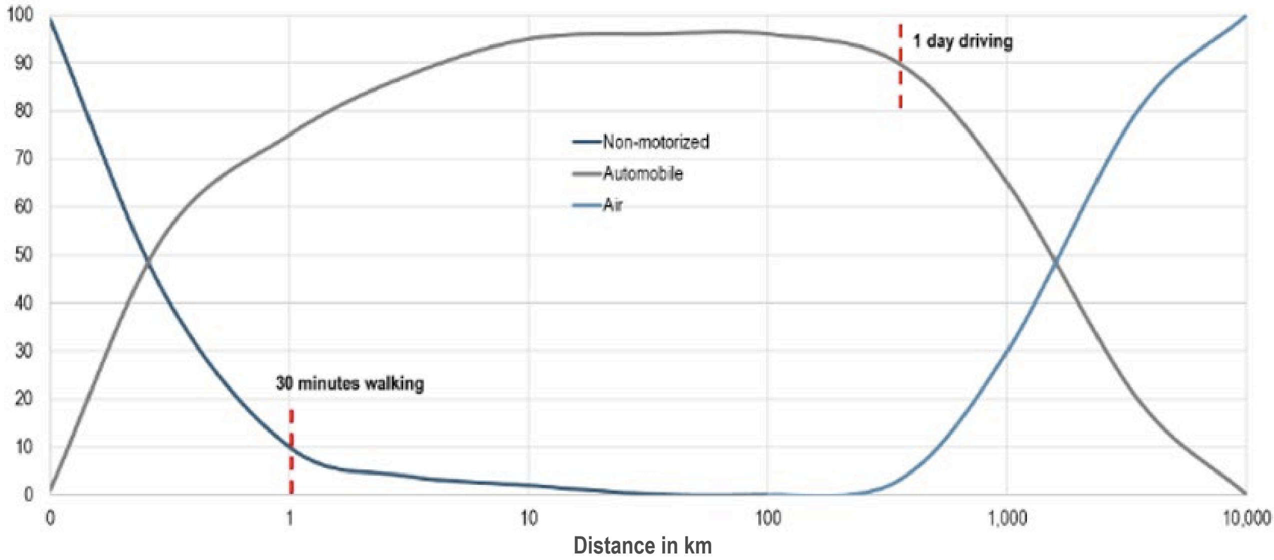
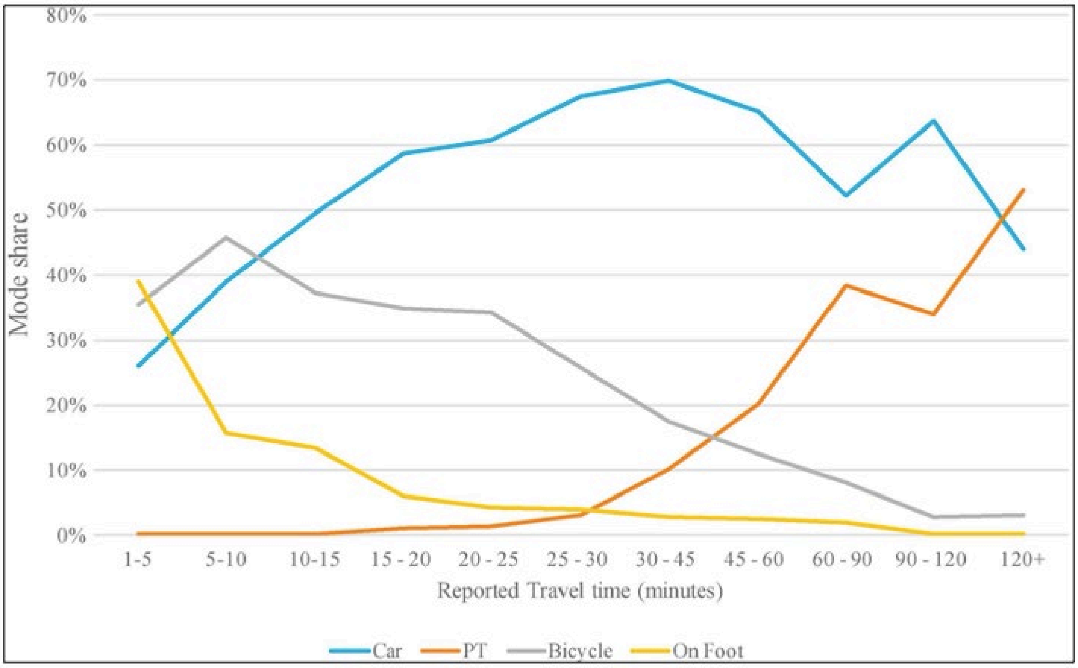


Figure 25: Modal share by passenger travel time (based on data from the Netherlands, 2018)[61,62]



What these figures do not clearly illustrate is the central importance of convenience as a determinant for modal choice between cars and public transportation. The data in Figure 25 suggests that public transportation use increases with travel time, but this likely refers to the increasing role of trains in a European context rather than the trade-off between cars and intracity public transportation. In Canada, passenger vehicles dominate modal

60 Graphic from Rodrigue, J-P (ed) (2017), The Geography of Transport Systems, Fourth Edition, New York: Routledge. https://transportgeography.org/?page_id=1818

61 Graphic from Cycling or walking? Determinants of mode choice in the Netherlands, Ton, Danique et al, 2019 https://www.sciencedirect.com/science/article/pii/S0965856417315525#f0010

62 PolicyLink and Prevention Institute. 2011. Healthy. Equitable Transportation Policy: Recommendations and Research.

convenience with 24-7 access, door-to-door service (no transfers or down time), widespread road and parking infrastructure, cargo and passenger space, ease of refueling and repairs, and personal comfort, with a seat guaranteed on every trip. Outside of the most highly congested urban areas in Canada, cars often present a faster means of transport than city buses or even LRT, streetcar and subway systems that require walking to and from stations and are dependent on schedules that either require planning or some degree of waiting time. Reliability is also a consideration, with cars often perceived as the most reliable way to get to a destination.

Despite the speed and convenience that privately-owned vehicles offer, it should be noted that the cost of ownership is a barrier that cannot be overcome by all citizens. Low-income households often have no options aside from public and active transit when it comes to mobility. As a result, these low-income citizens will tend to spend a longer amount of time to cover a given distance, and will do so without the many conveniences that passenger vehicles offer. Compounding this is the fact that many Canadian urban centres have growing low-income communities on their peripheries due to the ongoing gentrification of historically low-income central neighbourhoods. New or expanded transit development must acknowledge and address the predicament that many low-income communities are in, by prioritizing transit-captive communities for improved service. Expanded shared mobility networks also have benefits that accrue to other demographics, such as children and the elderly.

The modal choice and modal cost[63] data presented in this report suggest that convenience and reliability are likely more important than costs when it comes to the personal mobility of Canadians. The significant price differential between personal vehicle ownership and shared mobility options indicates that Canadians are willing to pay more for a mode that will be at their disposal 24/7. In order for other modes to eat into the user share of personal vehicles, they have to be made more convenient, reliable and available. Infrastructure throughout North America was tailor-made to accommodate passenger vehicles, so progress in shifting travel to lower carbon modes will require targeted investments in shared mobility infrastructure to heighten the convenience, reliability and availability of these modes.

The global best practice case study looking at the City of London, England in Section 5.1 shows that cost can play an increasingly larger role in modal choice decision-making as the costs of using a given mode become prohibitive.[64] However, the London example also shows that a multi-pronged approach that targets multiple decision factors simultaneously can help to facilitate modal shift in a socially equitable and stepwise manner. Because London simultaneously enacted punitive financial measures to deter the use of carbon-intensive modes alongside measures to significantly enhance the value proposition of lower-carbon modes, the commuting public approved of the measures and adapted their travel behaviour accordingly.

A discussion on modal shift opportunities for the movement of people would not be complete without addressing the technological readiness of emerging low-carbon modes. Although they do not represent a modal shift per se, electric passenger vehicles are expected to reach price parity with gas-powered vehicles sometime between 2023 and 2025. ZEVs represent an increasingly viable option for car-captive Canadians (e.g., rural

63 See Section 3.3 for details on passenger modal cost data.

64 The role of cost can also be evidenced through the rising popularity of aviation over the last two decades. Budget airlines and lower fares have contributed to aviation's growth, though other factors such as the global rise of the middle class have also played significant roles in driving this trend.

residents or those engaged in shift work during off-peak hours) to maintain mobility speed and convenience while reducing the carbon intensity of their travel. Three out of the six passenger modes explored in this report are amenable to electrification in the near term (cars, light trucks, and urban transit). These three modes encompass over 90% of total passenger kilometres travelled and total passenger transport GHGs in Canada annually. Each passenger ZEV that replaces a gas-powered vehicle would reduce GHG emissions by an average of between 3 and 5 tonnes per year (depending on distance driven and the carbon intensity of local electricity grids).[65]

4.1.2. Modal Shift Alternatives to Reduce GHG Emissions

In order to decrease the carbon intensity of passenger transport in Canada, the biggest opportunities are:

- **Shifting passenger vehicle users to urban transit:** Modelling for the GTHA case study in Section 5 of this report indicates that significant GHG reductions can be realized in Canadian cities through shifting car commuters into urban transit. In the case of the GTHA, results indicate that if all travellers who currently use passenger vehicles to commute into and out of the region during weekdays switched to urban transit (bus and rail), it would reduce passenger transportation emissions in the region by over 30%. If the number of commuters who made this switch was halved, so too would the emissions reductions. For intracity trips, a wholesale shift from cars to transit for weekday commuters would yield an emissions reduction from passenger transport of 15%. Comparable findings would be expected in other major Canadian cities, with variances dependent on the degree to which regional transit uses low-carbon technology (regional transit in the GTHA region exclusively relies on diesel buses and passenger rail). While a shift of such magnitude would necessitate additional transit capacity, this scenario nonetheless illustrates the levels of emissions reductions possible through shifting more of the driving public into transit. This shift would also see major benefits to local air quality and congestion. Significantly reduced congestion would lead to further emissions benefits in both the passenger and freight movement segments.
- **Shifting passenger vehicle or urban transit users to active transportation:** In any discussion related to modal shift, it is important to remember that no mode, including passenger ZEVs, urban transit, or even zero emission transit vehicles, can compete with active transportation in terms of GHG benefits. While active transportation is less versatile than vehicular modes, being limited by distance, cargo capacity, and sometimes weather, the only energy input required to power it is food. Ensuring that the populace has access to dedicated, well-connected and safe active transportation infrastructure will optimize usage rates and GHG reductions.

  GTHA modelling (Section 5) indicates that if all trips less than 5km in length were completed using active transportation, it would reduce passenger transport GHG emissions by 10%. Similar results would be expected in other large Canadian cities. The City of Toronto recently adopted a goal that by 2050, 75% of all trips in the city less than 5km will be completed using active transportation. Based on the modelling completed for this study, such a shift would decrease passenger transport GHG emissions in the city by 7.5%

65 Maroufmashat A. and M. Fowler. 2018. Policy Considerations for Zero-Emission Vehicle Infrastructure Incentives: Case study in Canada. World Electr. Veh. J. 9(3), 38. (https://www.mdpi.com/2032-6653/9/3/38/htm)

- **Shifting short haul aviation users to intercity bus or passenger rail:** The rate at which travellers use air travel, even for relatively short trips that could utilize ground-based modes, has been increasing consistently over the last two decades. The GHG intensity per passenger kilometre for flights is significantly greater for shorter flights, as planes use large amounts of fuel to power takeoffs. By contrast, cruising requires much less fuel. Aircraft are also responsible for a significant amount of non-CO_2 GHG emissions, including water vapour (which is an especially potent climate forcing agent at high altitudes), black carbon, and N_2O. The three most important variables when determining the environmental impacts of flying versus intercity bus or rail are: trip distance, occupancy rates, and vehicle fuel economy. In order for intercity bus and rail to offer significant GHG benefits over flying, their occupancy rates must be high and trip length should be below a threshold determined in part by vehicle fuel economy.[66]

4.1.3. Summary of Options for Movement of People

Passenger Vehicle to Urban Transit

Key stakeholders and the types of actions they can be involved in are shown in Table 10.

Table 10: Stakeholders for passenger vehicle to urban transit modal shift

Stakeholder	Passenger vehicles to urban transit
Federal and Provincial Government 	• Infrastructure development • Financial mechanisms (e.g. funding/incentive programs) • Education and awareness • Procurement best practice
Municipal Government 	• Education and awareness • Procurement best practice
Transit Authorities 	• Infrastructure development • Modal shift strategy • Education and awareness
Developers 	• Infrastructure (access to transit)
Electric Utilities 	• Infrastructure (power for transit)
Civil society, academia, research organizations, NGOs, associations 	• Education and awareness

66 Wihbey, J. 2015. Fly or drive? Parsing the evolving climate math. Yale Climate Connections. (https://www.yaleclimateconnections.org/2015/09/evolving-climate-math-of-flying-vs-driving/)

Infrastructure Development

Infrastructure plays a key role in enabling road to urban transit modal shift. Expanding existing urban transit infrastructure in dense urban areas is a time consuming, costly, and labour-intensive process. Public real estate assets will have to be leveraged to the greatest extent possible, and private lands might also have to be acquired by municipal governments.

