MINISTRY OF TRANSPORTATION ENVIRONMENTAL GUIDE FOR ASSESSING AND MITIGATING THE AIR QUALITY IMPACTS AND GREENHOUSE GAS EMISSIONS OF PROVINCIAL TRANSPORTATION PROJECTS

October
2019

Ontario

Ministry of Transportation

Environmental Standards and Practices

Environmental Guide for Assessing and Mitigating the Air Quality Impacts and Greenhouse Gas Emissions of Provincial Transportation Projects

Issued By:

Ontario Ministry of Transportation
Environmental Policy Office
301 St. Paul Street, Garden City Tower
St. Catharines, ON
L2R 7R4

Citation

Environmental Guide for Assessing and Mitigating the Air Quality Impacts and Greenhouse Gas Emissions of Provincial Transportation Projects (October 2019, Ontario Ministry of Transportation).

Acknowledgements

This Guide was developed in response to increased demand from provincial and federal regulatory agencies and the public to improve the assessment and mitigation of air quality and greenhouse gas emissions associated with provincial transportation projects. It outlines a standardized assessment approach and methodology for both individual and Class EA projects.

It was developed in consultation with technical and environmental assessment representatives from both levels of government, including Environment and Climate Change Canada, Health Canada, Transport Canada, Canadian Environmental Assessment Agency (Ontario Region), Metrolinx, Ontario Ministry of the Environment, Conservation and Parks and Ontario Ministry of Health and Long-Term Care. The time and effort expended by these individuals, to thoroughly review and provide comment on the document, throughout its development, is greatly appreciated. We hope that their interest and input regarding suggested improvements to the document will continue following implementation of the assessment approach and methodology.

This Guide is intended to be a living document that will be reviewed and revised as necessary.

Comments and Suggestions

The Ministry of Transportation welcomes comments and suggestions on ways to improve the document with the objective of providing a practical and pragmatic approach to environmental management in the Province of Ontario. MTO anticipates that changes will be warranted to clarify, improve and incorporate new information.

The format of the document is designed to accommodate such changes. Such revisions and amendments will be incorporated in later editions of this document. MTO will not formally respond to unsolicited comments submitted in response to the document.

Cette publication hautement spécialisée n’est disponible qu’en anglais conformément au Règlement 671/92, selon lequel il n’est pas obligatoire de la traduire en vertu de la Loi sur les services en français. Pour obtenir des renseignements en français, veuillez communiquer avec le ministère des Transports de l’Ontario au: 289-659-9176.

Alternate Format

The Ontario Public Service endeavours to demonstrate leadership for accessibility in Ontario. Our goal is to ensure accessibility for our employees and the public we serve in our services, products and facilities. This document is available in an alternate format upon request.

Version History

Version #	Date	Description of Major Change
1.0	June 2012	Original guidance document.
2.0	October 2019	Updated provincial and federal air quality standards, recommend modelling software MOVES, benzo(a)pyrene included as an air toxic, removal of “credible worst-case scenario” from Task 3, minor editing.

Table of Contents

List of Figures

List of Tables

List of Appendices

1. INTRODUCTION

The Ontario and Canadian Environmental Assessment (EA) Acts call for due consideration of the potential impacts of transportation projects on the social and physical environments.

The operation of large transportation facilities, highway construction, and highway traffic in particular, can have significant local, provincial, and cumulatively, global impacts on the atmosphere and the climate system. Specifically, pollutants in vehicle exhaust, evaporative emissions, and in re-entrained road surface contaminants adversely affect air quality. They also contribute to the gradual accumulation of greenhouse gases (GHGs) in the earth's atmosphere. These potential air quality and GHG impacts of road transportation are explained in Appendix 1 of this document.

Transportation's primary climate change impact is through its GHG emissions. The scope of the proposed approach for climate change impacts includes assessment and mitigation of these emissions. It does not include any attempt to assess how transportation might influence the climate or conversely be influenced by the climate. For additional guidance on incorporating climate change considerations in EA studies and processes see Section 2 Policy Framework.

The "tasks" described in this guidance align with various stages of the EA process to aid in the decision-making process, analysis of potential impacts and consideration of mitigation options.

1.1. Purpose

The purpose of this document is to recommend a systematic and generic approach to assess the potential air quality impacts and GHG emissions of provincial transportation undertakings for which the Ministry of Transportation (MTO) is directly responsible. It is also to address mitigation of impacts, where such mitigation is necessary and practical. It does not limit, however, the ability of project teams and regulatory agencies to address any project-specific issue in the manner that they deem to be appropriate.

Although MTO may consider a number of different modes of travel such as road, rail, air and marine, the focus of this guide will be on-road transportation impacts. However, the general methodology presented can be adapted for other modes of travel as well.

1.2. Corporate and Regulatory Support

The recommended approach has been presented to the Ministry of the Environment, Conservation and Parks (MECP), Ministry of Health and Long-Term Care, Metrolinx, Canadian Environmental Assessment Agency, Environment and Climate Change Canada, Health Canada, and Transport Canada.

With the review and acknowledgement of the regulatory agencies and MTO senior management, the approach will allow MTO staff and consultants to follow a defined analysis and mitigation methodology.

A Guide that has been reviewed and acknowledged by these agencies also:

- validates the extraordinary amount of time and effort put forward by all parties to develop the standardized approach;
- removes uncertainty, for both MTO and EA reviewers, resulting in more predictable timelines and budgets for all parties;
- results in more credibility with review agents, resulting in increased efficiencies in the EA process;
- increases public confidence and support for MTO's approach to assessing air quality impacts and GHG emissions;
- demonstrates intergovernmental collaboration; and
- promotes interest and potential adoption by other transportation service providers within Ontario (e.g., municipalities) and across Canada.

1.3. Scope

The detailed air quality and GHG assessment and mitigation approach proposed in this document is intended for individual EA and select Group A and B MTO projects (see details in Section 2 below). However, the mitigation options discussed in this document may still be applied to any MTO project where deemed appropriate. The approach in this Guide will not apply to ongoing, current MTO projects where:

MECP has been consulted on and accepted the air quality assessment methodology in accordance with MECP's existing air quality assessment requirements, and

MTO has:

- already initiated an air quality and GHG assessment and selected a preferred alternative; or
- issued a Notice of Completion of its Transportation Environmental Study Report (TESR); or
- submitted to MECP an Individual Environmental Assessment Report for approval (Terms of Reference excluded); or
- completed all Environmental Assessment Act requirements.

1.4. Administration

The Environmental Guide will be revisited every five years or sooner dependant on major advances in science, technology, or regulation. Updated versions will contain the most recent criteria air contaminant and GHG emission inventories, standards, and policies.

2. POLICY FRAMEWORK

2.1. Classification of Projects

The majority of MTO's transportation planning and design projects are subject to the Ontario and Canadian Environmental Assessment Acts. They involve new facilities or improvements to existing facilities.

Under the Ontario Environmental Assessment Act, projects that involve the planning of new large facilities such as provincial freeways are subject to an individual EA. Other projects, which are relatively small in scale, routinely performed, or have predictable and mitigable environmental effects, are subject to MTO's Class EA process.

Projects subject to the Class EA are divided into four groups – A, B, C, and D. Group A projects involve new facilities, Group B are major improvements to existing facilities, Group C entail minor improvements to existing facilities, and Group D include operation, maintenance, administration and other work on existing facilities.

Planners of new transportation projects should consult the EA web page of the Ministry of the Environment, Conservation and Parks for information about EA process and requirements in general, and for recent updates. On the same web page, a guide on considering climate change in the EA process provides tools and methods to project planners for considering climate change impacts in EA studies and processes.[1]

2.2. Air Quality Impact and Greenhouse Gas Emissions

The air quality and GHG implications of projects subject to an individual EA can be significant.[2] The same is also true for some Group A and B projects completed through the Class EA process. Group C and D projects, on the other hand, are not likely to have significant air quality or GHG impacts or offer opportunities to influence these impacts substantially. Hence, the detailed assessment and mitigation approach proposed in this document is intended for individual EA and select Group A and B projects. However, the mitigation options discussed in this document may still be applied to any MTO project where deemed appropriate.

---

[1] Ontario Ministry of the Environment, Conservation and Parks. 2018. *Considering climate change in the environmental assessment process*. Available at: https://www.ontario.ca/page/considering-climate-change-environmental-assessment-process.

[2] The word 'significant' is used in this document in its dictionary meaning – not in any specific meaning assigned to it in a legal document.

Under the Ontario Environmental Assessment Act, MTO is required to assess the environmental effects of an undertaking, including the effect on air quality. However, MECP may not require an air quality and GHG assessment for certain Group A and B MTO Class EA projects under the circumstances described below.

MTO provides MECP with supporting documentation so as to satisfy MECP that there is a:

1) relatively small increase in the number of emission sources (i.e., vehicles and/or traffic capacity); and
2) sufficient distance from the edge of the highway right-of-way to sensitive receptors (residential dwellings) and critical receptors (retirement homes, hospitals, childcare centres, schools and similar institutional buildings).

In consideration of the above, the MTO project team may decide that an air quality and GHG assessment is not required for a particular project.

2.3. Federal-Provincial EA Coordination

Projects that warrant detailed air quality and/or GHG assessments will be studied with the technical methodology defined in this document. This methodology will meet the needs of both provincial and federal regulatory agencies, in the spirit of the Canada-Ontario Agreement on EA Cooperation.

3. AIR QUALITY AND GHG IMPACT ASSESSMENT AND MITIGATION

3.1. General Methodology

The proposed methodology to conducting an air quality impact assessment relies on pollutant emission and dispersion modelling to predict the contribution of the project to ambient pollutant concentrations over a 20-year period. This contribution, added to background concentration levels, allows prediction of the cumulative impact of the proposed project and all other contributors to air pollution. The resulting concentration levels are compared to the provincial and federal ambient air quality criteria and standards to assist in the assessment and evaluation of transportation alternatives and to judge the need for any mitigation.

Similarly, the methodology to assess potential GHG impacts relies on emission modelling to predict the net amount of GHGs attributable to the project over the same 20-year period.

While there is no legal obligation for MTO to meet any specific air quality standards or GHG emission targets, MTO will endeavour to meet all relevant standards and minimize the air quality and GHG emission impacts of all of its projects whenever and wherever this is technically feasible and economically viable.

It should be noted that MECP, where appropriate, may require pre-construction and post-construction ambient air monitoring in such a manner that would measure actual impacts to local air quality.

The general methodology is described by the outline of individual tasks in Section 3.4 and in Appendices 2–5 of this document.

3.2. Limitations

The above-sketched general approach to air quality and GHG impact assessment is limited to prediction of emissions and ambient pollutant concentration levels. It does not extend to an explicit prediction of health and welfare effects. However, the likelihood of health and welfare effects of air pollution can be inferred by comparing predicted pollutant concentrations with the provincial Ambient Air Quality Criteria (AAQC) and federal Canadian Ambient Air Quality Standards (CAAQS).

Table 1 below summarizes provincial and federal air quality criteria for the most relevant transportation-related pollutants. These criteria are subject to change and it is the responsibility of the air quality assessor to ensure the most up-to-date values are used. MTO will consult with MECP before studies are conducted to determine whether a stricter criterion or additional emission factors are required.

Table 1: Provincial Ambient Air Quality Criteria[3] (AAQC) and Canadian Ambient Air Quality Standards[4,5] (CAAQS)

Pollutant	AAQC (μg/m^3 or ppm or ppb)	CAAQS[A] (μg/m^3 or ppb)
CO	30 ppm (1-hr) 36,200 μg/m^3 (1-hr)	
	13 ppm (8-hr) 15,700 μg/m^3 (8-hr)	
NO_2	200 ppb (1-hr) 400 μg/m^3 (1-hr)	2020: 60 ppb (1-hr)[B] 2025: 42 ppb (1-hr)[B]
	100 ppb (24-hr) 200 μg/m^3 (24-hr)	2020: 17 ppb (Annual)[C] 2025: 12 ppb (Annual)[C]
PM_{10}	50 μg/m^3 (24-hr)	
$PM_{2.5}$		2015: 28 μg/m^3 (24-hr)[D] 2020: 27 μg/m^3 (24-hr)[D]
		2015: 10.0 μg/m^3 (Annual)[E] 2020: 8.8 μg/m^3 (Annual)[E]

[3] Ontario Ministry of the Environment, Conservation and Parks. 2016. *Ontario's Ambient Air Quality Criteria*. Available at: https://www.ontario.ca/page/ontarios-ambient-air-quality-criteria-sorted-contaminant-name

[4] Canadian Council of Ministers of the Environment. 2012. *Canadian Ambient Air Quality Standards for Nitrogen Dioxide*. Available at: https://www.ccme.ca/en/current_priorities/air/caaqs.html

[5] Canadian Council of Ministers of the Environment. 2012. *Canadian Ambient Air Quality Standards for Fine Particulate Matter ($PM_{2.5}$) and Ozone*. Available at: https://www.ccme.ca/files/current_priorities/aqms_elements/caaqs_and_azmf.pdf

Pollutant	AAQC ($\mu g/m^3$ or ppm or ppb)	CAAQS[A] ($\mu g/m^3$ or ppb)
Ozone	80 ppb (1-hr) 165 $\mu g/m^3$ (1-hr)	2015: 63 ppb (8-hr)[F] 2020: 62 ppb (8-hr)[F]
Benzene	2.3 $\mu g/m^3$ (24-hr)	
	0.45 $\mu g/m^3$ (Annual)	
Benzo(a)pyrene[G]	0.00005 $\mu g/m^3$ (24-hr)	
	0.00001 $\mu g/m^3$ (Annual)	
1,3-Butadiene	10 $\mu g/m^3$ (24-hr)	
	2 $\mu g/m^3$ (Annual)	
Formaldehyde	65 $\mu g/m^3$ (24-hr)	
Acetaldehyde	500 $\mu g/m^3$ (24-hr)	
Acrolein	4.5 $\mu g/m^3$ (1-hr)	
	0.4 $\mu g/m^3$ (24-hr)	

Notes:

A. CAAQS as ppb or ppm should assume 10°C and 760 mmHg when converting to $\mu g/m^3$ consistent with the approach for converting AAQCs.

