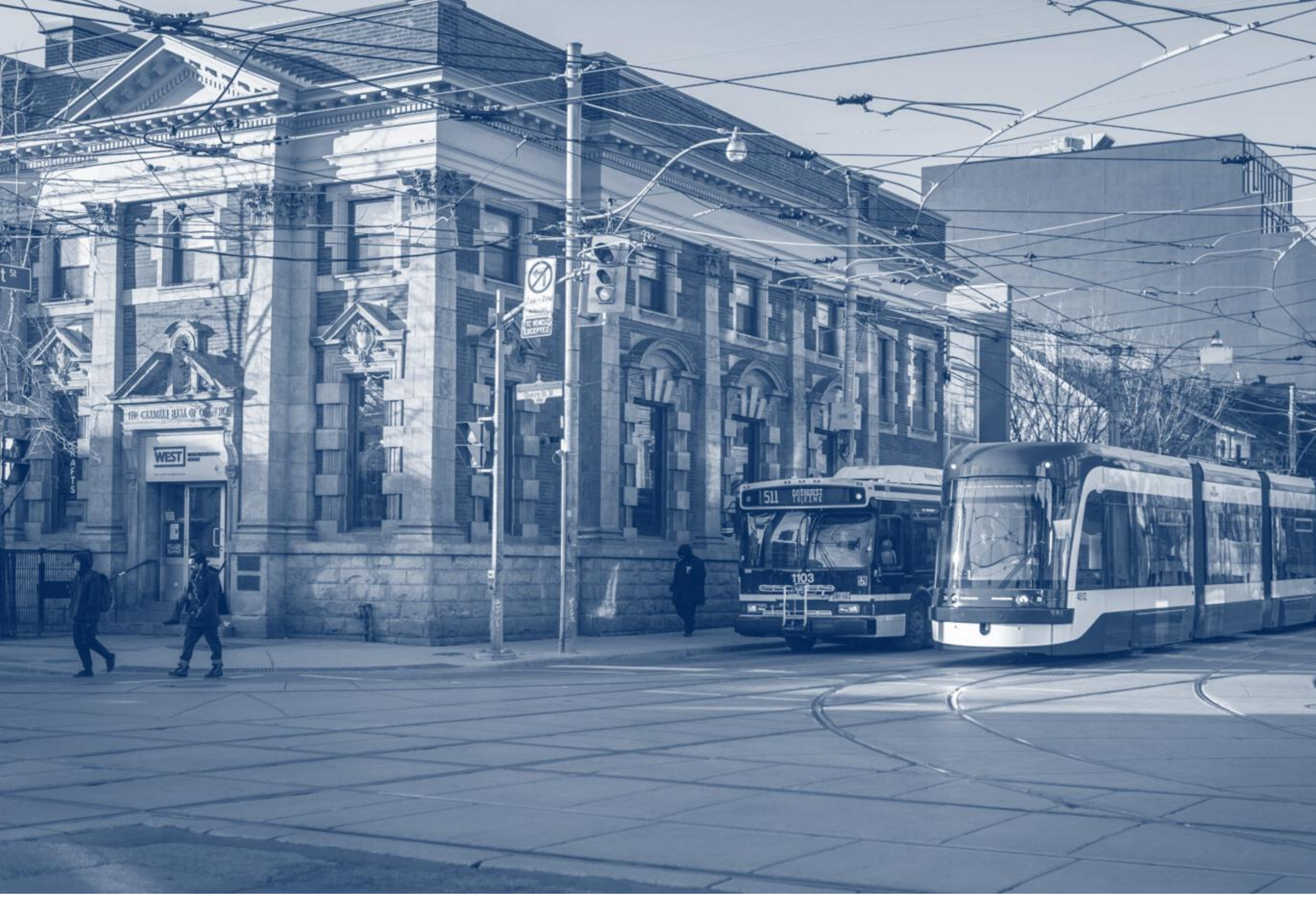

Transit for the Climate

Modelling how transit investment can boost ridership and reduce emissions

Prepared for:

environmental defence

Équiterre

January 2024

dunsky Energy + Climate

LEADING MOBILITY

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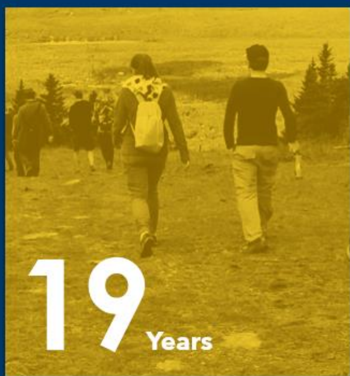
Thank you to the members of the Advisory Committee for their review of the methodology and results.
Participation as an Advisor does not necessarily constitute an endorsement of the findings presented in the report; any errors or omissions are the responsibility of the authors.

About Dunsky



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With deep expertise across the Buildings, Mobility, Industry and Energy sectors, we support our clients in two ways: through rigorous **Analysis** (of technical, economic and market opportunities) and by designing or assessing **Strategies** (plans, programs and policies) to achieve success.

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Executive Summary

Canada's ability to meet its **net zero carbon emissions targets** depends on our ability to **expand transit services and coverage** to help more people choose non-car modes of transportation. This considerable challenge has been exacerbated by the significant changes to the volume, peak periods, and distribution of transit ridership and demand since the start of the COVID-19 pandemic, spurred in part by the shift to working from home amongst certain sectors. Current ridership recovery rates vary across the country, with some regions seeing a full recovery and others still seeing ridership levels up to 25% lower than in 2019. The purpose of this study is to explore — ***at a rough approximation*** — how different policies and investments in Canadian transit systems that can contribute to **greenhouse gas (GHG) emissions reductions** by 2035.

Approach

This analysis looks beyond the significant challenge of full ridership recovery to ask **what it would take to further expand transit use across Canada** in line with climate and city-building objectives. We examined the potential impacts of four transit policies/investments on **ridership** and GHG emissions using a top-down model. The four policies/investments modelled are an **increase in operational funding, surface transit priority measures, bus fleet electrification, and the indirect land use effect of transit investments.**

We established quantitative relationships between these policies/investments and ridership, drawing from the literature and professional judgement, adjusting for possible recovery trajectories from the still-ongoing ridership declines in some regions. Regarding indirect land use effects, we applied guidance published by the Transportation Research Board's Transit Cooperative Research Program (TCRP) that quantified transit's impact on GHG emissions and energy use at the U.S. national scale.

Findings

Our model suggests that increased operating budgets and surface transit priority measures could increase transit ridership by **91% in 2035 compared to the baseline scenario in 2035**, and more than double transit ridership compared to 2023. In this scenario, annual transit trips taken in Canada rise from **1.8 billion in 2023 to 3.9 billion in 2035**.[1] Surface transit priority measures contribute much less to ridership increases than operating subsidies.

In this scenario, operational spending is increased by **14.3%** every year for the first four years, then by **3.5%** yearly between 2028 and 2031, and finally by **0.9%** between 2032 and 2035. This translates to additional spending on operations of **$12.2B in 2030** and **$13.7B in 2035**, relative to the baseline. All reported spending numbers in this study are gross and do not take into account additional passenger revenues, which would reduce the net cost to government.

[1] The transit ridership input data we used did not allow us to measure ridership in transit passenger kilometres travelled (PKT), which is best practice. Instead, we express ridership in terms of the number of trips taken in a year.

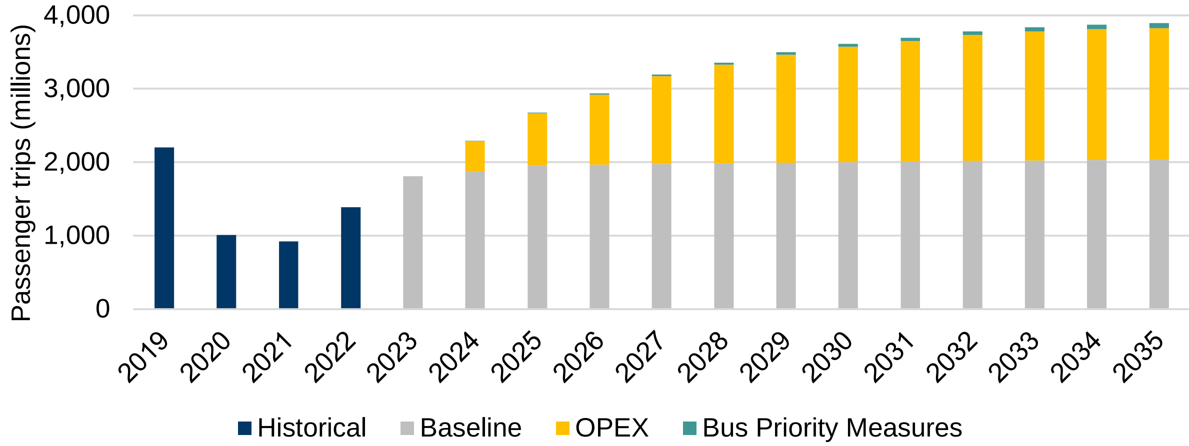

Figure 0-1 Transit ridership (in million linked trips)

Altogether, the combined benefits of increased service, surface transit priority measures, and indirect land use benefits could **increase transit mode share from 10% of all trips in Canada today to 21% of trips in 2035.** The most significant shift occurs in the largest transit service areas – such as Toronto, Montréal, and Vancouver – where the transit mode share increases to **47% of trips**. These changes would be transformative for communities across the country, providing greater accessibility to opportunities, good jobs connected by transit, and driving local economic growth.