Higher levels of government have a major funding role to play regarding infrastructure, but may also help to coordinate the connectivity and inter-operability of urban transit networks between municipalities.

Because electrification offers a cost-effective and low-carbon alternative to diesel-powered transit throughout Canada, local electrical utilities should be engaged to ensure adequate system-level capacity as well as more localized capacity at charging sites.

Financial Mechanisms

The role of federal and provincial governments would primarily be to provide capital and operational funding for transit infrastructure. Nine out of 13 provincial and territorial governments, as well as the Government of Canada, offer funding in these areas.[67] Additional funding for infrastructure is derived from fare collection and dedicated municipal taxes.

Government can provide both incentives for modal shift as well as price signals that drive modal shift. Incentives can also be targeted at ensuring that shifting is done to a low-GHG option within the new mode (e.g. from personal vehicle to urban transit using electricity or hydrogen). Incentives can include funding for infrastructure and low-carbon transit vehicles, such as Natural Resources Canada's EVAFIDI and ZEVIP programs, or tax credits, such as the Accelerated Capital Cost Allowance for ZEVs. Infrastructure Canada's Long-Term Infrastructure Plan allocates over $180 billion for new infrastructure spending out to 2030 within five areas: public transit, green, social, trade and transportation, and rural and northern communities.[68] Modal shift actions that drive more Canadians to urban transit is clearly within the scope of the Plan, and municipalities should explore options around utilizing the Plan to support local transit improvements. Infrastructure Canada also operates the Public Transit Infrastructure Fund, which was allocated $3.4 billion in 2016 to fund large-scale transit projects and other transit-oriented development.[69]

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67 Canadian Urban Transit Association (CUTA). 2013. Federal, Provincial & Territorial Public Transit Funding Programs in Canada. (https://cutaactu.ca/sites/default/files/cuta-federal_provincial_territorial_funding_report-2012.pdf)

68 Infrastructure Canada. 2019. Investing in Canada Plan. (https://www.infrastructure.gc.ca/plan/about-invest-apropos-eng.html)

69 Infrastructure Canada. 2018. Building Strong Cities Through Investments in Public Transit. (https://www.infrastructure.gc.ca/plan/ptif-fitc-eng.php)

Education and Awareness

In order to ensure the public and other stakeholder groups understand the rationale and benefits of transit expansion, as well as anticipated costs, timelines, and socio-economic impacts, an educational campaign aimed at different stakeholder groups likely to be impacted by new transit development is recommended. General educational guidance, tied to federal and provincial commitments on GHG reductions and transit availability, can be provided by higher levels of government. Municipalities, working collaboratively with local transit authorities and civil society groups, will spearhead local education campaigns and outreach.

Procurement Best Practice

Governments procure significant volumes of transportation equipment and are in a position to define urban transit best practice in their supply chains, driving energy efficiency and reducing GHG emissions and costs. Bulk procurement coordinated with multiple municipalities can serve to reduce costs for each municipality while ensuring inter-urban compatibility of vehicles and equipment. Such compatibility and coordination between municipalities will help to ensure a seamless transit experience for out-of-town commuters and will foster end-user familiarity with modern transit networks.

Passenger Vehicle or Urban Transit to Active Transportation

Key stakeholders and the types of actions they can be involved in are shown in Table 11.

Table 11: Stakeholders for passenger vehicle or urban transit to active transportation modal shift

Stakeholder	Passenger vehicles to urban transit
Federal and Provincial Government	• Infrastructure development • Financial mechanisms (e.g. funding/incentive programs) • Education and awareness • Procurement best practice
Municipal Government	• Education and awareness • Infrastructure development • Modal shift strategy • Financial mechanisms (e.g. funding/incentive programs)
Transit Authorities	• Infrastructure development • Modal shift strategy
Developers	• Infrastructure development
Civil society, academia, research organizations, NGOs, associations	• Modal shift strategy • Education and awareness

Infrastructure Development

Similarly to urban transit expansion, expanding active transportation infrastructure will necessitate that municipalities leverage their real estate assets and work with partners to secure space for active transportation infrastructure that effectively connects different neighbourhoods including residential, recreational and employment clusters. Civil society members such as bicycle and health advocacy groups as well as academia should be consulted to ensure that potential networks will meet the needs of existing and future cyclists and pedestrians. Transit authorities should be engaged in the process to help facilitate connections between active transportation and transit hubs. This will help to create an environment in which urban transit provides the bulk of travel distance, where required, and active transportation can facilitate the first and last mile of trips.

Financial Mechanisms

Funding for active transportation infrastructure can be sought through Infrastructure Canada's Long-Term Infrastructure Plan as well as provincial programs such as B.C.'s Active Transportation Infrastructure Grants Program[70] and Ontario's Municipal Commuter Cycling Program.[71] Municipal tax revenues and private donations can be used to supplement external sources of funding. Local events such as the Smart Commute program that is active in many Ontario municipalities (e.g., Oakville, Newmarket, Markham, Richmond Hill) can also be used to raise funds for active transportation networks, in addition to generating public and corporate buy-in and raising awareness.

Education and Awareness

In terms of energy efficiency, carbon intensity, and human health, there are no motorized forms of transport that can compete with active transportation. Communicating the benefits of active transportation to the general public will simultaneously help to drive more users to this mode and help to gain support for active transportation infrastructure expansion.

Education and awareness campaigns can take many forms and can be led and supported by different levels of government. While municipalities are at the forefront of local actions, efforts from higher levels of government can support and reinforce municipal actions, as well as facilitate inter-municipal collaboration and best practice sharing with regard to education and awareness. Local events such as a Smart Commute Week, Clean Air Challenge, Bike to Work Day or Car Free Day,[72] can also serve as springboards to advocate for and raise awareness around active transportation networks.

Modal Shift Strategy

Prior to the kick-off of programs or development, it is important that municipalities gain a clear understanding of the current state of active transportation in their regions. Baseline data gathering should include mapping existing networks, establishing user numbers and usage focal points, determining which factors are preventing greater usage, and conducting an inventory of municipal real estate. Once these steps have been taken, municipalities and their partners can begin setting targets and developing content for

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70 Government of British Columbia. 2020. B.C. Active Transportation Infrastructure Grants Program. (https://www2.gov.bc.ca/gov/content/transportation/funding-engagement-permits/funding-grants/active-transportation-infrastructure-grants)

71 Government of Ontario. 2017. Ontario Municipal Commuter Cycling (OMCC) Program. (https://collections.ola.org/mon/31006/340460.pdf)

72 Town of Newmarket. 2019. Smart Commute Newmarket. (https://www.newmarket.ca/LivingHere/Pages/Environment%20and%20Sustainability/Smart-Commute.aspx)

a local modal shift strategy. Strategies can include goals such as reducing congestion or transport emissions, increasing active transportation usage for trips within a given distance threshold, or enhancing the connectivity of certain neighbourhoods. Working collaboratively with academic institutions, local civil society groups and transit authorities will help municipalities ensure that they are prioritizing actions that will have the greatest impacts within uniquely local contexts.

Aviation to Intercity Bus or Passenger Rail

Key stakeholders and the types of actions they can be involved in are shown in Table 12.

Table 12: Stakeholders for passenger vehicle or urban transit to active transportation modal shift

Stakeholder	Passenger vehicles to urban transit
Federal and Provincial Government	• Infrastructure development • Financial mechanisms (e.g. funding/incentive programs) • Education and awareness • Procurement best practice
Municipal Government	• Education and awareness • Procurement best practice • Modal shift strategy
Intercity bus and rail operators	• Infrastructure development • Modal shift strategy • Education and awareness • Procurement best practice
Developers	• Infrastructure development
Electric Utilities	• Infrastructure development
Civil society, academia, research organizations, NGOs, associations	• Education and awareness

Infrastructure Development

Unlike the other modal shift possibilities explored around the movement of people, shifting intercity traffic from aviation to ground-based shared modes will require coordination between municipalities, and in some cases between provinces. Federal, provincial and other municipal governments should be involved in discussions from day one. Depending on the level of new or retrofitted infrastructure required, development may need to occur on lands under provincial and/or federal jurisdiction. An inter-governmental task force would be an asset to any buildout required to support such a modal shift. This is especially true in the case of rail. Once a project plan is drafted by the task force, developers, bus and rail operators, and utilities should be brought into the fold to test the viability of certain ideas and provide cost estimates and timelines.

The expansion of rail infrastructure, and/or the rollout of alternative rail motive technology, will take substantial time, effort and capital, in part because rail infrastructure is so long-lived. Demands on real estate may likewise be substantial, and extensive stakeholder consultation will have to take place in all impacted communities.

In the case of intercity buses, the level of new infrastructure required may be minor, however, depending on the propulsion technology selected, extensive new fueling infrastructure may be necessary. This fueling infrastructure should be deployed strategically on key intercity routes, situated adjacent to amenities that passengers can use while vehicles top up on fuel.

Financial Mechanisms

There is significant potential for federal funding to support a mode shift from air to ground-based shared modes. Low-carbon vehicle incentives can be sought from Natural Resources Canada through its EVAFIDI, ZEVIP or other programs, or costs can be mitigated through tax credits such as the Accelerated Capital Cost Allowance for ZEVs. Infrastructure funding can be sought from Infrastructure Canada's Long-Term Infrastructure Plan and its Public Transit Infrastructure Fund. The Government of Canada's Federal Gas Tax Fund is another potential source of capital for this type of initiative, although any such capital would likely have to flow through provincial project partners (the recipients of the Gas Tax Fund). Provincial and Territorial transportation departments would play central roles in facilitating this mode shift, and may be able to provide additional funding for certain projects. Industry partners and financial institutions could also be in a position to help secure financing for any major undertakings. Development to support such a modal shift could also be funded in part through the issuance of green bonds at the municipal, provincial or federal levels.

Education and Awareness

In order for a shift from air to shared ground-based modes to have the intended impact, a minimum threshold of riders must be attained. This challenge may be compounded by the fact that air travel has become commonplace in Canada for distances of approximately 400 km or greater. Modal shift stakeholders will need to ensure that the speed, reliability and convenience of the low-carbon modes made available to the public are sufficient to entice passengers out of airports.

Education, awareness and marketing campaigns will have to stress the benefits that ground-based modes offer over aircraft. Factors such as WiFi availability, expanded dining options, the avoidance of long lines, and fewer restraints around luggage should be stressed by project partners in outreach campaigns. Other factors such as low carbon intensity, safety and comfort can also be drawn upon to appeal to specific audiences. Introductory promotions can also be used to entice people accustomed to air travel to try ground-based mobility options.

Procurement Best Practice

Deciding which technology is best-suited and the most future-proofed for specific ground-based corridors can be difficult in the face of rapid technological innovation. Governmental project leads should consult with subject matter experts from industry and academia to determine the best procurement options. The leads should also solicit bids from providers of different types of technologies, and any such bids should go beyond vehicle and fuel cost estimates to include estimates on GHG reduction potential, ridership potential, and other non-financial metrics.

Modal Shift Strategy

As with most modal shift strategies, a strategy to drive passenger traffic from air into shared ground-based modes should start with baseline data collection on topics such as carbon intensity numbers for conventional vehicles, current and historic ridership levels, traveller expectations around travel speed, reliability and costs, technological feasibility, and other factors. Following that step, GHG reduction potential should be assessed on a corridor-by-corridor basis and project costs should be estimated. The project task force can then begin setting targets and priorities for a modal shift strategy, and stakeholder consultation can begin. Early stage market research may play a key role in this type of modal shift, to ensure there is sufficient public appetite to shift to an alternative mode.

4.2. Factors that Influence Modal Choice: Movement of Goods

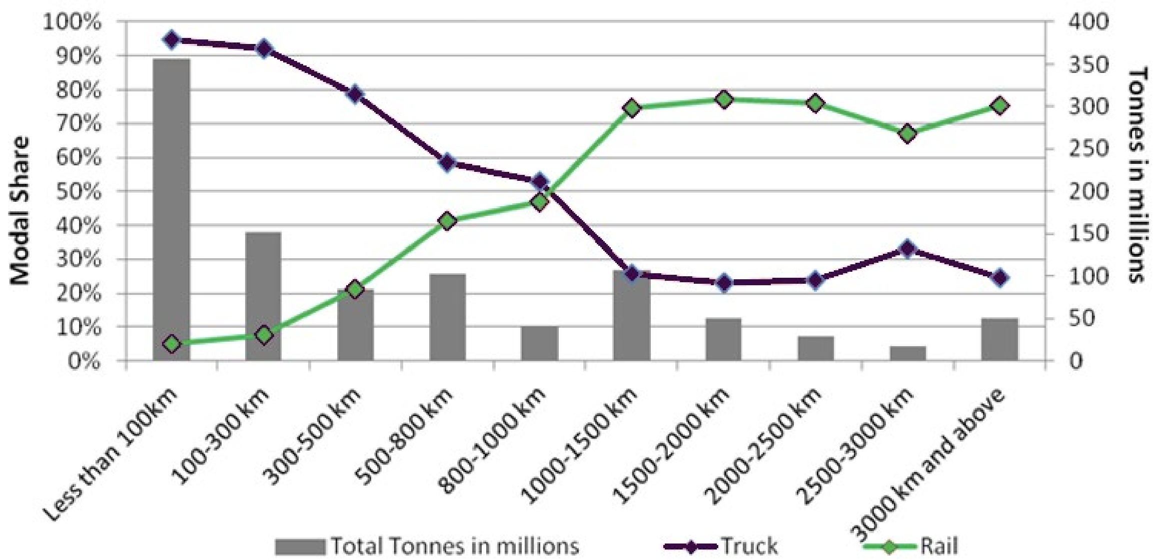
A growing proportion of GHG emissions from the movement of freight come from the trucking sector (See Figure 3 in section 3). Despite pressure for companies to reduce their carbon footprint, decisions around transportation of goods tend to be based on cost and delivery time/ speed[73] (sometimes jointly referred to as "level of service") of available modes, as well as on convenience, particularly given the relative flexibility of trucking.[74]

Compared to trucking, air, marine and rail all have limitations. Air transportation, due to its high cost, is limited to low weight, high value freight. Marine transportation is limited geographically by access to ports and shipping routes, which can be seasonal. Limitations of rail are based around scheduling and location of infrastructure.

