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Metrolinx / City of Mississauga

Climate Change and Sustainability Report

Dundas Bus Rapid Transit Mississauga East

Date: February 2022

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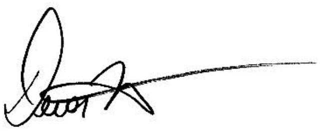
AECOM: 2015-04-13

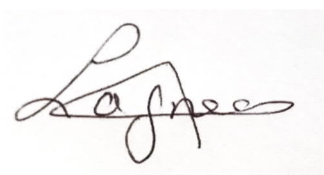
Authors

Report Prepared By:



Devon Waters, M.E.S, EP(CEA), ENV SP
EHS Compliance and Management Systems Specialist

Emma Orellana-Pepin, M. Env.
Resilience and Climate Change Specialist



Jérémy Lagneau, M. Sc. A.
Environmental Specialist

Report Reviewed By:

Derek R. Gray, P.Eng., A.A.E.
Climate Change Specialist

Report Approved By:

Joanne Wang, M.E.S., MCIP, RPP
Senior Environmental Planner

Executive Summary

ES 1. Project Background and Study Purpose

Previous municipal planning studies and the Metrolinx Initial Business Case confirmed the need for improved bus transit infrastructure along Dundas Street. Metrolinx is now advancing plans for the Dundas Bus Rapid Transit corridor. More than 20 kilometres of the 48-kilometre Bus Rapid Transit corridor will operate in bus lanes or in a dedicated right-of-way, separate from other traffic, allowing faster and more reliable transit connections.

In 2020, Metrolinx completed the Dundas Bus Rapid Transit Initial Business Case, which recommends a preferred Bus Rapid Transit alignment, and supportive service concept along Dundas Street between Kipling Station, in the City of Toronto, through the City of Mississauga and Halton Region, to Highway 6 in the City of Hamilton. AECOM Canada Limited (AECOM) was retained by Metrolinx and the City of Mississauga to evaluate the proposed 48-kilometre transit corridor. The evaluation involves the completion of the Preliminary Design, Preliminary Design Business Case and Transit Project Assessment Process.

A Transit Project Assessment Process is a focused environmental impact assessment process created specifically for transit projects. The process involves a pre-planning phase followed by a regulated (up to 120 days) consultation and documentation period. These phases include consultation, assessment of impacts, development of measures to mitigate negative impacts, and documentation. Consultation occurs with the public, stakeholders and Indigenous Nations throughout the process. Following these phases, there is a 30-day public review period where the public has the opportunity to review the Environmental Project Report and provide additional comments, followed by a 35-day Minister's review period.

The preliminary design phase will build upon the pre-planning completed as part of the Transit Project Assessment Process. In this phase, the project team will utilize the environmental impact assessment from the Transit Project Assessment Process to refine the Bus Rapid Transit design to a 30% design level. The Preliminary Design Business Case analyzes the Dundas Bus Rapid Transit corridor against strategic objectives, financial and economic impacts and operations considerations. The Preliminary Design Business Case will compare the corridor against a business-as-usual scenario (i.e., without the Project).

In 2018, the Dundas Connects Master Plan (Dundas Connects) was completed by the City of Mississauga. It guides future development and intensification along the Dundas Street Corridor in the City of Mississauga. Dundas Connects was developed over a 2-year period with extensive consultation from the public. It was endorsed by City Council on June 18, 2018. Bus Rapid Transit, cycling infrastructure, and an enhanced public realm for pedestrians were among the recommendations in the Plan. Dundas Connects is being implemented through various studies and initiatives, including this Transit Project Assessment Process.

- The Dundas Bus Rapid Transit Mississauga East (the Project) includes the planning and design of a 7-kilometre Bus Rapid Transit corridor from Confederation Parkway to the City of Toronto boundary at Etobicoke Creek, within the City of Mississauga. The Project has been submitted under the Government of Canada's Investing in Canada Infrastructure Program and is currently awaiting approval.
- Metrolinx has invested significant energy in planning for climate adaptation, resiliency and sustainability in recent years which has most recently included the refreshing of their Sustainability Strategy in 2021 along with revised goals and actions which are more specific, and the release of Sustainable Design Standard. The application of the Sustainable Design Standards will be mandatory for the design of all new, expanded, and reconstructed Metrolinx buildings and facilities in the future.
- A thorough review of Envision has indicated that up to 35 credits across the five streams are applicable to project along with the level of achievement that is likely possible. An early decision to the application of Envision to the Dundas Bus Rapid Transit Project is key to successful achievement.

A greenhouse gas inventory has been completed on both baseline case and the result of implementing the Project including both construction, operation and maintenance. At this time the challenge represented of the early phase of the Project has led to a number of assumptions being included to develop the inventories.

The methodology used for the quantification of greenhouse gases is based on modelling the kilometres travelled by vehicles (vehicle kilometres travelled) in the entire study area and a broader Regional area without the Project and with the Project. Since the available modelling results are based on the difference in kilometres travelled over the entire study area and a broader Regional area, and incorporates other projects by Metrolinx, it is not possible to define the impact of each of the Dundas Bus Rapid Transit Projects. The difference in vehicle kilometres travelled with and without the Project indicates that within the study area, the Bus Rapid Transit corridor will influence traffic behaviour. However, in the absence of vehicle kilometres travelled data by each Dundas Bus Rapid Transit Project, it is not possible to know where this change in traffic behaviour is occurring in the Region. Thus, the greenhouse gases quantification is for the entire Bus Rapid Transit corridor.

The Project case has been shown to be the preferred option with respect to greenhouse gas emissions. The greenhouse gases assessment shows emission reductions comparing baseline and Project cases over a 63-year lifecycle of 322,014 tonnes of CO2e. The Operations and Maintenance emissions drive the total greenhouse gas emissions.

Embodied carbon within the Project can be better tracked and estimated in future phases of the development of the Project with the adoption of Metrolinx's new DS-05 Sustainable Design Standard along with an early decision on the application of Envision to the Dundas Bus Rapid Transit corridor.

The effects of Climate Change on the Project have been determined by completing a Climate Change Risk Assessment based on the International Organization for Standardization 31000 Risk Management Standard and to document the existing condition of riverine flooding.

In order to determine the climate-related risks to the future Bus Rapid Transit system, climate indicators and their probabilities of occurring were analyzed for both the historical period and in the context of the changing climate. A total of 25 climate indicators were reviewed at a high-level to estimate the likelihood of climate risks to the Project. As a result of this initial review, 14 climate indicators were removed from the analysis as they were considered to have no impact or a very low impact on the Project resulting in 11 climate indicators which were selected. In addition, the climate parameters from the Metrolinx PIEVC Climate Change Vulnerability Assessment (AECOM 2016) where also reviewed.

Climate change vulnerability was first assessed, to determine the exposure, sensitivity, and adaptive capacity of each assets and elements to the 11 selected climate indicators. The risk assessment revealed 52 interaction showing risks out of 66 possible interactions, between 11 climate indicators and the six project components. Risk treatment and adaptation measures for each of the interactions have been developed in three types of measures, Design, Operations and Maintenance, and Policy.

In addition, within this 7.2-kilometre section of the Dundas Bus Rapid Transit Mississauga East Project there are three areas of significant riverine flooding which could impact the construction and future operation. Areas of riverine flooding are likely beyond the scope of the Dundas Bus Rapid Transit Project as they are a result of the upstream development of the watershed. As such operational procedures may need to be developed to ensure the safe operation of the Dundas Bus Rapid Transit.

Recommendations

At this time AECOM makes the following Recommendations associated with this 7.2-kilometre section of the Dundas Bus Rapid Transit:

- The application of the Sustainable Design Standards to the Dundas Bus Rapid Transit Project;
- An early decision to the application of Envision to the Dundas Bus Rapid Transit Project is key to successful achievement;
- Document embodied carbon within the Project with the adoption of Metrolinx's new DS-05 Sustainable Design Standard and Envision;
- The results of the greenhouse gas inventories be updated as the details of the Project crystalize;
- The results of the Climate Change Risk Assessment be shared and incorporated into the future detailed design and eventual operation and maintenance of the Project; and
- Operational procedures be developed for the Dundas Bus Rapid Transit Project to ensure the safe operation in areas of riverine flooding.

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1. Introduction

1.1 Background

Previous municipal planning studies and the Metrolinx Initial Business Case confirmed the need for improved bus transit infrastructure along Dundas Street. Metrolinx is now advancing plans for the Dundas Bus Rapid Transit corridor. More than 20 kilometres of the 48-kilometre Bus Rapid Transit corridor will operate in bus lanes or in a dedicated right-of-way, separate from other traffic, allowing faster and more reliable transit connections.

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The Dundas Bus Rapid Transit Mississauga East (the Project) includes the planning and design of a 7-kilometre Bus Rapid Transit corridor from Confederation Parkway to the City of Toronto boundary at Etobicoke Creek, within the City of Mississauga. The Project has been submitted under the Government of Canada's Investing in Canada Infrastructure Program and is currently awaiting approval. This Climate Change and Sustainability Report (the Report) has been prepared to support the Dundas Bus Rapid Transit – Mississauga East Transit Project Assessment Process.

1.2 Purpose

The purpose of this Climate Change and Sustainability Report is to review the work completed and recommendations to support the Transit Project Assessment Process.

1. The Methodology for:
    a. Background Information Review
    b. Effect of the Transit Project on Climate Change (Greenhouse Gas Mitigation Assessment)
    c. Effect of Climate Change on the Transit Project (Climate Change Resilience Assessment)
    d. Sustainability Initiatives
    e. Climate Change and Sustainability Report
2. The Existing Conditions for:
    a. Background Information Review
    b. Effect of the Transit Project on Climate Change (Greenhouse Gas Mitigation Assessment)
    c. Effect of Climate Change on the Transit Project (Climate Change Resilience Assessment)
    d. Sustainability Initiatives
    e. Climate Change and Sustainability Report

1.3 Study Area

The Project Area is the area of direct disturbance required for the construction and operation of the Project. It includes the proposed alignment for the Project and additional area for potential refinements as the design progresses. As the Project Area already accounts for refinements to the area of impact based on future design considerations there is no need to include a buffer to the Project Area. The Climate Change and Sustainability Study Area (the Study Area) identifies the area to be investigated as part of Climate Change and Sustainability Report. The Study Area for the Climate Change and Sustainability Report is shown in **Figure A1**, **Appendix A**.

The Study Area is primarily within the City of Mississauga, along Dundas Street starting just east of Etobicoke Creek at Neilson Drive in Toronto to Confederation Parkway.

2. Methodology

This section will provide an overview and summary of the Methodology to complete the five main tasks for the Climate Change and Sustainability scope of the work for the Project.

2.1 Background Information Review

AECOM has conducted a desktop background review that includes, but is not limited to, the following:

- Dundas Bus Rapid Transit Initial Business Case (Metrolinx, September 2020);
- Dundas Connects Master Plan (AECOM 2018);
- Dundas Connects Business Case Assessment (AECOM 2020a);
- Dundas Connects Climate Lens: Climate Change Resilience Assessment and Greenhouse Gas Mitigation Assessment (AECOM 2020b);
- Sustainability Strategy (Metrolinx, 2016);
- Metrolinx Public Infrastructure Engineering Vulnerability Committee Climate Change Vulnerability Assessment – Final Report (AECOM 2016);
- Metrolinx Design Standard – DS-05 Sustainable Design Standard – Version 1.0 (Metrolinx 2021);
- Planning for Resiliency: Toward a Corporate Climate Adaptation Plan (Metrolinx, 2017);
- Metrolinx Climate Adaptation Strategy (Metrolinx, 2018); and
- Climate Change Action Plan (City of Mississauga).

2.2 Effects of the Transit Project on Climate Change

The effects of the Project on Climate Change have been determined by completing a greenhouse gas inventory of both baseline case and the result of implementing the Project including both construction, operation and maintenance. The greenhouse gas emission inventory has been completed in line with the International Organization for Standardization 14064-2 standard. The key principles of the International Organization for Standardization 14064-2 standard, which has been utilized for the inventory, are summarized below:

- **Relevance:** The relevance of greenhouse gas sources, data and methodologies must be appropriate for the purpose of the emissions assessment.

- **Completeness:** All relevant greenhouse gas emissions should be included in the assessment with supporting information on criteria and procedures.
- **Consistency:** The assessment must enable meaningful comparisons in greenhouse gas related information. A key component of the assessment is the comparison of the Project to a baseline case. The baseline case has been defined as a conservative viable alternative and its design components and associated emission sources have been derived based on the same assumptions as the Project.
- **Accuracy:** The assessment must reduce bias and uncertainties as far as is practical. Quantification of the Project's anticipated baseline and Project emissions is based on available data, emissions factors and estimation methodologies used, recognizing that uncertainties exist due to the early stage of Project development, and the limited emissions factors available for the relevant activities. Where there is uncertainty, a conservative approach has been taken and described.
- **Transparency:** The assessment must disclose sufficient and appropriate greenhouse gas related information to allow conclusions and decisions to be made with reasonable confidence. For each emissions source, description of the information and references used in the emissions calculation has been provided.
- **Conservativeness:** The assessment must use conservative assumptions, values and procedures to ensure that greenhouse gas emission reductions are not overestimated. To avoid over or under estimation of emissions, the baseline and Project cases use identical assumptions for the fuel consumption by vehicles and the proportion of vehicles consuming gasoline or diesel in the regional vehicle fleet.

A high-level discussion of the embodied carbon is included along with general strategies that could be implemented to reduce embodied carbon in the Project and are discussed in Section 3.2.3. In addition, key exclusions from the assessments have been clearly documented along with key assumptions and represented in the Project's Climate Change and Sustainability Report.

2.3 Effects of Climate Change on the Transit Project

The effects of Climate Change on the Project have been determined by completing a Climate Change Risk Assessment based on the International Organization for Standardization 31000 Risk Management Standard. AECOM recently completed a Climate Change Risk Assessment following the Climate Lens General Guidance that will form a starting point for this Climate Change Risk Assessment and has been enhanced with the additional work completed by Metrolinx on Climate Change. At a high level the Climate Change Risk Assessment will utilize the following 5-step process:

1. **Establishing the context:**
   a. Establish the context of the climate risk assessment.
   b. Data collection on Project phases and asset components; past experience of extreme weather events and; climate data collection and analysis including climate change projections.
2. **Risk Identification:**
   a. Identify potential interactions between specific climate conditions and assets, systems and surrounding environment through a vulnerability assessment.
3. **Risk Analysis:**
   a. Determine a scale of likelihood or probability of a climate condition to occur and a scale for the severity of consequences, such as low, moderate and high.
   b. Use the scales to rate the severity of consequences for each identified interaction between a certain climate condition and each asset component.
4. **Risk Evaluation:**
   a. Compare, evaluate and rank each risk event and opportunity from the risk analysis results.
   b. Validate the risk analysis with the client.
   c. Prioritize risks according to this evaluation for risk treatment and adaptation measures.
5. **Risk Treatment and Adaptation Measures:**
   a. Identify risk treatment and adaptation measures.
   b. Recommend a set of adaptation measures for each phase of the Project.

Riverine flooding along Dundas Street for the Project has been discussed and highlighted in Section 5.7. The process and results of the Climate Change Risk Assessment has been clearly documented in Section 5 of this Climate Change and Sustainability Report.

2.4 Sustainability Initiatives

AECOM has highlighted some of the broader sustainability initiatives that Metrolinx is currently undertaking or has planned in relation to the construction and operation of the Project, with the goal of improving environmental and social outcomes. These broader sustainability initiatives are currently presented in Metrolinx's publicly available policy documents (Sustainability Strategy, 2016) and Metrolinx's Draft Sustainable Design Standard and will focus on the unique urban nature of the Project. In addition, a brief discussion in Section 3.2.6 will highlight the potential application of Envision to the Project.

2.5 Climate Change and Sustainability Report

This Report is structured into three parts as requested by Metrolinx.

Part 1 of the Project's Climate Change and Sustainability Report describes how the Transit Project Assessment Process incorporates the Ministry of the Environment, Conservation and Parks' guidance for considering climate change in environmental assessments/Transit Project Assessment Process, by summarizing the work completed in the previous tasks and includes the policy context, the effects of the transit project on climate change (mitigation), and the potential effects of climate change on the transit project (adaptation).

Part 2 of the Project's Climate Change and Sustainability Report highlights some of the broader sustainability initiatives that Metrolinx is undertaking or has planned that are relevant and of particular importance to the Project, with the goal of improving overall environmental and social outcomes.

Part 3 of the Project's Climate Change and Sustainability Report summarizes how the design considerations, mitigation measures, and other initiatives outlined in Parts 1 and 2 are helping to meet the Ministry of the Environment, Conservation and Parks' expectations, as well as the sustainability goals outlined in Metrolinx's public policy documents. A component of Part 3 contains a table that contains the following (as a minimum) column headings:

- Metrolinx Sustainability Strategy Goal;
- Project Component / Environmental Feature;
- Measures to Mitigate Effects of the Transit Project on Climate Change;
- Measures to Mitigate Effects of Climate Change on the Transit Project;
- Additional Measures to Promote Sustainability; and
- Outcomes.

3. Background and Policy Context

3.1 Background Information Review

Metrolinx has invested significant energy in planning for climate adaptation, resiliency and sustainability in recent years. Planning has included the development of a Climate Adaptation Strategy in 2018, which was stimulated by the document Planning for Resiliency: Toward a Corporate Climate Adaptation Plan, 2017. More recently, Metrolinx has created a Sustainable Design Standard. The application of the Sustainable Design Standards has been mandatory for the design of all new, expanded, and reconstructed Metrolinx buildings and facilities in the future. Metrolinx also established an overarching Sustainability Strategy for 2015 to 2020, which identified several organization level sustainability goals and actions, some of which can also be applied to a project implementation level. The Metrolinx Sustainability Strategy was refreshed in 2021, and the revised goals and actions have a higher specificity and are more easily applied to individual projects. Within each of these Plans, Standards and Strategies there exist many opportunities to integrate sustainability action into the Project and are highlighted in the following sections.

3.1.1 Metrolinx on Resilience and Climate Adaptation

Metrolinx is an agency of the Government of Ontario and is responsible for the co-ordination and integration of transportation in the Greater Toronto and Hamilton Area. Its operations consist of GO Transit regional bus and rail services (including Union Pearson Express), and its extensive assets include bus and train fleets, rail lines, stations, parking structures, maintenance facilities, and PRESTO, the electronic payment system (Metrolinx, 2017).

The Greater Toronto and Hamilton Area is already experiencing the effects of climate change and will continue to feel the impacts of the changing climate in the future. As climate change is driven by higher concentration of greenhouse gases in the atmosphere and concentrations are rising at alarming rates, Canada is likely to see its climate change more than the global average with increase in temperatures, precipitation, drought, wind gust events, freezing rain, and extreme weather events frequency throughout the Greater Toronto and Hamilton Area. Therefore, Metrolinx acknowledges the importance of adapting to the changing climate in order to increase resilience of infrastructure and the importance of being more mindful of the greenhouse gas emissions and the carbon footprint of their projects (Metrolinx, 2017).

Metrolinx has experienced firsthand how climate change can be costly and disruptive. In July 2013, the Greater Toronto and Hamilton Area experienced an extreme rainfall event with major repercussions in the region. During the event, more rain fell during rush hour that day than an entire typical July. Flooding occurred and caused a GO train to be partly submerged with passengers onboard. Insured damages across the Greater Toronto and Hamilton Area rose to over $1 billion, making it the costliest weather event in Ontario's history. In December, the same year, another extreme weather event occurred. This time, the Greater Toronto and Hamilton Area was hit by an ice storm that left about 300,000 households without power for several hours, some even days. Metrolinx was impacted because the power outage caused important delays on GO trains, GO buses, Toronto Transit Commission subways and streetcars, and other municipal bus systems. These two events clearly show how impactful weather can be to transit systems and infrastructures (Metrolinx, 2017).

In response to the changing climate, Metrolinx developed resiliency initiatives and climate adaptation strategies. Metrolinx adopted a proactive approach by appointing a senior advisor position focused in resilience and adaptation in 2014 and publishing their Five-Year Strategy 2015 to 2020 that committed the organization to establish a Corporate Climate Adaptation Plan covering facilities, practices and protocols, which was published in 2018. The Sustainability Strategy provides a framework for decision makers to make well thought and informed decision while keeping in mind Metrolinx's five sustainability goals:

1. Becoming climate resilient;
2. Reducing energy use and emissions;
3. Integrating sustainability in their supply chain;
4. Minimizing impact on ecosystems; and
5. Enhancing community responsibility (Metrolinx, 2016).

Their vision for resiliency considers a future where the impacts of climate change are more significant than those experienced in the past. Metrolinx hopes to apply robust solutions that are effective, economical, and efficient under a wide range of climate scenarios and plan for long term adaptations. Accompanied by stakeholder, decision makers and staff engagement, resiliency can be attained throughout four pillars:

1. Awareness, education, and communication;
2. Assessing risks and opportunities;
3. Building climate resilience across the enterprise, and
4. Monitoring and adaptive management (Metrolinx, 2018).

3.1.2 Regional Transportation in the Greater Toronto and Hamilton Area

The Greater Toronto and Hamilton Area is the economic engine of Ontario and is one of the fastest growing city-regions in North America. The rapid growing population is projected to grow from 7.2 million people in 2018 to 10.1 million people by 2041. It is essential that there be the development of an integrated regional transport system that serves the needs of businesses, residents, and institutions across the region. The 2041 Regional Transportation Plan works toward this objective and includes a range of new services, infrastructure projects and policies to keep the Greater Toronto and Hamilton Area moving as it undergoes significant growth in the coming decades (AECOM, 2020).

Transportation demands in the Greater Toronto and Hamilton Area are currently served by a network of regional and local transit services including:

a) GO Transit commuter rail and bus network which connects cities and towns across the Greater Toronto and Hamilton Area;
b) The Toronto Transit Commission operates its integrated subway, streetcar and bus network across the City of Toronto; and
c) A series of other local transit options in municipalities surrounding the City of Toronto, which includes bus services operated by Brampton Transit (including Bus Rapid Transit), Burlington Transit, Durham Region Transit, Hamilton Transit, Mississauga Transit (including Bus Rapid Transit), Oakville Transit, and York Region Transit (including Bus Rapid Transit) (AECOM, 2020).

Congestion on the Greater Toronto and Hamilton Area road network is common due to a lack of transit services that connect destinations from outside of central Toronto to one another. Traffic and congestion on road networks are bound to increase as population and employment grows in the area, which leads to higher travel demand (AECOM, 2020).

The Project in the area would concentrate on adapting the Dundas Street Corridor, which comprised an approximately 40-kilometre transport corridor that connects Toronto, Mississauga, Oakville, Burlington and Hamilton. Investment in the transportation network seeks to make up for the lack of alternatives to the automobile in the hopes of contributing to the overall livability and economic development potential of the corridor. An efficient transportation network would imply better transit travel times and fewer transfers, detours, and double fares during inter municipal journeys (AECOM, 2020).

3.1.3 Bus Rapid Transit

The analysis done by Dundas Connects and the Initial Business Case indicates that the expected growth and demand is best met through Bus Rapid Transit and priority bus initiatives. Bus Rapid Transit offers the most competitive solution to deliver high-quality, high-frequency services along the Dundas Street Corridor for multiple reasons. The Bus Rapid Transit is advantageous and is the better transit solution because of:

a) **Cost efficiency**: Bus Rapid Transit requires less capital investment and is cost saving relative to other transit infrastructure;

b) **Better passenger capacity**: Bus Rapid Transit can be operated closer to its theoretical capacity as its fixed infrastructure is less expensive, and its services are more configurable to be within acceptable ranges of anticipated demand as compared to other higher-order transit;

c) **Flexibility in service provision**: Bus Rapid Transit runs on existing roads which makes it a highly configurable system, and this provides flexibility in routing and levels of service provided;

d) **High-speed and high frequency**: Bus Rapid Transit has a comparative advantage in the levels of speed that can be reached if dedicated right-of-way is implemented; and

e) **Reliability**: a vast majority of the Project will operate on a segregated right-of-way, which is reliable when it comes to journey times and headway (AECOM, 2020).

In September 2020, Metrolinx approved the Dundas Bus Rapid Transit Initial Business Case which recommends a preferred Bus Rapid Transit alignment and supportive service concept along Dundas Street between Kipling Station, in the City of Toronto, through the City of Mississauga, Halton Region, to Highway 6 in the City of Hamilton. Bus Rapid Transit on Dundas Street is recognized as a regional transit priority connection by Metrolinx, the City of Toronto, the Toronto Transit Commission, and the City of Mississauga as well as members of the public as it connects people through the western end of the Greater Toronto and Hamilton Area. The Dundas Bus Rapid Transit will provide faster, more reliable public transit, encourage more sustainable transit, improve connectivity to areas currently underserved and integrate land use and transportation to support economic growth by facilitating transit-oriented development around the Dundas Street Corridor. The preliminary design and Transit Project Assessment Process completion will identify the preferred approach to project delivery.

3.1.4 Climate Lens Report

The purpose of the Dundas Connects Climate Lens: Climate Change Resilience Assessment and Greenhouse Gas Mitigation Assessment is to provide guidance and is a horizontal requirement applicable to Investing in Canada Infrastructure Program, Disaster Mitigation and Adaptation Fund and Smart Cities Challenge.

The Climate Lens Assessment Report aims to assess climate change impacts on the Project and to evaluate the impacts of the Project's greenhouse gas emissions on climate change. The Climate Lens has two components:

1. The Climate Change Resilience Assessment, which employs a risk management approach to anticipate, prevent, withstand, respond to, and recover from a climate change related disruption or impact; and
2. The Greenhouse Gas mitigation assessment, which estimates the anticipated greenhouse gas emissions impact of an infrastructure project.

Overall, the Climate Lens Assessment is intended to help decision makers understand the climate change risks and impacts associated with the design, construction and operations of their infrastructure project.

3.2 Sustainability Initiatives

Section 3.2 highlights some of the broader sustainability initiatives that Metrolinx is currently undertaking or has planned in relation to the construction and operation of the Project, with the goal of improving environmental and social outcomes. These broader sustainability initiatives are currently presented in Metrolinx's publicly available policy documents (Sustainability Strategy, 2016) and Metrolinx's Draft Sustainable Design Standard and will focus on the unique urban nature of the Project. In addition, a brief discussion will highlight the potential application of Envision to the Project follows.

3.2.1 Metrolinx Climate Adaptation Strategy

The Metrolinx Climate Adaptation Strategy, 2018 identified forty key actions to improve the climate resiliency, climate adaptation and sustainability of existing operations and new projects. A selection of these are directly applicable to the Project:

- Embed climate resilience and sustainability as a key principle within Capital Projects Group technical standards and specifications.
  - While the development of the contract for the Project has not been completed due to the early stage, Metrolinx should embed applicable

climate resilience and sustainability criteria into this procurement text as this represents a significant opportunity to integrate these considerations into the detailed design, construction and operation of the Project.

- Evaluate the viability of adopting a sustainability ratings framework (e.g., ENVISION) to a linear asset, station and/or facility.
  - As part of this scope of work Metrolinx has requested an initial review of the Envision credits which may apply to the Project, setting the foundation for determining if it is feasible for the Project to pursue Envision certification.
- Prioritize culverts, bridges and embankments most vulnerable to climate extremes for increased monitoring and maintenance.
  - Riverine flooding has been identified as a climate risk to the Project, this climate assessment is intended to identify areas such as bridges and culverts which have increased vulnerability to riverine flooding impacts from climate change.
- Build upon the Public Infrastructure Engineering Vulnerability Committee Protocol climate vulnerability assessment for selected assets and develop an Adaptation Action Plan.
  - A Public Infrastructure Engineering Vulnerability Committee Protocol assessment is being conducted for the proposed Dundas Bus Rapid Transit as part of this scope of work. The outcomes of this assessment will help to inform adaptation action for the project implementation.

3.2.2 Planning for Resiliency: Toward a Corporate Climate Adaptation Plan

Planning for Resiliency: Toward a Corporate Climate Adaptation Plan, 2017 was a precursor to the development of the Metrolinx Climate Adaptation Strategy, which identified several climate resiliencies, climate adaptation and sustainability elements that are applicable to the Dundas Bus Rapid Transit:

- Transit Project Assessment Process will include consideration of climate change resiliency.
  - This scope of work is being undertaken in support of the Transit Project Assessment Process and includes the identification of climate impacts on the Project through the execution of a climate risk assessment. The outcomes of the assessment will drive the identification of climate adaptation and resiliency considerations.

- The risk registry will include risk to climate change for various projections and time periods.
  - The Project risk register should include climate risk considerations.
- Project management requirements will include consideration of a work plan that outlines how climate change risks and resiliency are being considered.
  - Project management of climate change risks and responsibilities could be initially driven from the identification of risks within the risk register, allowing for planning regarding how to control climate change risks and integrate climate resiliency within the Project.
- Project specific sustainability plan should identify climate change risks and vulnerabilities and include the implementation of climate adaptation and resiliency measures where practicable. Climate change risks and vulnerabilities include, but are not limited to, riverine and overland flooding, high winds (over 120 kilometres per hour), wind gusts, freeze-thaw cycles, snow accumulation, lightning strikes, tornadoes and ice storms.
  - This requirement should be included in the future stages for the Dundas Bus Rapid Transit and should reference this Climate Change Risk Assessment as a resource that the Project can use to gather a baseline understanding of the potential climate change risks and vulnerabilities facing the Project.

3.2.3 Metrolinx Sustainable Design Standard

The Metrolinx Sustainable Design Standard, which was developed recently in 2020, has been mandatory for the design of all new, expanded, and reconstructed Metrolinx buildings and facilities. The Project will not involve the construction of buildings; however, the Standard still includes actions and principles in several areas which could be applied to the Dundas Bus Rapid Transit to enhance sustainability. These are presented below, subdivided by the topic areas of the Standard.

Embodied Carbon

Projects should consider using Life Cycle Analysis to support project decisions. While reducing carbon emissions is possible at all stages of project delivery, opportunities are greater and more cost-efficient in earlier stages. All building projects (new, reconstruction and expansion) and roadway and pavement construction with a capital cost of more than $30 Million shall develop a life-cycle assessment for embodied carbon.

- While the current phase of design is too preliminary to allow for an accurate estimate of embodied carbon, due to lack of specificity regarding the quantities of materials to be used, Metrolinx has initiated discussion regarding determining the Project's embodied carbon. In later phases of detailed design when material types and quantities are better defined it would be possible to achieve an estimate of the Project's embodied carbon with greater accuracy. At this time the Project will assess several strategies to reduce net embodied carbon during design and preconstruction phases. A non-exhaustive list of the strategies considered is as follows:
  - Define targets for reducing embodied carbon.
  - Design and size the Project to reduce overall materials used.
  - Use recycled or lower embodied carbon materials.
  - Use local contractors to reduce transportation emissions.
  - Consider maintenance and repair needs when selecting materials.
  - Minimize waste and provide sufficient space for waste separation and monitoring.

Material Life Cycle Impacts

All projects shall:

- Achieve a minimum 75% construction waste diversion by volume, excluding aggregate, fill and hazardous materials;
- Use optimal and compact building form to reduce overall building materials used;
- Use low carbon cement or Portland-limestone Cement for concrete or mortar which has a higher proportion of supplementary cementitious materials (e.g., slag, fly ash, etc.) as a partial substitute for Portland cement. The use of supplementary cementitious materials also reduces the Project's embodied carbon;
- Use products, where available, from manufacturers who have validated triple bottom line (environmental, economical, and social) life-cycle information relevant to the product through independent, consensus-based, third party certifications. The products must have earned and still maintain certification under the scheme; and

The above elements should be implemented in the future stages for the project to reduce material life cycle impacts associated with construction.

Lighting

- Use only Light Emitting Diode integrated light fixtures and avoid usage of Light Emitting Diode retrofit light bulbs, which are generally less energy efficient;
- Install automatic lighting control systems for exterior spaces; and

Outdoor lighting associated with shelters, stops and signage for the Dundas Bus Rapid Transit should be required to use Light Emitting Diode integrated fixtures with automatic lighting control systems.

Solar

- Install pole mounted solar panels.
- Provide shading structures such as canopies in parking lots with solar photovoltaic.
- Ensure external lighting is solar powered.
- Lighting, heating, ventilation and/or other electrical loads at stand-alone shelters, Station Access Modules and other buildings will be solar powered, with battery or grid power back-up.

The Dundas Bus Rapid Transit does not involve the construction of stations or buildings with roof areas greater than 100 square metres, which is the primary target of Sustainable Design Guidelines related to solar installations. However, opportunities will exist throughout the Project Area for small scale solar installations such as those mounted on poles or at stand-alone shelters.

Heat Island Mitigation

All landscape projects with new or reconstructed hardscapes shall:

- Provide a plan and calculations showing at least 50% of the site hardscape (excluding roads, bus loops, pick up and drop off locations, and surface parking lots) uses any combination of the following strategies:
  - Provide shade from the existing tree canopy or within 10 years of landscape installation. Landscaping (trees) must be in place at the time of operations;
  - Provide shade with solar canopies;
  - Use hardscape materials with a solar reflectance index of at least 29; and
  - Permeable paving.