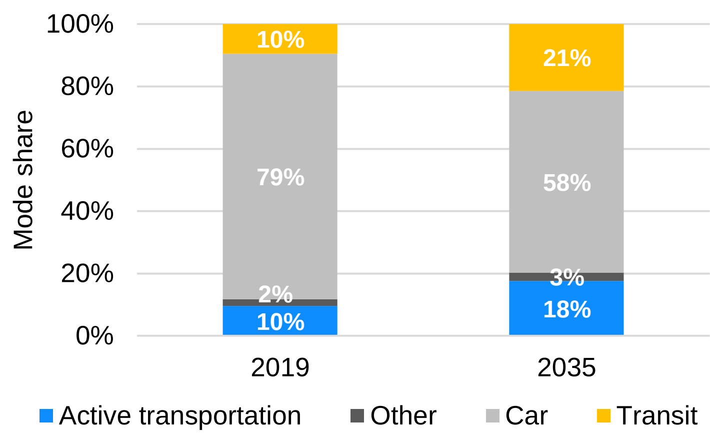

Figure 0-2 Mode share in Canada, for 2019 (baseline) and 2035 (with modeled policies)

Compared to the baseline scenario, increased operating budgets and bus electrification policies respectively avoid **1.8 MtCO_2e and 6.9 MtCO_2e** annually in 2035 (the bus priority measures have a negligible effect). Additionally, the change in travel patterns associated with the **land use** changes that will be spurred by increased transit have by far the greatest impact on GHG emissions, reducing the baseline GHG emissions by an additional cumulative **56.2 MtCO_2e** in 2035. It is important to note that these land use effects entail significant uncertainty and will take time to manifest; furthermore, realizing the full potential of increased transit to drive positive land use changes will require strong municipal and provincial policies. Nevertheless, this analysis suggests that the potential of such land use impacts is profound.

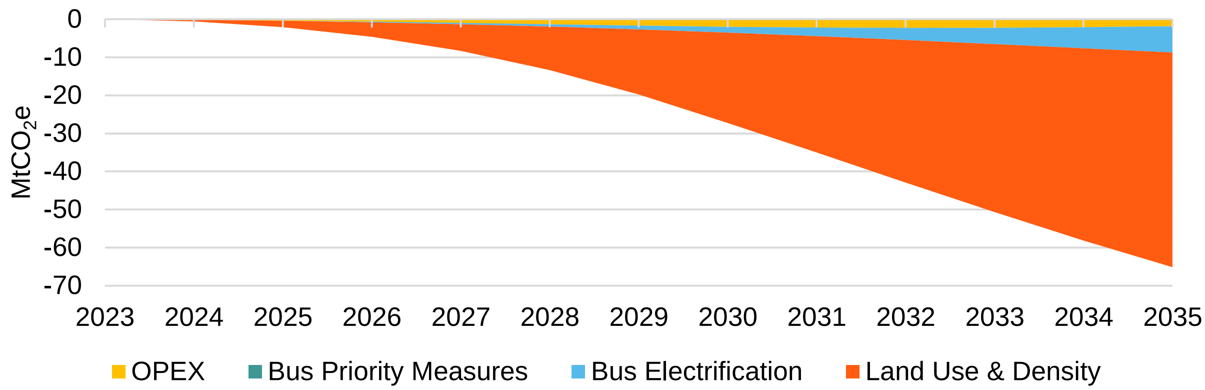

Figure 0-3 Cumulative passenger GHG emissions reductions by policy, with land use impact (in $MtCO_2e$)

Uncertainties

This study is a high-level estimate of the impact of different policies on overall transit mode share and relies on several assumptions and uncertainties. Chief among them are our assumptions about the magnitude of the land use effect; the elasticity between operating budgets and service levels; the elasticity between service levels and ridership; and our assumptions about continued ridership recovery as the Covid-19 situation evolves. Sensitivity analysis shows that even if these values are set to more conservative assumptions, the transit policies and investments still contribute to increased transit mode share and decreased transportation emissions by 2035.

Key takeaway

This study demonstrates that increasing transit operations subsidies is particularly important to achieve significant mode share increases in transit and active transportation, and an associated reduction in car travel. The vast majority of this impact will be realized by the **indirect land use effects[2] of increasing transit service and frequency**. Investments in transit **will have the most benefit when paired with effective local land use policy changes and investments**, such as zoning policies (especially near transit nodes and high frequency corridors), active transportation infrastructure investments, transportation demand management programs, etc. All policymakers, including the federal government, provinces, transit agencies and local governments should collaborate to achieve these outcomes.

[2] TCRP defines the indirect effect of transit as the mechanism through which "transit enabl[es] denser land use patterns that promote shorter trips, walking and cycling, and reduced car use and ownership". Transit Cooperative Research Program. 2015. Quantifying Transit's Impact on GHG Emissions and Energy Use— The Land Use Component. Report 176.

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1. Context

1.1 Public Transit Today

Canada's public transit systems are the backbone of economic activity and low-carbon transportation in communities of many sizes across the country. Unfortunately, drops in ridership (and therefore farebox revenue) during the COVID-19 pandemic have led to service cuts in some communities, impacting poor and racialized communities — who depend the most on transit for transportation — the most. Government responses across the country have been uneven; although temporary operating subsidies from the federal and some provincial governments has helped bridge the gap, Canada's transit systems face a highly uncertain future. Meanwhile, Canada's ability to meet its net zero carbon emissions targets relies not only on returning to historical rates of transit ridership, but on a vast expansion of transit services and coverage to facilitate more people to choose non-car modes of transportation resulting in a reduction of vehicle kilometers traveled.

1.2 Our Mandate

Environmental Defense and Équiterre commissioned Dunsky Energy + Climate Advisors ("Dunsky") and our partner Leading Mobility Consulting to quantify the potential impacts and benefits of policies and investments designed to increase transit ridership and reduce greenhouse gas (GHG) emissions at the national scale. Our study was designed to answer the following questions:

1. How much could **increased operating subsidies** and installation of **dedicated bus lanes** increase transit ridership in Canada?
2. Specifically, what level of investment in these measures would it take to **double transit ridership by 2035**?
3. If transit ridership is doubled, alongside continued **bus fleet electrification** and indirect **land use benefits**, how much could these measures contribute to **GHG emissions reductions** from the passenger transportation sector, by 2035?

1.3 In This Report

In **Section 2**, we summarize the **methodology** we used to model the impact of different policies and investments on transit ridership, mode share and passenger transportation GHG emissions across Canada. We highlight key modeling **assumptions** and **uncertainties**.

In **Section 3**, we present the **modelled effects** of each policy and investment on transit ridership, mode share and GHG emissions, as well as approximate **costs** of these measures.

In **Section 4**, we discuss the **findings** and **potential next steps**.

2. Methodology

2.1 Overall Approach

We used a **top-down approach** to model the potential impacts of transit policies and investments. We began with the set of Canadian transit systems as a whole, and modelled relationships at a **high level**, making assumptions about relationships across agencies without accounting for the specific dynamics of each system. The purpose of this study is to explore and understand — at a **rough approximation** — how different policies and investments in Canadian transit systems that can contribute to greenhouse gas (GHG) emissions reductions by 2035..

At the outset of this study, we recognized the inherent challenges and uncertainties associated with modelling the impacts of transit, particularly at an aggregate national scale. These challenges include, but are not limited to:

- The difficulty of **predicting human behaviour** in response to changed incentives.
- The difference between how transit systems (and riders) have behaved in the past versus **how they might behave in the future under different circumstances**. Most notably, temporary and permanent changes to travel patterns as a result of the COVID-19 pandemic mean that past elasticities established in the literature must be referenced with significant caution.
- The **diversity in transit systems, their size, operating characteristics (e.g. different transit modes) and their urban environments** across the country; the same measure in two different communities will have different impacts.

