BENEFITS OF TRANSIT INVESTMENT

Phase 2 Project Final Report to the Toronto Transit Commission

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the Value of Transit

Executive Summary

This study explores in detail the economic, environmental and social benefits of investment in TTC operations and infrastructure. Two modelling approaches are run in parallel to quantify these benefits: a macroeconomic model of the Canadian economy to assess of the macroeconomic impacts on the Ontario and Canadian economies of TTC investment, and a detailed microsimulation model of multi-model travel within the GTHA to compute trip-maker and societal benefits of transit investments.

The macroeconomic analysis clearly demonstrates the tremendous economic impact that the TTC has on the City of Toronto, the Province of Ontario and, indeed, Canada through its operating and capital investment expenditures. These impacts are concentrated in Ontario, Canada's industrial core. The TTC is clearly a "propulsive firm" playing a critical role in pushing the Greater Toronto Area (GTA), Ontario and Canada forward. Future research into the potential of TTC investment expenditures (especially those around electrification of the bus and locomotive fleets and associated infrastructures) to spark the creation and expansion of indigenous capacity in the advanced supply chain for electric vehicles and electric transit solutions specifically is warranted.

Four scenarios were modelled in the microsimulation modelling analysis:

1. May, 2023 service (RS). This is a "reduced service" case relative to pre-pandemic full service. It is used as the base case for computing investment benefits.
2. Fall, 2019 service (FS). This scenario is taken as represent "full service" under prepandemic conditions.
3. Line 2 shutdown (L2S). This hypothetical case illustrates the impact of a significant "disinvestment" in the TTC that results in a significant loss of benefits.
4. 2024 Service Plan (SP).

Metrics computed for each scenario include:

- Trips by mode and mode shares.[1]
- Vehicle kilometres travelled (VKT).
- Transit and auto travel times.
- Auto user costs (operating, parking, ownership).
- Road accidents.
- GHG emissions.
- Air pollution emissions and associated health impacts.
- Accessibilities to a variety of activity types, for different household types.

All metrics except the accessibility measures were converted into monetary values so that benefit/cost ratios could be computed for the FS and L2S scenarios relative to the RS base. This analysis indicates that

investment in TTC operations and infrastructure can yield very strong returns on investment, with B/C ratios on average in the order of 7.

The specific values obtained are, of course, very case-specific, but they illustrate the very strong case that exists in general for continuing investment in transit in the City of Toronto.

The analysis also clearly indicates the significant benefits that auto users receive from improved transit services in terms of reduced congestion (and, hence, travel times) and operating and vehicle ownership costs. It also demonstrates further societal benefits with respect to reductions in road accidents, GHG emissions and air pollution-related health impacts, as well as improvements in accessibility to jobs, schools, medical care and other essential services – especially for mobility disadvantaged population sub-groups.

This study has demonstrated the utility of using a large-scale, multi-model regional travel demand model to assess the region- and network-wideimpacts of transit investment. It providesa consistent and comprehensive computational framework for assessing a broad range of impacts in response to a similarly broad range of policy alternatives. While originally designed for longrange strategic planning analyses, this study has shown the usefulness of the model system for analyzing short-run, more operationally-oriented scenarios.

1 These trips are also characterized by origin, destination, trip purpose, time of day and trip-maker attributes.

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Authors

Editor

Dr. Eric J. Miller is the Principal Investigator on this project. He is a professor in the Department of Civil & Mineral Engineering at the University of Toronto, the director of Mobility Network at the University of Toronto School of Cities, and the research director of the Data Management Group and of the Travel Modelling Group. His research is centered in the implementation of activity-based travel models for use in operational practice, including the analysis of transit demand. He modelled the transit demand resulting from scenarios on capital investment.

Co-Investigators

Dr. Richard J. DiFrancesco is an associate professor in the Department of Geography & Planning and the department chair. Rick is an economic geographer interested in regional economic development implications of the changing spatial distribution of production caused by the proliferations of global production networks in all sectors of the global economy. Rick built the economic input/output model, analyzed investment scenarios and present the results.

Dr. Marianne Hatzopoulou is a professor in the Department of Civil & Mineral Engineering at the University of Toronto and the Canada Research Chair in Transportation and Air Quality. Her research expertise is in modelling road transport emissions and urban air quality as well as evaluating population exposure to air pollution. Marianne researched the impacts of road transport emissions on health and the environment.

Dr. Steven Farber is a professor in the Department of Human Geography at the University of Toronto Scarborough, the Project Director of Mobilizing Justice, and the Interim Director of the Mobility Network at the School of Cities. His research examines the social, economic, and distributional impacts of transport policy and travel behaviour. Steven developed the methodology for measuring the distribution of transit costs and benefits across different population groups in this study.

Introduction

As the TTC and the City of Toronto are debating TTC operating and capital budgets within a context of significant fiscal challenges, it is critical to understand the fundamental role that the TTC plays in the economic and social life of the residents of Toronto. In particular, it is essential for decision-makers to clearly understand that TTC operating and capital budgets represent investments in Toronto's current and future health and well-being. Public transit is a "must have", not a "nice to have" if the Toronto is to continue to grow and prosper.

Cities exist to bring people and their enterprises together to create economic and social interactions and, thereby, wealth and well-being. They are vast "social networks" that create both economies of scale (bigger cities are more efficient than smaller cities) and agglomeration benefits (bigger cities are more productive per person than smaller cities).[2] Agglomeration effects are particularly important since this is how increases in wealth and social well-being are generated. Investment in public transit accelerates the "positive feedback loops" within the economy in which the improved accessibility provided by the transit system generates increased economic activity, which, in turn, generates increased demand for transit, which justifies further improvement in these services, which then generate further economic development, and so on.[3] This is a "virtuous cycle" in which investment in transit begets economic growth, which stimulates (and enables financing of) further infrastructure (and other) investments. But feedback loops can run in both directions, which means that disinvestment in critical infrastructure, such as public transit, will lead to a "vicious cycle" of economic decline, resulting in further decline in infrastructure investments, such has been seen in a number of US cities, for example, which have failed to maintain their infrastructure and economic bases.

Public transit is integral to the effective functioning of these economic and social interactions. It enables the economy to operate by connecting workers to jobs, students to schools, shoppers to stores, etc. Neither active travel modes (walking and biking) nor the automobile are sufficient to support the vast number of daily interactions (trips) needed to keep a city the size of Toronto functioning. Transit is an intrinsic, critical part of the "wiring" or "machinery" of the city. Just as an assembly line in a factory must be maintained and kept in working order for the factory to remain in operation, so too must a city's transit system be kept in a state of good repair if the city is to function. And just as the factory's technology needs to be improved and upgraded over time if the factory is to grow and increase its productivity, so too must we invest in improved and expanded transit services if the city is to grow and increase its wealth and well-being. Thus, investment in transit operations has direct economic benefits in terms of enabling job growth[4] and, more generally, increased economic productivity and benefits.[5] Conversely, disinvestment in transit by failing to maintain a state of good repair and by allowing service quality to degrade will result in reductions in economic productivity and will hobble Toronto's ability to grow. Indeed, failure to invest in maintaining and improving public transit is a recipe for Toronto's decline as a place in which to invest and to live.

In particular, it is important to recognize that the City of Toronto and the Toronto-centredurbanized region of the Greater Toronto-Hamilton Area (GTHA) and Greater Golden Horseshoe (GGH) are engaged in a global competition for population, jobs and economic development. A comprehensive, effective, efficient and attractive local and regional public transit system is an essential prerequisite to succeed in this competition. Toronto's peer competitor global cities in North America, Europe, Asia and Australia all have extensive, well-funded transit systems that are typically well subsidized and being continuously expanded. TTC operations are among the least subsidized, and our capital investment in both system state of good repair and essential system expansions has been minor, compared to most competitors. Toronto has "gotten by" with this underinvestment over the past several decades through a combination of very efficient operations, a well-designed integrated network of buses, streetcars and subways, and wise investments in the system in the 1950's, 60's and early '70's. But investments since the mid-70's have not kept up with city and regional growth, and Toronto cannot hope to continue to be globally competitive unless we acknowledge this long-standing shortfall and act to rectify it.[6]

These challenges have been exacerbated by the COVID-19 pandemic, which resulted in massive declines in ridership (and, hence, revenues) and unprecedented operational challenges for the TTC. While ridership is returning and can be expected to eventually return to pre-pandemic levels,[7] the short- and medium-term fiscal challenges for the TTC remain. While in a time of fiscal challenges there is great temptation to "cut costs", in the case of public transit this would be an extremely "penny-wise and pound-foolish" strategy that could easily result in long-term (and perhaps even irreversible) decline in Toronto's national and global economic competitiveness and quality of life.

Public transit competes directly with the private automobile for riders. Having said that transit is essential to the city's economic functioning, it can only play this role if it provides a costeffective, attractive alternative to the car. Transit lines must run at high frequencies (especially in peak periods) to minimize waiting and transfer times. Transit vehicles must run at reasonable speeds and high reliability, with priority to minimize delays at signalized intersections and due to on-road congestion. And a spatially comprehensive, hierarchical transit network must exist that provides approximately door-to-door journeys and that cost-effectively matches line capacity (technology and performance) to demand. None of this is possible without adequate funding of day-to-day operations and on-going investment in the state of good repair of the system that ensures the required reliable, high-quality service.[8]

2 *Bettencourt, L.M.A. (2013) "The Origins of Scaling in Cities", Science, 340:1438-1441.*

3 *Dachis, B. and R. Godin (2021). Trains, Lanes add Automobiles: The Effect of COVID-19 on the Future of Public Transit. Commentary No. 598, Toronto: C.D. Howe Institute, April. Glaeser, E. (2011) Triumph of the City: How Our Greatest Invention Makes Us Richer, Smarter, Greener, Healthier, and Happier, New York: Penguin Press.*

4 *The Canadian Centre for Economic Analysis estimates that every $1 million in infrastructure investment in Ontario directly generates 9 job-years of additional economic activity before accounting for follow-on spin-off effects (CANCEA, 2020). See also ITF-C40 for the effect of public transit investment on job growth.*

5 *The C.D. Howe Institute, for example estimated an economic loss to the Toronto region due to mid-pandemic reduced TTC ridership of $1.2-1.4 billion (Dachis and Godin, 2021).*

6 *Toronto Region Board of Trade (2021) Next Stop, Building Universal Transit Access, Toronto, November.*

7 *Miller, E.J. (2022) "Transportation in an Age of Disruption: A Speculative Discussion", invited presentation to the Transportation Association of Canada Mobility Council Fall Meeting, Edmonton. October 2.*

8 *https://www.toronto.ca/services-payments/streets-parking-transportation/transit-in-toronto/transit-funding/*

It is essential to understand that automobile-based transportation cannot fully serve the travel needs of a large metropolitan area such as GTHA. It is a physical fact that one cannot build enough streets and highways to carry all the cars that would be needed to serve a city the size of Toronto in the absence of a comprehensive, efficient transit system. The Gardiner Expressway can, at best, carry about 6,000 cars or about 7,000 persons per hour per direction, while the Line 1 subway can serve 30,000-35,000 passengers per hour per direction. Downtown Toronto as we know it could not exist without the extensive subway, streetcar and bus network serving it

At the same time, an efficient, competitive transit system is also essential to support a wellfunctioning road system. We currently hear considerable discussion about roadway congestion in the city and region. We are very limited in our ability to expand our road system given the builtup nature of most of the city and much of the region. And while enhanced use of AI-enabled real-time traffic control systems can help improve roadway operations (ideally for cars, buses and pedestrians) this is not a "silver bullet" that will eradicate congestion, particularly as we continue to grow. Transit, with its intrinsically much higher people-carrying capacity, is the only technical solution available to contain congestion within acceptable levels and sustainably maintain regional growth. In particular, it is important to note that

transit is an auto-driver's "best friend"

in that by diverting trips from car to transit it frees up road space, thereby reducing congestion and speeding up auto travel times. Thus, investing in transit service is a "win-win" for both transit and auto users.

Further, public transit has a critical role to play in providing equitable accessibility to jobs, education, medical facilities, stores, etc. for mobility disadvantaged segments of our society who may have limited or no access to cars, or, if they do own cars, pay a disproportionate amount of their income to maintain minimally acceptable levels of accessibility. Transit provision and housing policy need to be tied together so that good transit service is being provided to areas of low-income housing, while, at the same time, development of new housing supply needs to be matched to viable transit service. Hence, the social benefits of transit investment are also very large, even if these cannot always be translated into monetary terms.

The City of Toronto has very ambitious greenhouse gas (GHG) reduction targets to address climate change concerns, as expressed in its TransformTO program.[9] Automobile emissions are also a major source of air pollution emissions in the city and the GTHA that represent a serious health hazard. Diverting car users to public transit is an important component of any plan to reduce both GHG and air pollution emissions. Thus, a third important dimension of the benefits of transit investment is its impact on GHG reductions and improved health outcomes.

This report builds upon an earlier discussion paper prepared by the University of Toronto for the TTC documenting global understanding of transit investment impacts.[10] It provides robust, detailed, quantitative support for these qualitative observations. Using state-of-the-art modelling methods and the best data available, it computes the economic, social and environmental benefits of operational and capital investments in the TTC for both the City of Toronto and the Greater Toronto-Hamilton Area (GTHA), as well as macroeconomic benefits for the Province of Ontario and Canada as a whole. Section 2 presents the macroeconomic modelling component of the study, while Section 3 presents the more detailed modelling of Toronto and GTHA benefits. Section 4 concludes the report by summarizing key findings and recommendations for further work.

9 *https://www.toronto.ca/services-payments/water-environment/environmentally-friendly-cityinitiatives/transformto/*

10 *Aitken, I.T., R. DiFrancesco, M. Hatzopoulou, W. Klumpenhouwer, E.J. Miller, M. Palm. A. Shalaby, M.Siemiatycki and D. Wolfe (2022) Economic, Social & Environmental Benefits of Transit Investment, A Discussion Paper, J.F. Farvolden and E.J. Miller (eds), prepared for the Toronto Transit Commission, Toronto: University of Toronto Mobility Network, December 21.*

Macroeconomic Benefits of Transit Investment

2.1 Introduction

This section presents the results of a macroeconomic analysis of the TTC's 2023 and 2024 operating and capital budgets and associated 10- and 15-year capital investment plans (CIPs). Twelve scenarios (eight scenarios for 2023 and four scenarios for 2024) as specified by the TTC.The economic analysis presented below represents the output of a Multiregional Input-Output (MRIO) model of the Canadian economy, defined as 13 Provinces and Territories interacting through 186 industrial sectors.