The Dundas Bus Rapid Transit will require the reconstruction of hardscapes in each segment to allow for stops, shelters, pedestrian walkways and crossings, and dedicated Bus Rapid Transit lanes. The Project travels through an urban environment, where heat island effect is high due to the built-up nature of the urban area. Integration of heat island mitigation requirements in landscaping procurement language could help to mitigate some heat island effects in the vicinity of the Project.

Flood Mitigation

All projects that must determine a floodplain, shall:

- apply the greater of the following storm events to account for the range of possible climate change outcomes to the high-water riverine flood elevation:
  - Regional storm (designated by the local conservation authority); or
  - 25% increase in the peak flow indicated within the approved hydraulic model for the 100-year storm event.
- For slope and channel bank protection along sites and downstream of the outlet structure, utilize the shear stress and velocities calculated for the flood mitigation event indicated above to properly select appropriate slope protection material.

Riverine flooding is being considered as part of this scope of work and it is recommended that flood mitigation requirements related to the climate change risk assessment be incorporated in the final project design.

Low Impact Development

All projects proposing Low Impact Development practices shall:

- Incorporate vegetation;
- Incorporate stormwater infiltration where supported by the soil characteristics and groundwater; and
- Design per recommendations in the Low Impact Development Stormwater Management Wiki codeveloped by the Credit Valley Conservation Authority, the Toronto and Region Conservation Authority, and the Lake Simcoe Region Conservation Authority (wiki. sustainabletechnologies.ca).

In order to reduce stormwater runoff associated with the Dundas Bus Rapid Transit there is opportunity to integrate requirement for Low Impact Development practices within the project design.

Light Pollution

All projects for buildings and sites that will not be operated under GO Transit proposing exterior lighting shall:

- Implement a cohesive and adaptable hierarchy of lighting that achieves other lighting objectives with the minimum light necessary;
- Restrict light spillage to sensitive areas (i.e., residential or natural habitats) such as through directional lighting or light shields;
- Meet the IES TM-15-11 Backlight, Uplight and Glare classification of outdoor fixtures, and have no glare;
- Provide a map and worksheet demonstrating Backlight, Uplight and Glare ratings meeting lighting zone requirements; and
- Use exterior light fixtures that meet the Illuminating Engineering Society of North America Full Cut-off Classification or an Uplight rating (as a part of the Backlight, Uplight and Glare rating system) of zero.

To reduce light pollution from the operation of Dundas Bus Rapid Transit the above requirements should be included in the design requirements.

Resilience

All project locations with capital costs over $50 Million shall:

- Undertake a preliminary climate risk and vulnerability assessment at no later than 30% design that identifies opportunities early in design to improve climate resiliency. The preliminary climate risk and vulnerability analysis can be predominantly qualitative. The preliminary climate risk and vulnerability analysis can be a review and update to the Transit Project Assessment Process analysis undertaken in line with the Ministry of the Environment, Conservation and Parks Guideline Considering Climate Change in the Environmental Assessment Process;
- Perform a Climate Vulnerability Risk assessment using the Public Infrastructure Engineering Vulnerability Committee Protocol method established by Engineers Canada and conduct their assessment using the Public Infrastructure Engineering Vulnerability Committee Protocol Vulnerability Assessment templates and instructions found in section 7.1.5 (https://pievc.ca/), or International Organization for Standardization 14091, or equivalent with prior approval by Metrolinx. The Public Infrastructure Engineering Vulnerability Committee Protocol summary report shall be submitted no later than 60% design;

- Address through the risk assessment, at a minimum, four critical changing climate parameters: Increase in extreme temperature; Increase in the occurrence of extreme rainfall events; Increase in the occurrence of freezing rain events; and Increase in the frequency of extreme wind events;
- Assess the impacts of climate change on both assets and operations;
- Demonstrate how the project will adapt to high risks in alignment with the Public Infrastructure Engineering Vulnerability Committee Protocol Scoring Matrix;
- Provide options for adapting to medium risks in alignment with the Public Infrastructure Engineering Vulnerability Committee Protocol Scoring Matrix;
- Consider through the vulnerability assessment the anticipated lifespan of the project, and of its individual elements;
- Include in the development of the vulnerability assessment, participation and/or review from key internal and external stakeholders including Metrolinx Operations and Maintenance, Engineering and Asset Management, and Transportation Policy and other departments, as follows: 1. Hold at least one workshop with key stakeholders to collect information on the severity of impacts. The workshop can be scoped based upon analysis from previous Public Infrastructure Engineering Vulnerability Committee Protocol reports deemed to be sufficient and applicable based on professional judgement; and 2. Prepare a report with a risk analysis of medium and high-risk items with high level cost estimation of each adaptation option; and
- Use internationally recognized climate projections, and conservative scenarios such as Representative Concentration Pathways 8.5 (not lower emissions scenarios), if supplemental climate parameters and associated probabilities are to be developed.

Dundas Bus Rapid Transit is undergoing a climate risk and vulnerability assessment as part of this scope of work. The information that comes from this work will help to drive the identification and implementation of resilience actions for the Project.

Design for Future Climate

All projects shall:

- Provide designs that account for future climatic conditions over the anticipated lifespan of the project and its individual elements (i.e., account for at a minimum potential increase in rainfall intensity, temperature, windspeed, among others);

- Incorporate the following adaptation measures, where applicable:
  - All assets, especially glass doors, windows, waiting shelter, signage, and solar photovoltaic panels, shall ensure design is able to withstand higher extreme wind gusts (typically ≥ 120 kilometre per hour);
  - All assets are designed to be resilient to freeze thaw cycles;
  - Design communication systems to withstand higher wind gusts (typically ≥ 120 kilometre per hour);
  - Installation of back-up (redundant or spare) sump pumps;
  - Installation of back-up power;
  - Other measures as appropriate to the climate vulnerabilities identified; and
  - Durability per Canadian Standards Association S478.
- Design assets to minimize the likelihood of hazardous conditions arising from snow and ice accumulation including;
- Slips, trips and falls; and
- Falling snow and ice that has accumulated on structures.

Sustainability Plan

All project locations with a minimum capital cost of $50 Million shall submit a Preliminary Sustainability Potential Analysis at no later than 30% design, which shall:

- Outline the sustainable design concept, including the functional and technical requirement;
- Provide a preliminary analysis of opportunities and strategies to achieve a sustainable design, covering each section of this standard, as appropriate to 30% design;
- Provide a checklist and strategy for any sustainability certifications being pursued;
- Provide a preliminary energy analysis; and
- Provide a preliminary climate vulnerability and risk assessment.

Dundas Bus Rapid Transit is undertaking the preliminary sustainability potential analysis as part of this scope of work.

All project locations with a minimum capital cost of $50 Million shall submit a draft Sustainability Plan at no later than 60% Design, which shall:

- Provide an updated checklist and strategy for any sustainability certifications being pursued;
- Include life-cycle cost analysis;

- Include LCA of embodied carbon;
- Include the submission of all design phase reports and analysis that have not yet been submitted;
- Provide sustainability goals, targets and metrics for construction sustainability goals, targets and metrics shall be proposed to align with the Project Agreement or MAPP and Metrolinx Sustainability Plan; and
- Provide the template for the construction sustainability report.

To ensure that the sustainability certifications being pursued by the Project are obtained, the requirement for a Sustainability Strategy should be included in the project agreement language for the Project.

Construction Sustainability Reporting

All project locations with a minimum capital cost of $50 Million, shall:

- Produce a Construction Sustainability Report that:
  - Tracks and monitors sustainable practices during project delivery, reported at six-month intervals;
  - Identifies any targets not met, with a rationale as well as a recovery plan for the next year to get the project back on track to meet the target;
  - Provides any updates as required to the Sustainability Plan; and
  - Updated targets and metrics, if required.
- Produce a Sustainability Substantial Completion Report that:
  - Summarizes the sustainability reporting results during construction prescribed metrics; and
  - Provide copies of any available Environmental Product Declarations for project materials.
- Establish targets for metrics that support the achievement of the project sustainability goals and align with design standards.
- Requiring reporting of construction sustainability metrics will provide data to help drive the implementation of the sustainability plan for the project.

3.2.4 Metrolinx Sustainability Strategy

The following goals and actions identified in the sustainability strategy (2021 to 2026) could be applied to the Project:

Goal 1: Improve our fleet fuel efficiency by 16%

- There is an opportunity to require minimum fuel efficiency levels for buses to be procured for use in the Dundas Bus Rapid Transit to align with the fleet fuel efficiency improvement target.

Goal 2: Capture climate resiliency benefits in 100% of major transit project business cases ($50 million or more)

- The Dundas Bus Rapid Transit Project Assessment Process will evaluate climate resiliency options:
  - Metrolinx should ensure that climate resiliency options identified in the Transit Project Assessment Process are carried over to design and construction through integration into project agreement language.

Goal 3: Divert waste from landfill by 75% at construction projects, 80% at office buildings and facility offices and reduce overall waste generation by 10% across streams

- Opportunity to require the implementation of construction waste diversion activities to achieve 75% construction waste diversion from landfill.
- Opportunity to require a minimum of 80% waste diversion from Bus and Station maintenance facilities.

Goal 4: Reduce our impact on the natural environment and decrease water use

- Require systems for monitoring of potable water use and salt use at facilities associated with the Project.
- Require 10 millimeters onsite retention of water from rainfall events at all new stations associated with the Dundas Bus Rapid Transit.

Goal 5: Achieve 64% of customers reaching a GO station using a sustainable mode of transportation by 2031

- Require the inclusion of bike parking facilities in the design of the Dundas Bus Rapid Transit.

3.2.5 City of Mississauga Climate Change Action Plan

The City of Mississauga is committed to decreasing their carbon footprint and to prepare the community for the effects of a changing climate. In this context, the City of Mississauga has put forward a Climate Change Action Plan that includes actions to both mitigate climate change by reducing emissions and adapt to climate change by managing the impacts (The Corporation of the City of Mississauga, 2019).

The Climate Change Action Plan is built around the central vision that Mississauga will be a low carbon and resilient community. The mitigation goals aim to reduce greenhouse gas emissions by 40% by 2030 and by 80% by 2050 below 1990 levels and position the City of Mississauga competitively in the emerging low carom economy, with the long-term goal of becoming a net zero community. As for adaptation goals, the City of Mississauga wants to increase resilience and capacity to withstand and respond to current and future climate events by taking action on the highest climate related risks (The Corporation of the City of Mississauga, 2019).

Within the next 10 years, the City of Mississauga will focus its goals towards buildings and clean energy, resilient and green infrastructure, accelerating discovery and innovation, low emissions mobility and engagement and partnerships (The Corporation of the City of Mississauga, 2019).

3.2.6 Envision - Preliminary Analysis

AECOM has completed a preliminary analysis of Envision Version 3 and the potential application to the Dundas Bus Rapid Transit. **Table 3-9** presents the potentially applicable credits from Envision version 3, which may be pursued in relation to the Project. Note that where credits relate to buildings and their operations these credits will not likely apply to the Project as no stations or buildings are proposed within the design. Due to the early design stage of the Project it is not possible to accurately determine the levels of achievement that could be anticipated for each credit; however, where information exists an attempt was made to identify potential levels of achievement.

Table 3-1: Potentially Applicable Credits from Envision Version 3

Envision Credit Name	Description of Applicability to Dundas Bus Rapid Transit Project
Quality of Life	
QL1.1 Improve Community Quality of Life	The Dundas Bus Rapid Transit Initial Business Case aligns the proposed project with community need for public transportation infrastructure. The Transit Project Assessment Process will help to gather community feedback and engage the community to identify how the project may support community needs or goals. For these reasons the credit could be applied to the project, with a minimum achievement level of Superior.
QL1.2 Enhance Public Health and Safety	Due to the Project's requirement to meet all applicable health and safety regulations for construction and operations this credit is automatically applicable to the project. Compliance with laws and improvements that exceed legal requirements would result in the Project achieving a level of Improved for this credit.
QL1.3 Improve Construction Safety	The requirement for Construction Management Plans and Construction Safety could result in an achievement level of Enhanced for the project. If contractors were required to provide programs to promote the health and well being of staff outside of the project site, a level of Conserving could be pursued.
QL1.4 Minimize Noise and Vibration	Noise and vibration assessments form part of the design process to mitigate noise impacts from operations. Conducting an assessment would result in the achievement of Improved with respect to the credit. In order to reach higher levels of achievement the project would need to engage stakeholders within the community to set target noise levels for the project.
QL1.5 Minimize Light Pollution	This credit would apply to the Dundas Bus Rapid Transit with respect to outdoor lighting associated with stops, shelters and signage. If Metrolinx Sustainable Design Guidelines for lighting can be implemented on the project, such as the use of exterior light fixtures that meet the Illuminating Engineering Society of North America Full Cutoff Classification or an Uplight rating (as a part of the Backlight, Uplight and Glare rating system) of zero, a level of Conserving could likely be achieved with respect to the credit.
QL1.6 Minimize Construction Impacts	The requirement for a Construction Safety Plan will help to identify and mitigate construction impacts such as noise, safety and access. The creation of a management plan to address construction impacts could result in a minimum achievement level of Improved.
QL2.1 Improve Community Mobility and Access	Due to the Project's intended outcome of the creation of a Bus Rapid Transit corridor connecting the communities of Toronto, Mississauga and Hamilton, the project easily aligns with the achievement of this credit. As the Project is intended to increase transit capacity and decrease congestion, it could achieve a level of Enhanced. If it is also possible for the Project team to engage the community to expand mobility and access options, higher levels of achievement such as Superior or Conserving could be pursued.

Envision Credit Name	Description of Applicability to Dundas Bus Rapid Transit Project
QL2.2 Encourage Sustainable Transportation	As a mass transit project, the Dundas Bus Rapid Transit would automatically achieve a level of Enhanced in relation to this credit because it creates access to mass transportation. If it is possible to encourage the use of active transit within the project design, for example through the integration of bike path connections and bike storage facilities, a level of Superior could be achieved.
Leadership	
LD1.1 Provide Effective Leadership and Commitment	Because of the Sustainable Design Standard requirements for projects to have a sustainability plan and semi-annual reporting of sustainability metrics it may be possible for the Dundas Bus Rapid Transit System to achieve a level of Superior for this credit.
LD1.2 Foster Collaboration and Teamwork	By requiring the development and implementation of a Sustainability Management Plan to guide the consideration of sustainability elements by the Project team, and to establish sustainability goals for the Project, it would be possible to achieve a level of Improved for this credit. In order to seek higher levels of achievement the project team must be able to demonstrate interdisciplinary collaboration throughout the design process which results in systems level performance enhancements to the Project.
LD1.3 Provide for Stakeholder Involvement	Because the Transit Project Assessment Process requires public consultation, the project could achieve a minimum level of Improved with regard to this credit.
LD2.1 Establish a Sustainability Management Plan	By requiring the development and implementation of a Sustainability Management Plan a minimum level of achievement of Improved could be expected for this credit. If it can be demonstrated that the Plan has been implemented and there are mechanisms within the Plan to review progress towards implementation and to revise the Plan when necessary (think International Organization for Standardization Plan-Do-Check-Act), then a level of achievement of Superior could be attained.
LD2.3 Plan for Long Term Monitoring and Maintenance	By requiring the completion of a vulnerability assessment Dundas Bus Rapid Transit System. Will be able to show that the Project design considered these vulnerabilities to develop infrastructure which is less vulnerable to impacts and requires less maintenance. Material selection should be encouraged to consider durability, lifespan and ease of replacement as well as level of disruption repair or replacement will cause to system users. The development and implementation of a formal monitoring and maintenance plan for the Bus Rapid Transit System infrastructure would qualify the Project for a level of Enhanced for this credit.
LD3.2 Develop Local Skills and Capabilities	In order to achieve a level of Improved for this credit the Project would have to demonstrate that it has implemented a training program to develop local skills – this could include designers, contractors, subcontractors or operators. Note that pre-existing internships and training programs do not qualify, and that 1-3 people trained does not qualify as a program. To achieve a level of Enhanced the Project would need to demonstrate that the training program has developed to satisfy an identified skill or capability gap in the work force. It may be possible to demonstrate the achievement of this credit through demonstrating training and skill development for new operators and maintenance staff for the Dundas Bus Rapid Transit operations.

Envision Credit Name	Description of Applicability to Dundas Bus Rapid Transit Project
LD3.3 Conduct a Life-Cycle Economic Evaluation	The Dundas Bus Rapid Transit Project has already had a business case evaluation conducted in 2020 which considers the economic impacts of the Project and alternatives. By expanding upon this information with life cycle economic evaluation of the Project as designed the Dundas Bus Rapid Transit System could achieve a level of Improved for this credit.
Resource Allocation	
RA1.1 Support Sustainable Procurement Practices	If Project agreement language requires the development and implementation of a sustainable procurement policy/program this credit would apply to the Project. The level of achievement is directly dependent upon the percentage of project materials which are procured in alignment with the sustainable procurement policy/program. 5% would give a level of Improved, 15% Enhanced, 25% Superior and 50% Conserving.
RA1.2 Use Recycled Materials	The construction of the Dundas Bus Rapid Transit will result in the generation of waste materials such as asphalt and concrete. Requiring reusing a minimum amount of material within construction could allow for the achievement of this credit. If 5% of material use on the Project (by weight, volume or cost) comes from material reuse, a level of Improved could be expected.
RA1.3 Reduce Operational Waste	The creation of an operational waste management plan which targets the recycling/reuse of 25% of materials from operations would garner a lever of achievement of Improved. This aligns well with Metrolinx's sustainability goal for waste reduction.
RA1.4 Reduce Construction Waste	By requiring to create and implement a construction waste management plan this credit could be achieved. Levels of achievement are based upon the waste diversion goal set within the plan and the amount of diversion that can be achieved. A level of superior would result from 75% material recycling/reuse.
RA2.2 Reduce Construction Energy Consumption	To achieve a level of Improved for this credit the Project must demonstrate that planning reviews were conducted to identify potential options to reduce construction energy consumption and analyze their feasibility for implementation during construction of the Bus Rapid Transit System. If at least 2 strategies are implemented to reduce construction energy consumption the level of achievement would rise to Enhanced. Examples of potential opportunities include: supplementing alternative fuels such as biodiesel for at least 5% of heavy equipment fuel consumption, use at least 50% electric or hybrid fleet vehicles, use Tier IV construction equipment or Tier III with Best Available Technology for at least 75% of non-road equipment fleet greater than 50 horsepower.
RA2.3 Use Renewable Energy	Due to the limited roof space for photovoltaic installations associated with the project it may be difficult to generate substantial energy from renewable sources. However, if the project can be shown to meet 5% of its energy needs (fuel and electricity) from renewable sources a level of Improved could be expected. Note that because the project is a Bus Rapid Transit the buses used would need to be electric or use biofuels.

Envision Credit Name	Description of Applicability to Dundas Bus Rapid Transit Project
RA3.3 Reduce Construction Water Consumption	To achieve a level of Improved for this credit the Project must demonstrate that planning reviews were conducted to identify potential options to reduce water consumption during construction. In addition, the project must provide evidence that at least one such strategy has been implemented. If it can be demonstrated that three strategies have been implemented to reduce construction water consumption a level of Enhanced may be achievable. Examples of potential strategies include: the use of high efficiency fixtures in trailers and offices to demonstrate a 40% reduction in water usage from these areas, the use of alternatives for dust suppression such as covering stockpiles with tarps or tackifiers, stormwater harvesting showing a 40% savings in water use by use of harvested rainwater, or use of alternatives for curing concrete showing a 50% reduction in water usage from baseline use in this activity.
Natural World	
NW2.2 Manage Stormwater	This credit is oriented towards the minimization of the impact of development on stormwater runoff quantity, rate and quality. Because of the high surface area of impermeable surface associated with a Bus Rapid Transit there is opportunity to integrate systems for detention and treatment of stormwater runoff from the project area. If the project is able to detain and treat 100% of the 85^{th} percentile local 24-hour event a level of Improved could be achieved. An erosion and sediment control plan would also be required for construction activities.
NW2.4 Protect Surface and Groundwater Quality	Through the development and implementation of a spill prevention plan, and the avoidance of impacts to surface water and groundwater quality during construction and operations a level of Improved could be achieved for this credit.
NW3.3 Maintain Floodplain Functions	The intent of this credit is to preserve floodplain functions by limited the development within floodplains. A level of achievement of Improved could be attained though the identification of 100-year floodplains in the vicinity of the project area, and avoidance of floodplain areas to allow at least 75% of the vegetated area within the floodplain to remain following completion of construction.
NW3.4 Control Invasive Species	Through the creation of a construction management plan which includes practices to prevent the unintentional introduction of invasive species to the Project area a level of Improved could be achieved for this credit.
Climate and Resilience	
CR1.1 Reduce Net Embodied Carbon	Metrolinx has expressed interest in calculating the net embodied carbon associated with the construction of the Dundas Bus Rapid Transit. Unfortunately, at the current Project phase there is not enough detail regarding the material types and quantities to be used for an accurate estimate of the project's embodied carbon to be performed. However, if embodied carbon is calculated for the project design, and modifications can be made to the design to show a 5% reduction in embodied carbon then a level of Improved could be achieved. Higher levels of achievement are attainable with greater reductions in project embodied carbon, to a maximum of 50% reduction for a level of Conserving.

Envision Credit Name	Description of Applicability to Dundas Bus Rapid Transit Project
CR1.2 Reduce Greenhouse Gas Emissions	This credit is intended to drive the reduction of greenhouse gas emissions associated with the operation of the completed project. A greenhouse gas comparison is being done between the baseline case and implementation of the project for the design construction and operation phases. This information could be used to support application for the credit Levels of achievement for this credit are based upon the reduction of emissions from baseline that are achieved. A reduction of 10% results in an Improved level of achievement whereas a 100% reduction would result in a Conserving level of achievement.
CR1.3 Reduce Air Pollutant Emissions	This credit is intended to reduce the air pollutant emissions from the operation of the infrastructure. Where strategies can be implemented to reduce air pollutants from operations, for example the use of electric buses) a level of Improved could be achieved. Where systems have also be installed for ongoing monitoring of air pollution sources a level of Enhanced could be expected.
CR2.1 Avoid Unsuitable Development	Where it can be shown that the project area has been assessed for potential hazards such as flood prone areas, steep slopes, and adverse geology and the project has been sited to avoid or minimize these hazards a level of Improved can be achieved. The Transit Project Assessment Process will involve considerations of risks to siting such as floodplains.
CR2.2 Assess Climate Change Vulnerability	Where it can be demonstrated that climate change threats and hazards to the project have been assessed, a level of improved could be achieved for this credit. Assessment of climate change threats and vulnerabilities for the project is being conducted as part of the Transit Project Assessment Process
CR2.3 Evaluate Risk and Resilience	This scope of work includes an assessment of the climate risks to the Project, which would fall within the Improved level of achievement for this credit. If the evaluation was expanded beyond the project boundaries to include a system level evaluation or a community level of evaluation, then a higher level of achievement would be possible.
CR2.4 Establish Resilience Goals and Strategies	This credit, CR2.3 and CR2.5 are linked. This credit can be achieved through the development of resilience goals and strategies that manage the results of the risk evaluation conducted in CR2.3. The development of the strategy would result in a level of Enhanced. Where stakeholder input is gathered for the strategy a level of Superior could be achieved. If the strategy can be aligned with broader community goals it is possible to seek a level of achievement of Conserving.
CR2.5 Maximize Resilience	If there is evidence of a comprehensive approach to implementing the resilience goals and strategies established in CR2.4 the project could achieve a level of Improved for this credit.
CR2.6 Improve Infrastructure Integration	This credit is intended to promote the integration of the infrastructure project into a connected and diverse infrastructure system. Because the Dundas Bus Rapid Transit is intended to connect public transportation networks across the Greater Toronto and Hamilton Area it lends itself well to the concept of infrastructure integration. It is likely that an achievement level of Superior could be justified for the project.

From this exhaustive listing of sustainability initiatives and potential Envision credits that can be incorporated into further phases of the project at Metrolinx discretion.

4. Effects of the Transit Project on Climate Change

4.1 Methodology

4.1.1 Assessment Boundary

The boundary of the assessment is defined in both a temporal and a technical basis. The temporal boundary defines the life of the Project for which the greenhouse gas emissions are estimated. Based on the information available at the time of the study, it was assumed that the construction period for the Project would be primarily between 2024 and 2026. The Project lifespan is 60 years from the start of the Bus Rapid Transit operation in 2027; therefore, greenhouse gas emissions has been projected out to the year 2086.

The technical boundary of the assessment is restricted to the construction, operation, and maintenance of the Mississauga East Study Area.

The methodology used for the quantification of greenhouse gases is based on modelling the kilometres travelled by vehicles (vehicle kilometres travelled) in a study area[1] without the Project and with the Project. Since the available modelling results are based on the difference in kilometres travelled over the entire study area, which also includes other projects by Metrolinx, it is not possible to define the impact of each of the Bus Rapid Transit segments.

The difference in kilometres travelled by vehicles with and without the Project indicates that within the study area, the Project will influence traffic behaviour. However, in the absence of kilometres travelled by vehicles data by Bus Rapid Transit segment, it is not possible to know where this change in traffic behaviour is occurring in the region. Thus, the greenhouse gas quantification is for the entire Bus Rapid Transit RT corridor.

The assessment does not include any indirect work that may or may not occur as a result of the Project.

1. Provided by the Metrolinx Modelling and Geomatics group and based on initial transportation demand modelling for the 2041 AM peak period using the Golden Greater Horseshoe Model v4 (GGHMv4), which considers the entire Greater Toronto and Hamilton Area (GTHA).

4.1.2 Greenhouse Gases Considered

This assessment considers the seven gases defined as greenhouse gases under the United Nations Intergovernmental Panel on Climate Change (IPCC):

- Carbon dioxide (CO_2),
- Methane (CH_4),
- Nitrous oxide (N_2O),
- Hydrofluorocarbons (HFCs – a family of gases),
- Nitrogen trifluoride (NF_3),
- Fluorocarbons (PFCs – another family of gases), and
- Sulfur hexafluoride (SF_6).

In the current assignment, greenhouse gases will mostly be emitted as CO_2. Small amounts of CH_4 and N_2O are also anticipated and are thus quantified using an appropriate emissions factor. The latter are converted into tonne of CO_2 equivalent (tCO_2e) using global warming potentials (GWP) sourced from the Intergovernmental Panel on Climate Change 4th Assessment Report (**Table 4-1**).

Table 4-1: Greenhouse Gases Considered

Greenhouse Gas	Chemical Formula	Global Warming Potential (100 years)
Carbon Dioxide	CO_2	1
Methane	CH_4	25
Nitrous oxide	N_2O	298

4.1.3 Emission Scopes

The scope of the emissions inventory includes all direct emissions (scope 1) from greenhouse gases sources that are owned or controlled by the Project (scope 1) and any major indirect emissions that are consequence to the Project (scope 2) from the construction and for the operation and maintenance of the Mississauga East Study Area.

The main emission sources are identified in **Table 4-2**.

Table 4-2: Emission Scopes

Source Scope	Construction Phase (2024-2026)	Operation and Maintenance (2027 – 2086)
Scope 1 – Direct Source	▪ Fuel combustion from construction equipment and vehicles ▪ Fuel combustion from temporary heating ▪ Fuel combustion from passenger pickup trucks (e.g., site inspector, Project manager)	▪ Fuel combustion from autos
Scope 2 – Energy Indirect Emission	▪ None	▪ Electricity consumption from buses and autos

4.1.4 Data and Calculation Procedures

The greenhouse gas emissions inventory has been completed in line with the ISO 14064-2 standard. The key principles of the ISO 14064-2 standard and how the assessment has addressed them are summarized below:

- **Relevance:** The relevance of greenhouse gases emission sources, data and methodologies must be appropriate for the purpose of the emissions assessment. As described in **Sections 4.1.1, 4.1.2, and 4.1.3** only greenhouse gases sources relevant to the construction, operation and maintenance of the Project itself have been considered. The data and methodologies for estimating baseline and Project greenhouse gas emissions are at a conceptual level. The Project is in the planning phase and a detailed design has not been completed; therefore, the data and methodologies are relevant to the stage of the Project but should still provide sufficient and relevant information for the purposes of the Climate Lens assessment. Emissions factors and estimates are sourced from Canada's National Inventory Report or Intergovernmental Panel on Climate Change sources where possible and are referenced in detail.
- **Completeness:** All relevant greenhouse gas emissions should be included in the assessment with supporting information on criteria and procedures. **Sections 4.1.3** and **4.1.5** describe what sources were included and excluded.
- **Consistency:** The assessment must enable meaningful comparisons of greenhouse gases-related information. A key component of the assessment is the comparison of the Project against a baseline case. The baseline case has been defined as a conservative viable alternative and its design components and associated emission sources have been derived based on the same assumptions as the Project case.

- **Accuracy:** The assessment must reduce bias and uncertainties as far as is practical. Quantification of the Project's anticipated baseline and Project emissions is based on available data, emissions factors and estimation methodologies used, recognizing that uncertainties exist due to the early stage of Project development, and the limited emissions factors available for the relevant activities. Where there is uncertainty, a conservative approach has been taken and described.
- **Transparency:** The assessment must disclose sufficient and appropriate greenhouse gases-related information to allow conclusions and decisions to be made with reasonable confidence. For each emissions source, description of the information and references used in the emissions calculation has been provided in **Sections 4.2 and 4.3**. All assumptions are identified in **Section 4.1.6**.
- **Conservativeness:** The assessment must use conservative assumptions, values and procedures to ensure that greenhouse gases emission reductions are not overestimated. To avoid over- or under-estimation of emissions, the baseline and Project cases use identical assumptions for fuel consumption by vehicle and the proportion of vehicles consuming gasoline or diesel in the regional vehicle fleet.

4.1.5 Exclusions from the Assessment

In addition to the direct (scope 1) and indirect (scope 2) greenhouse gas emissions of the Project which are included in this assessment, this type of Project could generate indirect emissions that occur in the Project value chain (scope 3) such as emissions resulting from production and transportation of construction materials, workers and staff commuting to site, production and transportation of consumables (e.g., chemicals, supplies), and upstream emissions associated with fuel and energy. However, these emissions have not been quantified, per the Climate Lens guideline that supply chain emissions are not required to be included.

The traffic modelling results provided by Metrolinx estimate that at a regional scale, the difference in kilometres travelled by vehicles-trucks between the Baseline Scenario and the Project Scenario would be 0.06%. This difference being negligible, therefore it was decided not to consider truck emissions in this assessment.

Because the 7.2-kilometre corridor segment will not change Metrolinx or the City's solid waste management system, the greenhouse gas emissions from solid waste generation, transportation, treatment, and disposal have not been quantified.

As the final project design is not completed, the number of lanes added or removed is not available at the time of this assessment. greenhouse gas emissions associated with pavement and vehicle maintenance are assumed to be equal for both scenarios and will not be evaluated.

Greenhouse gas emissions related to the potential increase in vehicle traffic due to the impact of road closures during construction work on the segment were not quantified in this assessment. Indeed, the vehicle traffic data used in this study are modelled at a regional scale and do not provide data on the consequences on the 7.2-kilometre segment. It is assumed that the potential traffic disruption on this segment is negligible at the regional scale during the construction of the Project. This assumption is supported by the results of a study[2] carried out during a highway reconstruction Project in New Jersey that showed that traffic disruption generated less than 1% of the total greenhouse gas emissions resulting from the construction work.

Finally, emissions associated with future major refit and/or decommissioning of the 7.2-kilometre corridor segment are not quantified. No emissions or emissions removals associated with this Project are anticipated to occur outside of Canada.

4.1.6 Assumptions

The key assumptions used in the development of the emission inventories are described below.

4.1.6.1 Construction Period

Construction emissions include activities associated with the use of heavy equipment for site preparation, structure build up and the installation of plumbing, drainage, mechanical and electrical services. Since the project design is not finalized, a detailed equipment list and energy usage demand are not yet available during the current phase of the Project. As a result, construction cost is used as a proxy to calculate emissions.

Emissions from the construction phase are estimated based on cost estimates using an energy intensity index related to construction value. The greenhouse gases intensity data are taken from a CEEDC study reporting greenhouse gas emissions data availability in the construction sector from combustion of fossil fuels. According to this study, the emission intensity of the construction industry in Ontario was evaluated in 2015 at 49.42 metric tonnes of CO_2 equivalents per million 2007$ (**Table 4-3**).

2. Life Cycle Greenhouse Gas Emissions associated with a Highway Reconstruction: A New Jersey case study Noland R.B., Hanson C.S. (2015) Journal of Cleaner Production, 107, pp. 731-740.

Table 4-3: Canadian Energy and Emissions Data Centre Emissions Intensity for Quantifying Greenhouse Gas Emissions from Construction Activity

Emission (metric tons of CO_2e)	Value Assessed in 2007 million $	Intensity (metric tons of CO_2e / 2007 million $)
1,795,053	**36,326**	**49.42**

Source: Canadian Energy and Emissions Data Centre 2017. Energy Use and Related Data: Canadian Construction Industry 1990 to 2015, Simon Fraser University, Burnaby.

The emission intensity is adapted for 2024, 2025 and 2026 through the following steps:

1. The amount of 36,326 million 2007 $ is adjusted to 2021 $ using the historical Canadian price index data from the inflation calculator of the Bank of Canada[3].
2. Conversion of 2021 values to 2024, 2025 and 2026 data are based on an expected annual inflation rate of 2%[4].
3. Emission intensity (tCO_2e/K $) is calculated for 2024, 2025 and 2026 using the following formula:

Intensity = Emission / Value assessed in the year

The following table presents the results of each of these steps.