4.2.1. Observable Trends

Figure 26 and Figure 27, below, tell a consistent story of modal shares across countries and decades. For freight shipments travelling less than 800 to 900 km, trucks are the dominant mode. As the distance travelled by the majority of shipments, as illustrated by the columns in both graphs, falls well under that threshold, on a per-trip basis, goods have tended to move primarily by truck.

Figure 26: Surface Freight Modal Shares and Tonnes by Distance in Canada, 2013[75]

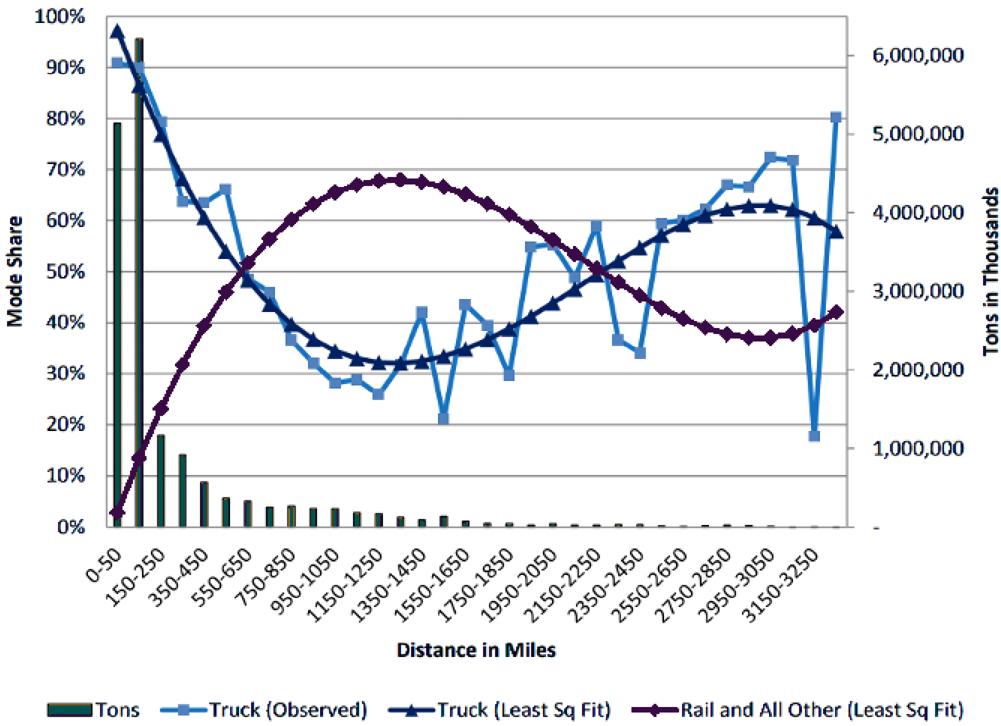


73 https://clearseas.org/en/air-pollution/

74 Impacts on Emissions, Air Quality, Population Exposure and Health Associated with Modal Shifts in Freight Transportation Options – A Review, by Texas A&M Transportation Institute for Health Canada, March 2018.

75 Graphic from Potential of GHG Emissions Reduction Through Optimizing Energy Efficiency of Multimodal Freight Supply Chain, ACSB, undated. Received from Transport Canada.

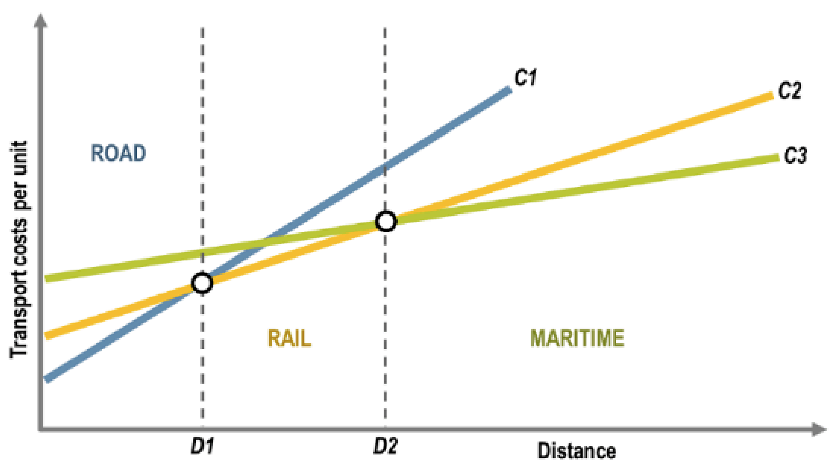
Figure 27: Freight Modal Shares and Tons by Distance in the U.S. 2007



Based purely on cost, this threshold should be lower. Figure 28 illustrates how cost varies with total distance for each mode of freight transportation. For distances shorter than D1, it is most cost-effective to ship by road. D1 typically occurs from 500 to 750 km of the point of departure. A literature review conducted for Health Canada in 2018 narrowed this further, finding that the modal shift from road to rail is economically feasible for distances over 400 miles (644 km).[76]

D2 occurs at about 1,500 km. For middle-distances (between D1 and D2), rail is most economical, and for long distances (over D2), maritime is the most economical option. Note that this analysis is based solely on cost and does not account for availability.

Figure 28: Cost per Mode Based on Distance[77]



76 Impacts on Emissions, Air Quality, Population Exposure and Health Associated with Modal Shifts in Freight Transportation Options – A Review, by Texas A&M Transportation Institute for Health Canada, March 2018.

77 Graphic from Rodrigue, J-P (ed) (2017), The Geography of Transport Systems, Fourth Edition, New York: Routledge. https://transportgeography.org/?page_id=1801

The considerations for choice of mode typically revolve around the broad concepts of cost and convenience, which can be further broken out as follows:[78]

Cost

External Cost: This would cover any costs incurred by the facility, outside its boundaries – e.g. shipping by truck is more expensive than shipping by rail or vice versa.

Internal Cost: This covers all items which result in a cost within the facility, such as overhead for facility staff and equipment.

Speed

Time-to-Market Sensitivity: Certain goods must be in the market within a certain time frame; examples include perishable goods or firms which offer "next day" delivery for their shipments. If shipping by a particular mode of transport results in an increased time-to-market for such goods, either due to scheduling issues or increased transit times, then it can be considered a barrier.

Scheduling: Scheduling may be a consideration to shipping by a particular mode if it results in a measurable impact on the operations of the facility, e.g. affecting sales, rate of flow of goods, additional expenditure on storage space, increased cost, etc.

Convenience

Access: Locations of shipping origin or destinations with respect to rail lines, highways and/or marine shipping options will necessarily impact modal choice, particularly in cases where opportunities for intermodal shipping require increased transit distances and may result in higher costs.

Capacity: Variations in quantities of goods being shipped without sufficient preparatory lead time may affect the mode of shipment used either due to availability or increased cost.

Other

Quantity: Quantity of good shipped in a single shipment may affect the mode of shipment available for use.

Required Freight Configuration: Some goods are better suited to transport using a specific mode of transport. This includes requirements for a controlled environment which may affect the mode of shipping.

78 BC Ministry of Environment, Freight Modal Shifting Offset Protocol, no longer in use.

Key Characteristics by Mode

Table 13: Freight Transport - Key Characteristics of Four Modes[79]

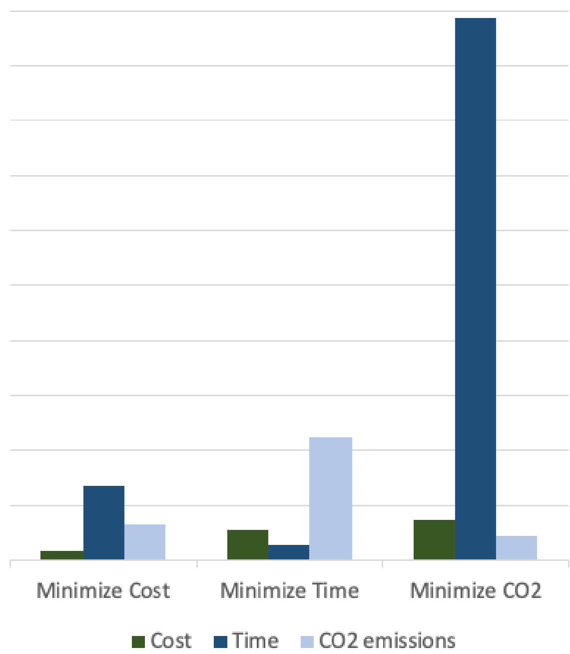
	Road	Rail	Marine	Air
Cost per tonne-km	More expensive than rail and marine; cheaper than air	Cheaper than road and air; more expensive than marine	Cheaper than all other modes	Most expensive of all modes
Capital Cost	Lowest	Second-lowest	Highest	Second-highest
Speed	Faster than rail and marine; slower than air	Slower than road	Slowest of all modes	Fastest of all modes (depending on circumstances)
Flexibility	Most flexible of all modes	Less flexible than road	Relatively inflexible (schedules, routes)	Less flexible than road
Availability	Most readily available at different times, locations	Less available than road (due to schedules, rail infrastructure)	Less available than road (due to schedules, port infrastructure)	Less available than road (due to schedules, airport infrastructure)
Goods Suited	Manufactured goods, equipment, machinery, vehicles	High-volume, low-value freight and commodities; auto products	Large-volume, heavy goods and commodities	High-value goods; perishable and urgent goods
Distance	Mostly national and international	National and international	Up to intercontinental	Regional to intercontinental

CASE STUDY

A 2018 study from the University of Laval examined a shipment of lumber traveling from Chibougamau, Quebec to Sioux Falls, South Dakota, a distance of 2325 km.

Modal selections and corresponding routes and times were mapped to minimize three criteria: cost, overall trip time, and carbon emissions. The findings, while case specific, serve to illustrate the possible scale of the relative differences in cost, time and emissions possible based on changes to mode and corresponding route.

In this case, cost was minimized by selecting rail as the primary mode, with truck for last mile delivery. This was the best option overall, despite taking additional time relative to Option 2. Time was minimized by using truck only. Carbon emissions were minimized using a customized intermodal route that was primarily by ship but also included train and truck. While successful in minimizing carbon, this was extremely time intensive.



79 The Conference Board of Canada; Roy, "By Road, Rail, Sea and Air", via Greening Freight: Pathways to Reducing GHG Emissions From Trucking, Conference Board of Canada, May 2018 https://www.conferenceboard.ca/temp/c741dbda-b565-4507-9d3e-5f2d5d64e7bb/9596_Greening-Freight_RPT.pdf

4.2.2. Modal Shift Alternatives to Reduce GHG Emissions

A 2013 study by the U.S. Department of Energy stated that "truck-to-rail modal shifts have the greatest overall potential for energy reduction, because trucks are the dominant mode in terms of freight tonnage and freight commodity value, while rail serves many of the same routes and uses substantially less energy."[80]

Based on the high proportion of goods shipped by truck and rail in Canada, and on the significant discrepancy in GHG emissions between the two, the main opportunity to optimize freight transportation for GHG reductions, is to transition truck freight to rail. There is some opportunity to shift freight onto ships in the Great Lakes/St. Lawrence inland waterway system, but given the limitations imposed by both the geography and seasonality of this option, it represents a very limited opportunity. There is no evidence that a shift away from air transportation of freight is possible given the specialized nature of this mode.

Note that the GHG benefits of a shift from rail to truck should consider two factors beyond a direct comparison of the GHG intensity of truck and rail:

- **Overall distance:** Rail and truck shipments between origins and destinations may involve different total distances of travel. Modal shift makes the most sense when rail is shorter, comparable, or only moderately longer (rail is sufficiently less GHG intensive that a degree of added distance will still result in an overall GHG reduction)
- **First and last-mile drayage:** most rail shipments require trucking to get the freight to rail and trucking from the rail terminal to the destination (some origins and destinations are directly connected to rail, such as facilities served by rail spurs). These emissions must be considered within a truck to rail modal shift GHG assessment.