We drew significant inspiration and guidance from Report 176 published by the Transportation Research Board's[3] Transit Cooperative Research Program (TCRP) that quantified transit's impact on GHG emissions and energy use at the U.S. national scale and provides a transparent methodology for replicating this analysis.[4]

The four transit policies/investments we modelled are presented in Figure 2-1.

Figure 2-1. Transit policies/investments modelled in this study.

[3] The Transportation Research Board is an organization within the US National Academies of Science.
[4] Gallivan, Frank, Eliot Rose, Reid Ewing, Shima Hamidi, and Thomas Brown. 2015. [Quantifying transit's impact on GHG emissions and energy use—The land use component.] *Transit Cooperative Research Program (TCRP).*

2.2 Data Sources

Table 1 shows the key sources of data we used in our model.

Table 1. Data sources

Source	Application
Canadian Urban Transit Association (CUTA). Canadian Conventional Transit Statistics. 2019-2022 Operating Data.	CUTA statistics was used to get historical service area population, ridership, annual Operating Expenditures (OPEX) and Capital Expenditures (CAPEX), passenger kilometers traveled, vehicle revenue hours, and annual energy consumption, at the transit agency level.
Statistics Canada. Projected population, by projection scenario. Table 17-10-0057-01.	The medium-growth (M1) scenario was used to estimate the population growth by province between 2023 and 2035. The same growth was applied to the service area population of all transit agencies within a given province.
Statistics Canada. Statistics Canada. Passenger bus and urban transit statistics, by NAICS. Table 23-10-0251-01.	Latest ridership data at the regional level (Monthly total passenger trips, up to June 2023) was used to estimate the post-COVID ridership recovery level.
Origin-Destination (O-D) surveys from different transit agencies.	Where available, jurisdiction-specific mode shares and average trip length by mode (car, transit) from the latest available O-D surveys were used in the analysis.
Statistics Canada. Main mode of commuting and distance (straight-line) from home to work – Canada, provinces and territories. Table 98-10-0457-01 and Table 98-10-0461-01.	For transit agencies without O-D survey data, commuting statistics at the provincial level were used to estimate mode shares and average trip length by mode.
Government of Canada (personal correspondence)	Provided background information about government datasets including GHG emission factors and bus lifespans.

2.3 Model Logic

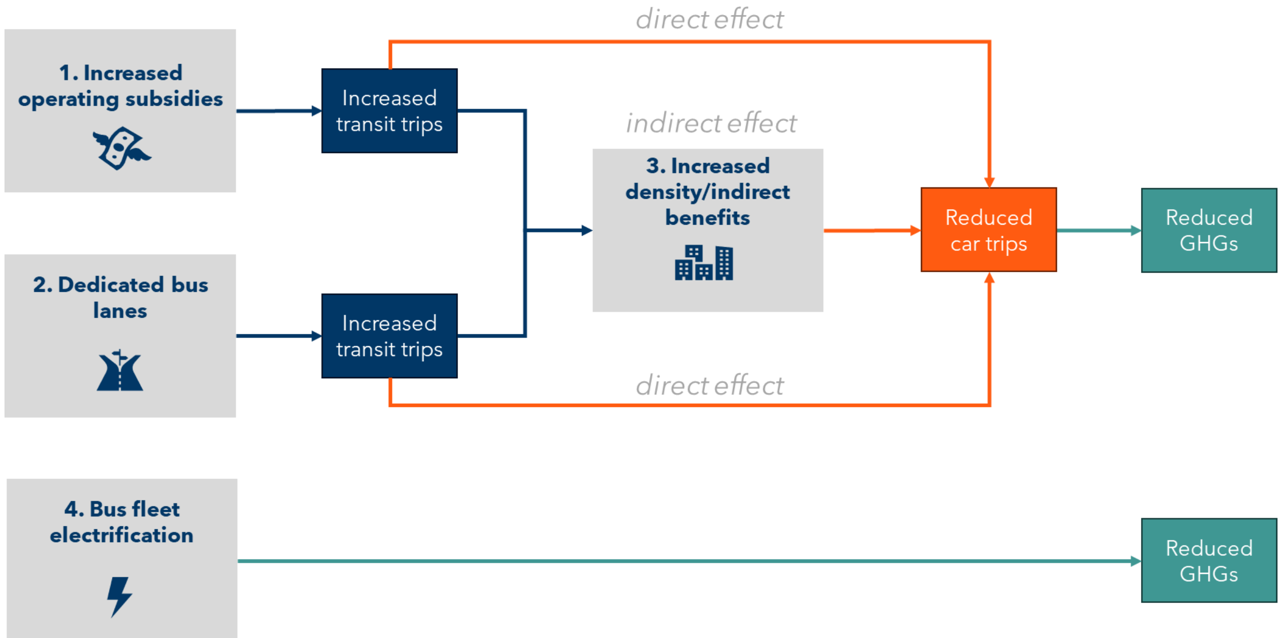

Figure 2-2 Model Logic

Figure 2-2 presents the high-level effect of each policy on GHG emissions reduction and transit ridership. As shown, (1) increased operating subsidies and (2) dedicated bus lanes are modelled as having a direct impact of increasing transit ridership, and hence decreasing car trips and GHG emissions. Increased transit ridership, in turn, also has an indirect impact – through (3) land use effects – on passenger transportation emissions. Finally, (4) bus fleet electrification directly decreases GHG emissions from transit trips.

2.3.1 Setting the baseline

Although CUTA ridership data is available up to the year 2022 at the time of our analysis, we used **2019** as the baseline year used for characterization since (1) travel behaviour during the pandemic is not representative, and (2) transit data for the years 2020-22 is considered less reliable due to measurement difficulties during the pandemic.[5] Ridership in 2023 is estimated at the regional-level based on the Statistics Canada Monthly Passenger Bus and Urban Transit Survey. Next, we assumed that all systems recover to at least **85% by 2025** relative to pre-pandemic 2019-levels (Figure 2-3). This assumption acknowledges that we are not starting from 2019 ridership levels in 2023.

Indeed, recovery rates have varied widely to date across the country depending on local context and investments. The Atlantic provinces had fully recovered to 2019 levels as of June 2023, however Québec and Ontario had rebounded to just over 75% of their 2019 ridership levels by then.

The baseline growth in ridership from 2023 and onward is assumed to be proportional to forecasted population growth (Figure 2-3), obtained regionally from Statistics Canada population

[5] Source: internal expertise and expert advisors.

growth scenario & regression from the literature[6,7]. The modeling horizon used is **2023-2035.** The ridership is measured in terms of number trips rather than Vehicle Kilometers Travelled (VKT), because although using VKT is now recognized as best practice, the data source we used (CUTA Operating Data) does not provide that information; it is only available from individual OD surveys.

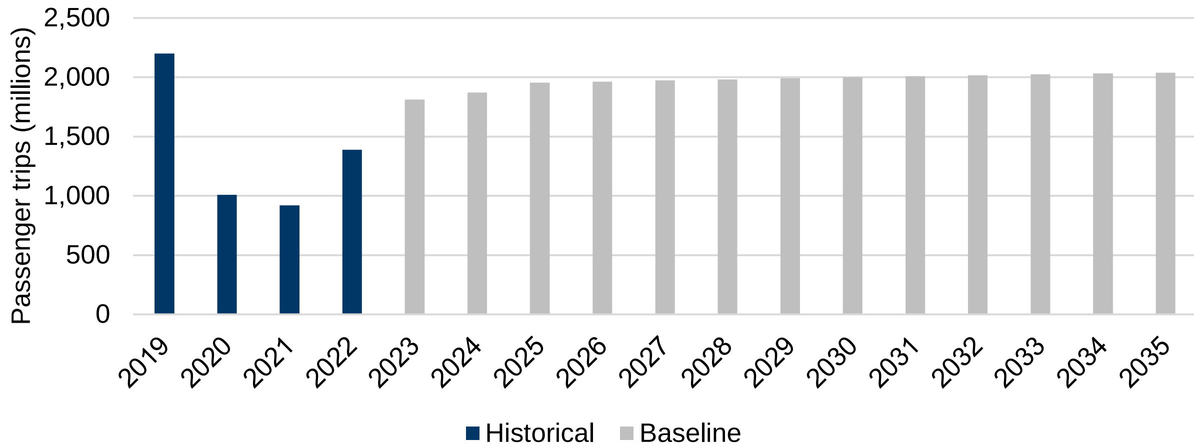

Figure 2-3 Transit ridership (in million of trips)

2.3.2 Segmentation of transit agencies

Modeling at the national level is complex, in part because there are few nation-wide datasets and each transit system/city collects separate data, often in different formats. Moreover, systems of various sizes and in different urban contexts face different challenges and realities. In our model, each CUTA transit system member is modeled individually. However, to ensure a manageable approach, we segmented the transit agencies into three typologies according to system size. Our analysis covers the 110 transit agency members of CUTA, which accounts for 95% of Canadian transit ridership[8].