Table 4-4: Emissions Intensities for Quantifying Greenhouse Gas Emissions from Construction Activity (2024 to 2026)

Year	Value Assessed Year $Million	Intensity Metric tons of CO2e / Year $Million
2007	36,326	49.42
2024	48,463	37.04
2025	49,433	36.31
2026	50,421	35.60

3. Bank of Canada (2021): https://www.bankofcanada.ca/rates/related/inflation-calculator/
4. Metrolinx (2019). Business Case Manual Volume 2: Guidance: http://www.metrolinx.com/en/regionalplanning/projectevaluation/benefitscases/Metrolinx-Business-Case-Guidance-Volume-2.pdf

4.1.6.2 Operations and Maintenance

The main source of greenhouse gas emissions during the operation and maintenance phase comes from vehicles using the 7.2-kilometre corridor segment. These emissions are calculated from the annual estimated fossil fuel and electricity consumption of autos.

For the buses, it has been assumed that the fleet would be entirely electric from the first year of operation. As such, only the annual electricity consumption was estimated. This assumption has been made exclusively in the Sustainability and Climate Change Report for the purpose of quantifying greenhouse gases, and is deemed appropriate for this purpose due to the length of the assessment of the Project (to 2086) the rapidly emerging technologies and anticipated changes in regulatory regimes.

Generally, alternate propulsion technologies for the fleet are a key interdependency for the Dundas Bus Rapid Transit, that is, it is a key factor in the transport network that may be impacted by or impact the performance of the Dundas Bus Rapid Transit.

Fuel consumption rates

Car fossil fuel consumption is obtained by multiplying the fuel consumption rate calculated using MOVES3 with the annual number of kilometres travelled by vehicles for autos.

MOVES3 is a United States Environmental Protection Agency software that generates pollutant emission rates. Although fuel consumption is not directly accessible from MOVES, it is easily obtained using the pollutant “Total Energy Consumption” by vehicles. The Table 4-5 shows the model parameters used.

Table 4-5: MOVES3 Parameters

Parameter Category	Parameter Used
Modelling type	Onroad, national scale, emission rate
Associated U.S. County	Cook County, Illinois
Modelling year	2027
Vehicle type	sourceTypeID=21 – Passenger Car
Fuel type	fuelTypeID=1 – Conventional Gasoline fuelTypeID=2 – Conventional Diesel Fuel
Road type	roadTypeID=5 - Urban Unrestricted Access
Modelled substance	pollutantID=91 – Total Energy Consumption

The rate calculated in MOVES for 2027 is held constant throughout the evaluation period without considering the likely evolution of technologies. This rate varies according to the speed of autos. The analysis assumes an average speed of 40 kilometre per hour for autos traveling on Dundas Street, based on Google Maps (**Table 4-6**). This theoretical speed is assumed to be representative of the average speed of autos in the study area.

Table 4-6: Fossil Fuel Consumption Rates – MOVES3

Vehicle Type	Average Speed (kilometre/h)	Fuel Type	Fuel Consumption (L/kilometre)
Passenger car	40	Conventional Gasoline	0.080
Passenger car	40	Conventional Diesel Fuel	0.069

Average emission rates from electricity consumption for buses and autos are presented in **Table 4-7**.

Table 4-7: Electricity Consumption Rates

Vehicle Type	Fuel Type	Fuel Consumption (kWh/kilometre)
Passenger car[5]	Electricity	0.20
Local Bus[6]	Electricity	1.15
Bus Rapid Transit[5]	Electricity	1.63

Annual number of kilometres travelled by autos and buses

The number of kilometres travelled by autos and buses with and without the Project for 2041 are provided by Metrolinx at a regional level (**Table 4-8**) which includes the project area and Toronto, Peel, Halton and Hamilton.

The annual kilometres travelled by vehicles for 2041 are extrapolated to the remainder of the operating years using the growth factors presented in **Table 4-8**. These factors are capped after 30 years of operations to reflect uncertainty.

5. 2020 Fuel Consumption Guide – Combined consumption. Government of Canada (2020).
6. ViriCiti Report E-Bus Performance. Viriciti (2020). https://viriciti.com/wp-content/uploads/2020/07/ViriCiti-E-Bus-Performance-Report-July2020.pdf

Table 4-8: Annual Vehicle Kilometres Travelled Estimation Parameters[7]

Parameter	Value
2041 Auto kilometres travelled in Regional Area under Baseline Scenario	31,410,262,764
2041 Auto kilometres travelled in Regional Area under Project Scenario	31,303,929,744
2041 Local Bus kilometres travelled in Regional Area under Baseline Scenario	65,340,220
2041 Local Bus kilometres travelled in Regional Area under Project Scenario	65,005,336
2041 Bus Rapid Transit Bus kilometres travelled in Regional Area under Baseline Scenario	3,779,604
2041 Bus Rapid Transit kilometres travelled in Regional Area under Project Scenario	11,059,020
Kilometres travelled annual growth rate – Auto	2%
Kilometres travelled growth rate – Bus	2%

The average diesel/gasoline distribution of the auto fleet is set based on the 2019 Statistics Canada study on Sales of fossil fuel used for road motor vehicles in Ontario[8] (**Table 4-9**).

Table 4-9: Fuel Used for Road Motor Vehicles in Ontario – 2019

Type of Fuel	Fuel Used (m^3)	Percentage
Gasoline	16,842,931	75 %
Diesel	5,569,736	25 %

The proportion of electric autos in the regional fleet is estimated based on data and future milestones for vehicle electrification provided by the City of Mississauga (**Table 4-10**). The growth in the proportion of electric vehicles between each milestone is assumed to be exponential.

Table 4-10: Proportion of Electric Autos in the Regional Fleet

Year	Electricity (%)
2018	0.6
2030	10
2050	100

7. Provided by the Metrolinx Modelling and Geomatics group and based on initial transportation demand modelling for the 2041 AM peak period using the Golden Greater Horseshoe Model v4 (GGHMv4), which considers the entire Greater Toronto and Hamilton Area (GTHA).
8. Statistics Canada. Table 23-10-0066-01 Sales of fuel used for road motor vehicles, annual (x 1,000)

With this distribution and fuel consumption rates, the annual number of kilowatt hours (kWh) and litres of fossil fuel consumed by autos are estimated as follows:

$$VKT_{total} = VKT_{fossil\ fuel} + VKT_{electricity} \tag{1}$$

Assuming,

$$p_{electricity} + p_{fossil\ fuel} = 1 \tag{2}$$

$$VKT_{fossil\ fuel} = VKT_{total} \times p_{fossil\ fuel} \tag{3}$$

$$VKT_{electricity} = VKT_{total} \times p_{electricity} \tag{4}$$

$$VKT_{total} = \left(\frac{L_{diesel}}{C_{diesel}} + \frac{L_{gasoline}}{C_{gasoline}}\right) + \frac{kWh_{total}}{C_{electricity}} \tag{5}$$

$$L_{total} = L_{diesel} + L_{gasoline} \tag{6}$$

Thus

$$L_{total} = \frac{VKT_{total} \times p_{fossil\ fuel}}{\left(\frac{0.25}{C_{diesel}} + \frac{0.75}{C_{gasoline}}\right)} \tag{7}$$

With

VKT_{total} : total annual number of kilometres travelled by autos (kilometre/y)

$VKT_{fossil\ fuel}$: annual number of kilometres travelled by fossil fuel-powered autos (kilometre/y)

$VKT_{electricity}$: annual number of kilometres travelled by electric-powered autos (kilometre/y)

$p_{electricity}$: annual proportion of electric-powered autos (%)

$p_{fossil\ fuel}$: annual proportion of fossil fuel-powered autos (%)

L_{total} : total annual number of litres of fuel consumed by autos (L/y)

L_{diesel} : annual number of litres of diesel consumed by autos (L/y)

$L_{gasoline}$: annual number of litres of gasoline consumed by autos (L/y)

kWh_{total} : annual number of kWh consumed by autos (kWh/y)

C_{diesel} : average diesel consumption rate of autos (L/kilometre)

$C_{gasoline}$: average gasoline consumption rate of autos (L/kilometre)

$C_{electricity}$: average electricity consumption rate of autos (kWh/kilometre)

For buses, the number of kilometres travelled per year is multiplied by the estimated electricity consumption rates (Table 4-7) specific to each type of bus.

Emission Factors

Emission factors for electricity and fossil fuels are taken from the National Inventory Report 1990-2018: Greenhouse Gas Sources and Sinks in Canada. Emissions factors used are shown in **Table 4-11**.

Table 4-11: Emission Factors Associated with Fuel Consumption

Fuel Type	Emission Factor			
	CO2	CH4	N2O	CO2e
Diesel[9]	2,681	0.068	0.21	
Gasoline[10]	2,307	0.23	0.47	
Electricity[11]			30 g CO_{2e}/kWh	

4.2 Baseline Case

4.2.1 Description

Without the Project, the most likely Baseline Scenario is the absence of any transit enhancement or public realm improvements in the Dundas Corridor. This baseline case represents the conditions most likely to occur in the absence of the proposed Project.

The main emission sources for the baseline are described in **Table 4-12**.

Table 4-12: Baseline Case Main Emissions Sources

Equipment / Emissions Category	Description
Operations and Maintenance Mobile Fuel Combustion	Fossil fuel for autos
Operations and Maintenance Electricity Consumption	Electricity for autos and buses

9. Table A6.1-13 Emissions Factors for Energy Mobile Combustion Sources – Diesel vehicles: Light-duty Diesel Vehicles – Moderate Control
10. Table A6.1-13 Emissions Factors for Energy Mobile Combustion Sources – Gasoline vehicles: Light-duty Gasoline Vehicles – Tier 1

11 Table A13-7.2 Electricity Generation and greenhouse gases Emission Details for Ontario, National Inventory Report 1990-2018: Greenhouse Gas Sources and Sinks in Canada.

4.2.2 Construction Emission

No emission was estimated for construction because the corridor already exists.

4.2.3 Operations and Maintenance Emissions

Operations and Maintenance emissions are estimated based on the annual fuel consumption of vehicles travelling on the segment.

According to the vehicle kilometres travelled data of the Metrolinx model and using equations 5 and 7, the emissions associated with fuel and electricity consumptions by autos and buses are estimated.

The 2030 Operations and Maintenance baseline emissions inventory breakdown is presented in **Table 4-13**. The annual emissions breakdown can be found in **Appendix B**.

Table 4-13: Baseline Operations and Maintenance Emissions

Parameter	Unit	Value
Diesel Consumption		
Vehicles on the Road Network		
Annual Vehicle Kilometres Travelled	kilometre/y	7,039,709,551
Average Fuel Consumption	L/kilometre	0.0691
Vehicle Annual Fuel Consumption	L/y	486,443,930
Emissions greenhouse gases = Fuel Consumption × Emission Factor	g CO_2e/L	
CO_2 Emission Factor	g CO_2/L	2,681
CH_4 Emission Factor	g CH_4/L	0.068
N_2O Emission Factor	g NO_2/L	0.21
CO_2 Emissions	g CO_2/y	1,304,156,176,265
CO_2 Emissions	kg CO_2/d	3,573,031
CH_4 Emissions	g CH_4/y	33,078,187
CH_4 Emissions	kg CH_4/d	91
N_2O Emissions	g N_2O/y	102,153,225
N_2O Emissions	kg N_2O/d	280
Gasoline Consumption		
Vehicles on the Road Network		
Annual Vehicle Kilometres Travelled	kilometre/y	18,296,153,646
Average Fuel Consumption	L/kilometre	0.0804
Vehicle Annual Fuel Consumption	L/y	1,471,010,753
Emissions greenhouse gases = Fuel Consumption × Emission Factor		
CO_2 Emission Factor	g CO_2/L	2,307
CH_4 Emission Factor	g CH_4/L	0.23
N_2O Emission Factor	g NO_2/L	0.47

Parameter	Unit	Value
CO_2 Emissions	g CO_2/y	3,393,621,807,410
CO_2 Emissions	kg CO_2/d	9,297,594
CH_4 Emissions	g CH_4/y	338,332,473
CH_4 Emissions	kg CH_4/d	927
N_2O Emissions	g N_2O/y	691,375,054
N_2O Emissions	kg N_2O/d	1,894
Electricity Consumption		
Buses on the Road Network		
Bus annual fuel consumption	kWh/y	65,388,200
Emissions greenhouse gases = Fuel Consumption × Emission Factor	g $CO_{2\ e}$/kWh	30
Total CO_{2e}	kg CO_{2e}/d	5,374
Vehicles on the Road Network		
Annual Vehicle Kilometres Travelled	kilometre/y	2,816,939,785
Average Fuel Consumption	kWh/kilometre	0.2
Vehicle Annual Fuel Consumption	kWh/y	563,387,957
Emissions greenhouse gases = Fuel Consumption × Emission Factor	g $CO_{2\ e}$/kWh	30
BASELINE TOTAL EMISSIONS IN CO_2 EQUIVALENT		
Total CO_2	kg CO_2/d	12,922,305
Total CH_4	kg CH_4/d	1,018
Total N_2O	kg N_2O/d	2,174
GWP CH_4	-	25
GWP N_2O	-	298
Total CO_2e	kg CO_2e/d	13,595,611
	tonnes CO_2e/y	4,962,398

Greenhouse gas emissions from vehicles travelling through the study area are estimated to be 4,962,398 tCO_2eq in 2030.

For the whole 60 years of operation, greenhouse gas emissions from the Baseline Scenario are estimated to be 107,978,400 tCO_2eq for the study area.

4.3 Project Case

4.3.1 Description

The Project case involves the greenhouse gas emissions from the Project as planned for implementation. The Project case represents the construction and operation and maintenance of a 7.2-kilometre corridor segment extending from Confederation Parkway to the City of Toronto boundary at Etobicoke Creek, within the City of Mississauga.

The Project will assess several strategies to reduce net embodied carbon during design and preconstruction phases. A non-exhaustive list of the strategies considered is as follows:

- Define targets for reducing embodied carbon;
- Design and size the Project to reduce overall materials used;
- Use recycled or lower embodied carbon materials;
- Use local contractors to reduce transportation emissions;
- Consider maintenance and repair needs when selecting materials; and
- Minimize waste and provide sufficient space for waste separation and monitoring.

The main greenhouse gases emission sources for the Project are described in **Table 4-14**.

Table 4-14: Project Case Main Greenhouse Gas Emissions Sources

Equipment / Emissions Category	Description
Operations and Maintenance Mobile Fuel Combustion	Fuel for autos
Construction On-Road Vehicles	Trucks used for material transportation
Construction Non-Road Vehicles and Site Trailer	Equipment necessary for the construction of the Project
Operations and Maintenance Electricity Consumption	Electricity for autos and buses

4.3.2 Construction Emission

The main construction phase is scheduled to occur in January 2024 with an overall completion by December 2026. The construction cost for the entire Bus Rapid Transit Project was estimated in 2020 at $460 M. Without a precise planned timing of each construction phase activity, the total quantity of greenhouse gas emissions during construction is distributed equally between 2024 and 2026 according to the estimated total construction costs. As stated in section 4.1.6.1, greenhouse gas emissions are valued based on cost estimates using an energy intensity index related to construction value (**Table 4-15**).

Table 4-15: Project Construction Greenhouse Gas Emissions

Year	Construction Costs Year $Million	Emissions Tonne CO_2e/y
2024	166	6,148

2025	169	6,148
2026	173	6,148

Greenhouse gas emissions during the construction phase are estimated at 18,443 tCO_2e.

4.3.3 Operations and Maintenance Emissions

Operations and maintenance emissions include the ongoing costs for operating the Bus Rapid Transit and for maintaining the infrastructure. These costs consider the implementation of Bus Rapid Transit and the reduction in frequency for local bus routes.

According to the results of the Metrolinx model and using equations 5 and 7, the emissions associated with fuel and electricity consumptions by autos and buses are estimated.

The Operations and Maintenance Project emissions inventory breakdown for year 2030 is presented in **Table 4-16**. The annual emissions breakdown can be found in **Appendix C**.

Table 4-16: 2030 Project Operations and Maintenance Emissions

Parameter	Unit	Value
Diesel Consumption		
Vehicles on the Road Network		
Annual vehicle kilometres travelled	kilometre/y	7,015,878,054
Average Fuel Consumption	L/kilometre	0.0691
Vehicle Annual Fuel Consumption	L/y	484,797,174
Emissions greenhouse gases = Fuel Consumption × Emission Factor		
CO_2 Emission Factor	g CO_2/L	2,681
CH_4 Emission Factor	g CH_4/L	0.068
N_2O Emission Factor	g NO_2/L	0.21
CO_2 Emissions	g CO_2/y	1,299,741,222,279
CO_2 Emissions	kg CO_2/d	3,560,935
CH_4 Emissions	g CH_4/y	32,966,208
CH_4 Emissions	kg CH_4/d	90
N_2O Emissions	g N_2O/y	101,807,406
N_2O Emissions	kg N_2O/d	279
Gasoline Consumption		
Vehicles on the Road Network		
Annual vehicle kilometres travelled	kilometre/y	18,234,215,760
Average Fuel Consumption	L/kilometre	0.0804
Vehicle Annual Fuel Consumption	L/y	1,466,030,947
Emissions greenhouse gases = Fuel Consumption × Emission Factor		
CO_2 Emission Factor	g CO_2/L	2,307

Parameter	Unit	Value
CH_4 Emission Factor	g CH_4/L	0.23
N_2O Emission Factor	g NO_2/L	0.47
CO_2 Emissions	g CO_2/y	3,382,133,394,905
CO_2 Emissions	kg CO_2/d	9,266,119
CH_4 Emissions	g CH_4/y	337,187,118
CH_4 Emissions	kg CH_4/d	924
N_2O Emissions	g N_2O/y	689,034,545
N_2O Emissions	kg N_2O/d	1,888
Electricity Consumption		
Buses on the Road Network		
Bus Annual Fuel Consumption	kWh/y	74,621,406
Emissions greenhouse gases = Fuel Consumption × Emission Factor	g CO_{2e}/kWh	30
Total CO_{2e}	kg CO_{2e}/d	6,133
Vehicles on the Road Network		
Annual vehicle kilometres travelled	kilometre/y	2,807,403,611
Average Fuel Consumption	kWh/kilometre	0.2
Vehicle Annual Fuel Consumption	kWh/y	561,480,722
Emissions greenhouse gases = Fuel Consumption × Emission Factor	g CO_{2e}/kWh	30
Total CO_2e	kg CO2e / d	46,149
PROJECT TOTAL EMISSIONS IN CO_2 EQUIVALENT		
Total CO_2	kg CO_2/d	12,879,336
Total CH_4	kg CH_4/d	1,014
Total N_2O	kg N_2O/d	2,167
GWP CH_4	-	25
GWP N_2O	-	298
Total CO_2e	kg CO_2e/d	13,550,363
Total CO_2e	tonnes CO_2e/y	4,945,882

Greenhouse gas emissions from vehicles travelling through the study area are estimated to be 4,945,882 tCO_2eq in 2030.

For the whole 60 years of operation, greenhouse gas emissions from the Project scenario are estimated to be 107,637,943 tCO_2eq for the study area.

4.4 Estimated Net Reduction in Emissions

The cumulative emission reduction over the lifetime of the Project is summarized in **Table 4-17**.

Table 4-17: Summary of Greenhouse Gas Emissions for the Two Scenarios

Period	Year	Emissions (tCO2eq) Baseline Scenario	Emissions (tCO2eq) Project Scenario
Construction Phase	2024-2026	-	18,443
Year of operation - Example	*2030*	*4,962,398*	*4,945,882*
Operation Phase (60 years)	2027-2086	107,978,400	107,637,943
Total Greenhouse Gas Emissions	2024-2086	107,978,400	107,656,386

As shown in **Table 4-17**, the Project will lower the greenhouse gas emissions by 16,516 tonnes of CO_2e in 2030 compared to the baseline scenario (non-cumulative). Over the Project's lifecycle, the accumulated greenhouse gases reduction is expected to be 322,014 tonnes of CO_2e.

4.5 Conclusion of the greenhouse gases Reductions Assessment

The Project case has been shown to be the preferred option with respect to greenhouse gas emissions. The greenhouse gases assessment shows emission reductions comparing baseline and Project cases over a 63-year lifecycle of 322,014 tonnes of CO_2e. The Operations and Maintenance emissions drive the total greenhouse gas emissions.

5. Effects of Climate Change on the Transit Project

The effects of Climate Change on the Project are being determined by completing a Climate Change Risk Assessment based on the International Organization for Standardization 31000 Risk Management Standard and to review the existing condition of riverine flooding.

5.1 Establishing Context

The Climate Change Resilience Assessment includes the following five steps: establishing context, risk identification, risk evaluation and risk treatment and adaptation measure. In order to better compare and integrate results obtained in the Metrolinx's Public Infrastructure Engineering Vulnerability Committee protocol assessment into the Climate Change Resilience Assessment, section 5.1.5 will map the Public Infrastructure Engineering Vulnerability Committee's 0 to 7 scoring scale into the Climate Lens' 1 to 5 scoring scale.

The scope and boundaries of the assessment encompass time periods and areas during and within which the Project components are likely to interact with or be influenced by climate risks. The scope of the assessment for this Project considers climate change impacts on the design as well as operation and maintenance phases of the future Bus Rapid Transit system. The assessment does not include any indirect work that may or may not occur as a result of the Project. The infrastructure lifespan is estimated at 60 years; therefore, the assessment has been carried out using the projections for 2081 to 2100.

5.1.1 Project Components

The following six project components of the future Bus Rapid Transit system were determined as relevant to the climate change resilience assessment for their potential sensitivity to certain climate conditions. **Table 5-1** presents the Project components as well as a list of elements associated to each component.

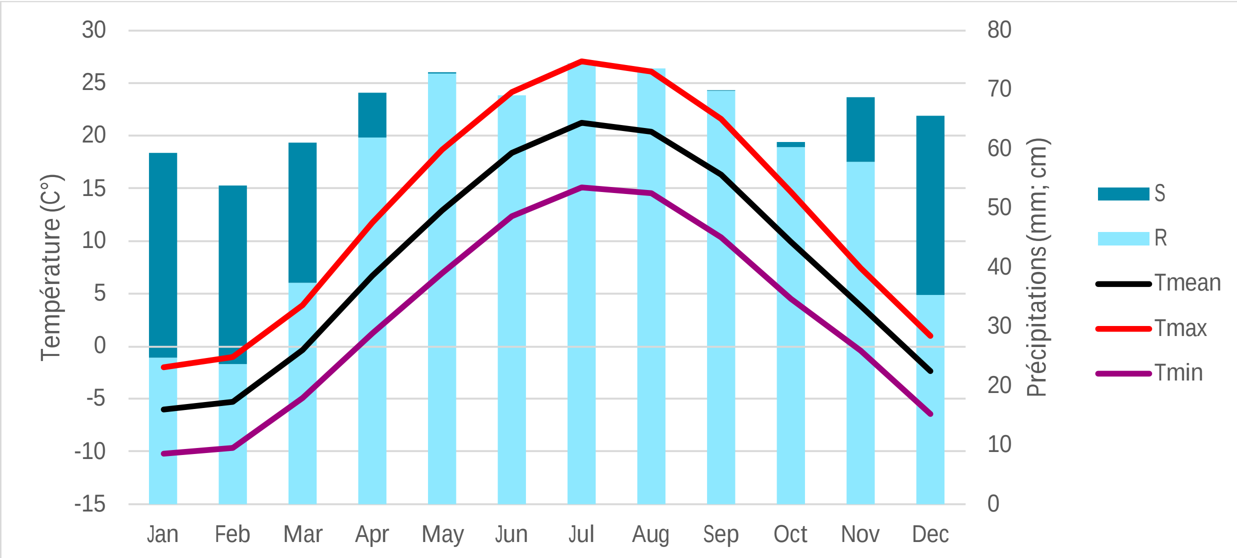
Table 5-1: List of Project Components and Elements

Project Components	Elements
Road Network	■ Lanes and dedicated right of ways ■ Interchanges ■ Curb-side bus bays ■ Cycling infrastructure ■ Road subsurface ■ Road surface
Transit Network	■ Platforms and ramps ■ Railings ■ Bus Rapid Transit stations ■ Pedestrian crossings
Systems, Signaling and Equipment	■ Signals (including traffic signals, transit signal priority, traffic signal cabinets, and pedestrian crossing signals) ■ Street lighting ■ Fare vending and fare gate infrastructure ■ Security cameras, speakers, emergency phones, variable messaging
Utilities	■ Drainage (Curbs and gutters, catch basins, storm sewers) ■ Electrical power supply ■ Fibre optic
People	■ Passengers ■ Staff ■ Vehicle traffic ■ Pedestrians ■ Cyclists
Surrounding Environment	■ Landscaping ■ Public art and benches ■ Fencing ■ Wayfinding/Signage ■ Bike lockers at major stops

5.1.2 Climate Data Analysis

The climate data analysis was carried out using temperature and precipitation data from the weather station based at the International Airport of Toronto, including climate means over the 1981 to 2010 period. **Figure 5-1** presents climate normals over the 1981 to 2010 period for temperature (mean, minimum and maximum) and for overall precipitation and snow and rain separately.

Figure 5-1: Climate Normals from Weather Station at the Toronto Pearson International Airport (1981 to 2010)



5.1.3 Climate Projections

Climate projections are based on assumptions regarding the evolution of greenhouse gas emissions. These are referred to as Representative Concentration Pathways and are named after their associated level of radiative forcing. For instance, Representative Concentration Pathway 2.6, Representative Concentration Pathway 4.5, Representative Concentration Pathway 6.0, and Representative Concentration Pathway 8.5 correspond to 2.6, 4.5, 6.0 and 8.5 watts per square metres of radiative forcing, respectively for each scenario. Projected carbon dioxide concentration levels are predicted from the anticipated growth in population and energy demand (the type of energy is an important factor), as well as by the anticipated changes vegetation cover and type (Van Vuuren et al., 2011)[12].

Table 5-2: Representative Concentration Pathways

Representative Concentration Pathways	Description
Representative Concentration Pathway 2.6	Stringent mitigation scenario; representative of a scenario that aims to keep global warming likely below 2 degrees Celsius (degrees Celsius) increase above preindustrial temperatures. Ambitious reduction of greenhouse gas emissions peak around 2020, then decline and become net negative before 2100.

12. Van Vuuren et al. (2011) The representative concentration pathways: an overview. Climatic Change 109:5-31.

Representative Concentration Pathways	Description
Representative Concentration Pathway 4.5	Intermediate mitigation scenario consistent with relatively ambitious emissions reductions and greenhouse gas emissions increasing slightly before starting to decline ~2040. This falls short of the 2 degrees Celsius limit agreed upon in the Paris Agreement.
Representative Concentration Pathway 6.0	High to intermediate emissions scenario with emissions peaking in 2060 and declining for the rest of the century.
Representative Concentration Pathway 8.5	Very high greenhouse gas emissions; consistent with no policy changes to reduce emissions (current policies or business as usual).

Source: United Nations Intergovernmental Panel on Climate Change, 2014.[13]

The high carbon future (Representative Concentration Pathway 8.5) scenario was selected as it represents the worst-case scenario, which would overestimate the associated risk. Given that the future rapid transit system is estimated to be operational for the next 60 years, climate projections were analyzed for the 2081-2100 timeframe.

5.1.4 Identification of Climate Indicators

A climate indicator represents a certain climate condition or a type of event (e.g., number of hot days with + 30 degrees Celsius), defined by a threshold above which the evaluated infrastructure would likely trigger a reaction resulting in a loss of productivity, damage to the infrastructure or more intensive maintenance plan. The likelihood or probability associated with an indicator is calculated from data recorded at a weather station and applies to a historical dataset or climate prediction.

In order to determine the climate-related risks to the future Bus Rapid Transit system, climate indicators and their probabilities of occurring were analyzed for both the historical period (1981 to 2010) and in the context of the changing climate. First, a total of 25 climate indicators were reviewed at a high-level to estimate the likelihood of climate risks to the Project. As a result of this initial review, 14 climate indicators were removed from the analysis as they were considered to have no impact or a very low impact on the Project (see **Table 5-3**).

13. IPCC, 2014: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp

Eleven (11) indicators were selected according to:

- Historical and future annual and seasonal variation for both temperature and precipitation were reviewed and provided insights on future trends;
- Relevant climate indicators showing significant increases in probability during the project's timeframe;
- Relevance of climate indicators to local reality;
- Potential interactions of a certain climate condition with a project component; and
- Significant indicators/parameters in the Metrolinx Public Infrastructure Engineering Vulnerability Committee Protocol Climate Change Vulnerability Assessment.

The eleven climate indicators considered in the next step of the assessment are:

1. **Hot temperature**: Days with maximum temperature ≥ 30 degrees Celsius
2. **Heat wave:** Instances of 3 days with minimum temperature ≥ 20 degrees Celsius and maximum temperature ≥ 33 degrees Celsius
3. **Diurnal variation**: Days with maximum temperature-minimum temperature ≥ 20 degrees Celsius
4. **Heavy rainfall:** Days with precipitation ≥ 25 millimetres
5. **Winter rain on snow:** Instances of precipitation ≥ 25 millimetres within Jan-Feb-Mar
6. **Drought:** Instance of precipitation < 0.2 millimetres for 10 days
7. **Heavy wind:** Days with wind ≥ 65 kilometre per hour
8. **Blowing rain:** Instances of (precipitation ≥ 5 millimetres) and (wind ≥ 65 kilometre per hour)
9. **Blowing snow:** Instances of ((snow ≥ 5 centimetres) or (snow depth ≥ 5 centimetres)) and (wind ≥ 65 kilometre per hour)
10. **Freezing rain:** Days with freezing rain
11. **Fog:** Days with fog

Climate projections for the data retrieved from the weather station based at the International Airport of Toronto, for the Greater Toronto and Hamilton Area, indicate that there will be precipitation increases, especially in spring and winter with a probability of heavy rainfall (>25 millimetres per day) to increase from 91.3% to 96.3% per year.

Increase in temperatures will result in much warmer summers, with significant increases in the probability of hot days (+30 degrees Celsius) increasing from 92.4% to 100% per year, and the probability of a heat wave will increase from 48% to 98.8% per year. Probabilities of blowing snow and blowing rain events will both increase. Probabilities for freezing rain are predicted to diminish but will still be considered in the assessment due to its relevance and significance in the Metrolinx Public Infrastructure Engineering Vulnerability Committee Protocol Climate Change Vulnerability Assessment. Winter rain on snow will significantly increase from 4.9% to 30.2% per year. Freeze-thaw cycles are not considered in the assessment as their probability of occurrence will be going down in the future from 4.6% to 0% per year. Integrating the probability of winter rain on snow in the Climate Change Resilience Assessment analysis takes into consideration the increase in precipitation during winter months that is projected to occur due to changes in freeze-thaw cycles, however, cumulative impacts are not considered in this assessment. **Table 5-3** below presents data for each climate indicator for the historical mean (1981 to 2010) and for both timeframes of climate projections, as well as justifications for excluding 14 of the 25 initial indicators.

5.1.5 Mapping the Public Infrastructure Engineering Vulnerability Committee 0 to 7 Scale into the Climate Lens 1 to 5 Scale

In 2016, AECOM analyzed six of Metrolinx's assets using Engineer Canada's Public Infrastructure Engineering Vulnerability Committee protocol. Metrolinx's Public Infrastructure Engineering Vulnerability Committee Protocol Climate Change Assessment provided climate parameters that were scored from 0 to 7 depending on the probability of occurrence for each event.

In order to complete the next steps of the climate change resilience assessment, the 0 to 7 Public Infrastructure Engineering Vulnerability Committee protocol scoring scale was converted and mapped into a scale from 1 to 5. **Table 5-4** represent the equivalences and thresholds for the conversion of the Public Infrastructure Engineering Vulnerability Committee protocol scoring into the Climate Lens scoring. With the conversion table, each climate parameter from the Public Infrastructure Engineering Vulnerability Committee protocol was adapted. **Table 5-5** represents each climate parameter, their Public Infrastructure Engineering Vulnerability Committee protocol scoring as well as their adapted scoring. The scoring is an estimate of likelihood of an event to occur. The scoring will help identify the significant climate indicators to consider for the assessment. If the scores of current and future climate conditions for a climate indicator are high (high probability of occurrence), or if the score significantly increases from current conditions to future conditions, the climate indicator is relevant and should be taken into account for the next steps of the assessment.