2.2 Methodology

The estimation of the economic impacts of TTC operating and investment expenditures was conducted using a national scale Multiregional Input-Output (MRIO) Model that was developed using the 2019 Symmetric Provincial/Territorial Input-Output Tables for Canada. The impact model is expressed as follows:

$$\Delta X = (I - CA)^{-1} C \Delta F$$

Where:
X = a vector of industry outputs (consists of 186 industries for each of 13 regions)
C = a matrix of interregional trade coefficients (computed using available interprovincial trade
data).
A = a matrix of technical coefficients showing how industries interact through the purchase and
sale of inputs and outputs.
F = a vector of Final Demand elements (e.g., Investment, Exports, Consumption).
Δ = delta operator meaning "change-in".
This model takes the given TTC operating and investment scenarios (as ΔF) and translates them into industry output levels (ΔX) across all industries (186) in all regions (13) as indicated by the
technical coefficient and interregional trade coefficient matrices (A and C).[11]

2.3 TTC Operating & Capital Investment Scenarios

Originally, the TTC provided the 2023 Operating and Capital Investment Budgets for this analysis. They also requested that several scenarios be tested in which significant components of the Capital Investment Plan are deleted, to identified the significant benefits of these components that would be lost if they are not funded and implemented. Later, they requested that the analysis be repeated for a number of scenarios based on the 2024 Operating and Capital Investment Budgets. Specifically, these 12 scenarios consist of:

- Scenario 1 (SC1) includes the operating budget for 2023.
- Scenario 2 (SC2) includes the capital budget for 2023.
- Scenario 3 (SC3) consists of all planned capital expenditures for the coming ten years.
- Scenario 4 (SC4) includes all planned capital expenditures for the coming 15 years.
- Scenario 5 (SC5) consists of the capital expenditures associated with necessary subway system improvements that are included in the previously listed 10- and 15-year capital investment scenarios. This scenario is used to show the economic impacts (i.e., only those associated with the multiplier effects of these investments) forgone if these subway improvement investments are not undertaken.
- Scenario 6 (SC6) consists of the capital expenditures tagged as being necessary for maintaining the "State of Good Repair" (or SOGR) of the TTC system. This scenario is used to show the economic impacts (i.e., only those associated with the multiplier effects of these investments) forgone if these investments are not undertaken.
- Scenario 7 (SC7) consists of the capital expenditures associated with the replacement of the Scarborough Rapid Transit (SRT) link. This scenario is used to show the economic impacts (i.e., only those associated with the multiplier effects of these investments) forgone if these investments are not undertaken.
- Scenario 8 (SC8) consists of the capital expenditures associated with the electrification of the bus fleet. This scenario is used to show the economic impacts (i.e., only those associated with the multiplier effects of these investments) forgone if these investments are not undertaken.
- Scenario 1A (SC1-A) consists of the 2024 TTC Operating Budget.
- Scenario 2A (SC2-A) consists of the 2024 TTC Capital Investment Budget.
- Scenario 3A (SC3-A) consists of the planned capital investment expenditures for the 10- year 2024-2033 period.
- Scenario 4A (SC4-A) consists of the planned capital investment expenditures for the 15- year 2024-2038 period.

Table 2.1 summarizes these 12 scenarios and the total investment associated with each one. Note that Scenarios SC1-8 are expressed in 2023 CAD, while Scenarios SC1-A -- SC4-A are expressed in 2024 CAD.

Table 2.1: TTC Operating and Investment Scenario Analyzed

No.	Scenario Description	Identifier	Dollar Amount
1	2023 Operating Budget	SC1	$628,814,355
2	2023 Capital Budget	SC2	$1,451,235,987
3	2023-2032 Capital Investment Plan - 10 year plan	SC3	$12,922,061,171
4	2023-2037 Capital Investment Plan - 15 year plan	SC4	$38,117,531,558
5	Unfunded Subway Capacity Improvements	SC5	$4,794,568,852
6	Unfunded State of Good Repair	SC6	$1,393,313,649
7	Unfunded Replacement of SRT	SC7	$55,700,00
8	Unfunded Electric Buses	SC8	$2,686,717,458
9	2024 Operating Budget	SC1-A	$758,599,334
10	2024 Capital Budget	SC2-A	$1,367,665,151
11	2024-2033 Capital Investment Plan - 10 year plan	SC3-A	$12,396,538,654
12	2024-2038 Capital Investment Plan - 15 year plan	SC4-A	$47,854,213,553

11 *See https://www150.statcan.gc.ca/n1/en/catalogue/15-211-X*

Table 2.2: Impact Summary by Scenario

ID	Canada	Investment	Delta-X	Delta-VA	Delta-Jobs
SC1	2023 Operating Budget	$628,814,355	$758,954,794	$381,470,144	5,553
SC2	2023 Capital Budget	$1,451,235,987	$3,694,785,926	$1,483,834,655	21,375
SC3	10 Year Capital Plan	$12,922,061,172	$31,759,017,438	$13,128,347,706	189,002
SC4	15 Year Capital Plan	$38,117,531,558	$93,004,483,736	$38,876,029,951	559,836
SC5	Unfunded Subway Capacity	$4,794,568,852	$12,217,092,830	$4,881,875,161	70,527
SC6	Unfunded SOGR	$1,393,313,649	$4,165,469,917	$1,472,696,592	21,369
SC7	Unfunded SRT Replacment	$55,700,000	$132,794,117	$57,342,594	825
SC8	Unfunded Electric Buses	$2,686,717,458	$7,976,110,227	$2,892,076,050	42,185
SC1-A	2024 Operating Budget	$758,599,334	$818,892,603	$411,596,424	5,992
SC2-A	2024 Capital Budget	$1,367,665,151	$3,481,190,258	$1,383,216,949	19,927
SC3-A	2024 10-year Capital Plan	$12,396,538,654	$30,392,520,620	$12,563,508,698	180,872
SC4-A	2024 15-year Capital Plan	$47,854,213,553	$118,310,250,514	$48,911,124,107	705,315
	Ontario	Investment	Delta-X	Delta-VA	Delta-Jobs
SC1	2023 Operating Budget	$628,814,355	$678,704,698	$340,652,007	5,053
SC2	2023 Capital Budget	$1,451,235,987	$3,303,598,399	$1,301,934,607	18,908
SC3	10 Year Capital Plan	$12,922,061,172	$27,998,944,363	$11,384,814,998	165,775
SC4	15 Year Capital Plan	$38,117,531,558	$82,327,295,084	$33,891,731,891	493,436
SC5	Unfunded Subway Capacity	$4,794,568,852	$10,345,057,419	$4,048,989,040	59,328
SC6	Unfunded SOGR	$1,393,313,649	$3,558,589,750	$1,214,227,913	17,670
SC7	Unfunded SRT Replacement	$55,700,00	$117,496,095	$49,792,757	733
SC8	Unfunded Electric Buses	$2,686,717,458	$7,234,664,720	$2,542,710,828	37,473
SC1-A	2024 Operating Budget	$758,599,334	$732,304,824	$367,554,710	5,452
SC2-A	2024 Capital Budget	$1,367,665,151	$3,050,184,262	$1,190,196,266	17,245
SC3-A	2024 10-year Capital Plan	$12,396,538,654	$26,706,278,997	$10,866,041,407	158,126
SC4-A	2024 15 -year Capital Plan	$47,854,213,553	$104,913,984,527	$42,681,697,680	621,835

2.4 Results

The MRIO model developed for this exercise allocated economic impacts of each investment scenario tested across 186 industrial sectors (i.e., the Statistics Canada L97 level of industry detail), and across 13 provinces and territories. Table 2.2 summarizes the impacts for each of the twelve scenarios described in Section 2.3 in terms of the change in gross domestic output (column "Delta-X"), economic value-added (column "Delta-VA") and jobs created (column "Delta-Jobs"). As indicated in the table, these impacts largely occur in the Province of Ontario with its share varying from 85% to 90% depending on the scenario.

The following sub-sections discuss these results in greater detail for: (1) the 2023 and 2024 Operating Budgets; (2) the 2023 and 2024 Capital Budgets; (3) the 10-Year and 15-Year Capital Investment Plans (CIPs); and (4) the impacts of not funding various portions of the 10/15-Year CIPs (Scenarios SC5-8, highlighted in red in Table 2.2).

2.4.1 Operating Budget Impacts (Scenarios SC1 & SC1-A)

Table 2.2 shows that the 2023 and 2024 operating budgets ($629 Million and $759 million respectively) generate substantial total gross output impacts, Canada-wide, of $759 million and $819 million respectively. In addition, these scenarios have value-added impacts of $381 million and $412 million respectively, and stand to create 5,553 and 5,992 jobs respectively. The majority of these impacts (89%) are captured inside the Province of Ontario.

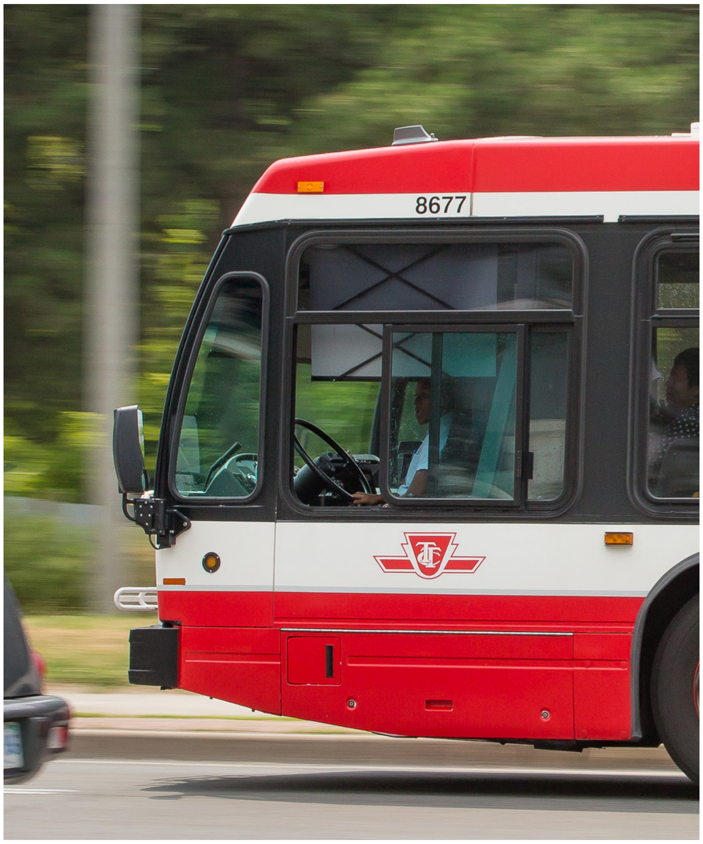
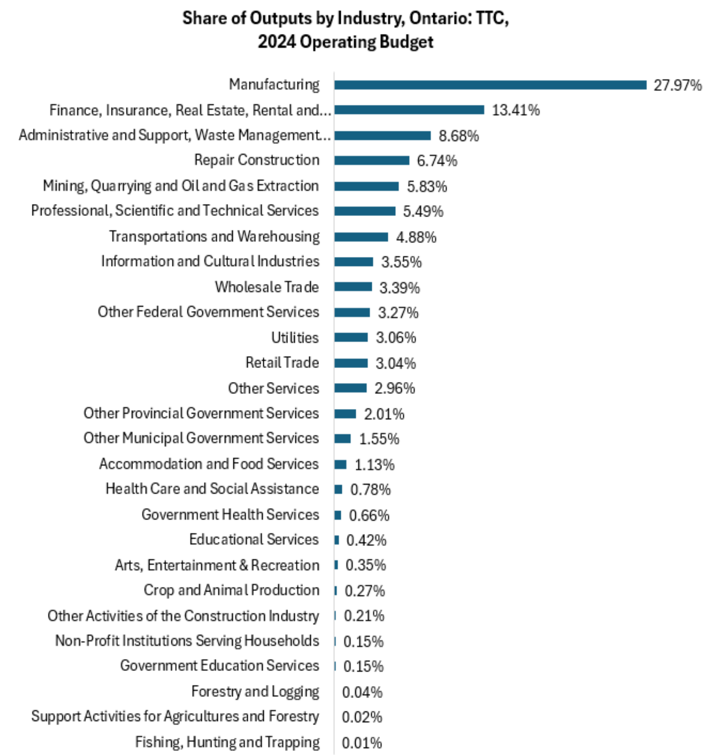


Figure 2.1 presents the gross industrial output impacts for Ontario from the 2024 Operating Budget (SC1-A) which is virtually identical to that for the 2023 operating budget. This figure clearly shows that

TTC operational expenditures have a substantial economic impact across many industries

in Ontario, with Manufacturing (28%), Finance, Insurance, Real Estate, Rental and Leasing and Holding Companies (14%), Administrative and Support, Waste Management and Remediation

Figure 2.1: Share of Output Impacts by Industry, Ontario, TTC 2024 Operating Budget



Services (9.3%), and Repair Construction (7.5%) accounting for nearly 60 percent of the total provincial output impact.[12] While these industries do capture the majority of the overall impact, it is important to note that many industries in Ontario are impacted by TTC operations.

2.4.2 Capital Budget Impacts (Scenarios SC2 & SC2-A)

As shown in Table 2.1 above, the TTC planned very sizeable capital expenditure budgets for the years 2023 and 2024, covering off many categories of improvements ranging from new locomotives and passenger cars, bus electrification, and new lines and stations. Table 2.2 shows that these scenarios amounted to $1.45 billion and $1.37 billion in expenditures respectively. Table 2.2 also shows that these scenarios would stimulate total gross output impacts Canadawide of nearly $3.7 billion and $3.5 billion respectively, with more than 89% of this captured within the Province of Ontario.

Table 2 shows that these scenarios translate into very substantial value-added impacts of $1.5 billion and $1.4 billion respectively and 21,375 and 19,926 jobs in 2023 and 2024 respectively, again with the majority of these (around 90%) in Ontario. Figure 2.2 shows the industrial breakdown of these impacts (Canada-wide) for the 2024 capital budget (which would be identical to that for 2023). Specifically, Figure 2.2 shows that manufacturing captures the lion's share (more than 50%) of the gross output (as well as value added and jobs) impacts followed by engineering construction (nearly 14%), non-residential building construction (12%), and professional, scientific and technical services (7%). As above, nearly 90% of these impacts are captured inside the Province of Ontario.