B. The 3-year average of the annual 98th percentile daily maximum 1-hour average concentrations.

C. The average over a single calendar year of all the 1-hour average concentrations.

D. The 3-year average of the annual 98th percentile of the daily 24-hour average concentrations.

E. The 3-year average of the annual average concentrations.

Pollutant	AAQC ($\mu g/m^3$ or ppm or ppb)	CAAQS[A] ($\mu g/m^3$ or ppb)
F. The 3-year average of the annual 4th-highest daily maximum 8-hour average concentrations.		
G. As a surrogate of total polycyclic aromatic hydrocarbons (PAHs).		

It is important to note that CAAQS should not be interpreted as levels below which air pollution has no health effect or be used as pollute-up-to levels. According to Health Canada, $PM_{2.5}$, ozone, and NO_2 have no recognized thresholds for health effects. In recognition of this, the CAAQS are supported by management levels, which call for increasing air quality management actions as pollution levels increase.[6]

Climate change impacts will be assessed indirectly and on a relative scale by comparing the net GHG emissions of a proposed initiative with relevant benchmarks, such as Ontario's transportation-related/ economy-wide GHG emissions or any applicable GHG emission-reduction targets.

3.3. Objectives

The air quality and GHG impact assessment will serve the following specific objectives:

1) Provide comparative pollutant emission estimates that can be used in the selection of the "preferred" transportation and route alternative(s). This information can become part of the set of traditional project planning and design criteria and enhance the societal value of the selection process.
2) For the preferred alternative and the planning timeframe (typically, 20 years):
    - Assess local[7] air quality impacts, specifically the likelihood, extent, and duration of exceeding provincial AAQC and national CAAQS. The results of this assessment are of direct interest to the agencies and to local residents, institutions, and businesses.

[6] See airquality-qualitedelair.ccme.ca/en/ for more information on CAAQS.

[7] The term "local" refers to the immediate vicinity of the transportation system where the concentration of transportation-related air pollutants may exceed ambient air quality criteria and standards for one or more hours in a typical year. For major roads, the collective experience of the scientific community suggests that the affected immediate vicinity is limited to the area within approximately 500 metres of the road.

- Assess the incremental increase or decrease in expected GHG emissions. This information is of particular interest to agencies responsible for achieving any applicable GHG emission-reduction targets and the federal agencies involved in the Pan-Canadian Framework on Clean Growth and Climate Change and Canada's international efforts on climate change.

3) Assess the need for and practicality of mitigation measures and predict their utility. This information can be useful to MTO, regulatory agencies, stakeholders, and the public.

3.4. Tasks

A comprehensive air quality and GHG study can pursue the above objectives by performing the six tasks listed below.

1) Assessment of transportation planning alternatives
2) Assessment of route alternatives
3) Detailed assessment of the preferred alternative (selected transportation planning and route option)
4) Assessment of need for mitigation
5) Evaluation of mitigation options
6) Reporting

Flowcharts of the tasks are presented in the figures below. Figure 1 illustrates the decision points and tasks associated with generating the inputs needed to aid in selecting a preferred alternative (Tasks 1 and 2). Figure 2 describes the steps needed once a preferred alternative has been selected (Tasks 3–6).

Tasks 1–6 apply to Individual and Group A projects. Tasks 3–6 apply to Group B projects. The balance of this document is devoted to a brief description of each task. The details of the scientific methodology recommended for each task are provided in individual appendices (Appendix 2–5).

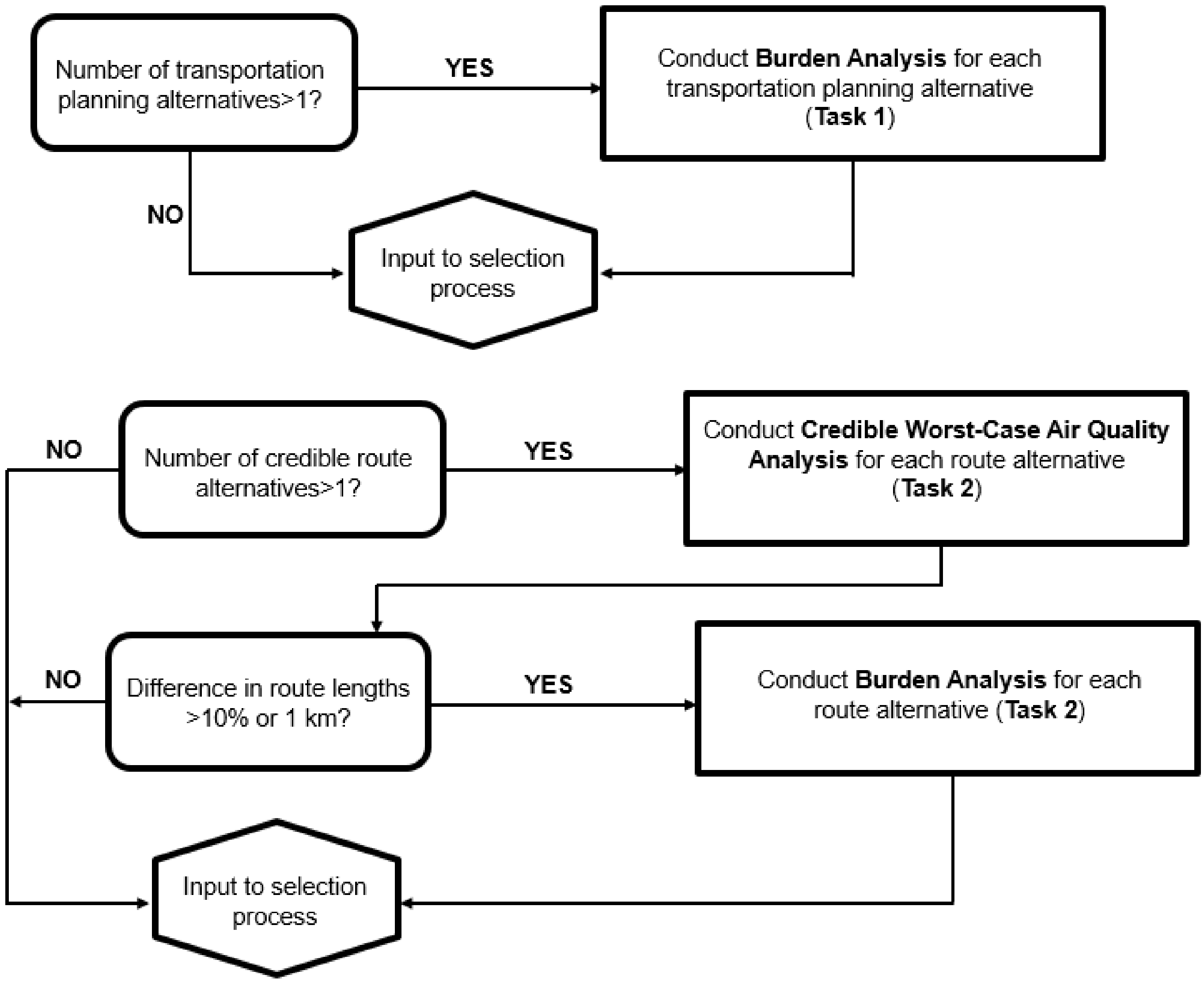

Figure 1: Selection of Preferred Alternative Flowchart

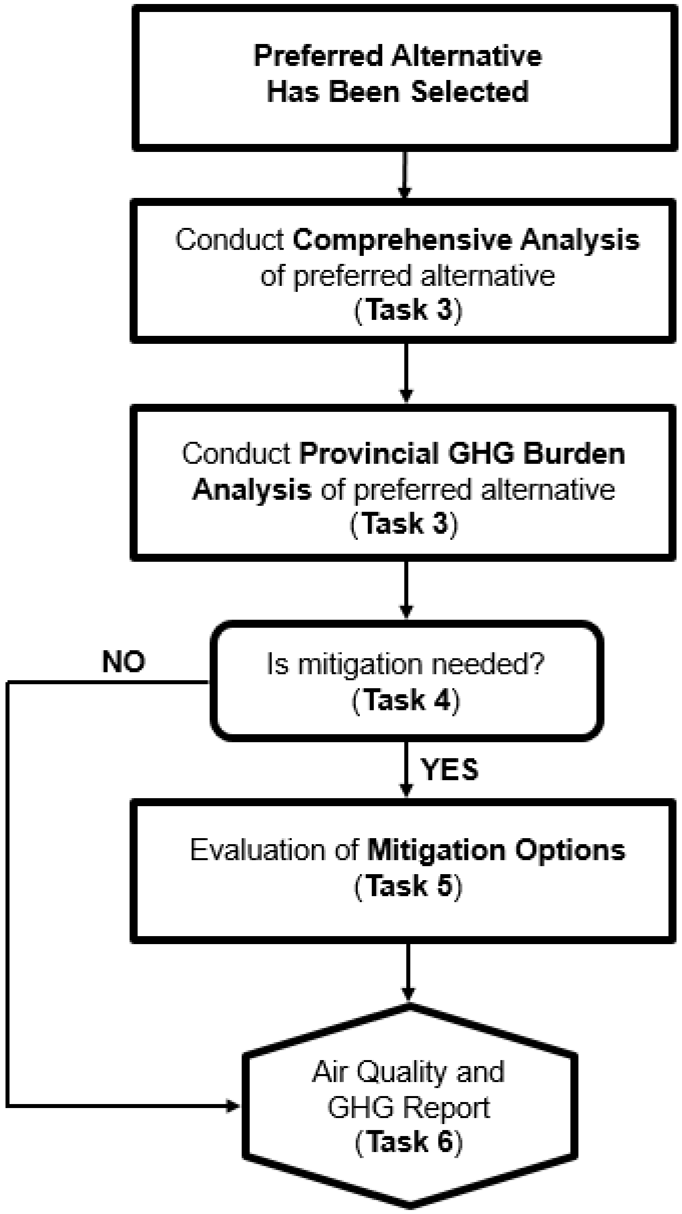

Figure 2: Assessment of Preferred Alternative Flowchart

Task 1: Assessment of Transportation Planning Alternatives (Burden Analysis)

- **Most appropriate in the "alternatives to" phase of the EA process to aid in selecting a transportation planning alternative. Required only when there is more than one "alternative to" for consideration.**
- **See Appendix 2 and 4 for detailed recommended scientific methodology**

The principal function of a transportation system is to provide access to people and/or goods at a certain capacity and level of service (performance). This capacity and level of service can be achieved, in theory, by a number of equivalent alternative transportation systems (e.g., road, rail, marine, transit) or a combination of these and/or transportation demand management, traffic control and road improvement.

The transportation demand management measures include transitways and high-occupancy vehicle (HOV) lanes. Under favourable conditions, these can be effective in reducing the total vehicle-kilometres travelled (VKT) and, hence, total vehicle emissions. Access management and Intelligent Transportation Systems (ITS) are part of the traffic control toolkit. They may improve traffic flow (reduce vehicle stops per distance and time spent at idle) and traffic-related total emissions. Road improvements with respect to geometric and structural design may contribute to lower vehicle fuel consumption and emissions.

The EA process affords the opportunity to compare these and other alternatives systematically with respect to a set of evaluation criteria. Air quality and GHG impacts are part of this set of criteria.

Some transportation alternatives may have significant air quality consequences for the local community and even for the province (airshed) at large. They may also contribute incrementally to the growing GHG content of the global atmosphere and the extent of anthropogenic climate change. Most of these consequences are proportional to the amount of pollutants (criteria air contaminants) and GHGs emitted by the transportation alternative studied. Hence, a comparative assessment of equivalent transportation alternatives with respect to air quality and GHGs can be conducted by estimating the total amount of pollutant and GHG emissions, in tonnes per year, for each transportation alternative studied. This approach is often referred to as burden analysis.

Burden analysis is most appropriate for the "alternatives to" phase of the EA process, where transportation planning alternatives are assessed and evaluated. The details of the recommended scientific methodology for burden analysis are provided in Appendix 4 although its principal steps are described as follows:

Burden Analysis: Key Steps

- Define credible transportation alternatives with equivalent passenger and/or goods movement capacity and level of service in one or more appropriate reference years. Alternatives may include a new highway, expansion of an existing highway, one or more transit routes, rail, etc.

- For each alternative, predict annual VKT by each major vehicle type (e.g., VKT for cars and light trucks, heavy trucks, buses, and freight trains) for the reference years.
- For each vehicle type, estimate emission factors in gram/VKT of principal pollutants (carbon monoxide (CO), nitrogen oxides (NOx), volatile organic compounds (VOCs), fine particulate matter (PM2.5), and inhalable particulate matter (PM10)) and GHGs (carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O)). The VOCs will include the following mobile-source air toxics: 1,3-butadiene, acetaldehyde, acrolein, benzene, benzo(a)pyrene and formaldehyde.
- Integrate the VKT and emission factors to estimate the total pollutant and GHG emissions for each credible transportation alternative in each reference year.
- Compare alternatives with respect to emissions in the context of relevant emission inventories (e.g., total emissions and/or transportation emissions in Ontario and in Canada). This information is available from Environment and Climate Change Canada.