Table 5-3: Climate Indicators and Associated Probabilities for 1981 to 2010 and 2081-2100 Timeframes

Climate indicator		Condition			Probability (%)				Included in Assessment (Y/N)	Exclusion Comments
		Variable and Threshold	Duration	Freq,	Past (1981 to 2010)		Representative Concentration Pathway 8.5 (2081-2100)			
					Year	Cumul	Year	Cumul		
Daily Data										
T1	Hot temperature	Days with Tmax ≥ 30 degrees Celsius	1	1	92.4	100.0	100.0	100.0	Y	-
T2	Cold temperature	Days with Tmin ≤ -30 degrees Celsius	1	1	0.0	0.3	0.0	0.2	N	Probability not significant/not relevant
T3	Heat wave	Instances of 3 days with Tmin ≥ 20 degrees Celsius and Tmax ≥ 33 degrees Celsius	3	3	48.0	100.0	98.8	100.0	Y	-
T4	Cold wave	Instances of 5 days with Tmin ≤ -30°Celsius	5	1	0.0	0.3	0.0	0.2	N	Probability not significant/not relevant
T5	Diurnal variation	Days with Tmax-Tmin ≥ 20 degrees Celsius	1	1	66.7	100.0	74.5	100.0	Y	-
T6	Freeze-thaw	Days with Tmin < 0°Celsius & Tmax > 0° Celsius	1	102	4.6	67.7	0.0	62.7	N	Probability not significant/not relevant
T7	Frost	Days with Tmin < 0°Celsius	1	162	0.9	20.1	0.0	17.8	N	Probability not significant/not relevant
T8	Frost season length	Days (consec,) with Tmin < 0°Celsius	1	109	0.0	0.3	0.0	0.2	N	Probability not significant/not relevant
P1	Extreme heavy rainfall	Days with P ≥ 67 millimetres	1	1	0.0	0.0	0.6	1.8	N	Probability not significant/not relevant
P2	Heavy rainfall	Days with P ≥ 25 millimetres	1	1	91.3	100.0	96.3	100.0	Y	-
P3	Rain frequency	Days with P ≥ 10 millimetres	1	35	1.1	22.7	5.0	31.5	N	Probability not significant/not relevant
P4	Heavy 5-day rainfall	Instances of P ≥ 130 millimetres within 5 days	5	1	0.0	0.0	0.0	0.0	N	Probability not significant/not relevant
P5	Winter rain on snow	Instances of P ≥ 25 millimetres within Jan-Feb-Mar	1	1	4.9	70.2	30.2	87.0	Y	-
P6	Wet days	Days with P ≥ 67 millimetres	1	1	0.0	0.0	0.6	1.8	N	Probability not significant/not relevant
P7	Heavy snowfall	Days with S ≥ 20 centimetres	1	1	0.2	3.7	12.0	33.1	N	Probability not significant/not relevant
P8	Snow accumulation	Instances of SD ≥ 38 centimetres for 5 days	5	1	0.6	13.6	0.6	13.6	N	Probability not significant/not relevant
P9	Drought	Instance of P < 0.2 millimetres for 10 days	10	1	82.8	100.0	87.5	100.0	Y	-
W	Heavy wind	Days with W ≥ 65 kilometre per hour	1	1	99.9	100.0	100.0	100.0	Y	-
PW1	Blowing rain	Instances of (P ≥ 5) and (W ≥ 65 kilometre per hour)	1	1	95.4	100.0	98.4	100.0	Y	-
PW2	Blowing snow	Instances of ((S ≥ 5) or (SD ≥ 5)) and (W ≥ 65 kilometre per hour)	1	1	84.2	100.0	91.6	100.0	Y	-
Hourly Data										
H1	Relative humidity	Days with Hmd ≥ 90%	1	216	36.8	100.0	36.8	100.0	N	Probability not significant/not relevant
H2	Humidex	Days with Hmdx ≥ 45 degrees Celsius	1	1	10.8	93.6	10.8	93.6	N	Probability not significant/not relevant
H3	Wind chill	Days with Wind Chill ≤ -45 degrees Celsius	1	1	0.0	0.0	0.0	0.0	N	Probability not significant/not relevant
H4	Freezing rain	Days with freezing rain	6	1	39.1	100.0	19.7	100.0	Y	-
H5	Fog	Days with fog	1	131	48.5	100.0	48.5	100.0	Y	-

Where, Variables are temperature (T), precipitations (P) in rain or snow, snow depth (SD), wind speed (W), wind combined with precipitation (PW).

Source: Environment Canada, 2021a-b-c-d

Duration represents the number of days (daily data) or the number of hours (hourly data) during which the threshold must reach for the climate condition associated with the indicator to occur.

The **frequency** is the number of days per year known to have a significative effect on the studied infrastructure.

Columns under **past** are linked to the baseline period (1981 to 2010) and those under "Representative Concentration Pathway 8.5" show the climate change projections according to the Representative Concentration Pathways 8.5 scenario for the 2081 to 2100 horizon. The **"Year"** columns show the probability that a climate condition occurs in a year, while the "**Cumul**" columns show the probability that a climate condition occurs once within the next 60 years.

Table 5-4: Public Infrastructure Engineering Vulnerability Committee Protocol Scoring Conversion to Climate Lens Scoring

Public Infrastructure Engineering Vulnerability Committee protocol		Climate Lens	
Score	**Probability of Occurrence**	**Score**	**Probability of Occurrence**
6 and 7	more than 70%	5	more than 70%
5	40%-70%	4	40%-70%
4	20%-40%	3	20%-40%
2 and 3	5%-20%	2	5%-20%
0 and 1	less than 5%	1	less than 5%

Table 5-5: Public Infrastructure Engineering Vulnerability Committee Protocol Climate Parameters and Probability of Occurrence Scoring and Adapted Scoring

Climate Parameter	Threshold	Annual Probability		Prob. of Occurrence for Study Period (2015-2050)	PIEVC Scoring			PIEVC Adapted Scoring		
		Historical	2050s		Annual: Historical	Annual: 2050s	Study Period (35 year)	Current	Future	Study Period
Extreme Temperatures	40°C	~0.01 per year	1-7 days per year	~100%	1	7	7	1	5	5
	32°C	6.5 days per year	27.5 days per year	100%	7	7	7	5	5	5
	-30°C	0.05 days per year[1]	<0.01 days per year	<70%	2	0-1[2]	5-6[3]	2	1	4
	-23°C	1.1 days per year	0.1 days per year	100%	7	3	7	5	2	5
Temperatures Range	60°C in one year	0.1 days per year	<0.01 events per year	<90%	3	0-1	6	2	1	5
Reduced Visibility *(e.g., fog, blowing snow)*	400 m (or ¼ mile)	49 hours per year, 15.1 days per year	strong trend ↓, stable recent period	100%	7	6-7	7	5	5	5
	200 m	33 hours per year, 11.9 days per year	strong trend ↓, stable recent period	100%	7	6-7	7	5	5	5
Frost Penetration	1.2 m or below	0.17[4] per year	Trend ↓ but some conflicting factors	>90%	4	3	6-7	3	2	5
High Winds (Gusts)	90 km/h	2 per year	>2.5 per year	100%	7	7	7	5	5	5
	120 km/h	0.05 days per year	Likely ↑	~85% or higher	2	2	6-7	2	2	5
Tornadoes	EF1 +	1-in-6,000	Unknown[5]	~0.6%	0	0	0-1	1	1	1
Overland Flood/Heavy Rainfall	≥25 mm in 2 hour	~ 0.8 events per year	Very likely ↑	100%	6	6	7	5	5	5
	≥60 mm in 2 hours	≤ 0.03 events or less per year	Very likely ↑	~70%	1-2	2[6]	6	1	2	5
Freezing Rain	≥ 10 mm	~0.2 days per year	~0.3 days per year	~100%	4	4-5	7	3	3	5
	≥ 25 mm	0.06 days per year	>0.09 days per year	>95%	2	3	7	2	2	5
Snow	Blowing snow	7.8 days per year	Trends not significant to scoring	100%	7	7	7	5	5	5
	≥ 20 cm in one day	0.1 days per year	Conflicting trends, likely remaining similar	>95%	3	3	6-7	2	2	5
	Design Loads (snow-water-equivalent)	184 mm (Willowbrook/ Port Credit[7])	No observed trend, some factors indicate ↑	~20%	1	1-2	4	1	1	3
		153 mm (Streetsville[8])		~40%	1	1-2	5	1	1	4
		133 mm (Oakville[9])		~40%	1	1-2	5	1	1	4
Hail *(Mississauga Area example)*	"Golf ball" / 45 mm or larger	0.07 per year	Unknown	>90%	2-3	Unknown	6	2	unknown	5
Horizontal Rain	Gusting 50 km/h + >25 mm rain	1.8 days per year	Slight trend ↑	100%	7	7	7	5	5	5
Lightning	Direct strikes	~0.3% per year	Likely ↑	>99%	1	Unknown	3	1	unknown	2

After mapping the Public Infrastructure Engineering Vulnerability Committee protocol scores into the 1 to 5 scale, it had to be determined if the results from the Metrolinx Public Infrastructure Engineering Vulnerability Committee protocol climate data were consistent with the results from the climate data used from the weather station based at the International Airport of Toronto. To do so, the significant Public Infrastructure Engineering Vulnerability Committee protocol climate parameters were identified from **Table 5-5** and categorized into Climate Lens indicators that were deemed equivalent, as shown in **Table 5-6**. **Table 5-6** also shows the Climate Lens scoring in comparison to the adapted Public Infrastructure Engineering Vulnerability Committee protocol scoring for current climate and future climate projections. No discrepancies within the scoring can be observed, therefore the data and scoring were judged as consistent.

The Public Infrastructure Engineering Vulnerability Committee Protocol parameter of extreme temperatures was categorized into the hot temperature Climate Lens indicator because the Climate Lens indicator has a more conservative threshold, which means that infrastructure adaptations for the indicator will be more robust. The same logic applies to high winds, which were categorized as heavy winds and freezing rain which remained categorized as freezing rain. Reduced visibility fog was categorized into fog days because the Public Infrastructure Engineering Vulnerability Committee protocol assessment considers fog as a contributor of reduced visibility. Even though thresholds for heavy rain and heavy rainfall differ, as for horizontal rain and blowing rain, the categorized indicators were deemed equivalent because their probability of occurrence were the same and impacts on the infrastructure would lead to the same adaptive measures. Finally, no thresholds for blowing snow were elaborated in the Public Infrastructure Engineering Vulnerability Committee protocol, therefore the Climate Lens thresholds were applied for the categorization.

Climate Lens projection for the 2081-2100 timeframe, under the RCP8.5 scenario predict a decrease in probability of occurrence of freezing rain. However, for the following sections of the assessment, based on professional judgement and to capture a better range in extreme events, the freezing rain scoring will be adjusted from a 2 (low probability of occurrence) to a 4 (high probability of occurrence), as seen in table 5-8. This will allow for better consideration of health and safety issues, as well as being more conservative and providing more consistent recommendations.

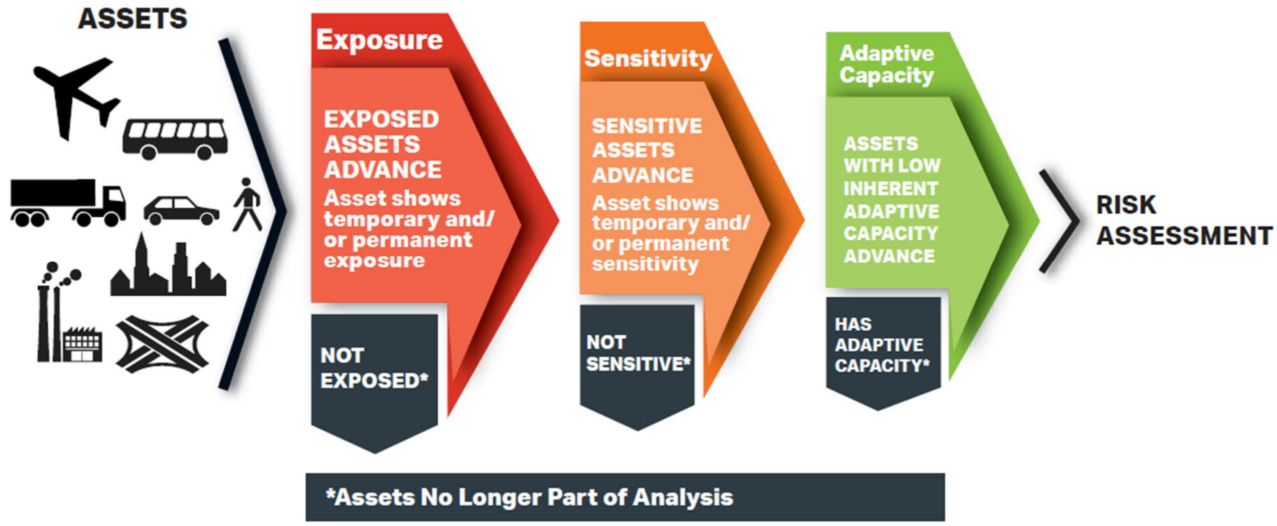
Table 5-6: Public Infrastructure Engineering Vulnerability Committee Protocol Parameter into Climate Lens Indicators Equivalents and their Probability of Occurrence Scoring

Public Infrastructure Engineering Vulnerability Committee Protocol Climate Parameter	Climate Lens Climate Indicator Equivalents	Climate Lens Current 1981 to 2010	Climate Lens Future (2081 to 2100)	Public Infrastructure Engineering Vulnerability Committee protocol historical adapted	Public Infrastructure Engineering Vulnerability Committee protocol 2050 adapted
Extreme Temperatures: Days with Tmax ≥ 32 degrees Celsius	Hot temperature: Days with Tmax ≥ 30 degrees Celsius	5	5	5	5
Reduced Visibility (Fog)	Fog: Days with fog	5	5	5	5
High Winds W= 90 kilometre per hour	Heavy wind: Days with W ≥ 65 kilometre per hour	5	5	5	5
Heavy Rain P ≥ 25 millimetres in two hours	Heavy rainfall: Days with P ≥ 25 millimetres	5	5	5	5
Freezing Rain days with ≥ 10 millimetres	Freezing rain: Days with freezing rain	3	2	3	3
Blowing Snow	Blowing snow: Instances of ((S ≥ 5 centimetres) or (SD ≥ 5 centimetres)) and (W ≥ 65 kilometre per hour)	5	5	5	5
Horizontal Rain (P ≥ 25 millimetres) and (W ≥ 50 kilometre per hour)	Blowing rain: Instances of (P ≥ 5 millimetre) and (W ≥ 65 kilometre per hour)	5	5	5	5

5.2 Risk Identification

Climate change vulnerability was first assessed, to determine the exposure, sensitivity, and adaptive capacity of each element to the 11 climate indicators, listed above. Climate vulnerability assessments evaluate an asset, community, ecosystem or region's exposure to a particular climate-related hazard or extreme weather event, the sensitivity to being exposed to the hazard or extreme weather event, and the asset entities' adaptive capacity. Assets and operations that are exposed, sensitive and have low inherent capacity to adapt proceed to the next stage of Risk Analysis.

Figure 5-2: Schematic of Climate Vulnerability Assessment Approach



5.3 Risk Analysis

A risk is defined as the product of the likelihood of an event to occur and the consequence or severity on an asset if the event were to occur. A risk assessment was conducted to evaluate the impacts of the climate indicators on each of the project components listed above, using an impact ranking matrix from *very low* to *very high* severity of consequences.

5.3.1 Climate Indicators' Likelihood of Occurrence

To determine the climate-related risks to the future Bus Rapid Transit system, relevant climate indicators were reviewed for the baseline (1981 to 2010) and in the context of the changing climate for the 2081 to 2100 timeframe. The probability/likelihood of occurrence scoring used is described in **Table 5-7**.

Table 5-7: Likelihood Scoring Description

Very High	Once every year or more	More than 70% (100%)	5
High	Once every 2 years	40%-70% (50%)	4
Moderate	Once every 5 years	20%-40% (20%)	3
Low	Once every 10 years	5%-20% (10%)	2
Very Low	Once every 30 years	5% or less (5%)	1

Considering climate normals and projected changes for the 2081 to 2100 timeframe, the Project Team associated the probability/likelihood of occurrence percentages that were previously calculated to a probability/likelihood score for each relevant and significant climate indicator. The climate indicator scoring is presented in **Table 5-8**.

Table 5-8: Climate Indicators Probability Scoring

	Code	Climate Indicators	1981-2010	2081-2100
Temperature	T1	Hot temperature: Days with maximum temperature ≥ 30 degrees Celsius	5	5
Temperature	T3	Heat wave: Instances of 3 days with minimum temperature ≥ 20 degrees Celsius and maximum temperature ≥ 33 degrees Celsius	4	5
Temperature	T5	Diurnal variation: Days with maximum temperature - minimum temperature ≥ 20 degrees Celsius	4	5
Precipitation	P2	Heavy rainfall: Days with precipitation ≥ 25 millimetres	5	5
Precipitation	P5	Winter rain on snow: Instances of precipitation ≥ 25 millimetres within Jan-Feb-Mar	1	3
Precipitation	P9	Drought: Instance of precipitation < 0.2 millimetres for 10 days	5	5
Wind	W1	Heavy wind: Days with wind ≥ 65 kilometres per hour	5	5
Wind	PW1	Blowing rain: Instances of (precipitation ≥ 5 millimetres) and (wind ≥ 65 kilometres per hour)	5	5
Wind	PW2	Blowing snow: Instances of ((snow ≥ 5 centimetres) or (snow depth≥ 5 centimetres)) and (wind ≥ 65 kilometres per hour)	5	5
Other	H4	Freezing rain: Days with freezing rain	3	4
Other	H5	Fog: Days with fog	4	4

5.3.2 Estimate of Consequences of Risks

To estimate the level of consequences, four impact categories were identified based on what is considered most relevant when managing risks for the future Bus Rapid Transit system.

These four impact categories are defined as follows:

1. **Impacts on health and safety** include occupational illness and injury to staff or the public as a result of incidents for which the municipality may be liable.
2. **Infrastructure integrity** include damages or deterioration of essential component materials.
3. **Operational impacts** include operational slow down or interruption of services.
4. **Financial impacts** include losses due to additional cost/expense directly attributed to the event, or damage to asset to be fixed immediately to maintain operations, or operations cannot be maintained. This category also includes financial impact caused by claims filed to Metrolinx due to flood events.

Each impact category was then defined on a scale of 1 (very low) to 5 (very high), as shown in **Table 5-9**. The table below presents the severity rating (1 – very low to 5 – very high) and impact categories which were used to guide the risk analysis.

5.4 Risk Evaluation

The risk assessment revealed 52 interaction showing risks out of 66 possible interactions, between 11 climate indicators and the six project components (**Figure 5-3**).

For the 1981-2010 timeframe, out of the 52 interactions:

- 12 interactions result in a low risk;
- 32 interaction result in a moderate risk;
- 3 interactions result in a high risk; and
- 5 interactions result in a special case.

Table 5-9: Impact Severity Rating and Impact Categories

Impact Severity Rating	Consequences	Impact Categories			
		Health & Safety	Infrastructure Integrity	Operational Impact	Financial Impact
1	**Very low**	First Aid Injury	Very low damage; repairable immediately	Operations slow down, requiring additional time (2 to 4 hours)	Less than $1k – loss of revenue or refunds, minor cosmetic damage to asset to be fixed in next routine service
2	**Low**	Medical treatment for a minor injury	Minor damage to component materials; Reduction of the service life of the material	Operations slow down, requiring additional time (4 to 6 hours)	$1k to $5k - loss of revenue or refunds, damage to asset requiring service call of staff or third-party contractor on the next shift
3	**Moderate**	Bodily injury / Illness with work restrictions	Moderate damage to component materials; Slow deterioration of the materials of certain essential components	Operations slow down, requiring additional time (1 day)	$5k to $25k - loss of revenue or refunds, damage to asset requiring immediate service call of staff or third-party contractor
4	**High**	Permanent disabling injury or multiple people injured	Accelerated deterioration of the materials of certain essential components	Operations slow down, requiring additional time (1 to 3 days)	$25k to $50k - loss of revenue or refunds, damage to asset requiring immediate service call of staff or third-party contractor and partial shutdown of stop while repairs are completed
5	**Very high**	Fatality or significant irreversible disability	Deterioration of materials causing the failure of several elements essential to the functionality of the network	Operations slow down, requiring additional time (3 to 5 days)	More than $50k - loss of revenue or refunds, damage to asset requiring immediate service call of staff or third-party contractor and complete shutdown of stop while repairs are completed

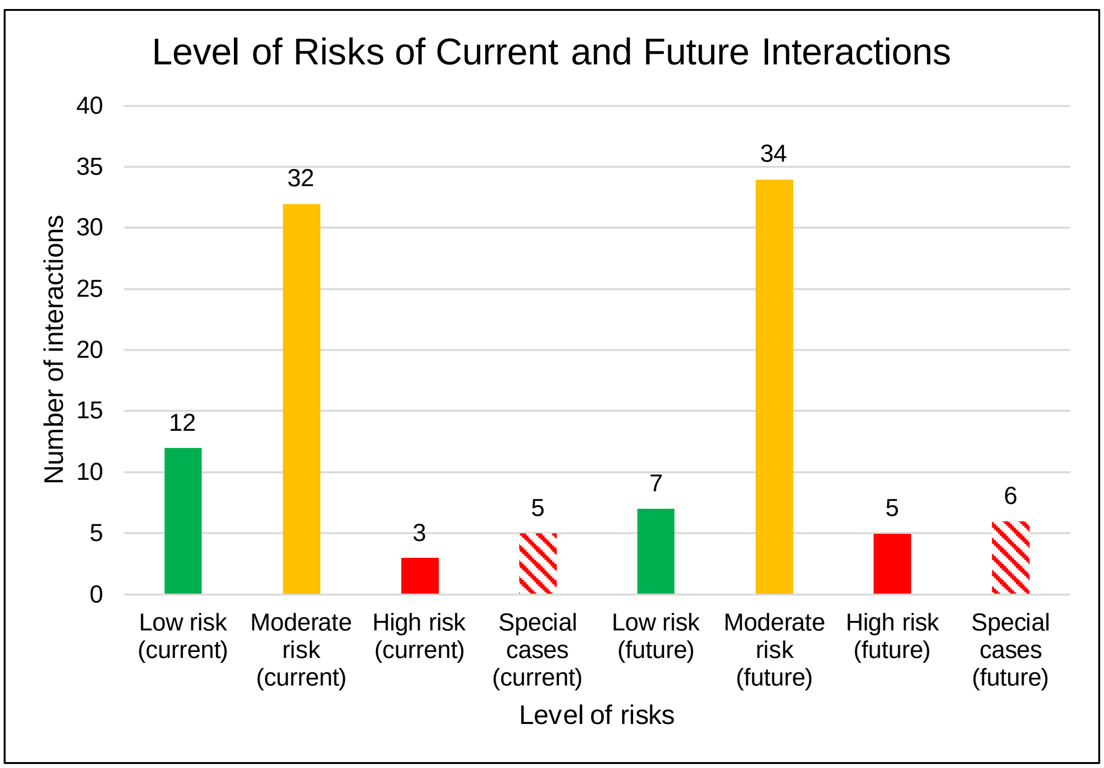
For the 2081-2100 timeframe, the 52 interactions resulted in the following levels of risk:

- 7 interactions result in a low risk of which 4 interaction changed from low to moderate risk;
- 34 interactions result in a moderate risk
- 5 interactions result in a high risk of which 2 interactions changed from moderate to high risk; and
- 6 interactions result in a special case of which 1 interaction changed from low risk to a special case.

Out of the 52 interactions, only the special cases and the ones presenting moderate and high risks were considered in the rest of the assessment, namely 40 in the current timeframe and 45 in the future timeframe. These were then analyzed further to recommend risk treatment and adaptation measures.

Interactions resulting in a risk rated "5" are considered special cases and are considered in the risk evaluation, as these can either be interactions with very low likelihood but very high severity or interactions with high likelihood and very low severity. While the former case may have very severe impacts, the latter case can trigger a slow deterioration of project components due to the high likelihood of the climate condition.

Figure 5-3: Level of Risk of Current and Future Interactions



It is worth noting that the high and moderate risk interactions are due to increases in temperatures, precipitation, heavy wind, ¸freezing rain and drought.

Based on the findings of the risk assessment, the number of risks associated with heat wave is expected to increase from 1981-2010 to 2081-2100 for road network as well as for people. The number of risks associated with winter rain on snow is also expected to increase for transit network and freezing rain risk are to increase for all infrastructure elements.

The detailed results of the risk evaluation are included in the matrix below in **Table 5-10**. The results are combined and presented with proposed mitigation and adaptation measures in the following section.

Only the interactions resulting in high and moderate risk and the special case interactions are included in the next step of the assessment, namely the recommendation of adaptation measures. Low risk interactions were discarded from further analysis.

Table 5-10 presents the summary of the risk analysis per climate indicators for each timeframe, namely the current timeframe based on 1981-2010 climate data and the 2081-2100 timeframe with RCP8.5 climate projections.

Table 5-10: Risk Evaluation Matrix

	Hot Temperature		Heat Wave		Diurnal Variation		Heavy Rainfall		Drought		Heavy Wind		Blowing Rain		Blowing Snow		Freezing Rain		Fog		Winter Rain on Snow		Total Number of Future Special Cases, Moderate and High Risks per Infrastructure Element
Infrastructure elements	1981-2010	2081-2100	1981-2010	2081-2100	1981-2010	2081-2100	1981-2010	2081-2100	1981-2010	2081-2100	1981-2010	2081-2100	1981-2010	2081-2100	1981-2010	2081-2100	1981-2010	2081-2100	1981-2010	2081-2100	1981-2010	2081-2100	Total
Road Network	15	15	16	20	4	5	20	20			5	5	5	5	10	10	9	12	4	4	2	6	8
Transit Network	10	10	8	10			20	20			5	5	10	10	10	10	9	12	4	4	3	9	8
Systems, Signalling and Equipment	10	10	8	10			5	5			10	10	10	10	10	10	6	8			1	3	7
Utilities	10	10	8	10			10	10			10	10	10	10	10	10	6	8					7
People	10	10	16	20			20	20			10	10	15	15	15	15	9	12	4	4	1	3	67
Surrounding Environment	5	5	8	10			10	10	10	10	10	10	10	10	10	10	6	8			1	3	78
Total number of risks per climate parameter and horizon	**6**	**6**	**6**	**6**	**2**	**2**	**6**	**6**	**1**	**1**	**6**	**6**	**6**	**6**	**6**	**6**	**6**	**6**	**3**	**3**	**5**	**5**	

Interactions resulting in a risk rated "5" are considered special cases and are considered in the risk evaluation, as these can either be interactions with very low likelihood but very high severity or interactions with high likelihood and very low severity. While the former case may have very severe impacts, the latter case can trigger a slow deterioration of project components due to the high likelihood of the climate condition.

Risk Evaluation Matrix Scoring

Severity of Consequences	**Very High (5)**	5	10	15	20	25
	High (4)	4	8	12	16	20
	Moderate (3)	3	6	9	12	15
	Low (2)	2	4	6	8	10
	Very Low (1)	1	2	3	4	5
		Very Low (1)	**Low (2)**	**Moderate (3)**	**High (4)**	**Very High (5)**
		Probability (Likelihood)				

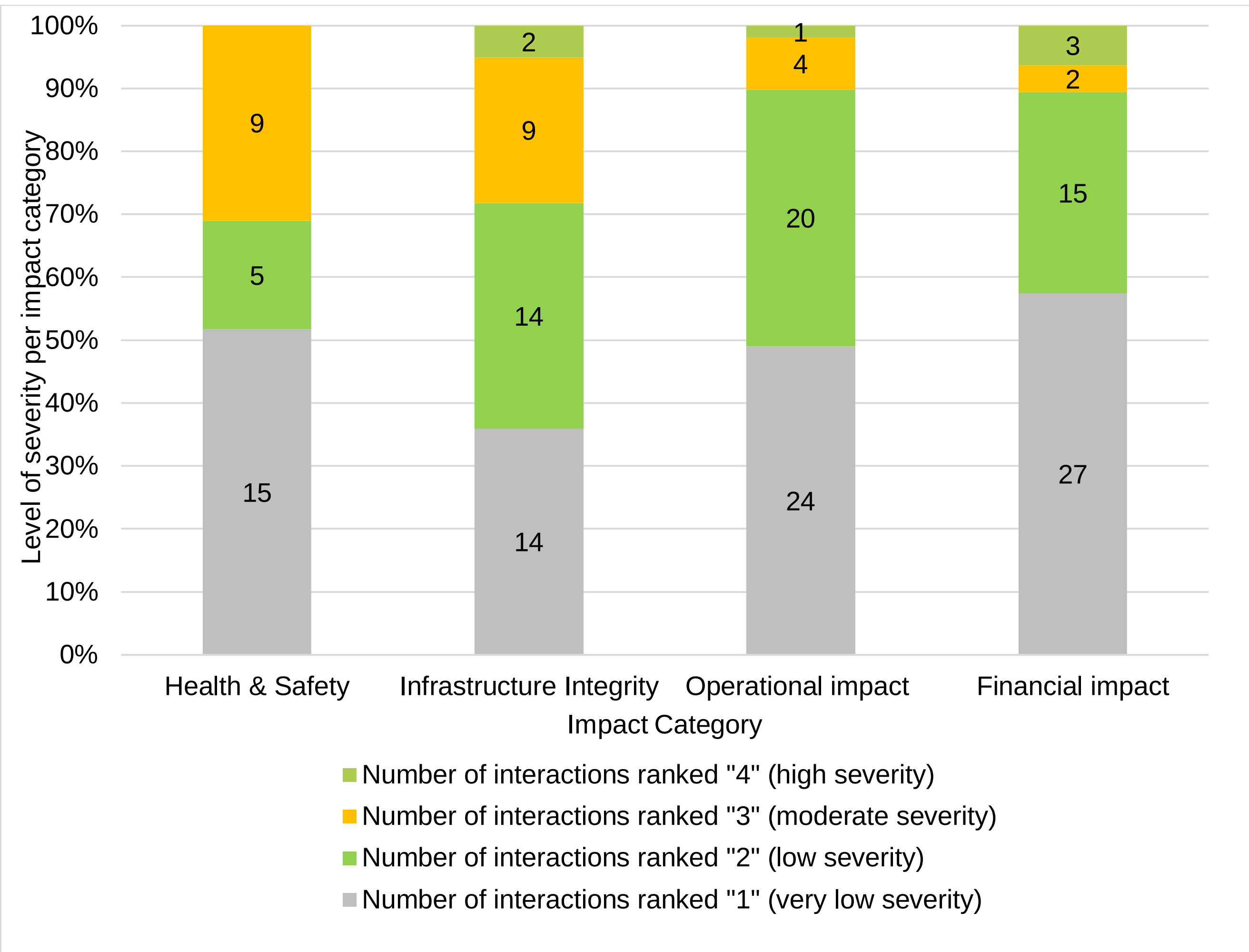
Risk Rating

Risk (R) = Probability (P) x Severity (G)	
Low Risk: < 6	Controls likely not required
Moderate Risk: 7 < R < 16	Some controls required to reduce risks to lower levels
High Risk: R > 20	High priority control measures required
R = 5	Special Cases: Interactions resulting in a risk rated "5" are considered special cases and are considered in the risk evaluation, as these can either be interactions with very low likelihood but very high severity or interactions with high likelihood and very low severity. While the former case may have very severe impacts, the latter case can trigger a slow deterioration of project components due to the high likelihood of the climate condition.

5.4.1 Risk Assessed by Impact Categories

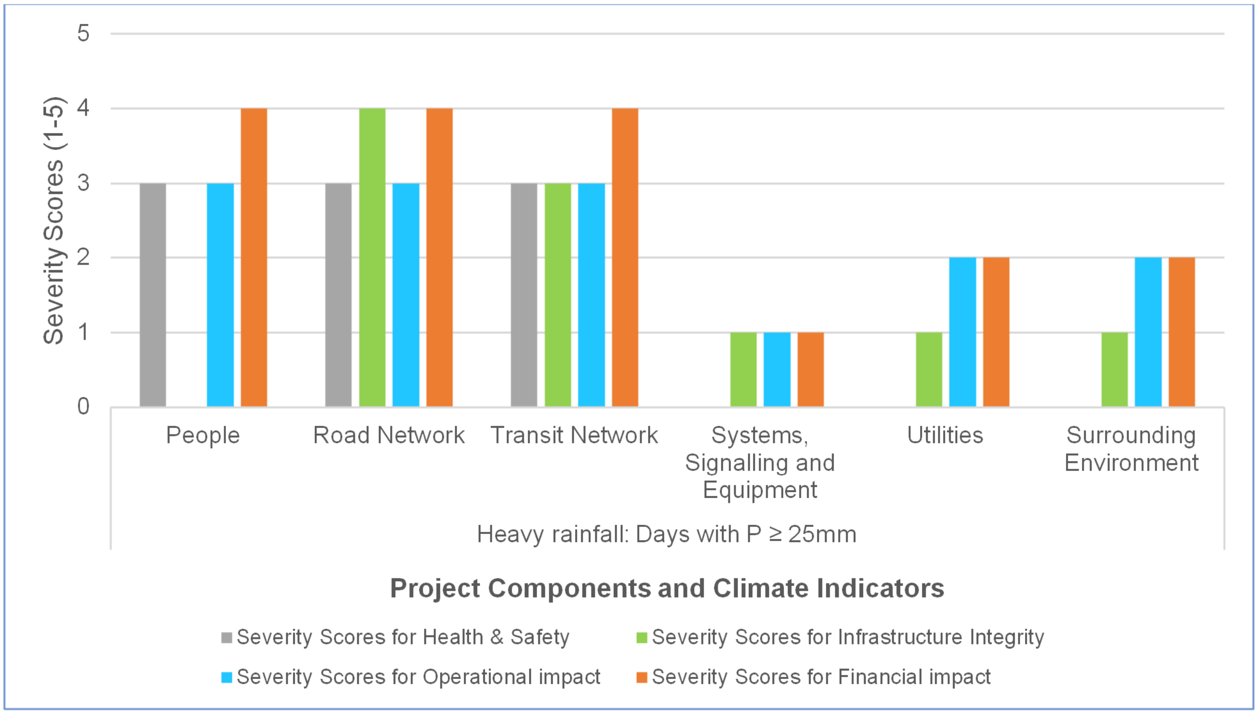
Figure 5-4 presents how climate risks will impact the five categories of impacts. This can be used to lead investment and help prioritize adaptation measures that will minimize financial impacts, health and safety impacts, operational impacts and infrastructure impacts. Four types of interaction were assessed in the risk analysis: very low severity interactions (ranked 1), low severity interaction (ranked 2), moderate severity interactions (ranked 3) and high severity interactions (ranked 4). No very high severity interactions (ranked 5) were identified in the risk analysis.