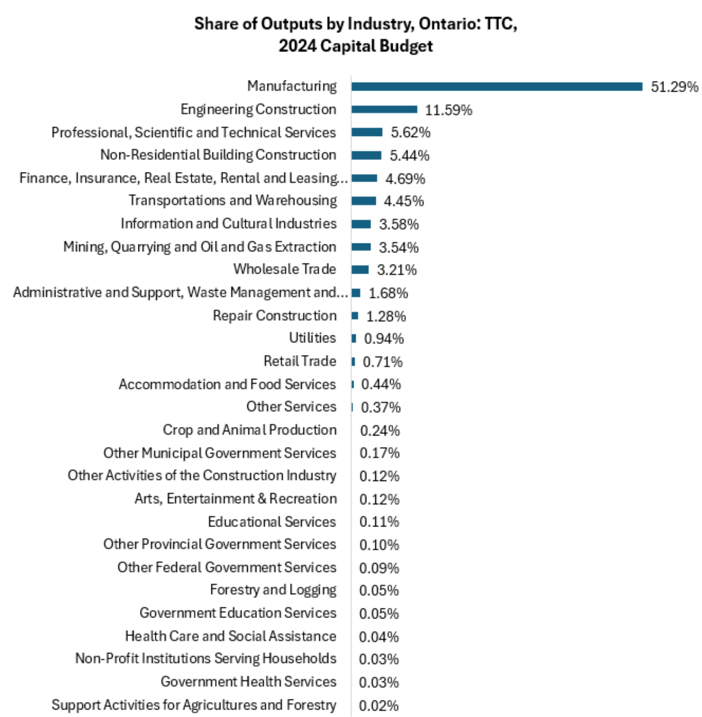
2.4.3 10-Year Capital Investment Plans (CIPS) (Scenarios SC3 & SC3-A)

The 2023 Capital Budget called for $12.9 billion in capital expenditures over the coming 10 years, while the 2024 Capital Budget called for slightly less at $12.4 billion. Table 2.1 above shows that the 2023 scenario translate into substantial Canada-wide output, value-added and jobs impacts of $31.8 billion, $13.1 billion and 189,000 jobs respectively. The 2024 10-year CIP stands to stimulate similar-scale impacts of $30.4 billion, $12.6 billion, and 181,000 jobs (in gross output, value-added and jobs respectively). Figure 2.2 above shows how these impacts would be distributed across industries with manufacturing, engineering construction, nonresidential building construction and professional, scientific and technical services accounting for more than 80% of all sectoral impacts and with more than 89% of these captured in Ontario.

2.4.4 15-Year Capital Investment Plans (Scenarios SC4 & SC4-A)

The 2023 & 2024 Capital Budgets call for $38.1 billion and $47.9 billion in investments over the following 15 years. These expenditures stand to have gross output, value-added and jobs impacts of $93 billion, $39 billion, and 560,000 respectively for the 2023 15-year CIP and $118 billion, $49 billion and more than 705,000 jobs for the 2024 15-year CIP. Given the sectoral and

Figure 2.2: Share of Output Impacts by Industry, Ontario, TTC 2024 Capital Investment Budget



12 The model inputs and outputs were at the L97 level of aggregation (186 industrial sectors). The data in Figure 2.1 are presented at a higher level of aggregation (the S level) consisting of 34 industrial sectors.

regional distributions discussed to this point, the TTC's CIPs stand to have very substantial impacts on most sectors and provinces of Canada, with Ontario and its manufacturing and construction industries capturing the majority.

2.4.5 Unfunded Subway Capacity (as of the 2023 CIP) (Scenario SC5)

SC5 represents the investments associated with planned and necessary expansion of capacity of the existing subway system (these are included in the 10- and 15-year capital plans). SC5 singles out these investments to illustrate those economic impacts potentially forgone (relative to SC3 and SC4) by choosing not to undertake these investments. Specifically, Table 2.2 shows that if these capacity improvements are not undertaken at all, the aforementioned nation-wide gross output and value-added impacts could be reduced by approximately $12.2 billion and $4.8 billion respectively, and that the nation-wide jobs impact could be reduced by nearly 71,000 over the timeline of these investments. As above, the Province of Ontario would experience the brunt of these forgone opportunities.

2.4.6 Unfunded State of Good Repair (SOGR) (Scenario SC6)

SC6 shows how a failure to implement planned SOGR investments over the coming 10-15 years will translate into a reduction of the economic impacts discussed above for SC3 and SC4. Specifically, Table 2.2 shows that a failure to fund the necessary SOGR investments could translate into reductions in the gross output and value-added impacts associated with SC3 and SC4 of $4.2 billion and $1.5 billion respectively, as well as the forgone opportunities associated with more than 21,000 jobs.

2.4.7 Unfunded Scarborough Rapid Transit (SRT) Replacement (Scenario SC7)

SC7 shows how a failure to implement SRT replacement investments over the coming 10-15-year period will translate into a reduction of the economic impacts previously discussed for SC3 and SC4. Specifically, Table 2.2 shows that a failure to fund the replacement of the SRT could translate into potential reductions in the gross output and value-added impacts shown above for SC3 and SC4 of $133 million and $57 million respectively. Table 2.2 also shows that this could result in the potential forgoing of some 825 jobs Canada-wide over the time frame (relative to SC3 and SC4). Given that the loss of the SRT also seriously affects transit access for a large and relatively less-wealthy portion of Toronto's population, this loss will also be measured in terms of equity, not to mention social and environmental sustainability.

2.4.8 Unfunded Investment in Electric Buses (Scenario SC8)

SC8 shows how a failure to implement necessary investments in electric buses over the coming 10-15-year period will translate into a reduction of the economic impacts previously discussed for SC3 and SC4. Specifically, Table 2.2 shows that a failure to fund the purchase of new electric buses will translate into potential reductions in the gross output and value-added impacts shown above for SC3 and SC4 of $7.98 billion and $2.89 billion respectively. Table 2.2 also shows that this will result in the potential forgoing of more than 42,000 jobs Canada-wide over the time frame.

2.5 Discussion & Conclusions

The economic impact analysis presented above clearly shows that

the TTC has a tremendous economic impact on the City of Toronto, the Province of Ontario and, indeed, Canada

through its operating and capital investment expenditures. These impacts stand to be concentrated in Ontario, Canada's industrial core, which accounts for the majority of all advanced manufacturing and high-end professional/technical services activity in Canada and the associated direct and indirect labour supply. The TTC is clearly a "propulsive firm" playing a critical role in pushing the Greater Toronto Area (GTA), Ontario and Canada forward.

Future research into the potential of TTC investment expenditures (especially those around electrification of the bus and locomotive fleets and associated infrastructures) to spark the creation and expansion of indigenous capacity in the advanced supply chain for electric vehicles and electric transit solutions specifically is highly recommended. It would not be unreasonable, as suggested by contemporary writing in the fields of local and regional economic development and in global production networks/value chains, to see such concentrated activity generate innovation and growth in Canada, likely concentrated in Ontario and the GTA. This would bode well for the economic future of our region and our nation.

3.1 Introduction

This section presents the microeconomic, social and environmental impacts for the City of Toronto and the Greater Toronto-Hamilton Area (GTHA) due to shifts in transit ridership and auto usage resulting from alternative TTC operating and capital investments. Section 3.2 provides a brief overview of the modelling methods used, while Section 3.3 defines the scenarios examined. Section 3.4 then presents the analysis results and Section 3.5 summarizes the main findings.

3.2 Modelling Methods

GTAModel Version 4 is a state-of-the-art activity-based model of travel demand that is used by the City of Toronto and most other transportation planning agencies in the GTHA to forecast travel demand in response to a wide range of policy alternatives.[13] Its primary inputs are the population and employment distributions, along with a detailed specification of the road and transit networks, for the forecast year. Its outputs characterize travel during a typical fall weekday and include:

- Origin-destination trip flows by mode (auto, transit, walking, etc.) by purpose (work, school, shopping, etc.) by time of day.
- Roadway link flows, speeds, level of service and congestion levels by time of day.
- Transit boardings and alightings by stop for every transit line by time of day.
- Transit travel times and crowding levels by transit line by time of day.
- Transit fares paid.

The model is an agent-based microsimulation, in which the travel behaviour of each person and household resident within the GTHA is individually modelled. It thus supports detailed equity analyses, by providing insights into the impacts of policies of various groups of interest, such as low-income households. It can also be linked with an emissions model for the GTHA which predicts GHG and air pollution emissions given the projected vehicle movements in the network.

For this study metrics of interest that are generated for each scenario tested include:

- Travel times by transit users.
- Travel times and vehicle-kilometres-travelled (VKT) by auto users.
- Auto ownership and operating costs (including tolls and parking).
- Social cost of road accidents.
- Transit fare revenues.
- GHG emissions.
- Air pollution emissions.
- Accessibility by transit to employment and other major activities.

Travel times and costs and accessibilities can be computed for different socio-economic groups. In this study these are: low-income households, residents of Neighbourhood Improvement Areas (NIAs), and recent immigrants.

The economic values of travel times, accidents, GHG emissions and pollution-related health outcomes can all be imputed by attaching a dollar value per unit output (shown in Table 3.1), thus allowing an overall economic assessment of the performance of the system in each scenario.

The one exception to this, is accessibility measures which cannot be robustly translated into monetary terms at this time. The "return on investment" for a given scenario can then be estimated by computing the savings (reduced travel times and costs, etc.) generated by the scenario relative to a base case versus the cost of the investment.[14] Daily travel statistics generated by the model are converted to expected annual amounts using the weekday to annual ratio shown in Table 3.1.

Table 3.1: Assumed Rates

Rate	Value	Units
Weekday to Annual Factor	320	Days/year
Value of Time	$15.00	$/hr
Auto Operating Cost	$0.083	$/vkt
Auto accident cost	$0.090	$/vkt
Cost of a new vehicle	$60,000	
Average years new auto owned	10	years
Cost of used vehicle	$30,000	
Average years used vehicle owned	5	years
Proportion new cars purchased per year	0.4	
Cost per tonne of CO_2	$100	$/tonne
Notes 1. The conversion factor approximates the effect of reduced ridership on weekends and holidays relative to weekdays.		

3.3 Scenarios

Four scenarios are examined in this analysis:

1. May, 2023 service (RS). This is a "reduced service" case relative to pre-pandemic full service. It is used as the base case for computing investment benefits.
2. Fall, 2019 service (FS). This scenario is taken as represent "full service" under prepandemic conditions.
3. Line 2 shutdown (L2S). This hypothetical case illustrates the impact of a significant "disinvestment" in the TTC that results in a significant loss of benefits.
4. 2024 Service Plan (SP).

In all cases, 2023 population and employment estimates are used to drive the forecasts. Also note that GTAModel V4 has been calibrated based on 2016 Transportation Tomorrow Survey (TTS) data, and so reflects pre-pandemic travel behaviour (notably work-from-home rates). Thus, it may somewhat over-estimate transit demand, given that it has not yet fully returned to prepandemic levels. This bias, however, is mitigated at least somewhat by the focus on the differences between scenarios, which should tend to "subtract out" systemic biases.

13 *https://tmg.utoronto.ca/doc/1.6/gtamodel/index.html*

14 *Or, in the case of a "disinvestment" (a reduction in spending on transit) the loss in benefits represented by increased travel times, etc.*

3.4 Results

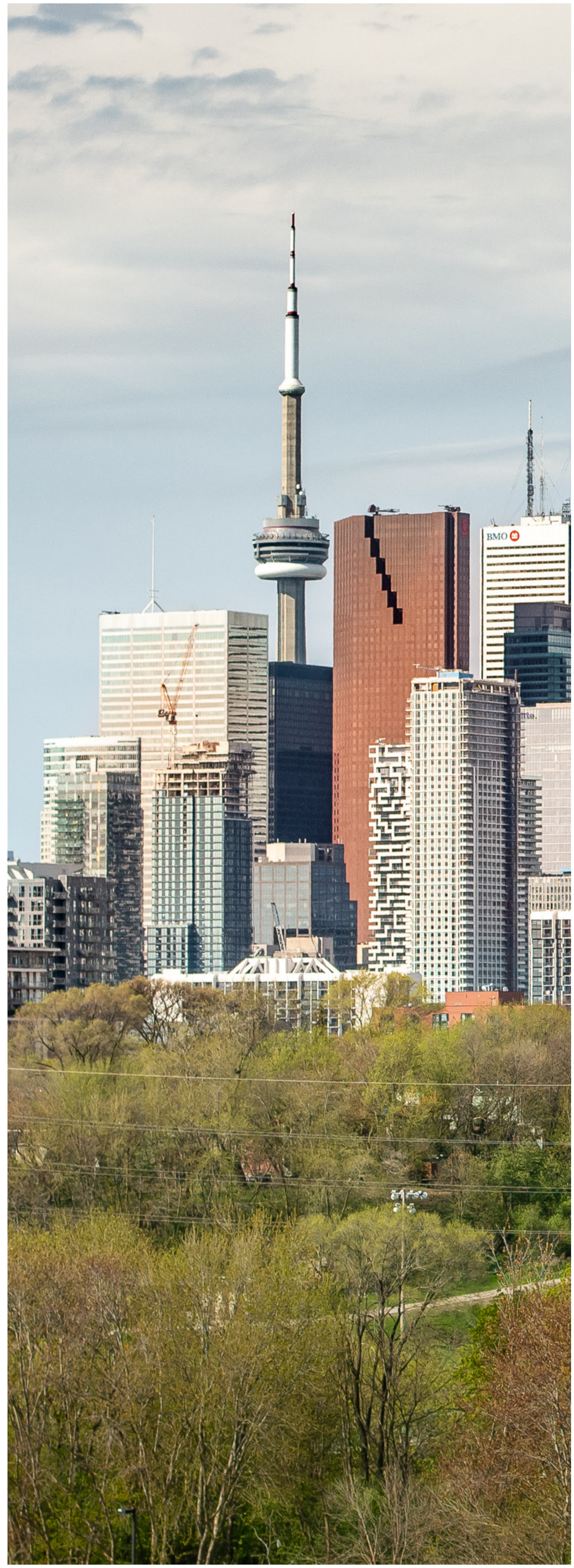
The following sub-sections present daily and (where appropriate) annualized results for each
scenario examined for:
1. Trips by mode.
2. Auto and transit travel times.
3. Auto VKT and auto user costs.
4. Transit fares.
5. Environmental and health impacts.
6. Accessibility metrics.

Sub-section 3.4.7 collates the results from the previous sub-sections to compute overall benefits of each scenario relative to the base 2023 Reduced Service scenario compared to the operating and capital costs associated with the scenario relative to the base.

3.4.1 Trips

Table 3.2 presents the estimated daily and annualized trips by mode for the four scenarios and the differences in modal trips relative to the base 2023 reduced service case. Total daily trips by mode are presented for: (a) all GTHA trips; (b) all trips to/from and within the City of Toronto; and (d) all trips to/from/within Toronto's Neighbourhood Improvement Areas (NIAs). Points to note from this table include:

- Restoring full service results in a GTHA-wide transit ridership increase of 98,000 trips per weekday or 31.36 million trips per year (a 3.73% increase in total ridership) relative to the 2023 reduced service base. The vast majority of this increase occurs within the City of Toronto (95,000 daily, 30.40 million annually; 4.80% increase). Transit trips to/from NIAs also increase significantly (38,000 daily, 12.16 million annually; 5.37% increase).
- This shift to transit largely comes from former auto users (drivers and passengers): 25 million GTHA-wide, 23.4 million of which are trips to/from/within the City of Toronto. Some longer active (walk and bike) trips also shift to transit (18,000 daily, 5.76 million annually).
- Conversely, in the event of a Line 2 shutdown, within-Toronto transit ridership would decline by 55.04 million trips annually (an 8.69% drop) while auto user trips would increase by 44.16 million trips annually.[15] Fully 40% of this reduction in transit usage is for NIA-based trips (22.40 million annually).
- The 2024 Service Plan (SP) results a bit complex to understand. The changes in service between the 2023 RS and the 2024 SP are generally small and dispersed across the TTC network. Critically, however, the 2024 SP scenario includes the shutdown of Line 3 (the "Scarborough RT"). This introduces a significant loss of service in the Line 3 corridor which has not be totally compensated for by additional bus service. The result is that, while in most areas the 2024 SP represents an improvement in service, there are also cases in which service has worsened due to the loss of Line 3. The aggregate results shown in Table 3.2 (and in subsequent tables, below) reflect these "mixed effects), with net transit ridership essentially unchanged from the 2023 RS base, and very marginal changes in other modes' shares. There is, however, a slight decrease in auto-drive trips.