80 An Evaluation of the Potential for Shifting of Freight from Truck to Rail and Its Impacts on Energy Use and GHG Emissions, Argonne National Laboratory 2017, https://publications.anl.gov/anlpubs/2017/08/137467.pdf

4.2.3. Summary of Options for Movement of Goods

Road to Rail

Key stakeholders and the types of actions they can be involved in are shown in Table 14.

Table 14: Stakeholders for road to rail modal shift

Stakeholder	Passenger vehicles to urban transit
Federal and Provincial Government	• Infrastructure development • Financial mechanisms (e.g. funding/incentive programs, freight pricing initiatives) • Education and awareness • Procurement best practice
Municipal Government	• Education and awareness • Procurement best practice
Digital Logistics Companies	• Infrastructure • Modal shift strategy • Logistics-based solutions
Rail Companies	• Infrastructure development • Modal shift strategy • Education and awareness
Shippers	• Infrastructure (access to rail) • Logistics-based solutions • Procurement best practice
Civil society, academia, research organizations, NGOs, associations	• Education and awareness

Infrastructure Development

Infrastructure plays a key role in enabling road to rail modal shift and can be categorized roughly into access, connectivity and network capacity. Access infrastructure is where goods are loaded onto trains and includes rail spurs, reload centres and intermodal terminals. Connectivity infrastructure connect access points to destinations and can include shortline rail where goods are transferred between shortline and mainline. Network capacity infrastructure includes double tracking, sidings and other infrastructure investments designed to allow for higher volumes of freight to operate on a given line.

Rail spurs: Rail spurs are sections of track that allow rail cars to be loaded directly at a facility. The cost of rail spurs is typically split between the facility owner and the rail company; however, in Quebec, the PREGTI program has provided funding for rail spur construction to promote truck to rail modal shift.

Reload centres: A reload centre is a location where goods are removed from trucks and placed in rail cars or vice versa. These can include bulk goods, liquids, forestry products etc.

Intermodal terminals: Intermodal terminals allow goods in shipping containers to be transferred from truck to rail and vice versa. Given this is a growth area for rail shipments, with potential further growth in the future, there is a need to increase intermodal terminal capacity in Canada.

Shortlines: Shortlines can connect origins and destinations for shipments, but also provide a means for goods to be transferred to mainline rail. One challenge for shortlines is that they tend to move goods originating from a small number of shippers and are hence more exposed to fluctuations in demand.

Sidings: Much of Canada's rail network is single track serving trains operating in both directions. Sidings allow trains to pull over and be passed. Increasing the number of sidings decreases the amount of time trains need to stay in these sidings, thereby increasing network fluidity and capacity.

Port access: Ports are the location where the highest volumes of goods are loaded on and off of rail. Port infrastructure can include double tracking to improve access (such as the Port of Vancouver).

Technological infrastructure includes the digitization of freight systems, driven by digital logistics/ freight brokerage companies. It is addressed in further detail below.

Financial Mechanisms

The Final Report of the Specific Mitigation Opportunities Working Group included the following relevant recommendations[81]

- Incentives for freight logistics and supply chain efficiencies
- Funding to support modal shift
- Pricing: per-kilometre charge on heavy goods vehicles

Government can provide both incentives for modal shift as well as price signals that drive modal shift. Incentives can include funding for infrastructure, such as Quebec's PREGTI program, or tax credits, such as the Short Line 45G Tax Credit in the US that helps shortlines with infrastructure costs. Incentives for freight logistics could also be

81 Specific Mitigation Opportunities Working Group Final Report https://www.canada.ca/content/dam/eccc/migration/cc/content/6/4/7/64778dd5-e2d9-4930-be59-d6db7db5cbc0/wg_report_specific_mitigation_opportunities_en_v04.pdf

modelled off of Quebec's PETMAF program, that provided an incentive per tonne GHGs reduced through modal shift. The historic data analysed in Section 4.3.2 suggests that other government policies that impact diesel price, such as a price on carbon, may drive modal shift through an increase in the relative costs of trucking vs. rail.

Logistics-Based Solutions

Freight digitization is an emerging disruptive approach that uses a marketplace-based approach to optimize factors including cost, speed and emissions in the shipment of long-haul freight via modal selection. The automation/ digitalization of freight logistics may be a key tool in the quest to reduce emissions from freight transportation. While logistics companies have traditionally been focussed on ensuring full truckloads, digital logistics can take a broader perspective by optimizing cost, speed, and emissions of the shipment of long haul freight via a multimodal approach. Shippers reportedly regularly accept time delays in order to reduce cost – and the most cost effective option is also typically the one with the least emissions.[82]

Digital freight is in its infancy: in early 2019, only 0.2% of global freight was going through digital freight platforms. This is expected to increase to 3.7% by 2025.[83]

Education and Awareness

New rail infrastructure can increase the number of trains (e.g. port infrastructure) and trucks (e.g. reload centres and intermodal terminals) operating in an area. This can lead to community pushback where local residents are impacted. Given the location of ports in busy metropolitan centres, and the demand for (and generation of) intermodal goods in large urban areas, there will be an ongoing need to navigate community impacts. An important part of this will be project design, however, there will also be necessary roles for all levels of government, NGOs and rail companies to engage the Canadian public on the broader environmental benefits of these projects.

Procurement Best Practice

Governments procure significant volumes of goods and are in a position to define freight best practice in their supply chains, driving energy efficiency and reducing GHG emissions. In the private sector, there is an increasing interest in addressing supply chain and product transportation emissions, with companies integrating transportation strategies within their overall sustainability strategies.

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82 Personal communication with E. Beckwitt, Freightera

83 CanadianShipper.com, https://www.canadianshipper.com/blogs/freightera-plan-become-amazon-freight-industry/

Road/Rail to Marine

Opportunity is limited by geography, so tends to be commodity specific. For example:

- Grain, bulk materials, and container shipments through the Great Lakes/St. Lawrence inland waterway system;
- Lumber products along the BC coastline; and
- Crude oil in Newfoundland.

A literature review for Health Canada completed in 2018 found that there was little information available on the feasibility of adopting a modal shift to (rail to marine), accounting for existing markets and demand variables.[84]

A study for the US DOE similarly found that a meaningful shift to marine was fraught with too many challenges to make this viable. These include insufficient infrastructure, cost based on drayage, loading and unloading fees, low frequency and flexibility, less reliability with respect to delivery windows.[85]

84 Impacts on Emissions, Air Quality, Population Exposure and Health Associated with Modal Shifts in Freight Transportation Options – A Review, by Texas A&M Transportation Institute for Health Canada, March 2018.

85 Freight Transportation Modal Shares: Scenarios for a Low-Carbon Future, Cambridge Systematics for the U.S. Department of Energy, 2013.

5. Case Studies and Best Practices

Given the complexity of modal selection, the approach to driving intermodal shifts may depend, to a certain extent, on location specific criteria. Case studies and best practices can nonetheless help to demonstrate how an optimal transportation system can be defined, what barriers may limit achievement of this system and how infrastructure can be deployed to overcome barriers. The case studies and best practices presented here highlight modal optimization approaches being employed in Canada and in other jurisdictions in order that the approaches may inform implementation for other Canadian municipalities and their inter-regional transportation networks.

One Canadian case study and one international best practice are provided for each of the movement of people and goods. Due to the proprietary nature of much of the information regarding the movement of freight, these case studies are necessarily less detailed than those pertaining to the movement of people.

5.1. Movement of People

5.1.1. Case Study: Household Transportation in the Greater Toronto and Hamilton Area (GTHA)

The GTHA is the largest metropolitan area in Canada and is home to more than 15% (about 7 million residents) of the total Canadian population. It consists of two municipalities (Toronto and Hamilton) and four regional municipalities (Durham, Halton, Peel and York), with Toronto as the most populated, with 2.7 million residents.[86] The GTHA's transportation sector is the second-largest emitter and accounts for 35% of total GHG emissions.

Four scenarios for altering mode choice and adopting EVs were tested to determine impacts on GHG emissions:

- Active transportation for all trips under 5 km;
- Public transit for all trips starting and ending within the City of Toronto;
- Switching of car trips to EVs (20% and 50%); and
- Regional transit for trips from inside to outside of Toronto City limits, in either direction.

The greatest decrease in GHG emissions came from replacing 50% of car trips to EV's with a 43.7% decrease (this lowered to 17.5% with a 20% replacement rate), followed by the regional transit scenario, which yielded a 30.3% decrease. The public transit scenario resulted in a 15.0 % decrease, and active transportation for short trip decreased overall emissions by 10.0%

Additional details about this study are available in Appendix B.

86 Government of Canada, 2016. Release and concepts overview 2016 Census of Population : Population and dwelling counts release. (https://www12.statcan.gc.ca/census-recensement/2016/rt-td/population-eng.cfm)

5.1.2. Best Practice: London, England

To raise funds for urban transit enhancements as well as address transportation-related air pollution and crippling congestion in its city centre, the City of London, England introduced a congestion charge in 2003. It began as a £5 charge on passenger vehicles entering a 21 square kilometre zone of London's downtown core. Today the charge stands at £11.50, although certain vehicles are exempt, including those with disability permits, motorcycles, taxis, and minicabs. Local residents receive a 90% discount on the charge, and there is also a discount for ZEVs. The charges are only in effect from Monday to Friday, between 7:00am and 6:00pm. Charges are enforced by a network of cameras that scans license plates, which are then cross-referenced to ensure vehicle owners have purchased a pass. Vehicles that enter the zone without a pass are fined £160.[87]

The charges and fines have led to a cash flow positive system. As of 2017 the approximate annual operating costs were £90 million and revenues were approximately £160 million. Excess funds raised continue to be allocated to transit enhancement and other low-carbon mobility initiatives.

The congestion charge demonstrated its effectiveness in shifting people out of cars and into urban transit soon after it was introduced. On day one of implementation 300 extra buses were put in service, bus routes were updated and service levels increased. One year after implementation, transit bus ridership inside the zone had increased by 16% during the morning rush hour. Bus riders also experienced a 30% reduction in average wait times due to less congestion and enhanced service levels. Average road speeds within the zone increased by 10-15%. 8,500 park and ride spaces were added around the zone's periphery to accommodate out of town commuters. In its first year, public approval of the congestion zone went from 40% to 55%.

Between 2002 and 2014, the number of privately-owned cars entering the zone decreased by 39%, and the total number of vehicles driving in the zone is 25% lower today than it was a decade ago. A portion of the road space inside the zone was reallocated for bicycle and pedestrian use. The number of cycling trips in the zone increased 210% between 2000 and 2016, demonstrating its effectiveness in shifting commuters to active transportation as well as transit.

With the recent rise of ridesharing services, whose vehicles are permitted within the zone, congestion levels have increased to the point that transit vehicles are being delayed and ridership is beginning to decline. Between 2013 and 2017 there was a 75% increase in ridesharing vehicle registrations in London. While this issue must now be addressed by regulators, congestion pricing was not the only action taken by London to address congestion, air pollution, raise transit revenues, and drive a modal shift out of private passenger vehicles.