Task 2: Assessment of Route Alternatives

- **Most appropriate in the “alternative methods” phase of the EA process to aid in selecting a route. Required only if there is more than one “alternative method” for consideration.**
- **See Appendix 2, 3 and 4 for detailed recommended scientific methodology**

An air quality impact assessment will be needed at the route planning phase of the EA process if the preferred transportation alternative (highway or other mode) involves potentially more than one new route alternative. The route of a highway and/or alternative transportation mode is of greatest significance to the local community. During planning, the project team may have the opportunity to keep the distance of the highway or other major transportation facilities from sensitive receptors (e.g., residences) and critical receptors (e.g., hospitals, retirement homes, childcare centres, and similar institutional buildings) at approximately 100 metres or greater. This would help, in most cases, to avoid the need for air quality impact mitigation.

For projects with more than one route alternative, the project team will always assess the local air quality implications of each route alternative for the critical and sensitive receptors affected by the pollution generated on each route and associated infrastructure. Commercial and industrial buildings are not included in this assessment, unless specifically called for by MECP.

Provincial air pollutant and GHG implications, on the other hand, warrant detailed analysis only if there is a significant difference in the expected emissions from the alternative routes, which can be estimated by comparing route lengths. A difference of 10% in route length corresponds to approximately 10% difference in most pollutant emissions and is deemed to be significant enough to warrant a burden analysis, as described under Task 1 of this Guide. A burden analysis is not warranted if the route lengths of the shortest and longest alternatives are less than 10% apart. At an absolute level, a route length difference of more than one km is deemed to be significant. Hence, a route length difference of more than 10% or one km is the recommended trigger for the burden analysis.

The proposed analysis is most appropriate for the “alternative methods” phase of the EA process. Its principal steps are described as follows:

- Define the credible alternative routes with equivalent passenger and goods movement capacity and performance in the reference years.
- To assess local air quality impacts, produce a site- and project-specific pollutant concentration profile with distance from the edge of the planned infrastructure for

a credible worst-case scenario as described in Appendix 3.[8] Concentration profiles should zoom in on all predicted exceedances (if any). If there are no predicted exceedances, a single concentration profile (for each pollutant and averaging period assessed) may be completed for the entire roadway. This profile will explain to the public the air quality implications of living at various distances from the highway.

- NO_x and $PM_{2.5}$ are the two key pollutants to be considered in this analysis. These are the principal transportation-related air pollutants of concern in Ontario. NO_x is most directly related to the volume and type of traffic (vehicle mix, driving cycle, etc.) while $PM_{2.5}$ reflects the influence of both traffic and road conditions (primarily silt loading of roads).
- Describe and compare the credible worst-case air quality (atmospheric concentration of pollutants) implications for living within approximately 500 metres of each route alternative with appropriate references to affected sensitive and critical receptors.
- Establish the need for a burden analysis, and if warranted, conduct this analysis according to the method outlined under Task 1. The burden analysis is to help assess, for each route alternative, the potential for provincial air quality and national climate change issues. The route with the “least” pollutant burden will affect provincial air quality less than its alternatives. It will also have the least climate change impact. However, it may not necessarily be the one with the least local air quality impacts. This issue is addressed by dispersion modelling, as described in the points above.

---

[8] The credible worst-case scenario is a hypothetical condition in which near-worst states for background pollution, meteorology, and traffic volume coincide – a highly conservative scenario.

Task 3: Detailed Assessment of the Preferred Alternative (Comprehensive Analysis)

- **Most appropriate in predicting local air quality and provincial GHG impacts once a preferred alternative has been selected.**
- **See Appendix 2, 3 and 4 for detailed recommended scientific methodology**

The preferred alternative – a combination of the preferred transportation and route alternative – has a high potential for implementation. The proposed approach for this alternative includes a methodology for more comprehensive local air quality and provincial GHG emissions analysis.

The operation of a typical transportation system, particularly a new highway, can have significant long-term local and provincial impacts. The local impacts involve primarily air quality. The provincial impacts, on the other hand, can involve both air quality and climate change – although climate change is largely a global phenomenon.

The local air quality impacts of the transportation system (e.g., highway and other major local vehicle traffic) can be assessed by emissions and dispersion modelling at the Preliminary or Detail Design stage of the EA process. The scientific methodology recommended for this analysis is presented in Appendix 3. Its principal steps are described below.

- For the preferred alternative, encompassing the preferred transportation alternative and the preferred route, identify sensitive and critical receptors that are in part or wholly within 500 metres of the edge of the travelled transportation infrastructure.
- For each community, select the infrastructure elements that will have a significant air quality impact. This selection will include the appropriate portion of the mainline highway with its associated road infrastructure and/or other transportation facility (e.g., commuter rail line, freight rail line, etc.).
- For each community and the relevant infrastructure elements, conduct a comprehensive analysis. This assessment will produce site-specific concentration distance profiles for CO, nitrogen dioxide (NO_2), VOCs, $PM_{2.5}$, and PM_{10}.
- Explain the implications of the cumulative impact analysis results in the context of relevant reference data, comparing also Build and No-Build scenarios.

The provincial GHG emissions analysis from transportation systems are described below.

- Estimate Build and No-Build scenario GHG emissions of the preferred alternative for the reference years and assess their implications for achieving any applicable GHG emission-reduction targets.

Task 4: Assessment of Need for Mitigation

- **Most appropriate once the initial local and provincial impacts from a preferred alternative is complete.**
- **See Appendix 5**

The local air quality impacts of the preferred alternative may warrant mitigation if these impacts are predicted to result in exceedances of provincial or federal ambient air quality criteria and standards for one or more criteria air contaminants over a significant period of time per year and at a significant number of receptors. The necessity to mitigate air quality impacts should be determined in consultation with MECP and consider a number of factors including (but not limited to):

- Extent – The number of receptors that do not meet provincial or federal ambient air quality criteria and standards.
- Frequency – The likelihood of exposure to air quality that does not meet provincial or federal ambient air quality criteria and standards.
- Severity – The degree to which provincial or federal ambient air quality criteria and standards are exceeded.
- Sensitivity – The types of receptors (sensitive vs. critical) that may be exposed to exceedances of provincial or federal ambient air quality criteria and standards. This document stipulates that exposure of only existing institutional buildings and residences, and those explicitly planned for in official municipal plans at the time the assessment is carried out will be taken into account in assessing this necessity.
- Build vs. No-Build – The incremental change in predicted concentrations due to the project compared to concentrations that would have existed even without the project due to background conditions and existing traffic-related sources.

The detailed analyses proposed under Task 3 are designed to deliver the transportation-related data necessary to assist in mitigation decisions. These data are however insufficient to make all decisions, since transportation is only one variable affecting air quality. Future air quality will depend in large part on how emissions from other Ontario and transboundary pollution sources will change over time.

Most long-term air quality trends are at present pointing in the right direction, thanks to efforts in Canada and the U.S. to curtail emissions from transportation and other sources of air pollution. It is more than likely that background pollutant concentrations will decrease in the foreseeable future. The magnitude of this decline is however very difficult to predict. Hence, the air quality modelling methodology recommended in this paper will assume that the background pollutant concentrations will persist at their most recent values over the entire study period (a conservative assumption).

Any mitigation decision should consider transportation's role (share) in the air quality issues of concern. The decision should also be informed by the relative cost of reducing emissions from transportation and other major provincial sources of air emissions and by a broad consideration of macroeconomic implications. As directed by the MECP code of practice on preparing, reviewing, and using class EAs, potential effects on the social, economic, cultural, and built environments must also be considered.[9]

[9] Ontario Ministry of the Environment, Conservation and Parks. 2018. *Preparing, reviewing and using class environmental assessments in Ontario*. Available at: https://www.ontario.ca/document/preparing-reviewing-and-using-class-environmental-assessments-ontario-0.

Task 5: Mitigation Options and their Evaluation

- **Appropriate if Task 4 identifies a need for mitigation.**
- **See Appendix 5**

MTO has jurisdiction over a very limited set of mitigation options. This set is often insufficient to influence local and provincial air quality and GHG emission impacts to a significant degree. There is however greater scope for mitigation within the combined jurisdictions of the local, provincial, and federal governments.

The mitigation options for regional impacts include transportation demand management, fiscal and financial measures to reduce demand for travel by single-occupancy vehicles, encouragement for the production and use of cleaner vehicles and fuels, and adoption of stricter new and in-use vehicle and fuel standards. These broader measures and their utility in reducing air quality and GHG impacts are discussed in Appendix 5.

Although many of them fall beyond MTO jurisdiction and cannot be delivered by MTO, a judicious assessment of their utility in the air quality and GHG emissions report can be useful to all three levels of government and provide the public with a broader perspective on mitigation initiatives that they can participate in.

The mitigation options for local impacts include traffic control measures to reduce and improve traffic flow, better geometric design, better landscaping, and dust control on the highway. The design and efficacy of these potential measures are discussed in Appendix 5.

Task 6: Reporting

The air quality and GHG emissions assessment and mitigation work will be documented in a stand-alone report, which provides the full context of the project and a detailed presentation and interpretation of the results. This project-specific report will not need to justify the methodology employed. This will be accomplished by referencing the appropriate sections of the Environmental Guide in hand.

4. GLOSSARY OF TERMS

AERMOD: AERMOD is a next-generation air dispersion model that incorporates concepts such as planetary boundary layer theory and advanced methods for handling complex terrain.

Ambient Air Quality Criteria (AAQC): Developed by MECP, an AAQC is a desirable concentration of a contaminant in air and is used to assess general air quality resulting from all sources of a contaminant to air.

Air Pollutant Emission Inventory (APEI): A comprehensive inventory of air pollutant emissions at the national and provincial/territorial levels prepared and published by Environment and Climate Change Canada.

Air Quality Health Index (AQHI): Used by MECP as a health-protection tool designed to inform the public on short-term exposure to air pollution.

Burden Analysis: The preferred approach to assess the provincial air pollutant implications of individual projects. A comparative assessment of equivalent transportation alternatives by estimating the total amount of air pollutant and GHG emissions, in tonnes per year, for each transportation alternative studied.

CALINE3: California Line Source Dispersion Model (CALINE) is a steady-state Gaussian dispersion model designed to determine air pollution concentrations downwind of highways located in relatively uncomplicated terrain.

CAL3QHC: Predicts inert pollutant concentrations from motor vehicles at roadway intersections based on the CALINE3 line source dispersion model.

CAL3QHCR: Enhanced version of CAL3QHC.

Canadian Ambient Air Quality Standards (CAAQS): Published by the federal government as non-binding objectives under the Canadian Environmental Protection Act as outdoor air quality targets that “set the bar” for air quality actions across the country.

Comprehensive Analysis: Used to assess local air quality impacts of projects through hour-by-hour prediction of ambient pollutant concentrations over a historical five-year time period.

Critical Receptors: Retirement homes, hospitals, childcare centres, schools and similar institutional buildings.

Global Warming Potential (GWP): A metric used to compare the ability of different greenhouse gases to absorb infrared radiation in the atmosphere relative to carbon dioxide.

MOVES (MOtor Vehicle Emission Simulator): The U.S. EPA's mobile source emission modelling system for criteria air contaminants, greenhouse gases, and air toxics.

Pasquill Stability Classes: A classification of the dispersive capacity of the atmosphere.

PCRAMMET: A meteorological preprocessor for use in CALINE3-based models

Sensitive Receptor: Residential dwellings.

Surface Roughness Length: A measure of the height of obstacles to the wind flow. It is a function of the predominant land-use feature adjacent to the project.

5. APPENDICES

Appendix 1: Air Quality and GHG Emissions – A Transportation Perspective

Appendix 2: Prediction of Criteria Air Contaminant and GHG Emissions of Road Transportation Vehicles

Appendix 3: Assessment of Local Air Quality Impacts

Appendix 4: Assessment of Provincial Air Pollutant and Greenhouse Gas Emission Impacts (Burden Analysis)

Appendix 5: Mitigation Options for Local Air Quality, Provincial Air Pollutant, and Greenhouse Gas Emission Impacts

APPENDIX 1: Air Quality and GHG Emissions - A Transportation Perspective

Air Quality

Measurement and Planning

The Air Quality Health Index (AQHI) is used by MECP as a health-protection tool designed to inform the public on short-term exposure to air pollution. This index is calculated based on the combined effects of ground-level ozone (O_3), $PM_{2.5}$, and NO_2. Their concentrations are measured hourly by a network of 39 air quality monitoring stations spread across the province.

The AQHI is a useful tool to convey general air quality conditions to the public. For a more detailed and source-specific assessment of air quality, the ambient concentration of each relevant pollutant is compared directly with its provincial or federal ambient air quality criterion or standard. This more detailed approach is adopted in transportation air quality impact assessments.

Transportation-Related Air Pollutants

Most on-road transportation vehicles run on hydrocarbons and emit essentially the same pollutants. These directly-emitted pollutants are called primary pollutants and include CO, NO_x, and VOCs. Nitrogen oxides include nitric oxide (NO), NO_2, and N_2O. Some of the VOCs emitted by transportation vehicles are deemed to have significant health impacts and are designated as mobile-source air toxics. Common mobile-source air toxics include 1,3-butadiene, acetaldehyde, acrolein, benzene, benzo(a)pyrene and formaldehyde.