Figure 5-4: Number of Interaction per Level of Severity by Impact Category



In order to use these results further, a pivot table set up in **Appendix E** will allow Metrolinx to select and visualize the level of severity for each climate indicator and each infrastructure component, as in the screenshot below (**Figure 5-5**).

Figure 5-5: Level of Severity for Each Climate Indicator and Each Infrastructure Component (fully displayed and interactive in Appendix D



5.5 Risk Treatment and Adaptation Measures

The project team identified risk treatment and adaptation measures for reducing unacceptable risks to acceptable levels. These are presented in **Table 5-11**, according to the risks results from the 2081-2100 timeframes which will bring most severe consequences. The first column presents the Moderate Risk Interactions and High-Risk Interactions combined by type of event; i.e. high-level risk events related to hot temperatures (+30 °C) and the number of heat waves were combined as their impacts are similar on asset components. Similarly, events related to heavy winds, blowing snow and blowing rain were combined. The last column describes potential impacts on the project and its elements if adaptation measures were not to be implemented. A detailed version of this table is also presented in **Appendix D**, with additional information on the effectiveness of the risk or adaptation measures as well as the recommended timeframe for implementing these measures.

Table 5-11: Risk Treatment and Adaptation Measures

Risk Event	Project Components	Risk	Adaptation Measure or Risk Treatment	Comments
MODERATE RISK **Hot temperature: Days with Tmax ≥ 30°C - Heat wave: Instances of 3 days with Tmin ≥ 20°C and Tmax ≥ 33°C**	Road Network	15	■ Design: Use light colored materials for pavement surfaces on sidewalks. ■ Design: Use heat resistant paving materials with higher solar reflectance to reduce damages (e.g., potholes and cracks) and urban heat island effect. Also consider use of additives in asphalt mix to reduce shoving/rutting. ■ Operations and Maintenance: Track impacts of extreme heat to identify "hot-spots" that may require an increased rate of inspection. ■ Operations and Maintenance: Conduct frequent inspections of pavement surfaces to ensure cracks are properly sealed.	■ Hot temperatures may cause premature deterioration to road pavements and pedestrian asphalt (e.g., potholes, rutting, cracking), particularly in high-traffic areas, which could result in increased maintenance costs.
	Transit Network	10	■ Design: Use light colors or heat resistant materials for railings and bus shelter roofs to reduce solar heat gain. ■ Design: Provide adequate shade around bus shelters and platforms to reduce urban heat island effects.	■ Hot temperatures may cause bus shelters and railings to become very hot, which could have adverse effects on the health and safety of passengers waiting outside. Also, heat waves may exacerbate the urban heat island effect (UHI) near bus shelters and station infrastructure.
	Systems, Signaling and Equipment	10	■ Operations and Maintenance: Increase inspection after hot temperature events to make sure systems are working correctly.	■ The heat may cause surveillance cameras to break down or cause them to erode away causing them to malfunction
	Utilities	10	■ Design: Consider adding solar panels as an alternative source of power, on the roof of bus shelters. Solar panels can also be pole mounted. ■ Design: Install a backup generator or battery backup system to provide emergency power during an outage. Alternatively, have dedicated webpage/app for bus rapid transit operational impact that could be readily available to users. ■ Design: Use certified electrical and optical fibre components that are resilient to higher temperatures and humidity.	■ During heat waves and hot temperatures, there is an increase in energy demands and the efficiency and reliability of the power system is threatened. Heat waves and extreme temperatures can cause blackouts.
	People	10	■ Operations and Maintenance: Communicate the health risks of extreme heat events with the public. For example, share heat wave warnings and health safety tips on digital display signs.	■ Hot temperatures could impact staff wellbeing and productivity and the health and wellbeing of passengers waiting in bus shelters (e.g., heat exhaustion and heat stroke, dehydration, heat stress)
	Surrounding Environment	10	■ Design: Consider nature-based solutions, green infrastructure and landscape design, such as planting local species that have a greater heat tolerance or are drought resistant, retaining water. ■ Design: Use heat resistant materials for public benches. ■ Operations and Maintenance: Ensure proper maintenance of landscaping during summer months.	■ Hot temperatures and heat waves could cause vegetation to dry out, resulting in an increased demand for maintenance and water supply.
HIGH RISK **Heat wave: Instances of 3 days with Tmin ≥ 20°C and Tmax ≥ 33°C**	Road Network	20	■ Design: Use light colored materials for pavement surfaces on sidewalks.and/or use heat resistant paving materials with higher solar reflectance to reduce damages (e.g., potholes and cracks) and urban heat island effect. Also consider use of additives in asphalt mix to reduce shoving/rutting . ■ Design: Increase roadside vegetation and trees to increase shade and decrease exposure to heat ■ Operations and Maintenance: Track impacts of extreme heat to identify "hot-spots" that may require an increased rate of inspection. ■ Operations and Maintenance: Conduct frequent inspections of pavement surfaces to ensure cracks are properly sealed.	■ Heat waves may cause premature deterioration to road pavements and pedestrian asphalt (e.g., potholes, rutting, cracking), particularly in high-traffic areas, which could result in increased maintenance costs. Also, heat waves may exacerbate UHI due to increased surface temperatures of the pavement.-high road-surface temperature due to heat waves can lead to dangerous driving conditions as tires blowouts and deformation induced by thermal stress on roads
	People	20	■ Design: System of ventilation in buses. ■ Design: Drinking water fountains beside transit stops where feasible. ■ Design: The main walking and cycling paths should be shaded and greened. ■ Operations and Maintenance: Shift maintenance work to cooler parts of the day. ■ Operations and Maintenance: Communicate the health risks of extreme heat events with the public. For example, share heat wave warnings and health safety tips on digital display signs. ■ Policy: Implement worker safety measures to protect the health and safety of staff.	■ Increase in the number of heat waves could impact staff wellbeing and productivity and the health and wellbeing of passengers waiting in bus shelters (e.g., heat exhaustion and heat stroke, dehydration, heat stress) Heat waves could result in potential delays in construction activities
SPECIAL CASE RISK – DIURNAL VARIATION	Road Network	5	■ Design: Use materials and pavements that are resistant to significant changes in temperature	■ Premature deterioration of pavement surfaces

Risk Event	Project Components	Risk	Adaptation Measure or Risk Treatment	Comments
MODERATE RISK **Heavy rainfall: Days with P ≥ 25 mm**	Systems, Signaling and Equipment	5	■ -Operations and Maintenance: Increase inspections and maintenance following heavy rainfall events.	■ Over time, repeated exposure to heavy rain can damage almost any piece of electronic equipment, even if it is very well protected. This includes cameras. What's more, if rainwater ends up on the lens of a camera, it may distort or partially obscure the image that the camera records.
	Utilities	10	■ Design: Consider adding solar panels as an alternative source of power, on the roof of bus shelters. Solar panels can also be pole mounted. ■ Design: Install a back-up generator or battery backup system to provide emergency power during an outage. ■ Operations and Maintenance: Conduct regular inspections of electrical components and equipment before winter and spring seasons to prevent water-related damages.	■ Heavy rainfall may cause water damages to transformers located outside. Electrical systems can be damaged as a result of flooding or standing water in the basement. Potential power outages due heavy rainfall may cause delays in operations and services due to water getting into conduit/access exacerbated in low lying areas.
	Surrounding Environment	10	■ Design: in order to limit runoff and erosion, design landscaping with plants that can help hold the soil firmly in place, such as fast-growing ground covers and even flower plants such as daylilies and sages. Make sure that the plants used can absorb a lot of water. ■ Design: Mulching can help mitigate erosion on moderate slopes in the landscape. applying mulch protects soil, increases surface area and improves water penetration	■ Increased surface runoff and erosion of topsoil exacerbated in low lying areas. ■ Increased maintenance of vegetation and landscape around stations.
HIGH RISK **Heavy rainfall: Days with P ≥ 25 mm**	Road Network	20	■ Design: Design drainage systems to cope with heavy rainfall (P ≥ 25 mm) with well-defined overland flow routes.and/orIncorporate low impact development practices or green Infrastructure to manage stormwater runoff and prevent flood damages. Some examples include, bioretention planters, bioswales, etc. ■ Design: Avoid new mass transit corridors in flood prone areas. Use cities' risk assessment plan for modelling flood risks & identify alternative routes ■ Design: for transit station, avoid underground or low-lying depots prone to flooding for bus fleets ■ Operations and Maintenance: Monitor water levels to assess the risk of flooding during heavy rainfall (see Toronto Region Conservation Authority's real-time flood monitoring website). ■ Operations and Maintenance: Clear drainage systems of debris (e.g., objects, leaves) to prevent sewer back up. ■ Operations and Maintenance: Plan alternative routes to provide redundancy in the event of a major flood.	■ Heavy rainfall may result in flash floods, which could result in delays and reduced road safety. Heavy rainfall could cause premature deterioration to road pavements and pedestrian asphalt (e.g., potholes, rutting, cracking), particularly in high-traffic areas) exacerbated in low lying areas. Increased maintenance and repair costs.
	Transit Network	20	■ Design: Providing safe access for all (with ramps) to bus rapid transit stations ■ Operations and Maintenance: Implement an early warning system that alert staff in advance so that necessary resources can be deployed on site before, during and after an extreme weather event.	■ Heavy rainfall may result in localized flash floods, which could cause damages to bus shelters or station infrastructure, platforms, railings, and ramps and impact operations and people; exacerbated in low lying areas. Increased maintenance and repair costs.
	People	20	■ Policy: Provide real-time flood alerts so that commuters can plan their travel accordingly. ■ Operations and Maintenance: Share weather information, climate-related risks and extreme events on digital display signs to alert commuters of potential delays in operations and services. ■ Operations and Maintenance: Modify work schedules under conditions induced by climate-related disruptions.	■ Heavy rainfall may cause disruption of construction work and maintenance work, resulting in delays in operations and services. exacerbated in low lying areas. Heavy rainfall can cause flash floods. When this occurs, bus shelters, platforms and ramps may be difficult to access. Floods could reduce road safety for drivers, pedestrians and cyclists. Also, people may file claims to the city for damages caused by storm sewer overflows.
MODERATE RISK **Winter rain on snow: Instances of P ≥ 25 mm within Jan-Feb-Mar**	Transit Network	9	■ Design: Design bus shelters with arched or sloped roof (no flat roof) to prevent snow loads. ■ Design: Use corrosion resistant materials or treatments for metal railings to prevent premature deterioration.	■ Winter rain on snow may result in damages to roofs of bus rapid transit stops due to heavy loads. There can be accumulation of slush on bus platforms and ramps. This can lead to increased snow removal costs.

Risk Event	Project Components	Risk	Adaptation Measure or Risk Treatment	Comments
MODERATE RISK **Drought: Instance of P < 0.2 mm for 10 days**	Surrounding Environment	**10**	■ Design: Consider nature-based solutions, green infrastructure and landscape design, such as planting local species that have a greater heat tolerance or are drought resistant, retaining water. ■ Operations and Maintenance: Ensure proper maintenance of landscaping during summer months.	■ Drought can cause reduced soil quality, resulting in loss of vegetation and increased demand for water.
MODERATE RISK **Heavy wind: Days with W ≥ 65 kilometre/h - Blowing rain: Instances of (P ≥ 5 mm) and (W ≥ 65 kilometre/h)- Blowing snow: Instances of ((S ≥ 5 cm) or (SD ≥ 5 cm)) and (W ≥ 65 kilometre/h)**	Road Network	**10**	■ Operations and Maintenance: Clear sidewalks of debris or objects that may be blown away. ■ Operations and Maintenance: Conduct snow clearing of bus lanes to maintain good road conditions.	■ Blown objects may cause obstructions on pedestrian sidewalks and roadways. There can be accumulation of snow on road pavement which can lead to snow removal costs and reduced road safety due to slippery pavement and reduced visibility.
	Transit Network	**10**	■ Design: Use wind resistant glass materials (W ≥ 65 kilometre/h) to prevent damages caused by flying objects. ■ Design: Consider adding heaters in bus shelters to provide thermal comfort for passengers. ■ Design: Install signs that indicate icy conditions near bus platforms to prevent slip and fall injuries. ■ Design: Install sign poles to withstand heavy winds (W ≥ 65 kilometre/h). Some examples include, increasing the installation depth, securing poles with an anchor base mounting or using concrete foundations. ■ Operations and Maintenance: Increase the frequency of inspections for bus shelter roofs to prevent water infiltration.	■ Blown objects may cause obstructions on pedestrian sidewalk. There can be accumulation of debris around bus shelters and station infrastructure due to heavy winds. Strong wind gusts could damage bus rapid transits stop elements. Blowing rain and blowing snow could result in water infiltration in bus shelters infrastructure All this can lead to increased maintenance costs and snow removal costs.
	Systems, Signaling and Equipment	**10**	■ Design: Install traffic signal light poles that withstand heavy winds (W ≥ 65 kilometre/h). Some examples include, increasing the installation depth, securing poles with an anchor base mounting or using concrete foundations. ■ Operations and Maintenance: Conduct regular inspection during these extreme weather events and apply necessary measures (snow-clearing, debris clearing, use of abrasive material to de-ice) to maintain road safety and traffic signal lights visibility and prevent slippery pavement.	■ Streetlights and signs may be damaged by strong winds which can lead to reduced road safety and increased maintenance & operations costs. Snow and ice affect outdoor surveillance system cameras in optic and mechanical disruptions. An unshielded camera can be damaged by ice. If there is moisture around an outdoor camera below the temperatures drop below freezing, the frost that is formed by that moisture and temperature can form on the cameras lens and disallowing the viewer to see any activities going on outside besides the crystalline patterns from the snow.
	Utilities	**15**	■ Design: Consider adding solar panels as an alternative source of power, on the roof of bus shelters. Solar panels can also be pole mounted. ■ Design: Install a backup generator or battery backup system to provide emergency power during an outage. Alternatively, have dedicated webpage/app for bus rapid transit operational impact that could be readily available to users.	■ Heavy winds may cause power outages which can cause disruption to the operations and reliance on back-up generator systems. Blowing rain and blowing snow may cause water damages (e.g., infiltration, corrosion) to transformers located outside. Snow accumulation may increase loads on transformers located outside, which may result in increased maintenance and snow removal costs.
	People	**15**	■ Design: Consider directions of prevailing wind by strategically locating barriers or including enclosed areas on bus rapid transit stops to mitigate impacts of prevailing winds on passengers. ■ Design: Consider adding emergency push buttons within the bus rapid transit stop amenities to assist in safety related platform if someone trips and falls for instance. ■ Operations and Maintenance: Share weather information, climate-related risks and extreme events on digital display signs. ■ Operations and Maintenance: Remove debris from sidewalks and cycle tracks to ensure public safety. ■ Operations and Maintenance: Increase snow removal around bus platforms and ramps to ensure public safety. ■ Policy: Implement worker safety measures to protect the health and safety of staff working outdoors.	■ Blown objects could cause injuries to staff- Blowing snow can blow away debris or objects, which could cause injuries to pedestrians and cyclists or damage vehicles. Pedestrians may have trouble accessing bus platforms and sidewalks if they are not properly cleared.
	Surrounding Environment	**15**	■ Design: Consider incorporating windbreaks (e.g., vegetation) in the landscape design. ■ Operations and Maintenance: Cover fragile trees, shrubs and other vulnerable plants with protective sheets. ■ Operations and Maintenance: Properly secure objects in public spaces (e.g., art, benches) before fall and winter seasons.	■ Trees and branches could blow away in the wind and heavy winds could damage objects in public spaces (e.g., benches, art, etc.).

Risk Event	Project Components	Risk	Adaptation Measure or Risk Treatment	Comments
MODERATE RISK **Freezing rain: Days with freezing rain** 	Road Network	**12**	■ Operations and Maintenance: Conduct ice clearing of bus lanes to maintain good road conditions.	■ Freezing rain may cause pavements to become slippery, which could compromise or reduce road passenger/pedestrian safety. Increased maintenance costs (e.g., de-icing).
	Transit Network	**12**	■ Operation and Maintenance: Increase inspections and de-icing of bus shelter roofs and platforms to ensure public safety during freezing rain. Alternatively consider inground pavement de-icing systems	■ 'Freezing rain may cause ramps and platforms to become slippery, which could result in slips and falls. Increased maintenance of bus platforms and ramps (e.g., de-icing)
	Systems, Signaling and Equipment	**8**	■ Operation and Maintenance: Increase inspections and maintenance on surveillance cameras	■ Ice affect outdoor surveillance system cameras in optic and mechanical disruptions. An unshielded camera can be damaged by ice. If there is moisture around an outdoor camera below the temperatures drop below freezing, the frost that is formed by that moisture and temperature can form on the cameras lens and disallowing the viewer to see any activities going on outside besides the crystalline patterns from the snow. Increase maintenance cost
	Utilities	**8**	■ Design: Consider an alternate source of power in prevision of power outages.	■ Potential power outages due to freezing rain could cause delays in operations and services. Increased maintenance costs.
	People	**12**	■ Design: Consider adding heaters in bus shelters to provide thermal comfort for passengers. ■ Design: Install signs that indicate icy conditions near bus platforms to prevent slip and fall injuries. ■ - Operation and Maintenance: Show real-time weather information, climate-related risks and extreme events on digital display signs to alert commuters of potential delays in operations and services. ■ Operation and Maintenance: Modify work schedules under conditions induced by climate-related disruptions. ■ Operation and Maintenance: Implement an early warning system that alert staff in advance so that necessary resources can be deployed on site before, during and after an extreme weather event. ■ Operation and Maintenance: Clear sidewalks around bus platforms and ramps to reduce ice build-up.	■ Freezing rain could compromise the health and safety of workers conducting maintenance or construction (e.g., frostbites, hypothermia). Workers can slip or fall if pavement surfaces become too slippery due to freezing rain. Disruptions in construction and maintenance work, resulting in delays in operations and services. Freezing rain can cause ice to build up and fall from bus shelter roofs, which may result in injuries. People can slip or fall if ramps or platforms become too slippery due to freezing rain (reduced public safety).
	Surrounding Environment	**8**	■ Operation and Maintenance: Cover fragile trees, shrubs and other vulnerable plants with protective sheets	■ Freezing rain may cause damages to trees and vulnerable plants.

Adaptation measures were identified based on the following three types of measures at this and are anticipated to be refined as the project proceeds to detail design and eventual operation:

- **Design**: Measures to incorporate in the future design of assets for these to be resilient to future climate risks.
- **Operations and Maintenance (Operations and Maintenance)**: Measures to incorporate for the facility to reach resiliency in its Operations and Maintenance.
- **Policy**: Measures to provide and maintain safe and healthy working conditions.

5.6 Riverine Flooding

Riverine (or fluvial) flooding occurs when water levels of rivers, streams and creeks rise and overflow their banks and spill onto adjacent areas (Toronto and Region Conservation Authority, n.d.)[14]. This section will present an overview of potential flood vulnerable areas within the Mississauga East Rapid Bus Transit Project.

The riverine flooding along Dundas Street is indicative that the existing infrastructure cannot handle the existing climate let alone any future projected changes. If significant improvements to the infrastructure along Dundas Street are not planned to eliminate the flooding, the climate change adaptation measures included in table 6.11 would also apply in situations of riverine flooding along Dundas Street. In addition, the City of Mississauga is examining flooding along Dundas Street as Special Policy Areas.

The beginning of the Project Area near the Toronto/Mississauga boundary intersects with the Little Etobicoke Creek as shown in **Figure 5-6**. In spring, Little Etobicoke Creek can experience high flows as a result of heavy rainfall and accumulation of melting snow into the river. During the summer, Little Etobicoke Creek can flood as a result of heavy rainfall and thunderstorms. In the fall, heavy rainfall and saturated soils can also cause rivers to rise. (Toronto and Region Conservation Authority, n.d.)

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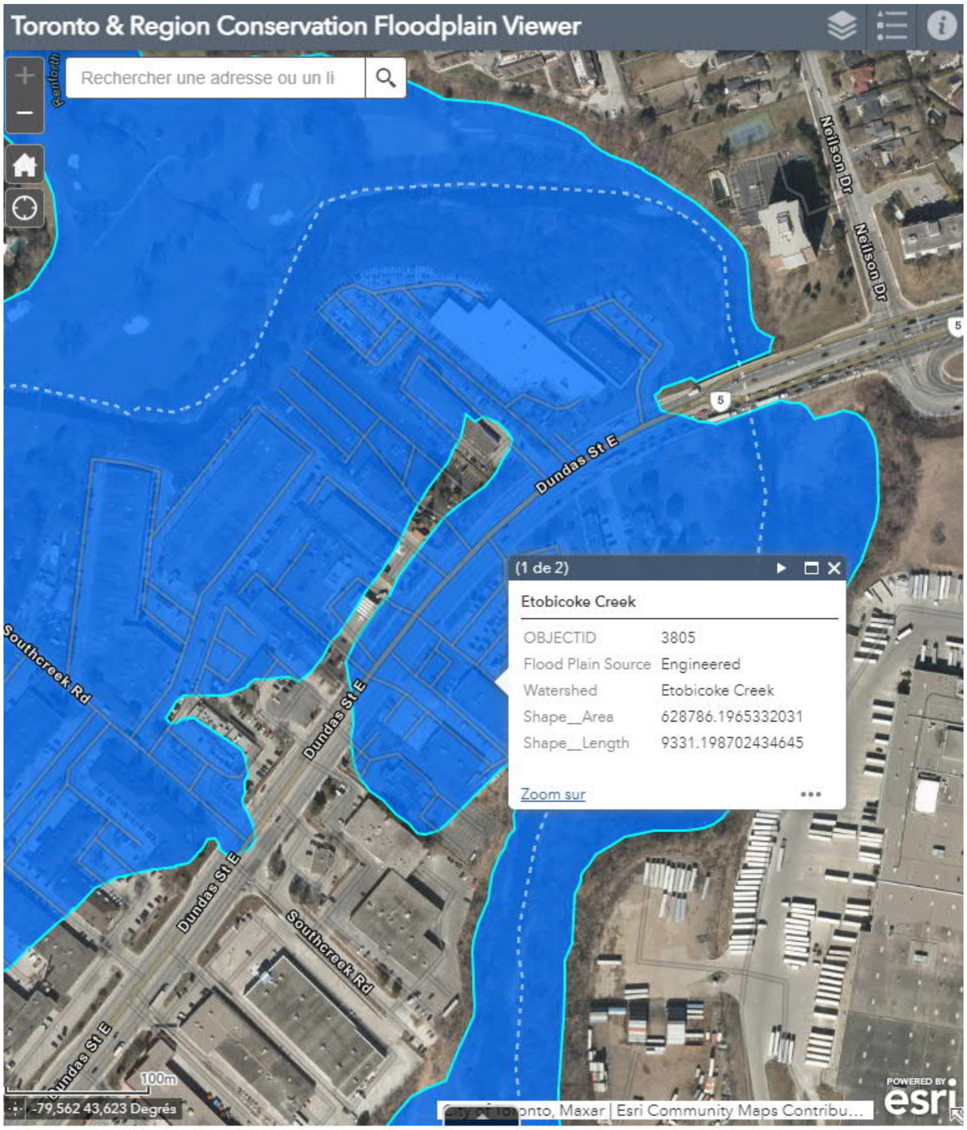
14. Toronto and Region Conservation Authority. (n.d.). Living in a flood vulnerable area: Dixie-Dundas. https://trca.ca/conservation/flood-risk-management/flood-risk-area-dixie-dundas/

Figure 5-6: Intersection of Dundas Street East and Little Etobicoke Creek



Source: Toronto and Region Conservation Authority. (2021). Floodplain Viewer.

Further along Dundas Street towards the west, at the intersection with Dixie Street, the Project is located within the Etobicoke Creek Watershed as shown in **Figure 5-7**. This area is prone to flooding due to numerous factors, such as capacity constraints in the river channel, backwater from multiple culvert crossings, and severe thunderstorms (Toronto and Region Conservation Authority, n.d.). During the storm of July 8, 2013, the area experienced significant flooding when flows exceeded the capacity of the channel and began flowing south along Queen Frederica Drive (Toronto and Region Conservation Authority, n.d.).

Figure 5-7: Intersection of Dundas Street East and Dixie Road Located within Etobicoke Creek Watershed

Source: Toronto and Region Conservation Authority. (2021). Floodplain Viewer.

Throughout Dundas Street, within the City of Mississauga, the Project intersects with the Credit River Watershed and other associated creeks at several locations. Those locations are vulnerable to riverine flooding and will be further reviewed by the AECOM's Water Resources team. The following figure demonstrate where Dundas Street is located within the regulatory floodplain of the Credit River Watershed for the Mississauga East Bus Rapid Transit Project.

The Credit River is almost 90 kilometres long and meanders southeast from its headwaters in Orangeville, Erin and Mono, through nine municipalities, eventually draining into Lake Ontario at Port Credit, Mississauga. The Credit River watershed is located in an urbanized area, with most people living in the lower part of the watershed in the Mississauga region. It is part of the Greater Toronto Area, which is one of North America's fastest growing areas. (Credit Valley Conservation, n.d.)[15]

Figure 5-8: Intersection of Dundas Street East and Cooksville Creek between Kirwin Avenue and Hurontario Street

Source: Credit Valley Conservation. (2021). Regulation Mapping

15. Credit Valley Conservation. (n.d.). Watershed Science: our watershed. https://cvc.ca/watershed-science/our-watershed/

As shown in **Figure 5-8**, Dundas Street East intersects with Cooksville Creek between Kirwin Avenue and Hurontario Street. The Cooksville Creek watershed is vulnerable to flooding and drainage issues in area where development has reduced channel conveyance and restricted floodplain capacity. In August 2009, significant flood damages occurred within the Cooksville Creek watershed where 68 millimeters of rainfall was recorded in one hour. The Majority of the lands within the Cooksville Creek watershed were developed without the benefits of stormwater management in terms of quantity and quality (Aquafor Beech Ltd., 2011[16]; Aquafor Beech Ltd., 2012[17]).

16. Aquafor Beech Ltd. (2011). Executive summary (phase 1): Cooksville creek watershed study and impact monitoring characterization report (Report Reference No 64990). Credit Valley Conservation (CVC).
17. Aquafor Beech Ltd. (2012). Cooksville creek flood evaluation master plan EA final report. City of Mississauga.

6. Summary and Recommendations

6.1 Sustainability Initiatives

Metrolinx has invested significant energy in planning for climate adaptation, resiliency and sustainability in recent years which has most recently included the refreshing of their Sustainability Strategy in 2021 along with revised goals and actions which are more specific, and the release of Sustainable Design Standard. The application of the Sustainable Design Standards will be mandatory for the design of all new, expanded, and reconstructed Metrolinx buildings and facilities in the future.

A thorough review of Envision has indicated that up to 35 credits across the five streams are applicable to project along with the level of achievement that is likely possible. An early decision to the application of Envision to the Dundas Bus Rapid Transit Project is key to successful achievement.

6.2 Effects of the Transit Project on Climate Change

A greenhouse gas inventory has been completed on both baseline case and the result of implementing the Project including both construction, operation and maintenance. At this time the challenge represented of the early phase of the Project has led to a number of assumptions being included to develop the inventories.

The methodology used for the quantification of greenhouse gases is based on modelling the kilometres travelled by vehicles (vehicle kilometres travelled) in the entire study area and a broader Regional area without the Project and with the project. Since the available modelling results are based on the difference in kilometres travelled over the entire study area and a broader Regional area, which also includes other projects by Metrolinx, it is not possible to define the impact of each of the Bus Rapid Transit segments. The difference in vehicle kilometres travelled with and without the project indicates that within the study area, the Bus Rapid Transit Project will influence traffic behaviour. However, in the absence of vehicle kilometres travelled data by Bus Rapid Transit segment, it is not possible to know where this change in traffic behaviour is occurring in the region. Thus, the greenhouse gases quantification is for the entire Bus Rapid Transit corridor.

The Project case has been shown to be the preferred option with respect to greenhouse gas emissions. The greenhouse gases assessment shows emission reductions comparing baseline and Project cases over a 63-year lifecycle of 322,014 tonnes of

CO_2e. The Operations and Maintenance emissions drive the total greenhouse gas emissions.

Embodied carbon within the Project can be better tracked and estimated in future phases of the development of the Project with the adoption of Metrolinx's new DS-05 Sustainable Design Standard along with an early decision on the application of Envision to the Dundas Bus Rapid Transit Projects.

6.3 Effects of Climate Change on the Transit Project

The effects of Climate Change on the Project have been determined by completing a Climate Change Risk Assessment based on the International Organization for Standardization 31000 Risk Management Standard and to document the existing condition of riverine flooding.

In order to determine the climate-related risks to the future Bus Rapid Transit system, climate indicators and their probabilities of occurring were analyzed for both the historical period and in the context of the changing climate. A total of 25 climate indicators were reviewed at a high-level to estimate the likelihood of climate risks to the Project. As a result of this initial review, 14 climate indicators were removed from the analysis as they were considered to have no impact or a very low impact on the Project resulting in 11 climate indicators which were selected. In addition, the climate parameters from the Metrolinx PIEVC Climate Change Vulnerability Assessment (AECOM 2016) where also reviewed.

Climate change vulnerability was first assessed, to determine the exposure, sensitivity, and adaptive capacity of each assets and elements to the 11 selected climate indicators. The risk assessment revealed 52 interaction showing risks out of 66 possible interactions, between 11 climate indicators and the six project components. Risk treatment and adaptation measures for each of the interactions have been developed in three types of measures, Design, Operations and Maintenance, and Policy.

In addition, within this 7.2-kilometre section of the Dundas Bus Rapid Transit Mississauga East Project there are three areas of significant riverine flooding which could impact the construction and future operation. Areas of riverine flooding are likely beyond the scope of the Dundas Bus Rapid Transit Project as they are a result of the upstream development of the watershed. As such operational procedures may need to be developed to ensure the safe operation of the Dundas Bus Rapid Transit.

6.4 Recommendations

At this time AECOM makes the following Recommendations associated with this 7.2-kilometre section of the Dundas Bus Rapid Transit:

- The application of the Sustainable Design Standards to the Dundas Bus Rapid Transit Project;
- An early decision to the application of Envision to the Dundas Bus Rapid Transit Project is key to successful achievement;
- Document embodied carbon within the Project with the adoption of Metrolinx's new DS-05 Sustainable Design Standard and Envision;
- The results of the greenhouse gas inventories be updated as the details of the Project crystalize;
- The results of the Climate Change Risk Assessment be shared and incorporated into the future detailed design and eventual operation and maintenance of the Project; and
- Operational procedures be developed for the Dundas Bus Rapid Transit Project to ensure the safe operation in areas of riverine flooding.