15 *GTHA-wide, the annual transit ridership drip is 600,000 less, reflecting a very slight shift of a few suburban trips to transit, taking advantage of transit line capacity freed up by former Toronto-bound trip-makers shifting to auto.*

Table 3.2: Daily and Annual Trips by Mode

All GTHA Trips	Daily Weekday Trips[4]				Change from 2023 RS Base Case			Annual Change from RS Base Case		
	Scenario				Scenario			Scenario		
Mode	2023 RS	2019 FS	2023 L2S	2024 SP	2019 FS	2023 L2S	2024 SP	2019 FS	2023 L2S	2024 SP
Auto-Drive	8,378,000	8,329,000	8,456,000	8,377,000	-49,000	78,000	-1,000	-15,680,000	24,960,000	-320,000
Auto-Passenger[1]	2,955,000	2,926,000	3,015,000	2,958,000	-29,000	60,000	3,000	-9,280,000	19,200,000	960,000
Transit[2]	2,624,000	2,722,000	2,454,000	2,624,000	98,000	-170,000	0	31,360,000	-54,400,000	0
Active[3]	1,773,000	1,755,000	1,802,000	1,802,000	-18,000	29,000	-1,000	-5,760,000	9,280,000	-320,000
Total	15,730,000	15,732,000	15,727,000	15,731,000	2,000	-3,000	1,000	640,000	-960,000	320,000
	Daily Weekday Trips				Change from 2023 RS Base Case			Percent Change in Modal Trips		
	Scenario				Scenario			Scenario		
Mode	2023 RS	2019 FS	2023 L2S	2024 SP	2019 FS	2023 L2S	2024 SP	2019 FS	2023 L2S	2024 SP
Auto-Drive	53.3%	52.9%	53.8%	53.3%	-0.3%	0.5%	0.0%	-0.58%	0.93%	-0.01%
Auto-Passenger[1]	18.8%	18.6%	19.2%	18.8%	-0.2%	0.4%	0.0%	-0.98%	2.03%	0.10%
Transit[2]	16.7%	17.3%	15.6%	16.7%	0.6%	-1.1%	0.0%	3.73%	-6.48%	0.00%
Active[3]	11.3%	11.2%	11.5%	11.3%	-0.1%	0.2%	0.0%	-1.02%	1.64%	-0.06%
All Toronto Trips	Daily Weekday Trips				Change from 2023 RS Base Case			Annual Change from RS Base Case		
	Scenario				Scenario			Scenario		
Mode	2023 RS	2019 FS	2023 L2S	2024 SP	2019 FS	2023 L23	2024 SP	2019 FS	2023 L2S	2024 SP
Auto-Drive	3,446,000	3,403,000	3,523,000	3,446,000	-43,000	77,000	0	-13,760,000	24,640,000	0
Auto-Passenger[1]	1,209,000	1,179,000	1,270,000	1,210,000	-30,000	61,000	1,000	-9,600,000	19,520,000	320,000
Transit[2]	1,979,000	2,074,000	1,807,000	1,979,000	95,000	-172,000	0	30,400,000	-55,040,000	0
Active[3]	916,000	897,000	945,000	915,000	-19,000	29,000	-1,000	-6,080,000	9,280,000	-320,000
Total	7,550,000	7,553,000	7,545,000	7,550,000	3,000	-5,000	0	960,000	-1,600,000	0
	Daily Mode Shares				Change from 2023 RS Base Case			Percent Change Modal Trips		
	Scenario				Scenario			Scenario		
Mode	2023 RS	2019 FS	2023 L2S	2024 SP	2019 FS	2023 L23	2024 SP	2019 FS	2023 L2S	2024 SP
Auto-Drive	45.6%	45.1%	46.7%	45.6%	-0.6%	1.1%	0.0%	-1.25%	2.23%	0.00%
Auto-Passenger[1]	16.0%	15.6%	16.8%	16.0%	-0.4%	0.8%	0.0%	-2.48%	5.05%	0.08%
Transit[2]	26.2%	27.5%	23.9%	26.2%	1.2%	-2.3%	0.0%	4.80%	-8.69%	0.00%
Active[3]	12.1%	11.9%	12.5%	12.1%	-0.3%	0.4%	0.0%	-2.07%	3.17%	-0.11%
NIA Trips	Daily Weekday Trips[4]				Change from 2023 RS Base Case			Annual Change from RS Base Case		
	Scenario				Scenario			Scenario		
Mode	2023 RS	2019 FS	2023 L2S	2024 SP	2019 FS	2023 L23	2024 SP	2019 FS	2023 L2S	2024 SP
Auto-Drive	1,459,000	1,443,000	1,493,000	1,460,000	-16,000	34,000	1,000	-5,120,000	10,880,000	320,000
Auto-Passenger[1]	538,000	524,000	564,000	539,000	-14,000	26,000	1,000	-4,480,000	8,320,000	320,000
Transit[2]	707,000	745,000	637,000	704,000	38,000	-70,000	-3,000	12,160,000	-22,400,000	-960,000
Active[3]	277,000	270,000	285,000	277,000	-7,000	8,000	0	-2,240,000	2,560,000	0
Total	2,981,000	2,982,000	2,979,000	2,980,000	1,000	-2,000	-1,000	320,000	-640,000	-320,000
	Daily Mode Shares				Change from 2023 RS Base Case			Percent Change in Modal Trips		
	Scenario				Scenario			Scenario		
Mode	2023 RS	2019 FS	2023 L2S	2024 SP	2019 FS	2023 L23	2024 SP	2019 FS	2023 L2S	2024 SP
Auto-Drive	48.9%	48.4%	50.1%	49.0%	-0.6%	1.2%	0.0%	-1.10%	2.33%	0.07%
Auto-Passenger[1]	18.0%	17.6%	18.9%	18.1%	-0.5%	0.9%	0.0%	-2.60%	4.83%	0.19%
Transit[2]	23.7%	25.0%	21.4%	23.6%	1.3%	-2.3%	-0.1%	5.37%	-9.90%	-0.42%
Active[3]	9.3%	9.1%	9.6%	9.3%	-0.2%	0.3%	0.0%	-2.53%	2.89%	0.00%

Notes:
1. Includes intra-household ridesharing, inter-household carpooling, taxi, Private Transportation Company (PTC) (Uber/Lyft) and schoolbus trips.
2. Includes trips by all transit modes to/from City of Toronto zones.
3. Walk-allway and bicycle trips.

3.4.2 Travel Time Savings

Travel time savings represent a major economic benefit of transportation investments, since time has economic value. Travel time reductions due to infrastructure and/or service improvements represent a "consumer surplus" in that people can engage in a given set of activities (from which they derive benefit) at lower "cost", in this case expressed in the time spent travelling. This time spent travelling can be converted into monetary terms by assuming a "value of time". In this study, as indicated in Table 3.1, $15/hour is assumed as a representative, relatively conservative value to use. Investment in transit reduces average transit travel times. But, to the extent that improved transit service attracts former auto users to switch to transit and thereby reducing roadway congestion, it also results in travel time savings for auto users

Hence both transit and auto users benefit from transit improvements, since both experience reduced travel times.

This is illustrated in Figure 3.1, which plots the frequency distribution of travel times for transit users and auto drivers for the FS, RS and L2S scenarios. It is seen that as service improves from the RS to the FS case, more trips occur at shorter travel times for both modes, while the decrease in service represented by the L2S scenario lengthens travel times on average relative to both of the other two scenarios. This benefit that accrues to auto users due to transit improvements is too often neglected in the debate concerning the value of transit investments. Table 3.3 presents average daily travel time savings (expressed in hours) for transit and autouser[16] modes for the RFS, L2S and SP scenarios relative to the RS base. The formula for computing consumer surplus when comparing two scenarios when the demand level changes between scenarios is given by:

$CS_{12} = (P_1 - P_2)(X_1 + X_2)/2$ [3.1]
$P_i = Avg.Travel\ Time_i\ (VoT/60)$ [3.2]

Where P_1 and X_1 are the cost of the travel time and the volume of trips in the base case and P_2 and X_2 are the post-investment values. Using these formulae, daily and annualized consumer surplus (benefits) dues to transit and auto travel time savings of each scenario relative to base 2023 reduced service case. Note that in the case of the Line 2 shutdown, this is a disinvestment and so the "benefit" is negative.

16 Includes both auto-drivers and auto-passengers. While analysis often focuses on derivers, auto passengers experience the same impacts of roadway congestion as drivers do.

Figure 3.1: Transit & Auto Travel Time Distributions for the FS, RS, & L2S Scenarios

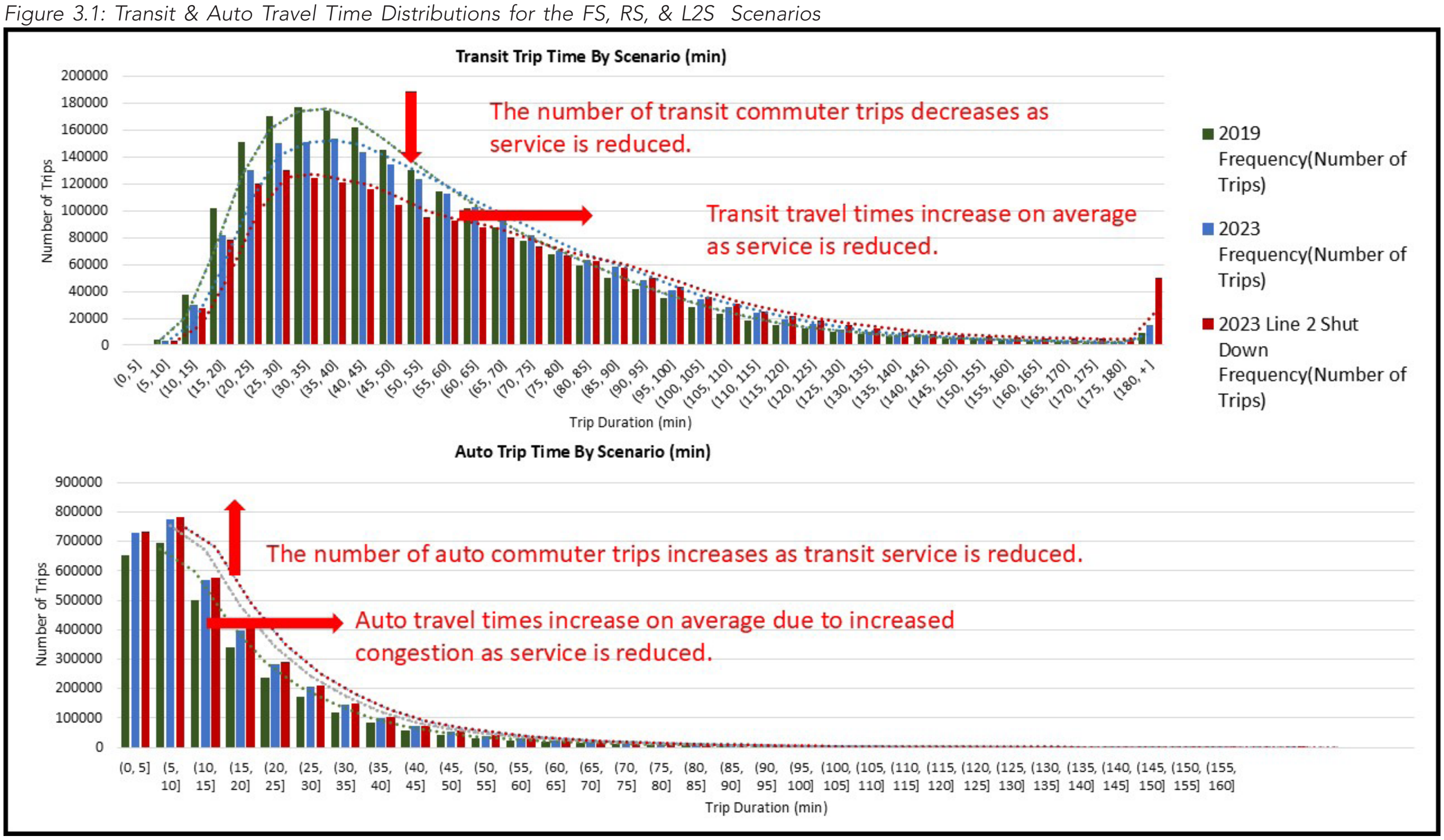


Table 3.3: Transit and Auto Travel Time Savings & Economic Benefits

	Transit Travel Time Savings (+)			Auto Travel Time Savings (+)		
All GTHA Trips	2019 FS	2023 L2S	2024 SP	2019 FS	2023 L2S	2024 SP
Daily Travel Time Savings (hr)	91,000	-353,000	0	5,000	-4,000	0
Daily Travel Time Saviings ($)	1,365,000	-5,295,000	0	75,000	-60,000	0
Annual Travel Time Savings ($)	436,800,000	-1,694,400,000	0	24,000,000	-19,200,000	0
	Transit Travel Time Savings (+)			Auto Travel Time Savings (+)		
To/From/Within Toronto	2019 FS	2023 L2S	2024 SP	2019 FS	2023 L2S	2024 SP
Daily Travel Time Savings (hr)	88,000	-357,000	0	3,000	-5,000	0
Daily Travel Time Savings ($)	1,320,000	-5,355,000	0	45,000	-75,000	0
Annual Travel Time Savings ($)	422,400,000	-1,713,600,000	0	14,400,000	-24,000,000	0
	Transit Travel Time Savings (+)			Auto Travel Time Savings (+)		
To/From/Within NIAs	2019 FS	2023 L2S	2024 SP	2019 FS	2023 L2S	2024 SP
Daily Travel Time Savings (hr)	17,000	-124,000	2,000	1,000	-2,000	0
Daily Travel Time Savings ($)	255,000	-1,860,000	30,000	15,000	-30,000	0
Annual Travel Time Savings ($)	81,600,00	-595,200,000	9,600,000	4,800,000	-9,600,000	0

Points to note from this table include:

- Restoring full service results in very significant daily and annual travel time savings for both transit and auto users. While the transit user benefits account for the majority of total travel time savings, the benefits to auto users are also quite significant.
- Conversely, the shutdown of Line 2 would result in significant increases both transit and auto travel times, with associated losses in economic benefits.
- Given no aggregate net change in transit ridership for the 2024 SP scenario, both transit and auto travel savings are insignificantly different from zero. This presumably reflets the negative impact of the Line 3 shutdown which negates marginal benefits achieved by service improvements elsewhere in the system. There is, however, a slight travel time savings for NIA neighbourhoods, presumably since they are less dependent on the former Line 3 and they benefit to some degree from service improvements in the 2024 service plan, relative to the reduced service base case.