There are also secondary pollutants, which are formed in the atmosphere through chemical and physical transformation of primary pollutants, some significant distance downstream of their point of emission. These include ground-level O_3 and $PM_{2.5}$, which are the two principal constituents of smog and a focus of attention of public health officials.

Ground-level O_3 is formed through complex photochemical reactions of NO_x and VOCs. The rate of this reaction is a function of the composition of the atmosphere and weather conditions. Under ordinary conditions, the rate is relatively slow. Hence, ground-level O_3 is typically formed many kilometres downwind of the source of its precursors, such as highway traffic. In fact, ground-level O_3 concentrations are usually depressed around highways since NO emissions react relatively rapidly to convert O_3 into oxygen gas (O_2). This phenomenon is commonly referred to as “scavenging of ozone” and is represented by the following chemical reaction:

$$NO + O_3 \rightarrow NO_2 + O_2$$

Particulate matter consists mainly of liquid droplets and solid particles with absorbed or adsorbed gaseous substances and has many sources. Some of the transportation-related sources are: road dust; vehicle brake- and tire-wear products; incomplete combustion products emitted through vehicle exhaust; sulphates formed from the sulphur dioxide emitted by vehicles; and nitrates formed from the nitrogen oxides emitted by vehicles. The first three of these are deemed to be primary while the last two secondary pollutants. Sulphates and nitrates are formed over time and cannot be traced to a single source or group of sources. Many stationary sources such as smelters, refineries, power plants, and all kinds of fossil fuel combustors contribute to these pollutants.

Particulate matter of greatest relevance to transportation air quality impacts is commonly classified into two size fractions: those smaller than 10 micrometres in diameter (PM_{10}, inhalable particulate matter) and those smaller than 2.5 micrometres ($PM_{2.5}$, respirable particulate matter). PM_{10} includes $PM_{2.5}$ and is commonly split into two fractions: the fine fraction ($PM_{2.5}$) and the coarse fraction (PM_{10} minus $PM_{2.5}$). The principal transportation source of $PM_{2.5}$ is vehicle exhaust. Currently, health professionals are paying greater attention to the fine fraction and ultrafine fraction (particles less than 0.1 micrometres in diameter), since they appear to be more directly related to respiratory and cardiovascular health effects attributable to particulate matter. Although ultrafine particles are emitted from vehicle exhaust, standards for this fraction in Ontario are not yet available.

The pollutants of greatest relevance to transportation air quality impact assessments are the ones that are subject to provincial or federal ambient air quality criteria and standards. These include CO, NO_2, ground-level O_3, particulate matter ($PM_{2.5}$ and PM_{10}), 1,3-butadiene, acetaldehyde, acrolein, benzene, benzo(a)pyrene and formaldehyde. Most of these pollutants, but not all, are found in the provincial AAQC and federal CAAQS. These criteria and standards for these contaminants were listed earlier in Table 1.

Air quality studies subject to this Environmental Guide will address the potential direct impacts of proposed projects on the ambient air concentrations of the pollutants listed in Table 1.

Local and Provincial Air Quality

Large transportation projects can have a significant air quality impact on their immediate vicinity. This constitutes their local air quality impact and is usually of greater interest to the local community. Hence, project-level air quality impact assessments are largely devoted to this topic. However, air pollution does not respect geographic boundaries and can affect a larger geographical area – a region. The definition of a region is specific to a project and its location. Its boundaries may be defined by various considerations such as jurisdictional borders, geographic features (e.g., mountain chains or large watersheds), or simply by the distance from the source over which pollutant concentrations drop to background levels.

Regional air quality is typically not a strong function of a single source of pollution. It is rather a function of all sources within the region and transboundary pollution. Specifically, air quality in Ontario is influenced by emissions in Ontario as well as in the U.S. In fact, in many regions of Ontario a large fraction of the regional pollution can be attributed to U.S. sources and global background concentrations. This is the principal cause for many regions in Ontario to exceed the particulate matter and ground-level O_3 ambient air quality criteria on some days of the year. Hence, local air quality can exceed the criteria without the contribution of a nearby source such as highway traffic.

In short, transboundary pollution complicates Ontario's efforts to improve air quality. However, over the last decade, progress has been made in controlling emissions through a number of bilateral agreements: the 1980 Memorandum of Understanding on Air Quality; the 1991 Canada-U.S. Air Quality Agreement; the 2000 Ozone Annex, and the 2003 Border Air Quality Strategy. This subject is discussed further in Appendix 4.

Transportation's Contribution to Air Pollutants

Ontario is part of a large North American airshed burdened by pollution from various sources on both sides of the Canada-U.S. border. Transportation is one of these sources. Environment and Climate Change Canada produces an annual inventory of airborne pollutant emissions by each major sector and is available through the Air Pollutant Emission Inventory (APEI). This information is also summarized by the MECP in an annual report on air quality in Ontario.[10]

Transportation-related emissions are broken down as road (i.e., motorcycles, passenger cars, light-duty trucks, and heavy-duty vehicles) and other transportation (i.e., rail,

---

[10] Ontario Ministry of the Environment and Climate Change. 2018. *Air Quality in Ontario 2016 Report*.

marine, air, and off-road) emissions. Table 2 presents the transportation component of the Ontario inventory for four important air pollutants: CO, NO_x, VOCs, and $PM_{2.5}$.

Table 2: Transportation-Related Air Pollutants Share for Ontario (2016) [11]

Pollutant	Road Transportation (%)	Other Transportation (%)	Total Transportation (%)
Carbon Monoxide	35	36	71
Nitrogen Oxides	34	35	69
Volatile Organic Compounds	11	17	28
Particulate Matter ($PM_{2.5}$)	5	7	12

Transportation-related emissions, unlike most industrial emissions, occur often in highly-populated locations and in the immediate vicinity of where people live and work. Hence, transportation's role in local air quality can be significant. The concentrations of some pollutants can be substantially above their respective regional levels within approximately 100 metres of major local roads and 500 metres of major highways. The extent of this elevation depends on many factors, particularly traffic volume and meteorological conditions. Ontarians living near transportation facilities are subject to the sum of regional pollution and the impact of the nearby transportation facility.

Greenhouse Gas Emissions (Climate Change)

It is widely accepted that anthropogenic GHG emissions have started to influence the global climate. Most climatologists concur that while the exact timing and magnitude of climate change impacts are difficult to predict, they are likely to be serious and irreversible. Hence, most leaders of the developed world have pledged to stabilize and then reduce global GHG emissions.

[11] Ibid.

Transportation produces over one-third of Ontario's total anthropogenic GHG emissions – about 60 megatonnes (Mt) in 2016.[12] Approximately 80% of this amount is attributable to road transportation.

The principal transportation-related GHG is CO_2. Other important GHGs include CH_4 and N_2O. Carbon dioxide is a direct product of hydrocarbon combustion. Methane is a by-product of hydrocarbon combustion but can also be emitted as unburnt fuel from natural-gas-powered equipment. Nitrous oxide is formed in small quantities as a by-product of combustion.

The relative impacts of various GHGs are often expressed in terms of their global warming potential (GWP) relative to CO_2. The two primary determinants of GWP are the ability to absorb infrared radiation and residence time in the atmosphere. On a 100-year time scale, the GWP of CH_4 and N_2O are 25 and 298, respectively.[13]

This Environmental Guide addresses GHG emissions by providing the methodology to assess GHG emissions attributable to transportation projects (Appendix 2) and proposing mitigation measures such as transportation demand management and fuel efficiency improvements (Appendix 5).

[12] Environment and Climate Change Canada. 2018. National Inventory Report 1990–2016: Greenhouse Gas Sources and Sinks in Canada.

[13] Ibid.

APPENDIX 2: Prediction of Criteria Air Contaminant and GHG Emissions of On-Road Vehicles

Prediction of Criteria Air Contaminant Emissions

Background

The central task in a transportation air quality impact assessment is the prediction of the long-term air quality effects of transportation projects. These effects arise mainly from future vehicle emissions attributable to the project. Hence, prediction of vehicle emissions is a crucial element of an air quality impact assessment. It is also a broad and complex technical subject covering four major transportation modes and numerous factors that shape emissions. The mode of greatest relevance to MTO is road transportation, which also happens to be the predominant source of transportation-related air pollution and GHG emissions in Ontario. Hence, this Appendix is devoted to emissions from road transportation.

The term "vehicle emissions" commonly refers to the amount of criteria air contaminants[14] released into the atmosphere by one or more transportation vehicles over a specific time period or travelled distance. For road vehicles, most of this amount is generated by fuel combustion (vehicle exhaust emissions), fuel evaporation from parked and driven vehicles, re-entrainment of road dust, and tire and brake wear.

It is very difficult to quantitatively predict vehicle emissions from first principles. Hence, emission predictions are usually based on vehicle emission test results. The U.S. Environmental Protection Agency (EPA) is the principal source of these results. It annually tests a cross section of vehicle models under controlled laboratory conditions. These emission test laboratories employ sophisticated chassis dynamometers, which allow repeated simulation of representative driving conditions. Exhaust and evaporative emissions are continuously sampled and averaged over entire driving cycles. The test data thus generated on individual vehicles are used in the EPA emission model MOVES (MOtor Vehicle Emission Simulator) to predict fleet-average emissions.

The methodology sketched above applies to cars, light trucks, and motorcycles. A similar methodology is employed for heavy trucks and buses. With these larger road vehicles, only engines and associated equipment, rather than the entire vehicle, are

---

[14] Environment and Climate Change Canada designates the following substances as criteria air contaminants: sulphur oxides (SO_x), VOCs, CO, O_3, NO_x, PM, and ammonia (NH_3). The presence and interaction of these substances give rise to air issues such as smog and acid rain.

emission tested. The results of the engine tests are used to deduce vehicle emissions over representative driving cycles.

The methodology for the rail, air, and marine modes is less developed. However, the emissions of these modes are, in principle, easier to predict. This is due to the smaller variety within each of these modes with respect to powertrain characteristics and operating conditions.

Criteria Air Contaminants

The criteria air contaminants most relevant to transportation are CO, NO_x, VOCs, PM, and ground-level O_3. Among the VOCs, the following mobile-source air toxics are typically included in air quality impact assessments: 1,3-butadiene, acetaldehyde, acrolein, benzene, benzo(a)pyrene and formaldehyde.

With the exception of O_3, all of the above contaminants are primary pollutants (i.e., they are directly emitted into the atmosphere). Ozone, on the other hand, is a secondary pollutant. It is not a direct emission; it is formed in the atmosphere through complex photochemical reactions of NO_x and VOCs. Particulate matter is emitted by vehicles and hence is a primary pollutant; however, it is also formed in the atmosphere through chemical and physical transformations of gas-phase precursors such as nitrogen and sulphur oxides. Therefore, PM is both a primary and secondary pollutant. VOCs consist of a large group of chemicals with very diverse natural- and man-made sources. Transportation vehicles are one of the many sources of some VOCs, the mobile-source air toxics being the most relevant to human health.

The emission prediction approach proposed here deals with all primary criteria air contaminants listed above.

Prediction of Emissions: General Methodology

The air quality impact assessment approach in this document addresses local and provincial impacts. Both assessments rely on the use of individual emission factors for each primary criteria air contaminant listed above. Emission factors are intrinsic parameters that characterize the emission rate of a specific contaminant over one kilometre of travel by a specific fleet over a specific driving cycle. In typical MTO projects, there is more than one relevant fleet and driving cycle. In these projects, one will need to apply the emission model with more than one set of input parameters to predict emission factors representative of each relevant vehicle fleet and driving cycle. These emission factors multiplied with corresponding vehicle fleet size and kilometres of distance travelled will produce the requisite total emissions.

In North America, the most commonly used model to predict fleet-average emission factors is the aforementioned MOVES model. It estimates emission factors for past, current, and future models of cars, light trucks, heavy trucks, buses, and motorcycles. It is based on emission testing of tens of thousands of vehicles over many years. It accounts for a large range of factors such as emission standards, fuel economy regulations, fuel quality (composition) standards, vehicle technology, vehicle population, vehicle activity, inspection and maintenance programs, fuel properties, and environmental conditions.

MOVES explicitly predicts vehicle exhaust and evaporative emission rates of CO, NO_x, VOCs, including six specific mobile-source air toxics relevant to Canada (i.e., 1,3-butadiene, acetaldehyde, acrolein, benzene, benzo(a)pyrene, and formaldehyde). It also predicts emission rates of particulate matter generated by vehicle exhaust, tire wear and brake wear in two size groups: $PM_{2.5}$ and PM_{10}. It does not model, however, particulate matter generated through the re-entrainment of road dust by vehicle travel. This latter component of particulate matter is addressed separately through a specific EPA-recommended method described later in this Appendix.

MOVES can simulate emission factors of almost all highway vehicles up to model year 2050. Source types are placed into 13 major groups of vehicles with similar activity and usage patterns (Table 3). The accuracy of model predictions depends, in part, how accurately the relevant vehicle fleet is described in terms of this classification for all relevant years.

Table 3: On-Road Source Types in MOVES

Source Type ID	Source Type Name	HPMSV ** Type ID	Description
11	Motorcycles	10	Motorcycles
21	Passenger cars	25	Light-Duty Vehicles
31	Passenger trucks (primarily personal use)	25	Light-Duty Vehicles
32	Light commercial trucks (primarily non-personal use)	25	Light-Duty Vehicles
41	Intercity Buses (non-school, non-transit)	40	Buses
42	Transit Buses	40	Buses
43	School Buses	40	Buses

Source Type ID	Source Type Name	HPMSV ** Type ID	Description
51	Refuse Trucks	40	Single-Unit Trucks
52	Single-Unit Short-Haul Trucks	50	Single-Unit Trucks
53	Single-Unit Long-Haul Trucks	50	Single-Unit Trucks
54	Motor Homes	50	Single-Unit Trucks
61	Combination Short-Haul Trucks	60	Combination Trucks
62	Combination Long-Haul Trucks	60	Combination Trucks

**HPMSV - Highway Performance Monitoring System Vehicle

There is also recognition of the strong dependence between emission rates and vehicle driving conditions. MOVES provides predictions for five roadway types: urban restricted access, urban unrestricted access, rural restricted access, rural unrestricted access, and off-network. The model represents each roadway type by a typical driving cycle representative for driving on that specific roadway type.