We divided the transit agencies into the three following segments:

- **Segment 1** covers Montréal (including Exo), Toronto (Toronto Transit Commission and GO Transit) and Metro Vancouver (TransLink), the biggest transit agencies in the country, with a service population larger than two million.
- **Segment 2** covers 13 jurisdictions with a population between 400,000 and 2,000,000, including cities such as Calgary, Edmonton, Laval, Ottawa, and Winnipeg.
- **Segment 3** covers all remaining jurisdictions with populations below 400,000.

[6] Statistics Canada. Table 17-10-0057-01. Projected population, by projection scenario, age and sex, as of July 1 (x 1,000). Accessed September 2023.
[7] CUTA/ACTU Urban Mobility Issue Paper n49. 2021. How to Grow Transit Ridership in Canada.
[8] CUTA. Canadian Conventional Transit Statistics, 2019-2022 Operating Data.

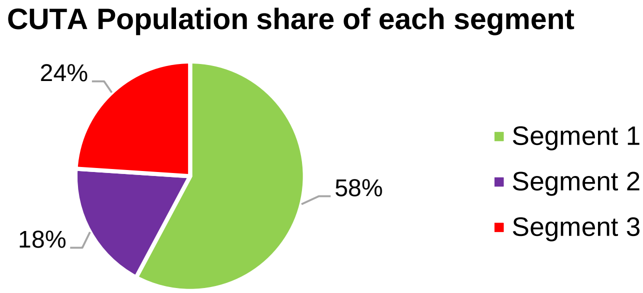

Figure 2-4 CUTA population share of each segment.

The segmentation of jurisdictions allows to use segment-specific data and assumptions; for example, we used different mode shift factors across segments. Transit agencies in Segment 1 cover large and highly populated cities, with a dense urban network and established transit agencies providing frequent service in at least two modes. They usually exhibit higher transit mode shares, making for a faster adoption of transit incentives.

This segmentation approach also allows us to report results at the segment level and to offer a more detailed breakdown of the policies' effects.

2.3.3 Modelling the impact of policies and investments

2.3.3.1 Mode shift factors

With policies and investments that support transit, transit ridership increases due to:

1. Existing trips being **transferred from other modes** to transit (some come from personal vehicle trips, while others come from active transportation and other modes). This phenomenon is accounted for by using segment-specific **mode shift factors** that indicate the share of public transit passenger kilometers that would have otherwise been personal vehicle kilometers, such as through driving, carpooling, or ride hailing.
2. New transit trips that would not otherwise have occurred (**induced demand**).

Table 2. Mode shift factors per segment.

Segment	Mode Shift Factor
1	50%
2	60%
3	80%

The mode shift factors for segment one are based on studies done in relevant regions[9,10].

[9] Golder Associés. 2016. Rapport de quantification des émissions de gaz à effet de serre évitées par le transport collectif dans la région métropolitaine de Montréal. *Société de Transport de Montréal*.
[10] Golder Associés. 2022. Quantification des émissions de gaz à effet de serre évitées par le transport collectif dans les régions métropolitaines des villes de Gatineau et de Québec-Lévis. *Association du Transport urbain du Québec*.

They showed drastically different values than the ones observed at the national scale in the United States, where the TCRP analysis found a 30% mode shift factor.

In our model, the potential modes for a trip are divided into four categories: active transportation, transit, car, and others. To evaluate the mode shares, we compute the impact of each policy on transit ridership, then we use the mode shift factors shown in Table 2 to estimate the reduction in car trips, and finally estimate the active transportation using a final target mode share for 2035. When estimating the transfer of passenger kilometers traveled between transit and cars, we assume an average car occupancy of 1.2 passengers per car.[11]

2.3.3.2 Impact of increased operating subsidies

Operating subsidies allow transit systems to increase operating budgets through revenue outside of transit fares. Increased operating budgets, in turn, allow systems to expand services, whether running more frequent/expanded service on existing routes or operating on new routes. Expanded service, in turn, can lead to more ridership because people are able to get to where they need to go faster, more comfortably and more reliably by transit.

Two of the most important assumptions in our model are the relationships between the following factors:

1. **The Operating budgets and service levels**. Service levels are represented in our model as Vehicle Revenue Hours, or VRH. VRH is the aggregate number of total transit hours in revenue service, including layover/recovery time but excluding deadhead, operator training and vehicle maintenance testing, as well as school bus and charter services.
2. **Service levels and ridership,** reflecting how many people take transit when service increases.

The elasticities of these relationships are subject of significant uncertainty and debate. We arrived at our assumptions through a thorough literature review, discussions with the advisory committee, and professional judgement. We also conducted a sensitivity analysis (Section 3.5) to understand the impact of varying these assumptions on our findings.

Our main scenario is based on the following assumptions:

- The OPEX to VRH elasticity is 1.0, meaning that a **10% increase in operating budget leads to 10% increase in VRH.** This assumes that increasing VRH has the same marginal OPEX as the average OPEX of an entire fleet. This may be a conservative assumption, as presumably some OPEX is fixed.
- The VRH to ridership elasticity is 0.9, meaning that a **10% increase in VRH leads to 9% increase in ridership.** This elasticity is roughly consistent with meta-analysis by the Victoria Transportation Policy Institute (which found an elasticity of 0.7 to 1.1 in the literature) [12]. and a 2018 *Canadian Transit Ridership Trends Study* (which found an elasticity of 1.0).[13]

In short, the model presupposes **there is latent demand for transit** that can be captured by more frequent and reliable service and/or with new services. We conducted iterations to

[11] Professional judgement.
[12] Todd Liman. 2023. Transit Price Elasticities and Cross-Elasticities. *Victoria Transport Policy Institute*.
[13] Miller, Eric J. et al. 2018. “Canadian Transit Ridership Trends Study.” Canadian Urban Transit Association (CUTA)

determine the annual increases in operating budgets necessary to approach the study's target, a doubling of transit mode share by 2035.

2.3.3.3 Impact of surface transit priority measures

Increasing the operating budget is not the only way to achieve faster and more reliable service. Bus priority measures, including dedicated lanes, spot treatments to address bottlenecks on specific route segments, transit signal priority to reduce bus wait time, and more accessible bus stops, are one of the most effective ways to *quickly* and *affordably* improve transit speed and reliability, and hence boost ridership. Many municipalities across Canada are pursuing transit priority measures, such as **dedicated bus/streetcar lanes**, on existing surface routes to help buses and streetcars move, with measurable results.[14,15,16,17]

We modeled the impact of transit priority measures in Segments 1 and 2, not transit agencies in Segment 3. Indeed, the former are denser and are assumed to have a sufficient transit mode share to justify dedicating road lanes to transit. Our analysis is based on the following assumption drawn from results of real-world transit priority projects in Canada: **a four-year program could improve speed/reliability of 7% of trips on a given system, leading to 25% increase in ridership on those lines**. This example project scope and timeline are drawn from Toronto's RapidTO plan, results on the Toronto King Street Transit Priority project, TransLink Bus Speed and Reliability Projects, and guidance from North American City Transportation Officials (NACTO). [18]

We assume these measures can be applied to both bus and streetcar trips. We do not quantify additional or saved operational spending associated with these measures.

2.3.3.4 Impact of fleet electrification

Transit fleet

Our scenario models a reduction in the GHG intensity of bus fleets according to a hypothetical country-wide green procurement mandate, wherein **all new buses purchased by any transit agency will be electric starting in 2026** for Segment 1 jurisdictions and starting in 2030 for agencies in Segments 2 and 3. This leads to a reduced GHG emissions intensity per transit vehicle kilometre traveled. We assume an average lifespan for the buses of 14 years[19]. Transit GHG emissions in 2035 vary by agencies, depending on the remaining numbers of existing diesel buses that have not yet been replaced, and the GHG intensity of the provincial electrical grid.

