Knowledge Synthesis Grant Final Report

Public Transit and Active Transportation: Activity, Structural and Energy Efficiency Effects on Mobility and the Environment

Paul D. Larson, Ph.D., University of Manitoba

Robert V. Parsons, Ph.D., University of Manitoba

Arne Elias, Ph.D., Elias Consulting

Bengu Yesiltas, M.Sc. student, University of Manitoba

Public Transit and Active Transportation: Activity, Structural and Energy Efficiency Effects on Mobility and the Environment is co-funded by the Social Sciences and Humanities Research Council and Infrastructure Canada. *Transport en commun et transport actif : effets d'activité, de structure et d'efficacité énergétique sur la mobilité et l'environnement* est cofinancé par le Conseil de recherches en sciences humaines et Infrastructure Canada.

January 17, 2022

Table of Contents

Executive Summary

Background: In 2016, 15.9 million Canadians commuted to work. While 74 percent of them drove alone, six percent rode as car passengers. The car is the clear mode of choice for most Canadian commuters. Passenger vehicles account for approximately 50 percent of Canada's transportation-related emissions. Two widely-recognized solutions to the reliance on cars are to: (1) increase public transit ridership and (2) promote active transportation, including integrated transit/active commuting. The pandemic has led to a tremendous slide in public transit ridership and revenue. Commuting across all modes has declined during COVID-19, while working from home (i.e. tele-commuting) has increased sharply. The pandemic has spawned a surge in active transportation, but this has been largely for recreational purposes rather than commuting.

Objectives: The project has four main objectives, as follows: (1) to review and synthesize the literature on public transit and active transportation, with special reference to studies that integrate these travel alternatives; (2) to benchmark an initial sample of Canadian cities, in terms of public transit and active transportation practices; (3) to draw implications for public policy and practice from the current state of knowledge; and (4) to identify gaps in the literature—and propose opportunities for future research to address those gaps.

Results: While there is a growing literature on active transportation, there is considerably more extant literature on public transit. The active transportation literature is multi-disciplinary, spanning academic journals in transportation, public health, urban planning and sustainability. The *Journal of Transport and Health* appears to be a leading outlet for active transportation research. While there is scant literature on integrating transit and active transportation, it is well-known that transit ridership implies a certain amount of active commuting, at a minimum walking to and from bus stops or rail stations.

The literature also identifies a variety of relevant factors and presents statistical analysis of antecedents and consequences of active transportation commuting, as well as public transit ridership. The potential antecedents of public transit ridership and/or active commuting include carbon taxes, car ownership, climatological factors, community culture, demographics, incentives, infrastructure and service factors, and perceptions of safety. Consequences include fewer greenhouse gas (GHG) emissions, less traffic congestion, and improved public health outcomes (e.g. lower rates of obesity and fewer incidences of diabetes).

Finally, recent literature describes the impact of the COVID-19 pandemic on public transit and active transportation. The big story seems to be the staggering plunge in transit ridership, starting in March 2020.

Benchmarking across select municipalities is a useful approach to learning about effective policies and practices in support of integrated transit and active commuting. In this project, three different western cities are analyzed and compared, in terms of their relevant characteristics, along with infrastructure, services and policies in support of transit and active commuting.

Key messages: Five key messages emerging from the study are briefly outlined below.

1. COVID-19 caused a collapse in public transit ridership across Canada. While it also spawned a surge of cycling, that has been largely recreational. Research is needed to clarify preferred policies and practices to support transit ridership recovery – including incentive systems; and to better understand transitional strategies for capturing and disseminating the true cost of private vehicle (car) ridership to commuters (i.e. fuel costs, parking, mobility pricing, public health costs, etc.).

2. There is an ongoing, overall decline in active transportation commuting in Canada, led by a decline in walking to work. Research is required to understand causes and develop potential solutions to increase active transportation, in particular to promote more walking. The policy and practice gaps include issues in marketing, infrastructure and capacity development – and regulation.

3. Active transportation by cycling has been increasing slowly, across Canada and in many municipalities. As noted, a substantial portion of new cycling activity is recreational rather than for commuting. While such activity is important from a public health perspective, it makes little if any contribution to emission reductions. If the goal is to reduce emissions, cycling needs to replace private vehicle commuting.

4. Multi-modal commuting in Canada represents a largely untapped opportunity. The literature clearly shows the benefits of multimodal commuting, whereby commuters combine public transit and active transportation. This is particularly useful as a means to further reduce GHG emissions. However, multi-modal data are inadequate. Statistics Canada currently only considers single modes for classifying and analyzing commuting. More detailed data are required to understand the nature and scope of multi-modal commuting, and to determine appropriate policies and practices to increase uptake.

5. Statistical modeling is useful to evaluate active transportation and public transit within municipalities. CMA population was found to be a significant predictor of public transit use. Temperature (number of days above 0 C.) was identified as a significant predictor of active transportation use. More research is needed to identify and incorporate additional predictors of transit ridership and active commuting.

Methodology: Three methods were used: literature review, secondary data analysis, and benchmarking. The literature review started with a search for articles in *scholarly journals* with “active transportation” and “commuting” in their abstracts. This yielded eighty unique hits from 2007 to 2021. A similar search for articles in scholarly journals with the terms “transit” and “commuting” in their abstracts yielded 411 unique hits from 2012 to 2021. Abstracts of the active transportation articles were scanned for content specifically addressing matters of policy, public health and the integration of active transportation and transit. Similar scanning was done on the titles of the transit articles, due to their considerably greater volume. Additional articles and a variety of industry and government reports, identified by members of the research team, were added to the relevant collection of literature. The focus was on literature on commuting issues in Canada and the United States.

Preliminary analysis of secondary data was conducted to better understand determinants of commuter use of public transit and active transportation in Canadian cities. Using regression techniques, transit ridership and active transportation use were estimated based on population and climate, respectively. Benchmarking the commuting scene in several Canadian municipalities was also conducted, with special focus on integration of active transportation and public transit. Three cities (Edmonton, Vancouver, and Winnipeg) were selected as initial cases, due to the current locations and familiarities of team members.

Background

In 2016, 15.9 million Canadians commuted to work. While 74 percent of them drove alone, another six percent rode as car passengers. Quite clearly, the car remains the mode of choice for most Canadian commuters (Yaropud et al. 2019). Unfortunately, passenger cars and light trucks account for about half of Canada's emissions due to transportation (NRCan 2020). Canada faces persistently high greenhouse gas (GHG) emissions, as the country attempts to achieve reduction targets consistent with the 2015 Paris Agreement. Heavy-reliance on private vehicles for commuting continues to be a particular concern (Neufeld and Massicotte 2017). Two widely-recognized solutions to this dependence on cars are: (1) to increase public transit ridership (CUTA 2005) and (2) to promote active transportation (WWF-Canada 2012), including integrating active transportation and public transit.

This project is being done during the ongoing COVID-19 pandemic. In Canada, as well as other nations, the pandemic has caused a tremendous decline in public transit ridership and revenue. Upon analyzing Canadian National Survey Data, Harris and Branion-Calles (2021) found that commuting across all modes declined during COVID-19, while working from home (tele-commuting) increased sharply. Indeed, they observed that only 18 percent of pre-pandemic transit riders were still commuting by transit during the pandemic. The pandemic has also spawned a surge in active transportation, but this is largely limited to recreational travel (as opposed to commuting).

Objectives

The project has four primary objectives, as follows:

1. To review and synthesize the literature on public transit and active transportation, with special focus on studies that integrate these travel alternatives.
2. To benchmark an initial sample of Canadian cities, in terms of public transit and active transportation practices.
3. To draw implications for public policy and practice from the current state of knowledge.
4. To identify gaps in the literature—and propose opportunities for future research addressing those gaps.

Methods

This section briefly describes the three research methods used in the project: literature review, analysis of secondary data, and case study benchmarking.

Literature Review

The literature search commenced using a university electronic library database. A search for articles in *scholarly journals* with "active transportation" and "commuting" in their abstracts yielded eighty unique hits from 2007 to 2021. Figure 1 shows the slow, steady increase in active transportation commuting research during those years. While this literature is growing, it remains relatively light compared to the related area of transit commuting. A similar search for articles in scholarly journals with "transit" and "commuting" in their abstracts yielded 411 unique hits from 2012 to 2021. Figure 2 reveals this surging interest in transit among scholars. Indeed, 2021 saw more articles published on transit and commuting (85) than were published on active transportation and commuting during the fifteen-year span shown in Figure 1.

Figure 1. Number of Articles on Active Transportation Commuting, 2007-2021

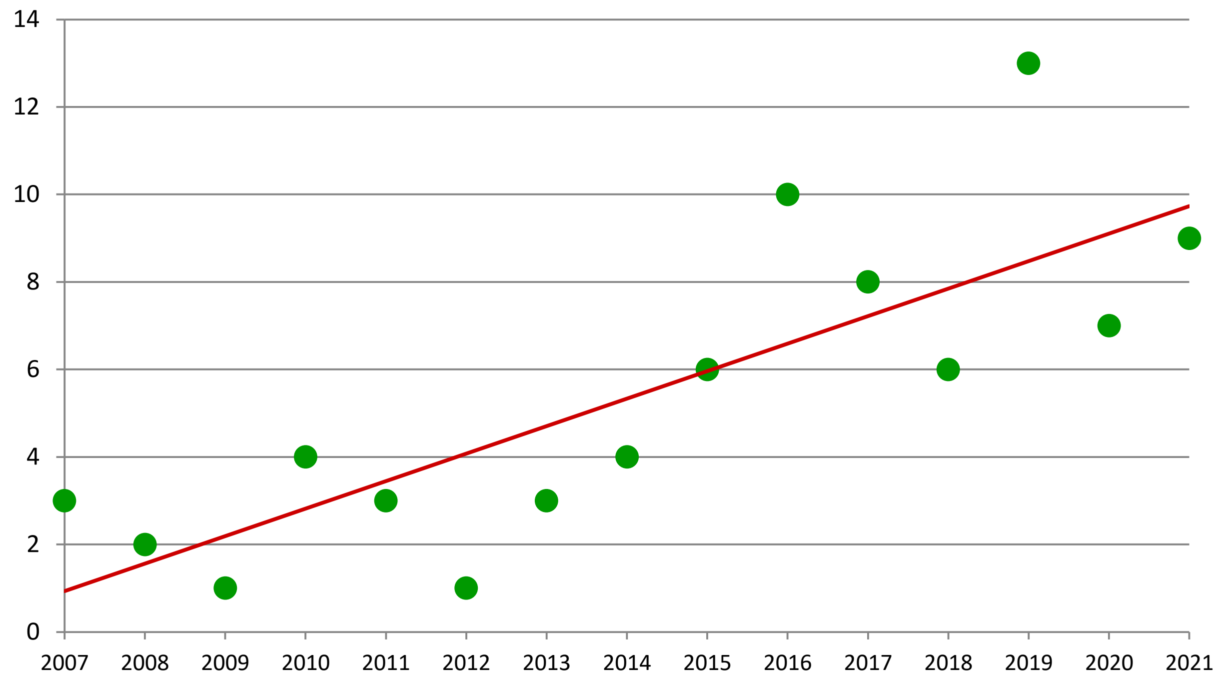
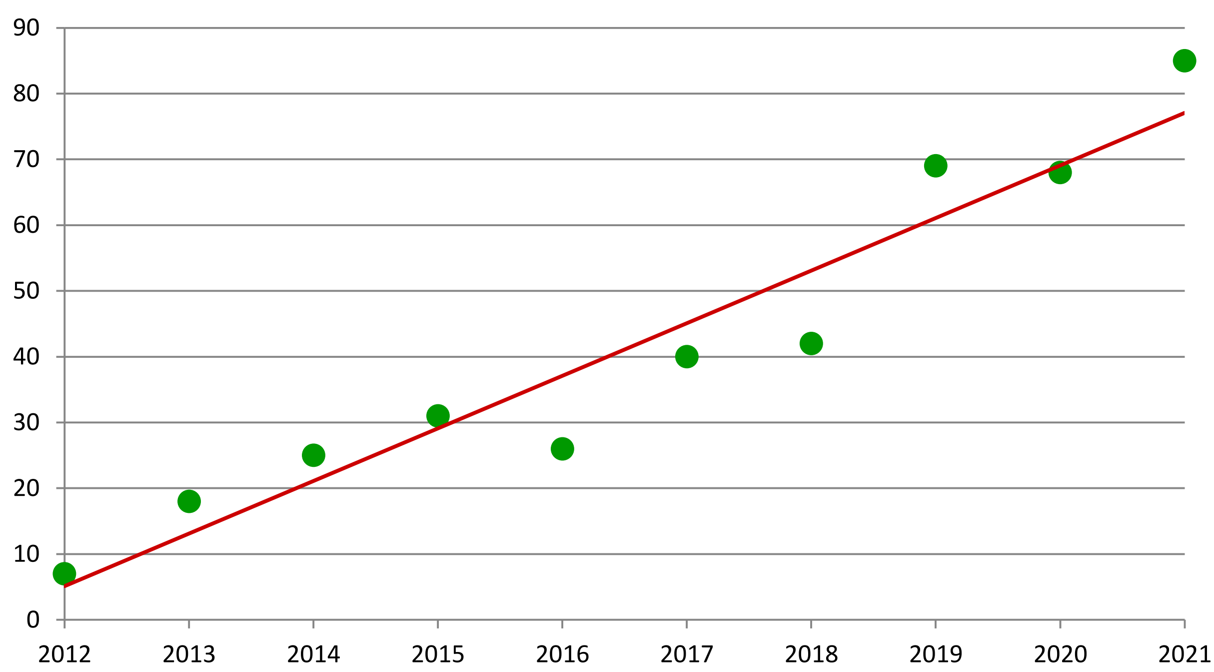


Figure 2. Number of Articles on Transit Commuting, 2012-2021



Abstracts of the active transportation articles were scanned for content specifically addressing matters of policy, public health and integration of active transportation and transit. Similar scanning was done on the titles of the transit articles, due to their considerably greater volume. Additional articles and a variety of industry and government reports, identified by members of the research team, were added to the relevant collection of literature. The focus was on gathering literature on commuting issues in North America (i.e. in Canada and the United States). The remaining sections of the report draw on/synthesize this literature.

Secondary Data

Preliminary analysis of secondary data was conducted to better understand determinants of commuter use of public transit and active transportation within Canadian census metropolitan area (CMAs). Using regression techniques, transit ridership and use of active transportation are estimated based on CMA population and climate, respectively. To anticipate, this sort of statistical modeling will be discussed as an important area for future research.

Benchmarking

This report includes a benchmarking study of several Canadian municipalities, with special emphasis on integration of active transportation and public transit. Three western cities (Edmonton, Vancouver, and Winnipeg) were selected as initial cases, due to the current locations and familiarities of team members. Each of the three cities was profiled in terms of demographic and climatological characteristics, along with relevant features of their commuting scenes.

Results

The results are organized into a series of important topic areas, guided by the literature review and team discussions.

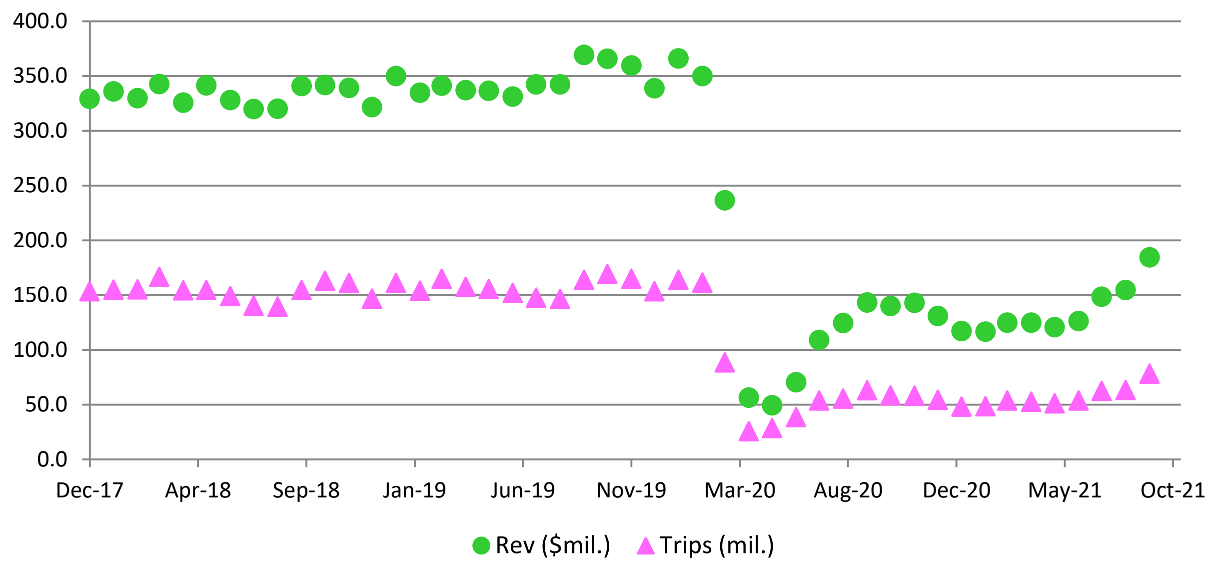
Public transit: COVID-19 collapse

Transit ridership dropped dramatically as a result of COVID-19, especially compared to other modes of commuting. The decline of transit has been recently described in the U.S. (Liu et al. 2020), and Canada (Savage and Turcotte 2020; Simeus-Kabo et al. 2021). Data on monthly passenger bus and rail transit ridership from Statistics Canada are presented in Figure 3, showing a severe decline in early spring of 2020 as the pandemic emerged. Over the period from April 2020 to May 2021, monthly ridership sat at about one-third of the monthly average for the thirty months leading up to COVID-19. From June to September 2021, ridership edged upward, but only to about half of pre-COVID-19 levels. Anecdotal evidence from transit personnel suggests the upward trend was primarily associated with a return to in-person classes at educational institutions. Given uncertainties associated with new variants of COVID-19, recovery to normal levels of ridership remains unpredictable.