Prediction of Emissions: Practices for MTO MOVES Applications

U.S. and Canadian agencies (including MTO) and consultants previously used the MOBILE model to generate project-specific emission factors since the early 1980s. The adequacy of the model in this application has since been tested with roadside and tunnel air pollutant concentration monitoring. MTO conducted the first Canadian test of an earlier version of the model[15] (MOBILE 5.1C) in 1994, by extensively monitoring upwind and downwind roadside pollutant concentrations along with traffic volumes and meteorological conditions. These efforts established that, with sufficiently detailed and

[15] Topaloglu, T. and D. Elliott. 1996. Air Quality Impact Assessment of Highway 404 Widening. MTO Report.

accurate input data, MOBILE was capable of producing valid project-level emission factors.

However, the U.S. EPA has replaced MOBILE with the MOVES model. MOVES builds and improves upon the capabilities of the MOBILE model and is used in developing region-wide emission inventories, as required by the U.S. Clean Air Act for developing and then proving conformity with State Implementation Plans. These inventories are estimates of total emissions generated by the entire road vehicle activity in a region. Hence, the model is very elaborate and requires a large amount of input data.

Representative emission factors for MTO's air quality impact assessments of roadway projects can be achieved by using project-specific input data along with some of the default variables in MOVES. The following is a list of practices MTO and its consultants will follow, unless there is a compelling technical reason to diverge. These relate to the specification of input variables of greater consequence for the results.

- **Selection of the Month of Evaluation:** For MTO studies, results should be generated for both January and July. Of the two sets generated, the maximum emission factors should be selected for use.
- **Temperature of the Evaluation Day:** For MTO studies, typical or average month-specific temperatures should be used. These averages can be obtained from the daily temperature records for the region of interest.
- **Humidity of the Evaluation Day**: This parameter has no major influence on results. A typical or average historic value for the absolute humidity (mass of water vapour per unit mass of dry air) can be adopted.
- **Vehicle Characteristics**: These characteristics include the age distribution and fuel type for the 13 sources (see Table 3) of the relevant vehicle fleet over 30 years. For simplicity, the characteristics of the Ontario fleet are assumed to apply to a specific project. However, this should be adjusted if provided with additional project-specific data.
- **Vehicle-Kilometres Travelled by MOVES Source Type:** This is an important parameter that permits the customization of MOVES predictions to individual projects. Specifically, with detailed traffic volume data, VKT estimates are assigned to various source types, thus simulating a representative traffic composition. Unfortunately, traffic volume data and projections hardly ever provide the detailed classification needed in MOVES. Hence, approximations are needed.

Typical vehicle counts and projections distinguish between cars, light trucks, medium trucks, heavy trucks, and buses. These data can be combined with knowledge of Ontario-wide fleet composition to assign VKT to the appropriate source types required by MOVES. This will result in an input file that replicates fleet composition accurately in terms of gasoline, diesel, and other alternative vehicle fuels and technology.

- **Emissions Inspection and Maintenance (I/M) Program**: Program(s) intended to identify vehicles most in need of emissions-related repair and requiring repairs of those vehicles. Descriptive parameters of current and future programs in Ontario can be specified in consultation with MECP.
- **Roadway Type and Average Speed***:* These two parameters help predict emission factors that more closely represent project-level driving conditions. The five road type options along with observed and future expected average traffic speeds provide the input needed to generate project-specific emission factors.
- **Fuel Composition and Properties**: There are many default fuel formulations available through MOVES. The fuels-related database contains hundreds of gasoline-based fuel formulations, which are primarily based on ethanol content. A fuel formulation or combination of formulations that best reflect the Ontario supply mix should be selected. There is less variability for diesel-based fuels, where the two primary properties are sulphur and biodiesel content. There is also a compressed natural gas option, although it is only compatible with the Transit Bus source type.

Prediction of Emissions: Re-Entrained Road Dust

The contribution of re-entrained road dust to PM emissions is not well quantified. It is generally accepted, however, that this component of PM emissions consists primarily of larger particles (see Table 4), which have a relatively short lifetime in suspended state and hence do not travel too far from the road and do not play a major role in health effects.[16]

[16] Watson, J. G. and J. C. Chow. 2000. Reconciling Urban Fugitive Dust Emissions Inventory and Ambient Source Contribution Estimates: Summary of Current Knowledge and Needed Research. Desert Research Institute Document No. 6110.4F.

Table 4: Size Distribution of Road Dust[17]

Size Class	Abundance (% By Weight)
<1.0 μm	4.5
<2.5 μm	10.7
<10 μm	52.3
>10 μm	47.7

The most widely-used model to predict re-entrained road dust emissions for paved roads is provided in the EPA AP-42 document.[18] This is an empirical model that relates emission factors to the silt (crustal material of <75 μm geometric diameter) loading of the road in g/m^2 and the average weight of the vehicles on the road, in tons:

$$E = k \times (sL)^{0.91} \times (W)^{1.02}$$

where: *E* = particulate emission factor (having units matching the units of *k*),

k = particle size multiplier for particle size range and units of interest,

sL = road surface silt loading (g/m^2), and

W = average weight (tons) of the vehicles travelling the road.

The EPA-recommended values for *k* are listed below in Table 5.

Table 5: Parameter Values for the Paved Road Equation[19]

PM Size Range	k (g/VKT)
$PM_{2.5}$	0.15
PM_{10}	0.62

[17] Ibid.

[18] EPA. 2011. Emission Factor Documentation for AP-42 Section 13.2.1 – Paved Roads (Fifth Edition).

[19] Ibid.

The success of the equation depends on the accuracy of the silt loading and mean vehicle weight data. Both parameters should ideally be based on measurements. For existing roads, the mean vehicle weight may be estimated from traffic volume data. The same is not possible, however, with silt loading – particularly, on heavily-travelled highways.

Furthermore, for most MTO projects, the impacts of future roads or future conditions are of relevance.

Hence, the EPA-recommended silt loading factors are of great value. These factors, in g/m^2, are summarized in Table 6 which applies to dry paved roads. Their magnitude depends strongly on the annual daily traffic (ADT) volumes and on road type (limited access).

Table 6: Recommended Silt Loading Factors[20]

ADT Category	<500	500 – 5,000	5,000 – 10,000	>10,000
Silt Loading Factor (g/m^2)	0.6	0.2	0.06	0.03 0.015 (limited access road

The recommended value for limited access highways with ADT>10,000 is 0.015 g/m^2.

According to the EPA, application of ordinary rock salt and other chemical de-icers add little to silt loading. The application of antiskid material and/or trackout from construction sites, on the other hand, can significantly increase silt loading.

Prediction of Greenhouse Gas Emissions

Road transportation vehicles emit significant quantities of three GHGs: CO_2, CH_4, and N_2O. Carbon dioxide is by far the most prevalent GHG. It is emitted in large quantities by transportation vehicles while CH_4 and N_2O are emitted in smaller quantities.

These GHGs can be directly predicted by MOVES similar to the approach described in Section 1.4 above.

[20] EPA. 2011. Emission Factor Documentation for AP-42 Section 13.2.1 – Paved Roads (Fifth Edition).

APPENDIX 3: Credible Worst-Case and Comprehensive Air Quality Analysis

Introduction

A new or expanded transportation facility may mean measurable changes in pollutant emissions and air quality to its immediate vicinity. Recognizing the potential for significant changes, MTO started in 1994 to include science-based local air quality impact assessments in some of its environmental studies. These assessments have contributed to at least one of the following functions:

- Selection of preferred transportation option(s)
- Selection of preferred facility location (route location for a highway)
- Assessment of the overall preferred option with respect to air quality implications
- Assessment of the need for mitigation
- Assessment of the effectiveness of mitigation options

The methodology described in this Appendix is based on MTO's cumulative experiences. It is directly applicable to highway projects; however, with the few adaptations suggested in this Appendix, it can also be applied to other transportation projects.

The air quality impacts of transportation facilities are assessed primarily in terms of changes in pollutant concentrations that are directly attributable to the facility. The most relevant pollutants are CO, NO_2, $PM_{2.5}$, PM_{10}, and the six mobile-source air toxics. Ground-level O_3 is not considered here since it is not a primary pollutant. Photochemical ground-level O_3 production from its precursors takes at least a few hours, which almost always ensures its transport out of the local environment. Furthermore, vehicle emissions of NO rapidly neutralize O_3 leading to depressed concentrations near highways (i.e., scavenging of ozone).

- Experience to date suggests that MTO's stakeholders are most interested in the following specific local air quality impacts.
- Near- and long-term impacts of the new or expanded facility as quantified by expected increases/decreases of local air pollutant concentrations.
- Near- and long-term changes in ambient pollutant concentrations in response to project alternatives and any mitigation measure that is deemed necessary.

The calculation of the changes in the first two points necessitates assessment of current pollutant concentrations (Current scenario) and prediction of future ones with and without the project – comparison of Current conditions and the Build and No-Build scenarios in the two timeframes. This approach recognizes that, in all likelihood, future pollutant concentrations will be different from Current concentrations in the Build as well as No-Build scenarios.

MTO and its stakeholders are interested not only in air quality impacts, which are based on differences in pollution levels, but also in expected cumulative impacts. The cumulative effect signifies the concentrations that local residents are expected to experience and includes the collective contribution of all sources of pollution (not just local sources) to the local air pollution. They are calculated as the sum of the predicted changes in pollutant concentrations due to the project and the background pollutant concentrations as measured by MECP and Environment and Climate Change Canada air quality monitoring stations nearest to the study site.

Comparison of predicted absolute pollution concentrations with the provincial AAQC and federal CAAQS is the recommended approach to assess the need for mitigation.

General Approach

A highway is a conduit for road vehicles with individually small but collectively large air pollutant emission rates. Each vehicle constitutes a distinct and variable pollution source. The emission rate of each vehicle is often different from that of any other vehicle, and it varies instant-by-instant as a function of driving conditions and driver behaviour.

The air quality impact of such a large number of diverse and variable sources of pollution cannot be easily accomplished without some simplifications. The principal simplifications inherent to the recommended method are summarized below:

- Highway traffic is viewed as a continuous “line source” of pollution.
- The highway or highway section of interest and its ramps are divided into a set of contiguous links, with each link small enough to present a uniform geometry and traffic conditions. Separate sets of links are devised for each direction of travel.
- Each link is assigned a single emission rate, in grams of pollutant emitted per unit time, based on the product of a composite emission factor (in grams per kilometre per vehicle) and a traffic volume (number of vehicles per unit of time) specific to the link and time period of interest. For a period of one hour:

$$Emission\ Rate\ \left(\frac{g}{h}\right) = Emission\ Factor\ \left(\frac{g}{VKT}\right) \times Volume\ \left(\frac{Veh}{h}\right) \times Link\ Length\ (km)$$

This approach implicitly assumes that pollutants are well mixed over the highway, presenting a uniform and continuous source of pollution.

- The impact of highway traffic at a given receptor location is assessed by adding the impacts of all links at that location (principle of superposition).
- Dispersion occurs only in the downwind direction, upwind receptors are not affected. This commonly-made assumption is to neglect the very small rate of molecular diffusion of pollution in the upwind direction.

- All gas-phase air pollutants are assumed to disperse at the same rate from the line source, subject to the Gaussian dispersion equation (defined below, in this Appendix).
- The unique dispersion characteristics of particulate matter are addressed through corrections for settling and deposition of particles.
- Chemical reactions among pollutants are omitted, except for the instantaneous conversion of NO to NO_2 through reaction with ambient O_3:

$$NO + O_3 \rightarrow NO_2 + O_2$$

It is assumed that the rate of conversion of NO to NO_2 is controlled by the availability of O_3 (i.e., ozone-limiting method). Given sufficient amounts of O_3 in the atmosphere, all NO emitted by vehicles will immediately transform into NO_2 and disperse like any other stable gas-phase compound.

The dispersion and dissipation of pollutants is a complex process, which is strongly influenced by meteorological conditions, the characteristics of the emission source, and the local topography. A large number of computer models have been developed to model this process for various emission sources.

In 1972, the California Department of Transportation (Caltrans) issued one of the very first line source dispersion models, CALINE1. This led to a series of improved versions: CALINE2 in 1975, CALINE3 in 1979, and CALINE4 in 1984.

The CALINE models are highly specialized and well-developed line source dispersion models. They are ideally suited to modelling dispersion of emissions from highway traffic and rail traffic. They are, however, not suited to model emissions from area sources. Transportation facilities such as parking lots, construction sites, bus or train terminals, harbours and airports can be better represented as area sources. For these and similar applications, the EPA and MECP recommend AERMOD, which is a sophisticated Gaussian dispersion model. MTO recommends AERMOD to predict dispersion from transportation facilities, equipment, and activities that CALINE-based models cannot model effectively.

Consideration of Dispersion Models

MTO is aware of the U.S. EPA recommendation for the use of AERMOD in transportation dispersion modelling and is not opposed to the phase-in of AERMOD over CALINE3-based models. However, MTO would like to review the results of an ongoing study that is not yet complete (as of the writing of this update) before making a final recommendation on the preferred dispersion model.