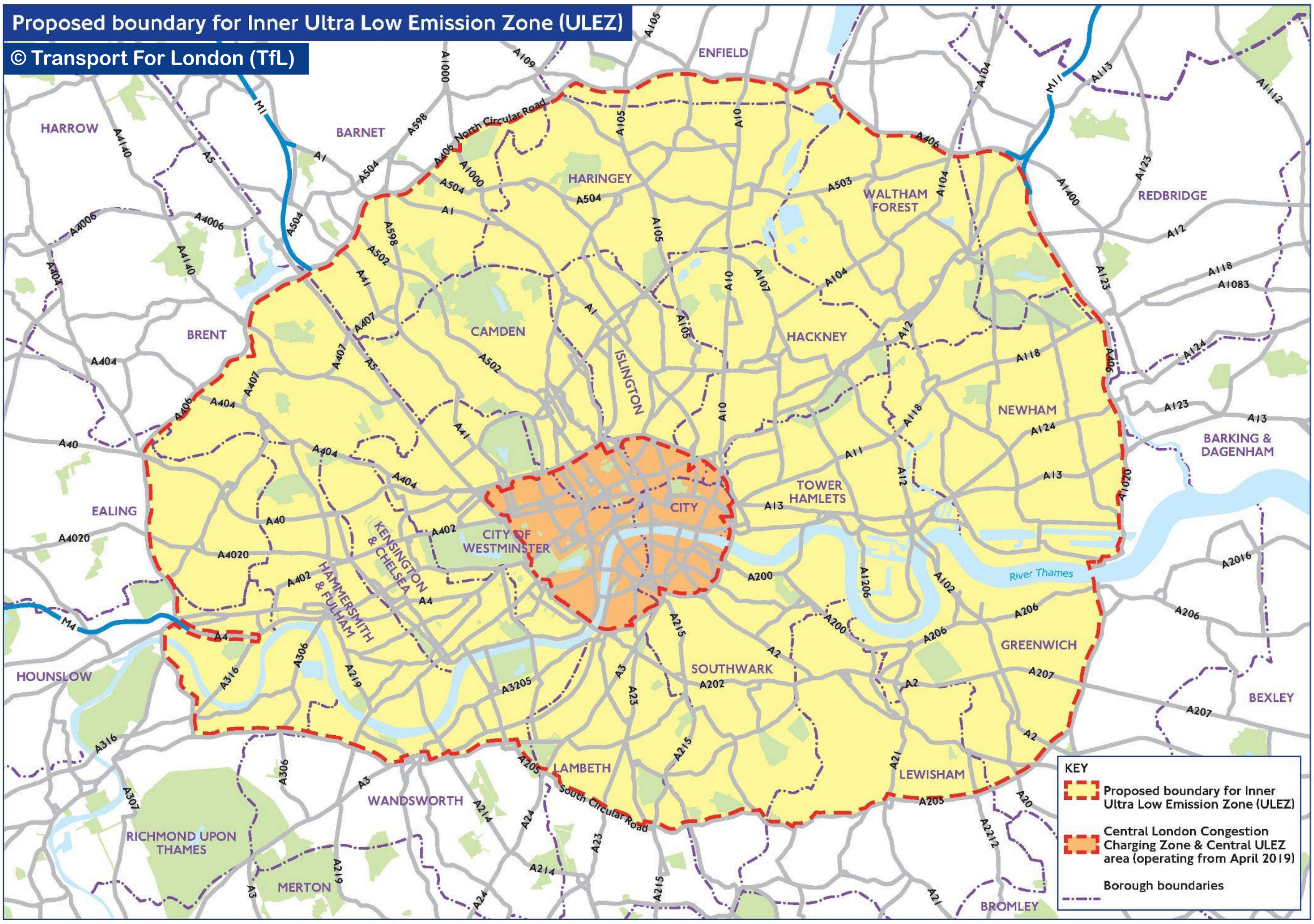
In 2008, London implemented a low emission zone (LEZ) for heavy duty vehicles which covered Greater London and operated 24/7, 365 days a year. The minimum standard for large vans and minibuses was Euro 3, and Euro 4 for buses, trucks, and specialist heavy vehicles. If these standards were not met, the daily charge was £100 for vans and minibuses and £200 for heavy trucks.

87 The Delphi Group and Pollution Probe. 2020. Opportunities for Low-Carbon Mobility Actions in Canadian Municipalities: Best Practices and Guidance.

London enhanced the stringency of its LEZ by launching an ultra-low emission zone (ULEZ) in April 2019. The ULEZ is being phased in, starting with the same 21 square kilometre area covered by the congestion charge, and will expand to cover the entire city (inside the north and south Circular roads) in 2021. All vehicles in the zone will be subject to restrictions. The ULEZ limits are:

- Euro 3 or better for motorcycles, mopeds, etc.
- Euro 4 or better for gas cars, vans, minibuses and specialist vehicles
- Euro 6 or better for diesel cars, vans, minibuses and specialist vehicles
- Euro 6 for trucks, buses, and specialty heavy duty vehicles

Fines for non-compliance range from £160 for cars, vans, and motorcycles, to £1,000 for trucks, buses, and specialty vehicles. Rather than banning vehicles that don't meet emissions limits, those vehicles have to pay to enter the ULEZ. The charges are £12.50 for cars, motorcycles, and vans and £100 for heavier vehicles (over 3.5 t) and buses over 5 t. The ULEZ is in effect 24/7, 365 days a year. The ULEZ charges are in addition to the congestion charge.



The expansion of the ULEZ in October 2021 is estimated to cost £700 million for new monitoring infrastructure. The ULEZ is expected to raise £220 million per year, which is intended to cover operating and installation costs. Any additional revenues that may be generated from the ULEZ will be used on initiatives to make public transit "clean and green" and reduce transport network pollution overall. Unlike the congestion charge, the ULEZ has not been designed and implemented to raise funds. Its primary goal is to change driver behaviour by getting people into cleaner vehicles and modes.

Key outcomes from the first six months of ULEZ implementation (April to September 2019) include:

- 3 to 9% reduction in traffic flows compared to the same period in 2018
- Average daily compliance rate was 77%
- Average compliance rate during congestion charging hours was 74%
- 38% reduction of non-compliant vehicles in the zone during congestion charging hours
- 36% reduction of roadside concentration of NO_2
- 4% reduction of CO_2 from road transport in central zone

To ensure that a socially equitable transition to low-carbon transportation in the ULEZ, London introduced the following measures:

- The establishment of bicycle superhighways in the zone to make it safer to choose cycling
- Additional buses and routes were added to the zone
- Residents within the ULEZ and vehicles for disabled people have been given more time to comply (until 2021 and 2025, respectively)
- Small businesses and charities are supported in replacing older vehicles with ZEVs with up to £6000 for purchase and operating costs
- £18 million initiative to install 75 DCFCs in the zone to support the transition to ZEVs

London is currently considering taking the ULEZ one step further by implementing a zero-emission zone (ZEZ) for central London by 2022, with the goal of 90% of all vehicles entering the zone being ZEVs by 2030.

The combined effect of London's congestion charge and ULEZ has been to price carbon-intensive vehicles and modes out of the market. The combined costs of vehicle ownership and fees to enter the zone have proven to make using carbon intensive modes of transport prohibitively expensive in London. This shows that while vehicle ownership costs may not be the primary determinant of modal choice, when total transportation costs rise beyond a certain level they can start to impact travel decisions. When rising costs of passenger vehicle use are coupled with an increasingly convenient, reliable, accessible, and safe public and active transit system, this can create ideal conditions for modal shift to occur.

5.2. Movement of Goods

5.2.1. Case Study: CentrePort Canada

Inland ports are hubs designed to move international shipments more efficiently from seaports to inland for handling and redistribution. While they share many features with multimodal transportation hubs, they typically add warehousing and distribution infrastructure. The number and size of inland ports is increasing as the marketplace becomes increasingly global and the number of imports to Canada increases. The growth in containerization of freight has also led to the increased growth of inland ports. Canadian inland ports include Ashcroft Terminal in British Columbia, Port Alberta in Edmonton, the Calgary Region Inland Port and the Global Transportation Hub in Regina.

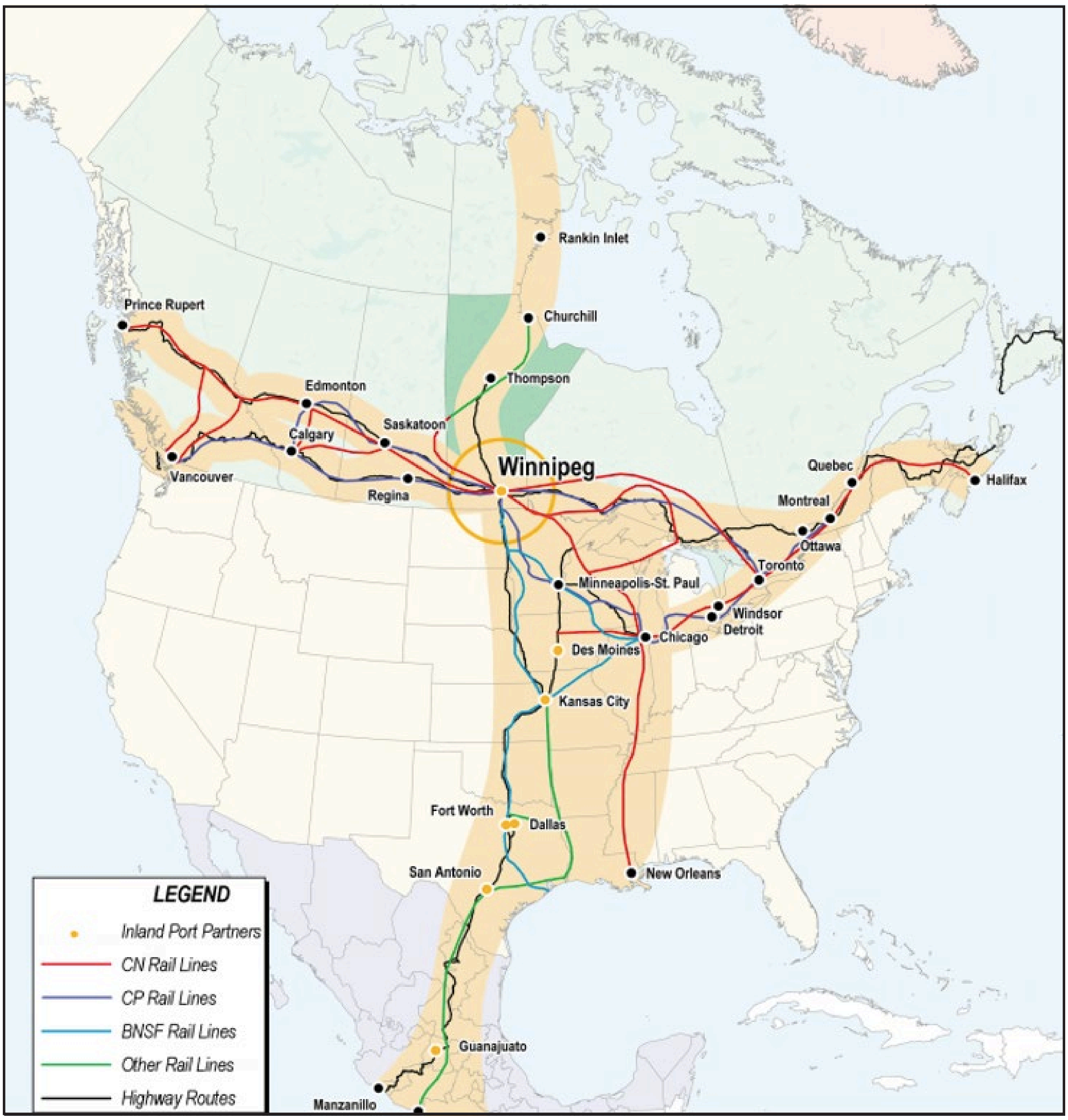
Winnipeg's CentrePort is a trimodal inland port and transportation hub with warehousing and distribution, as well as on-site industry including manufacturing and assembly, agribusiness, food processing and packaging, and transportation-related logistics. Adjacent to the James Armstrong Richardson International Airport, it is serviced by CP, CN and BNSF rail lines, and serves as a national and international trucking hub, connected to Canada's highway system via CentrePort Canada Way.

CentrePort opened in 2008 as a Public Private Partnership between a private sector board of directors and both the regional and provincial governments. It is continuing to develop and expand with both private and public sector investment. CentrePort Canada Way, a four-lane expressway connecting the port to the West Perimeter Highway was developed in 2013 with assistance from the federal and provincial governments. Currently a rail park is in development that will reduce drayage requirements by providing co-location opportunities for rail-intensive businesses.

Located at the geographical center of North America, Centre Port offers access to global markets through established trade and transportation corridors:

- South to the U.S., Mexico and South America via truck and rail. Winnipeg is the only major city between Thunder Bay and Vancouver with direct rail connections to the United States via three Class 1 carriers.
- West to Alberta and British Columbia via the Western Corridor (truck and rail) and to Asia via the Pacific ports
- East to Ontario, Quebec and the Maritime provinces, and beyond to Europe, Africa and the Middle East through the Continental and Atlantic corridors and their respective ports.
- Nationally and internationally via air.

Figure 29: Transportation infrastructure accessible via CentrePort



Inland ports can contribute to reducing congestion at seaports and can increase the intermodal capacity for inland freight distribution by speeding up the flow of cargo between ships and major land transportation networks. They are heavily used by major importers as they can serve as a buffer in supply chains, acting as both temporary warehousing facilities and distribution centres, this improving speed-to-market.[88]

88 A Supply Chain's Guide to Inland Ports, Johnston et al, University of Calgary, 2015

5.2.2. Best Practice: The United Kingdom's Rail Freight Strategy

The UK has committed through its' Climate Change Act to reduce its total carbon emissions by 80% by 2050 compared to 1990 levels. This is being implemented through incremental and legally binding Carbon Budgets. The most current of these is the Fifth Carbon Budget, set in 2016, which will drive a 57% reduction over 1990 levels by 2032.

As in Canada, heavy duty freight trucks are a significant contributor to the UK's emissions, representing 17% of the total transportation emissions in 2017[89] as compared with only 2% of the total from rail (including both passenger and freight rail). The Rail Freight Strategy, published by the UK's Department of Transportation in 2016, lays out the UK's approach for increasing the use of rail for the transportation of freight as a means of reducing GHG emissions.

Like Canada, the UK has experienced a changing freight landscape in recent years. This is a result of the decrease in traditional bulk rail freight commodities (in particular, coal) and of increases in internet shopping and next-day deliveries. In order to better assess the challenges presented by these changes, the UK Department of Transport commissioned a study to assess rail freight by commodity and to identify barriers.