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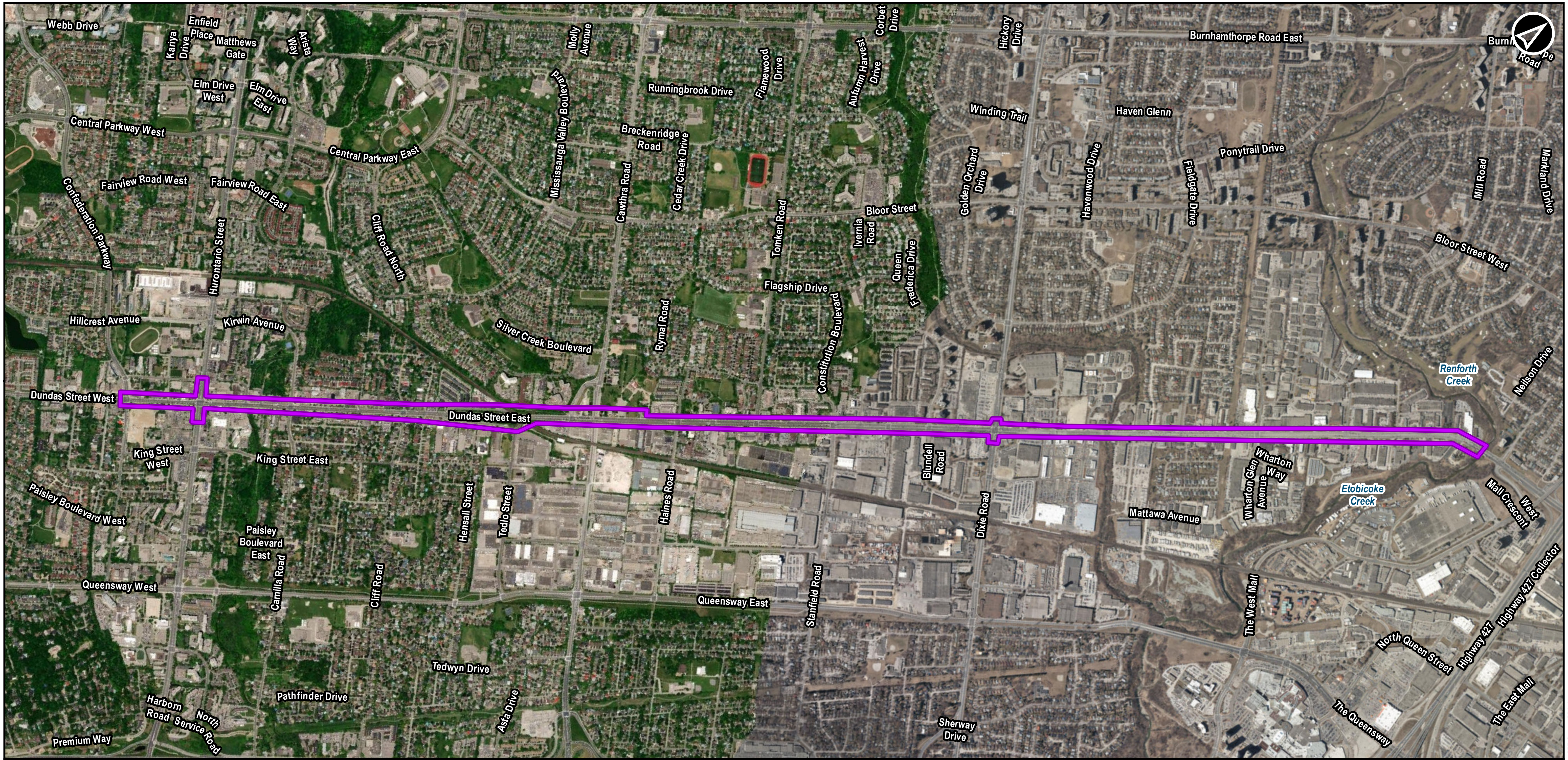
Appendix A

Figures



Legend

Dundas Bus Rapid Transit Mississauga East Project Area

Dundas Bus Rapid Transit

Mississauga East Project Area

0 750 1,500
Meters
DATUM: NAD 1983 CSRS MTM 10

Data Sources:
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Figure 1

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Appendix B

Greenhouse Gases Calculations – Baseline Scenario

Calculations based on 2006 IPCC Guidelines for National Greenhouse Gas Inventories	Year	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036
Annual VKT	km/y	7,006,252,665	7,047,992,787	7,062,079,173	7,039,709,551	7,083,643,434	7,113,928,666	7,128,732,404	7,125,421,621	7,100,975,069	7,051,927,054
Average fuel consumption	L/km	0.0691	0.0691	0.0691	0.0691	0.0691	0.0691	0.0691	0.0691	0.0691	0.0691
Vehicle annual fuel consumption	L/y	484,132,059	487,016,302	487,989,671	486,443,930	489,479,761	491,572,471	492,595,409	492,366,634	490,677,377	487,288,159
Emissions GHG = Fuel consumption x Emission Factor	g CO_2 e/L	-	-	-	-	-	-	-	-	-	-
CO_2 Emission Factor	g CO_2/L	2681	2681	2681	2681	2681	2681	2681	2681	2681	2681
CH_4 Emission Factor	g CH_4/L	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068
N_2O Emission Factor	g NO_2/L	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21
CO_2 emissions	g CO_2/y	1,297,958,050,659	1,305,690,704,522	1,308,300,307,565	1,304,156,176,265	1,312,295,239,985	1,317,905,794,192	1,320,648,291,894	1,320,034,945,790	1,315,506,048,388	1,306,419,555,477
CO_2 emissions	kg CO_2/d	3,556,049	3,577,235	3,584,384	3,573,031	3,595,329	3,610,701	3,618,214	3,616,534	3,604,126	3,579,232
CH_4 emissions	g CH_4/y	32,920,980	33,117,109	33,183,298	33,078,187	33,284,624	33,426,928	33,496,488	33,480,931	33,366,062	33,135,595
CH_4 emissions	kg CH_4/d	90	91	91	91	91	92	92	92	91	91
N_2O emissions	g N_2O/y	101,667,732	102,273,423	102,477,831	102,153,225	102,790,750	103,230,219	103,445,036	103,396,993	103,042,249	102,330,513
N_2O emissions	kg N_2O/d	279	280	281	280	282	283	283	283	282	280
Annual VKT	km/y	18,209,199,444	18,317,681,715	18,354,292,130	18,296,153,646	18,410,337,486	18,489,048,582	18,527,523,390	18,518,918,689	18,455,382,278	18,327,906,847
Average fuel consumption	L/km	0.0804	0.0804	0.0804	0.0804	0.0804	0.0804	0.0804	0.0804	0.0804	0.0804
Vehicle annual fuel consumption	L/y	1,464,019,635	1,472,741,610	1,475,685,087	1,471,010,753	1,480,191,134	1,486,519,506	1,489,612,881	1,488,921,063	1,483,812,735	1,473,563,711
Emissions GHG = Fuel consumption x Emission Factor	g CO_2 eq/L	-	-	-	-	-	-	-	-	-	-
CO_2 Emission Factor	g CO_2/L	2307	2307	2307	2307	2307	2307	2307	2307	2307	2307
CH_4 Emission Factor	g CH_4/L	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23
N_2O Emission Factor	g NO_2/L	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47
CO_2 emissions	g CO_2/y	3,377,493,298,721	3,397,614,894,015	3,404,405,496,211	3,393,621,807,410	3,414,800,945,795	3,429,400,500,247	3,436,536,915,483	3,434,940,891,364	3,423,155,979,966	3,399,511,480,130
CO_2 emissions	kg CO_2/d	9,253,406	9,308,534	9,327,138	9,297,594	9,355,619	9,395,618	9,415,170	9,410,797	9,378,510	9,313,730
CH_4 emissions	g CH_4/y	336,724,516	338,730,570	339,407,570	338,332,473	340,443,961	341,899,486	342,610,963	342,451,844	341,276,929	338,919,653
CH_4 emissions	kg CH_4/d	923	928	930	927	933	937	939	938	935	929
N_2O emissions	g N_2O/y	688,089,229	692,188,557	693,571,991	691,375,054	695,689,833	698,664,168	700,118,054	699,792,899	697,391,986	692,574,944
N_2O emissions	kg N_2O/d	1,885	1,896	1,900	1,894	1,906	1,914	1,918	1,917	1,911	1,897
Bus annual fuel consumption	kWh/y	61,616,761	62,849,096	64,106,078	65,388,200	66,695,964	68,029,883	69,390,481	70,778,290	72,193,856	73,637,733
Emissions GHG = Fuel consumption × Emission Factor	g $CO_{2\ e}$/kWh	30	30	30	30	30	30	30	30	30	30
Total CO_2e	kg CO_2e / d	5,064	5,166	5,269	5,374	5,482	5,591	5,703	5,817	5,934	6,052
Annual VKT	km/y	1,313,562,919	1,693,920,828	2,184,415,934	2,816,939,785	3,221,878,121	3,687,198,974	4,219,723,951	4,829,159,031	5,526,611,981	6,324,794,813
Average fuel consumption	kWh/km	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Vehicle annual fuel consumption	kWh/y	262,712,584	338,784,166	436,883,187	563,387,957	644,375,624	737,439,795	843,944,790	965,831,806	1,105,322,396	1,264,958,963
Emissions GHG = Fuel consumption × Emission Factor	g $CO_{2\ e}$/kWh	30	30	30	30	30	30	30	30	30	30
Total CO_2e	kg CO_2e / d	21,593	27,845	35,908	46,306	52,962	60,611	69,365	79,383	90,848	103,969
Total CO_2	**kg CO_2 / d**	12,836,113	12,918,780	12,952,700	12,922,305	13,009,393	13,072,522	13,108,453	13,112,532	13,079,418	13,002,983
Total CH_4	**kg CH_4 / d**	1,013	1,019	1,021	1,018	1,024	1,028	1,030	1,030	1,026	1,019
Total N_2O	**kg N_2O / d**	2,164	2,177	2,181	2,174	2,188	2,197	2,202	2,201	2,193	2,178
GWP CH_4	-	25	25	25	25	25	25	25	25	25	25
GWP N_2O	-	298	298	298	298	298	298	298	298	298	298
Total CO_2e	**kg CO_2e / d**	13,506,219	13,592,878	13,628,145	13,595,611	13,686,901	13,752,926	13,790,273	13,794,036	13,758,584	13,677,458
Total CO_2e	**tonnes CO_2e / y**	4,929,770	4,961,400	4,974,273	4,962,398	4,995,719	5,019,818	5,033,450	5,034,823	5,021,883	4,992,272

Calculations based on 2006 IPCC Guidelines for National Greenhouse Gas Inventories	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047
Annual VKT	6,974,303,088	6,863,546,235	6,714,432,826	6,520,975,993	6,276,315,268	5,972,590,236	5,600,795,932	5,150,617,354	4,610,240,071	3,966,133,475	3,202,802,720
Average fuel consumption	0.0691	0.0691	0.0691	0.0691	0.0691	0.0691	0.0691	0.0691	0.0691	0.0691	0.0691
Vehicle annual fuel consumption	481,924,343	474,271,045	463,967,308	450,599,441	433,693,385	412,705,985	387,014,999	355,907,659	318,567,589	274,059,823	221,313,668
Emissions GHG = Fuel consumption x Emission Factor	-	-	-	-	-	-	-	-	-	-	-
CO_2 Emission Factor	2681	2681	2681	2681	2681	2681	2681	2681	2681	2681	2681
CH_4 Emission Factor	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068
N_2O Emission Factor	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21
CO_2 emissions	1,292,039,164,603	1,271,520,671,173	1,243,896,353,426	1,208,057,101,570	1,162,731,965,277	1,106,464,746,668	1,037,587,212,070	954,188,434,197	854,079,705,873	734,754,385,703	593,341,943,728
CO_2 emissions	3,539,833	3,483,618	3,407,935	3,309,745	3,185,567	3,031,410	2,842,705	2,614,215	2,339,944	2,013,026	1,625,594
CH_4 emissions	32,770,855	32,250,431	31,549,777	30,640,762	29,491,150	28,064,007	26,317,020	24,201,721	21,662,596	18,636,068	15,049,329
CH_4 emissions	90	88	86	84	81	77	72	66	59	51	41
N_2O emissions	101,204,112	99,596,919	97,433,135	94,625,883	91,075,611	86,668,257	81,273,150	74,740,608	66,899,194	57,552,563	46,475,870
N_2O emissions	277	273	267	259	250	237	223	205	183	158	127
Annual VKT	18,126,162,726	17,838,306,475	17,450,761,815	16,947,968,921	16,312,097,487	15,522,718,350	14,556,427,672	13,386,416,839	11,981,980,233	10,307,951,898	8,324,060,848
Average fuel consumption	0.0804	0.0804	0.0804	0.0804	0.0804	0.0804	0.0804	0.0804	0.0804	0.0804	0.0804
Vehicle annual fuel consumption	1,457,343,483	1,434,199,841	1,403,041,250	1,362,616,701	1,311,492,638	1,248,026,555	1,170,336,785	1,076,267,914	963,351,211	828,759,333	669,254,492
Emissions GHG = Fuel consumption x Emission Factor	-	-	-	-	-	-	-	-	-	-	-
CO_2 Emission Factor	2307	2307	2307	2307	2307	2307	2307	2307	2307	2307	2307
CH_4 Emission Factor	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23
N_2O Emission Factor	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47
CO_2 emissions	3,362,091,415,756	3,308,699,032,216	3,236,816,163,564	3,143,556,729,707	3,025,613,515,736	2,879,197,263,150	2,699,966,962,588	2,482,950,077,302	2,222,451,243,086	1,911,947,780,329	1,543,970,113,497
CO_2 emissions	9,211,209	9,064,929	8,867,989	8,612,484	8,289,352	7,888,212	7,397,170	6,802,603	6,088,908	5,238,213	4,230,055
CH_4 emissions	335,189,001	329,865,963	322,699,487	313,401,841	301,643,307	287,046,108	269,177,461	247,541,620	221,570,778	190,614,647	153,928,533
CH_4 emissions	918	904	884	859	826	786	737	678	607	522	422
N_2O emissions	684,951,437	674,073,925	659,429,387	640,429,850	616,401,540	586,572,481	550,058,289	505,845,920	452,775,069	389,516,886	314,549,611
N_2O emissions	1,877	1,847	1,807	1,755	1,689	1,607	1,507	1,386	1,240	1,067	862
Bus annual fuel consumption	75,110,488	76,612,698	78,144,951	79,707,851	81,302,008	82,928,048	84,586,609	86,278,341	88,003,908	89,763,986	91,559,265
Emissions GHG = Fuel consumption × Emission Factor	30	30	30	30	30	30	30	30	30	30	30
Total CO_2e	6,173	6,297	6,423	6,551	6,682	6,816	6,952	7,091	7,233	7,378	7,525
Annual VKT	7,238,255,474	8,283,643,005	9,480,010,988	10,849,164,828	12,416,059,181	14,209,252,789	16,261,428,998	18,609,991,461	21,297,745,864	24,373,680,118	27,893,857,233
Average fuel consumption	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Vehicle annual fuel consumption	1,447,651,095	1,656,728,601	1,896,002,198	2,169,832,966	2,483,211,836	2,841,850,558	3,252,285,800	3,721,998,292	4,259,549,173	4,874,736,024	5,578,771,447
Emissions GHG = Fuel consumption × Emission Factor	30	30	30	30	30	30	30	30	30	30	30
Total CO_2e	118,985	136,169	155,836	178,342	204,100	233,577	267,311	305,918	350,100	400,663	458,529
Total CO_2	12,876,201	12,691,014	12,438,183	12,107,123	11,685,701	11,160,015	10,514,138	9,729,827	8,786,185	7,659,280	6,321,704
Total CH_4	1,008	992	971	943	907	863	810	745	666	573	463
Total N_2O	2,154	2,120	2,074	2,014	1,938	1,844	1,730	1,591	1,424	1,225	989
GWP CH_4	25	25	25	25	25	25	25	25	25	25	25
GWP N_2O	298	298	298	298	298	298	298	298	298	298	298
Total CO_2e	13,543,251	13,347,471	13,080,379	12,730,816	12,285,993	11,731,257	11,049,820	10,222,453	9,227,127	8,038,617	6,628,033
Total CO_2e	4,943,287	4,871,827	4,774,338	4,646,748	4,484,387	4,281,909	4,033,184	3,731,195	3,367,901	2,934,095	2,419,232

Calculations based on 2006 IPCC Guidelines for National Greenhouse Gas Inventories	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060
Annual VKT	2,302,504,840	1,244,923,855	6,798,952	6,934,931	7,073,629	7,215,102	7,359,404	7,506,592	7,656,724	7,656,724	7,656,724	7,656,724	7,656,724
Average fuel consumption	0.0691	0.0691	0.0691	0.0691	0.0691	0.0691	0.0691	0.0691	0.0691	0.0691	0.0691	0.0691	0.0691
Vehicle annual fuel consumption	159,103,084	86,024,238	469,808	479,204	488,788	498,564	508,535	518,706	529,080	529,080	529,080	529,080	529,080
Emissions GHG = Fuel consumption x Emission Factor	-	-	-	-	-	-	-	-	-	-	-	-	-
CO_2 Emission Factor	2681	2681	2681	2681	2681	2681	2681	2681	2681	2681	2681	2681	2681
CH_4 Emission Factor	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068
N_2O Emission Factor	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21
CO_2 emissions	426,555,369,371	230,630,983,019	1,259,554,101	1,284,745,183	1,310,440,086	1,336,648,888	1,363,381,866	1,390,649,503	1,418,462,493	1,418,462,493	1,418,462,493	1,418,462,493	1,418,462,493
CO_2 emissions	1,168,645	631,866	3,451	3,520	3,590	3,662	3,735	3,810	3,886	3,886	3,886	3,886	3,886
CH_4 emissions	10,819,010	5,849,648	31,947	32,586	33,238	33,902	34,580	35,272	35,977	35,977	35,977	35,977	35,977
CH_4 emissions	30	16	0	0	0	0	0	0	0	0	0	0	0
N_2O emissions	33,411,648	18,065,090	98,660	100,633	102,645	104,698	106,792	108,928	111,107	111,107	111,107	111,107	111,107
N_2O emissions	92	49	0	0	0	0	0	0	0	0	0	0	0
Annual VKT	5,984,193,242	3,235,547,995	17,670,426	18,023,835	18,384,311	18,751,998	19,127,038	19,509,578	19,899,770	19,899,770	19,899,770	19,899,770	19,899,770
Average fuel consumption	0.0804	0.0804	0.0804	0.0804	0.0804	0.0804	0.0804	0.0804	0.0804	0.0804	0.0804	0.0804	0.0804
Vehicle annual fuel consumption	481,129,137	260,138,059	1,420,702	1,449,116	1,478,099	1,507,661	1,537,814	1,568,570	1,599,941	1,599,941	1,599,941	1,599,941	1,599,941
Emissions GHG = Fuel consumption x Emission Factor	-	-	-	-	-	-	-	-	-	-	-	-	-
CO_2 Emission Factor	2307	2307	2307	2307	2307	2307	2307	2307	2307	2307	2307	2307	2307
CH_4 Emission Factor	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23
N_2O Emission Factor	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47
CO_2 emissions	1,109,964,918,244	600,138,501,571	3,277,560,112	3,343,111,314	3,409,973,541	3,478,173,012	3,547,736,472	3,618,691,201	3,691,065,025	3,691,065,025	3,691,065,025	3,691,065,025	3,691,065,025
CO_2 emissions	3,041,000	1,644,215	8,980	9,159	9,342	9,529	9,720	9,914	10,113	10,113	10,113	10,113	10,113
CH_4 emissions	110,659,701	59,831,754	326,762	333,297	339,963	346,762	353,697	360,771	367,987	367,987	367,987	367,987	367,987
CH_4 emissions	303	164	1	1	1	1	1	1	1	1	1	1	1
N_2O emissions	226,130,694	122,264,888	667,730	681,085	694,706	708,600	722,772	737,228	751,973	751,973	751,973	751,973	751,973
N_2O emissions	620	335	2	2	2	2	2	2	2	2	2	2	2
Bus annual fuel consumption	93,390,451	95,258,260	97,163,425	99,106,694	101,088,827	103,110,604	105,172,816	107,276,272	109,421,798	109,421,798	109,421,798	109,421,798	109,421,798
Emissions GHG = Fuel consumption × Emission Factor	30	30	30	30	30	30	30	30	30	30	30	30	30
Total CO_2e	7,676	7,829	7,986	8,146	8,309	8,475	8,644	8,817	8,994	8,994	8,994	8,994	8,994
Annual VKT	31,922,437,135	36,532,846,072	41,809,114,901	42,645,297,199	43,498,203,143	44,368,167,206	45,255,530,550	46,160,641,161	47,083,853,985	47,083,853,985	47,083,853,985	47,083,853,985	47,083,853,985
Average fuel consumption	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Vehicle annual fuel consumption	6,384,487,427	7,306,569,214	8,361,822,980	8,529,059,440	8,699,640,629	8,873,633,441	9,051,106,110	9,232,128,232	9,416,770,797	9,416,770,797	9,416,770,797	9,416,770,797	9,416,770,797
Emissions GHG = Fuel consumption × Emission Factor	30	30	30	30	30	30	30	30	30	30	30	30	30
Total CO_2e	524,752	600,540	687,273	701,019	715,039	729,340	743,927	758,805	773,981	773,981	773,981	773,981	773,981
Total CO_2	4,742,073	2,884,450	707,690	721,843	736,280	751,006	766,026	781,347	796,973	796,973	796,973	796,973	796,973
Total CH_4	333	180	1	1	1	1	1	1	1	1	1	1	1
Total N_2O	711	384	2	2	2	2	2	2	2	2	2	2	2
GWP CH_4	25	25	25	25	25	25	25	25	25	25	25	25	25
GWP N_2O	298	298	298	298	298	298	298	298	298	298	298	298	298
Total CO_2e	4,962,294	3,003,520	708,340	722,507	736,957	751,696	766,730	782,064	797,706	797,706	797,706	797,706	797,706
Total CO_2e	1,811,237	1,096,285	258,544	263,715	268,989	274,369	279,856	285,454	291,163	291,163	291,163	291,163	291,163

Calculations based on 2006 IPCC Guidelines for National Greenhouse Gas Inventories	2061	2062	2063	2064	2065	2066	2067	2068	2069	2070	2071	2072	2073
Annual VKT	7,656,724	7,656,724	7,656,724	7,656,724	7,656,724	7,656,724	7,656,724	7,656,724	7,656,724	7,656,724	7,656,724	7,656,724	7,656,724
Average fuel consumption	0.0691	0.0691	0.0691	0.0691	0.0691	0.0691	0.0691	0.0691	0.0691	0.0691	0.0691	0.0691	0.0691
Vehicle annual fuel consumption	529,080	529,080	529,080	529,080	529,080	529,080	529,080	529,080	529,080	529,080	529,080	529,080	529,080
Emissions GHG = Fuel consumption x Emission Factor	-	-	-	-	-	-	-	-	-	-	-	-	-
CO_2 Emission Factor	2681	2681	2681	2681	2681	2681	2681	2681	2681	2681	2681	2681	2681
CH_4 Emission Factor	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068
N_2O Emission Factor	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21
CO_2 emissions	1,418,462,493	1,418,462,493	1,418,462,493	1,418,462,493	1,418,462,493	1,418,462,493	1,418,462,493	1,418,462,493	1,418,462,493	1,418,462,493	1,418,462,493	1,418,462,493	1,418,462,493
CO_2 emissions	3,886	3,886	3,886	3,886	3,886	3,886	3,886	3,886	3,886	3,886	3,886	3,886	3,886
CH_4 emissions	35,977	35,977	35,977	35,977	35,977	35,977	35,977	35,977	35,977	35,977	35,977	35,977	35,977
CH_4 emissions	0	0	0	0	0	0	0	0	0	0	0	0	0
N_2O emissions	111,107	111,107	111,107	111,107	111,107	111,107	111,107	111,107	111,107	111,107	111,107	111,107	111,107
N_2O emissions	0	0	0	0	0	0	0	0	0	0	0	0	0
Annual VKT	19,899,770	19,899,770	19,899,770	19,899,770	19,899,770	19,899,770	19,899,770	19,899,770	19,899,770	19,899,770	19,899,770	19,899,770	19,899,770
Average fuel consumption	0.0804	0.0804	0.0804	0.0804	0.0804	0.0804	0.0804	0.0804	0.0804	0.0804	0.0804	0.0804	0.0804
Vehicle annual fuel consumption	1,599,941	1,599,941	1,599,941	1,599,941	1,599,941	1,599,941	1,599,941	1,599,941	1,599,941	1,599,941	1,599,941	1,599,941	1,599,941
Emissions GHG = Fuel consumption x Emission Factor	-	-	-	-	-	-	-	-	-	-	-	-	-
CO_2 Emission Factor	2307	2307	2307	2307	2307	2307	2307	2307	2307	2307	2307	2307	2307
CH_4 Emission Factor	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23
N_2O Emission Factor	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47
CO_2 emissions	3,691,065,025	3,691,065,025	3,691,065,025	3,691,065,025	3,691,065,025	3,691,065,025	3,691,065,025	3,691,065,025	3,691,065,025	3,691,065,025	3,691,065,025	3,691,065,025	3,691,065,025
CO_2 emissions	10,113	10,113	10,113	10,113	10,113	10,113	10,113	10,113	10,113	10,113	10,113	10,113	10,113
CH_4 emissions	367,987	367,987	367,987	367,987	367,987	367,987	367,987	367,987	367,987	367,987	367,987	367,987	367,987
CH_4 emissions	1	1	1	1	1	1	1	1	1	1	1	1	1
N_2O emissions	751,973	751,973	751,973	751,973	751,973	751,973	751,973	751,973	751,973	751,973	751,973	751,973	751,973
N_2O emissions	2	2	2	2	2	2	2	2	2	2	2	2	2
Bus annual fuel consumption	109,421,798	109,421,798	109,421,798	109,421,798	109,421,798	109,421,798	109,421,798	109,421,798	109,421,798	109,421,798	109,421,798	109,421,798	109,421,798
Emissions GHG = Fuel consumption × Emission Factor	30	30	30	30	30	30	30	30	30	30	30	30	30
Total CO_2e	8,994	8,994	8,994	8,994	8,994	8,994	8,994	8,994	8,994	8,994	8,994	8,994	8,994
Annual VKT	47,083,853,985	47,083,853,985	47,083,853,985	47,083,853,985	47,083,853,985	47,083,853,985	47,083,853,985	47,083,853,985	47,083,853,985	47,083,853,985	47,083,853,985	47,083,853,985	47,083,853,985
Average fuel consumption	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Vehicle annual fuel consumption	9,416,770,797	9,416,770,797	9,416,770,797	9,416,770,797	9,416,770,797	9,416,770,797	9,416,770,797	9,416,770,797	9,416,770,797	9,416,770,797	9,416,770,797	9,416,770,797	9,416,770,797
Emissions GHG = Fuel consumption × Emission Factor	30	30	30	30	30	30	30	30	30	30	30	30	30
Total CO_2e	773,981	773,981	773,981	773,981	773,981	773,981	773,981	773,981	773,981	773,981	773,981	773,981	773,981
Total CO_2	796,973	796,973	796,973	796,973	796,973	796,973	796,973	796,973	796,973	796,973	796,973	796,973	796,973
Total CH_4	1	1	1	1	1	1	1	1	1	1	1	1	1
Total N_2O	2	2	2	2	2	2	2	2	2	2	2	2	2
GWP CH_4	25	25	25	25	25	25	25	25	25	25	25	25	25
GWP N_2O	298	298	298	298	298	298	298	298	298	298	298	298	298
Total CO_2e	797,706	797,706	797,706	797,706	797,706	797,706	797,706	797,706	797,706	797,706	797,706	797,706	797,706
Total CO_2e	291,163	291,163	291,163	291,163	291,163	291,163	291,163	291,163	291,163	291,163	291,163	291,163	291,163

Calculations based on 2006 IPCC Guidelines for National Greenhouse Gas Inventories	2074	2075	2076	2077	2078	2079	2080	2081	2082	2083	2084	2085	2086
Annual VKT	7,656,724	7,656,724	7,656,724	7,656,724	7,656,724	7,656,724	7,656,724	7,656,724	7,656,724	7,656,724	7,656,724	7,656,724	7,656,724
Average fuel consumption	0.0691	0.0691	0.0691	0.0691	0.0691	0.0691	0.0691	0.0691	0.0691	0.0691	0.0691	0.0691	0.0691
Vehicle annual fuel consumption	529,080	529,080	529,080	529,080	529,080	529,080	529,080	529,080	529,080	529,080	529,080	529,080	529,080
Emissions GHG = Fuel consumption x Emission Factor	-	-	-	-	-	-	-	-	-	-	-	-	-
CO_2 Emission Factor	2681	2681	2681	2681	2681	2681	2681	2681	2681	2681	2681	2681	2681
CH_4 Emission Factor	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068
N_2O Emission Factor	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21
CO_2 emissions	1,418,462,493	1,418,462,493	1,418,462,493	1,418,462,493	1,418,462,493	1,418,462,493	1,418,462,493	1,418,462,493	1,418,462,493	1,418,462,493	1,418,462,493	1,418,462,493	1,418,462,493
CO_2 emissions	3,886	3,886	3,886	3,886	3,886	3,886	3,886	3,886	3,886	3,886	3,886	3,886	3,886
CH_4 emissions	35,977	35,977	35,977	35,977	35,977	35,977	35,977	35,977	35,977	35,977	35,977	35,977	35,977
CH_4 emissions	0	0	0	0	0	0	0	0	0	0	0	0	0
N_2O emissions	111,107	111,107	111,107	111,107	111,107	111,107	111,107	111,107	111,107	111,107	111,107	111,107	111,107
N_2O emissions	0	0	0	0	0	0	0	0	0	0	0	0	0
Annual VKT	19,899,770	19,899,770	19,899,770	19,899,770	19,899,770	19,899,770	19,899,770	19,899,770	19,899,770	19,899,770	19,899,770	19,899,770	19,899,770
Average fuel consumption	0.0804	0.0804	0.0804	0.0804	0.0804	0.0804	0.0804	0.0804	0.0804	0.0804	0.0804	0.0804	0.0804
Vehicle annual fuel consumption	1,599,941	1,599,941	1,599,941	1,599,941	1,599,941	1,599,941	1,599,941	1,599,941	1,599,941	1,599,941	1,599,941	1,599,941	1,599,941
Emissions GHG = Fuel consumption x Emission Factor	-	-	-	-	-	-	-	-	-	-	-	-	-
CO_2 Emission Factor	2307	2307	2307	2307	2307	2307	2307	2307	2307	2307	2307	2307	2307
CH_4 Emission Factor	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23
N_2O Emission Factor	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47
CO_2 emissions	3,691,065,025	3,691,065,025	3,691,065,025	3,691,065,025	3,691,065,025	3,691,065,025	3,691,065,025	3,691,065,025	3,691,065,025	3,691,065,025	3,691,065,025	3,691,065,025	3,691,065,025
CO_2 emissions	10,113	10,113	10,113	10,113	10,113	10,113	10,113	10,113	10,113	10,113	10,113	10,113	10,113
CH_4 emissions	367,987	367,987	367,987	367,987	367,987	367,987	367,987	367,987	367,987	367,987	367,987	367,987	367,987
CH_4 emissions	1	1	1	1	1	1	1	1	1	1	1	1	1
N_2O emissions	751,973	751,973	751,973	751,973	751,973	751,973	751,973	751,973	751,973	751,973	751,973	751,973	751,973
N_2O emissions	2	2	2	2	2	2	2	2	2	2	2	2	2
Bus annual fuel consumption	109,421,798	109,421,798	109,421,798	109,421,798	109,421,798	109,421,798	109,421,798	109,421,798	109,421,798	109,421,798	109,421,798	109,421,798	109,421,798
Emissions GHG = Fuel consumption × Emission Factor	30	30	30	30	30	30	30	30	30	30	30	30	30
Total CO_2e	8,994	8,994	8,994	8,994	8,994	8,994	8,994	8,994	8,994	8,994	8,994	8,994	8,994
Annual VKT	47,083,853,985	47,083,853,985	47,083,853,985	47,083,853,985	47,083,853,985	47,083,853,985	47,083,853,985	47,083,853,985	47,083,853,985	47,083,853,985	47,083,853,985	47,083,853,985	47,083,853,985
Average fuel consumption	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Vehicle annual fuel consumption	9,416,770,797	9,416,770,797	9,416,770,797	9,416,770,797	9,416,770,797	9,416,770,797	9,416,770,797	9,416,770,797	9,416,770,797	9,416,770,797	9,416,770,797	9,416,770,797	9,416,770,797
Emissions GHG = Fuel consumption × Emission Factor	30	30	30	30	30	30	30	30	30	30	30	30	30
Total CO_2e	773,981	773,981	773,981	773,981	773,981	773,981	773,981	773,981	773,981	773,981	773,981	773,981	773,981
Total CO_2	796,973	796,973	796,973	796,973	796,973	796,973	796,973	796,973	796,973	796,973	796,973	796,973	796,973
Total CH_4	1	1	1	1	1	1	1	1	1	1	1	1	1
Total N_2O	2	2	2	2	2	2	2	2	2	2	2	2	2
GWP CH_4	25	25	25	25	25	25	25	25	25	25	25	25	25
GWP N_2O	298	298	298	298	298	298	298	298	298	298	298	298	298
Total CO_2e	797,706	797,706	797,706	797,706	797,706	797,706	797,706	797,706	797,706	797,706	797,706	797,706	797,706
Total CO_2e	291,163	291,163	291,163	291,163	291,163	291,163	291,163	291,163	291,163	291,163	291,163	291,163	291,163