There is a National Cooperative Highway Research Program (NCHRP) project (NCHRP 25-55) titled “Assessment of Regulatory Air Pollution Dispersion Models to Quantify the Impacts of Transportation Sector Emissions” in progress. The objective of this research is to "produce a technical report for decision makers to identify the appropriate air quality dispersion models for regulatory applications in the transportation sector." Once the results of this study are available, MTO will reassess the current recommendation to use CALINE3-based dispersion models and will update this guidance as needed (possibly before the five-year update period).

CAL3QHC/R Dispersion Models: A Brief Review

In 1980, after careful validation with field data, the EPA endorsed CALINE3 as the official model for estimating concentrations of non-reactive (stable) pollutants near highways. Since then, it has developed CALINE3 further into CAL3QHC and CAL3QHCR, which are more versatile and user-friendly than the original CALINE3 model.

CAL3QHC is most suited to predict concentrations for a single set of meteorological conditions. Hence, it is the preferred model for the credible worst-case analysis method covered in Section 5 of this Appendix. CAL3QHCR, on the other hand, can process a full year's worth of meteorological data in a single computer run. This makes it most suited for the full-year comprehensive analysis method recommended in Section 6 of this Appendix.

CAL3QHC and CAL3QHCR are equipped with a built-in routine to account for the initial mixing of pollutants over the roadway by the movement of vehicles and their hot exhaust. They can also account for pollutant removal by dry deposition. They can model depressed and elevated roads as well as curved alignments. However, they are not capable of handling complex topography, chemical reactions, and wet deposition. They are also weak in modelling extremely stable and unstable atmospheric conditions and dispersion beyond 10 km.

The judicious application of these models and the quality of the input data plays a large part in the accuracy of their results. Hence, a thorough understanding of their workings and their theoretical basis is crucial. The following paragraphs are intended to provide a brief introduction to this theory.

CAL3QHC/R and AERMOD are both based on the Gaussian dispersion model, which has proven itself as one of the most practical mathematical descriptions of the dispersion of plumes (plumes arise from continuous emission of pollutants, such as from highway traffic). This model accounts for the effects of the wind and the atmospheric turbulence on the spread of plumes. The wind carries the plume away from the source and turbulence spreads it out.

For a ground-level source-receptor pair and under homogeneous and steady-state meteorological conditions (reasonable assumptions for pollutant dispersion from busy highway traffic), the general and more complex Gaussian dispersion equation can be simplified to the following equation, which may serve to illustrate the dependence of pollutant concentration on the most relevant source and meteorological parameters.

$$C(x,y) = \frac{q}{\pi \sigma_y \sigma_z u} exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right]$$

This is a two-dimensional Gaussian dispersion equation, with *x* measured from the source along the direction of the wind and *y* axially perpendicular to it. The average concentration of a pollutant at point (*x,y*) downwind from the source is represented by *C* while *q* represents the source strength (i.e., the rate at which the pollutant is emitted). The parameters σ_y and σ_z represent the extent of plume spread at distance *x* along the *y* and *z* axes (i.e., axial and vertical spread). They are usually referred to as dispersion coefficients or eddy diffusivities. The parameter *u* represents the average wind speed. The equation does not explicitly contain the distance from the source *x* although σ_y and σ_z are both functions of *x*.[21]

Extensive field data has established the validity of this equation as a good approximation of the physics of dispersion, provided that long enough averaging times are used (e.g., at least one hour). As predicted by this equation, the concentration-distance profile of pollutants across the wind direction follows roughly the normal Gaussian curve. Similarly, pollutant concentrations increase with source intensity and decrease with wind speed and the level of turbulence.

Turbulence (or mixing) plays a critical role in dispersion. It has two components: mechanical and thermal turbulence. Mechanical turbulence arises from the interaction of moving air with objects on the ground, such as trees and buildings. Higher wind speeds and taller objects generally lead to more turbulence. The latter arises from changes in atmospheric temperature with altitude. Declines in temperature with altitude (usually, temperature drops by 1^{o}C per 100 metres of rise) lead to a more turbulent and less stable atmosphere. Increases in temperature with altitude lead to a less turbulent and more stable atmosphere. Unfavourable changes in the slope of temperature profiles leads to a thermal inversion, which limits the atmospheric height available to mixing and vertical dilution.

The relation of turbulence intensity to measurable parameters, such as wind speed and temperature profile, is very complex. At present, the best relations in the literature are based on empirical data. These relations find their way into CAL3QHC/R and other

---

[21] For distances up to 500 metres from the source, the functional relation is $\sigma = ax^b$, where *a* and *b* are empirically-determined constants.

dispersion models via the following key parameters: surface roughness length (affecting mechanical turbulence or mixing), atmospheric stability, and mixing height (affecting thermal turbulence and mixing).

Surface roughness length is a function of the predominant land-use feature of the area adjacent to the highway. Representative roughness lengths are provided in Table 7 below.

CAL3QHC/R employs internal routines to calculate the dispersion coefficients, σ_y and σ_z, based on the six atmospheric stability classes, as defined by Pasquill[22] in 1968 and reproduced in Table 8 below. The relation of stability classes to easily measurable meteorological parameters is provided in Table 9. This table helps predict daytime atmospheric stability as a function of wind speed and solar insolation. Night-time atmospheric stability is a function of wind speed and cloud cover. The relation of solar insolation to solar altitude is provided in Table 10. The information in Tables 9 and 10 is extracted from Schnelle and Partha (2000).[23]

[22] Pasquill, F. 1961. *The Estimation of the Dispersion of Wind-Borne Material*. The Meteorological Magazine. Vol. 90, pp. 33–49.

[23] Schnelle, K.B. and R.D. Partha. 2000. *Atmospheric Dispersion Modeling Compliance Guide*. McGraw-Hill Professional, New York.

Table 7: Seasonal Values for Surface Roughness[24]

Land Use Class Name	Spring	Summer	Autumn	Winter
Open water	0.001	0.001	0.001	0.001
Perennial Ice/ Snow	0.002	0.002	0.002	0.002
Low intensity residential	0.4	0.4	0.4	0.3
High intensity residential	1	1	1	1
Commercial/industrial/transport (airport)	0.07	0.07	0.07	0.07
Commercial/industrial/transport (other)	0.7	0.7	0.7	0.7
Bare rock/sand/clay (Arid Region)	0.05	0.05	0.05	
Bare rock/sand/clay (Non-arid Region)	0.05	0.05	0.05	0.05
Quarries/strip mines/gravel	0.3	0.3	0.3	0.3
Transitional	0.2	0.2	0.2	0.2
Deciduous forest	1	1.3	1.3	0.5
Coniferous forest	1.3	1.3	1.3	1.3
Mixed forest	1.15	1.3	1.3	0.9
Shrubland (arid region)	0.15	0.15	0.15	
Shrubland (non-arid region)	0.3	0.3	0.3	0.15
Orchards/vineyards/other	0.2	0.3	0.3	0.05

[24] Ontario Ministry of the Environment and Climate Change. 2017. Air Dispersion Modelling Guideline for Ontario [Guideline A-11] Version 3.0, PIBs # 5165e03.

Land Use Class Name	Spring	Summer	Autumn	Winter
Grassland/herbaceous	0.05	0.1	0.1	0.005
Pasture/hay	0.03	0.15	0.15	0.01
Row crops	0.03	0.2	0.2	0.01
Small grains	0.03	0.15	0.15	0.01
Fallow	0.02	0.05	0.05	0.01
Urban/recreational grass	0.015	0.02	0.015	0.005
Open Water	0.001	0.001	0.001	0.001
Woody wetlands	0.5	0.5	0.5	0.3
Emergent herbaceous wetland	0.2	0.2	0.2	0.1

Table 8: Pasquill Stability Classes

Stability Class	Description
A	Extremely Unstable
B	Moderately unstable
C	Slightly unstable
D	Neutral
E	Slightly stable
F	Moderately stable

Table 9: Prediction of Pasquill Stability Classes

Wind Speed (m/s)	Day-Time Insolation Strong	Day-Time Insolation Moderate	Day-Time Insolation Slight	Night-Time Cloudiness ≥ 1/2	Night-Time Cloudiness <3/8
<2	A	A-B	B		
2-3	A-B	B	C	E	F
3-5	B	B-C	C	D	E
5-6	C	C-D	D	D	D
>6	C	D	D	D	D

Notes:

1) The degree of cloudiness is defined as that fraction of sky above the local apparent horizon that is covered by clouds.
2) Insolation is the rate of radiation from the sun received per unit of earth's surface.
3) Strong insolation corresponds to sunny mid-day in summer. Slight insolation corresponds to similar conditions in mid-winter.
4) Night-time refers to the period one hour before sunset to one hour after sunrise.

Table 10: Insolation as a Function of Solar Altitude

Solar Altitude (A)	Insolation
A>60	Strong
60>A>35	Moderate
35>A>15	Slight
A<15	Weak

Credible Worst-Case Analysis: Methodology

The outlined approach in this section allows a somewhat quicker scientific assessment to compare the relative difference in impacts to air quality from potential route alternatives as required in Task 2.

The credible worst-case analysis is still based on route-specific parameters. However, the entire study area is assumed to be subject to constant traffic and meteorological conditions, namely, the credible worst-case condition. The results of this analysis are a set of ambient pollutant concentrations predicted under a credible worst-case condition likely to reflect a much worse condition than expected under usual conditions. Despite this, the results of the credible worst-case should be sufficient to compare the approximate difference in air quality impacts from multiple new route alternatives.

The credible worst-case analysis is conducted with the computer models recommended in this document, which are MOVES for the prediction of emissions and CAL3QHC/CAL3QHCR for the prediction of ambient pollutant concentrations. AERMOD is recommended for transportation facilities that are best represented as area sources such as parking lots.

The definition of a "credible worst case" and its application are subject to judgement. Hence, it is particularly important for MTO to specify how the credible worst case will be defined and applied in major transportation projects. This is presented below, in point form.

1. Local air quality impacts will be assessed for each route alternative.
2. Each alternative will be assessed for three timeframes: i) year of inauguration of the complete facility; ii) ten years from inauguration; and iii) twenty years from inauguration. Certain changes expected over this 20-year timeframe can be predicted with some degree of accuracy. These include changes in traffic conditions and vehicle emission rates.
3. The local air quality impacts are assumed to be limited to a distance of approximately 500 metres from the transportation facility, in each direction.[25] For highways, the 500 metres will be measured from the edge of the mixing zone (travelled road plus three metres on each side) to the appropriate lived-in property (point of property closest to the highway). The choice of a 500-

[25] For a highway, this amounts to a 500-metre band on each side of the highway, with appropriate adjustments for interchanges and ramps.

metre limit is based on empirical evidence for heavily-travelled large highways, which clearly indicates that the concentrations of road-related pollutants drop to within 10% of their background pollution levels over this distance.[26] The same criterion may not apply to transportation facilities of a vastly different nature such as harbours and airports.

4. Within the 500-metre range (as defined above), pollutant concentrations will be assessed for critical and sensitive receptors. Using the same input data, the dispersion model will be run to generate site-specific isoconcentration contour maps that allow easy assessment of the variation of concentrations over the entire study area.
5. Commercial and industrial buildings will be deemed outside of the scope of this analysis. The air quality requirements of this sector are addressed by occupational health and safety rules.
6. Outdoor and indoor air pollutant concentrations will be assumed equal. This is a conservative assumption.
7. The assessment will include the proposed mainline highway, on/off ramps, interchanges, bridges, service roads and any other travelled structures. It will also include any existing arterial roads within 500 metres of the mainline highway that carry 10% or more of the expected traffic on the mainline highway. All other planned new arterial roads within 500 metres of the highway will be included.
8. In the CAL3QHC application, the mainline highway and its ancillary travelled elements will be split into links with substantially uniform geometry and traffic conditions. Separate links will be defined for each traffic direction. Queuing conditions such as at signalized intersections have substantially different emissions than free-flow conditions and will be modelled as individual links. No link will stretch over 10 km.
9. Uniformity in mainline highway geometry will be assessed in terms of road width, curvature and slope. Mainline highway links will be devised so as to present substantially constant width, curvature, and slope.
10. Traffic conditions will be quantified in terms of three parameters: i) traffic volume (vehicles per hour); ii) average traffic speed (km/h); and iii) percentage of the total traffic volume represented by heavy-duty vehicles

[26] Topaloglu, T. and D. Elliott. Air Quality Impact Assessment of Highway 404 Widening. MTO Report.

(GVWR>8,500 lb). These traffic conditions will be assessed for the three analysis timeframes.