Survey results from the United States (Nerad 2020; Tribby et al. 2020), and statistical evidence in Canada (Harris and Branion-Calles 2021), suggest that commuters are trending away from public transit. Transit has been hit hard by: (1) workplace shut-downs and the shift to working remotely; (2) the transition of education, especially post-secondary institutions, to on-line formats; (3) passenger fear of being in close proximity with other passengers; and (4) social-distancing requirements on-board public transit vehicles. While the first three issues reduce transit demand, the fourth one reduces effective capacity.

Recent data reveal persistently high office vacancy rates across Canada into the third quarter of 2021 (Canadian Press 2021). It appears that the “tele-work” option remains strong. Therefore, any return to public transit remains unlikely as long as lots of folks are working from home. Saltman (2020) suggests a three-year or even longer delay could be encountered in the recovery of transit ridership, based on prior experience with SARS. Interestingly, Hung et al. (2021) note that pandemic restrictions on public transit service have diverted commuters into their cars, and this trend continues despite a lack of evidence that transit presents a high risk of COVID-19 transmission.

Figure 3. Impact of COVID-19 on Monthly Canadian Passenger Bus and Transit Ridership



Source: Statistics Canada. Table 23-10-0251-01: Passenger bus and urban transit statistics, by the North American Industry Classification System (NAICS) (x 1,000,000). https://doi.org/10.25318/2310025101-eng

On a positive note, the collapse of commuting and transition to "tele-work" has yielded lower GHG emissions (Statistics Canada 2021a). A critical question for the future is: When folks return to places of work, will they commute via public transit, or in single-occupancy vehicles? How long will the structural (modal) shift away from transit last? There is a need to identify priorities and actions required to avoid a downward spiral (i.e. lower demand leading to lower revenues, followed by cuts to service …) propelled by response to COVID-19.

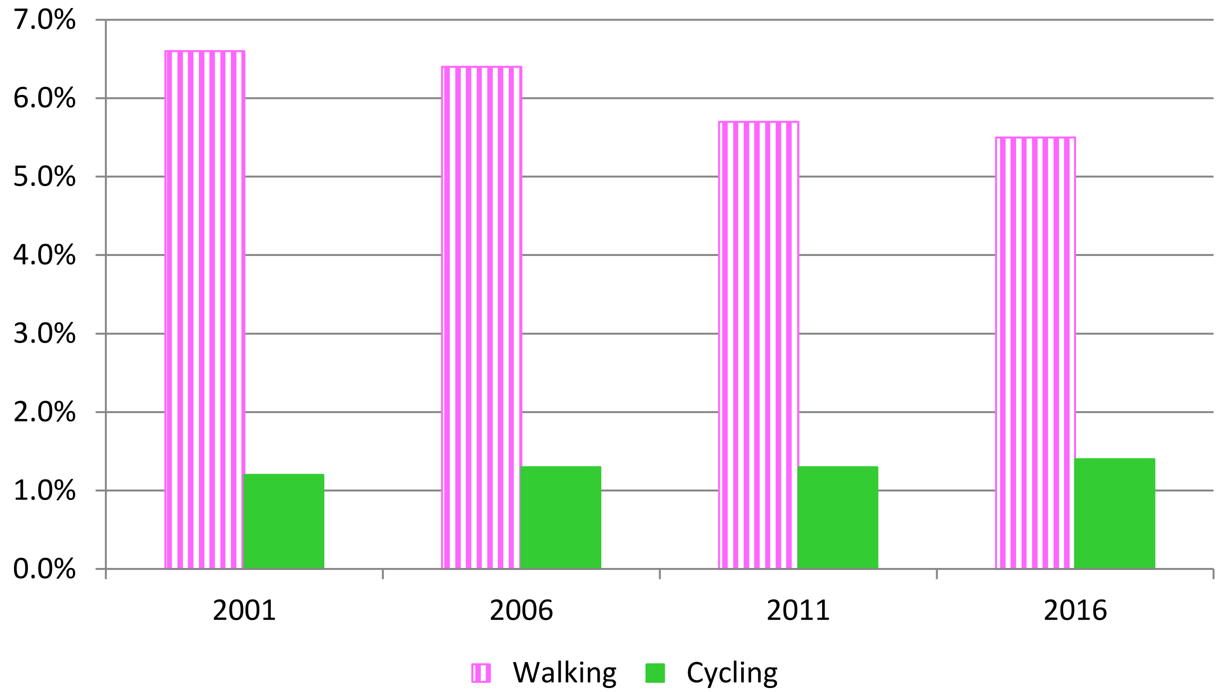
Active transportation: Long-term slide led by less walking

Commuting via active transportation has been in long-term decline in Canada, going back at least to 2001 based on readily available census data. However, cycling has been increasing slightly. Figure 4 presents Statistics Canada data on commuting by pedestrians and cyclists over the past four census periods. While these data reflect the country as a whole, municipal differences will be presented and discussed later, in the benchmarking section. Note that commuting by walking is in a state of decline, dominating the overall drop in active transportation.

Tsafos (2019) summarizes data on proportional use of commuting modes for the United States over time, starting in 1960. Data for the U.S. and Canada on walking to work are summarized in Figure 5. While census data from 2001 to 2016 reveals that a higher proportion of Canadian commuters walk to work compared to the Americans, a steady decline is seen in both nations.

There are a variety of reasons behind these trends. An article in the popular press identified several factors that could determine commuting choices, including size and density of urban areas; education, income, social class and political perspective of commuters; and weather conditions (Florida 2019). North American cities have traditionally catered to car drivers rather than cyclists and pedestrians.

Figure 4. Active Transport Commuting in Canada: 2001, 2006, 2011 and 2016



Sources: 1. https://www12.statcan.gc.ca/census-recensement/2006/dp-pd/hlt/97-561/T603-eng.cfm?Lang=E&T=603&GH=8&GF=0&G5=0&SC=17&RPP=144&SR=1&SO=0&O=A&D1=1

2. https://www12.statcan.gc.ca/census-recensement/2006/dp-pd/hlt/97-561/T603-eng.cfm?SR=1

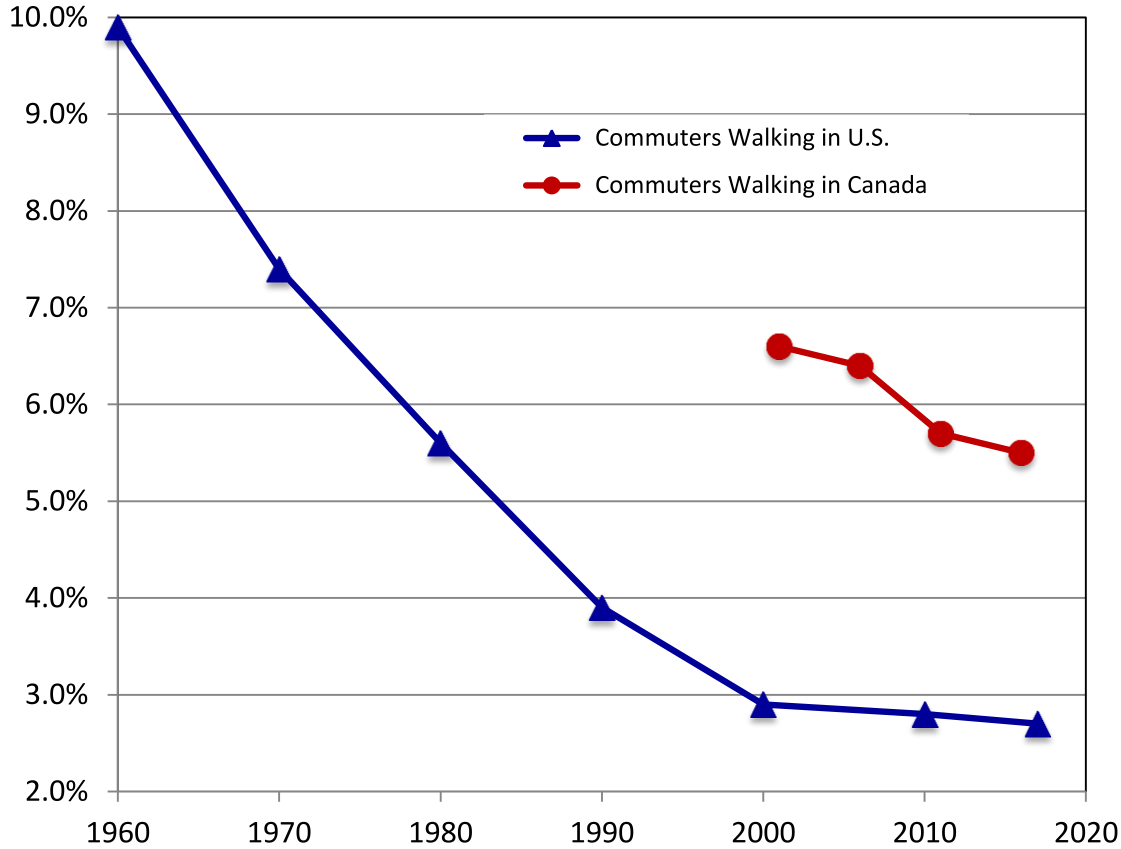
3. Statistics Canada (2013), *Commuting to work*, National Household Survey (NHS), 2011. https://www12.statcan.gc.ca/nhs-enm/2011/as-sa/99-012-x/99-012-x2011003_1-eng.pdf

4. Table 1. Proportion of workers commuting to their usual place of work or no fixed workplace location by main mode of commuting, census metropolitan area, 2016, Statistics Canada, Census of Population. https://www150.statcan.gc.ca/n1/daily-quotidien/171129/t001c-eng.htm

Earlier, in a study on increasing stress faced by commuters, Schaefer (2005) linked increases in car-based commuting to longer commuting distances, as American workers moved further away from their places of work in search of more affordable locations and desirable lifestyles. Statistics Canada (2019a) data reveal similar trends in Canada, with workers moving further away from the workplace. This confirms the importance of urban planning in influencing commuter choice.

The shift away from walking is also connected to concerns of transportation equity. There is a tendency for pedestrian infrastructure to be de-emphasized relative to heavily subsidized vehicular infrastructure. Perhaps this reflects the prominence of the private automobile as commuters' mode of choice. For instance, in a recent study into traffic collisions involving pedestrians in Winnipeg, Viáfara (2021) observes insufficient attention to safe pedestrian crossings in the planning of urban infrastructure.

Figure 5. Proportion of Commuters Walking to Work in the U.S. and Canada



Sources: For Canada, see sources for Figure 2; for U.S., https://www.csis.org/blogs/energy-headlines-versus-trendlines/slowly-changing-us-commute

Increased commuting by cycling

Active transportation via cycling has been slowly increasing over time, across Canada and within many municipalities. The shift toward cycling appears to have been bolstered by COVID-19, as part of a cycling renaissance in Canadian cities (Iassinovskaia 2021) and around the world (Bernhard 2020). Interestingly, a substantial portion of the pandemic surge in cycling appears to be recreational rather than functional (i.e. for commuting purposes). While this is a positive development, it has little if any impact on modal shifting from automobile to active transportation.

Cusack (2021) studied commuting behavior of essential workers in Philadelphia during the pandemic. Based on over 200 responses to an online survey conducted in mid-2020, she found that almost half of the essential workers switched commuting travel modes during the COVID-19 outbreak. While workers have done more active transportation commuting during the pandemic, sustaining the change is likely to require substantial investments toward greater safety for cyclists and pedestrians.

To contribute to GHG emission reductions, cycling must replace personal vehicular commuting, whether it's door-to-door cycling or multi-modal (i.e. cycling integrated with public transit). Recreational cycling is great, but to make a difference more commuting cyclists are needed.

Benefits

The environmental benefits of cycling include: reduced GHG emissions and smog pollutants, i.e. criteria air contaminants (CACs); reduced noise levels; less traffic congestion; and less need for parking lots and roadway infrastructure. Parking lots and roadways come with embedded emissions, and loss of habitat or green-spaces. Brand et al. (2021a; 2021b) discuss the various environmental benefits of cycling.

There are also health-related benefits of cycling, including reductions/improvements in: weight, blood pressure, cardiovascular fitness, strength, posture and balance, flexibility, etc. The easing of numerous health problems (obesity, heart disease, diabetes, osteoporosis, high blood pressure and depression) is directly linked to cycling. These health issues lead to increased mortality and morbidity, at substantial public health costs. The public health benefits of cycling have been widely chronicled in the literature (e.g. Oja et al. 2011; Nieman 2011; KCL 2014; Gotschi et al. 2016; Central YMCA 2016; Celis-Morales et al. 2017; Jhingan and Jhingan 2017; Bourne et al. 2018; Leyland et al. 2019; da Silveira et al. 2021), including substantial public and private return on investment.

Barriers

There is also considerable literature on barriers to cycling as a commuter mode of travel, as well as steps to encourage uptake. FHWA (1992a) identified factors impacting cycling uptake, across two categories: *objective*, measurable factors and *subjective* factors, based on perceptions and interpretation. Potential barriers to cycling include: safety concerns; inconvenience (due to weather, effort required and carriage capacity); lack of facilities; excessive travel distances; the need to have a vehicle as part of employment; and simple inertia. Recent literature confirms these FHWA findings, especially the importance of safety – and the need for complete systems of safe infrastructure (Bidordinova 2010; Shikaze 2012; Manaugh et al. 2017; Santacreu 2018; Fowler et al. 2017; Wang 2018; Assuncao-Denis and Tomalty 2019; Useche et al. 2019; Daraei et al. 2021).

Improvements and adaptations to physical infrastructure for cycling have received recent emphasis, in the form of guidance materials (e.g. City of Toronto 2015; NACTO n.d.; Verlinden et al. 2019). Such guides address inconvenience, the lack of facilities, and safety, in terms of separation of cycling from motor vehicle traffic.

Complete active transportation systems, especially for cycling, are a necessary condition for widespread adoption. These systems must mimic vehicle infrastructure, with protected arteries and secondaries, and public space calming. This requires considerable funding – $40/capita per annum is a rough guide, comparable to what leading countries spend on cycling. Design of such systems can be facilitated by interactive mapping, e.g. project OttoCycle, which offered Winnipeg cyclists an opportunity to track their routes to determine where cycling infrastructure is needed (Elias et al. 2009). Su et al. (2010) designed a similar route planner for cyclists in Vancouver, incorporating distance, elevation, safety and links to transit.

Multi-modal (active/transit) commuting

A critical focus of this project is on opportunities for multi-modal commuting, especially integration of cycling and public transit. The basic principles involved in linking cycling and public transit have been identified in reports from the E.U. (European Commission ND), the United States (FHWA 1992b; TREC 2017; APTA 2018) and Canada (Gatein and Baghaie 2019). One intended outcome of combining cycling and public transit is enlarging catchment areas for public transit (Bachand-Marleau et al. 2011), while synergistically addressing the distance constraint of cycling.

Another issue identified earlier (FHWA 1992a) is the "inadequate state of data collection for non-motorized transportation." This remains a problem, though data sources are beginning to emerge

(Kuzmyak and Dill 2012; Lee and Sener 2020). Whitfield et al. (2020) studied American Community Survey (ACS) estimates of cycling, walking, and riding public transit to work at the state level. Active transportation in 2017 varied widely across the 50 states, from 1.7% of commuters in Alabama and Mississippi to 35.0% of commuters in New York.

The lack of data concern clearly applies to multi-modal transport. While a variety of variables possibly affecting integration of cycling and transit have been identified (Wang and Liu 2013; Heinen and Bohte 2014; van Mil et al. 2021), data on multi-modal commuting is scant. This gap includes the census data produced by Statistics Canada, which reports modes of commuting singularly. Multi-modal uptake by commuters seems low and uncertain, amplifying the need for better empirical data.

There is a small but growing literature on multi-modal commuting. It is known that most commuters walk to their nearest bus stop or rail station. Day et al. (2014) surveyed bus rapid transit (BRT) riders and local bus riders in New York City, hypothesizing that BRT riders do more walking due to the longer distances between BRT bus stops. Indeed, on an average trip, the BRT riders reported walking half a block more than local bus riders.