Appendix C

Greenhouse Gases Calculations – Project Scenario

Calculations based on 2006 IPCC Guidelines for National Greenhouse Gas Inventories	Year	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038
Annual VKT	km/y	6,982,534,430	7,024,133,249	7,038,171,948	7,015,878,054	7,059,663,208	7,089,845,915	7,104,599,539	7,101,299,964	7,076,936,170	7,028,054,198	6,950,693,011	6,840,311,103
Average fuel consumption	L/km	0.0691	0.0691	0.0691	0.0691	0.0691	0.0691	0.0691	0.0691	0.0691	0.0691	0.0691	0.0691
Vehicle annual fuel consumption	L/y	482,493,129	485,367,607	486,337,682	484,797,174	487,822,728	489,908,353	490,927,828	490,699,827	489,016,289	485,638,545	480,292,887	472,665,497
Emissions GHG = Fuel consumption x Emission Factor	g CO_2 e/L	-	-	-	-	-	-	-	-	-	-	-	-
CO_2 Emission Factor	g CO_2/L	2681	2681	2681	2681	2681	2681	2681	2681	2681	2681	2681	2681
CH_4 Emission Factor	g CH_4/L	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068
N_2O Emission Factor	g NO_2/L	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21
CO_2 emissions	g CO_2/y	1,293,564,079,160	1,301,270,555,705	1,303,871,324,470	1,299,741,222,279	1,307,852,732,864	1,313,444,293,687	1,316,177,507,224	1,315,566,237,478	1,311,052,671,732	1,301,996,939,284	1,287,665,230,282	1,267,216,198,015
CO_2 emissions	kg CO_2/d	3,544,011	3,565,125	3,572,250	3,560,935	3,583,158	3,598,478	3,605,966	3,604,291	3,591,925	3,567,115	3,527,850	3,471,825
CH_4 emissions	g CH_4/y	32,809,533	33,004,997	33,070,962	32,966,208	33,171,945	33,313,768	33,383,092	33,367,588	33,253,108	33,023,421	32,659,916	32,141,254
CH_4 emissions	kg CH_4/d	90	90	91	90	91	91	91	91	91	90	89	88
N_2O emissions	g N_2O/y	101,323,557	101,927,198	102,130,913	101,807,406	102,442,773	102,880,754	103,094,844	103,046,964	102,693,421	101,984,094	100,861,506	99,259,754
N_2O emissions	kg N_2O/d	278	279	280	279	281	282	282	282	281	279	276	272
Annual VKT	km/y	18,147,555,924	18,255,670,950	18,292,157,428	18,234,215,760	18,348,013,054	18,426,457,689	18,464,802,249	18,456,226,677	18,392,905,356	18,265,861,467	18,064,800,310	17,777,918,537
Average fuel consumption	L/km	0.0804	0.0804	0.0804	0.0804	0.0804	0.0804	0.0804	0.0804	0.0804	0.0804	0.0804	0.0804
Vehicle annual fuel consumption	L/y	1,459,063,496	1,467,755,944	1,470,689,457	1,466,030,947	1,475,180,250	1,481,487,198	1,484,570,101	1,483,880,625	1,478,789,591	1,468,575,262	1,452,409,945	1,429,344,650
Emissions GHG = Fuel consumption x Emission Factor	g CO_2 e/L	-	-	-	-	-	-	-	-	-	-	-	-
CO_2 Emission Factor	g CO_2/L	2307	2307	2307	2307	2307	2307	2307	2307	2307	2307	2307	2307
CH_4 Emission Factor	g CH_4/L	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23
N_2O Emission Factor	g NO_2/L	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47
CO_2 emissions	g CO_2/y	3,366,059,485,983	3,386,112,963,732	3,392,880,577,734	3,382,133,394,905	3,403,240,835,649	3,417,790,966,296	3,424,903,222,658	3,423,312,601,551	3,411,567,585,561	3,388,003,129,343	3,350,709,742,942	3,297,498,108,396
CO_2 emissions	kg CO_2/d	9,222,081	9,277,022	9,295,563	9,266,119	9,323,947	9,363,811	9,383,297	9,378,939	9,346,761	9,282,200	9,180,027	9,034,241
CH_4 emissions	g CH_4/y	335,584,604	337,583,867	338,258,575	337,187,118	339,291,457	340,742,056	341,451,123	341,292,544	340,121,606	337,772,310	334,054,287	328,749,270
CH_4 emissions	kg CH_4/d	919	925	927	924	930	934	935	935	932	925	915	901
N_2O emissions	g N_2O/y	685,759,843	689,845,294	691,224,045	689,034,545	693,334,717	696,298,983	697,747,947	697,423,894	695,031,108	690,230,373	682,632,674	671,791,986
N_2O emissions	kg N_2O/d	1,879	1,890	1,894	1,888	1,900	1,908	1,912	1,911	1,904	1,891	1,870	1,841
Bus annual fuel consumption	kWh/y	70,317,417	71,723,766	73,158,241	74,621,406	76,113,834	77,636,111	79,188,833	80,772,610	82,388,062	84,035,823	85,716,540	87,430,870
Emissions GHG = Fuel consumption × Emission Factor	g CO_{2e}/kWh	30	30	30	30	30	30	30	30	30	30	30	30
Total CO_2e	kg CO_2e / d	5,780	5,895	6,013	6,133	6,256	6,381	6,509	6,639	6,772	6,907	7,045	7,186
Annual VKT	km/y	1,309,116,121	1,688,186,405	2,177,021,040	2,807,403,611	3,210,971,112	3,674,716,716	4,205,438,939	4,812,810,901	5,507,902,767	6,303,383,514	7,213,751,841	8,255,600,426
Average fuel consumption	kWh/km	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Vehicle annual fuel consumption	kWh/y	261,823,224	337,637,281	435,404,208	561,480,722	642,194,222	734,943,343	841,087,788	962,562,180	1,101,580,553	1,260,676,703	1,442,750,368	1,651,120,085
Emissions GHG = Fuel consumption × Emission Factor	g CO_{2e}/kWh	30	30	30	30	30	30	30	30	30	30	30	30
Total CO_2e	kg CO_2e / d	21,520	27,751	35,787	46,149	52,783	60,406	69,131	79,115	90,541	103,617	118,582	135,709
Total CO_2	**kg CO_2 / d**	12,793,391	12,875,793	12,909,613	12,879,336	12,966,145	13,029,076	13,064,901	13,068,983	13,035,998	12,959,840	12,833,504	12,648,961
Total CH_4	**kg CH_4 / d**	1,009	1,015	1,017	1,014	1,020	1,025	1,027	1,026	1,023	1,016	1,005	989
Total N_2O	**kg N_2O / d**	2,156	2,169	2,174	2,167	2,180	2,190	2,194	2,193	2,186	2,170	2,147	2,112
GWP CH_4	-	25	25	25	25	25	25	25	25	25	25	25	25
GWP N_2O	-	298	298	298	298	298	298	298	298	298	298	298	298
Total CO_2e	**kg CO_2e / d**	13,461,229	13,547,609	13,582,772	13,550,363	13,641,359	13,707,177	13,744,414	13,748,180	13,712,865	13,632,031	13,498,296	13,303,196
Total CO_2e	**tonnes CO_2e / y**	4,913,348	4,944,877	4,957,712	4,945,882	4,979,096	5,003,120	5,016,711	5,018,086	5,005,196	4,975,691	4,926,878	4,855,667

Calculations based on 2006 IPCC Guidelines for National Greenhouse Gas Inventories	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051
Annual VKT	6,691,702,487	6,498,900,562	6,255,068,087	5,952,371,254	5,581,835,583	5,133,180,992	4,594,633,046	3,952,706,941	3,191,960,286	2,294,710,181	1,240,709,419	6,775,935	6,911,454
Average fuel consumption	0.0691	0.0691	0.0691	0.0691	0.0691	0.0691	0.0691	0.0691	0.0691	0.0691	0.0691	0.0691	0.0691
Vehicle annual fuel consumption	462,396,642	449,074,029	432,225,205	411,308,854	385,704,839	354,702,807	317,489,143	273,132,050	220,564,456	158,564,473	85,733,021	468,217	477,581
Emissions GHG = Fuel consumption x Emission Factor	-	-	-	-	-	-	-	-	-	-	-	-	-
CO_2 Emission Factor	2681	2681	2681	2681	2681	2681	2681	2681	2681	2681	2681	2681	2681
CH_4 Emission Factor	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068
N_2O Emission Factor	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21
CO_2 emissions	1,239,685,396,746	1,203,967,471,346	1,158,795,774,031	1,102,719,036,582	1,034,074,672,789	950,958,224,421	851,188,393,721	732,267,025,015	591,333,305,938	425,111,353,415	229,850,228,999	1,255,290,138	1,280,395,941
CO_2 emissions	3,396,398	3,298,541	3,174,783	3,021,148	2,833,081	2,605,365	2,332,023	2,006,211	1,620,091	1,164,689	629,727	3,439	3,508
CH_4 emissions	31,442,972	30,537,034	29,391,314	27,969,002	26,227,929	24,119,791	21,589,262	18,572,979	14,998,383	10,782,384	5,829,845	31,839	32,476
CH_4 emissions	86	84	81	77	72	66	59	51	41	30	16	0	0
N_2O emissions	97,103,295	94,305,546	90,767,293	86,374,859	80,998,016	74,487,589	66,672,720	57,357,730	46,318,536	33,298,539	18,003,934	98,326	100,292
N_2O emissions	266	258	249	237	222	204	183	157	127	91	49	0	0
Annual VKT	17,391,685,830	16,890,595,038	16,256,876,217	15,470,169,362	14,507,149,863	13,341,099,863	11,941,417,689	10,273,056,435	8,295,881,443	5,963,934,980	3,224,594,709	17,610,606	17,962,819
Average fuel consumption	0.0804	0.0804	0.0804	0.0804	0.0804	0.0804	0.0804	0.0804	0.0804	0.0804	0.0804	0.0804	0.0804
Vehicle annual fuel consumption	1,398,291,541	1,358,003,841	1,307,052,848	1,243,801,617	1,166,374,849	1,072,624,429	960,089,982	825,953,737	666,988,868	479,500,372	259,257,415	1,415,893	1,444,211
Emissions GHG = Fuel consumption x Emission Factor	-	-	-	-	-	-	-	-	-	-	-	-	-
CO_2 Emission Factor	2307	2307	2307	2307	2307	2307	2307	2307	2307	2307	2307	2307	2307
CH_4 Emission Factor	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23
N_2O Emission Factor	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47
CO_2 emissions	3,225,858,584,493	3,132,914,861,375	3,015,370,920,031	2,869,450,329,721	2,690,826,776,682	2,474,544,557,673	2,214,927,588,978	1,905,475,272,185	1,538,743,318,478	1,106,207,359,043	598,106,855,425	3,266,464,603	3,331,793,895
CO_2 emissions	8,837,969	8,583,328	8,261,290	7,861,508	7,372,128	6,779,574	6,068,295	5,220,480	4,215,735	3,030,705	1,638,649	8,949	9,128
CH_4 emissions	321,607,054	312,340,883	300,622,155	286,074,372	268,266,215	246,703,619	220,820,696	189,969,360	153,407,440	110,285,086	59,629,205	325,655	332,168
CH_4 emissions	881	856	824	784	735	676	605	520	420	302	163	1	1
N_2O emissions	657,197,024	638,261,805	614,314,838	584,586,760	548,196,179	504,133,482	451,242,292	388,198,257	313,484,768	225,365,175	121,850,985	665,470	678,779
N_2O emissions	1,801	1,749	1,683	1,602	1,502	1,381	1,236	1,064	859	617	334	2	2
Bus annual fuel consumption	89,179,488	90,963,077	92,782,339	94,637,986	96,530,745	98,461,360	100,430,588	102,439,199	104,487,983	106,577,743	108,709,298	110,883,484	113,101,154
Emissions GHG = Fuel consumption × Emission Factor	30	30	30	30	30	30	30	30	30	30	30	30	30
Total CO_2e	7,330	7,476	7,626	7,778	7,934	8,093	8,255	8,420	8,588	8,760	8,935	9,114	9,296
Annual VKT	9,447,918,350	10,812,437,199	12,374,027,152	14,161,150,270	16,206,379,256	18,546,991,141	21,225,646,701	24,291,168,009	27,799,428,284	31,814,370,253	36,409,171,594	41,667,578,694	42,500,930,268
Average fuel consumption	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Vehicle annual fuel consumption	1,889,583,670	2,162,487,440	2,474,805,430	2,832,230,054	3,241,275,851	3,709,398,228	4,245,129,340	4,858,233,602	5,559,885,657	6,362,874,051	7,281,834,319	8,333,515,739	8,500,186,054
Emissions GHG = Fuel consumption × Emission Factor	30	30	30	30	30	30	30	30	30	30	30	30	30
Total CO_2e	155,308	177,739	203,409	232,786	266,406	304,882	348,915	399,307	456,977	522,976	598,507	684,946	698,645
Total CO_2	12,397,005	12,067,085	11,647,108	11,123,220	10,479,550	9,697,914	8,757,487	7,634,418	6,301,391	4,727,129	2,875,818	706,449	720,578
Total CH_4	967	939	904	860	807	742	664	571	461	332	179	1	1
Total N_2O	2,067	2,007	1,932	1,838	1,724	1,585	1,419	1,221	986	709	383	2	2
GWP CH_4	25	25	25	25	25	25	25	25	25	25	25	25	25
GWP N_2O	298	298	298	298	298	298	298	298	298	298	298	298	298
Total CO_2e	13,037,026	12,688,665	12,245,368	11,692,529	11,013,419	10,188,872	9,196,936	8,012,470	6,606,683	4,946,605	2,994,484	707,097	721,239
Total CO_2e	4,758,515	4,631,363	4,469,559	4,267,773	4,019,898	3,718,938	3,356,882	2,924,552	2,411,439	1,805,511	1,092,987	258,090	263,252

Calculations based on 2006 IPCC Guidelines for National Greenhouse Gas Inventories	2052	2053	2054	2055	2056	2057	2058	2059	2060	2061	2062	2063	2064	2065	2066
Annual VKT	7,049,683	7,190,677	7,334,490	7,481,180	7,630,804	7,630,804	7,630,804	7,630,804	7,630,804	7,630,804	7,630,804	7,630,804	7,630,804	7,630,804	7,630,804
Average fuel consumption	0.0691	0.0691	0.0691	0.0691	0.0691	0.0691	0.0691	0.0691	0.0691	0.0691	0.0691	0.0691	0.0691	0.0691	0.0691
Vehicle annual fuel consumption	487,133	496,876	506,813	516,950	527,289	527,289	527,289	527,289	527,289	527,289	527,289	527,289	527,289	527,289	527,289
Emissions GHG = Fuel consumption x Emission Factor	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO_2 Emission Factor	2681	2681	2681	2681	2681	2681	2681	2681	2681	2681	2681	2681	2681	2681	2681
CH_4 Emission Factor	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068
N_2O Emission Factor	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21
CO_2 emissions	1,306,003,859	1,332,123,937	1,358,766,415	1,385,941,744	1,413,660,578	1,413,660,578	1,413,660,578	1,413,660,578	1,413,660,578	1,413,660,578	1,413,660,578	1,413,660,578	1,413,660,578	1,413,660,578	1,413,660,578
CO_2 emissions	3,578	3,650	3,723	3,797	3,873	3,873	3,873	3,873	3,873	3,873	3,873	3,873	3,873	3,873	3,873
CH_4 emissions	33,125	33,788	34,463	35,153	35,856	35,856	35,856	35,856	35,856	35,856	35,856	35,856	35,856	35,856	35,856
CH_4 emissions	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
N_2O emissions	102,298	104,344	106,431	108,559	110,731	110,731	110,731	110,731	110,731	110,731	110,731	110,731	110,731	110,731	110,731
N_2O emissions	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Annual VKT	18,322,075	18,688,516	19,062,287	19,443,533	19,832,403	19,832,403	19,832,403	19,832,403	19,832,403	19,832,403	19,832,403	19,832,403	19,832,403	19,832,403	19,832,403
Average fuel consumption	0.0804	0.0804	0.0804	0.0804	0.0804	0.0804	0.0804	0.0804	0.0804	0.0804	0.0804	0.0804	0.0804	0.0804	0.0804
Vehicle annual fuel consumption	1,473,095	1,502,557	1,532,608	1,563,260	1,594,525	1,594,525	1,594,525	1,594,525	1,594,525	1,594,525	1,594,525	1,594,525	1,594,525	1,594,525	1,594,525
Emissions GHG = Fuel consumption x Emission Factor	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO_2 Emission Factor	2307	2307	2307	2307	2307	2307	2307	2307	2307	2307	2307	2307	2307	2307	2307
CH_4 Emission Factor	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23
N_2O Emission Factor	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47
CO_2 emissions	3,398,429,773	3,466,398,368	3,535,726,336	3,606,440,862	3,678,569,680	3,678,569,680	3,678,569,680	3,678,569,680	3,678,569,680	3,678,569,680	3,678,569,680	3,678,569,680	3,678,569,680	3,678,569,680	3,678,569,680
CO_2 emissions	9,311	9,497	9,687	9,881	10,078	10,078	10,078	10,078	10,078	10,078	10,078	10,078	10,078	10,078	10,078
CH_4 emissions	338,812	345,588	352,500	359,550	366,741	366,741	366,741	366,741	366,741	366,741	366,741	366,741	366,741	366,741	366,741
CH_4 emissions	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
N_2O emissions	692,355	706,202	720,326	734,732	749,427	749,427	749,427	749,427	749,427	749,427	749,427	749,427	749,427	749,427	749,427
N_2O emissions	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Bus annual fuel consumption	115,363,177	117,670,440	120,023,849	122,424,326	124,872,812	124,872,812	124,872,812	124,872,812	124,872,812	124,872,812	124,872,812	124,872,812	124,872,812	124,872,812	124,872,812
Emissions GHG = Fuel consumption × Emission Factor	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
Total CO_2e	9,482	9,672	9,865	10,062	10,264	10,264	10,264	10,264	10,264	10,264	10,264	10,264	10,264	10,264	10,264
Annual VKT	43,350,948,874	44,217,967,851	45,102,327,208	46,004,373,752	46,924,461,227	46,924,461,227	46,924,461,227	46,924,461,227	46,924,461,227	46,924,461,227	46,924,461,227	46,924,461,227	46,924,461,227	46,924,461,227	46,924,461,227
Average fuel consumption	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Vehicle annual fuel consumption	8,670,189,775	8,843,593,570	9,020,465,442	9,200,874,750	9,384,892,245	9,384,892,245	9,384,892,245	9,384,892,245	9,384,892,245	9,384,892,245	9,384,892,245	9,384,892,245	9,384,892,245	9,384,892,245	9,384,892,245
Emissions GHG = Fuel consumption × Emission Factor	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
Total CO_2e	712,618	726,871	741,408	756,236	771,361	771,361	771,361	771,361	771,361	771,361	771,361	771,361	771,361	771,361	771,361
Total CO_2	734,989	749,689	764,683	779,976	795,576	795,576	795,576	795,576	795,576	795,576	795,576	795,576	795,576	795,576	795,576
Total CH_4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Total N_2O	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
GWP CH_4	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
GWP N_2O	298	298	298	298	298	298	298	298	298	298	298	298	298	298	298
Total CO_2e	735,663	750,377	765,384	780,692	796,306	796,306	796,306	796,306	796,306	796,306	796,306	796,306	796,306	796,306	796,306
Total CO_2e	268,517	273,887	279,365	284,953	290,652	290,652	290,652	290,652	290,652	290,652	290,652	290,652	290,652	290,652	290,652

Calculations based on 2006 IPCC Guidelines for National Greenhouse Gas Inventories	2067	2068	2069	2070	2071	2072	2073	2074	2075	2076	2077	2078	2079	2080	2081
Annual VKT	7,630,804	7,630,804	7,630,804	7,630,804	7,630,804	7,630,804	7,630,804	7,630,804	7,630,804	7,630,804	7,630,804	7,630,804	7,630,804	7,630,804	7,630,804
Average fuel consumption	0.0691	0.0691	0.0691	0.0691	0.0691	0.0691	0.0691	0.0691	0.0691	0.0691	0.0691	0.0691	0.0691	0.0691	0.0691
Vehicle annual fuel consumption	527,289	527,289	527,289	527,289	527,289	527,289	527,289	527,289	527,289	527,289	527,289	527,289	527,289	527,289	527,289
Emissions GHG = Fuel consumption x Emission Factor	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO_2 Emission Factor	2681	2681	2681	2681	2681	2681	2681	2681	2681	2681	2681	2681	2681	2681	2681
CH_4 Emission Factor	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068
N_2O Emission Factor	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21
CO_2 emissions	1,413,660,578	1,413,660,578	1,413,660,578	1,413,660,578	1,413,660,578	1,413,660,578	1,413,660,578	1,413,660,578	1,413,660,578	1,413,660,578	1,413,660,578	1,413,660,578	1,413,660,578	1,413,660,578	1,413,660,578
CO_2 emissions	3,873	3,873	3,873	3,873	3,873	3,873	3,873	3,873	3,873	3,873	3,873	3,873	3,873	3,873	3,873
CH_4 emissions	35,856	35,856	35,856	35,856	35,856	35,856	35,856	35,856	35,856	35,856	35,856	35,856	35,856	35,856	35,856
CH_4 emissions	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
N_2O emissions	110,731	110,731	110,731	110,731	110,731	110,731	110,731	110,731	110,731	110,731	110,731	110,731	110,731	110,731	110,731
N_2O emissions	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Annual VKT	19,832,403	19,832,403	19,832,403	19,832,403	19,832,403	19,832,403	19,832,403	19,832,403	19,832,403	19,832,403	19,832,403	19,832,403	19,832,403	19,832,403	19,832,403
Average fuel consumption	0.0804	0.0804	0.0804	0.0804	0.0804	0.0804	0.0804	0.0804	0.0804	0.0804	0.0804	0.0804	0.0804	0.0804	0.0804
Vehicle annual fuel consumption	1,594,525	1,594,525	1,594,525	1,594,525	1,594,525	1,594,525	1,594,525	1,594,525	1,594,525	1,594,525	1,594,525	1,594,525	1,594,525	1,594,525	1,594,525
Emissions GHG = Fuel consumption x Emission Factor	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO_2 Emission Factor	2307	2307	2307	2307	2307	2307	2307	2307	2307	2307	2307	2307	2307	2307	2307
CH_4 Emission Factor	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23
N_2O Emission Factor	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47
CO_2 emissions	3,678,569,680	3,678,569,680	3,678,569,680	3,678,569,680	3,678,569,680	3,678,569,680	3,678,569,680	3,678,569,680	3,678,569,680	3,678,569,680	3,678,569,680	3,678,569,680	3,678,569,680	3,678,569,680	3,678,569,680
CO_2 emissions	10,078	10,078	10,078	10,078	10,078	10,078	10,078	10,078	10,078	10,078	10,078	10,078	10,078	10,078	10,078
CH_4 emissions	366,741	366,741	366,741	366,741	366,741	366,741	366,741	366,741	366,741	366,741	366,741	366,741	366,741	366,741	366,741
CH_4 emissions	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
N_2O emissions	749,427	749,427	749,427	749,427	749,427	749,427	749,427	749,427	749,427	749,427	749,427	749,427	749,427	749,427	749,427
N_2O emissions	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Bus annual fuel consumption	124,872,812	124,872,812	124,872,812	124,872,812	124,872,812	124,872,812	124,872,812	124,872,812	124,872,812	124,872,812	124,872,812	124,872,812	124,872,812	124,872,812	124,872,812
Emissions GHG = Fuel consumption × Emission Factor	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
Total CO_2e	10,264	10,264	10,264	10,264	10,264	10,264	10,264	10,264	10,264	10,264	10,264	10,264	10,264	10,264	10,264
Annual VKT	46,924,461,227	46,924,461,227	46,924,461,227	46,924,461,227	46,924,461,227	46,924,461,227	46,924,461,227	46,924,461,227	46,924,461,227	46,924,461,227	46,924,461,227	46,924,461,227	46,924,461,227	46,924,461,227	46,924,461,227
Average fuel consumption	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Vehicle annual fuel consumption	9,384,892,245	9,384,892,245	9,384,892,245	9,384,892,245	9,384,892,245	9,384,892,245	9,384,892,245	9,384,892,245	9,384,892,245	9,384,892,245	9,384,892,245	9,384,892,245	9,384,892,245	9,384,892,245	9,384,892,245
Emissions GHG = Fuel consumption × Emission Factor	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
Total CO_2e	771,361	771,361	771,361	771,361	771,361	771,361	771,361	771,361	771,361	771,361	771,361	771,361	771,361	771,361	771,361
Total CO_2	795,576	795,576	795,576	795,576	795,576	795,576	795,576	795,576	795,576	795,576	795,576	795,576	795,576	795,576	795,576
Total CH_4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Total N_2O	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
GWP CH_4	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
GWP N_2O	298	298	298	298	298	298	298	298	298	298	298	298	298	298	298
Total CO_2e	796,306	796,306	796,306	796,306	796,306	796,306	796,306	796,306	796,306	796,306	796,306	796,306	796,306	796,306	796,306
Total CO_2e	290,652	290,652	290,652	290,652	290,652	290,652	290,652	290,652	290,652	290,652	290,652	290,652	290,652	290,652	290,652

Calculations based on 2006 IPCC Guidelines for National Greenhouse Gas Inventories	2082	2083	2084	2085	2086
Annual VKT	7,630,804	7,630,804	7,630,804	7,630,804	7,630,804
Average fuel consumption	0.0691	0.0691	0.0691	0.0691	0.0691
Vehicle annual fuel consumption	527,289	527,289	527,289	527,289	527,289
Emissions GHG = Fuel consumption x Emission Factor	-	-	-	-	-
CO_2 Emission Factor	2681	2681	2681	2681	2681
CH_4 Emission Factor	0.068	0.068	0.068	0.068	0.068
N_2O Emission Factor	0.21	0.21	0.21	0.21	0.21
CO_2 emissions	1,413,660,578	1,413,660,578	1,413,660,578	1,413,660,578	1,413,660,578
CO_2 emissions	3,873	3,873	3,873	3,873	3,873
CH_4 emissions	35,856	35,856	35,856	35,856	35,856
CH_4 emissions	0	0	0	0	0
N_2O emissions	110,731	110,731	110,731	110,731	110,731
N_2O emissions	0	0	0	0	0
Annual VKT	19,832,403	19,832,403	19,832,403	19,832,403	19,832,403
Average fuel consumption	0.0804	0.0804	0.0804	0.0804	0.0804
Vehicle annual fuel consumption	1,594,525	1,594,525	1,594,525	1,594,525	1,594,525
Emissions GHG = Fuel consumption x Emission Factor	-	-	-	-	-
CO_2 Emission Factor	2307	2307	2307	2307	2307
CH_4 Emission Factor	0.23	0.23	0.23	0.23	0.23
N_2O Emission Factor	0.47	0.47	0.47	0.47	0.47
CO_2 emissions	3,678,569,680	3,678,569,680	3,678,569,680	3,678,569,680	3,678,569,680
CO_2 emissions	10,078	10,078	10,078	10,078	10,078
CH_4 emissions	366,741	366,741	366,741	366,741	366,741
CH_4 emissions	1	1	1	1	1
N_2O emissions	749,427	749,427	749,427	749,427	749,427
N_2O emissions	2	2	2	2	2
Bus annual fuel consumption	124,872,812	124,872,812	124,872,812	124,872,812	124,872,812
Emissions GHG = Fuel consumption × Emission Factor	30	30	30	30	30
Total CO_2e	10,264	10,264	10,264	10,264	10,264
Annual VKT	46,924,461,227	46,924,461,227	46,924,461,227	46,924,461,227	46,924,461,227
Average fuel consumption	0.2	0.2	0.2	0.2	0.2
Vehicle annual fuel consumption	9,384,892,245	9,384,892,245	9,384,892,245	9,384,892,245	9,384,892,245
Emissions GHG = Fuel consumption × Emission Factor	30	30	30	30	30
Total CO_2e	771,361	771,361	771,361	771,361	771,361
Total CO_2	795,576	795,576	795,576	795,576	795,576
Total CH_4	1	1	1	1	1
Total N_2O	2	2	2	2	2
GWP CH_4	25	25	25	25	25
GWP N_2O	298	298	298	298	298
Total CO_2e	796,306	796,306	796,306	796,306	796,306
Total CO_2e	290,652	290,652	290,652	290,652	290,652

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Appendix D

Detailed Climate Change Risk Assessment

Likelihood

Very high	Once every year or more	More than 70% (100%)	5
High	Once every 2 years	40%-70% (50%)	4
Moderate	Once every 5 years	20%-40% (20%)	3
Low	Once every 10 years	4%-20% (10%)	2
Very low	Once every 30 years	4% or less (4%)	1

Infrastructure Components	Climate (Probability / Likelihood)			Impact Categories (Consequences)				Severity Rating		Justification	Risk Results	
	Climate Indicators	Current	Future	Health & Safety	Infrastructure Integrity	Operational impact	Financial impact	Impacted (Y/N)	Impact Severity Rating (1-5)		Current	Future
Road Network												
Road Network	Hot temperature: Days with Tmax ≥ 30°C	5	5	1	3	1	3	Yes	3	Hot temperatures may cause premature deterioration to road pavements and pedestrian asphalt (e.g., potholes, rutting, cracking), particularly in high-traffic areas, which could result in increased maintenance costs.	15	15
Road Network	Heat wave: Instances of 3 days with Tmin ≥ 20°C and Tmax ≥ 33°C	4	5	2	4	2	3	Yes	4	Heat waves may cause premature deterioration to road pavements and pedestrian asphalt (e.g., potholes, rutting, cracking), particularly in high-traffic areas, which could result in increased maintenance costs. Also, heat waves may exacerbate the Urban Heat Island effect due to increased surface temperatures of the pavement. High road-surface temperature due to heat waves can lead to dangerous driving conditions as tires blowouts and deformation induced by thermal stress on roads	16	20
Road Network	Diurnal variation: Days with Tmax-Tmin ≥ 20°C	4	4	0	1	0	1	Yes	1	Premature deterioration of pavement surfaces	4	4
Road Network	Heavy rainfall: Days with P ≥ 25 mm	5	5	3	4	3	4	Yes	4	Heavy rainfall may result in flash floods, which could result in delays and reduced road safety. Heavy rainfall could cause premature deterioration to road pavements and pedestrian asphalt (e.g., potholes, rutting, cracking), particularly in high-traffic areas) exacerbated in low lying areas. Increased maintenance and repair costs	20	20
Road Network	Drought: Instance of P < 0.2 mm for 10 days	5	5	0	0	0	0	No	0	not impacted	0	0
Road Network	Heavy wind: Days with W ≥ 65 km/h	5	5	1	1	1	1	Yes	1	Blown objects may cause obstructions on pedestrian sidewalks and roadways which would reduce road safety	5	5
Road Network	Blowing rain: Instances of (P ≥ 5 mm) and (W ≥ 65 km/h)	5	5	1	1	1	1	Yes	1	Blown objects may cause obstructions on pedestrian sidewalks and roadways which would reduce road safety	5	5
Road Network	Blowing snow: Instances of ((S ≥ 5 cm) or (SD ≥ 5 cm)) and (W ≥ 65 km/h)	5	5	2	2	2	1	Yes	2	Accumulation of snow on road pavement can cause an increase in snow removal costs. Reduced road safety can occur due to slippery pavement and reduced visibility.	10	10
Road Network	Freezing rain: Days with freezing rain	3	4	3	2	2	1	Yes	3	Freezing rain may cause pavements to become slippery, which could compromise or reduce road passenger/pedestrian safety and increase maintenance costs (e.g., de-icing).	9	12
Road Network	Fog: Days with fog	4	4	1	0	1	0	Yes	1	Reduced road safety due to reduced visibility	4	4
Road Network	Winter rain on snow: Instances of P ≥ 25 mm within Jan-Feb-Mar	1	3	1	1	2	1	Yes	2	Winter rain on snow may result in an accumulation of slush on road pavements and impact passengers/pedestrians safety.	2	6
Transit Network												
Transit Network	Hot temperature: Days with Tmax ≥ 30°C	5	5	1	2	0	2	Yes	2	Hot temperatures may cause bus shelters and railings to become very hot, which could have adverse effects on the health and safety of passengers waiting outside. Also, heat waves may exacerbate the urban heat island effect near bus shelters and station infrastructure.	10	10
Transit Network	Heat wave: Instances of 3 days with Tmin ≥ 20°C and Tmax ≥ 33°C	4	5	2	2	0	2	Yes	2	Bus shelters and railings may become very hot due to heat waves. Heat waves may exacerbate the urban heat island effect near bus shelters and station infrastructure. This can cause an increase in maintenance costs	8	10
Transit Network	Diurnal variation: Days with Tmax-Tmin ≥ 20°C	4	4	0	0	0	0	No	0	not impacted	0	0
Transit Network	Heavy rainfall: Days with P ≥ 25 mm	5	5	3	3	3	4	Yes	4	Heavy rainfall may result in localized flash floods, which could cause damages to bus shelters or station infrastructure, platforms, railings, and ramps and impact operations and people, exacerbated in low lying areas. This can cause an increase in maintenance and repair costs	20	20
Transit Network	Drought: Instance of P < 0.2 mm for 10 days	5	5	0	0	0	0	No	0	not impacted	0	0
Transit Network	Heavy wind: Days with W ≥ 65 km/h	5	5	1	1	1	1	Yes	1	Blown objects may cause obstructions on pedestrian sidewalk. There can also be accumulation of debris around bus shelters and station infrastructure due to heavy winds. Strong wind gusts could damage bus rapid transit stop elements and increased maintenance costs.	5	5