Passenger vehicle fleet

We assume that **the proportion of new light-duty vehicle sales that are electric vehicles increases to 100% by 2035** in line with Canada's proposed Zero-Emissions Vehicle Sales Regulation, causing a decrease in the average GHG intensity of the car fleet over the modelling

[14] Autorité régionale de transport métropolitain. 2021. Plan Stratégique de développement du Transport Collectif 2021 – 2035.
[15] Stewart, O., Vernez Moudon, A., Saelens B. 2018. "The Causal Effect of Bus Rapid Transit on Changes in Transit Ridership". *Journal of Public Transportation*.
[16] Viva Next. Next Generation of Bus Rapid Transit. Accessed December 2023.
[17] Translink. Bus Speed and Reliability. Accessed December 2023.
[18] NACTO. 2022. Move! That! Bus!, Tactics for transforming Transit in Two Years.
[19] Infrastructure Canada, Government of Canada Average expected useful life of new publicly owned public transit assets. Accessed September 2023.

horizon. The electrification of passenger car transportation is accounted for in both the baseline and the policy scenarios.

Electricity grid emission intensity

In estimating the emissions from electricity consumption, both for transit and personal vehicle fleets, we incorporate the **decarbonization of the electricity grid**. Historical grid emission intensities are taken from the 2023 Canadian National Inventory Report[20], while projected reductions in grid emission intensities until 2035 are estimated based on Canada's Eighth National Communication and Fifth Biennial Report on Climate Change[21]. We used the "additional measures" scenario, which on top of all policies and measures funded, legislated, and implemented, accounts for additional policies and measures that are under development but have not yet been fully implemented (e.g., Clean Electricity Regulations, strengthened methane regulations in the oil and gas sector targeting 75% reduction by 2030 and proposed landfill gas regulations).

2.3.3.5 Indirect land use impacts

Policies and investments to support transit reduce emissions in two ways:

1. By shifting trips away from car use (as described in Section 2.3.3.1)
2. Through **land use effects**, by avoiding or shifting *other* car trips because of the way that transit reshapes cities.[22] The land use effect, through changing the built environment, increases the proximity of people to desired destinations. This leads to shorter trips and more trip-chaining, factoring in a reduction of overall vehicle kilometres travelled. Moreover, a decline in car use means a reduction in parking space required. This parking provision reduction frees new space for mixed-use development, increasing people's proximity to destinations.

This land use effect can be significant. It is explored in detail in the TRCP Research Report 226, which lays out a replicable methodology for estimating its impact. We replicated this approach in our study with adjustments for the Canadian context, and we included a five-year lag to more accurately represent the fact that land use and development takes time to catch up to transit changes.

We expect the land use effect to be stronger in Segment 1 jurisdictions, due to their high density. The land-use factor estimates how many car vehicle kilometers traveled are avoided for every new transit passenger kilometer traveled, as an **indirect result of the modification and densification of the built environment**. It can translate into an increase of attraction points, with a mix of commercial, residential and businesses, reducing the need for people to travel. By decreasing the travel distance, the land use effect attracts passengers out of their private vehicles, and towards active mobility and transit.

This phenomenon adds up on top of the direct effect of transit, where the improved transit service attracts new riders.

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[20] Environment and Climate Change Canada. 2023. National Inventory Report 1990-2021: Greenhouse Gas Sources and Sinks in Canada, Part 3, Table A13-2 to Table A13-14, 2019-2021 values.
[21] Government of Canada. Canada's Greenhouse Gas Emissions Projections. Accessed September 2023.
[22] McGraw, Jen, Peter Haas, Reid Ewing, and Sadegh Sabouri. 2021. An update on public transportation's impacts on greenhouse gas emissions. *Transit Cooperative Research Program (TCRP).*

2.4 Key Uncertainties

Our model includes several uncertainties which we review below. In Section 3.5 we present the results of a sensitivity analysis that shows the potential impact of shifting some of our assumptions.

The **land use effect** reflects the densification of land use with the intensification of transit service. In many circumstances, high-frequency and reliable transit service will attract more residential or commercial buildings, inducing more mixed-use development and associated jobs and services This transformation increases the walkability of the neighborhood and generally reduces travel distance or avoids trips due to a densification of the destinations. However, this effect greatly varies between communities and neighborhoods; there are examples of new high order transit lines that have not seen this result because of inhibitive land use policies, for example. The land use multipliers vary across the literature, and most of them are derived from observations across neighborhoods with different levels of transit service at a single point in time, not as a reaction to a change in the level of service in the same place over time, as we are proposing. This is why we included a five-year time lag to account for the slow adaptation of the built environment and travel patterns to the updated transit service, based on professional judgment.

The impact of the increased operating subsidies on the ridership is modeled through two **elasticities**. The first elasticity shows the impact of increasing operating subsidies on vehicle revenue hours (VRH), and the second illustrates the impact of the increased VRH on ridership. The elasticity from VRH to ridership has been computed by CUTA, analyzing data across all CUTA transit agencies, between 2002 and 2016. The Z-Score is excellent (significant at 99%).

The **post-COVID ridership recovery** (2023-2025 ridership levels) was estimated using the latest data available from Statistics Canada Monthly Passenger Bus and Urban Transit Survey, available only at the regional level (Atlantic; Québec and Ontario; Prairies, British Columbia and Territories). However, most mode shares and average trip distances used were taken from pre-COVID O-D surveys, and the travel patterns across all modes are likely to have changed significantly. While most major cities have not yet published new post-Covid O-D survey results, it will be useful to compare our estimations with the new travel patterns obtained from those surveys once available.

The **mode shares** and **average trip distances** come from existing Origin-Destination surveys in specific communities where available, however, we had to use Statistics Canada commuting data as the baseline for many jurisdictions. Unfortunately, this survey does not provide data on the mode share for non-work trips. The lack of jurisdiction-specific data limits the precision of the model to assess the exact mode shares.

There are very few studies estimating the mode shift and induced demand from the land-use effect as it applies to **active transportation**. Moreover, new transit trips will generate active transportation trips for the last-mile connection, trips that were not previously made with car trips. To estimate the new share of active transportation after the different policies, we fixed **target mode shares** for each segment based on results achieved in similar contexts. The total number of trips in 2035 is then computed by applying the target mode share to the 2035 total baseline trips.

This study is a high-level estimate of the impact of different policies on overall transit mode share and relies on multiple assumptions to evaluate the causality relations.

3. Results

3.1 Transit Ridership Growth

Our model suggests that increased operating budgets and surface transit priority measures could increase transit ridership by **91% in 2035 compared to the baseline scenario in 2035.** In this scenario, annual transit trips taken in Canada rises from **1.8 billion in 2023 to 3.9 billion in 2035** by improving service with a more frequent and reliable transit system.

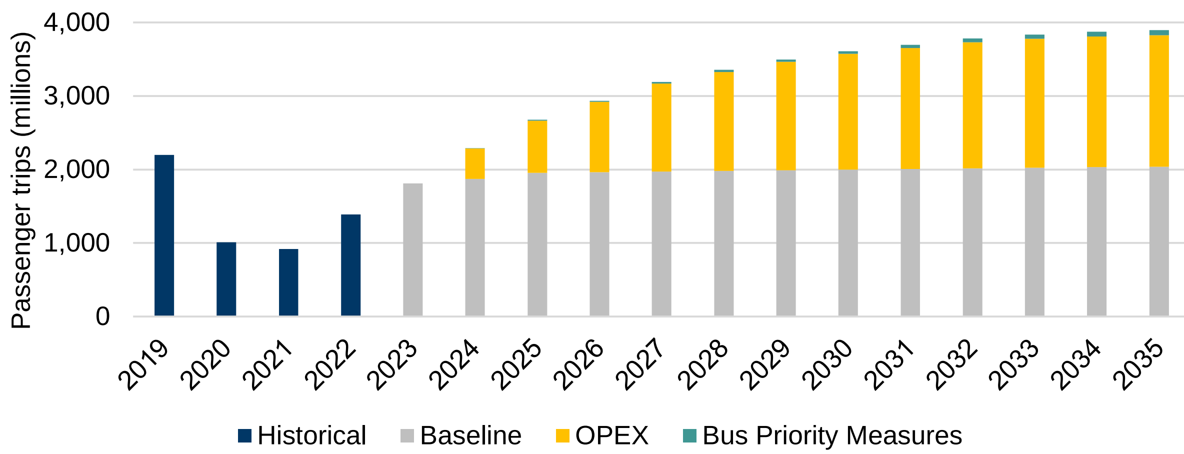

Figure 3-1 Transit ridership (in million linked trips)