3.4.3 Additional Auto-Related Benefits

When auto-drivers switch to transit (or any other non-auto travel mode), they incur savings in auto operating and ownership costs, and society as whole experiences reduced costs due to fewer road accidents. Auto operating costs include the average per-kilometre cost of operating the car (assumed to be 0.083 $/km, see Table 3.1), and any road toll and/or parking payment charges, both of which are computed within GTAModel. Based on Metrolinx practice, an average cost of 0.090 $/km is assumed for the societal cost of road accidents (see Table 3.1). GTAModel predicts the number of automobiles owned/leased by every household in the GTHA. Improved transit services will encourage households to reduce their auto ownership levels, thereby saving the very significant amount spent annually on owning and maintaining these vehicles. To estimate the amount of these savings, as per Table 3.1, it is assumed that an average new car costs $60,000 and is used for an average of 10 years, an average used car costs $30,000 and is used for 5 years, and that 40% of all cars purchased are new.[17] Hence, each car (whether new or used) not purchased due to improved transit service results in an average annual saving for the household of $6,000.

17 *Based o data for 2023 provided by AutoTrader Canada.*

Table 3.4: Additional Auto-Related Benefits

	Totals				Savings (+) From 2019 RS Base Case		
All GTHA	2023 RS	2019 FS	2023 L2S	2024 SP	2019 FS	2023 L2S	2024 SP
Daily VKT[1]	135,500,000	134,900,000	136,200,000	135,500,00	600,000	-700,000	0
Daily Operating Cost	$11,246,500	$11,196,700	$11,304,600	$11,246,500	$49,800	-$58,100	$0
Daily Parking Cost	$13,852,100	$13,537,000	$14,199,100	$13,825,500	$315,100	-$347,000	$26,600
Total Daily Auto User Costs	$25,098,600	$24,733,700	$25,503,700	$25,072,000	$364,900	-$405,100	$26,600
No. of household vehicles	4,115,700	4,101,300	4,135,300	4,115,700	14,400	-19,600	0
Annual Auto Ownership Cost	$24,694,200,000	$24,607,800,000	$24,811,800,000	$24,694,200,000	$86,400,000	-$117,600,000	$0
Annual Auto Costs, Total	$32,725,752,000	$32,522,584,000	$32,972,984,000	$32,717,240,000	$203,168,000	-$247,232,000	$8,512,000
Daily Accident Cost	$12,195,000	$12,141,000	$12,258,000	$12,195,000	$54,000	-$63,000	$0
Annual Accident Cost	$3,902,400,000	$3,885,120,000	$3,922,560,000	$3,902,400,000	$17.280,000	-$20,160,000	$0

Given these assumptions, Table 3.4 presents the additional, non-travel-time related GTHA auto user costs for the four scenarios and the associated savings for the FS, L2S and SP scenarios relative to the RS base case. Points to note from the table include:

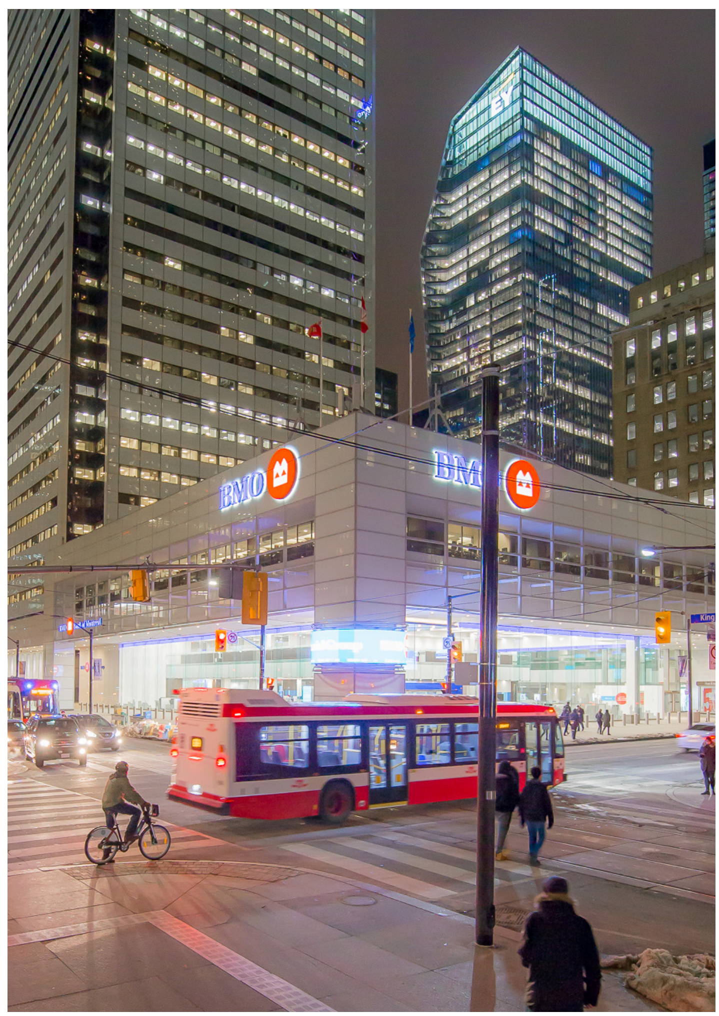
- **The total annual auto usage and ownership cost savings due to a return to full service are very large ($211.8 million).** Combined with the annual auto travel time savings from Table 3.3 ($45.4 million), they actually marginally exceed transit users' travel time savings benefits ($256 million vs. $248 million). These very large cost savings, however, are rarely, if ever considered when discussing transit investment impacts.
- Conversely, a Line 2 shutdown would have an even larger negative impact on auto users due to the increased congestion, auto operating, parking and ownership costs involved.
- While the change in both total VKT and auto ownership levels for the 2024 SP relative to the 2023 SP is essentially nil, shifts in the spatial-temporal distribution of auto trips is such that a small reduction in overall auto user costs is achieved with this scenario.

3.4.4 Transit Fare Revenues

Increased revenues from increased transit ridership are obviously a benefit to the TTC (the operator). These revenues, however, are a cost to the new riders (users). Thus, from a societal point of view, the operator benefit is cancelled by the user cost. Thus, transit revenues are excluded from the calculation of net economic benefits in this study.

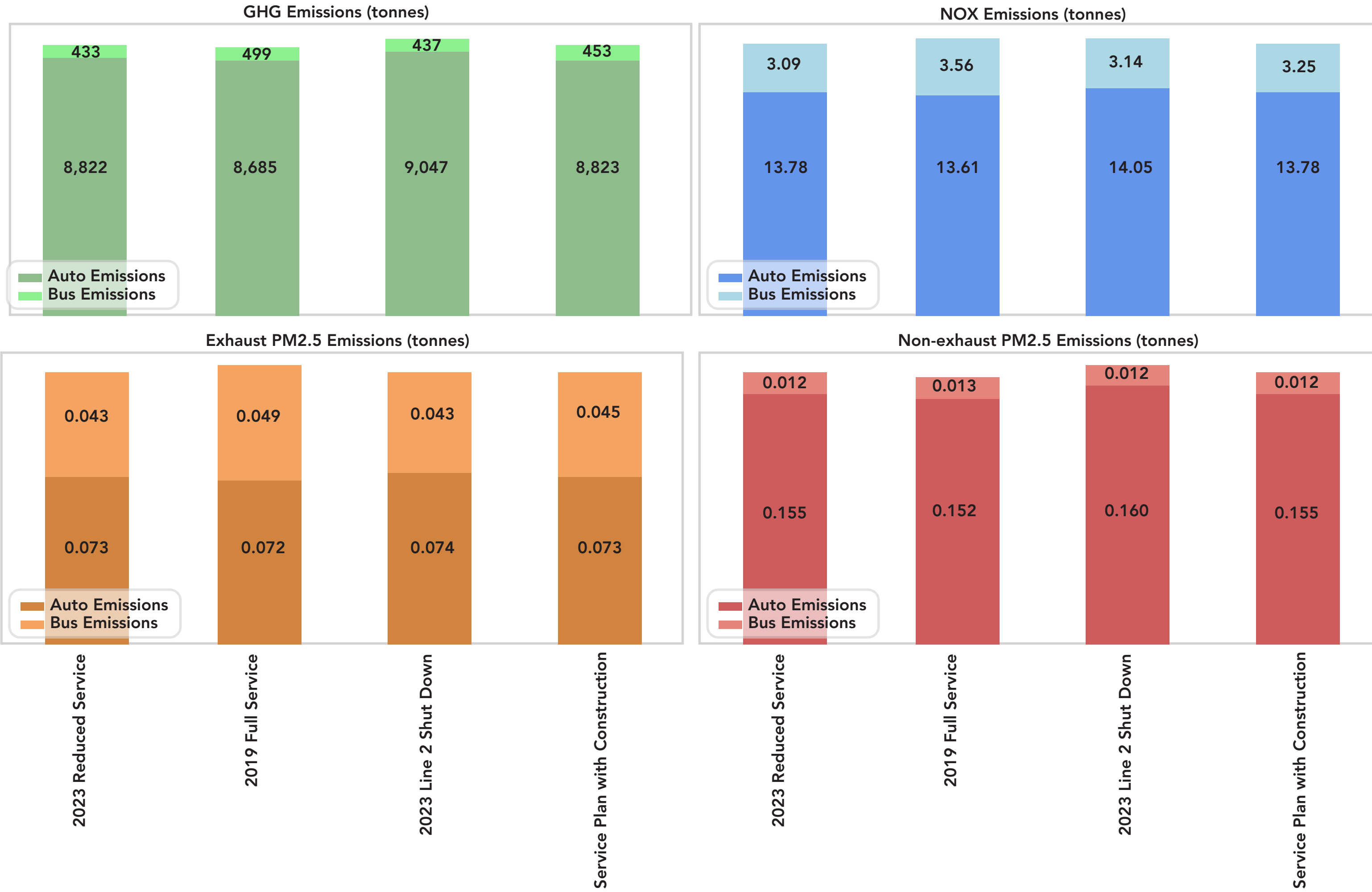
3.4.5 Environmental & Health Benefits

Emissions were estimated by combining vehicle movement information extracted from the GTAModel with emission factors from the EPA Motor Vehicles Emission Simulator (MOVES)[18]. The emission factors were generated based on the local fleet composition. We computed the daily transportation-related (road and transit) GHG and air pollution emissions with major health impacts (notably nitrogen dioxide (NO2) and fine particulate matter (PM2.5)) for each scenario. We assume emissions from other transit modes (light rail, passenger train, and streetcar) are negligible. The transit bus fleet composition was obtained from the Toronto Transit Commission (TTC), consisting of 65% diesel, 32% hybrid diesel, and 3% battery electric buses. The daily GHG and air pollutant emissions for the City of Toronto are summarized in Figure 3.2.



18 https://www.epa.gov/moves

Figure 3.2: Daily GHG, NOx, and PM2.5 emissions for the city of Toronto under each scenario.



We constructed a scenario with 2019 Full Service and 100% bus electrification, in which we assume GHG, NOx, and exhaust PM2.5 emissions are zero. The daily GHG emissions for the City of Toronto are summarized in Figures 3.3 and the difference in emissions compared against the 2023 Reduced Service scenario in Figure 3.4. To annualize emissions in the final table, we multiply by 320 days to discount weekends and holidays.

The carbon cost reduction was calculated using the social cost of carbon, which designates the economic cost caused by an additional tonne of carbon dioxide emissions.[19] We calculated the cost of each tonne of CO2eq reduced or increased from the base case scenario (2023 Reduced Service) assuming a social cost of carbon of $100 CAD. Estimates for the social cost of carbon vary depending on geography, warming scenarios, and policies to address climate change.Barrage and Nordhaus (2024) estimate approximately $94 CAD/tonne CO2 for the 2020 period (in 2019 $)20. In 2024, the government of Canada set a price of $252/ tonne CO2[21].

The air pollution emissions are next inputs into a chemical transport model (CTM) which simulates air pollutant concentrations by considering different mechanisms affecting air emissions including atmospheric chemical reactions, long-range transport, and deposition. The CTM, Polair3D version 1.11.1, was used, which is part of a series of air quality models integrated within the Polyphemus air quality modeling platform[22]. The model set up consisted of three nested domains centered around the GTHA, with spatial resolutions of 12 km2, 4 km2, and 1 km2 (Figure 3.5). Each scenario (including the base case) was run for one week (as well as a one-week spin-up) in August 2016 (August 14 - August 20).

19 Nordhaus, WD (2017). Revisiting the social cost of carbon, Proc. Natl. Acad. Sci. U.S.A. 114 (7) 1518-1523, https://doi.org/10.1073/pnas.1609244114

20 Barrage, L and Nordhaus, W (2024). Policies, projections, and the social cost of carbon: Results from the DICE-2023 model, Proc. Natl. Acad. Sci. U.S.A. 121 (13) e2312030121, https://doi.org/10.1073/pnas.2312030121.

21 https://www.canada.ca/en/environment-climate-change/services/climate-change/science-research-data/social-costghg.html#toc8

22 Mallet, V.; Quélo, D.; Sportisse, B.; Ahmed de Biasi, M.; Debry, E.; Korsakissok, I.; Wu, L.; Roustan, Y.;Sartelet, K.; Tombette, M. The Air Quality Modeling System Polyphemus. Atmos Chem Phys2007, 7 (20), 5479–5487.

Figure 3.3: Daily GHG emissions (bus and auto) for the City of Toronto.