Noting a lack of research on use of public transit for getting to school, Voss et al. (2015) studied school-trips taken by high school students in Vancouver. In terms of distance and duration, they failed to find significant differences between walking-only trips and the walking segment of public transit trips. Using data from Canada's General Social Survey, Lachapelle and Pinto (2016) observed that transit riders reach physical activity targets by walking to transit stations and/or to other destinations. Those researchers advocate development of transit infrastructure to gain community health benefits. In a similar study, on active transportation and transit in Baltimore and Seattle, transit users reported doing more walking and cycling compared to non-users of transit (Lachapelle et al. 2016). Drawing on a large sample of travelers in the United States, Lachapelle (2015) found a negative relationship between car availability and use of public transit and active transportation. Thus, public policies to make car ownership more expensive or otherwise less attractive could facilitate modal shifts to cycling, walking and transit.

Another policy lever to promote active transportation and transit in the United States is zoning transit-oriented developments or districts (TODs). TODs are high density, mixed-use areas located at or around transit stops. Thrun, Leider and Chriqui (2016) found that TODs are associated with lower rates of car ownership – and higher rates of commuting to work by public transit and active transportation. Public transit riders have been found to do more walking and cycling, when compared to commuters by car and other non-riders, in Raleigh-Durham-Chapel Hill (Mansfield and Gibson 2016) and Houston (Knell et al. 2018).

According to Biehl and Stathopoulos (2020), "seamless integration of mobility services is critical to matching the convenience and comfort of the private vehicle." Their empirical study found that active transportation/public transit multi-modal use is driven by navigational skills, openness to learning, and physical infrastructure. Chan and Farber (2020) study factors affecting use of active transportation by commuters to access rail stations in Toronto and Hamilton. The rail station is their unit of analysis. The following factors were identified as predictors of active/transit integration: population density and age, car ownership and median income. (Note: lower car ownership was linked to greater integration.)

Comparing transit and active commuting across Canadian CMAs

Comparative data analysis and benchmarking can facilitate identification of future opportunities for modes of commuting. From the 2016 census, Statistics Canada provides data on commuting modes for all of Canada's Census Metropolitan Areas (CMAs). The data include proportions of commuters using public transit and active transportation, separated into walking and cycling. Although multi-modal data are not available, comparative analysis of single-modal options can be done.

Comparative analysis should consider objective, "uncontrollable" factors, such as the weather or local cultural norms, with remaining differences reflecting controllable factors, e.g. local policies to promote transit and active transportation, commuter attitudes, etc.

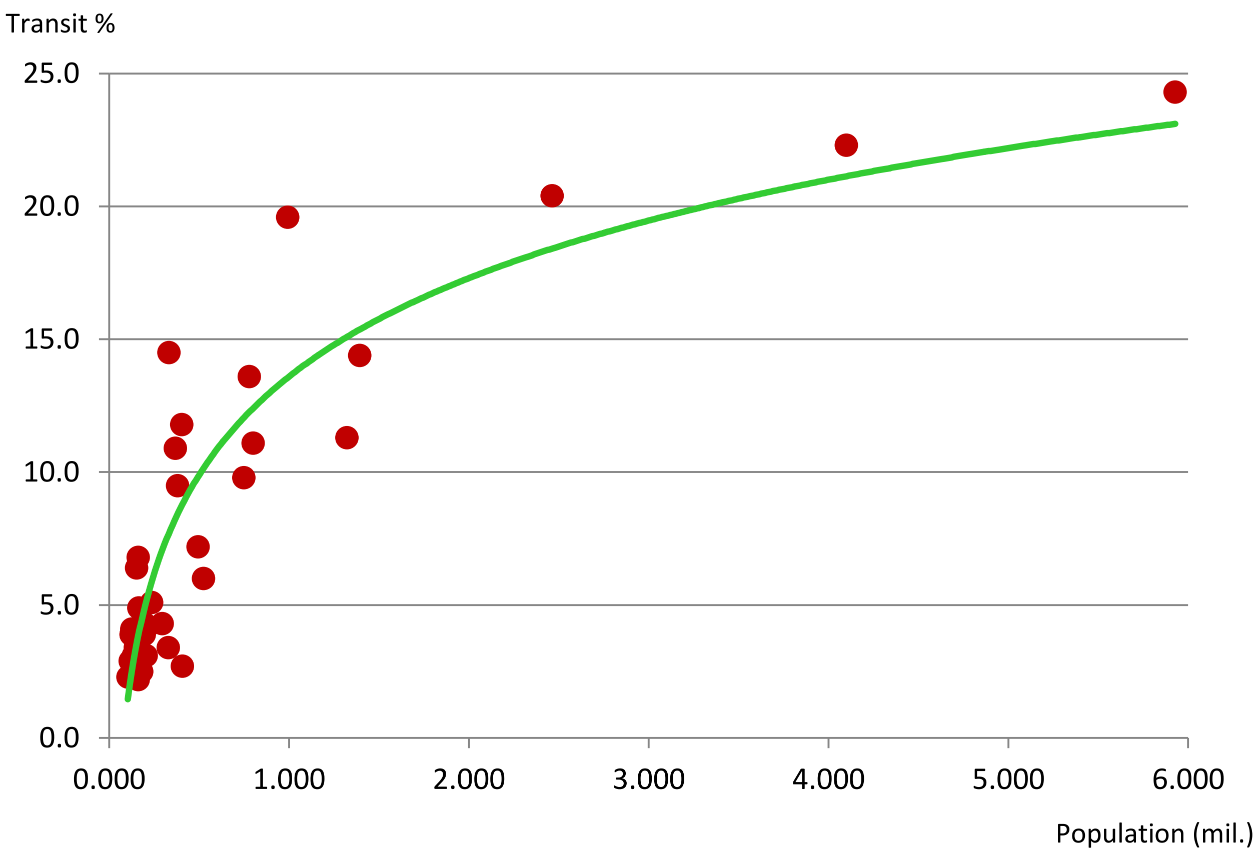
Transit

For public transit, measurable factors affecting uptake include population size or density. All else equal, greater population implies more transit ridership. An initial model uses percent of folks commuting by transit as the dependent variable, and population of the CMA (in millions of people) as the independent variable. The plot of transit commuting proportion as a function of CMA population (millions) for 2016 is presented in Figure 6. Each point represents a Canadian CMA.

Given the clear asymptotic appearance of the plot, population data were transformed to model percent of commuters on public transit (TP) as a function of the logarithm of population, yielding the following regression result: TP = 5.343 × log (Population) – 60.220

This regression is statistically significant (F-statistic = 139.91; p-value = .000), with R-square = .805. Thus, the logarithm of CMA population explains 80 percent of the variance in the percent of commuters using transit. Figure 7 is a plot of the data, including the regression line.

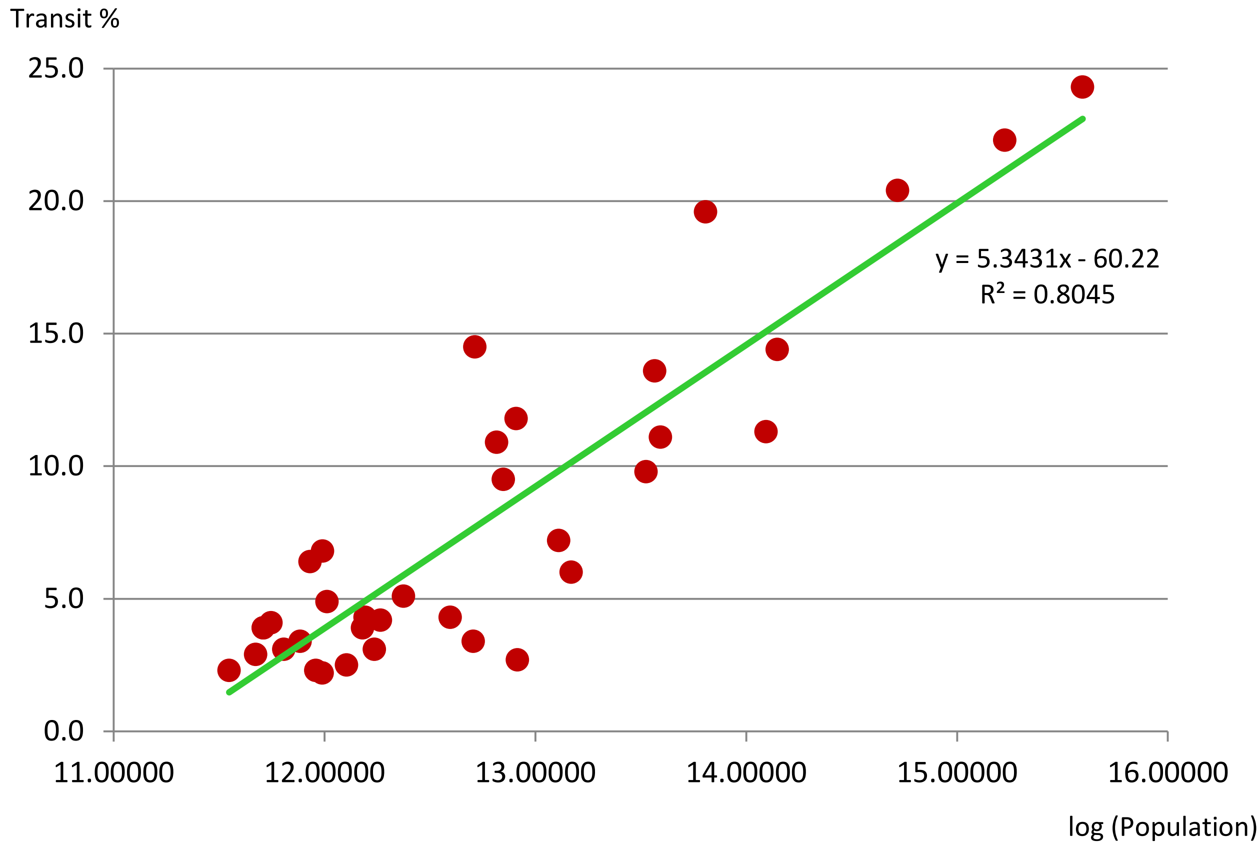
Figure 6. 2016 Commuter Transit Proportions across CMAs by Population (millions)



Sources: 1. Table 1. Proportion of workers commuting to their usual place of work or no fixed workplace location by main mode of commuting, census metropolitan area, 2016, Statistics Canada, Census of Population. https://www150.statcan.gc.ca/n1/daily-quotidien/171129/t001c-eng.htm;

2. Population and Dwelling Count Highlight Tables, 2016 Census. https://www12.statcan.gc.ca/census-recensement/2016/dp-pd/hlt-fst/pd-pl/Table.cfm?Lang=Eng&T=201&S=3&O=D

Figure 7. 2016 Commuter Transit Proportions across CMAs by Log (Population)



Sources: Same as for Figure 6.

Active transportation

A similar analysis of active transportation commuting across CMAs might start with climate-related variables, such as temperature and precipitation. Colder climates, and those with more precipitation, are expected to be less attractive for active transportation, especially cycling. This initial analysis is based on climate-related factors used by *Maclean's* magazine in their annual rankings of "Canada's Best Communities" (Brownell 2021). Three variables are employed in the *Maclean's* rankings: (1) number of days with low temperature > 0°C; (2) number of days with high temperature > +20°C; and (3) number of days with precipitation. These data are available for the year 2019, with the expectation that values for 2016 would be similar. Using this data from *Maclean's* (Naraghi 2019), regression analysis yields the following equation to predict percent of commuters using active transportation (AT) in the 36 Canadian CMAs:

AT = .028 x (Days with low > 0°C) – .027 x (Days with high > 20°C) – .015 x (Days of precipitation)

This regression is statistically significant at the .05 level of alpha (F-statistic = 3.07; p-value = .042), with R-square = .224. Thus, the *Maclean's* climate indicators explain 22 percent of the variance in percent of commuters using active transportation. While the overall regression model is significant, only one of the *Maclean's* factors (number of days with low temperature above 0°C) is a significant predictor (t-statistic = 2.79; p-value = .009). Thus, there is a need to identify and weight additional variables in any model seeking to explain active transportation use in Canadian CMAs.

Selected case studies for benchmarking – a tale of three cities

Becerra et al. (2013) study three South American cities – Bogotá, Curitiba and Santiago – with a focus on initiatives to promote active transportation, including bicycle lanes, bus rapid transit and restrictions on car usage. Similarly, Larson, Parsons and Elias (2021a) analyze and benchmark the active transportation and transit scene across three large western Canadian cities. This section is based on the latter paper.

Characteristics of the three cities

For analysis purposes, the cities proper are considered, with occasional reference to their metropolitan areas. Population, area and resulting density for the three cities and their metro areas are presented in Table 1, based on 2016 Statistics Canada census data. In terms of city population, the three cities are of similar size, with Edmonton being larger than the other two. However, Vancouver's metropolitan area is home to considerably more people than the other two. Vancouver also contains the highest population density, by a substantial margin.

Table 1. Characteristics of the Three Cities

Characteristic	Edmonton	Vancouver	Winnipeg
City (metro) population	980,000 (1,320,000)	680,000 (2,460,000)	750,000 (820,000)
City (metro) area	680 (9,400) km^2	120 (2,900) km^2	460 (7,800) km^2
City (metro) density	1,400 (140) pop./km^2	5,700 (850) pop./km^2	1,600 (110) pop./km^2
Average high (low) temp.	+24 (-14) °C	+23 (+2) °C	+27 (-19) °C
Average 2019 income	$53,500	$52,000	$46,500
Number of transit buses	930	1,460	640
Light-rail transit	Yes	Yes	No

Vancouver has one of mildest climates of any major city in Canada. Edmonton and Winnipeg have similar climates, although Winnipeg experiences greater temperature variation – and the coldest winters of the three cities. Table 1 includes average high and low temperatures, based on data up to 2016. Average income levels for the three cities are shown for 2019 (Statistics Canada 2021b). That year, national average income was $49,000. Thus, folks in Edmonton and Vancouver enjoyed above average incomes, while Winnipeggers had below average incomes.

All three cities have public transit systems, with the respective operating agencies: Edmonton Transit Service (ETS), Translink in Vancouver, and Winnipeg Transit. Approximate numbers of transit buses in operation are provided in Table 1 (including 35-foot through 60-foot units). Vancouver and Edmonton both have light-rail transit (LRT) operations, but Winnipeg does not.

Translink is the largest of the three transit agencies; it serves the city of Vancouver as well as its greater metropolitan area. Translink also use the most diverse energy sources for its existing fleet: 20 percent trolley-electric, 20 percent compressed natural gas, 30 percent hybrid-diesel and, finally 30 percent conventional diesel. Edmonton and Winnipeg have traditionally relied mostly on conventional diesel. However, all three cities have some zero emission bus (ZEB) experience.

Commuter modal distributions

The 2016 census report includes estimates of commuter travel by different modes in cities across the country (Statistics Canada 2019b). Table 2 presents modal split data for the three cities of interest, as well as the overall averages in Canada.

Table 2. Commuter Modal Choice in the Three Cities (2016)

Transport mode	Edmonton	Vancouver	Winnipeg	Canada
Vehicle total	78.8%	49.0%	77.4%	79.5%
As driver	73.4%	45.4%	70.0%	74.0%
As passenger	5.4%	3.6%	7.4%	5.5%
Public transit	14.6%	29.7%	14.9%	12.4%
Active transport	5.1%	20.1%	6.7%	6.9%
Other	1.5%	1.2%	1.0%	1.2%

Source: Statistics Canada (2019b)

In 2016, private vehicle was the primary mode of choice for Canadian commuters, commanding nearly 80 percent of the traffic. The remaining 20 percent was mostly spilt between public transit and active transportation. Of the three cities, Vancouver is the clear leader in sustainable commuting. Commuters in Vancouver are twice as likely to ride public transit and three or four times more likely to use active transportation, compared to commuters in Edmonton and Winnipeg.

As an aside, commuters in Toronto (37.0 percent) and Montreal (36.6 percent) are even more likely to use public transit than those in Vancouver. Moreover, active transportation is more popular in Victoria (36.1 percent) vis-à-vis Vancouver. Edmonton and Winnipeg are somewhat above the Canadian national average for commuters via public transit, but lower for active transport. On the other hand, Vancouver is considerably above the national averages for public transit and active transportation.

Results for the three cities show some consistent trends and confirm prior research, in that two factors appear to be the primary determinants: (1) population/density for public transit share of commuters (Miller et al. 2018); and (b) climatic conditions in terms of the active transportation share of commuters (Saneinejad et al. 2012; Böcker et al. 2019). Of course other factors, such as infrastructure, culture and geography, are also relevant for understanding potential modal shifts away from private vehicles.

Public transit and active transportation policies and interactions

For each of the three cities, relevant documents were gathered, and interviews or discussions were held with experts in public transit and active transportation, with a focus on integration of the two modes. These discussions centered on gaining a sense of the current situation, notable successes, and remaining challenges.