11. Traffic conditions will be derived with validated travel demand forecasting models. The air quality modeller will assess the accuracy of the data and seek explanations where anomalies are detected.
12. Emission factors will be derived according to the methodology in Appendix 2 of this document.
13. In the one-hour credible worst-case analysis, the weekday morning or afternoon peak hour traffic conditions will be used.
14. In the 24-hour credible worst-case analysis, the weekday 24-hour traffic volume predicted by traffic modelling will be used. This 24-hour figure will be used to create a table of hour-by-hour traffic volumes by applying the best available traffic engineering input.
15. In the one-hour and 24-hour analyses, credible worst-case meteorological inputs are listed below. Meteorological inputs should be developed in consultation with MECP:
    - The wind speed will be set at 1 m/s. This is the lowest wind speed that can be handled by CAL3QHC. It is a very rare condition to prevail for 24 hours.
    - The wind direction will be set at 5º off the mainline highway axis, to the right or to the left of the axis so as to produce the highest concentration at the nearest receptor. This is a very rare condition to prevail over 24 hours.
    - The stability class for urban regions will be set at D and that for rural and suburban regions at E, unless there is a compelling scientific reason to set it at a different level. A setting worse than class D cannot be deemed credible.
    - The mixing height will be set at 500 metres.
16. The worst traffic hour and the worst meteorological hour will be assumed to coincide. This is one of the assumptions leading to a worst-case scenario.
17. The surface roughness length will be set for the prevailing land use in the study area in accordance with Table 7 of this Appendix.
18. The settling and deposition velocities of gas-phase compounds will be set at zero, indicating no measurable deposition under any condition.
19. The settling velocities for $PM_{2.5}$ and PM_{10} will be set at 0.02 and 0.3 cm/s, respectively.
20. The deposition velocities for $PM_{2.5}$ and PM_{10} will be set at 0.1 and 0.5 cm/s, respectively.
21. The concentrations predicted by the dispersion model represent the impact of the highway (i.e., the expected change in concentration).

Comprehensive Analysis: Methodology

As required in Task 3, the comprehensive analysis involves hour-by-hour prediction of ambient pollutant concentrations for a full year. In this approach, the air quality effects of the proposed and preferred alternatives can be assessed over the spectrum of meteorological conditions expected over a year.

1. Local air quality impacts will be assessed for the Build and No-Build scenarios. The comprehensive analysis is highly suited to compare scenarios and to assess the “acceptability” of the preferred alternative with respect to local air quality.

2. The No-Build scenario applies to projects that involve improvements to an existing transportation system or facility (Class B projects); not to projects that involve a new system. The No-Build scenario will be assessed to four timeframes: i) current conditions (base case); ii) year of inauguration of the improved facility; iii) ten years from inauguration; and iv) twenty years from inauguration.

3. The Build scenario will be assessed for three timeframes: i) year of inauguration of the complete facility; ii) ten years from inauguration; and iii) twenty years from inauguration. Certain changes expected over this 20-year timeframe can be predicted with some degree of accuracy. These include changes in traffic conditions and vehicle emission rates. Other potential changes, such as those in background pollution cannot be predicted with any degree of accuracy.

4. The local air quality impacts are assumed to be limited to a distance of approximately 500 metres from the transportation facility, in each direction.[27] For highways, the 500 metres will be measured from the edge of the mixing zone (travelled road plus three metres on each side) to the appropriate lived-in building (point of the building closest to the highway). The choice of a 500-metre limit is based on empirical evidence for heavily-travelled large highways, which clearly indicates that the concentrations of road-related pollutants drop to essentially their background pollution levels over this distance. The same criterion may not apply to transportation facilities of a vastly different nature such as harbours and airports.

[27] For a highway, this amounts to a 500-metre band on each side of the highway, with appropriate adjustments for interchanges and ramps.

5. Within the 500-metre range, pollutant concentrations will be assessed for all critical receptors and representative sensitive receptors (i.e., residences). Isoconcentration contour maps will be also produced to allow easy assessment of concentrations over the entire study area.

6. Commercial and industrial buildings will be deemed outside of the scope of this analysis. The air quality requirements of this sector are addressed by occupational health and safety rules.

7. Outdoor and indoor air pollutant concentrations will be assumed equal. This is a conservative assumption.

8. The assessment will include the proposed mainline highway, on/off ramps, interchanges, bridges, service roads and any other travelled structures. It will also include any existing arterial roads within 500 metres of the mainline highway that carry 10% or more of the expected traffic on the mainline highway. All other planned new arterial roads within 500 metres of the highway will be included. This guideline presumes that the air quality impacts of existing roads are already included in the background pollution levels unless they carry a large traffic volume (more than 10% allocated to the highway).

9. In the CAL3QHCR application, the mainline highway and its ancillary travelled elements will be split into links with substantially uniform geometry and traffic conditions. Separate links will be defined for each traffic direction. Queuing conditions such as at signalized intersections have substantially different emissions than free-flow conditions and will be modelled as individual links. No link will stretch over 10 km.

10. Uniformity in mainline highway geometry will be assessed in terms of road width, curvature and slope. Mainline highway links will be devised so as to present substantially constant width, curvature and slope.

11. Traffic conditions will be quantified in terms of three parameters: i) traffic volume (vehicles per hour); ii) average traffic speed (km/h); and iii) percentage of the total traffic volume represented by heavy-duty vehicles (GVWR>8,500 lb). These traffic conditions will be assessed for the three analysis timeframes.

12. Traffic conditions will be derived with validated traffic demand forecasting models. The air quality modeller will assess the accuracy of the data and seek explanations where anomalies are detected.

13. Emission factors will be derived according to the methodology in Appendix 2 of this document.

14. Two sets of traffic conditions will be needed. The first set will apply to weekdays and the second to weekends (no special provision is made for holidays). Each set will include, hour-by-hour, total traffic volume, average traffic speed and percentage of the traffic represented by heavy-duty vehicles. The weekday conditions will be applied to each weekday of the year. Similarly, the weekend conditions will apply to each Saturday and Sunday of the year.

15. The meteorological data requirements for the comprehensive analysis include surface wind direction and velocity, stability class, and mixing height. These are obtained from public and private meteorological stations that monitor surface and upper air. Meteorological inputs should be developed in consultation with MECP.

16. The full-year meteorological data (surface and upper air data) will be acquired from the nearest meteorological station(s) (usually, the nearest airport). The five-year average meteorology for the most recent five years constitutes the preferred data set. Generally, five years of meteorological data are available. In the circumstance where less than five years of meteorological might be considered appropriate is when using representative on-site meteorological data, which should be developed in consultation with MECP. The meteorological data will be processed with the EPA PCRAMMET data processor to generate the inputs for the dispersion model.

17. The meteorological data used in dispersion modelling will be documented in the study report as wind roses and frequency distributions.

18. The surface roughness length will be set for the prevailing land use in the study area in accordance with Table 7 of this Appendix.

19. The settling and deposition velocities of the gas-phase compounds will be set at zero, indicating no measurable deposition under any condition.

20. The settling velocities for $PM_{2.5}$ and PM_{10} will be set at 0.02 and 0.3 cm/s, respectively.

21. The deposition velocities for $PM_{2.5}$ and PM_{10} will be set at 0.1 and 0.5 cm/s, respectively.

22. The concentrations predicted by the dispersion model represent the impact of the highway (i.e., the expected change in concentration). They are added

to background pollutant concentration levels to predict final concentration levels.

23. The background pollutant concentration levels to be used in the comprehensive analysis are those concurrently measured with the meteorological data. In case these data are not available or difficult to process, the 90th percentile of the most recently measured and complete concentration data from the nearest MECP or Environment and Climate Change Canada air quality monitoring station will be accepted.

24. The potential pollutant concentration effects of existing and planned large sources of pollution in the immediate vicinity of the project site will be explicitly taken into account in a limited cumulative effects analysis.

25. For each pollutant studied, the predictions of the comprehensive analysis will be presented as cumulative frequency curves of concentration versus time at critical receptors and representative sensitive receptors (i.e., residences). These curves will display, among other things, the percentage of time over a year the pollutant is expected to spend at, above, or below any concentration level within the range of concentrations predicted.

26. In addition to the cumulative frequency charts the study report will include the maximum, mean, and median concentrations predicted for each pollutant and a comparison of these with applicable provincial and federal criteria and standards.

27. The cumulative frequency charts will be used to assess the period over which any pollutant may exceed the ambient pollution criteria or standards.

The results of the comprehensive analysis provides a means to assess the acceptability of the preferred option. This assessment will include a rigorous discussion of the following considerations:

- Are the AAQC and CAAQS met at all critical receptors? If not, what are the extent, magnitude, and duration of the exceedances?
- Are the AAQC and CAAQS met at all sensitive receptors? If not, what is the extent and duration of the exceedances?
- What are the causes of any exceedances? The causes will include the contributions of highway traffic-related pollution and background pollution.
- What are the contributions of the principal traffic-related pollution (i.e., exhaust emissions, evaporative emissions, brake- or tire-wear products, and re-entrained road dust)?

- What are the trends over time? Is highway traffic-related pollution expected to increase or decrease over time? What are the principal contributors to the predicted trends?
- What are the differences between the Build and No-Build scenarios over the 20-year timeframe? What are the principal contributors to the predicted differences?

Thorough scientific discussion of above considerations is expected to lead to a rational assessment of the air quality implications of the preferred option. If warranted, this discussion will be continued in Appendix 5 to address mitigation options.

APPENDIX 4: Burden Analysis

Introduction

Large provincial transportation projects have the potential of influencing transportation and other economic and social activities much beyond their confines. In this process, they may significantly alter the distribution and the rate of emissions to air in the province and thereby affect air quality and contribute to global climate change.

This Appendix is intended to provide a reasoned recommendation that practically assesses provincial air pollutant and GHG emission impacts. It includes a short discussion of provincial air quality and GHG emissions in Ontario and recommends a uniform practical approach to assess emission impacts.

Describing Provincial Air Quality

Provincial air quality is commonly described in terms of the concentrations of provincially-important air pollutants. These concentrations vary with time and location. Hence, they have to be treated statistically. The two statistical parameters of special interest are the average and the peak (or near-peak) values of the concentrations. The averages take on a more precise meaning with the stipulation of the averaging period and the extent of the province.

The definition of the provincially-important pollutants, the averaging periods of pollutant concentrations, and the spatial extent of the province are integral to the assessment methodology and are discussed in this section.

Provincially-Important Pollutants

Current knowledge on health and environmental effects clearly identifies ground-level O_3 and $PM_{2.5}$ as the two pollutants of greatest provincial importance. They are the major constituents of smog and are produced by numerous physical and chemical processes that usually take place over extended periods of time and over large geographic areas. During air pollution episodes, their concentrations are elevated over large areas in parts of Canada. Hence, the Canadian Council of Ministers of the Environment has seen fit to impose national O_3 and $PM_{2.5}$ standards (Table 1), which came into effect in 2010.

Ozone and most $PM_{2.5}$ are secondary pollutants. They are formed from primary pollutants or precursors, which include NO_x, NH_3, SO_2 and VOCs. Provincial air quality management encompasses measurement and control of these primary pollutants. They not only contribute to the formation of O_3 and $PM_{2.5}$ but also to smog, acid rain and other pollution phenomena and present direct human health hazards. Hence, they need to be included in both local and provincial air pollutant impact assessments.

Averaging Periods for Pollutant Concentrations

In local air quality impact assessments, the averaging periods for air pollutants are dictated by the AAQC and CAAQS (Table 1). An annual averaging period is deemed relevant to pollutants that may pose chronic health risks such as $PM_{2.5}$.

From a regulatory perspective, the near-peak 8-hour average for O_3 (fourth-highest measurement annually, averaged over three consecutive years) and the near-peak 24-hour average for $PM_{2.5}$ (98th percentile ambient measurement annually, averaged over three consecutive years) are of particular interest. They establish whether the CAAQS are met. The highest concentrations of these provincially-important pollutants occur during air pollution episodes, which are often caused by unfavourable large-scale meteorological conditions.

Spatial Extent of the Region

Emissions in the airshed shape Ontario's air quality. The contribution of neighbouring jurisdictions varies with meteorological conditions. Higher levels of ground-level O_3 and $PM_{2.5}$ are generally associated with slow-moving high-pressure systems south of the Great Lakes.

From a jurisdictional perspective, the spatial extent of the region may be defined as the Windsor-Ottawa corridor or southern Ontario.[28] This is the most populated area and arguably most polluted portion of Ontario.

From a practical project-level air quality impact assessment perspective, the area of study may be confined to the total geographic area serviced by the transportation project and its immediate transportation network. This operational definition encompasses the sources of pollution the project may have an influence on and omits all other sources in the airshed.

Provincial Air Quality in Ontario

The most recent report on Ontario's air quality indicates that air quality in the province has significantly improved over the past ten years due to decreases in pollutants such

[28] The Clean Air Act divides the country into air quality control regions and holds each region and its state government responsible to meet National Ambient Air Quality Standards. There is no parallel arrangement in Canada.

as CO, NO_2, and SO_2.[29] However, annual ground-level O_3 concentrations have increased 1% over the 10-year period from 2007 to 2016. In 2016, 19 sites in 16 locations across Ontario measured ground-level O_3 levels above the one-hour AAQC of 80 ppb for at least one hour. According to a 2005 report, Ontario's ground-level O_3 problems are largely attributable to long-range transport of pollutants from the U.S. Midwest and Ohio Valley.[30] Hence, reducing emissions across the entire airshed appears to be necessary for reducing Ontario's ground-level O_3 levels significantly.

Provincial $PM_{2.5}$ emissions have decreased approximately 16% over the 10-year period from 2007 to 2016. However, three air quality monitoring stations measured daily averages above the 24-hour $PM_{2.5}$ reference level of 28 $\mu g/m^3$ on at least one occasion in 2016.

On the other hand, NO_2 and CO concentrations, which are more directly related to local transportation activity, did not exceed the AAQC at any one of the province's monitoring sites during 2016. The NO_2 annual mean concentrations across Ontario have decreased 30% over the 10-year period from 2007 to 2016. Similarly, the composite means of the one-hour and eight-hour CO maximums have decreased 53% and 24%, respectively.

Climate Change and GHG Emissions

Climate change is attributed to anthropogenic GHG emissions, irrespective of where they occur. According to Environment and Climate Change Canada, Ontario's economy-wide GHG emissions were 161 Mt in 2016, of which transportation contributed 60.2 Mt (or 37%).[31] Although transportation-related GHG emissions decreased by 6.2% over 2005–2016, the sector is likely to remain the largest contributor in the foreseeable future.