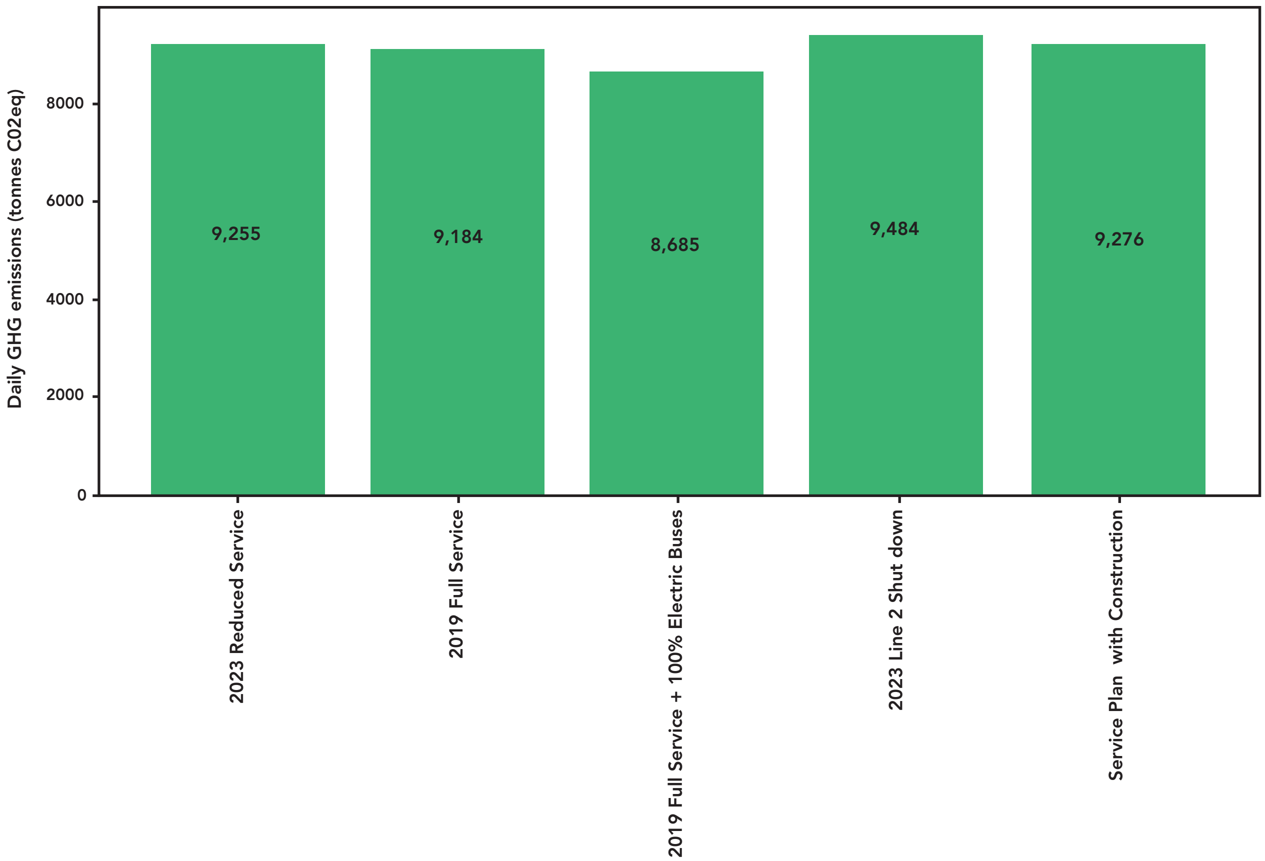


Figure 3.4: Difference in tonnes daily GHG emissions (bus and auto) from the 2023 Reduced Service Scenario.

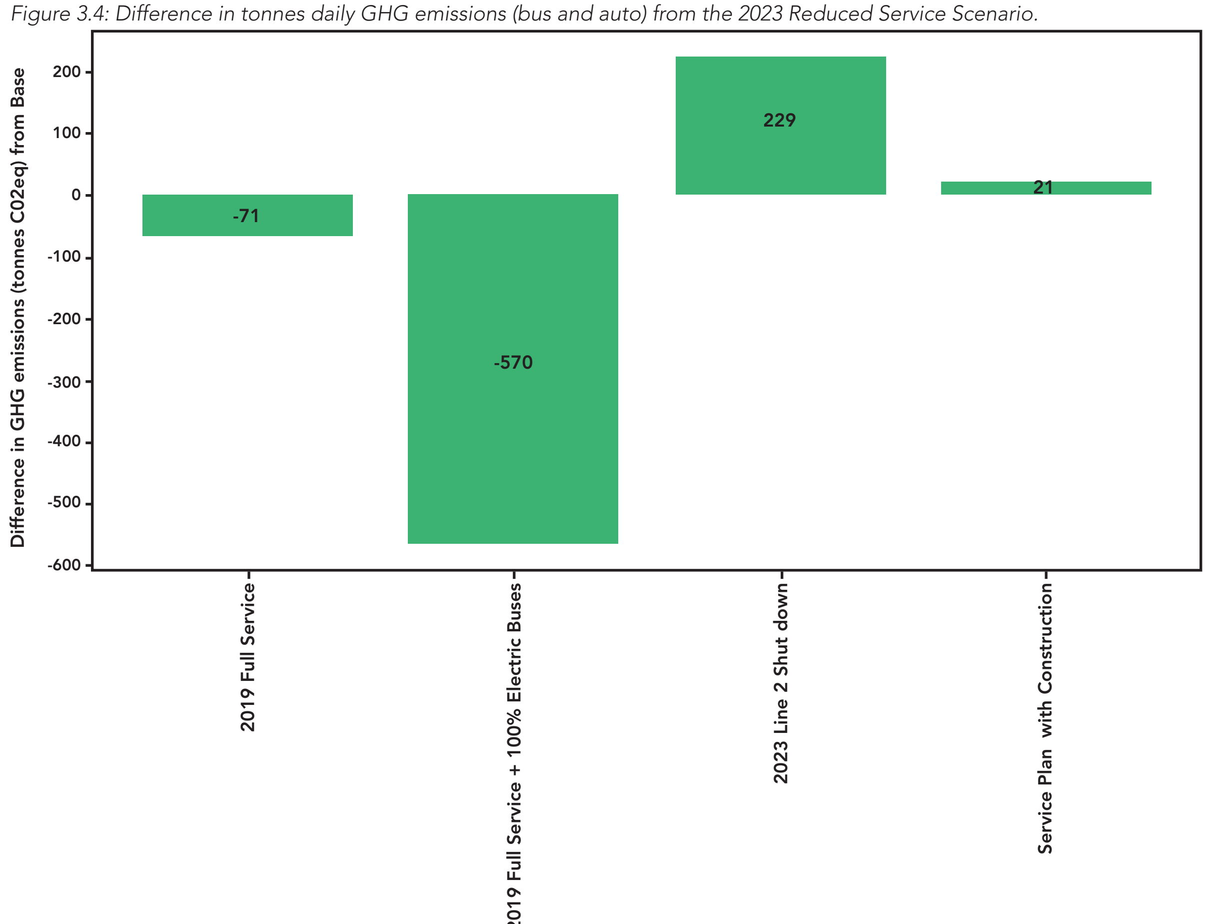
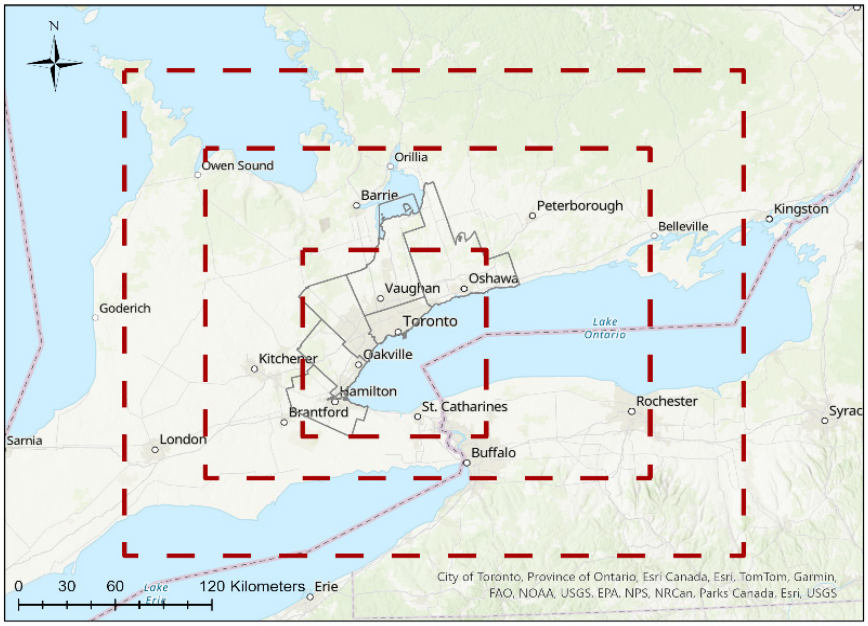


Figure 3.5 Study Domains



Using population data in Dissemination Areas (DAs) and concentration-response (C-R) functions specific to Canadian and local conditions, population exposures to main air pollutants (including NO_2, $PM_{2.5}$, and Ozone (O_3)) under different scenarios were used to quantify the impacts of the considered transit bus scenarios along various health outcomes. Figure 3.6 captures a summary of the methodology.

With the application of CTM outputs (estimated at the DA level) and socioeconomic characteristics of residents, a spatial analysis was performed to illustrate the disparities in air pollution exposures across the GTHA. The four Ontario Marginalization (On-Marg) indices were used to express inequalities from the socioeconomic and ethnocultural perspectives (material deprivation, residential instability, dependency, and ethnic concentration)[23].

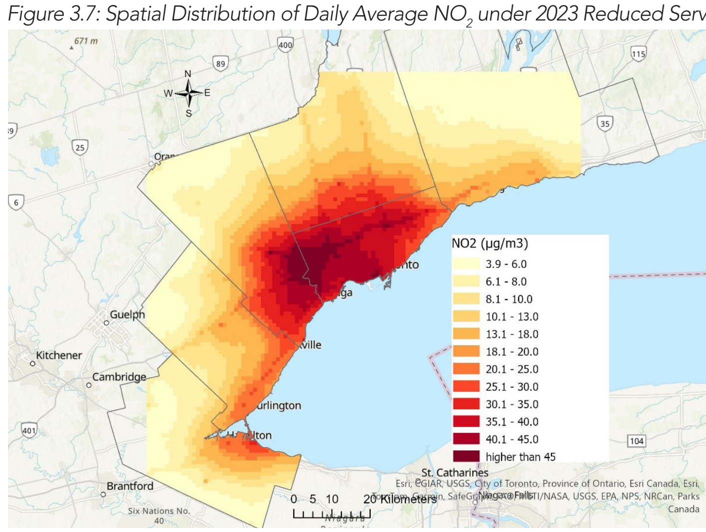
The health impacts associated with air pollution changes in each scenario were estimated based on C-R functions derived from epidemiological studies (mostly from the Canadian Census Health and Environment Cohort (CanCHEC)). Each function relates a change in the concentration of a pollutant to a change in the incidence of risk of death or disease. This analysis was conducted via Health Canada's Air Quality Benefits Assessment (AQBAT) tool[24] as the modeled air pollutant concentrations were taken as inputs to link air pollution exposure with health outcomes. AQBAT estimates the number of premature deaths and other health outcomes in Canada associated with a specified change in air pollutant concentration, in this case, the change occurs under each considered scenario. In this application, we only reported the health outcomes associated with changes in concentrations of $PM_{2.5}$ (daily average, chronic exposure).

The spatial distribution of daily NO_2 concentrations for the 2023 RS case is shown by Figure 3.7. For traffic sources, NO2 is primarily an indicator of diesel fueled vehicles. Residents living near major highways, the industrial centers in Mississauga and Brampton, and the east end of the Toronto central area are exposed to higher levels of NO_2.

Figure 3.8 displays the change in PM2.5 exposure relative to the RS base case for the "most deprived" and "least deprived" Toronto residents, as defined by the Ontario Marginalization Index for "Material Deprivation". A fourth scenario is included in Figure 3.6 (part b), which is the 2019 FS scenario with 100% of the bus fleet replaced with electric buses (2019 FS + 100% EB). A similar trend was observed when considering other indices of Ontario Marginalization such as residential instability and ethnic concentration.

The "Most Deprived" group is seen to receive the greatest benefit from service improvements, as well as experience the greatest disbenefit from the L2S service cut.

Figure 3.7: Spatial Distribution of Daily Average NO_2 under 2023 Reduced Service



23 Matheson, F. I.; Van Ingen, T. Ontario Marginalization Index: User Guide. In Ontario Agency for Health Protection and Promotion; Public Health Ontario, 2016; Vol. 2018, p 23.

24 Judek, S.; Stieb, D.; Jovic, B.; Edwards, B. Air Quality Benefits Assessment Tool (AQBAT) User Guide 3.0;Health Canada, 2021.