The study assessed the market for fourteen key commodities and evaluated network capacity across all key corridors, including identifying existing pinch points. It concluded that the potential for growth in rail would not come from traditional sectors (coal and ore), but rather from intermodal (both from ports and domestic), construction, express parcels and automotive. Further, it forecasted that this growth would be taken up by the trucking industry unless key constraints on the rail network were removed. It recommended twenty five specific actions in four broad areas:

- Investment in rail infrastructure including new terminals and track upgrades to permit longer and heavier trains;
- Increased use of innovative technologies including ITS (intelligent transportation technologies) to allow for tracking of individual loads;
- Increasing awareness of the benefits of rail freight; and
- Increasing uptake of rail for freight through both funding and regulatory interventions.[90]

The UK has begun to implement some of these recommendations:

- A pop-up rail depot was established to service a growing construction market in the North West. It is expected to handle 125,000 tonnes of aggregate per year, which would require 150 trucks if it were carried by road.
- A collaboration between network rail and freight operators is delivering technology-based solutions including collection and communication of timetable and performance data.

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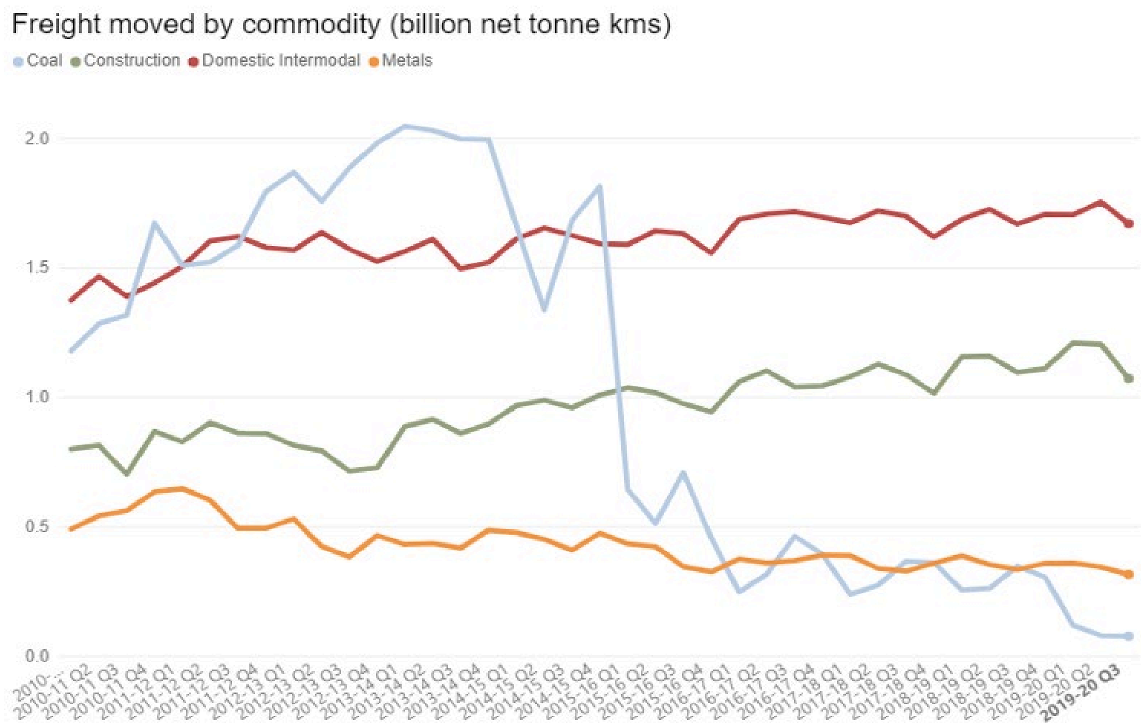
89 Freight Carbon Review 2017, UK Department for Transport https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/590922/freight-carbon-review-2017.pdf

90 Future Potential for Modal Shift in the UK Rail Freight Market, AECOM for the UK Department of Transport, 2016 https://www.arup.com/perspectives/publications/research/section/future-potential-for-modal-shift-in-the-uk-rail-freight-market

- A pilot program is testing the use of converted rolling stock to carry goods from warehouses to central urban rail stations.
- To date, the strategy is having an impact. While traditional commodities carried by rail have decreased (notably coal, as a result of the decommissioning of coal-fired power plants), those identified as critical to the growth of rail, including construction and intermodal, have continued to increase.[91]

Figure 28: UK Freight by Commodity Moved by Rail, 2010-2019



91 https://dataportal.orr.gov.uk/statistics/usage/freight-rail-usage-and-performance/

6. Implementation Advice

Transportation is an integrated system designed to move people, goods and services. At any given time, the system will be transitioning towards a steady state based on a nuanced set of criteria that incorporates indicators of desirability (speed, cost and convenience) and availability. In order to create change, the way in which a particular mode evaluates against the criteria must be changed.

6.1. Recommended Locations for Modal Optimization

6.1.1. Movement of People

Regarding the movement of people, government and key stakeholders should work towards making public transit and active transportation more convenient and reliable than they are at present. As public transit ridership levels increase, the carbon intensity of this mode will decrease even further. This decrease will be further compounded through fuel switching in transit vehicles. Vehicle right-sizing can also play a role here by ensuring reasonably high occupancy levels for given routes and schedules, as long as occupancy rates don't grow so high that they begin to decrease the reliability or convenience of transit. In addition to direct emissions reductions, increased transit ridership will also reduce congestion in and around Canadian cities. Reduced congestion will lead to improved fuel economy, and therefore reduced emissions, for remaining passenger vehicles and on-road freight vehicles, compounding the benefits of a shift from cars to transit.

To complement these efforts, and as the push to decarbonize transportation networks accelerates in future years, cities may wish to explore methods to gradually make the use of privately-owned passenger vehicles less convenient. Methods to be explored in this area include:

- Limiting public parking availability
- Restricting access to certain areas or streets based on time or type/powertrain of vehicle
- Narrowing streets (which can include expanding dedicated active and public transit infrastructure)
- Lowering speed limits

Complementary steps that could be taken concurrently should include actions that make lower-carbon modes of travel more convenient. Such steps might include:

- Expanding service levels and coverage for urban transit, intercity buses, and passenger rail, and engaging in route and scheduling optimization and vehicle right-sizing assessments to ensure occupancy rates of shared mobility vehicles are high (this will help to shift people out of passenger vehicles as well as short haul flights)
- Addressing the need for "last-mile" solutions at shared mobility hubs, so travellers and their belongings can reach their final destinations with minimal effort
- Building dedicated and interconnected active transportation infrastructure throughout Canadian cities

- Providing citizens with modal cost tools to inform them on how significant the total costs of vehicle ownership are (especially when compared to shared modes)

The benefits of such actions will accrue to all members of society, including those that are unable to drive due to cost or age constraints. It is important that any such actions are phased in slowly, beginning with demonstration projects, and that members of the public and other stakeholder groups are consulted throughout the planning and implementation process. All mode-shift activities should be preceded with baseline data gathering and ongoing monitoring to gauge environmental and socio-economic impacts.

With regard to the movement of people, it is clear that rural Canadians will remain car-captive for the foreseeable future, and that modal shift opportunities should be focused on cities, where over 80% of Canadians reside and where an even greater proportion find employment.

The urban sprawl, or suburbanization, that has led to the spatial expansion of Canada's major cities over the last two decades has resulted in longer average commuting distances and has made the widespread provision of urban transit more difficult. Highly densified cities with short average commuting distances tend to have the highest urban transit utilization rates. Yet as cities have expanded to accommodate more detached single-family homes, transit infrastructure has not been able to keep pace with this low-density development and the value proposition of private vehicle ownership in the suburbs remains strong.[92]

Globally, a majority of commuters who live within 5 km of a city centre use urban transit or active transportation to commute to and from work. This is intuitive, as city centres are where urban transit accessibility tends to be the greatest (along with on-road congestion and parking constraints), and also because most commuters who live in a city centre are likely to work within that city. However, in many major Canadian cities this trend is reversed, with a majority of commuters using privately-owned vehicles despite living in city centres. Only in Toronto (25%), Montreal (36%) and Vancouver (42%) do less than 50% of commuters who live within 5 km of city centres commute to work in a private vehicle. In other major Canadian cities such as Calgary (63%), Ottawa-Gatineau (57%), Edmonton (67%), Québec (70%) and Winnipeg (72%), commuters close to city centres continue to use personal vehicles as their default commuting mode.[93] These numbers suggest that these car-oriented cities, and others with comparable demographics, have a significant modal shift opportunity that could be realized through public transit and active transportation network enhancements – enhancements that should include improved access and service levels in city centres.

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92 Statistics Canada. 2019. Results from the 2016 Census: Commuting within Canada's largest cities. (https://www150.statcan.gc.ca/n1/pub/75-006-x/2019001/article/00008-eng.htm)

93 Statistics Canada. 2019. Results from the 2016 Census: Commuting within Canada's largest cities. (https://www150.statcan.gc.ca/n1/pub/75-006-x/2019001/article/00008-eng.htm)

Figure 29: Percentage of Commuters Using Passenger Vehicles, Based on Proximity to City Centres (2016)[94]

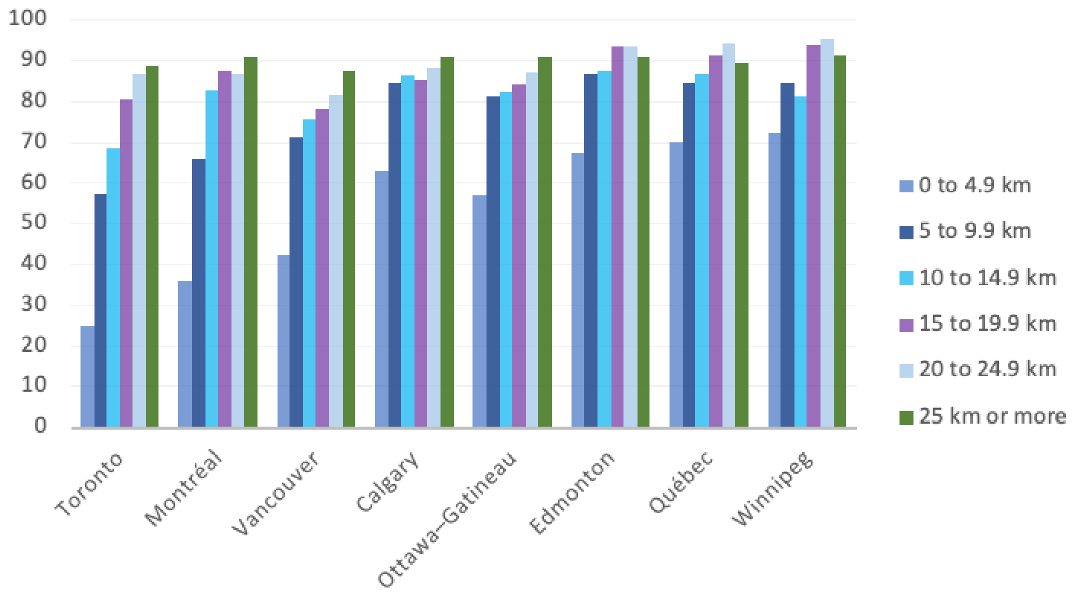
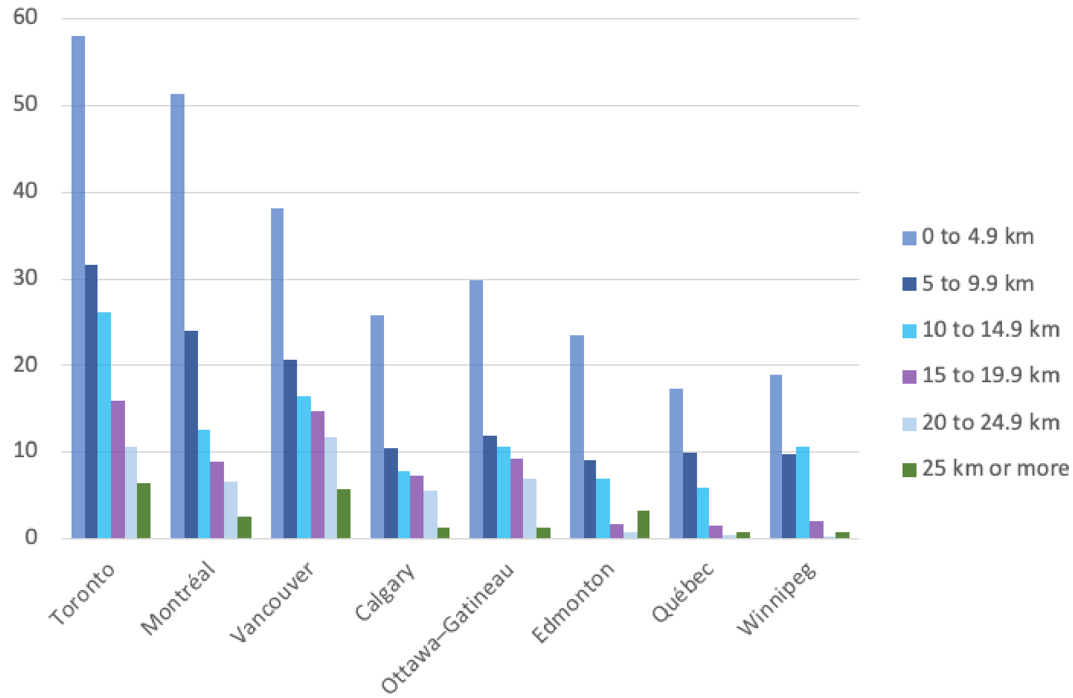