Edmonton

The City of Edmonton (2018) *Smart Transportation Action Plan* contains thirty-five actions, including the following (paraphrased) actions of special relevance to active transportation:

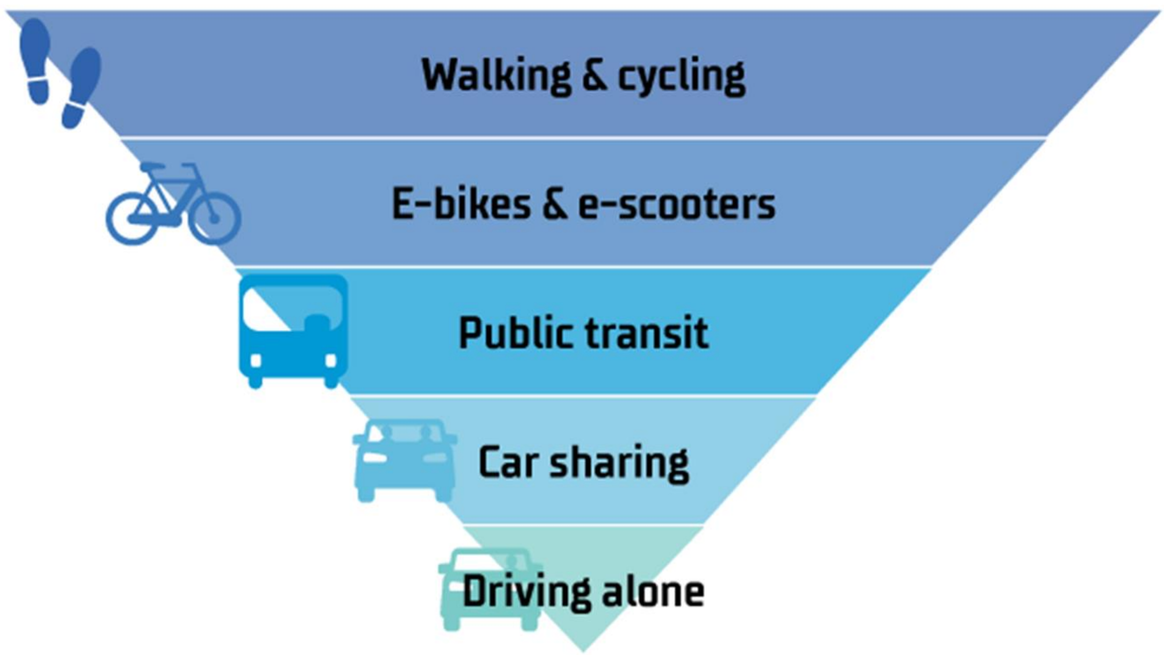
- Assess the potential for a “Mobility as a Service” system to support integrated trip planning and fare payment for public transit, ride-share, bike-share, car-share, etc. to enable multi-modality and sustainable transportation options
- Study mobility pricing to understand the impact of pricing of transport modes on travel behaviour and modal choice
- Implement actions to bridge first-mile/last-mile gaps in transit service for areas of the city without fixed route transit service

The plan's guiding principles on "Climate Leadership" are to: "harness (the) mobility transition to help achieve a low-carbon Edmonton and create a mobility system that is transit-centric, focused on shared-mobility, and enables active transportation." Another one of the thirty-five actions, of special relevance here, is to "engage other major cities across the country to exchange best practices and collaborate on research and pilots."

Active transportation is any mode of transportation a person powers on his/her own. Examples include walking, running, cycling, inline skating and skateboarding (Machell 2009). It also includes vehicles such as e-bikes where the user must contribute all or some of the motive power required.

Overall, transportation accounts for 30 percent of Edmonton's greenhouse gas (GHG) emissions and 42 percent of the city's energy consumption. Private cars are a major contributor to these levels of energy use and emissions. Sustainable mobility supports healthy, vibrant and livable communities by reducing emissions and promoting active transportation. To guide its commuters, the city puts out a five-level "sustainable mobility pyramid" (Figure 8). The most sustainable options, walking and cycling, are atop the inverted pyramid, followed by e-bikes and e-scooters. Public transit sits in third position, in the middle of the pyramid. Next is car sharing, and finally driving alone, at the bottom of the sustainable mobility pyramid (City of Edmonton 2021a).

Figure 8. The Sustainable Mobility Pyramid



Source: City of Edmonton (2021a)

The Bikes on Buses initiative (City of Edmonton 2021b), encouraging the city to equip its ETS buses with bike racks, was started by former Bike Edmonton president Tooker Gomberg. Bike Edmonton won a grant to purchase half of the bike racks installed on ETS buses involved in a pilot test. The program has been in operation since 1996 in the City of Edmonton. In 2013, it was expanded to include all full-size ETS buses. Historical note: Bike Edmonton was established as the Edmonton Bicycle Commuters Society in 1980, and now has over 1,700 paid members (https://bikeedmonton.ca/).

Bikes on Buses – ETS now has bike racks on all full sized and articulated buses. Loading and unloading a bike takes about 20 seconds. Each rack holds up to two bicycles. Bicycles are not allowed inside the bus for safety reasons. Bicycles are loaded and unloaded individually from the curb side of the bus. Cyclists are responsible for properly securing their bikes to the rack. For safety reasons, bus operators cannot help load or unload bikes. Bikes ride the bus free.

Bikes on LRT – Outside of peak hours cyclists can travel with their bicycles in any direction on the LRT. Bicycles are not permitted on the LRT during peak hours (Monday to Friday, 7:30-9:00 a.m. and 4:00-5:30 p.m.) There are no hourly restrictions for bicycles on Saturday, Sunday and holidays. Passengers pay the regular ETS fare; their bikes ride free.

Bicycle Parking at ETS Facilities – Bicycle parking areas are available at many Transit Centres and LRT Stations. Twelve transit centres and LRT stations have bike racks.

The Funicular – Edmonton's 100 Street funicular is an inclined elevator that operates from downtown, near the historic Hotel Macdonald, into the North Saskatchewan River Valley. It was awarded a National Urban Design Award of Excellence for the way it connects downtown Edmonton to the river, "creating an urban space for people to connect with nature" (Ramsay 2020).

The funicular opened to the public in December 2017. Costing $24 million, the project received funding from all three levels of government (federal, provincial and municipal), and the River Valley Alliance. During its first year of operation, city staff recorded up to 135 passengers riding the funicular per hour and as many as 28 trips in an hour. An estimated 22 percent of funicular riders use it for their commute to work and 31 percent take it to access the river valley (Heidenreich 2019).

The large elevation difference (~50 metres) and steep slope makes access between the river and down-town Edmonton rather difficult, especially for folks with mobility challenges. The funicular enables people in wheelchairs, cyclists, parents with strollers and others to move along the steep grade easily, as well as free of charge. The funicular offers dramatic views of the spectacular valley below. The funicular track is 66 metres long, on a 23.5 degree incline. Its top speed is about two metres per second. For those up to the challenge, a stairway runs parallel to the funicular. At the bottom of the funicular, a pedestrian bridge crosses a busy roadway and then a glass elevator completes the descent to the river (van Es 2019).

In 2020, operating costs for the 100 Street Funicular and its surrounding site were $531,602, excluding snow removal costs. Largely due to the pandemic, funicular ridership plummeted from 218,965 over June 5 – December 31, 2019 to 134,630 over the same period the following year (City of Edmonton 2020b).

Vancouver

Vancouver is a core municipality in the greater Metro Vancouver Regional District (MVRD), consisting of 23 local authorities, 21 of which are municipalities. This makes it challenging to isolate data for active transport (AT), especially cycling, and for transit. Vancouver city has a population of 680,000 out of 2,606,000 – approximately 26 percent of the MVRD.

TransLink is the primary authority responsible for transportation in the MVRD, including infrastructure and public transit, which consists of three SkyTrain rapid transit lines; regular and rapid bus routes; and Seabus and West Coast Express. TransLink conducts continuous planning processes, e.g. the recent engagement process for Transport 2050, the region's transportation blueprint for the next 30 years (TransLink 2021a). The focus is on electrification, rapid transit, People First streets and autonomous vehicles.

Cycling infrastructure is relatively well developed in the downtown core with East/West and North/ South protected bikeways providing some basic routes for the rest of the municipality. However, most of the cycling infrastructure is unprotected (City of Vancouver 2021).

Vancouver has relatively high levels of AT and transit mode share at 21.3 percent and 29.7 percent, respectively. A 2019 survey showed combined (walking, cycling and transit) mode share at 54.1 percent (https://vancouver.ca/streets-transportation/walk-bike-and-transit.aspx). This is facilitated by a mild climate, high population density (especially in the downtown core), reasonably developed and relatively safe infrastructure and cultural factors, e.g. high levels of environmental awareness. Thus, Vancouver and BC have higher sustainable transportation adoption rates. For example, BC has the largest Plug-in Electric Vehicles (PEV) market share in Canada at 8.4 per cent, followed by Quebec with 6.7 percent and Ontario with 2 percent. Vancouver has the second highest PEV proportion of total new vehicle sales at 10.9 percent. Only Victoria, at 12.9 percent, is higher (Statistics Canada 2021c).

Current trends in Vancouver are similar to many Canadian and international municipalities, due to the COVID-19 pandemic, including high levels of telecommuting; increased cycling and walking; and a large decline in transit use. The challenge is to maintain AT gains of the COVID-19 era while reversing the collapse of public transit.

Restoring transit ridership may be difficult for several reasons. First, some of the recent commuting patterns are highly desirable, such as increased cycling, walking and telecommuting. These patterns are beneficial from an economic, societal, and environmental perspective – and every effort should be made to retain AT share gains. Second, new and returning commuters may be attracted to private vehicle use in post-COVID times. As patterns of travel are re-established, transit service models and plans to attract travelers must be coordinated with changing commuter needs.

One challenge for cycling in Vancouver is topography – hilly terrain and a large number of chokepoints, such as bridges, require additional treatments and costs (Moovit Insights 2021a). Cycling infrastructure needs to be more effectively built out to connect all residents safely and conveniently, from doorstep to destination. Furthermore, deficiencies in transit and bus service capacity vis-à-vis demand levels have restricted transit (even pre-COVID) and AT mode share, as have social capacity shortfalls, along with difficulties in fulfilling convenient origin/destination travel. For example, SkyTrain is very expensive to build, full bus rapid transit (BRT) is limited, and there is minimal capacity and coordination for bike (and vehicle) park and ride.

However, there is some good news in the pre-COVID data. For example, the average time people in Vancouver spend commuting with public transit on a weekday is 43 minutes (Moovit Insights 2021a), which is less than other large cities in Canada. Wait times for transit are also lower than comparable cities. Implementing proposed modal shifts will involve a complex recipe requiring the mixing of many ingredients. The challenge will be increasing infrastructural and technological investments, along with social marketing capacity building, to turn around existing issues as well as shortfalls created by COVID. The task is to build a better customer experience, primarily for transit, but also for cycling.

Vancouver has distinct advantages for building out a comprehensive and integrated transit and AT system. The climate is mild with few large snowstorms, and most folks are accustomed to and able to handle outdoor activities and rain. The two other cities in this study, Edmonton and Winnipeg, have far harsher climates. Still, even in these cities all-year cycling can be achieved with the proper knowledge, equipment and clothing, as well as supportive infrastructure and operating support such as prioritized snow clearing of protected bikeways (Winter Cycling Federation 2020). To a lesser extent, Vancouver needs to implement similar tactics for rain.

Vancouver also has high population density in the central core and relatively accessible, dense and constrained bedroom communities and suburbs. Thus, Vancouver has a distinct advantage for both AT and transit over many other municipalities in Canada. Vancouver's opportunity to "build back better" is significant. Planning, constrained by the cost of rapid transit, density and expensive real estate is well developed. It includes expansion of SkyTrain, rapid bus (B-Line) and increases in cycling infrastructure (TransLink 2021b).

TransLink has made significant advances in fare collection, information and planning services, including such elements as real time information, scheduling and route fine-tuning. Transport 2050, the region's transportation blueprint for the next 30 years (TransLink 2021a), supports significant expansion of the SkyTrain lines. Although expensive, these lines have high passenger throughput and are well-liked and used by Vancouver citizens. Proposals include expansion of the Millennium Line to Arbutus and of the Expo Line to Langley Centre. Additional 30-year timeframes offer about 100-200 km. or more of light rapid transit, and as much as 350 km. of bus rapid transit (BRT), depending on the scenario.

While implementation schedules from TransLink (2021c) and the municipality are ambitious from a planning perspective, they are modest against the timelines for achieving climate goals. A far more audacious roll-out is required. That is dependent on fiscal and policy recognition of the value and role of AT and transit along with the tremendous overall costs of using fossil fuels – as outlined elsewhere in this paper.

For cycling in Vancouver, the high rate of e-bike adoption, which increases range and over-comes local terrain challenges, minimizing effort and perspiration, is a game changer. E-bikes are an acknowledged gateway to higher commuter cycling adoption, providing convenience and predictable commuting times. They may stimulate much higher cycling participation, especially if subsidies can be provided for e-bikes – as they are for e-vehicles – and safe and connected infrastructure and services are developed.

The opportunity in these planning scenarios is integrating AT, transit, and vehicle (autonomous or otherwise) routing for efficient origin/destination travel and building a coordinated service model to create the best customer experience. The ultimate objective is to develop policies and regulations to divert private vehicle use, e.g. through mobility pricing, to more appropriate uses such as in un-serviced areas, for group trips, multi-destination trips or where loads are unmanageable for cargo bikes or transit. Another opportunity is to recognize transition costs for transit users and develop a post-COVID rollout using community-based social marketing techniques and re-introducing transit, in particular for returning and potential new riders. For example, welcome back events (e.g. concerts) prioritizing transit use could be created around post-COVID plans to build back better. Free one week, or even one month, passes would bring customers into the transit fold – a short-term cost for long-term gain.

Ultimately, TransLink and municipalities like Vancouver, in consort with provincial and federal partners, must internalize the strong cost/benefit case and the positive return on investment (ROI) of funding modal winners like transit and AT. This understanding supports the rationale for using data-driven decision-making that leads to the right infrastructure, social support, and appropriate technology for creating an attractive customer experience for AT and public transit users (Moovit Insights 2021b).

Winnipeg

Recent work on active transportation in Winnipeg began with the Marr (2005) report, which referenced an earlier national document by Go-for-Green (2004). Active transportation was already recognized, including its public health, social, economic and environmental benefits. Stronger emphasis emerged regarding its potential for GHG reductions, in connection to the Kyoto Protocol, and possible "binding" national targets. In Winnipeg, the award-winning *Winnipeg Pedestrian and Cycle Strategies* (Urban Strategies 2014) has become a blueprint for further actions across the city.

Support in Winnipeg for active transportation involves a combination of recreational- and destination-oriented facilities. While the latter are critical for commuter modal shift, the two overlap in terms of longer-term benefits. Naturally, active transportation networks involve a range of facilities, similar to car and truck transportation networks.

In 2018, Winnipeg's network had 431 km. of "active transportation facilities," including: 223 km. of multi-use paths, 53 km. of *bike lanes* (on-street bicycle lanes physically separated from motorized transport lanes); 56 km. of *bike boulevards* (signed bicycle routes); and 37 km. of on-street bicycle lanes not physically separated from motorized transport lanes, called "sharrows" (City of Winnipeg 2020b, p. 2-8). Winnipeg Public Works (2020a) provides a full cycling map of the city.

The City of Winnipeg has an annual capital budget of about $2 million to support active transportation infrastructure (Winnipeg Public Works 2020b). However, the City has adopted a relevant and novel policy framework that understates actual support of active transport. On major roadway rework projects, costs of accommodating active transport upgrades, including widening and adding bike lanes, are embedded in the project capital budgets.

The recent focus at Winnipeg Transit has been completion of the Southwest Transitway, now running from its downtown terminus, at the University of Winnipeg, to its southern terminus, at the University of Manitoba. This transit way is roughly 15 km. in length. The full system, known as the "Blue Line," was officially opened and fully operational in April 2020. Of course, by then, COVID-19 was starting to take a heavy toll on ridership.

The Transitway connects the two largest transit destinations in Winnipeg, i.e. the two universities noted above. This connection underscores the collapse in ridership caused by COVID-19, as both institutions transitioned to on-line learning in the spring of 2020. The Southwest Transitway accommodates active transportation, including pedestrian and cycling pathways along most of its length, as well as bike racks and storage bins at major stations. Thus, the line enables passengers to choose intermodal transit/cycle movement.

In the past, Winnipeg Transit had a portion of its buses equipped with bicycle racks. Today, especially on newer buses, bike racks are largely absent. The problem is not a policy change, but rather garage space limitations. Winnipeg Transit has been moving away from standard 40-foot buses, to larger and longer, 60-foot articulated buses. A bike rack adds two feet to the length of a bus, increasing garage space requirements. Nonetheless, Winnipeg Transit intends to install bike racks, particular for use along the new Transitway.