Figure 3.6: Integrated Modeling Framework

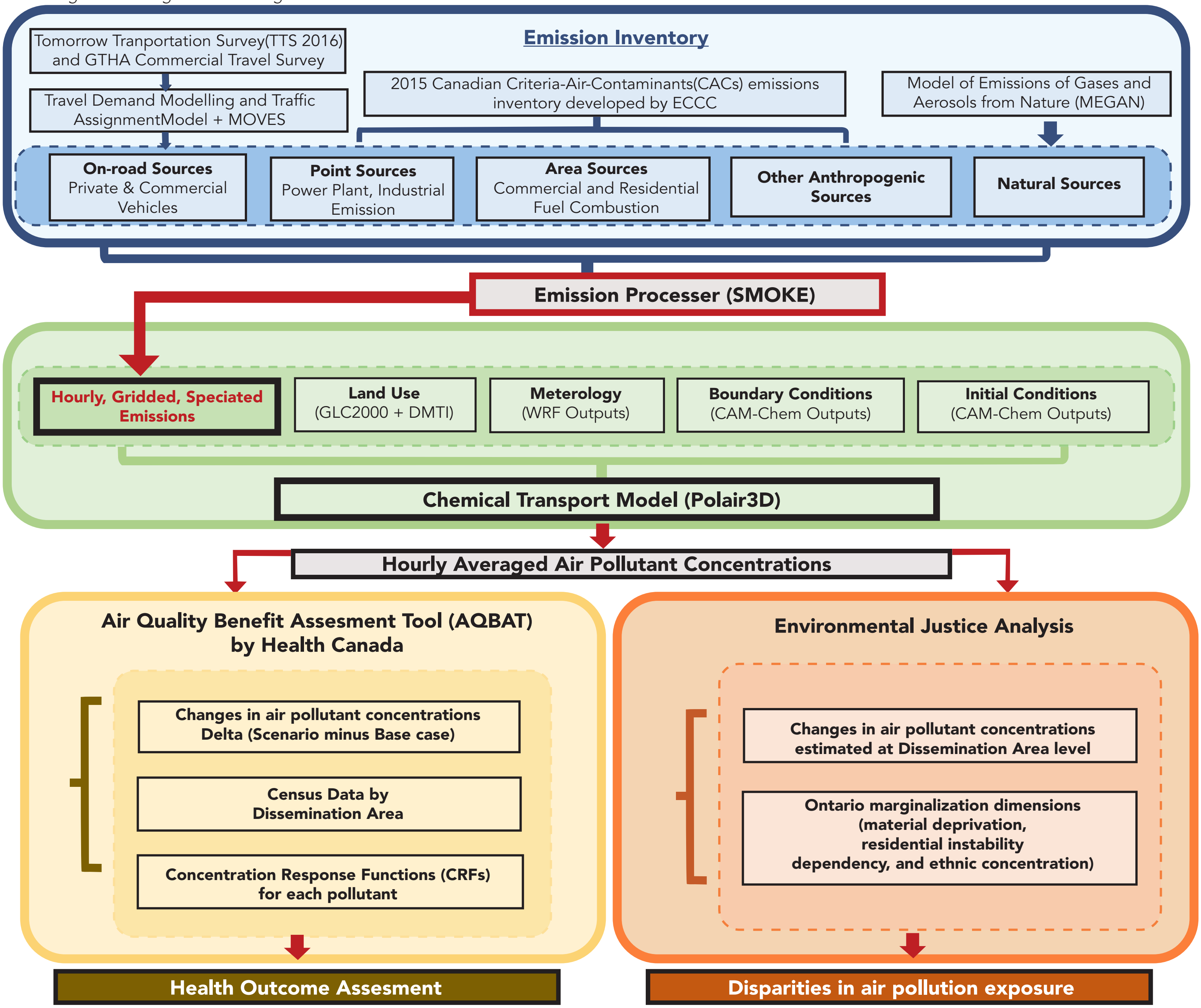
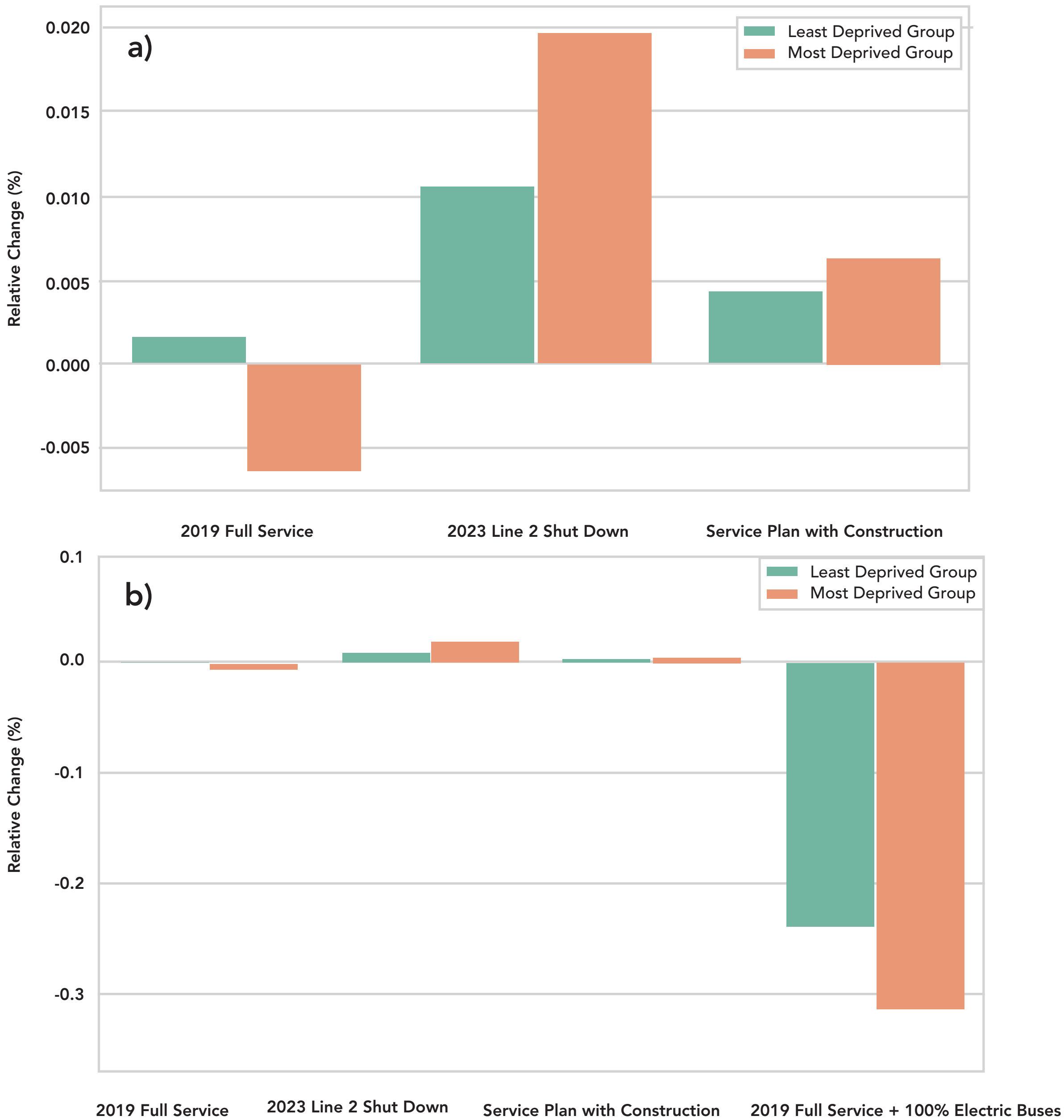


Figure 3.8: Air Pollution Impacts (Median Relative Change in PM2.5 Concentration wiht respect to 2023 Reduced Service) of Transit Service Scenarios



Investing in bus electrification reduces annual health and mortality costs by $253 million

Table 3.5: GHG Reduction & Health Improvement Benefit

	Scenario (Improvement/Reduction +)			
Impact Metric	2019 FS	2019 FS + EB	2023 L2S	2024 SP
GHG reduction (+) (tonnes/year)	22,700	182,400	-73,300	-6,700
Carbon cost reduction/year	$2,270,000	$18,240,000	-$7,330,000	-$670,000
Reduced deaths annually	1	25	-3	-1
Reduced adult chronic bronchitis annually	1	27	-4	-1
Reduced acute childhood bronchitis annually	3	124	-14	-3
Annual health & morality cost reduction (+)	$7,400,000	$253,300,000	-$32,500,000	-$6,300,000

Table 3.5 summarizes the annual transportation GHG and health cost reductions for the three scenarios relative to the RS base case. The fourth scenario is included, which is the 2019 FS scenario with 100% of the bus fleet replaced with electric buses (2019 FS + EB).

Points to note from this table include:

- As usual, a return to full service results in positive benefits (GHG emission reductions and improvement in health impacts), while a Line 2 shutdown would generate quite significant disbenefits.
- The 2024 SP scenario generates a very slight increase in GHG emissions and adverse health impacts. This presumably reflects the negative impacts of the Line 3 shutdown.
- **The positive impact of electrifying the TTC bus fleet is very dramatic.** While transit ridership does not change (relative to the 2019 FS scenario), this change in fleet technology results in a huge reduction in both GHG and air pollution emissions by the TTC and significant health benefits.

3.4.6 Social Benefits

A significant advantage of a disaggregate, agent-based microsimulation model of travel demand such as GTAModel V4 is that trip-making (and other model outputs) are computed for each person and household resident within the study area. Thus, it is possible to look at the impact of any given scenario or policy on individuals belonging to sub-groups of policy interest, as well as for any type of trip/activity and/or spatial aggregation. Three such groups within the City of Toronto considered in this study are low-income households[25], recent immigrant households,[26] and residents within Toronto's NIAs.[27]

To this point in the analysis, aggregate, population-wide impacts of varying transit service levels have been investigated, such as travel time saving, auto user cost savings, etc. Another approach to assessing impacts is to look at the changes which transit service improvements have on the accessibility that various residents have to important activities and services. Accessibility is defined as the potential to interact to fulfil our daily activity needs.[28] Accessibility is a function of availability of points of interaction (e.g., the number and spatial distribution of stores at which one might be able to shop), mediated by how easy it is to travel to these points in order to interact (e.g., travel times to these stores). Numerous accessibility metrics exist.[29] In this study, a cumulative opportunities measure is used, consisting of the total number of interaction points of interest (stores jobs, schools, etc.) that are within a given threshold travel time, in this case, the zone-to-zone travel time, given a household's residential zone. I.e.:

$$A_i^p = \Sigma_{jEDi} N_j^p$$

A_i^p = The accessibility of a household living in zone i to activities of type p
D_i = The set of zones that can be reached within τ^p minutes travel time by transit from zone i.
N_j^p= The number of establishments of type p located in zone j

As shown in Table 3.6, six activity types are considered in this study. Table 3.6 also defines the transit travel time thresholds for the calculation of each zone's accessibility to a given activity type.

Table 3.6: Accessibility Thresholds by Activity Type

	Accessibility Threshold
Activity Type	(min. travel time)
Jobs	45
High Schools	15
Doctor Offices	30
Hospitals	30
Grocery Stores	15
Attractions	30

Average accessibilities for each activity type for each of the four scenarios were computed for all Toronto residents, the sub-set of residents of the NIAs, low-income households and recentimmigrant households. The changes in accessibility for each of the FP, L2S and SP scenarios relative to the RS base were then computed and are displayed in Tale 3.7 for these four household groups.

Points to note from Table 3.7 include:

- As expected, **the return to full service improves accessibility significantly (generally double-digit percentage increases) across all activity categories and household types.**
- Similarly, a Line 2 shutdown would significantly reduce accessibility across the board.
- The 2024 SP scenario, again, has modest and mixed impacts, with some accessibilities increasing slightly and some decreasing margi0nally. As with other impacts examined, this likely reflects the effects of the Line 3 shutdown, as well as, possibly, lack of focus with respect to the service change impacts on various elements of the trip-making population.

Unlike the other metrics constructed in this study, these accessibility changes have not been monetized. While accessibility can be (at lease loosely) interpreted as a consumer surplus (i.e., a benefit that residents receive from the existence of the transit system), no standard method currently exists for converting the accessibility measure used in this study into monetary terms. Thus, while a very important metric for assessing the impact of transit service changes on sub-populations of policy interest, it is not included in the economic benefit/cost calculations in the next sub-section.

25 *Where "low income" is defined by the "Low-Income Cut-off" (LICO) method, see https://www.justice.gc.ca/eng/rp-pr/csj-sjc/jsp-sjp/rr03_la5-rr03_aj5/p3.html#:~:text=The%20LICO%20measure%20distinguishes%20between,be%20living%20in%20straitened%20circumstances.*

26 *Defined as households identified in the 2021 Census who have immigrated to Canada during the past five years.*

27 *Another possible group of policy interest is "visible minorities". In a preliminary analysis, however, it was found that "visible minorities", as an overall group, are so prevalent and (relatively) ubiquitously distributed with the city, that the results did not differ much from the all-residents results. While a more detailed parsing of different subgroups within the catch-all "visible minorities" would be possible, it was felt, for the purposes of this study, that income, recent immigration, and NIA residency would be more informative categorizations to investigate.*

28 *Handy, S.L .and D.A. Niemeier (1997) "Measuring accessibility: An exploration of issues and alternatives", Environmental Planning A, 29:7, 1175-1184. Páez, A., D.M. Scott and C. Morency (2012) "Measuring accessibility: positive and normative implementations of various accessibility indicators", Journal of Transport Geography, 25, 141-153.*

29 *Miller, E.J. (2020) Measuring Accessibility: Methods & Issues, International Transport Forum Discussion Paper 2020/25, Paris: OECD Publishing*

Table 3.7: Percent Change in Accessibility by Activity Type & Scenario

	Change in Access Relative to 2023 RS Base (Improvement +)					
	All Toronto Residents			All NIA Residents		
Access to:	2019 FS	2023 L2S	2024 SP	2019 FS	2023 L2S	2024 SP
Jobs	10%	-17%	0%	15%	-16%	-3%
High Schools	31%	-9%	-1%	19%	-13%	2%
Doctor Offices	14%	-14%	1%	11%	-7%	-5%
Hospitals	12%	-5%	-3%	3%	-1%	-4%
Grocery Stores	12%	-5%	-3%	30%	-2%	-8%
Attractions	11%	-15%	1%	20%	-21%	-21%
	Change in Access Relative to 2023 RS Base (Improvement +)					
	Low-Income Households			Recent Immigrants		
Access to:	2019 FS	2023 L2S	2024 SP	2019 FS	2023 L2S	2024 SP
Jobs	10%	-17%	0%	7%	-11%	0%
High Schools	31%	-9%	-2%	41%	-9%	-2%
Doctor Offices	14%	-14%	1%	12%	-10%	1%
Hospitals	12%	-5%	-3%	6%	-2%	-3%
Grocery Stores	12%	-5%	-3%	6%	-2%	-3%
Attractions	11%	-15%	1%	4%	-9%	0%

Table 3.8: Transit Investment Benefit-Cost Calculations

	Scenario	
Annual Benefits Relative to 2023 RS Base	2019 FS	2023 L2S
Transit travel time savings	$436,800,000	-$1,694,400,000
Auto travel time savings	$24,000,00	-$19,200,000
Auto operating & ownership cost savings[1]	$203,168,000	-$247,232,000
Road accident reductions	$17,280,000	-$20,160,000
Transit revenue increases	$0	$0
GHG reductions	$2,270,000	-$7,330,000
Health outcome improvements	$7,400,000	-$32,500,000
Total ridership-related benefits (+)	$690,918,000	-$2,020,822,000
Incremental TTC Cost Relative to 2023 RS	$96,000,000	$407,000,000
Return on Investment (B/C)[2]	7.20	-4.97
Economic & Regional Development	0.57	-1.02
Total B/C	7.77	-5.99

3.4.7 Total Benefits & Return on Investment

Table 3.8 assembles the results from the previous sections to tabulate the total transit ridership benefits of the FS and L2S scenarios relative to the RS base. The 2024 SP scenario is not included in this table, since the marginal changes relative to the base do not provide useful insights. Table 3.8 also shows the incremental operating and capital costs associated with each scenario, again relative to the RS base. Dividing the benefits by the costs yields a benefit-cost (B/C) ratio for each scenario. These ridership-related benefits computed in this section of the report can be added to the economic and regional development B/C ratio (as derived in Section 2) to yield a total B/C ratio for each scenario.