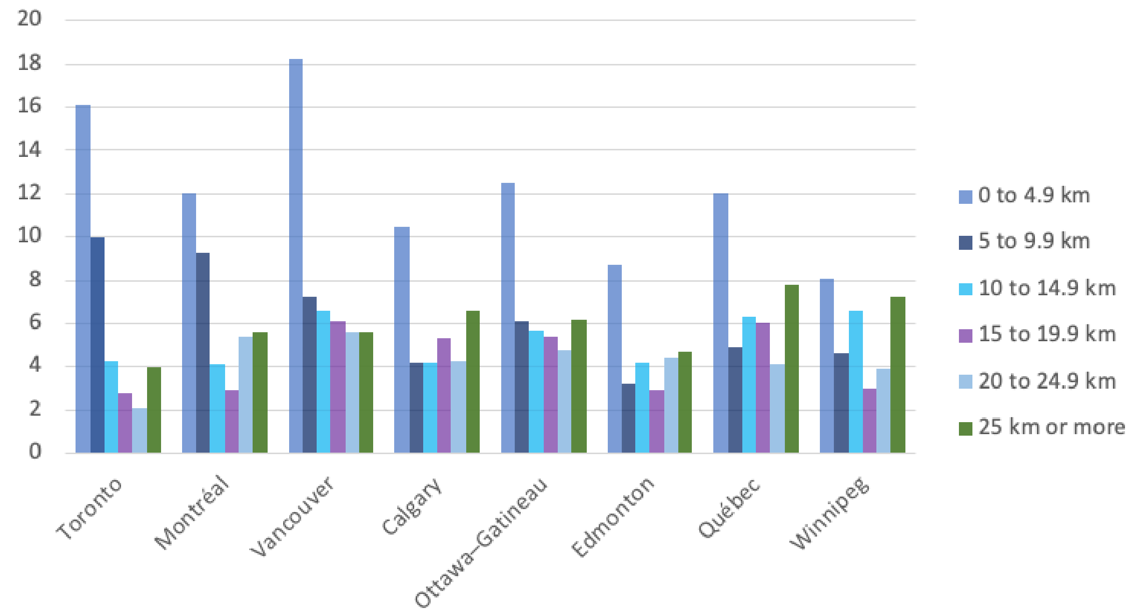
Figure 30: Percentage of Commuters Using Urban Transit, Based on Proximity to City Centres (2016)[95]



94 Statistics Canada. 2019. Results from the 2016 Census: Commuting within Canada's largest cities. (https://www150.statcan.gc.ca/n1/pub/75-006-x/2019001/article/00008-eng.htm)

95 Statistics Canada. 2019. Results from the 2016 Census: Commuting within Canada's largest cities. (https://www150.statcan.gc.ca/n1/pub/75-006-x/2019001/article/00008-eng.htm)

Figure 31: Percentage of Commuters Using Active Transportation, Based on Proximity to City Centres (2016)[96]



As the GTHA case study in Section 5 demonstrates, shifting weekday commuter trips from the existing share of passenger vehicles to transit would yield a maximum GHG emissions reduction from passenger transport of 45% (30% for intercity and 15% for intracity). Comparable results would be expected for other large Canadian cities, with variances based on factors such as the fuel economy of transit vehicles, transit service areas, pre-existing levels of transit usage, and percentage of out-of-town commuters. It is important to note, however, that the GTHA already sees the highest rates of transit ridership in the country, and its intercity transit is powered exclusively by diesel buses and passenger locomotives. It should therefore be expected that the maximum GHG reduction potential from a car-to-transit shift (as a percentage of regional passenger transport emissions) in car-oriented cities such as Calgary, Ottawa-Gatineau, Edmonton, Québec and Winnipeg, is even greater than that of Toronto. Localized transportation emissions modelling undertaken in each of these cities can be used to determine the range of GHG emissions reductions possible from a car-to-transit shift.

96 Statistics Canada. 2019. Results from the 2016 Census: Commuting within Canada's largest cities. (https://www150.statcan.gc.ca/n1/pub/75-006-x/2019001/article/00008-eng.htm)

6.1.2. Movement of Goods

Section 5.2.2 identified the truck to rail modal shift as having the greatest potential to reduce GHG emissions from the transportation of freight. While rail can be more cost effective, especially over long distances, truck may be selected over rail based on speed and convenience.

Statistics Canada's Canadian Freight Analysis Framework provides a comprehensive picture of freight flows across the country by geography, commodity and mode of transport. It provides tonnage, value, and tonne-kilometers by origin and destination, by commodity type, and by mode, allowing for the identification of "hotspot" origins and destinations of goods transported long distances by truck.

As discussed in section 5.2.1, a modal shift from road to rail is economically feasible for distances over 400 miles (644 km). Due to data complexity, a limit of 1000 km was used a proxy for this benchmark. The truck to rail ratio was calculated by origin for all shipments that travelled over 1000 km in order to identify origins where freight shipment by truck is preferentially used over rail.

Table 15: Proportion of 1000+km shipments by truck from Canadian origins

Freight Origin	Freight tonne.km		Ratio Truck to Rail
	Truck	Rail	
Vancouver	7,152,779,284	39,142,076,922	15%
Rest of British Columbia	1,611,093,842	67,721,481,012	2%
Calgary	2,858,660,440	7,337,782,618	28%
Edmonton	4,949,695,506	40,543,129,396	11%
Rest of Alberta	4,658,569,929	55,137,757,099	8%
Saskatoon	628,864,727	18,667,500,839	3%
Rest of Saskatchewan	1,471,241,031	72,062,432,134	2%
Winnipeg	2,948,933,565	4,598,658,730	39%
Rest of Manitoba	4,414,362,930	9,498,052,509	32%
Toronto	37,626,600,158	22,992,303,210	62%
Hamilton	2,430,397,261	1,212,801,194	67%
Oshawa	185,680,548	615,191,143	23%
Windsor	38,468,528	654,555,248	6%
Rest of Ontario	19,355,162,338	14,410,028,781	57%
Montréal	6,241,221,580	12,839,810,525	33%
Quebec City	1,966,955,916	1,071,860,064	65%
Rest of Quebec	8,952,880,838	10,428,489,810	46%
New Brunswick	4,066,920,910	3,270,506,031	55%
Halifax	1,343,037,405	3,106,956,860	30%
Rest of Nova Scotia	1,718,471,778	606,269,794	74%
Prince Edward Island	1,231,400,932	0	100%
Newfoundland and Labrador	969,771,053	0	100%
Northwest Territories	60,167,482	1,532,491	98%
Yukon	24,307,614	0	100%

Historical shipping patterns for trade between Canada and the United States were also examined.

Table 16: Canada-US Trade by Modal Share[97]

Canada-US Trade	Modal Share %					
	Truck	Rail	Marine	Air	Other	Ratio Truck to Rail
2009	59.1	15.1	4.8	6.4	14.6	80%
2010	57.9	16.9	5.3	5.3	14.5	77%
2011	56.4	16.9	5.8	5.0	15.9	77%
2012	56.7	17.8	5.5	4.9	15.1	76%
2013	55.3	17.8	6.1	4.9	16.0	76%
2014	54.4	16.8	6.2	5.0	17.6	76%
2015	59.8	16.7	5.1	5.9	12.5	78%
2016	62.1	17.3	3.6	5.7	11.3	78%
2017	59.5	17.4	4.2	5.4	13.5	77%
2018	57.8	17.6	5.1	5.5	14.0	77%

Some clear trends with respect to shipments over 1000km emerged from this analysis:

- Rail is the predominant means of shipping freight in Western Canada, and trucking becomes more dominant moving eastward.
- Ontario and Quebec, while well serviced by rail, nonetheless have a very high reliance on trucks.
- The Atlantic provinces and the Northern Territories have little to no rail service, and therefore a much stronger reliance on trucks.
- Freight transported to the U.S. (and through the U.S. to Mexico) has historically travelled by truck more than by rail.

These trends were further examined to assess possible opportunities for shifting some of the existing truck traffic to rail.

Predominance of Rail in Western Canada

Rail is predominant in Western Canada, with some variations across and within the western provinces. It is as yet unclear whether this trend is commodity-based, infrastructure-based, or due to some other factor or combination of factors. Based on this analysis of trips of over 1000 km (i.e. trips for which rail is the more cost effective mode), there appears to be a higher predominance of trucking for shipments originating in urban centres. This is particularly evident in Calgary, which has a significantly higher reliance on trucking (28%) than the rest of Alberta (only 8%), and than Edmonton (11%).

Possible Opportunity

Further investigation is required to understand the reasons behind this trend, and to identify possible best practices that could be applied in jurisdictions that are more reliant on trucking.

97 Excerpted from Statistical Addendum Table EC6

Ontario and Quebec – Reliance on Trucks

Analysis of the data points to the GTHA and Quebec City as origins of a higher than usual proportion of freight shipped long distances by truck.

Greater Toronto and Hamilton Area

62% of freight that will be transported over 1000 km leaves the GTHA by truck. Further analysis indicates that there are a few key commodities that are largely transported by truck rather than rail:

A. “Base metals and Articles of Base metals” are shipped from Hamilton all over Canada and to the US/ Mexico. There is a small quantity that goes by rail (mostly to the United States), but it is dwarfed by the overall tonnage and number of shipments that go by truck

B. “Miscellaneous Products” and “Other Manufactured Goods” move from the GTHA all over Canada and into the United States. Vancouver and the U.S. are the two biggest destinations

Quebec City

The ratio of freight leaving Quebec City by truck vs. by rail is 65%, as compared with only 46% in the rest of the province and 33% in Montréal. Forest products represent the largest single share of this freight. Of the forest products leaving Quebec City by truck, 64% are bound for the U.S. This is significantly more tonnage than is shipped by rail.

Possible Opportunity

Further investigation is required to determine whether there are underlying reasons why these commodities are primarily moving by truck (for example, access to infrastructure, delivery timelines etc.)

Areas with no Rail Service

Goods that originate in Atlantic provinces that have no access to rail (NL, PEI) necessarily move by truck. It is to be expected that in both cases, goods must leave the island by truck, but based on overall distances, the data indicates that those shipments tend to continue by truck to their final destination.

Possible Opportunity

Building intermodal or reloading terminals in strategic location(s) may accommodate the shift of freight shipments onto rail in the Atlantic provinces. This is at least partially dependent on type of commodities currently being transported by truck, and on rail capacity.
Note that while the same is true of the northern territories not serviced by rail lines, (Yukon and Nunavut, with only limited service to NWT), this region is geographically very large and it exports very little freight interprovincially so the opportunity is much smaller.

Freight Shipping to the United States/ Mexico

This trend is particularly strong in Ontario. This is notable due to the fact that the freight rail corridor from Canada into the U.S. travels through Ontario and into the central and southern U.S. Research by the Railway Association of Canada suggests that this is very commodity-dependent: raw materials and parts tend to travel by rail and finished products – consumer goods by truck. The study did not identify a reason for this trend, however a factor may be that many large retail companies have their own fleets.[98]

Table 17: Canada-United States Trade, 2017-2018[99]

From	To	Share %	Main Modes Used (%)
Canadian Region	US Region[1]	2018	2018[p]
Ontario	Central	24.7	Road (76), Rail (18)
Ontario	South	11.8	Road (73), Rail (18)
Ontario	North-East	8.6	Road (86), Air (8)
Alberta	Central	8.6	Pipeline (84), Rail (10)
Ontario	West	7.0	Road (49), Rail (39)
Quebec	North-East	4.7	Road (74), Rail (9)
Quebec	South	4.2	Road (48), Marine (24)
Manitoba and Saskatchewan	Central	4.1	Road (65), Rail (18)
Alberta	South	3.8	Rail (41), Pipeline (37)
British Columbia	West	3.5	Road (66), Pipeline (11)
Alberta	West	3.4	Pipeline (45), Road (27)
Quebec	Central	2.6	Road (64), Rail (16)
Atlantic Provinces	North-East	2.4	Marine (61), Road (30)
Manitoba and Saskatchewan	South	2.0	Road (56), Rail (26)
Total Canada/US		**100.0**	**Road (58), Rail (18)**

Possible Opportunity

Further investigation required to better understand the reasons behind current modal selections and opportunity for shifting cross border traffic from road to rail.

Changing Natural Resources and Commodities Landscape

Freight transportation requirements are constantly evolving. A significant portion of the commodities transported in Canada consist of natural resources. Examples of changes in this sector that will impact transportation include:

- The forestry industry in British Columbia moving further north. This will require an extension of rail lines to accommodate continuing provision of service.
- The emerging bioeconomy sector is expected to create geographical pockets of requirements for transportation of freight related to feedstocks and products from this industry.