The city is in the process of updating its Transportation Master Plan (City of Winnipeg 2020a). The plan will cover the next 30 years, to 2050, based on eight strategic priorities: (1) transportation and land-use; (2) environmental sustainability; (3) equity and inclusiveness; (4) economic development; (5) strategic approach; (6) mode choice; (7) transportation demand; and (8) transportation supply. Active transport and public transit are integral components across these priorities, as reflected in the Winnipeg Transit (2021) Master Plan.

Winnipeg's active transportation networks are generally viewed positively, though evidence of this is mostly anecdotal. An important success during 2020 was Winnipeg's "Open Streets" initiative, in which selected roadways throughout the summer were closed to vehicular traffic, in favor of pedestrians and cyclists. This was largely in response to COVID-19, and similar to other programs noted by Fischer and Winters (2021). Public response was highly positive, and an updated version of the initiative is planned for 2021. However, this year's plan will be more limited, since the Government of Manitoba will not consider amendments to its *Highway Traffic Act* prohibiting the co-mingling of pedestrians and vehicles on roadways (Pursaga 2021).

One interesting example of modal shift is the active transportation infrastructure installed and used to approach the University of Manitoba's Bannatyne Campus as a destination. This large and busy complex includes the Health Sciences Centre, Manitoba's largest tertiary hospital. A recent, still unpublished survey undertaken by Probe Research for the City of Winnipeg found that 60 percent of Winnipeggers would ride bicycles if they were safe. This result suggests the importance of safety to facilitate a modal shift to bicycles.

A common problem for active transportation has been a lack of data compared to other modes, such as public transit, which collects a treasure trove of data during regular operations. People ride their bikes but no one knows about it. Pioneering work in this area has occurred in Winnipeg, with GPS data and in-depth interviews used to identify commuter cycling routes, traffic levels and needs (Elias et al. 2009).

There are indirect measurements available, e.g. gasoline consumption, which can be linked to vehicular travel. An area of special relevance for bicycles, as noted previously, is safety related information. The reporting of collisions and injuries for other modes are more rigorous, e.g. vehicular data gathered by Manitoba Public Insurance. There is no such source of safety data for cycling. This lack of information may make people fearful due to uncertainty about safety. This sort of information could also clarify and justify the need for protected cycling infrastructure.

In Winnipeg, the commuting public may not be aware of various seamless multi-modal transportation options that are available to them. The integration of public transit and cycling could be communicated more effectively. Some folks may not aware of cycling-to-bus-to-walking options, and thus resort to use of a private vehicle as the sole perceived options.

Another pressing issue, faced by Winnipeg as well as other municipalities, is a general infrastructure deficit. Active transportation competes with a backlog of other critical infrastructure upgrades. Here, a promising development is the recently announced National Active Transportation Fund, which provides $400 million over five years to build and upgrade bike paths, pedestrian walkways and bridges, and nature trails. The Fund is part of the $14.9 billion, eight-year public transit plan unveiled by the federal government (Rabson 2021).

An additional limitation to active transportation for Winnipeg is simply winter! As noted above, the city endures rather cold winter temperatures. In a rare example of research on winter cycling, Nahal and Mitra (2018) study facilitators and barriers in Toronto. They found that only 27 percent of "cyclists" claim to commute by bicycle during the winter. Of course, winter in Toronto is different than winter in Winnipeg! There has also been recent attention on winter cycling in Nordic countries, e.g. the Finnish cities of Oulu and Rovaniemi (Swanson 2016; Steensig 2021). While conditions in Oulu and Winnipeg are different, these municipalities offer interesting benchmarking opportunities.

Implications

Implications for policy, practice and research are organized around various themes gleaned from the results.

Impact of COVID-19 on transit

Regaining the benefits of public transit post-COVID, especially GHG reductions, will depend on restoring ridership. This requires urgent action. Municipal leaders across Canada have collectively requested funding assistance (Press 2021).

The Government of Canada, through Infrastructure Canada, has been increasing spending commitments toward zero emission bus (ZEB) implementation. However, if transit ridership does not recover, these investments will be significantly under-utilized, and the opportunity to shift to a lower emission, higher value mode will be wasted. Similarly, success of multi-modal sustainable transport options, especially cycling/transit combinations, also depend on public transit availability and restored ridership. Thus, assistance should not be focused solely on ZEB but needs to broadly cover transit agencies across the country, including conventional systems.

Electric buses can provide enhanced quality of service, e.g. a quieter ride, reduced odours and reduced GHG emissions. During the pandemic, emissions have declined due to less activity. After the pandemic, ZEB could build on this improvement in the form of an energy efficiency effect (Haggiag 2020).

Parsons et al. (2017) advocate that transit-driven GHG reductions require a modal shift: from personal vehicles to buses or trains. Clean Energy Canada and CUTRIC acknowledge the severity of the current predicament—and the need for solutions and new funding to reinvigorate public transit across Canada. While Clean Energy Canada (2020) included "A Note about COVID-19" in their recent report, amongst CUTRIC's (2020a) proposed Five-Point Plan, is: "Finding smart solutions for a safe return; investing in research to identify issues and pose solutions to bring back ridership safely." Similarly, Iacobacci et al. (2020) argue that the first step in transit's recovery is to understand demand going forward.

According to Tirachini and Cats (2020), "The economic and social effects of the COVID-19 outbreak in public transportation extend beyond service performance and health risks to financial viability, social equity, and sustainable mobility." The uncertainties and situation affecting public transit imply several research questions and needs, including the following:

- How to make transit systems more resilient to COVID-19? This will likely require a combination of new technologies (George 2021; CUTRIC 2020b), and better understanding of rider decision-making. What sort of marketing campaigns are needed to enhance trust—and increase ridership? While this question has recently attracted a variety of perspectives (e.g. APTA 2020; Dia 2020; Moore 2020; Rousakis 2020; FTA 2021; McGowan 2021; Yen et al. 2021), numerous opportunities to study some possible solutions – and to assess outcomes – remain.
- Since different jurisdictions may vary in responsiveness (Bert et al. 2020), socially-oriented solutions that work in one place may not work elsewhere, in terms of enhancing confidence. Thus, there is a need for surveys and analysis tools that can be applied across a range of locations to measure local characteristics and outcomes.
- Another potential strategy is the provision of incentives and incentive systems, such as free short-term passes and passenger discounts. Post-COVID research on approaches to more comprehensive pricing (such as carbon and mobility pricing) of conventional high emission vehicles may facilitate shifts towards transit and active transportation.

To immediately assist transit agencies, the Government of Canada could exempt public transit agencies from carbon pricing in provinces covered by the Federal Carbon-Pricing Backstop, with provinces not under the federal system encouraged to do the same. Similar exemptions are already provided for many agricultural applications.

While carbon taxation provides a signal of the importance of environmental issues, recent research suggests it may be less effective than planned in yielding overall emissions reduction (Parsons 2021). Canadian carbon taxation started in 2008 in British Columbia, ultimately inspiring the rationale for national implementation. The Government of Canada is counting on carbon taxation to reduce GHG emissions by 80 to 90 million tonnes by 2022 (ECCC 2018).

The rationale for the transit carbon tax exemption is straightforward. While municipalities have been receiving gasoline tax rebates from the federal government, the carbon tax is a separate and increasing tax. Transit agencies must either absorb the cost, a loss of scarce resources running into millions of dollars for medium to large systems, or pass it on to transit riders, raising social equity and ridership concerns, especially in the time of COVID. Recent analysis shows that to make a difference in favour of ZEB, carbon taxes must be considerably higher to reflect actual costs (Parsons et al. 2020). Incentives may represent a preferred alternative, and are discussed further later in the report. Enabling a modal shift toward public transit is critical post-COVID, irrespective of energy form used in buses. Removing carbon tax would provide some immediate relief where it is needed – and would facilitate a modal shift back to transit.

Decline in active commuting

There are also important unanswered questions about the long-term decline of walking. Has the plunge in pedestrian activity been exacerbated by reduced infrastructure? Or, has the decline in infrastructure funding been a response to less walking? Is this a result of demographic, psychographic or other social shifts in Canadian society? How can this trend away from walking be reversed through urban planning, design and other policies?

What are the reasons for the decline in walking by commuters? What can be done to increase walking? This includes better characterizing the multi-modal nature of personal transportation, and how walking fits. For instance, most transit riders walk to and from bus stops (Voss et al. 2016). Transportation inequity regarding pedestrians, including an apparent reduced emphasis on infrastructure to support walking as a viable commuting option, also needs to be investigated.

Increased cycling; uncertain multi-modal commuting

An ongoing concern for cycling, including cycling/transit multi-modal commuting, is the lack of action to move things forward. While lack of political will is a substantial obstacle, there are “low-hanging fruit” related to data and information. More and better quality data are needed. The call for relevant, on-going, up-to-date and localized data on active transportation (walking and cycling) has been issued globally (Grossman 2018) and echoed in Canada (Montufar et al. 2020; Branion-Calles et al. 2021).

Of particular concern is a lack of adequate safety-related data, including systematic accident and near-miss compilations. Again, such data should be ongoing, up-to-date and local. At an international level, data reflecting local issues has been identified as critical to confirm the efficacy of safety-related active transportation improvements (Auert et al. 2020). Similar needs are expressed in Canada (Teschke et al. 2013; Viáfara 2021). In previous research addressing this issue, Ismail et al. (2009) use AI recognition software on traffic cameras to qualify and quantify near misses and minor unreported collisions with vulnerable road users.

Another opportunity involves enhancing on-line information availability, to assist in mapping and route planning for cyclists. Active transportation networks are typically outlined, but using less accessible and less useful formats, especially while on-route, e.g. physical or PDF-based maps. While on-line tools are available, especially for mobile devices, they are often unreliable. For example, the Google Maps app includes cycling and walking for route selection, but availability can be inconsistent in certain locations and situations. Further, the connectedness of active transportation networks is a major issue in many municipalities. However, there is intrinsic, often subtle, knowledge available within cycling communities on preferred routes and options. Such knowledge could be better and more broadly communicated. A nation-wide coordinated effort to improve on-line information for route planning and adaptation would be useful, without requiring extensive resources.

Transit and active commuting across Canada

The plot of transit commuting proportion for 2016 as a function of CMA population (see Figure 4) is clearly asymptotic. The relationship is strongly influenced by a relatively large number of smaller CMA, all having rather small transit commuting proportions. This observation emphasizes the importance of implementing transit not just in large cities, but in smaller cities as well. This suggests there is a need for simplified programming, oriented to smaller cities having fewer resources and less ability to manage complex programs. Regarding ZEBs for smaller cities, one idea recently advanced is use of per-vehicle incentives, similar to programs promoting uptake of light-duty zero emission vehicles (e.g. electric cars) for consumers (Melo and Parsons 2019).

The finding of a link between transit commuting proportion and CMA population is important. It implies a need for further research to identify additional predictors of transit uptake, such as service frequency, safety and cost.

More complete data are also needed to further understand active transportation relationships. In this report, climatic data from *Maclean's* magazine is employed since it: (1) is readily and publicly available; (2) is useful for ranking Canadian communities; and (3) offers a straightforward way to make preliminary comparisons. However, additional data are clearly needed to conduct more detailed analysis of active transportation. For instance, what is the role of commuter perceptions of safety and weather on use of active transportation?

For benchmarking purposes, further in-depth evaluation of top-performing CMAs, in terms of transit use and active transportation uptake, is warranted. This would enable identification of factors or policies that lead to higher performance levels. In addition, new data from Statistics Canada for the 2021 census are anticipated. These data will enable further assessment and estimation of temporal changes, albeit still subject to the skewing impact of COVID-19.

Conclusions

Key Finding #1: COVID-19 caused a collapse in public transit ridership across Canada. It also spawned a surge of cycling, especially for recreational purposes. Research is needed to better understand possible mechanisms and best practices to support transit ridership recovery – including incentive systems; and to understand transitional strategies for transmitting and capturing the true cost of private vehicle (car) ridership to travelers (e.g. whole costing with fuel costs future parking and mobility pricing). This could inform marketing and capacity development narratives in support of sustainable transportation goals. While it remains uncertain how this pandemic will play out, there is a need to develop scenarios and study possible strategies and policies for the post-COVID context, e.g. marketing campaigns, temporary free transit, mobility pricing, etc.

Key Finding #2: There is an ongoing, overall decline in active transportation-based commuting in Canada, evident since at least 2001, led by a decline in walking to work. More research is required to understand causes and develop potential solutions to increase active transportation, in particular to promote more walking. The research and policy gaps appear to include issues in marketing, infrastructure and capacity development, along with regulatory/legal changes.

Key Finding #3: Active transportation via cycling has been increasing slowly over time, across Canada and in many urban areas. This trend is being bolstered by COVID-19, with a recent cycling renaissance. However, a substantial portion of new cycling activity is recreation-oriented rather than for commuting. While such activity is important from a public health perspective, it makes little contribution to emission reductions. If the goal is to reduce emissions, cycling needs to replace vehicular-based commuting.

Cycling routes within cities tend to be highly fragmented. There is a need to create reasonable routes. A frequent problem occurs when the cyclist reaches the end of an obvious section, and then faces the tricky question of: "where do I go from here?" While applications like Google Maps now include cycling as an option, it works well in some cities but not so well in others. There is a need for some nation-wide interactive mapping of urban and rural cycling routes. Many cities have active transport maps in PDF form, but these generally lack the detail needed by cyclists.

The following research questions are particularly applicable to key findings #2 and #3:

1. What communication and marketing strategies are needed to build social capacity and increase knowledge transfer on cycling? How should the business case, including benefits and return on investment, for active transportation be developed and disseminated?
2. Research is needed to understand the current state of cycling infrastructure in Canada, along with what an ideal would look like. How much would it cost to create a "complete system," i.e. safe, accessible, and efficient cycling infrastructure for all ages, abilities and incomes? What is the role of cycling in healthy, vibrant and livable communities, both rural and urban? What needs to be done to develop the cycling tourism sector?
3. There is also a need for mapping the coordination of behavioural tools and societal mechanisms to support cycling uptake and ongoing participation through refining laws and regulations, e.g. Motor Vehicle Acts (MVAs), as well as standards, education and training. There's a need for harmonization of Provincial MVAs – to protect vulnerable road users (VRUs), such as cyclists and pedestrians, and to address other issues. Regarding education: What sort of educational programming would be helpful to promote cycling in Canada? Who is the best target for such programming?
4. What are the best tax, financial and regulatory tools to leverage economic growth, safety and quality of life, while supporting cycling? How can the uptake of cycling be facilitated? What is needed to make it more affordable for all (e.g. no tax on bicycle gear, e-bike rebates, etc.)?

Key Finding #4: Multi-modal commuting in Canada remains uncertain, and represents a largely untapped opportunity. The literature clearly shows the mutual and synergistic benefits of multimodal commuting, whereby commuters combine transit and active transportation. This is particularly useful as a means to further reduce GHG emissions. However, it is also clear that available information is inadequate, which represents an important priority for the future. Statistics Canada currently only considers single modes for classifying and analyzing commuting. More detailed data are required to understand the nature of multimodal commuting, and to determine the best approaches to increase uptake.

We propose the concept of *transportation literacy*, and enhancing peoples' ability to utilize a "tool belt" of transportation options, as a basic principle underlying multi-modal and mode shift advancement.

Key Finding #5: Simple statistical models are useful to evaluate active transportation and public transit within municipalities. CMA population was found to be a significant predictor of public transit use. On the other hand, a climate variable (days above 0^{o} C.) was identified as a significant predictor of active transportation use, inspired by the annual evaluation reported by *Maclean's* magazine.

There is a need for better data to enable statistical testing of the factors that may predict commuter use of public transit and active transportation. Predictors to consider include population density (or simply population), climate, availability of infrastructure and services, and community culture (i.e. receptivity toward active transportation and progressive action on the environment and public health). A critical question is: How can this sort of analysis be leveraged to deliver greater rates of transit ridership and active transportation adoption where factors such as climate and density are not favourable?

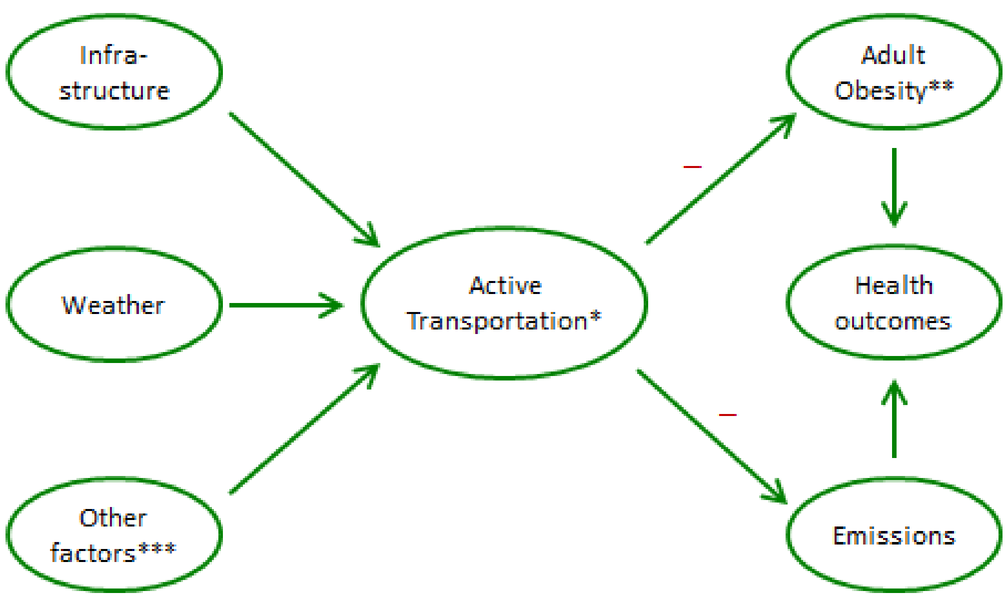
The latest 2021 census has just completed, and there is important potential to evaluate how CMA have changed from 2016 to 2021, and to what extent overall correlations change. Of course, this requires the newest census data, which will open the door to lots of research opportunities.