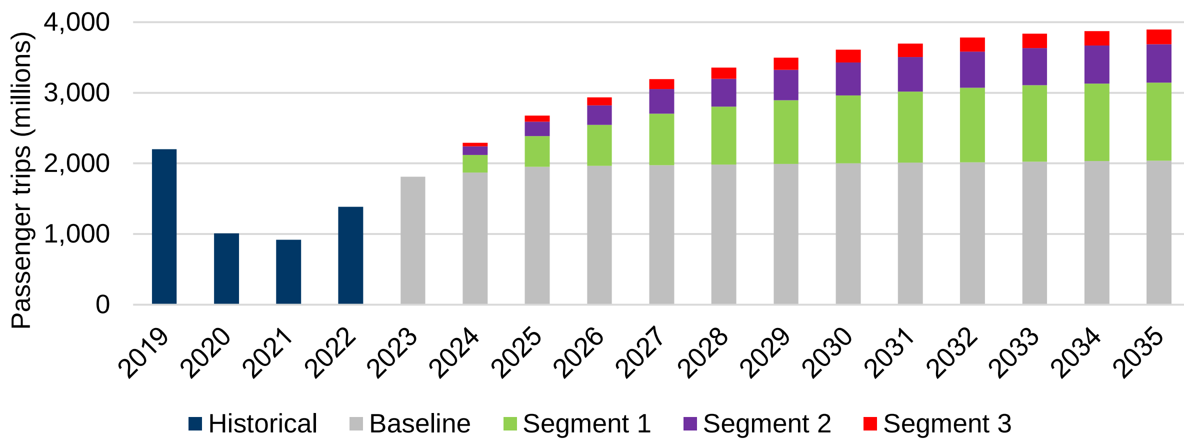

Figure 3-2 Additional transit ridership by Segment (in million linked trips)

Figure 3-2 shows that, in this scenario, most of the growth is coming from transit systems in Segment 1 (Canada's largest transit systems, accounting for 58% of the CUTA population as seen in Figure 2-4). Of the new transit trips, 60% are taken by riders in Segment 1, 29% in Segment 2, and 11% in Segment 3 in 2035. The increase in Segment 3 riders is the most difficult to achieve because the initial transit mode share in Segment 3 in 2019 is only 3%.

3.1.1 Impact of operational investment

All spending numbers reported in this study are gross numbers.

Most of the increase in ridership is due to service improvements resulting from increased operating budgets, as shown by the yellow bars in Figure 3-1. The operating budget increase is frontloaded on the first four years in order to achieve GHG reductions as early as possible.

In this scenario:

- Operational spending is increased by **14.3%** every year for the first four years, then by **3.5%** yearly between 2028 and 2031, and finally by **0.9%** between 2032 and 2035.
- This translates to **additional spending** on operations of **$12.2B in 2030** and **$13.7B in 2035** relative to the baseline.
- Overall, **$127.0B** cumulatively is needed to reach the target mode share (before factoring in passenger revenues, which would of course reduce net funding required), with **total operational spending** reaching $25.4B in 2030 and $**26.9B in 2035**.

This analysis assumes that additional spending is strategically allocated to areas/times with **latent demand**, for example, evenings and weekends and other non-commute trips.

The proportion of increased operational spending is equal across transit system segments, but because of their starting point in terms of size and ridership, two thirds of operating spending is allocated to agencies in Segment 1.

No additional operational costs were included to represent the surface transit priority measures. Rather, the operating investments are assumed constant in real terms, assuming that operations become more efficient, not more costly, with these measures (for instance, a given driver will transport more passengers for the same salary during the same shift because the bus can travel more quickly and reliably).

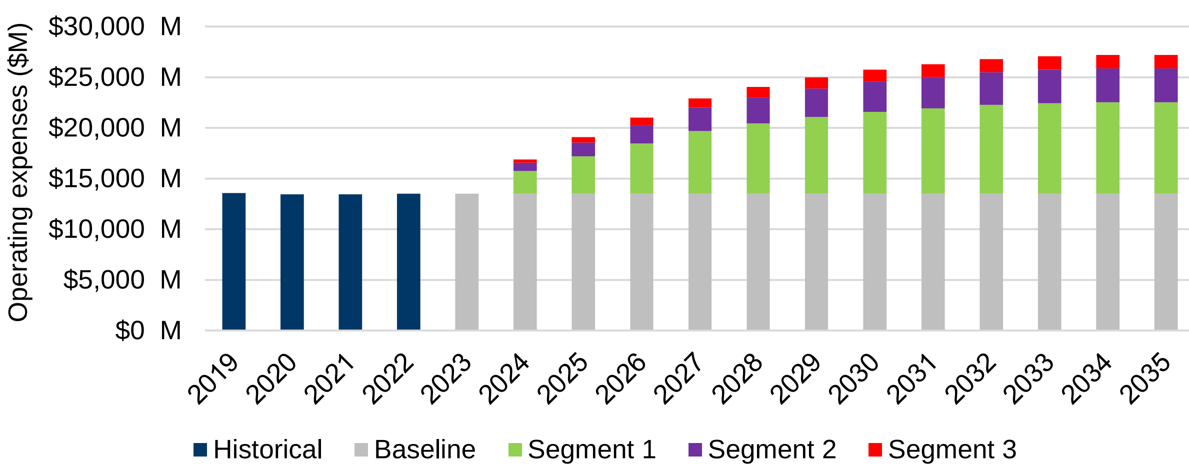

Figure 3-3 Operating expenses by segment (in $M)

The change in operational cost from bus electrification is not included in the analysis, see Section 3.4. for more details.

3.1.2 Impact of surface transit priority measures

Surface transit priority measures contribute much less to ridership increases compared to operating subsidies at the national scale (despite their importance at the local scale). Our model suggests that a dedicated surface transit lane plan applied in communities with large and medium transit systems (Segments 1 and 2) every four years could increase total transit trips in Canada by **up to 5% by 2035**, relative to the base case in 2035 (surface transit priority measures are only applied to a limited number of relevant routes, as discussed in Section 2.3.3.3).

We do not quantify additional or saved operational spending associated with these measures.

3.2 Reduced Car Trips and Mode Share Changes

As discussed in Section 2.3.3.1, car trips are reduced through **two key mechanisms**:

- A share of new transit trips from increased service and faster trips that **would otherwise have been done by car** (direct benefits).
- Overall changes to urban form and resident behavior from increased transit service result in **car trips being shifted or avoided** altogether (indirect benefits).

Overall, our model suggests that transit investments can reduce the number of car trips in 2035 by 47% compared to the baseline for that year.

3.2.1 Impact of operational investment

The increased transit level of service from the increased operating budgets leads to a mode transfer from all modes to public transit. Between 50% and 80% of new transit passenger kilometers come from private vehicle kilometers, depending on the segment. The increased operating budgets lead to a **reduction of 7%** of car trips in 2035 compared to the baseline scenario, across all segments.

3.2.2 Impact of surface transit priority measures

The increased service from the surface transit priority measures will increase transit ridership, transferring passenger kilometers from private vehicles to transit. The effect is of a smaller order of magnitude compared to the operating budget or land use, and it reduces the car trips by **0.3% in 2035** compared to the baseline scenario.

3.2.3 Impact of land use transformation

The land use effect has the biggest impact on car trip reduction compared to the other policies and achieves a **40% reduction of car trips in 2035** compared to the baseline scenario. This suggests that the indirect benefits of transit in densifying cities and changing travel patterns are a significant part of the benefit of improved transit service.

We observed a disproportionate effect of the land-use factor on Segment 1 jurisdictions. Thus, we limited the car trip reduction in Segment 1 transit systems by using a minimum threshold of one billion car trips remaining in 2035, which is equivalent to a 20% car mode share in that year. This assumption was based on professional judgement regarding likely lower-bound vehicle usage patterns based on international cities with high transit mode shares.

3.2.4 Overall mode share

Altogether, the combined benefits of increased service, surface transit priority measures, and indirect land use benefits could increase transit mode share to <u>21% of all trips in 2035</u> (47% in the large transit service areas) (Figure 3-4).