Return to Full Service

The return to full service from the 2019 reduced service scenario

highlights the very large economic benefits that can be generated by investment in high quality transit service,

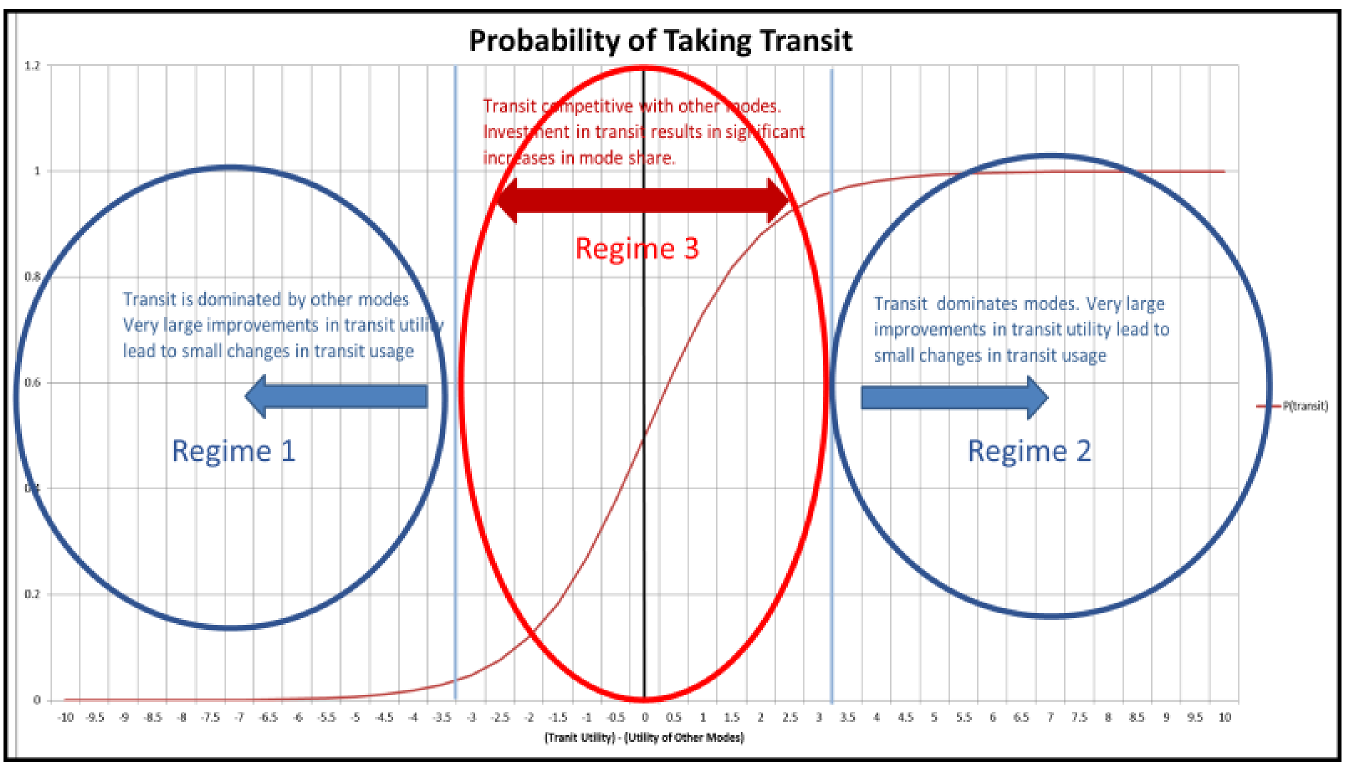
and, in particular, the very high benefits that accrue to trip-makers due to service improvements. A 7.2 B/C ratio is extremely high compared to many transportation investments, and when, combined with the broader macroeconomic benefits, yields a total, combined B/C ratio of 8.29. This highlights the need to appreciate the critical, essential role that transit plays in urban life and to understand the size of these benefits when making decisions concerning transit operating and capital budgets.

The large B/C ratio compared to some other studies reflects several factors:

- Many analyses of transit impacts fail to account for the full impact (if any impact at all) on auto users, in addition to the direct benefits accruing to transit riders. As indicated in this analysis, the auto user benefits are large and commensurate to those for transit users, a fact that is generally not appreciated by many decision-makers. Auto ownership and road accident cost savings are, in particular, very high, a result that is, again, typically ignored in policy discussions.
- Many analyses are still based on aggregate, trip-based travel demand models which are overly rigid and fail to "understand" the contexts within which trip-makers actually make their travel decisions. As a result, they are very "inelastic" in their response to service changes and tend to reproduce the base case status quo, with little change in predicted behaviour, despite a service improvement. Disaggregate agent- and activity-based microsimulation models of individual behaviour are found to be much more "elastic" in their ability to respond to service changes that actually do improve their travel options.[30]
- Many studies focus on a single "project", such as a new subway or LRT line, and its immediate catchment area. They fail to take into account the full network-wide impacts of the service change. But transit intrinsically operates as a network, connecting millions of origin-destination trip pairs, and it is the overall network effect that ultimately matters. The TTC is a highly integrated, multi-modal network providing dense connectivity throughout the city. Thus, improvement in service on any one transit route may well have effects that ripple through the network as overall connectivity / accessibility is improved.

30 *Cf. Miller, E.J., J. Vaughan and M. Nasterska (2016) SmartTrack Ridership Analysis, Project Final Report, report to the City of Toronto, June. (http://uttri.utoronto.ca/research/projects/2015-16-smarttrack-ridership-study/)*

Figure 3.9: A Simple Model of Transit Mode Choice



Further, the impact of a given service improvement depends very much on the overall travel market context. Figure 3.9 presents a simple, abstract model of transit mode choice, in which the probability of taking transit for a given trip is an S-shaped function of the "utility" of taking transit relative to the "utility" of competing modes, where "utility" is a function of the mode's travel time and cost, and the trip-maker's personal attributes (income, auto ownership, etc.).[31]

Three regimes are highlighted in this figure:

1. Regime 1 occurs in typical low-density, auto-oriented suburban settings[32] in which transit service is very poor and auto is by far the dominate mode of travel. In this case, even very significant transit service improvements will have very little impact on transit ridership, and hence will return a very low B/C ratio (i.e., less than 1.0, sometimes significantly so).[33]

2. 2. Regime 2 corresponds to high-density, high-transit-service, highly congested roadway contexts, such as in high-density city cores and high-density radial corridors connecting these cores to more suburban locations. In this case, transit is very attractive relative to auto and attracts a majority of trips. This clearly corresponds to the Toronto central area and the high-capacity rail (TTC and GO) corridors servicing it. In this case, improved service will again generate relatively small improvements in transit mode share. This, however, may still generate a reasonable rate of return given the large trip volumes involved; i.e., even a small percentage change on a high total trip volume may be economically justified.

3. Regime 3 is a very important intermediate case in which neither transit nor other modes (notably auto) are dominant, but rather are quite competitive with one another. In this case relatively small changes in transit service can generate relatively large changes in transit demand. That is, as opposed to the two inelastic cases previously discussed, transit usage is fairly elastic in this context, and, so, can return high benefits relative to the cost of the service improvements. Given its ubiquitous, relatively dense network and its relatively high (by North American standards) transit mode shares throughout much of the city, arguably much of the Toronto transit market falls into this regime. To the extent that this is true, one can expect high returns on investment in this context from welldesigned service improvements.

Line 2 Shutdown

The hypothetical Line 2 shutdown scenario also shows a very high B/C ratio relative to the reduced service scenario of 5 based on ridership and system impacts and 6,[34] once the wider macroeconomic and regional development benefits are included. While slightly smaller than the FS scenario, these are still very high B/C ratios. The FS scenario represents relatively low operating cost investments to existing services that generate high user benefits, illustrating the potential considerable benefits that can accrue from getting more productivity out of existing capital stock. The L2S scenario is intended to assess the impact of a high-cost capital investment. It is to be expected that this will return somewhat lower overall benefits relative to the high cost of the capital investment. But, again, the rate of return is still very high compared to many other competing investments.

Clearly, different combinations of operating and capital investments will inevitably yield different B/C ratios, depending on the specifics of the benefits accruing from the expenditures made. If we somewhat naively average the results from the two case studies examined, the result is a B/C ratio of 6.88 which might be used as representative of the return on investment in full TTC operations circa 2023 conditions.

2024 Service Plan

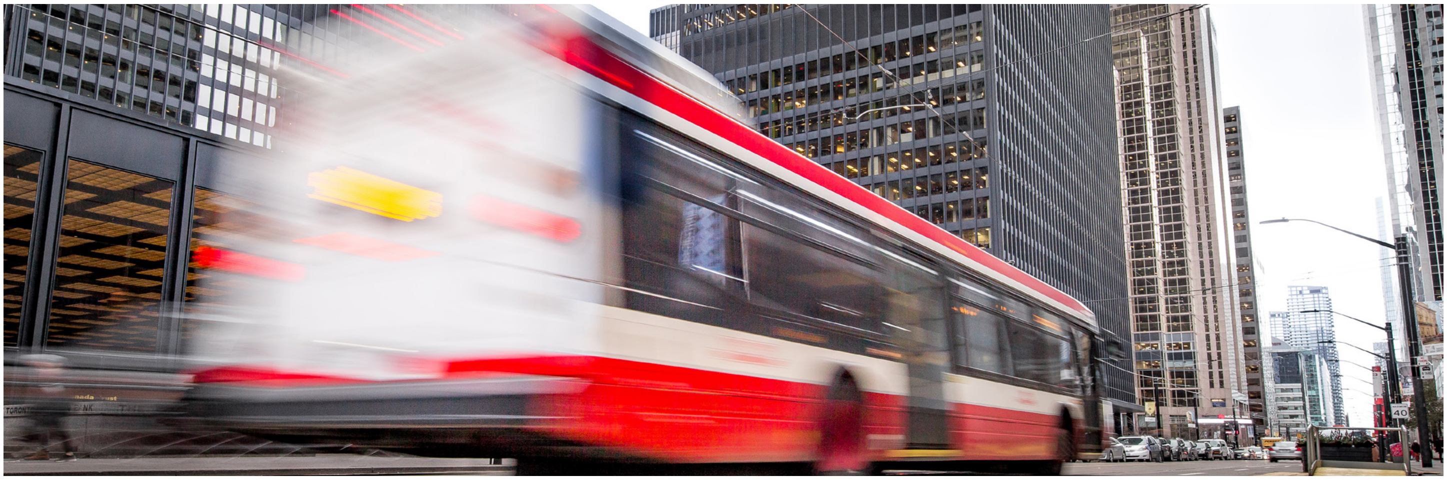
As has been discussed above, the SP scenario tested is quite a "mixed bag" of incremental service improvements dispersed through the system and the loss a high-order rail line, Line 3. The result is a similar "mixed bag" of marginal gains and losses. It is also likely the case that the analysis is stretching the current capabilities of GTAModel V4, which was originally designed to model long-range, major strategic transportation investments ("build a new subway line"), to precisely measure system changes in response to fairly minor short-run "tweaks" to the system. The result is that the model predicts very little changes in travel time savings and other benefits relative to the base case. These results are likely largely due to the Line 3 shutdown effects, which could well have pushed many Scarborough residents onto the road system, and/or simply be within the modelling error of the model system. Given this, a 2024 SP benefit-cost calculation is not included in Table 3.8.

31 *Figure 3.3 is a "logit model", which is an extremely common functional form for modelling mode choice. GTAModel V4 uses a more complex mathematical formulation, but the basic principles being described here very much still hold.*

32 *Or any other context in which transit service is extremely poor relative to auto.*

33 *This does not mean that investment in transit is not warranted in such instances, but the case for investment will have to go beyond a simple economic argument.*

34 *In Table 3.8 the B/C ratios are shown as negatives, indicating the economic loss of disinvestment. Taking the positive value represents the economic gain of investing in Line 2.*



Summary of Findings & Recommendations

This study has explored in detail the economic, environmental and social benefits of investment in TTC operations and infrastructure. Two modelling approaches were run in parallel to quantify these benefits: a macroeconomic model of the Canadian economy to assess of the macroeconomic impacts on the Ontario and Canadian economies of TTC investment, and a detailed microsimulation model of multi-model travel within the GTHA to compute trip-maker and societal benefits of transit investments.

The macroeconomic analysis clearly demonstrates the tremendous economic impact that the TTC has on the City of Toronto, the Province of Ontario and, indeed, Canada

through its operating and capital investment expenditures. These impacts are concentrated in Ontario, Canada's industrial core, which accounts for the majority of all advanced manufacturing and high-end professional/technical services activity in Canada and the associated direct and indirect labour supply. The TTC is clearly a "propulsive firm" playing a critical role in pushing the Greater Toronto Area (GTA), Ontario and Canada forward. Future research into the potential of TTC investment expenditures (especially those around electrification of the bus and locomotive fleets and associated infrastructures) to spark the creation and expansion of indigenous capacity in the advanced supply chain for electric vehicles and electric transit solutions specifically is warranted, given their clear potential for such activity to generate innovation and growth in Canada, likely concentrated in Ontario and the GTA.

Four scenarios were modelled in the microsimulation modelling analysis:

5. May, 2023 service (RS). This is a "reduced service" case relative to pre-pandemic full service. It is used as the base case for computing investment benefits.

6. Fall, 2019 service (FS). This scenario is taken as represent "full service" under prepandemic conditions.

7. Line 2 shutdown (L2S). This hypothetical case illustrates the impact of a significant "disinvestment" in the TTC that results in a significant loss of benefits.

8. 2024 Service Plan (SP).

Metrics computed for each scenario include:

- Trips by mode and mode shares.[35]
- Vehicle kilometres travelled (VKT).
- Transit and auto travel times.
- Auto user costs (operating, parking, ownership).
- Road accidents.
- GHG emissions.
- Air pollution emissions and associated health impacts.
- Accessibilities to a variety of activity types, for different household types.

All metrics except the accessibility measures were converted into monetary values so that benefit/cost ratios could be computed for the FS and L2S scenarios relative to the RS base.

This analysis indicates that investment in TTC operations and infrastructure can yield very strong returns on investment, with B/C ratios on average in the order of 7.

The specific values obtained are, of course, very case-specific, but they illustrate the very strong case that exists in general for continuing investment in transit in the City of Toronto. The analysis also clearly indicates the significant benefits that auto users receive from improved transit services in terms of reduced congestion (and, hence, travel times) and operating and vehicle ownership costs. It also demonstrates further societal benefits with respect to reductions in road accidents, GHG emissions and air pollution-related health impacts, as well as improvements in accessibility to jobs, schools, medical care and other essential services – especially for mobility disadvantaged population sub-groups.

This study has demonstrated the utility of using a large-scale, multi-model regional travel demand model to assess the region- and network-wide impacts of transit investment. It provides a consistent and comprehensive computational framework for assessing a broad range of impacts in response to a similarly broad range of policy alternatives. While originally designed for longrange strategic planning analyses, this study has shown the usefulness of the model system for analyzing short-run, more operationally-oriented scenarios. Future work with respect to use of the model system could include:

- Updating the model system to a post-pandemic (2022) base year using the recently available 2022 Transportation Tomorrow Survey data.
- Fine-tuning the model system components (notably the mode choice and transit route assignment models) to provide more precise responses to marginal changes in transit route-level service changes.
- Continuing the work begun in this project to automate within the model system software the flexible extraction of detailed metrics (by sub-areas, sub-populations, etc.) for use in a variety of applications, including service planning, budget planning and longer-term system planning.
- Transferring the model system to the TTC and training TTC staff in its use, so that it can be run in-house by staff for both service planning and longer-run policy analysis purposes.

35 *These trips are also characterized by origin, destination, trip purpose, time of day and trip-maker attributes.*