Figure 9 depicts some of the antecedents and consequences of active transportation (e.g. cycling and walking) for commuting. Within any given jurisdiction, elements of infrastructure, safety, the weather, car ownership and various geographic, demographic and cultural factors impact active transportation uptake. The figure expands on a previous version presented by Larson, Parsons and Elias (2021b). The literature provides considerable guidance on relevant variables for this sort of modeling.

Grabow et al. (2019) found physically active, educated, unmarried men living in urban environments to be the most likely folks to use active transportation. “Bicycle friendliness” of commuting infrastructure was another strong predictor of active transportation. In a recent study, Eldeeb, Mohamed and Páez (2021) focus on effects of the “built environment” on active transportation. Their results reveal positive links between sidewalk density and both walking and use of public transit. While bike lane density and cycling are linked in a positive direction, the connection between bike lane density and transit ridership is negative.

A Danish study found active commuting to be associated with several transit infrastructure and service elements, including distance to the nearest bus stop, density of bus stops and variety of transportation modes available (Djurhuus et al. 2014). An earlier study in Jackson, Michigan focused on the impact of partnerships and promotion on physical infrastructure, policy, and increases in cycling and walking in the community (TenBrink, McMunn and Panken 2009).

Figure 9. Antecedents and Consequences of Active Transportation (AT)



* Lack of AT, i.e. physical inactivity, leads to obesity

** Other causes of obesity include diet and genetics

*** Location, safety, demographics, car ownership, culture, etc.

In terms of consequences, active transportation has been linked to positive health outcomes, led by lower likelihood or rates of obesity (Fenton 2005). Bassett et al. (2008) compared rates of obesity and active transportation across Australia and countries in Europe and North America; and reported that countries with the highest active transportation usage tend to have the lowest rates of obesity. Earlier, Gordon-Larsen et al. (2005) found a similar result among Americans – overweight folks were less likely to commute via active transportation.

Chen and Menifield (2017) study the impact of mode of travel for commuting on obesity across the 50 United States. While commuting by car was found to contribute to rising obesity in America, travel to work using active transportation was linked to lower rates of obesity. Among residents of Los Angeles County, California, Hu et al. (2014) found that proximity to rail stations and quality (availability) of bus service were associated with lower likelihood of obesity, presumably attributed to active transportation needed to access transit services.

Based on their study in Ottawa, Arnason et al. (2019) predict that municipal policies to increase active transportation could prevent hundreds of diabetes incidents. To the west, Frank et al. (2022) conducted a large-scale survey on active transportation and health outcomes in British Columbia. They identified direct associations of greater neighborhood walkability on lower rates of obesity and diabetes. Obesity also mediated the link between walkability and diabetes.

Active transportation commuters have expressed higher levels of subjective well-being and work-life balance (Herman and Larouche 2021), less dissatisfaction with their commuting experiences (Páez and Whalen 2010), and greater happiness (Smith 2017).

While Figure 9 focuses on active transportation, a complementary model is needed for further study of antecedents and consequences of public transit ridership in Canadian cities (Flores 2016; Litman 2021; Zheng 2008).

Knowledge mobilization activities

These activities have already been happening, and will continue after the January 18, 2022 KSG event. Three team members presented some selected, preliminary project results at the last Transportation Association of Canada (TAC) Health and Transportation track (Larson, Parsons and Elias 2021b). Also, the fourth team member, Yesiltas, is developing her M.Sc. thesis on active transportation in Canada.

This report will be posted on the lead author's University of Manitoba web-site and promoted by the University through its *UM Today* magazine. An "evidence brief," supplemental to this report, will also be provided for dissemination.

The team plans to submit papers for presentation at the 2022 Canadian Transportation Research Forum (CTRF), scheduled for June 12-15 in Montreal and the 2022 TAC conference and exhibition, scheduled for October 2-5 in Edmonton. The lead researcher also recently joined the TAC Active Transportation committee. Further, there may be an opportunity to organize a virtual conference or webinar event about active transportation and public transit, in cooperation with the University of Manitoba Transport Institute (UMTI). Currently, such an event is tentative, partly due to the ongoing pandemic.

Finally, the project team is determined to submit up to two manuscripts for review at relevant scholarly journals, e.g. *Journal of Transport and Health*, *Journal of Public Transportation* and/or *Transport Policy*.

Bibliography

APTA (2018), *Bicycle and Transit Integration: A Practical Transit Agency Guide to Bicycle Integration and Equitable Mobility*, Report APTA SUDS-UD-RP-009-18, American Public Transit Association, Urban Design Working Group, Washington, DC. https://www.apta.com/wp-content/uploads/Standards_Documents/APTA-SUDS-UD-RP-009-18.pdf

APTA (2020), *Moving the Nation through Crisis: Mobility Recovery & Restoration Task Force Report*, American Public Transit Association, Washington, DC. https://www.apta.com/wp-content/uploads/APTA-Task-Force-Report-2020.pdf

Arnason, Trevor, Peter Tanuseputro, Meltem Tuna and Douglas Manuel (2019), "Municipal transportation policy as a population health intervention: estimating the impact of the City of Ottawa Transportation Master Plan on diabetes incidence," *Canadian Journal of Public Health*, 110(3), 285-293. https://doi.org/10.17269/s41997-018-0168-9

Assunçao-Denis, Marie-Ève and Ray Tomalty, (2019), "Increasing cycling for transportation in Canadian communities: Understanding what works," *Transportation Research Part A: Policy and Practice*, 123, 288-304. https://doi.org/10.1016/j.tra.2018.11.010

Auert, Joëlle, Kaitlyn Friedman, Soames Job, Meleckidzedeck Khayesi and Alessandra Senisse (2020), *Cyclist Safety: An Information Resource for Decision-Makers and Practitioners*, World Health Organization, Geneva. https://www.who.int/publications/i/item/cyclist-safety-an-information-resource-for-decision-makers-and-practitioners

Bachand-Marleau, Julie, Jacob Larsen and Ahmed M. El-Geneidy (2011), "Much anticipated marriage of cycling and transit: How will it work?" *Transportation Research Record: Journal of the Transportation Research Board*, 2247(1), 109-117. https://doi.org/10.3141/2247-13

Bassett, Jr., David R., John Pucher, Ralph Buehler, Dixie L. Thompson and Scott E. Crouter (2008), "Walking, Cycling, and Obesity Rates in Europe, North America, and Australia," *Journal of Physical Activity and Health*, 5(6), 795-814. https://doi.org/10.1123/jpah.5.6.795

Becerra, Janeth Mosquera, Rodrigo S. Reis, Lawrence D. Frank, Farah A. Ramirez-Marrero, Benjamin Welle, Eugenio Arriaga Cordero, Fabian Mendez Paz, Carlos Crespo, Veronica Dujon, Enrique Jacoby, Jennifer Dill, Lynn Weigand, Carlos M. Padin (2013), "Transport and health: a look at three Latin American cities," Cadernos de Saude Publica, 29(4),p654-666. https://doi.org/10.1590/S0102-311X2013000400004

Bernhard, Adrienne (2020), "The great bicycle boom of 2020," *BBC News*. https://www.bbc.com/future/bespoke/made-on-earth/the-great-bicycle-boom-of-2020.html

Bert, Julien, Daniel Schellong, Markus Hagenmaier, David Hornstein, Augustin K. Wegscheider and Thomas Palme (2020), *How COVID-19 Will Shape Urban Mobility*, Boston Consulting Group (June 16), https://www.bcg.com/en-ca/publications/2020/how-covid-19-will-shape-urban-mobility

Bidordinova, Asya (2010), "Motivators and barriers to utilitarian cycling in downtown Toronto," Canadian Transportation Research Forum 45th Annual Conference, Toronto. https://ctrf.ca/wp-content/uploads/2014/07/10BidordinovaMotivatorsandBarriers.pdf

Biehl, Alec and Amanda Stathopoulos (2020), "Investigating the interconnectedness of active transport-ation and public transit usage as a primer for Mobility-as-a-Service adoption and deployment," *Journal of Transport and Health*, 18, 100897. https://doi.org/10.1016/j.jth.2020.100897

Böcker, Lars, Tanu Priya Uteng, Chengxi Liu and Martin Dijst (2019), "Weather and daily mobility in international perspective: A cross-comparison of Dutch, Norwegian and Swedish city regions," *Transportation Research Part D: Transport and Environment*, 77, 491-505, https://www.sciencedirect.com/science/article/pii/S1361920918306199.

Bourne, Jessica E., Sarah Sauchelli, Rachel Perry, Angie Page, Sam Leary, Clare England & Ashley R. Cooper (2018), "Health benefits of electrically-assisted cycling: a systematic review," *International Journal of Behavioral Nutrition and Physical Activity*, 15, 116. https://doi.org/10.1186/s12966-018-0751-8

Brand, Christian, Evi Dons, Esther Anaya-Boig, Ione Avila-Palencia et al. (2021a), "The climate change mitigation effects of daily active travel in cities," *Transportation Research Part D: Transport and Environment*, 93, 102764. https://doi.org/10.1016/j.trd.2021.102764

Brand, Christian, Thomas Götschi, Evi Dons, Regine Gerike et al. (2021b), "The climate change mitigation impacts of active travel: Evidence from a longitudinal panel study in seven European cities," *Global Environmental Chang*, 67, 102224. https://doi.org/10.1016/j.gloenvcha.2021.102224

Branion-Calles, Michael, Kay Teschke, Mieke Koehoorn, Osvaldo Espin-Garcia and M. Anne Harris (2021), "Estimating walking and bicycling in Canada and their road collision fatality risks: The need for a national household travel survey," *Preventive Medicine Reports*, 22, 101366. https://doi.org/10.1016/j.pmedr.2021.101366

Brownell, Claire (2021), "Best communities in Canada 2021: Methodology (Here's how Maclean's picked the best communities in Canada to live and work remotely)," *Maclean's*, (Posted April 8, 2021). https://www.macleans.ca/economy/best-communities-in-canada-2021-methodology/

Canadian Press (2021), "Vacancy rate hits highest point since 1994 as working from home wallops office demand: Office vacancy rate rose to 15.7% in the third quarter of 2021." *CBC News* (Posted September 23). https://www.cbc.ca/news/business/office-vacancy-rate-1.6186595

Chan, Kevin and Steven Farber (2020), "Factors underlying the connections between active transportation and public transit at commuter rail in the Greater Toronto and Hamilton Area," *Transportation*, 47(5), 2157–2178. https://doi.org/10.1007/s11116-019-10006-w

Chen, Can and Charles E. Menifield (2017), "An Ecological Study on Means of Transportation to Work and Obesity: Evidence from U.S. States," *Transport Policy*, 59, 174–80. https://doi.org/10.1016/j.tranpol.2017.07.017

CUTA (2005), Public Transit: A Climate Change Solution, Issue Paper 16, December, Canadian Urban Transit Association, Toronto, 4 pages.

CUTRIC (2020a), *Five-Point Plan for Building Back Better Transit*, Canadian Urban Transit Research and Innovation Consortium, September 14. https://cutric-crituc.org/five-point-plan-for-building-back-better-transit/

CUTRIC (2020b), "Return to Transit Webinar," Canadian Urban Transit Research and Innovation Consortium, December 11. https://events.bizzabo.com/returntotransit

Celis-Morales, Carlos A., Donald M. Lyall, Paul Welsh, Jana Anderson et al. (2017), "Association between active commuting and incident cardiovascular disease, cancer, and mortality: prospective cohort study," *British Medical Journal*, 357, j1456. https://doi.org/10.1136/bmj.j1456

Central YMCA (2016), *Eudaimonia: How do humans flourish? A research report into the impact of lifestyle factors on people's wellbeing*, Central YMCA, London, U.K. https://ymca-central-assets.s3-eu-west-1.amazonaws.com/s3fs-public/Central-YMCA-Eudaimonia-How-do-humans-flourish.pdf

City of Edmonton (2018), *Smart Transportation Action Plan*, September, 33 pages, https://www.edmonton.ca/city_government/documents/smart-transportation-action-plan.pdf.

City of Edmonton (2020b), *Funicular Year-in-Review*, https://www.edmonton.ca/activities_parks_recreation/parks_rivervalley/mechanized-river-valley-access.aspx.

City of Edmonton (2021a), *Mobility Choices*, https://www.edmonton.ca/city_government/environmental_stewardship/transportation-choices.aspx

City of Edmonton (2021b), *Bikes & E-scooters on ETS*, https://www.edmonton.ca/ets/bikes-on-ets.aspx.

City of Toronto (2015), Toronto Multi-Use Trail Design Guidelines. https://www.toronto.ca/wp-content/uploads/2017/11/96a5-TORONTO_TRAIL_DESIGN_GUIDELINES.pdf

City of Vancouver (2021), Cycling routes and maps, https://vancouver.ca/streets-transportation/cycling-routes-maps-and-trip-planner.aspx.

City of Winnipeg (2020a), *Transportation Master Plan: 2050*, https://www.winnipeg.ca/publicworks/transportation/transportationmasterplan.stm.

City of Winnipeg (2020b), 2020 Preliminary Budget: Operating and Capital, Volume 2, Transportation Planning and Traffic Management, Service Level Statistics, page 2-8. https://www.winnipeg.ca/finance/files/2020PreliminaryBudget_Volume2.pdf.

Clean Energy Canada (2020), *Catching the Bus: How Smart Policy Can Accelerate Electric Buses Across Canada*. Burnaby: Simon Fraser University, Canada. https://cleanenergycanada.org/wp-content/uploads/2020/06/CEC-Bus-RoundtableReport-5.pdf

Cusack, Meagan (2021), "Individual, social, and environmental factors associated with active transportation commuting during the COVID-19 pandemic," *Journal of Transport & Health*, 22, 101089. https://doi.org/10.1016/j.jth.2021.101089

Daraei, Sara, Konstantinos Pelechrinis and Daniele Quercia (2021), "A data-driven approach for assessing biking safety in cities," *EPJ Data Science*, 10, 11. https://epjdatascience.springeropen.com/articles/10.1140/epjds/s13688-021-00265-y

da Silveira, Matheus P., Kimberly Kamila da Silva Fagundes, Matheus Ribeiro Bizuti et al. (2021), "Physical exercise as a tool to help the immune system against COVID-19: an integrative review of the current literature," *Clinical and Experimental Medicine*, 21, 15-28. https://doi.org/10.1007/s10238-020-00650-3

Day, Kristen, Lawrence Loh, Ryan Richard Ruff, Randi Rosenblum, Sean Fischer and Karen K. Lee (2014), "Does Bus Rapid Transit Promote Walking? An Examination of New York City's Select Bus Service," *Journal of Physical Activity and Health*, 11(8), 1512-1516. https://doi.org/10.1123/jpah.2012-0382

Dia, Hussein (2020), "Coronavirus recovery: public transport is key to avoid repeating old and unsustainable mistakes." *The Conversation* (May 25), https://theconversation.com/coronavirus-recovery-public-transport-is-key-to-avoid-repeating-old-and-unsustainable-mistakes-138415

Djurhuus, Sune, Henning S. Hansen, Mette Aadahl and Charlotte Glümer (2014), "The Association between Access to Public Transportation and Self-Reported Active Commuting," *International Journal of Environmental Research and Public Health*, 11(12), 12632-12651. https://doi.org/10.3390/ijerph111212632

Eldeeb, Gamal, Moataz Mohamed and Antonio Páez (2021), "Built for active travel? Investigating the contextual effects of the built environment on transportation mode choice," *Journal of Transport Geography*, 96, 103158. https://doi.org/10.1016/j.jtrangeo.2021.103158

Elias, Arne et al. (2009), "Ottocycle: Building Better Biking in Winnipeg, GPS study of Winnipeg cycling commuters, Centre for Sustainable Transportation, University of Winnipeg.