This analysis assumes that the active transportation mode share grows from an average of 7-11% in 2019 to 10-30% in 2035 (varies by community size), while the share of other modes remains constant.[23]

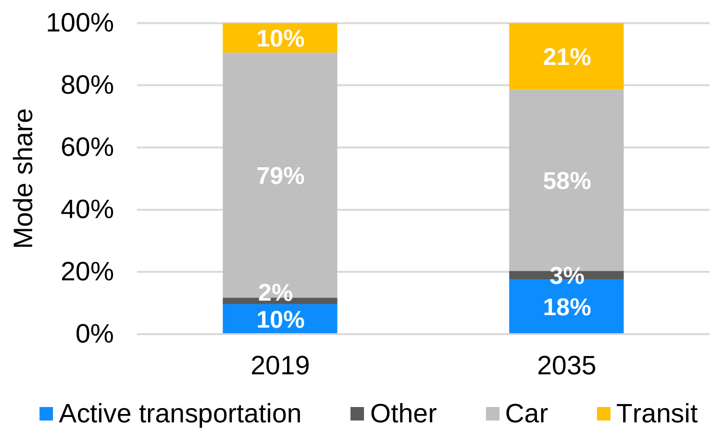

Figure 3-4 Mode share in Canada, for 2019 (baseline) and 2035 (with modeled policies)

As can be expected, communities in Segment 1 see the highest levels of transit ridership in 2035, as is the case today. The 2035 transit mode shares vary from almost 50% in large cities in Segment 1, a three-fold increase compared to 2019, to a doubling in Segment 3 to reach 6%.

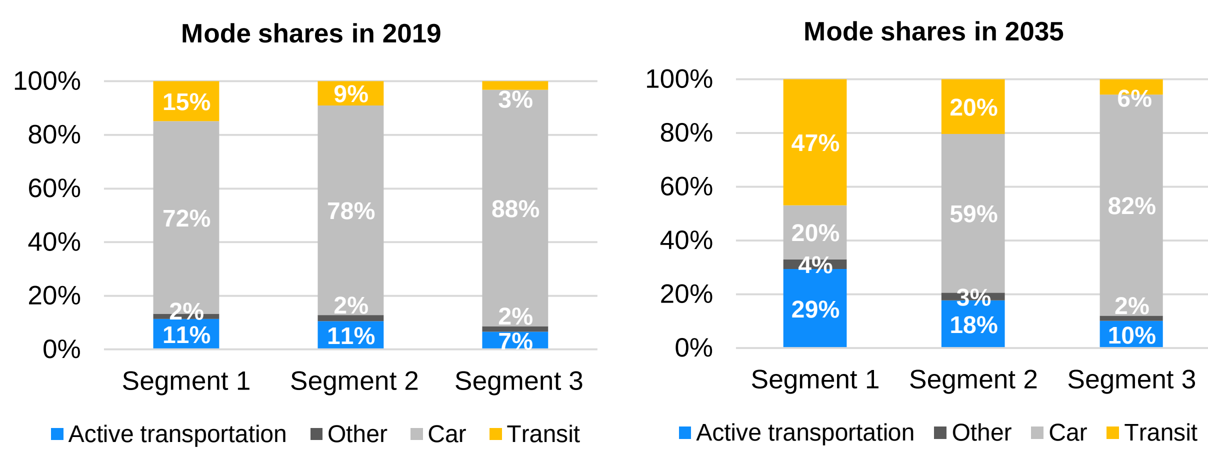

Figure 3-5 Mode share in Canada by Segment in 2019 and in 2035

[23] These mode shares were an assumption, not an input to our model, while transit and car mode share are model outputs.

3.3 GHG Reduction

3.3.1 Impact of operational investments, surface transit priority measures and bus fleet electrification

The GHG intensity of a passenger kilometer travelled is lower for transit riders than for car users. Thus, GHG emissions reductions are achieved from shifting car trips to transit trips, as well as avoided car trips and bus fleet electrification.

Figure 3-6 shows that, compared to the baseline scenario, increased operating budgets ("OPEX") and bus electrification policies respectively avoid annually **1.8 $MtCO_2e$ and 6.9 $MtCO_2e$** in 2035 (the bus priority measures have a negligible effect).

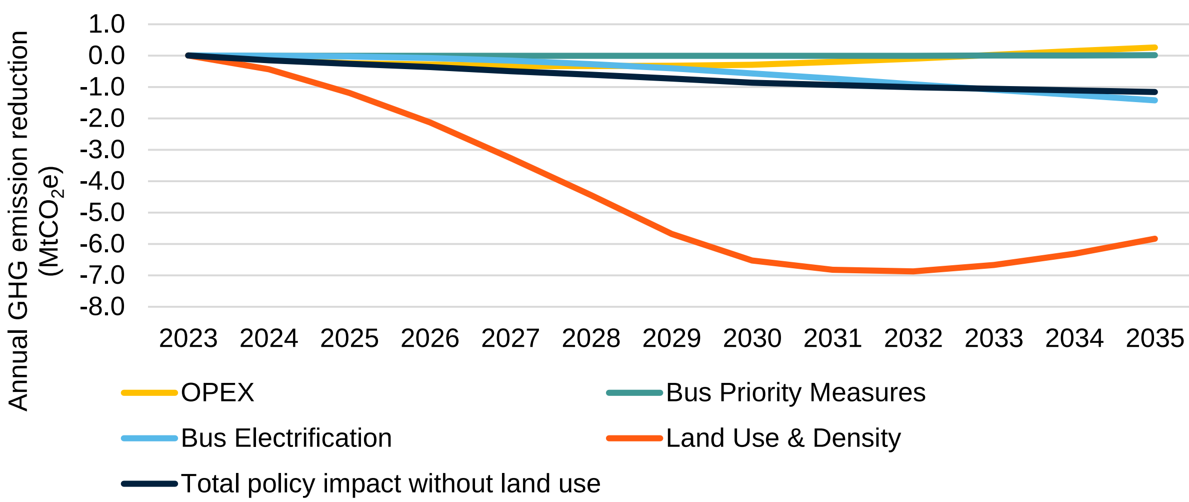

Figure 3-6 Annual passenger GHG Emissions ($MtCO_2e$)

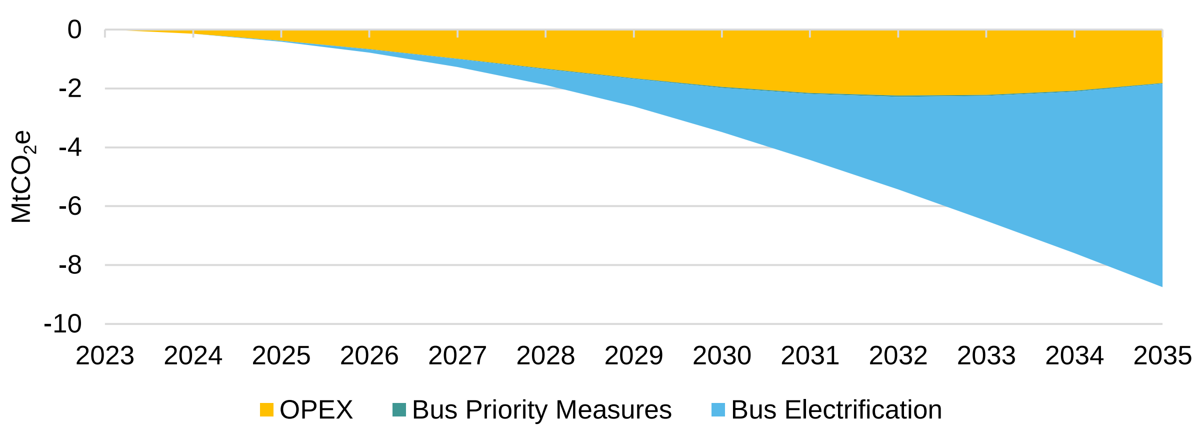

Figure 3-7 Cumulative passenger GHG emissions reductions by policy (in $MtCO_2e$)

The emission reduction achieved through the impact of increased transit operating budgets exhibits an inflection point in 2033 shown in Figure 3-7. This is caused by the decreasing GHG intensity of cars with the increased adoption of zero emission vehicles. More car trips are avoided with the increased transit service, but those avoided car trips are marginally less polluting, decreasing the overall magnitude of the GHG emission reduction.

In 2035, under our green procurement scenario, 65% of the bus fleet is made up of e-buses, the remaining 35% being diesel buses. The residual transit emissions are due to the combustion of fuel by the diesel buses, and the GHG intensity of the electricity used by e-buses in the different provinces/territories which varies greatly between 29 tCO_2e/GWh in Alberta to 0.1 tCO_2e/GWh in Québec in 2035.

3.3.2 Emissions reduction with the land use effect

The transformation of **land use** has a much greater overall impact on avoided car trips and thus GHG emissions, reducing the baseline GHG emissions by an additional cumulative **56.2 $MtCO_2e$** in 2035. However, the impact of the land use effect involves greater uncertainty and takes both time and strong municipal/provincial policies to change the built environment and people's travel habits.