98 Personal communication with E. Rosales, Railway Association of Canada.
99 Excerpted from Statistical Addendum Table EC8

6.1.3. Next Steps

A key finding from this work is that the opportunities for modal shift, and the GHG reduction benefits that can be achieved through modal shift, are functions of the specific conditions that exist in particular locations and/or for particular commodities. This work has established the types of factors that affect modal choice and the activities that can enable modal shift, but further work will be required to pursue some of the potential opportunities identified as well as identify further opportunities. Recommendations for next steps include:

1. **Engage stakeholders:** Canada's transportation network involves a huge number of interconnected stakeholders, many of whom will need to cooperate in new ways to enable modal shift. Key findings of this report can be tested with stakeholders as a means to translate some of the more general areas for action present in the report into specific ideas for modal shift initiatives.
2. **Engage in further work on barriers and solutions, focusing on freight:** Modal shift is complicated, especially with respect to the movement of goods where the competitive landscape presents significant challenges.
3. **Close data gaps:** Data available on the movement of services was unavailable, and numerous additional data challenges have been identified in this report. Better modal usage and environmental impact data will be critical to identify modal shift opportunities and predict impacts and benefits.
4. **Develop a flexible methodology, or framework, that can be used to assess modal shift opportunities:** The framework can leverage the research on optimal modes presented in this report as well as the work on quantifying environmental impacts to create a best practice means of analysis. The framework could include multiple lenses based on different types of activities and the needs of different stakeholders. For example, the framework could have a tailored lens by which to assess different means of government intervention with respect to costs, GHG reductions achieved, stakeholder impacts etc.
5. **Perform more detailed feasibility work:** The report identifies a number of potential areas of opportunity for modal shift, but further work specific to individual locations and commodities will be required to identify opportunities and how they could be actionable.
6. **Develop a Canadian modal shift strategy:** Leveraging this report and some of the areas of work identified above, create a modal shift strategy that includes targets, actions and an implementation plan.

Appendix A: Regional Overview of Transportation

British Columbia

This geographically diverse province encompasses mountains, valleys, plains and coastline. Highways and rail lines are rarely straight in BC, instead they tend to follow river routes and mountain passes. This makes them both circuitous and hilly, which impacts on fuel efficiency for both road and rail transportation.

BC's economy relies primarily on the service sector, but natural resources including forestry, mining and fishing are also important. With a population of 4.6 million people, B.C. is the third most populated province.[100] Its population resides largely in the south – nearly 60% in Vancouver alone. BC's urban population is growing.

B.C.'s location makes it a strategic hub for international trade with the Asian Pacific Region: Prince Rupert is the closest port to the Asia Pacific Rim. The emerging opportunities for trade with countries such as India and China have taxed the province's transportation infrastructure in recent years as a quarter of Canada's imports and exports flow through the province.[101]

The Prairies

Alberta is the most populated of the three prairies provinces (4.1 million) and growing. Saskatchewan (1.1 million) and Manitoba (1.3 million) are more sparsely populated. In all cases, the population is concentrated in the south. The region has extensive road and rail infrastructure for the movement of people and goods. This includes winter roads that provide seasonal access to remote communities, primarily in Manitoba.

Urban centres in this region are prone to sprawl, as they have few natural barriers to outward expansion and due to their relatively young age, most were planned around the automobile. This has historically taxed the urban transportation systems.[102]

The economy is dominated by extraction of natural resources: primarily oil and gas in Alberta. Freight transportation is land based with a heavy reliance on both rail and road.

Ontario

Ontario is the most populated province (13.4 million), and it is growing: the population is expected to increase by 28.6 % from 2014 to 2036.[103] Over 90% of the population is

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100 All population data in this section from the 2016 Census, Statistics Canada.

101 Based on Statistics Canada, 2015a from Climate Risks & Adaptation Practices For the Canadian Transportation Sector 2016 https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/earthsciences/pdf/assess/2016/ClimatRisk-E-ACCESSIBLE.pdf

102 Changing Transportation Behaviour in the Prairies and Northern Territories, Transport Canada 2011. https://sharonboddy.files.wordpress.com/2015/01/changing-transportation-behaviour-in-the-prairies-and-northern-territories.pdf

103 Based on census data analysis by Statistics Canada and the Ontario Ministry of Finance, from Climate Risks & Adaptation Practices For the Canadian Transportation Sector 2016

concentrated in the south, primarily in census metropolitan areas (CMA's). Future growth is expected to continue to strengthen this trend, meaning that densification and access to transit will continue to increase.

The economy of the southern part of the province is dominated by the service and manufacturing sectors, with some agriculture. Central and northern Ontario rely on natural resources, primarily mining. Ontario's largest domestic trading partners are Quebec, Alberta and BC.

This region is immediately adjacent to Canada's largest trading partner, the United States. It is home to Canada's largest transportation corridor, which runs from Windsor to Quebec City; as well as to the Great Lakes/St. Lawrence inland waterway system, the most important stretch of navigable water in Canada.

Quebec

Quebec is the second most populated province (8.1 million), and 60% of the population lives within a 10 km swath on either side of the St. Lawrence river. The province's economy is largely industrial in nature. There is also a reliance on extraction of raw materials including minerals and lumber.

Quebec's road infrastructure is aging and prone to congestion but remains the preferred mode for movement of goods and people. The rail network extends from the Ontario border along the St Lawrence valley and towards the north of the province. The increasing demand for rail service led to a tripling of track distance in the province from 1993 to 2015. The Quebec ports along the St. Lawrence river are some of the largest in eastern Canada: the Port of Montréal, closely tied in to the road and rail infrastructure, specializes in shipping containers. The deep water port in Québec City is also an intermodal hub for trade in the Great Lakes/St. Lawrence inland waterway system. The port in Sept-Îles is the third largest port in Canada in terms of bulk tonnage handled.

Atlantic

The four Atlantic provinces are home to 2.3 million people. The population is increasingly moving towards CMAs, but there remains a large rural population. The economy is based largely on oil and gas, fishing, mining, lumber and agriculture. Nova Scotia and New Brunswick trade with each other and with Ontario and Quebec. Newfoundland and Labrador's domestic trade is primarily with Ontario and Quebec. Prince Edward Island has the smallest national share of domestic trade which is nearly exclusively with Ontario.

Both road and rail are key to the movement of people and goods in the provinces. Marine infrastructure in the Atlantic region is both significant and highly specialized. The Port of Halifax provides services for both international and domestic intermodal shipping. The Ports of Saint John (New Brunswick) and Placentia Bay (Newfoundland and Labrador) specialize in crude oil and refined petroleum products, which comprise the majority of Atlantic Canada's marine freight.

The North

Canada's north is the most sparsely populated area of the country, with a total population of only 113.7 thousand across the three territories. The vast size and harsh climate pose significant barriers to transportation as well as to economic and social development.

All three territories have resource-based economies, relying on mining and oil and gas. Transportation is largely land-based in both the Yukon and Northwest Territories, relying on both all-weather roads and seasonal so-called "winter roads". Nunavut lacks all-weather roads both between communities and to connect it to southern Canada, so freight shipping is largely by sea. Rail is limited to one line that connects Hay River, NWT with Alberta. Air transportation is important in all three of the territories.

Appendix B: GHG emissions from Household Transportation in the Greater Toronto and Hamilton Area (GTHA)

Introduction

This exercise focuses on developing a GHG emission inventory for all household transportation modes (private vehicles and all forms of transit) in the Greater Toronto and Hamilton Area (GTHA), where the transportation sector is the second-largest emitter and accounts for 35% of total GHG emissions.[104] The GTHA is the largest metropolitan area in Canada, and is home to more than 15% (about 7 million residents) of the total Canadian population. It consists of two municipalities (Toronto and Hamilton) and four regional municipalities (Durham, Halton, Peel and York), with Toronto as the most populated, with 2.7 million residents.[105]

Data and methods

Trip information

The total GHG emissions are estimated for all household trips in the GTHA based on the 2016 Transportation Tomorrow Survey (TTS), which is a comprehensive travel survey conducted every five years in the GTHA. It samples 5% of the total population within the region by collecting both demographic information and travel activity (e.g., transportation mode, trip origin and destination, and trip purpose) on a typical weekday.[106]

GHG emission factors

For private vehicles, GHG emission factors (EFs) for passenger cars and passenger trucks were estimated based on EPA's MOtor Vehicle Emission Simulator (MOVES).[107] Age and type distributions were obtained from the Ontario Ministry of Transportation (MTO) vehicle registry. An average EF for public transit of 11.73g of GHG in CO2eq/passenger kilometre travelled (PKT) was used based on previously published studies by Professor Marianne Hatzopoulou and her team.[108]

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104 Ministry of the Environment and Climate Change, 2016. Ontario's Five Year Climate Change Action Plan 2016 – 2020. (https://www.ontario.ca/page/climate-change-action-plan)

105 Government of Canada, 2016. Release and concepts overview 2016 Census of Population : Population and dwelling counts release. (https://www12.statcan.gc.ca/census-recensement/2016/rt-td/population-eng.cfm)

106 University of Toronto Data Management Group. 2018. Transportation Tomorrow Survey Reports. (http://dmg.utoronto.ca/transportation-tomorrow-survey/tts-reports)

107 United States Environmental Protection Agency (US EPA). 2014. MOVES and Related Models. (https://www.epa.gov/moves/latest-version-motor-vehicle-emission-simulator-moves)

108 Minet, L., Chowdhury, T., Wang, A., Gai, Y., Posen, I.D., Roorda, M., Hatzopoulou, M., 2020. Quantifying the air quality and health benefits of greening freight movements. Environ. Res. 183, 109193. (https://doi.org/10.1016/j.envres.2020.109193)

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Wang, A., et al. 2020. Capturing uncertainty in emission estimates related to vehicle electrification and implications for metropolitan greenhouse gas emission inventories. Appl. Energy 265, 114798. (https://doi.org/10.1016/j.apenergy.2020.114798)

For electric vehicles (EVs), energy consumption was calculated as the product of the travel distance and energy consumption rate.[109] The electricity generation mix was obtained from the Ontario Independent Electricity System Operator (IESO).[110] For 2016, the Ontario electricity grid was supplied by 61.0% nuclear, 23.7% hydro, 8.4% natural gas, 6.2% wind, 0.3% biofuel and 0.3% solar power. The average emission intensity is estimated at 59.0g CO2eq/kWh.

Scenarios

Regional GHG emissions (in CO2eq) were estimated as the sum of vehicle operating emissions for all passenger transportation modes. A number of scenarios for altering mode choice and adopting EVs were tested for their impacts on vehicle operating GHG emissions.

(1) Scenario 1: Active Transportation:
If any trips were shorter than 5km, their transportation modes were switched to active transportation. Thus, their GHG emissions were assumed as zero.

(2) Scenario 2: Public Transit:
All weekday car trips that start and end within the City of Toronto were switched to public transit. The corresponding EFs were changed to the average EF for public transit in the region.

(3) Scenario 3: EV Adoption:
A certain proportion of car trips were replaced by EVs and assigned the EF for Ontario electricity generation.

(4) Scenario 4: Commuter Bus and Rail:
Car trips that originated outside the City of Toronto and were destinated to the City of Toronto, or originated inside the City of Toronto and destinated outside the City of Toronto, were replaced by regional transit (passenger bus and rail).

Results

In the base case, the daily total GHG emissions from household transportation in the GTHA was estimated at 21,375.1 tonnes of GHGs in CO2eq. A total of 98% (21,014.5 tonnes) of the vehicle operating passenger GHG emissions are from private cars, while the share of public transit is about 2% (360.6 tonnes). Figure 1 presents the comparison of GHG emissions estimated in the base case and different scenarios.

In scenario 1, any trips that were shorter than 5km were switched to active transportation, such as walking and biking. Thus, their corresponding GHG emissions were calculated as zero. The total emissions decreased to 19,219.9 tonnes (a decrease of 10.0% compared to the base case estimate).

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109 Gai, Y., et al. 2019. Marginal Greenhouse Gas Emissions of Ontario's Electricity System and the Implications of Electric Vehicle Charging. Environ. Sci. Technol. 53, 7903–7912. (https://doi.org/10.1021/acs.est.9b01519)

110 Ontario Independent Electricity System Operator, 2017. Ontario's Independent Electricity System Operator Releases 2016 Electricity Data. (http://www.ieso.ca/en/corporate-ieso/media/news-releases/2017/01/ontarios-independent-electricity-system-operator-releases-2016-electricity-data)

In scenario 2, any car trips that started and ended within the City of Toronto were replaced by public transit. The estimated total emissions decreased to 18,166.0 tonnes (a 15.0% decrease from the base case).

In scenario 3, two proportions (20% and 50%) of car trips were replaced by EVs. The case where 20% of car trips were replaced by EVs led to 17,637.7 tonnes (a 17.5% decrease) and with 50% leading to 12,030.6 tonnes (a 43.7% decrease).

In scenario 4, all car trips originating outside the City of Toronto and destinated to the City of Toronto as well as car trips originating inside the City of Toronto and destinated outside the City of Toronto were replaced by regional transit. The estimated total GHG emissions decreased to 14,906.1 tonnes (a 30.3% decrease).

It is important to note that these results are scalable. For example, in the case of scenario 1, if 50% of car trips less than 5km in length within the GTHA were replaced by active transportation, it would result in a total passenger transportation emissions reduction of 5.0%.

Figure 32: Comparison of GHG emissions estimated in the base case and different scenarios