ECCC (2018), *Estimated Results of the Federal Carbon Pollution Pricing System*, Document En4-326/2018E-PDF; Environment and Climate Change Canada, Gatineau. https://www.canada.ca/content/dam/eccc/documents/pdf/reports/estimated- impacts-federal-system/federal-carbon-pollution-pricing-system_en.pdf

European Commission, Section 1.9 Multimodal Integration, in *Clean Transport, Urban Transport*. [Accessed October 24, 2021] https://ec.europa.eu/transport/themes/urban/cycling/guidance-cycling-projects-eu/cycling-measure/19-multimodal-integration_en

Federal Highway Administration (1992a), *Case Study No. 1: Reasons Why Bicycling And Walking Are Not Being Used More Extensively As Travel Modes*, Report FHWA-PD-92-041, U.S. Department of Transportation, Washington, DC. https://safety.fhwa.dot.gov/ped_bike/docs/case1.pdf

Federal Highway Administration (1992b), *Case Study No. 9: Linking Bicycle/Pedestrian Facilities with Transit: Enhancing Bicycle and Pedestrian Access to Transit*, Report FHWA-PD-93-012, U.S. Department of Transportation, Washington, DC. https://rosap.ntl.bts.gov/view/dot/41365/dot_41365_DS1.pdf

Federal Transit Administration (2021), FTA National Transit Renewal Summit Highlights Best Practices by Transit Industry Partners to Increase Ridership (August 27). https://www.transit.dot.gov/about/news/fta-national-transit-renewal-summit-highlights-best-practices-transit-industry-partners

Fenton, Mark (2005), "Battling America's Epidemic of Physical Inactivity: Building More Walkable, Livable Communities," *Journal of Nutrition Education and Behavior*, 37(Supplement 2), S115-S120. https://doi.org/10.1016/S1499-4046(06)60211-X

Fischer, Jaimy and Meghan Winters (2021), "COVID-19 street reallocation in mid-sized Canadian cities: socio-spatial equity patterns," *Canadian Journal of Public Health*, Special Section on COVID-19: Population Health Intervention Research, 112, 376-390, https://link.springer.com/content/pdf/10.17269/s41997-020-00467-3.pdf.

Flores, Paula (2016), "Improving Health through Walking, Biking, and Transit," *ITE Journal*, 86(9), 4.

Florida, Richard (2019), "The great divide in how Americans commute to work," *Bloomberg News*, (Posted January 22). https://www.bloomberg.com/news/articles/2019-01-22/how-americans-commute-to-work-in-maps

Fowler, Stephanie L., David Berrigan and Keshia M. Pollack (2017), "Perceived barriers to bicycling in an urban U.S. environment," *Journal of Transport & Health*, 6, 474-480. https://www.sciencedirect.com/science/article/abs/pii/S2214140517301263

Frank, Lawrence D., Binay Adhikari, Katherine R. White, Trevor Dummer, Jat Sandhu, Ellen Demlow, Yumian Hu, Andy Hong and Matilda Van den Bosch (2022), “Chronic disease and where you live: Built and natural environment relationships with physical activity, obesity, and diabetes,” *Environment International*, 158, 106959. https://doi.org/10.1016/j.envint.2021.106959

Gatien, Alex and Aida Mas Baghaie (2019), *Improving Active Transportation and Public Transit Integration: A Guidebook for Policy and Planning*, The Centre for Active Transportation at Clean Air Partnership. https://www.tcat.ca/wp-content/uploads/2019/06/Active-Transportation-and-Public-Transit-Integration-web-3.pdf

George, Justin (2021), "Metro launches pilot program to test new air filtration system in subway cars,” *Washington Post*, January 20. https://www.washingtonpost.com/local/trafficandcommuting/metro-coronavirus-air-quality/2021/01/19/cad5f48a-5a89-11eb-a976-bad6431e03e2_story.html

Go-for-Green (2004), *The Business Case for Active Transportation: The Economic Benefits of Walking and Cycling*, https://nacto.org/docs/usdg/business_case_for_active_transportation_campbell.pdf.

Gordon-Larsen, Penny, Melissa C. Nelson and Kristen Beam (2005), “Associations among active transportation, physical activity, and weight status in young adults,” *Obesity research*, 13(5), 868-875. https://doi.org/10.1038/oby.2005.100

Götschi, Thomas, Jan Garrard and Billie Giles-Corti (2016), “Cycling as a part of daily life: A review of health perspectives,” *Transport Reviews*, 36(1), 45-71. https://doi.org/10.1080/01441647.2015.1057877

Grabow, Maggie L., Milena Bernardinello, Andrew J. Bersch, Corinne D. Engelman, Ana Martinez-Donate, Jonathan A. Patz, Paul E. Peppard, and Kristen M.C. Malecki (2019), “What Moves Us: Subjective and Objective Predictors of Active Transportation,” *Journal of Transport and Health*, 15, 100625. https://doi.org/10.1016/j.jth.2019.100625

Grossman, Alice (2018), “Bicycle and Pedestrian Safety Treatments Lack Data for Implementation Decision-Making,” *Eno Transportation Weekly*, December 7, Eno Centre for Transportation, Washington, DC. https://www.enotrans.org/article/bicycle-and-pedestrian-safety-treatments-lack-data-for-implementation-decision-making/

Haggiag, Amos (2020), “3 ways sustainable transport can prolong the COVID-19 effect on air pollution,” *World Economic Forum*, August 12. https://www.weforum.org/agenda/2020/08/sustainable-transport-covid-19-air-pollution/

Harris, M. Anne and Michael Branion-Calles (2021), “Changes in Commute Mode Attributed to COVID-19 Risk in Canadian National Survey Data,” *Findings*, February. https://doaj.org/article/e274942ce3024260aa4bece978e2148f

Heidenreich, Phil (2019), “Edmonton’s funicular was a popular river valley ride in its first year: report,” *Global News*, February 16, https://globalnews.ca/news/4968662/edmonton-funicular-report-first-year/.

Heinen, Eva and Wendy Bohte (2014), “Multimodal commuting to work by public transport and bicycle: Attitudes toward mode choice,” *Transportation Research Record: Journal of the Transportation Research Board*, 2468(1), 111-122. https://doi.org/10.3141/2468-13 https://journals.sagepub.com/doi/10.3141/2468-13

Herman, Katya M. and Richard Larouche (2021), "Active commuting to work or school: Associations with subjective well-being and work-life balance," *Journal of Transport and Health*, 22, 101118. https://doi.org/10.1016/j.jth.2021.101118

Hu, Hsi-Hwa, Joongkoo Cho, Guoxiong Huang, Frank Wen, Simon Choi, Margaret Shih and Amy S. Lightstone (2014), "Neighborhood environment and health behavior in Los Angeles area," *Transport Policy*, 33, 40-47. https://doi.org/10.1016/j.tranpol.2014.02.004

Hung, C., A. Rojhani, M. Cordoba Asprilla and R. Kancharla (2021), "COVID-19, Public Transportation, and Public Health Communication," *European Journal of Public Health*, 31, iii15-iii16. https://doi.org/10.1093/eurpub/ckab164.034

Iacobacci, Mario, Simon Dixon, Yvonne Rene de Cotret and Ian Davidson (2020), *Tackling public transit's funding gap during the recovery: Short-term fixes and long-term opportunities*. Toronto: Deloitte Canada, https://www2.deloitte.com/content/dam/Deloitte/ca/Documents/public-sector/ca-tackling-public-transits-funding-gap-en-aoda.pdf

Iassinovskaia, Katia (2021), "How pandemic bike lanes made some Canadian cities more accessible: Cycling advocates say temporary bike lanes should be made permanent," *CBC News* (Posted: March 18) https://www.cbc.ca/news/science/pandemic-bike-lanes-canada-1.5951863

Ismail, Karim, Tarek Sayed, Nicolas Saunier and Clark Lim (2009), "Automated Analysis of Pedestrian–Vehicle Conflicts Using Video Data," *Transportation Research Record: Journal of the Transportation Research Board*, 2140(1), 44-54. https://doi.org/10.3141/2140-05

Jhingan, Ashok and Ram Mohan Jhingan (2017), "Effect of cycling on glycaemia, blood pressure, and weight in young individuals with Type 2 Diabetes," *Journal of Clinical and Diagnostic Research*, 11(7), OC09-11. https://doi.org/10.7860/JCDR/2017/28111.10162

Kings College London (2014), London air pollution: which mode of transport has the highest exposure? Video, *The Guardian*, London. https://kclpure.kcl.ac.uk/portal/en/activities/london-air-pollution-which-mode-of-transport-has-the-highest-exposure(c8622d75-43a4-4da7-a8cd-25b6e567922d).html

Knell, Gregory, Casey P. Durand, Kerem Shuval, Harold W. Kohl, III, Deborah Salvo, Ipek Sener and Kelley Pettee Gabriel (2018), "Transit use and physical activity: Findings from the Houston travel-related activity in neighborhoods (TRAIN) study," *Preventive Medicine Reports*, 9, 55-61. https://doi.org/10.1016/j.pmedr.2017.12.012

Kuzmyak, J. Richard and Jennifer Dill (2012), "Walking and bicycling in the United States: The who, what, where, and why," *TR News*, 280 (May-June), 4-15, Transportation Research Board, Washington, DC. https://onlinepubs.trb.org/onlinepubs/trnews/trnews280www.pdf

Lachapelle, Ugo (2015), "Walk, Bicycle, and Transit Trips of Transit-Dependent and Choice Riders in the 2009 United States National Household Travel Survey," *Journal of Physical Activity and Health*, 12(8), 1139-1147. https://doi.org/10.1123/jpah.2014-0052

Lachapelle, Ugo and Diogo Gianini Pinto (2016), "Longer or more frequent walks: Examining the relationship between transit use and active transportation in Canada," *Journal of Transport and Health*, 3(2), 173-180. https://doi.org/10.1016/j.jth.2016.02.005

Lachapelle, Ugo, Lawrence D. Frank, James F. Sallis, Brian E. Saelens and Terry L. Conway (2016), "Active Transportation by Transit-Dependent and Choice Riders and Potential Displacement of Leisure

Physical Activity," *Journal of Planning Education and Research*, 36(2), 225-238. https://doi.org/10.1177/0739456X15616253

Larson, Paul D., Robert V. Parsons and Arne Elias (2021a), "Interactions between public transit and active transportation: A tale of three cities," Transportation Association of Canada (TAC) Conference and Exhibition.

Larson, Paul D., Robert V. Parsons and Arne Elias (2021b), "Active transportation and public health: A tale of three cities," Health and Transportation, Transportation Association of Canada (TAC) Conference and Exhibition, September 23.

Lee, Kyuhyun and Ipek N. Sener (2020), "Emerging data for pedestrian and bicycle monitoring: Sources and applications," *Transportation Research Interdisciplinary Perspectives*, 4, 100095. https://doi.org/10.1016/j.trip.2020.100095

Leyland, Louise-Ann, Ben Spencer, Nick Beale, Tim Jones and Carien M. van Reekum, (2019), "The effect of cycling on cognitive function and well-being in older adults," *PLoS ONE*, 14(2), e0211779. https://doi.org/10.1371/journal.pone.0211779

Litman, Todd (2021), *Evaluating Public Transit Benefits and Costs: Best Practices Guidebook*, Victoria Transport Policy Institute, August 31. https://www.vtpi.org/tranben.pdf

Liu, Luyu, Harvey J. Miller and Jonathan Scheff (2020), "The impacts of COVID-19 pandemic on public transit demand in the United States," *PLoS ONE*, 15(11), e0242476. https://doi.org/10.1371/journal.pone.0242476

Machell, Aryn (2009), "What do we mean by active transportation?" City of Edmonton, December 4, https://transforming.edmonton.ca/what-do-we-mean-by-active-transportation/.

Manaugh, Kevin, Geneviève Boisjoly and Ahmed El-Geneidy (2017), "Overcoming barriers to cycling: Understanding frequency of cycling in a University setting and the factors preventing commuters from cycling on a regular basis," *Transportation*, 44(4), 871-884. https://www.springerprofessional.de/en/overcoming-barriers-to-cycling-understanding-frequency-of-cyclin/10910692

Mansfield Theodore J. and Jacqueline MacDonald Gibson (2016), "Estimating active transportation behaviors to support health impact assessment in the United States," *Frontiers in Public Health*, 4, 63. https://doi.org/10.3389/fpubh.2016.00063

Marr Consulting and Communications (2005), *The City of Winnipeg Active Transportation Study: Final Report*, February, http://www.onegreencity.com/images/crucial/atfinalreportwpg.pdf.

McGowan, Ellen (2021), *Transit Agency Responses to COVID-19: A review of challenges and opportunities for continued service delivery*. Kingston: School of Urban and Regional Planning, Queen's University, Kingston, Canada. https://qspace.library.queensu.ca/bitstream/handle/1974/28836/McGowan_Ellen_Master%27s%20Report_April%202021.pdf?sequence=1&isAllowed=y

Melo, Fernando and Robert Parsons (2019), "Simplified rebates would get more electric buses on Canadian roads: We've fallen behind in adopting electric buses, but predictable and streamlined funding would help transit agencies make the jump," *Policy Options*, (Posted August 22). https://policyoptions.irpp.org/magazines/august-2019/simplified-rebates-would-get-more-electric-buses-on-canadian-roads/

Miller, Eric J., Amer Shalaby, Ehab Diab and Dena Kasraian (2018), *Canadian Transit Ridership Trends Study*, October, Toronto: Canadian Urban Transit Association, https://cutaactu.ca/wp-content/uploads/2021/01/cuta_ridership_report_final_october_2018_en.pdf.

Montufar, Jeannette, Stephen Chapman, Rob Poapst and Geni Bahar (2020), *Safety Performance of Bicycle Infrastructure in Canada*, Transportation Association of Canada, Ottawa. https://bikehub.ca/sites/default/files/imce/safety_performance_of_bicycle_infrastructure_in_canada.pdf

Moore, Oliver (2020), "A better way: Can urban transit systems bounce back from the pandemic?" *The Globe and Mail* (Published November 13; updated November 19). https://www.theglobeandmail.com/canada/toronto/article-a-better-way-can-urban-transit-systems-bounce-back-from-the-pandemic/

Moovit Insights (2021a), "Facts and usage statistics about public transit in Vancouver, Canada," https://moovitapp.com/insights/en/Moovit_Insights_Public_Transit_Index_Canada_Greater_Vancouver_BC-145.

Moovit Insights (2021b), "Helping Cities and Agencies Recover from COVID-19," https://moovit.com/covid-19-resources/.

Nahal, Tamara and Raktim Mitra (2018), "Facilitators and barriers to winter cycling: Case study of a downtown university in Toronto, Canada" *Journal of Transport and Health*, 10, 262-271. https://doi.org/10.1016/j.jth.2018.05.012

Naraghi, Alireza (2019), "Where to find the best weather in Canada 2019: Two provinces dominated this ranking of best communities for weather in Canada," *Macleans* (posted August 8). https://www.macleans.ca/society/best-communities-canada-weather-2019/

National Association of City Transportation Officials (NACTO), *Urban Bikeway Design Guide*. [Retrieved October 25, 2021] https://nacto.org/publication/urban-bikeway-design-guide/

NRCan (2020), Energy and Greenhouse Gas Emissions (GHGs), Natural Resources Canada. https://www.nrcan.gc.ca/science-and-data/data-and-analysis/energy-data-and-analysis/energy-facts/energy-and-greenhouse-gas-emissions-ghgs/20063

Nerad, Jack. R. (2020), "COVID-19 Could Change Commuting Forever; Results Aren't What You'd Guess." *Forbes Magazine* (August 27). https://www.forbes.com/sites/jacknerad2/2020/08/27/covid-19-could-change-commuting-forever-results-arent-what-youd-guess/?sh=295248aa7ac0

Neufeld, Richard and Paul J. Massicotte (2017), *Decarbonizing Transportation in Canada: Report of the Standing Senate Committee on Energy, the Environment and Natural Resources*, June, Senate of Canada, Ottawa, 65 pages. https://sencanada.ca/content/sen/committee/421/ENEV/reports/TransportationReport_FINAL_e.pdf

Nieman, David C. (2011), "Moderate Exercise Improves Immunity and Decreases Illness Rates," *American Journal of Lifestyle Medicine*, 5(4), 338-345. https://doi.org/10.1177/1559827610392876

Oja, P., S. Titze, A. Bauman and B. De Geus, (2011), "Health benefits of cycling: A systematic review," *Scandinavian Journal of Medicine and Science in Sports*, 21(4), 496-509. https://doi.org/10.1111/j.1600-0838.2011.01299.x

Páez, Antonio and Kate Whalen (2010), "Enjoyment of commute: A comparison of different transportation modes," *Transportation Research Part A*, 44(7), 537-549. https://doi.org/10.1016/j.tra.2010.04.003

Parsons, R.V., E.G. Kwan, N.L. Wood, M. Hall, A.A. Akerstream, J.E. Sinnock, T.N.N. Nguyen, I.D. Frank, J.E. Kopp, K. Shah and N.P.A. Nguyen, (2017), *Cost Benefit Analysis of Externality Factors for Battery Electric Transit Buses*, University of Manitoba, Winnipeg. Compendium report presented through auspices of Canadian Urban Transit Research and Innovation Consortium (CUTRIC). https://cpb-ca-c1.wpmucdn.com/www.rrc.ca/dist/3/78/files/2019/05/UofM-AsperMBA-2017-EBus-Externalities-CBA-sgs15r.pdf

Parsons, R.V., M.J. Kizuik, T.G. Miles, S.C. Prud'homme, J.S. Sodomsky and M. Wang, (2020), *Preliminary Cost Benefit Analysis (CBA) of Zero-Emission Transit Bus Options for the City of Winnipeg*, University of Manitoba, Winnipeg. https://umanitoba.ca/faculties/management/faculty_staff/media/CBA_for_Zero_Emission_Bus_Options_June_2020_V3.pdf

Parsons, Robert V. (2021), "Canada as a case study for balanced presentation to address controversy on emission reduction policies," *Sustainability*, 13, 7909. https://www.mdpi.com/2071-1050/13/14/7909/pdf

Press, Jordan (2021), "Mayors ask federal Liberals for help covering transit shortfalls," The Canadian Press (posted by *Winnipeg Free Press* October 13), https://www.winnipegfreepress.com/arts-and-life/life/health/mayors-ask-federal-liberals-for-help-covering-transit-shortfalls-575518732.html

Pursaga, Joyanne (2021), "Provincial law blocks city's open streets encore," *Winnipeg Free Press*, April 17, https://www.winnipegfreepress.com/local/provincial-law-blocks-citys-open-streets-encore-574225242.html.