Infrastructure Components	Climate (Probability / Likelihood)			Impact Categories (Consequences)				Severity Rating		Justification	Risk Results	
	Climate Indicators	Current	Future	Health & Safety	Infrastructure Integrity	Operational impact	Financial impact	Impacted (Y/N)	Impact Severity Rating (1-5)		Current	Future
Transit Network	Blowing rain: Instances of (P ≥ 5 mm) and (W ≥ 65 km/h)	5	5	1	2	1	1	Yes	2	Blown objects may cause obstructions on pedestrian sidewalk. There can be accumulation of debris around bus shelters and station infrastructure due to heavy winds. Strong wind gusts could damage bus rapid transit stop elements. Blowing rain could result in water infiltration in bus shelters infrastructure. All this can increase maintenance costs.	10	10
Transit Network	Blowing snow: Instances of ((S ≥ 5 cm) or (SD ≥ 5 cm)) and (W ≥ 65 km/h)	5	5	1	2	1	1	Yes	2	Blown objects may cause obstructions on pedestrian sidewalk. There can be accumulation of snow on road and pedestrian pavement which can cause snow removal costs. There can be accumulation of debris around bus shelters and station infrastructure due to heavy winds. Strong wind gusts could damage bus rapid transit stop elements. Blowing snow could result in water infiltration in bus shelters infrastructure. This can cause increased maintenance and snow removal costs.	10	10
Transit Network	Freezing rain: Days with freezing rain	3	4	3	1	1	1	Yes	3	Freezing rain may cause ramps and platforms to become slippery, which could result in slips and falls and cause increased maintenance of bus platforms and ramps (e.g., de-icing)	9	12
Transit Network	Fog: Days with fog	4	4	0	0	1	0	Yes	1	Reduced safety due to reduced visibility. Fog could result in reduced speed resulting in slower operations	4	4
Transit Network	Winter rain on snow: Instances of P ≥ 25 mm within Jan-Feb-Mar	1	3	1	3	2	1	Yes	3	Winter rain on snow may result in damages to roofs of bus rapid transit stops due to heavy loads. There can be accumulation of slush on bus platforms and ramps. Increased snow removal costs.	3	9
Systems, Signalling and Equipment												
Systems, Signalling and Equipment	Hot temperature: Days with Tmax ≥ 30°C	5	5	0	2	1	1	Yes	2	The heat may cause surveillance cameras to break down or cause them to erode away causing them to malfunction	10	10
Systems, Signalling and Equipment	Heat wave: Instances of 3 days with Tmin ≥ 20°C and Tmax ≥ 33°C	4	5	0	2	1	1	Yes	2	The heat may cause surveillance cameras to break down or cause them to erode away causing them to malfunction	8	10
Systems, Signalling and Equipment	Diurnal variation: Days with Tmax-Tmin ≥ 20°C	4	4	0	0	0	0	No	0	not impacted	0	0
Systems, Signalling and Equipment	Heavy rainfall: Days with P ≥ 25 mm	5	5	0	1	1	1	Yes	1	Over time, repeated exposure to heavy rain can damage to almost any piece of electronic equipment, even if it is very well protected. This includes cameras. What's more, if rainwater ends up on the lens of a camera, it may distort or partially obscure the image that the camera records	5	5
Systems, Signalling and Equipment	Drought: Instance of P < 0.2 mm for 10 days	5	5	0	0	0	0	No	0	not impacted	0	0
Systems, Signalling and Equipment	Heavy wind: Days with W ≥ 65 km/h	5	5	1	1	2	2	Yes	2	Street lights and signs may be damaged by strong winds resulting in delays in operations and services, reduced road safety and an increase in maintenance & operations costs	10	10
Systems, Signalling and Equipment	Blowing rain: Instances of (P ≥ 5 mm) and (W ≥ 65 km/h)	5	5	1	1	2	2	Yes	2	Street lights and signs may be damaged by strong winds resulting in delays in operations and services, reduced road safety and an increase in maintenance & operations costs	10	10
Systems, Signalling and Equipment	Blowing snow: Instances of ((S ≥ 5 cm) or (SD ≥ 5 cm)) and (W ≥ 65 km/h)	5	5	1	2	2	2	Yes	2	Street lights and signs may be damaged by strong winds resulting in delays in operations and services, reduced road safety and an increase in maintenance & operations costs. Snow and ice affect outdoor surveillance system cameras in optic and mechanical disruptions. An unshielded camera can be damaged by ice. If there is moisture around an outdoor camera below the temperatures drop below freezing, the frost that is formed by that moisture and temperature can form on the cameras lens and disallowing the viewer to see any activities going on outside besides the crystalline patterns from the snow	10	10
Systems, Signalling and Equipment	Freezing rain: Days with freezing rain	3	4	0	2	2	1	Yes	2	Ice affect outdoor surveillance system cameras in optic and mechanical disruptions. An unshielded camera can be damaged by ice. If there is moisture around an outdoor camera below the temperatures drop below freezing, the frost that is formed by that moisture and temperature can form on the cameras lens and disallowing the viewer to see any activities going on outside besides the crystalline patterns from the snow. This can increase maintenance cost	6	8
Systems, Signalling and Equipment	Fog: Days with fog	4	4	0	0	0	0	No	0	not impacted	0	0

Infrastructure Components	Climate (Probability / Likelihood)			Impact Categories (Consequences)				Severity Rating		Justification	Risk Results	
	Climate Indicators	Current	Future	Health & Safety	Infrastructure Integrity	Operational impact	Financial impact	Impacted (Y/N)	Impact Severity Rating (1-5)		Current	Future
Systems, Signalling and Equipment	Winter rain on snow: Instances of P ≥ 25 mm within Jan-Feb-Mar	1	3	0	1	1	1	Yes	1	Snow and ice affect outdoor surveillance system cameras in optic and mechanical disruptions. An unshielded camera can be damaged by ice. If there is moisture around an outdoor camera below the temperatures drop below freezing, the frost that is formed by that moisture and temperature can form on the cameras lens and disallowing the viewer to see any activities going on outside besides the crystalline patterns from the snow	1	3
Utilities												
Utilities	Hot temperature: Days with Tmax ≥ 30°C	5	5	0	0	2	2	Yes	2	During heat waves and hot temperatures, there is an increase in energy demands and the efficiency and reliability of the power system is threatened. Heat waves and extreme temperatures can cause blackouts.	10	10
Utilities	Heat wave: Instances of 3 days with Tmin ≥ 20°C and Tmax ≥ 33°C	4	5	0	0	2	2	Yes	2	During heat waves and hot temperatures, there is an increase in energy demands and the efficiency and reliability of the power system is threatened. Heat waves and extreme temperatures can cause blackouts.	8	10
Utilities	Diurnal variation: Days with Tmax-Tmin ≥ 20°C	4	4	0	0	0	0	No	0	not impacted	0	0
Utilities	Heavy rainfall: Days with P ≥ 25 mm	5	5	0	1	2	2	Yes	2	Heavy rainfall may cause water damages to transformers located outside. Electrical systems can be damaged as a result of flooding or standing waterPotential power outages due heavy rainfall may cause delays in operations and services due to water getting into conduit/access exacerbated in low lying areas. Heavy rainfall may increase the risk of the drainage system being overwhelmed and cause flooding	10	10
Utilities	Drought: Instance of P < 0.2 mm for 10 days	5	5	0	0	0	0	No	0	not impacted	0	0
Utilities	Heavy wind: Days with W ≥ 65 km/h	5	5	0	3	2	2	Yes	3	Heavy winds may cause power outages which can cause disruption to the operations and reliance on back-up generator systems	15	15
Utilities	Blowing rain: Instances of (P ≥ 5 mm) and (W ≥ 65 km/h)	5	5	0	3	2	2	Yes	3	Heavy winds may cause power outages which can cause disruption to the operations and reliance on back-up generator systems. Blowing rain and blowing snow may cause water damages (e.g., infiltration, corrosion) to transformers located outside.	15	15
Utilities	Blowing snow: Instances of ((S ≥ 5 cm) or (SD ≥ 5 cm)) and (W ≥ 65 km/h)	5	5	0	3	2	2	Yes	3	Heavy winds may cause power outages which can cause disruption to the operations and reliance on back-up generator systems. Blowing rain and blowing snow may cause water damages (e.g., infiltration, corrosion) to transformers located outside. Snow accumulation may increase loads on transformers located outside, which may result in increased maintenance and snow removal costs.	15	15
Utilities	Freezing rain: Days with freezing rain	3	4	0	2	2	2	Yes	2	Potential power outages due to freezing rain could cause delays in operations and services and increased maintenance costs	6	8
Utilities	Fog: Days with fog	4	4	0	0	0	0	No	0	not impacted	0	0
Utilities	Winter rain on snow: Instances of P ≥ 25 mm within Jan-Feb-Mar	1	3	0	0	0	0	No	0	not impacted	0	0
People												
People	Hot temperature: Days with Tmax ≥ 30°C	5	5	2	0	2	0	Yes	2	Hot temperatures could impact staff wellbeing and productivity and the health and wellbeing of passengers waiting in bus shelters(e.g., heat exhaustion and heat stroke, dehydration, heat stress)	10	10
People	Heat wave: Instances of 3 days with Tmin ≥ 20°C and Tmax ≥ 33°C	4	5	2	0	4	1	Yes	4	Increase in the number of heat waves could impact staff wellbeing and productivity and the health and wellbeing of passengers waiting in bus shelters(e.g., heat exhaustion and heat stroke, dehydration, heat stress). Heat waves could result in potential delays in construction activities	16	20
People	Diurnal variation: Days with Tmax-Tmin ≥ 20°C	4	4	0	0	0	0	No	0	no impact	0	0
People	Heavy rainfall: Days with P ≥ 25 mm	5	5	3	0	3	4	Yes	4	Heavy rainfall may cause disruption of construction work and maintenance work, resulting in delays in operations and services. Heavy rainfall can cause flash floods. When this occurs, bus shelters, platforms and ramps may be difficult to access. Floods could reduce road safety for drivers, pedestrians and cyclists. Also, people may file claims to the city for damages caused by storm sewer overflows.	20	20
People	Drought: Instance of P < 0.2 mm for 10 days	5	5	0	0	0	0	No	0	not impacted	0	0
People	Heavy wind: Days with W ≥ 65 km/h	5	5	3	0	1	1	Yes	3	Blown objects could cause injuries to staff. Heavy winds could blow away debris or objects, which could cause injuries to pedestrians and cyclists or damage vehicles.	15	15
People	Blowing rain: Instances of (P ≥ 5 mm) and (W ≥ 65 km/h)	5	5	3	0	1	1	Yes	3	Blown objects could cause injuries to staff. Blowing rain can blow away debris or objects, which could cause injuries to pedestrians and cyclists or damage vehicles.	15	15

Infrastructure Components	Climate (Probability / Likelihood)			Impact Categories (Consequences)				Severity Rating		Justification	Risk Results	
	Climate Indicators	Current	Future	Health & Safety	Infrastructure Integrity	Operational impact	Financial impact	Impacted (Y/N)	Impact Severity Rating (1-5)		Current	Future
People	Blowing snow: Instances of ((S ≥ 5 cm) or (SD ≥ 5 cm)) and (W ≥ 65km/h)	5	5	3	0	1	1	Yes	3	Blown objects could cause injuries to staff. Blowing snow can blow away debris or objects, which could cause injuries to pedestrians and cyclists or damage vehicles. Pedestrians may have trouble accessing bus platforms and sidewalks if they are not properly cleared. People may file claims to the city.	15	15
People	Freezing rain: Days with freezing rain	3	4	3	0	3	2	Yes	3	Freezing rain could compromise the health and safety of workers conducting maintenance or construction (e.g., frostbites, hypothermia) Workers can slip or fall if pavement surfaces become too slippery due to freezing rain. Disruptions in construction and maintenance work, resulting in delays in operations and services. Freezing rain can cause ice to build up and fall from bus shelter roofs, which may result in injuries. People can slip or fall if ramps or platforms become too slippery due to freezing rain (reduced public safety). People may file claims for injuries	9	12
People	Fog: Days with fog	4	4	1	0	1	0	Yes	1	Foggy days may result in reduced visibility, which could cause road safety concerns (e.g., difficult to see curbs and ramps). Potential delays in construction	4	4
People	Winter rain on snow: Instances of P ≥ 25 mm within Jan-Feb-Mar	1	3	1	0	1	0	Yes	1	Winter rain and snow could cause an accumulation of slush on sidewalks, which may result in falls and slips as well as difficult working conditions for staff. People can file claims for injuries	1	3
Surrounding Environment												
Surrounding Environment	Hot temperature: Days with Tmax ≥ 30°C	5	5	0	1	1	1	Yes	1	Hot temperatures and heat waves could cause vegetation to dry out, resulting in an increased demand for maintenance and water supply.	5	5
Surrounding Environment	Heat wave: Instances of 3 days with Tmin ≥ 20°C and Tmax ≥ 33°C	4	5	0	2	2	1	Yes	2	Heat waves may result in increased maintenance of vegetation and landscape which can result in increased watering	8	10
Surrounding Environment	Diurnal variation: Days with Tmax-Tmin ≥ 20°C	4	4	0	0	0	0	No	0	not impacted	0	0
Surrounding Environment	Heavy rainfall: Days with P ≥ 25 mm	5	5	0	1	2	2	Yes	2	Increased surface runoff and erosion of topsoil exacerbated in low lying areas. Increased maintenance of vegetation and landscape around stations	10	10
Surrounding Environment	Drought: Instance of P < 0.2 mm for 10 days	5	5	0	2	2	2	Yes	2	Drought can cause reduced soil quality, resulting in loss of vegetation and increased demand for water.	10	10
Surrounding Environment	Heavy wind: Days with W ≥ 65 km/h	5	5	0	3	1	1	Yes	3	Trees and branches could blow away in the wind. Heavy winds could damage objects in public spaces (e.g., benches, art, etc.)	15	15
Surrounding Environment	Blowing rain: Instances of (P ≥ 5 mm) and (W ≥ 65 km/h)	5	5	0	3	1	1	Yes	3	Trees and branches could blow away in the wind. Heavy winds could damage objects in public spaces (e.g., benches, art, etc.)	15	15
Surrounding Environment	Blowing snow: Instances of ((S ≥ 5 cm) or (SD ≥ 5 cm)) and (W ≥ 65 km/h)	5	5	0	3	1	1	Yes	3	Trees and branches could blow away in the wind. Heavy winds could damage objects in public spaces (e.g., benches, art, etc.)	15	15
Surrounding Environment	Freezing rain: Days with freezing rain	3	4	0	2	1	1	Yes	2	Freezing rain may cause damages to trees and vulnerable plants.	6	8
Surrounding Environment	Fog: Days with fog	4	4	0	0	0	0	No	0	not impacted	0	0
Surrounding Environment	Winter rain on snow: Instances of P ≥ 25 mm within Jan-Feb-Mar	1	3	0	1	1	1	Yes	1	Increased snow removal costs and environmental impacts from salt use	1	3

Risk Evaluation Matrix

Severity of Consequences						
	Very High (5)	5	10	15	20	25
	High (4)	4	8	12	16	20
	Moderate (3)	3	6	9	12	15
	Low (2)	2	4	6	8	10
	Very Low (1)	1	2	3	4	5
		Very Low (1)	Low (2)	Moderate (3)	High (4)	Very High (5)
		Probability (Likelihood)				

Risk Rating

Risk (R) = Probability (P) x Severity (G)	
Low Risk: < 6	Controls likely not required
Moderate Risk: 7 < R < 16	Some controls required to reduce risks to lower levels
High Risk: R > 20	High priority control measures required
R = 5	Special Cases: Interactions resulting in a risk rated "5" are considered special cases and are considered in the risk evaluation, as these can either be interactions with very low likelihood but very high severity or interactions with high likelihood and very low severity. While the former case may have very severe impacts, the latter case can trigger a slow deterioration of project components due to the high likelihood of the climate condition.

Risk Event	Project Components	Risk	Adaptation Measure or Risk Treatment	Comments	Implementation timeframe	Effectivenessi
MODERATE RISK **Hot temperature:** **Days with Tmax ≥ 30°C** **Heat wave:** **Instances of 3 days with Tmin ≥ 20°C and Tmax ≥ 33°C**	Road Network	15	■ Design: Use light colored materials for pavement surfaces on sidewalks. ■ Design: Use heat resistant paving materials with higher solar reflectance to reduce damages (e.g., potholes and cracks) and urban heat island effect. Also consider use of additives in asphalt mix to reduce shoving/rutting. ■ O&M: Track impacts of extreme heat to identify "hot-spots" that may require an increased rate of inspection. ■ O&M: Conduct frequent inspections of pavement surfaces to ensure cracks are properly sealed.	■ Hot temperatures may cause premature deterioration to road pavements and pedestrian asphalt (e.g., potholes, rutting, cracking), particularly in high-traffic areas, which could result in increased maintenance costs.	Design and O&M	Very Effective
	Transit Network	10	■ Design: Use light colors or heat resistant materials for railings and bus shelter roofs to reduce solar heat gain. ■ Design: Provide adequate shade around bus shelters and platforms to reduce urban heat island effects.	■ Hot temperatures may cause bus shelters and railings to become very hot, which could have adverse effects on the health and safety of passengers waiting outside. Also, heat waves may exacerbate the urban heat island effect (UHI) near bus shelters and station infrastructure.	Design	Very Effective
	Systems, Signalling and Equipment	10	■ O&M: Increase inspection after hot temperature events to make sure systems are working correctly.	■ The heat may cause surveillance cameras to break down or cause them to erode away causing them to malfunction	O&M	Effective
	Utilities	10	■ Design: Consider adding solar panels as an alternative source of power, on the roof of bus shelters. Solar panels can also be pole mounted. ■ Design: Install a backup generator or battery backup system to provide emergency power during an outage. Alternatively, have dedicated webpage/app for bus rapid transit operational impact that could be readily available to users. ■ Design: Use certified electrical and optical fiber components that are resilient to higher temperatures and humidity.	■ During heat waves and hot temperatures, there is an increase in energy demands and the efficiency and reliability of the power system is threatened. Heat waves and extreme temperatures can cause blackouts.	Design	Very Effective
	People	10	■ O&M: Communicate the health risks of extreme heat events with the public. For example, share heat wave warnings and health safety tips on digital display signs.	■ Hot temperatures could impact staff wellbeing and productivity and the health and wellbeing of passengers waiting in bus shelters (e.g., heat exhaustion and heat stroke, dehydration, heat stress)	O&M	Very Effective
	Surrounding Environment	10	■ Design: Consider nature-based solutions, green infrastructure and landscape design, such as planting local species that have a greater heat tolerance or are drought resistant, retaining water. ■ Design: Use heat resistant materials for public benches. ■ O&M: Ensure proper maintenance of landscaping during summer months.	■ Hot temperatures and heat waves could cause vegetation to dry out, resulting in an increased demand for maintenance and water supply.	Design and O&M	Effective
HIGH RISK **Heat wave:** **Instances of 3 days with Tmin ≥ 20°C and Tmax ≥ 33°C**	Road Network	20	■ Design: Use light colored materials for pavement surfaces on sidewalks.and/or use heat resistant paving materials with higher solar reflectance to reduce damages (e.g., potholes and cracks) and urban heat island effect. Also consider use of additives in asphalt mix to reduce shoving/rutting . ■ Design: Increase roadside vegetation and trees to increase shade and decrease exposure to heat ■ O&M: Track impacts of extreme heat to identify "hot-spots" that may require an increased rate of inspection. ■ O&M: Conduct frequent inspections of pavement surfaces to ensure cracks are properly sealed.	■ Heat waves may cause premature deterioration to road pavements and pedestrian asphalt (e.g., potholes, rutting, cracking), particularly in high-traffic areas, which could result in increased maintenance costs. Also, heat waves may exacerbate UHI due to increased surface temperatures of the pavement.-high road-surface temperature due to heat waves can lead to dangerous driving conditions as tires blowouts and deformation induced by thermal stress on roads	Design and O&M	Very Effective
	People	20	■ Design: System of ventilation in buses and metros. ■ Design: Drinking water fountains beside transit station. ■ Design: The main walking and cycling paths should be shaded and greened. ■ O&M: Shift maintenance work to cooler parts of the day. ■ O&M: Communicate the health risks of extreme heat events with the public. For example, share heat wave warnings and health safety tips on digital display signs. ■ Policy: Implement worker safety measures to protect the health and safety of staff.	■ Increase in the number of heat waves could impact staff wellbeing and productivity and the health and wellbeing of passengers waiting in bus shelters(e.g., heat exhaustion and heat stroke, dehydration, heat stress) Heat waves could result in potential delays in construction activities	Policy and O&M	Very Effective

Risk Event	Project Components	Risk	Adaptation Measure or Risk Treatment	Comments	Implementation timeframe	Effectivenessi
SPECIAL CASE RISK – DIURNAL VARIATION	Road Network	5	■ Design: Use materials and pavements that are resistant to significant changes in temperature	■ Premature deterioration of pavement surfaces	Design	Very Effective
MODERATE RISK **Heavy rainfall: Days with P ≥ 25 mm**	Systems, Signalling and Equipment	5	■ O&M: Increase inspections and maintenance following heavy rainfall events.	■ Over time, repeated exposure to heavy rain can damage almost any piece of electronic equipment, even if it is very well protected. This includes cameras. What's more, if rainwater ends up on the lens of a camera, it may distort or partially obscure the image that the camera records	O&M	Effective
	Utilities	10	■ Design: Consider adding solar panels as an alternative source of power, on the roof of bus shelters. Solar panels can also be pole mounted. ■ Design: Install a back-up generator or battery backup system to provide emergency power during an outage. ■ Design: increased culvert sizing, add sump pumps, add walls ■ O&M: Conduct regular inspections of electrical components and equipment before winter and spring seasons to prevent water-related damages.	■ Heavy rainfall may cause water damages to transformers located outside. Electrical systems can be damaged as a result of flooding or standing water in the basement. Potential power outages due heavy rainfall may cause delays in operations and services due to water getting into conduit/access exacerbated in low lying areas ■ Heavy rainfall may increase the risk of the drainage system being overwhelmed and cause flooding.	Design	Very Effective
	Surrounding Environment	10	■ Design: in order to limit runoff and erosion, design landscaping with plants that can help hold the soil firmly in place, such as fast-growing ground covers and even flower plants such as daylilies and sages. Make sure that the plants used can absorb a lot of water. ■ Design: Mulching can help mitigate erosion on moderate slopes in the landscape. applying mulch protects soil, increases surface area and improves water penetration	■ Increased surface runoff and erosion of topsoil exacerbated in low lying areas Increased maintenance of vegetation and landscape around stations	Design	Very Effective
HIGH RISK **Heavy rainfall: Days with P ≥ 25 mm**	Road Network	20	■ Design: Design drainage systems to cope with heavy rainfall (P ≥ 25mm) with well-defined overland flow routes.and/orIncorporate low impact development practices or green Infrastructure to manage stormwater runoff and prevent flood damages. Some examples include, bioretention planters, bioswales, etc. ■ Design: Avoid new mass transit corridors in flood prone areas. Use cities' risk assessment plan for modelling flood risks & identify alternative routes ■ Design: for transit station, avoid underground or low-lying depots prone to flooding for bus fleets ■ O&M: Monitor water levels to assess the risk of flooding during heavy rainfall (see Toronto Region Conservation Authority's real-time flood monitoring website). ■ O&M: Clear drainage systems of debris (e.g., objects, leaves) to prevent sewer back up. ■ O&M: Plan alternative routes to provide redundancy in the event of a major flood.	■ Heavy rainfall may result in flash floods, which could result in delays and reduced road safety- Heavy rainfall could cause premature deterioration to road pavements and pedestrian asphalt (e.g., potholes, rutting, cracking), particularly in high-traffic areas) exacerbated in low lying areas- Increased maintenance and repair costs	Design and O&M	Very Effective
	Transit Network	20	■ Design: Providing safe access for all (with ramps) to bus rapid transit stations ■ O&M: Implement an early warning system that alert staff in advance so that necessary resources can be deployed on site before, during and after an extreme weather event.	■ Heavy rainfall may result in localized flash floods, which could cause damages to bus shelters or station infrastructure, platforms, railings, and ramps and impact operations and people; exacerbated in low lying areas. Increased maintenance and repair costs	O&M	Very Effective
	People	20	■ Policy: Provide real-time flood alerts so that commuters can plan their travel accordingly. ■ O&M: Share weather information, climate-related risks and extreme events on digital display signs to alert commuters of potential delays in operations and services. ■ O&M: Modify work schedules under conditions induced by climate-related disruptions.	■ Heavy rainfall may cause disruption of construction work and maintenance work, resulting in delays in operations and services. exacerbated in low lying areas. Heavy rainfall can cause flash floods. When this occurs, bus shelters, platforms and ramps may be difficult to access. Floods could reduce road safety for drivers, pedestrians and cyclists. Also, people may file claims to the city for damages caused by storm sewer overflows.	Policy and O&M	Very Effective

Risk Event	Project Components	Risk	Adaptation Measure or Risk Treatment	Comments	Implementation timeframe	Effectivenessi
MODERATE RISK **Winter rain on snow:** **Instances of P ≥ 25 mm within Jan-Feb-Mar**	Transit Network	9	■ Design: Design bus shelters with arched or sloped roof (no flat roof) to prevent snow loads. ■ Design: Use corrosion resistant materials for metal railings to prevent premature deterioration.	■ Winter rain on snow may result in damages to roofs of bus rapid transit stops due to heavy loads. There can be accumulation of slush on bus platforms and ramps. This can lead to increased snow removal costs.	Design	Very Effective
MODERATE RISK **Drought:** **Instance of P < 0.2 mm for 10 days**	Surrounding Environment	10	■ Design: Consider nature-based solutions, green infrastructure and landscape design, such as planting local species that have a greater heat tolerance or are drought resistant, retaining water. ■ O&M: Ensure proper maintenance of landscaping during summer months.	■ Drought can cause reduced soil quality, resulting in loss of vegetation and increased demand for water.	Design	Effective
MODERATE RISK **Heavy wind:** **Days with W ≥ 65 km/h** **Blowing rain:** **Instances of (P ≥ 5 mm) and (W ≥ 65 km/h)** **Blowing snow:** **Instances of ((S ≥ 5 cm) or (SD ≥ 5 cm)) and (W ≥ 65 km/h)**	Road Network	10	■ O&M: Clear sidewalks of debris or objects that may be blown away. ■ O&M: Conduct snow clearing of bus lanes to maintain good road conditions.	■ Blown objects may cause obstructions on pedestrian sidewalks and roadways. There can be accumulation of snow on road pavement which can lead to snow removal costs and reduced road safety due to slippery pavement and reduced visibility.	O&M	Very Effective
	Transit Network	10	■ Design: Use wind resistant glass materials (W ≥ 65km/h) to prevent damages caused by flying objects. ■ Design: Consider adding heaters in bus shelters to provide thermal comfort for passengers. ■ Design: Install signs that indicate icy conditions near bus platforms to prevent slip and fall injuries. ■ Design: Install sign poles to withstand heavy winds (W ≥ 65km/h). Some examples include, increasing the installation depth, securing poles with an anchor base mounting or using concrete foundations. ■ O&M: Increase the frequency of inspections for bus shelter roofs to prevent water infiltration.	■ Blown objects may cause obstructions on pedestrian sidewalk. There can be accumulation of debris around bus shelters and station infrastructure due to heavy winds. Strong wind gusts could damage bus rapid transits stop elements. Blowing rain and blowing snow could result in water infiltration in bus shelters infrastructure All this can lead to increased maintenance costs and snow removal costs.	Design and O&M	Very Effective
	Systems, Signalling and Equipment	10	■ Design: Install traffic signal light poles that withstand heavy winds (W ≥ 65km/h). Some examples include, increasing the installation depth, securing poles with an anchor base mounting or using concrete foundations. ■ O&M: Conduct regular inspection during these extreme weather events and apply necessary measures (snow-clearing, debris clearing, use of abrasive material to de-ice) to maintain road safety and traffic signal lights visibility and prevent slippery pavement.	■ Street lights and signs may be damaged by strong winds which can lead to reduced road safety and increased maintenance & operations costs. Snow and ice affect outdoor surveillance system cameras in optic and mechanical disruptions. An unshielded camera can be damaged by ice. If there is moisture around an outdoor camera below the temperatures drop below freezing, the frost that is formed by that moisture and temperature can form on the cameras lens and disallowing the viewer to see any activities going on outside besides the crystalline patterns from the snow.	Design and O&M	Effective
	Utilities	15	■ Design: Consider adding solar panels as an alternative source of power, on the roof of bus shelters. Solar panels can also be pole mounted. ■ Design: Install a backup generator or battery backup system to provide emergency power during an outage. Alternatively, have dedicated webpage/app for BRT operational impact that could be readily available to users	■ Heavy winds may cause power outages which can cause disruption to the operations and reliance on back-up generator systems. Blowing rain and blowing snow may cause water damages (e.g., infiltration, corrosion) to transformers located outside. Snow accumulation may increase loads on transformers located outside, which may result in increased maintenance and snow removal costs.	Design	Very Effective

Risk Event	Project Components	Risk	Adaptation Measure or Risk Treatment	Comments	Implementation timeframe	Effectivenessi
	People	15	■ Design: Consider directions of prevailing wind by strategically locating barriers or including enclosed areas on BRT stops to mitigate impacts of prevailing winds on passengers. ■ Design: Consider adding emergency push buttons within the BRT stop amenities to assist in safety related platform if someone trips and falls for instance. ■ O&M: Share weather information, climate-related risks and extreme events on digital display signs. ■ O&M: Remove debris from sidewalks and cycle tracks to ensure public safety ■ O&M: Increase snow removal around bus platforms and ramps to ensure public safety. ■ Policy: Implement worker safety measures to protect the health and safety of staff working outdoors (as per the Ontario Occupational Health and Safety Act).	■ Blown objects could cause injuries to staff- Blowing snow can blow away debris or objects, which could cause injuries to pedestrians and cyclists or damage vehicles. Pedestrians may have trouble accessing bus platforms and sidewalks if they are not properly cleared. People may file claims to the city.	Design and O&M and Policy	Very Effective
	Surrounding Environment	15	■ Design: Consider incorporating windbreaks (e.g., vegetation) in the landscape design. ■ O&M: Cover fragile trees, shrubs and other vulnerable plants with protective sheets. ■ O&M: Properly secure objects in public spaces (e.g., art, benches) before fall and winter seasons.	■ Trees and branches could blow away in the wind and heavy winds could damage objects in public spaces (e.g., benches, art, etc.)	Design and O&M	Very Effective
MODERATE RISK **Freezing rain: Days with freezing rain**	Road Network	12	■ Operations and Maintenance: Conduct ice clearing of bus lanes to maintain good road conditions.	■ Freezing rain may cause pavements to become slippery, which could compromise or reduce road passenger/pedestrian safety. Increased maintenance costs (e.g., de-icing)	O&M	Effective
	Transit Network	12	■ Operation and Maintenance: Increase inspections and de-icing of bus shelter roofs and platforms to ensure public safety during freezing rain. Alternatively consider inground pavement de-icing systems	■ 'Freezing rain may cause ramps and platforms to become slippery, which could result in slips and falls. Increased maintenance of bus platforms and ramps (e.g., de-icing)	O&M	Effective
	Systems, Signaling and Equipment	8	■ Operation and Maintenance: Increase inspections and maintenance on surveillance cameras	■ Ice affect outdoor surveillance system cameras in optic and mechanical disruptions. An unshielded camera can be damaged by ice. If there is moisture around an outdoor camera below the temperatures drop below freezing, the frost that is formed by that moisture and temperature can form on the cameras lens and disallowing the viewer to see any activities going on outside besides the crystalline patterns from the snow. Increase maintenance cost	O&M	Effective
	Utilities	8	■ Design: Consider an alternate source of power in prevision of power outages.	■ Potential power outages due to freezing rain could cause delays in operations and services. Increased maintenance costs	Design	Very Effective
	People	12	■ Design: Consider adding heaters in bus shelters to provide thermal comfort for passengers. ■ Design: Install signs that indicate icy conditions near bus platforms to prevent slip and fall injuries. ■ Operation and Maintenance: Show real-time weather information, climate-related risks and extreme events on digital display signs to alert commuters of potential delays in operations and services. ■ Operation and Maintenance: Modify work schedules under conditions induced by climate-related disruptions. ■ Operation and Maintenance: Implement an early warning system that alert staff in advance so that necessary resources can be deployed on site before, during and after an extreme weather event. ■ Operation and Maintenance: Clear sidewalks around bus platforms and ramps to reduce ice build-up.	■ Freezing rain could compromise the health and safety of workers conducting maintenance or construction (e.g., frostbites, hypothermia). Workers can slip or fall if pavement surfaces become too slippery due to freezing rain. Disruptions in construction and maintenance work, resulting in delays in operations and services. Freezing rain can cause ice to build up and fall from bus shelter roofs, which may result in injuries. People can slip or fall if ramps or platforms become too slippery due to freezing rain (reduced public safety).	Design and O&M	Very Effective
	Surrounding Environment	8	■ Operation and Maintenance: Cover fragile trees, shrubs and other vulnerable plants with protective sheets	■ Freezing rain may cause damages to trees and vulnerable plants.	O&M	Effective

i. Qualitative assessment, based on design being most effective down to policy, similar to the hierarchy of control within the Health Safety and Environment realm.

Appendix E

Climate Change Risk Assessment Pivot Table

Line Label	Severity Scores for Health & Safety	Severity Scores for Infrastructure Integrity	Severity Scores for Operational impact	Severity Scores for Financial impact
Freezing rain: Days with freezing rain	9	9	11	8
People	3	0	3	2
Road Network	3	2	2	1
Transit Network	3	1	1	1
Systems, Signalling and Equipment	0	2	2	1
Utilities	0	2	2	2
Surrounding Environment	0	2	1	1
General Total	9	9	11	8