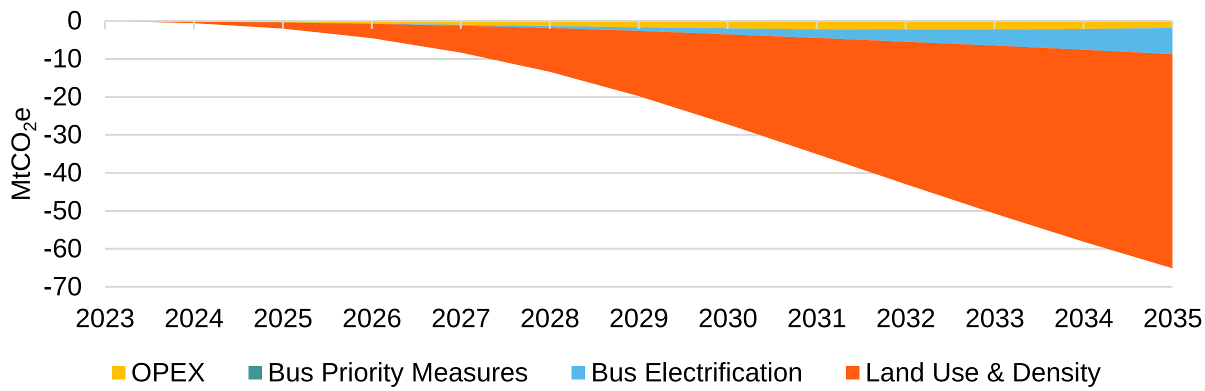

Figure 3-8 Cumulative passenger GHG emissions reductions by policy, with land use impact (in $MtCO_2e$)

3.4 Capital Costs

The capital cost for bus fleet electrification is estimated **at an additional $4.5B between 2023 and 2035**, accounting for the procurement of the electric buses and excluding the maintenance and infrastructure costs associated with the e-fleet.[24] These costs reflect the incremental cost of purchasing a new electric bus rather than a diesel bus, and not the total cost of procurement.

Capital costs for transit expansion, which would presumably be required alongside increased operations, are also not calculated.

3.5 Sensitivity Analysis

We conducted a sensitivity analysis on three key input variables — **VRH to ridership elasticity, car vehicle kilometer displaced per trip and land use factors** — to understand how a change to these inputs would affect the overall forecast of annual GHG emission reduction and transit mode shares. Table 3 presents the input values used for the sensitivity analysis.

[24] Estimate produced using in-house Dunsky tools and market information.

Table 3 Reference values for the sensitivity analysis

Measure		Low scenario	Base scenario	High scenario
Service level (VRH) to ridership elasticity		0.5	0.9	1.1
Land use multiplier	Segment 1	2	3	4
	Segment 2	1.5	2	3
	Segment 3	1.2	1.5	2

The results, presented in Figure 3, show that both the transit mode share and emissions results are most sensitive to the ridership elasticity value. In other words, **the extent to which increased transit service is able to attract more transit use is a key element of success**. If expanded services are designed to successfully capture latent demand, the impact of the investment is increased. The land use multipliers, which affect the personal vehicle travel avoided for every new passenger kilometer of transit service, also have a significant impact on GHG emissions reductions.

Overall, Figure 3 shows that even if these values are set to more conservative assumptions, the transit policies and investments still contribute to increased transit mode share and decreased transportation emissions by 2035.

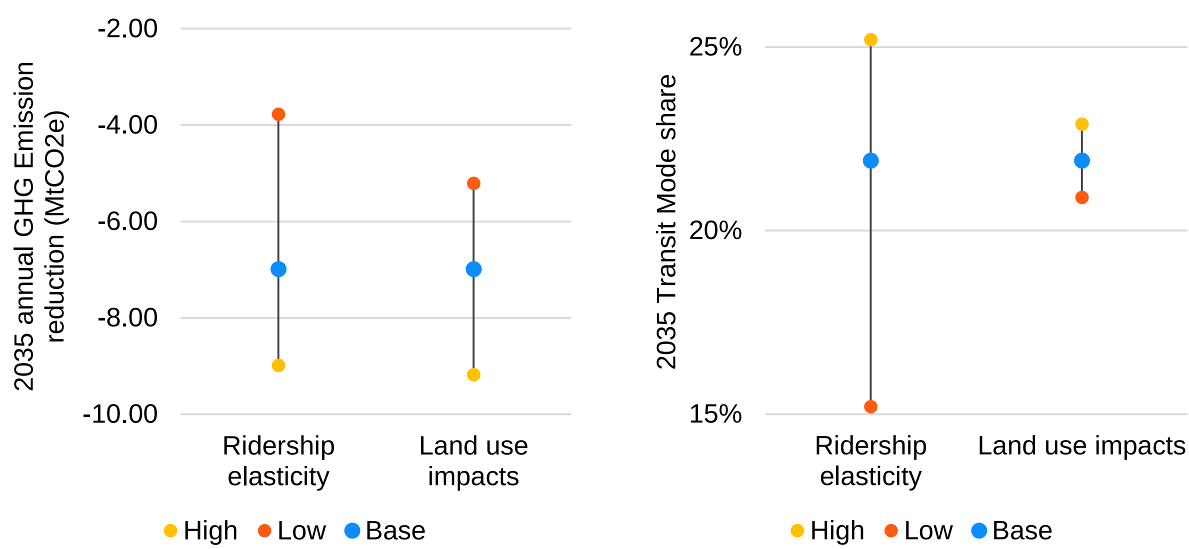

Figure 3-9 Sensitivity analysis of the annual GHG emission reduction and transit mode share in 2035

4. Discussion

Forecasting the impact of transit investment on the ridership levels and avoided GHG emissions is a highly uncertain exercise. We have grounded our analysis in the best available information and literature, which will change over time, especially with regards to the new Origin Destination surveys post Covid-19 that will provide more accurate insights on ridership recovery levels and new travel behaviour.

The main conclusions from this analysis are that:

- **Doubling transit ridership** and achieving a **21% transit mode share** for all trips in Canada by 2035 (from 10% transit mode share in 2019) could be achieved by increasing transit system's operating budgets over the modelling horizon. These changes would be transformative for communities across the country, providing greater accessibility to opportunities, good jobs in transit, and driving local economic growth.
- Our results were obtained under a scenario where operational spending is increased most in the first four years (2024-28), translating to **additional spending** on operations of **$12.2B in 2030** and **$13.7B in 2035** relative to the baseline. These numbers are gross and do not account for additional passenger revenues, which would reduce the net cost to government.
- The ridership growth that comes from the spending increase, combined with bus electrification, could generate nearly **9 Mt CO_2e in direct cumulative GHG emissions reductions** between 2023 and 2035. In 2021, Canada's transportation sector emitted over 150 Mt CO_2e.
- The **indirect land use effects of transit investment are powerful** and lead to the greatest emissions benefit due to their positive spillover impacts in communities. Indeed, the land use effects could lead to an additional **56 Mt CO_2e in indirect GHG emissions reductions** between 2023 and 2035, provided complementary policies are enacted to best enable the catalytic impacts of better transit.
- Overall, the cumulative passenger GHG emissions reductions (direct and indirect) could reach **65 Mt CO_2e** between 2023 and 2035.
- Investments in transit **will have the most benefit when paired with effective local land use policy changes and investments**, such as zoning policies especially near transit nodes and high-frequency corridors, active transportation infrastructure investments, transportation demand management programs, etc. Walkable, high-density, mixed-use areas allow fewer and shorter trips, favouring transit and active mobility and decreasing the GHG emissions associated with those trips. All policymakers, including the federal government, provinces, transit agencies and local governments should collaborate to achieve these outcomes. We can expect the land use effects to strengthen over time as communities incorporate the improved transit in their transportation patterns and urban planners promote transit-oriented development around high frequency transit stops.

APPENDIX

Appendix A

Advisory Committee

An Advisory Committee was formed and consulted on the methods and findings of the analysis. Together with Environmental Defence and Équiterre (the clients), the following members were chosen for the Advisory Committee:

- Ilan Elgar, PhD, Director of Research & Analytics at TransLink
- Eric Miller, PhD, Professor of Civil Engineering at the University of Toronto's Department of Civil & Mineral Engineering
- Catherine Morency, PhD, professor at Polytechnique Montréal University, Department of Civil, Geological and Mining Engineering

Participation as an Advisor does not constitute an endorsement of the findings presented in the report; any errors or omissions are the responsibility of the authors

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