Rabson, Mia (2021), "Bike paths, trails, walkways: Canada unveils first-ever 'active transportation' fund," *The Canadian Press*, March 12, https://cisnfm.com/news/7692394/canada-active-transportation-funding/

Ramsay, Caley (2020), "Edmonton funicular wins urban design award for connectivity to river valley," *Global News*, February 20, https://globalnews.ca/news/6573188/edmonton-funicular-wins-urban-design-award/.

Rousakis, Tom (2020), *How to rebuild consumer trust and revive ridership in public transit*, Ernst and Young U.S., https://www.ey.com/en_us/government-public-sector/how-to-rebuild-consumer-trust-and-revive-ridership-in-public-transit

Saltman, Jennifer (2020), "Future of post-pandemic transit in Metro Vancouver uncertain: Ridership recovery will likely take years for TransLink and other agencies suffering during COVID-19," *Vancouver Sun*, June 2. https://vancouversun.com/news/future-of-post-pandemic-transit-in-metro-vancouver-uncertain

Saneinejad, Sheyda, Matthew J. Roorda and Christopher Kennedy (2012), "Modelling the impact of weather conditions on active transportation travel behaviour," *Transportation Research Part D: Transport and Environment*, 17(2), 129-137, https://www.sciencedirect.com/science/article/abs/pii/S1361920911001143.

Santacreu, Alexandre (2018), *Cycling Safety: Summary and Conclusions of the ITF Roundtable on Cycling Safety 29-30 January 2018, Paris*, International Transportation Forum (ITF), Organization for

Economic Cooperation and Development (OECD), Paris, France. https://www.itf-oecd.org/sites/default/files/docs/cycling-safety-roundtable-summary.pdf

Savage, Katherine and Martin Turcotte (2020), "Commuting to work during COVID-19," *Statcan COVID-19: Data to Insights for a Better Canada*, Ottawa: Statistics Canada, August 10. https://www150.statcan.gc.ca/n1/en/pub/45-28-0001/2020001/article/00069-eng.pdf?st=1KZhoRDW

Schaefer, Annette (2005), "Commuting takes its toll: Workers are traveling ever longer to attain the job or home life they want, but the daily stress may outweigh the gains," *Scientific American Mind*, 16(3), 14-15. https://doi.org/10.1038/scientificamericanmind1005-14

Shikaze, S. (2012), "Creating bicycle-friendly communities: How cycling can achieve multiple goals," *Municipal World*, (April edition), 9. https://www.municipalworld.com/articles/creating-bicycle-friendly-communities-how-cycling-can-achieve-multiple-goals/

Simeus-Kabo, Marlene, Michelle Tait and Lawrence McKeown (2021), "Public transit in a post-COVID-19 Canada," *StatCan COVID-19: Data to Insights for a Better Canada*. Catalogue no. 45-28-0001. Ottawa: Statistics Canada, https://www150.statcan.gc.ca/n1/en/pub/45-28-0001/2021001/article/00030-eng.pdf?st=goXDGNzo

Smith, Oliver (2017), "Commute well-being differences by mode: Evidence from Portland, Oregon, USA," *Journal of Transport and Health*, 4, 246-254. https://doi.org/10.1016/j.jth.2016.08.005

Statistics Canada, (2019a), "Study: Long commutes to work by car," *The Daily*, (February 25), Ottawa. https://www150.statcan.gc.ca/n1/en/daily-quotidien/190225/dq190225a-eng.pdf?st=16yWbc9P

Statistics Canada (2019b), *2016 Census topic: Journey to work* (released November 29, 2017; updated December 2, 2019), https://www12.statcan.gc.ca/census-recensement/2016/rt-td/jtw-ddt-eng.cfm.

Statistics Canada, (2021a), "Working from home: Potential implications for public transit and greenhouse gas emissions." *The Daily*, (April 22). Ottawa. https://www150.statcan.gc.ca/n1/en/daily-quotidien/210422/dq210422b-eng.pdf?st=BzufbYvo

Statistics Canada (2021b), Table 11-10-0239-01: Income of individuals by age group, sex and income source, Canada, provinces and selected census metropolitan areas, https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=1110023901.

Statistics Canada (2021c), Zero-emission vehicles in Canada / British Columbia, third quarter of 2020. https://www150.statcan.gc.ca/n1/pub/11-627-m/11-627-m2021012-eng.htm

Steensig, Sara Lilja (2021), "Meet the bike-loving Finnish city that keeps pedaling even in the snow," *EuroNews*, January 25, https://www.euronews.com/2021/01/22/meet-the-bike-loving-finnish-city-that-keeps-pedalling-even-in-the-snow.

Su, Jason G., Meghan Winters, Melissa Nunes and Michael Brauer (2010), "Designing a route planner to facilitate and promote cycling in Metro Vancouver, Canada," *Transportation Research Part A*, 44(7), 495-505. https://doi.org/10.1016/j.tra.2010.03.015

Swanson, Anders (2016), "Ice cycles: the northerly world cities leading the winter bicycle revolution," *The Guardian*, International Edition, February 12, https://www.theguardian.com/cities/2016/feb/12/ice-cycles-northerly-world-cities-winter-bicycle-revolution.

TenBrink, David S., Randall McMunn and Sarah Panken (2009), "Project U-Turn: Increasing active transportation in Jackson, Michigan," *American Journal of Preventive Medicine*, 37(6, S2), S329-S335. http://dx.doi.org/10.1016/j.amepre.2009.09.004

Teschke, Kay, M. Anne Harris, Conor C.O. Reynolds, Hui Shen, Peter A. Cripton and Meghan Winters (2013), "Exposure-based traffic crash injury rates by mode of travel in British Columbia," *Canadian Journal of Public Health*, 104(1), e75, 5 p.

Thrun, Emily, Julien Leider and Jamie Friedman Chriqui (2016), "Exploring the Cross-sectional Association between Transit-Oriented Development Zoning and Active Travel and Transit Usage in the United States, 2010-2014," *Frontiers in Public Health*, 4, 113. https://doi.org/10.3389/fpubh.2016.00113

Tirachini, Alejandro and Oded Cats (2020), "COVID-19 and Public Transportation: Current Assessment, Prospects, and Research Needs," *Journal of Public Transportation*, 22(1). https://doi.org/10.5038/2375-0901.22.1.1

TransLink (2021a), *Transport 2050*, https://www.transport2050.ca/.

TransLink (2021b), *The 10-Year Vision for Metro Vancouver Transportation*, https://tenyearvision.translink.ca/.

TransLink (2021c), *TransLink Tomorrow*, https://www.translink.ca/plans-and-projects/programs-and-studies/translink-tomorrow.

Transportation Research & Education Center, Portland State University (TREC), (2017), *Manual on Pedestrian and Bicycle Connections to Transit*, FTA Report No. 0111, Federal Transit Administration, U.S. Department of Transport, Washington, DC. https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/research-innovation/64496/ftareportno0111.pdf

Tribby, Calvin P., Barry I. Graubard and David Berrigan (2020), "National and metropolitan trends in public transit use, transit-related walking, and ridesharing between 2009 and 2017," *Journal of Transport and Health*, 19, 100918. https://doi.org/10.1016/j.jth.2020.100918

Tsafos, Nikos (2019), "The Slowly Changing U.S. Commute," Center for Strategic & International Studies (June 12), Washington, DC. https://www.csis.org/blogs/energy-headlines-versus-trendlines/slowly-changing-us-commute

Urban Strategies (2014), *Winnipeg Pedestrian and Cycling Strategies*, Dec., 326 pages, https://winnipeg.ca/publicworks/pedestriansCycling/strategiesActionPlan/pdf/strategy.pdf.

Useche, Sergio A., Luis Montoro, Jaime Sanmartin and Francisco Alonso (2019), "Healthy but risky: A descriptive study on cyclists' encouraging and discouraging factors for using bicycles, habits and safety outcomes," *Psychology and Behaviour*, 62, 587-598. https://doi.org/10.1016/j.trf.2019.02.014

van Es, Karl (2019), "New funicular and lookout connects Edmonton with North Saskatchewan River Valley," *Åvontuura*, October 8, https://www.avontuura.com/mrva-by-dialog/.

van Mil, Joeri F. P., Tessa S. Leferink, Jan Anne Annema and Niels van Oort (2021), "Insights into factors affecting the combined bicycle-transit mode," *Public Transport*, 13(3), 649-673. https://doi.org/10.1007/s12469-020-00240-2

Verlinden, Y., K. Manaugh, B. Savan, N. Smith Lea, R. Tomalty, M. Winters, (2019). *Increasing Cycling in Canada: A guide to what works*, The Centre for Active Transportation, Clean Air Partnership.

https://www.tcat.ca/wp-content/uploads/2019/09/Increasing-Cycling-in-Canada-A-Guide-to-What-Works-2019-09-25.pdf

Viáfara, Jairo (2021), *Traffic Collisions Involving Pedestrians in Winnipeg (2012-2019): A Transportation Equity Analysis*.

Voss, Christine, Meghan Winters, Amanda Frazer and Heather McKay (2015), "School-travel by public transit: Rethinking active transportation," *Preventive Medicine Reports*, 2, 65-70. https://doi.org/10.1016/j.pmedr.2015.01.004

Voss, Christine, Joanie Sims-Gould, Maureen C. Ashe, Heather A. McKay, Caitlin Pugh, and Meghan Winters (2016), "Public transit use and physical activity in community-dwelling older adults: Combining GPS and accelerometry to assess transportation-related physical activity," *Journal of Transport and Health*, 3(2), 191-199. https://doi.org/10.1016/j.jth.2016.02.011

Wang, Luqi (2018), "Barriers to implementing pro-cycling policies: A case study of Hamburg," *Sustainability*, 10, 4196. https://doi.org/10.3390/su10114196

Wang, Rui and Chen Liu (2013), "Bicycle-transit integration in the United States, 2001-2009," *Journal of Public Transportation*, 16(3), 95-119. http://doi.org/10.5038/2375-0901.16.3.6

Whitfield Geoffrey P., Brian McKenzie, Kaitlin A. Graff and Susan A. Carlson (2020), "Monitoring State-Level Changes in Walking, Biking, and Taking Public Transit to Work - American Community Survey, 2006 and 2017," *Preventing chronic disease*, 17, 200097. https://doi.org/10.5888/pcd17.200097

Winnipeg Public Works (2020a), Full cycling map, https://winnipeg.ca/publicworks/pedestriansCycling/maps/default.stm.

Winnipeg Public Works (2020b), *Public Works, General Capital Fund: Pedestrian and Cycling Program*, https://winnipeg.ca/publicworks/pedestriansCycling/pdf/PedestrianAndCyclingProgram2020CapitalBudget.pdf.

Winnipeg Transit (2021), *Winnipeg Transit Master Plan*, March, https://winnipegtransit.com/assets/2794/Winnipeg_Transit_Master_Plan-reduced.pdf.

Winter Cycling Federation (2020), "Can the bike boom survive the snow?" Media Advisory, November 2, https://wintercycling.org/Media.

WWF-Canada (2012), *Road Transportation: Emissions Reduction Strategies, Climate Change and Energy Program*, World Wildlife Federation-Canada Toronto, August, 22 pages.

Yaropud, Tetyana, Jason Gilmore and Sébastien LaRochelle-Côté (2019), "Results from the 2016 Census: Long commutes to work by car," Insights on Canadian Society, February, Statistics Canada, Ottawa, 12 pages.

Yen, Hope, Christopher Weber, Sophia Tareen and David Porter (2021), "Public transit hopes to win back riders after crushing year," *AP News*, May 2. https://apnews.com/article/coronavirus-government-and-politics-environment-and-nature-politics-lifestyle-56d36574e38cec038f77339ef12076bc

Zheng, Yan (2008), "The Benefit of Public Transportation: Physical Activity to Reduce Obesity and Ecological Footprint," *Preventive Medicine*, 46(1), 4-5. https://doi.org/10.1016/j.ypmed.2007.11.019

Additional relevant references (not cited in this report)

Christiana, Richard W., Erin D. Bouldin and Rebecca A. Battista (2021), "Active living environments mediate rural and non-rural differences in physical activity, active transportation, and screen time among adolescents," *Preventive Medicine Reports*, 23, 101422. https://doi.org/10.1016/j.pmedr.2021.101422

Coughenour, Courtney, Hanns de la Fuente-Mella and Alexander Paz (2019), "Analysis of Self-Reported Walking for Transit in a Sprawling Urban Metropolitan Area in the Western U.S.," *Sustainability*, 11(3), 852. https://doi.org/10.3390/su11030852

Cradock, Angie L., Jessica L. Barrett, Jamie F. Chriqui, Kelly R. Evenson, Karin Valentine Goins, Jeanette Gustat, Katie M. Heinrich, Cynthia K. Perry, Michele Scanze, Thomas L. Schmid, Rachel G. Tabak, and M. Renee Umstattd Meyer, Cheryl Valko (2018), "Driven to Support: Individual- and County-Level Factors Associated With Public Support for Active Transportation Policies," *American Journal of Health Promotion*, 32(3), 657-666. https://doi.org/10.1177/0890117117738758

Frank, Lawrence D., Michael J. Greenwald, Steve Winkelman, James Chapman and Sarah Kavage (2010), "Carbonless footprints: Promoting health and climate stabilization through active transportation," *Preventive Medicine*, 50(Supplement), S99-S105. https://doi.org/10.1016/j.ypmed.2009.09.025

Graystone, Matthew and Raktim Mitra (n. d.), "What Makes the Gears Go 'Round? Factors Influencing Bicycling to Suburban Regional Rail Stations," *Transport Findings*. https://doaj.org/article/abc2f36dcc5e4ec3a828dee21b233555

Larsen, Jacob, Ahmed El-Geneidy and Farhana Yasmin (2010), "Beyond the Quarter Mile: Re-examining Travel Distances by Active Transportation," *Canadian Journal of Urban Research*, 19(1), 70-88.

Morency, Patrick, Céline Plante, Anne-Sophie Dubé, Sophie Goudreau, Catherine Morency, Pierre-Léo Bourbonnais, Naveen Eluru, Louis-François Tétreault, Marianne Hatzopoulou, Naveen Chandra Iraganaboina, Tanmoy Bhowmik and Audrey Smargiassi (2020), "The Potential Impacts of Urban and Transit Planning Scenarios for 2031 on Car Use and Active Transportation in a Metropolitan Area," *International Journal of Environmental Research and Public Health*, 17(14), 5061. https://doi.org/10.3390/ijerph17145061

Saidla, Karl (2018), "Health promotion by stealth: active transportation success in Helsinki, Finland," *Health Promotion International*, 33(4), 600-609. https://doi.org/10.1093/heapro/daw110

Sreedhara, Meera, Karin Valentine Goins, Christine Frisard, Milagros C. Rosal and Stephenie C. Lemon (2019), "Stepping Up Active Transportation in Community Health Improvement Plans: Findings from a National Probability Survey of Local Health Departments," *Journal of Physical Activity and Health*, 16(9), 772-779. https://doi.org/10.1123/jpah.2018-0623

Tetreault, Louis-Francois, Naveen Eluru, Marianne Hatzopoulou, Patrick Morency, Celine Plante, Catherine Morency, Frederic Reynaud, Maryam Shekarrizfard, Yasmin Shamsunnahar, Ahmadreza Faghih Imani, Louis Drouin Anne Pelletier, Sophie Goudreau, Francois Tessier, Lise Gauvin and Audrey Smargiassi (2018), "Estimating the health benefits of planned public transit investments in Montreal," *Environmental Research*, 160, 412-419. https://doi.org/10.1016/j.envres.2017.10.025

Ukkusuri, Satish, Luis F. Miranda-Moreno, Gitakrishnan Ramadurai and Jhael Isa-Tavarez (2012), "The role of built environment on pedestrian crash frequency," *Safety Science*, 50(4), 1141-1151. https://doi.org/10.1016/j.ssci.2011.09.012