---

[29] Ontario Ministry of the Environment and Climate Change. 2018. *Air Quality in Ontario 2016 Report*.

[30] Yap, D., Reid, N., De Brou, G., and R. Bloxam. 2005. *Transboundary Air Pollution in Ontario*. Ontario Ministry of the Environment.

[31] Environment and Climate Change Canada. 2018. National Inventory Report 1990–2016: Greenhouse Gas Sources and Sinks in Canada.

Assessment of Air Pollutant Emissions

Rationale for Assessment

Individual transportation projects are not likely to lead to large changes in Ontario's air pollutant emission inventory. On the other hand, the local impacts of major undertakings are expected to be much more significant. Hence, while recognizing the importance of provincial air quality, MTO and other Canadian transportation agencies are more concerned with local impacts of planned transportation projects.

Provincial and federal agencies responsible for the environment and human health have the additional concern of protecting regional air quality. They have expressed their interest in the regional air impacts of individual transportation projects.

There is a North American precedent for regional air quality impact assessment. State agencies conduct such assessments as part of a State Implementation Plan (SIP) for complying with the federal Clean Air Act and to demonstrate attainment of National Ambient Air Quality Standards, particularly with respect to ground-level O_3 and $PM_{2.5}$.[32] These two pollutants can be assessed only at the regional level, not at the local level. It is important to note that the scope of SIPs is regional emissions from all sources – not individual project emissions.

Ontario can benefit from air quality impact assessments, if these include the broader area-wide network effects of individual transportation projects and thus provide the opportunity for a more comprehensive assessment of project options.

Air Pollutant Burden Analysis

The linkages between regional pollutant concentrations and emissions are inherently complex. Current models, even in the hands of experts, do not have the resolution to accurately predict changes in regional pollutant concentrations due to individual projects. Air quality in Ontario is heavily influenced by emissions in the U.S., but remains relatively good. Transportation emissions of criteria air contaminants are on a declining trend thanks to stringent emission standards. Hence, project-level regional air quality impact assessment with mathematical or empirical airshed models is neither advisable nor necessary.

---

[32] The EPA expects U.S. states with nonattainment areas to demonstrate the conformity of their transportation plans with SIPs and thus attain National Ambient Air Quality Standards. In Ontario, regional transportation planning is not subject to the environmental assessment process. Hence, regional air quality implications of transportation are not addressed in the provincial transportation planning process.

It is important however to minimize the pollution burden of individual transportation projects by deploying the best available planning and technological means. To ensure that this general principle is upheld, project-related emissions should be quantified in the most comprehensive and accurate manner. This approach is often called burden analysis. It is equally applicable to primary air pollutants and GHGs.

Burden analysis entails quantitative assessment of the net increase or decrease in pollutant emissions attributable to the project. Its scope includes the project as well as its effects on the existing transportation network. Thus, it involves a more regional and comprehensive approach, which should help identify the best transportation and route options with respect to provincial air pollutant emissions at the project planning and design stage.

Burden analysis is a practical and systematic approach to recognize and compare contributions to air pollution of a project and its alternatives. At a project level, mathematical or empirical airshed modelling is not as practical and useful in guiding project planning and design. They are more suited to assess the regional air quality implications of a whole sector or of broad measures such as the adoption of new emission standards.

Recommended Methodology for Air Pollutant Burden Analysis

In the broadest sense, the pollution burden of a project entails the net effect of the project on emissions of relevant primary pollutants. It includes the emissions incurred/avoided by the transportation project (e.g., a new highway or transitway) and the associated transportation network over a 20-year timeframe. The methodology to calculate the emission rates of the relevant pollutants is similar to that recommended for the assessment of local air quality impacts in Appendix 2 and 3. The assessment of net effects adds, however, an important task; namely, the assessment of the network effects of the project.

The prediction of the project's network effects over a 20-year timeframe is a major transportation demand modelling task. The methodology for this task is beyond the scope of this document and is well known to MTO and the transportation engineering community. The outline below provides the principal tasks involved in burden analysis. It has been written with large highway projects in mind, but can be generalized to other transportation projects.

1. Estimate total transportation demand associated with the transportation project proper for three time frames: immediately following completion of project, 10 years from project completion, and 20 years from project completion. These estimates will be generated by integrated land-use and transportation demand modelling and will encompass passenger and freight

transportation. Demand will be expressed in vehicle-kilometres travelled per year by facility and vehicle type.

2. Estimate emission factors specific to each pollutant (designated by the subscript *i*), facility type, and vehicle type. The pollutants of provincial significance are CO, VOCs, NO_x, and $PM_{2.5}$. The emission factors will account for exhaust and evaporative emissions as well as tire and brake wear. However, they will not include re-entrained road dust, since this component of provincial $PM_{2.5}$ is small, has lesser health implications, and is difficult to predict accurately. Most road dust falls into the coarse fraction of PM_{10}, which will not be included in provincial air quality impact assessment due to its short range and lesser significance in provincial air pollution. The facility types are dictated by the nature of the transportation project. For highways, the principal types include mainline highway, service roads, and ramps. Two vehicle classes will be considered: light- and heavy-duty vehicles. At present, the vast majority of light-duty vehicles run on gasoline and heavy-duty vehicles on diesel fuel. Emission factors will be derived with the MOVES computer model or an equivalent model. The recommendations of this Environmental Guide regarding the application of MOVES are included in Appendix 2.

3. Estimate total annual vehicle emissions for the project proper by carrying out the following nested summation for each individual pollutant:

$$Total\ Annual\ Emissions\ of\ Pollutant\ i = \sum_{Facility} \sum_{Vehicle} EF_i(Facility, Vehicle) \times VKT(Facility, Vehicle)$$

In this equation, EF_i stands for the emission factor specific to a pollutant (designated by the subscript *i*), facility type, and vehicle class; *VKT* stands for the corresponding annual vehicle-kilometres travelled. Summation of the product of emission factors and vehicle-kilometres travelled, first over all vehicle classes and then facility types, will produce the grand total of expected annual emissions on all facilities making up the project.

4. Estimate transportation network effects. This involves the passenger and freight transportation demand impact of the project on all significantly affected regional transportation facilities, in VKT per year by facility and vehicle type, for three time frames: immediately following completion of project, 10 years from project completion, and 20 years from project completion. The decision on which facilities are significantly affected will be made by the responsible MTO transportation/traffic engineer and will include assessment of

foreseeable traffic conditions as well as expected demographic, employment, land use and other relevant developments. The overall net demand change on affected facilities may be negative (a reduction) as the new facility (the project) attracts demand from existing and presumably less “efficient” facilities.

5. Based on the passenger and freight transportation demand (VKT) estimates of step 4, predict total annual vehicle emissions of CO, VOCs, NO_x, and $PM_{2.5}$ generated on all affected regional transportation facilities (the network effect) by applying the methodology described under steps 2 and 3 above. Emissions will be segregated by year, facility type and vehicle type.

6. Calculate the net emission impacts of the project proper and its associated transportation network by combining the results of steps 3 and 5 above. Net emission impacts will be estimated for the three time frames specified in step 1 and will be segregated by year, facility type, and vehicle type.

7. Assess provincial significance of the projected net emission impacts by comparison with appropriate statistics, such as those provided in Table 11, and published provincial airshed modelling studies for Ontario and other jurisdictions.

8. Perform the analyses in steps 1–7 for each relevant transportation and/or route alternative to provide the opportunity for a comprehensive assessment of all relevant options from a provincial air pollutant emissions perspective.

Table 11: Air Pollutant Emissions in Ontario (2016)[33]

Provincial Pollution Source	Annual Emission Rate (tonnes/year)			
	CO	VOCs	NO_x	$PM_{2.5}$
All Provincial Sources	1,412,969	351,393	299,714	71,941
All Transportation Sources	1,003,592	98,760	208,130	8,642
Road Transportation – Passenger	397,703	32,467	37,378	786

[33] Environment and Climate Change Canada. 2018. Air Pollutant Emission Inventory Report 1990–2016.

Provincial Pollution Source	Annual Emission Rate (tonnes/year)			
	CO	VOCs	NO_x	$PM_{2.5}$
Road Transportation – Freight	93,085	6,480	63,681	2,161
Rail Transportation	3,508	1,192	24,138	564
Marine Transportation	1,064	344	10,143	239
Air Transportation	13,142	2,054	32,810	329
Off-Road Transportation	495,089	56,222	39,981	4,027

Note: Excludes open and natural sources (consistent with MECP methodology).

Assessment of GHG Emission Impacts

With climate change, the most appropriate and practical metric to assess the impact of the project is annual GHG emissions. The global atmospheric concentrations of these gases have been gradually rising since the industrial revolution, mainly due to the rising consumption of hydrocarbons but also many other anthropogenic (man-made) influences. This is a truly global phenomenon with global causes and consequences. It is very difficult to associate concentrations of GHGs in the atmosphere with specific regions or activities. However, it is relatively easy to associate GHG emissions with specific regions and activities and to make comparisons with any applicable provincial and national targets. The most prevalent transportation-related GHGs are CO_2, CH_4, and N_2O. Carbon dioxide, along with water vapour, is the main combustion product of common transportation fuels. It is the most abundant anthropogenic GHG. Methane and N_2O are by-products of the combustion of common transportation fuels. Although their atmospheric concentrations are smaller than that of CO_2, they are more potent GHGs as measured through GWP (see Section 2 of Appendix 1).

The GWP of each gas is taken into account to express GHG emissions in terms of CO_2-equivalents (CO_2e). Specifically, for transportation vehicles, GWPs are used to calculate the weighted sum of the emission rates of CO_2, CH_4, and N_2O, which yields the CO_2-equivalent mass emitted per unit of distance (with the usual units of “grams of CO_2e per kilometre”). This convention is adopted here.

In transportation, the term “GHG emissions” usually refers to tailpipe emissions of GHGs – consistent with the emissions of criteria air contaminants. This definition omits the GHGs emitted and/or absorbed in the production and distribution of the fuel. Hence, it does not account for all the GHGs associated with the fuel. Furthermore, it does not recognize the amount of CO_2 absorbed in the production of biofuels. With full accounting for all the GHGs created and absorbed in the life cycle of the fuel, one can, in principle, associate a fuel-cycle emission factor with each type of fuel.

The calculation of fuel-cycle GHG emission factors is, however, complicated by the fact that there is no unique life cycle for any fuel. Fuels are produced with different raw materials and processes, distributed through different means, and used in different ways – implying a spectrum of GHG emission factors for the same fuel. Hence, one can at best speak of a representative GHG emission factor for a fuel, representing the dominant life cycle(s) of that fuel for a given country or region. This approach has been adopted in a number of computer models that essentially integrate the empirical data available for various transportation fuels and their respective dominant life cycles.

University of California (Mark Delucci) developed the first publicly-available fuel-cycle GHG emission model: The LEM. With U.S. Department of Energy sponsorship, Argonne National Laboratory (Michael Q. Wang) developed a second model: GREET. Natural Resources Canada sponsored Connor and Levelton Associates to “Canadianize” the LEM, producing GHGenius. These models build primarily on empirical data that reflect current and past industry practices in various parts of the world. They need periodic updates to maintain relevance. However, even then, their use to predict future fuel cycles and corresponding emission factors is problematic.

Given above issues with fuel-cycle GHG emission factors and the inconsistency with how criteria air contaminant emissions are treated (tailpipe only), the utility of fuel-cycle emission factors in this Environmental Guide is debatable. The GHG emission implications of transportation projects can be assessed, consistent with the approach proposed for criteria air contaminants, by comparing the Build and No-Build scenario emissions and assessing their significance relative to benchmarks such as provincial transportation GHG emissions. These comparative analyses can be carried out, without loss of accuracy or relevance, with tailpipe emissions, unless the use of alternative fuels or electricity is central to the project, in which case project relevant fuel-cycle emission factors can be developed and used. This general approach is described in the recommended methodology below.

The methodology in the previous section for criteria air contaminant emissions (burden analysis) is directly applicable to GHG emissions and will not be repeated here. In fact, once the transportation demand projections are available, the criteria air contaminant (pollutant) and GHG emission implications of the project can be calculated readily with appropriate emission factors.

MOVES estimates fleet-average emission factors for target years. This level of aggregation is tailor-made for emission impact assessments at a regional scale.

However, MOVES is designed to estimate only vehicle emissions, not fuel-cycle emissions.

The following steps are recommended to derive GHG emission factors for GHG emission impact assessment:

- In projects that do not include a transportation option dedicated to an alternative fuel or source of energy, only tailpipe emissions will be accounted for by employing tailpipe emission factors of CO_2, CH_4, and N_2O derived with the MOVES model.
- In those projects that include one or more transportation options dedicated to vehicles powered by alternative fuels or electricity, fuel-cycle emission factors will be employed to compare options with each other and with the No-Build option. However, tailpipe emissions will be used to compare project emissions with targets or benchmarks such as Ontario's total GHG emissions and any applicable emission-reduction targets.

APPENDIX 5: Mitigation Options for Local Air Quality, Provincial Air Pollutant, and Greenhouse Gas Emission Impacts

Introduction

Motorized transportation is almost invariably associated with some air pollutant and GHG emissions. Highway traffic, in particular, can elevate local pollutant concentrations and add to the pollutant and GHG burden of the province and beyond.

At the planning and design stage of a new transportation project, there is the opportunity to avoid or minimize these impacts by making appropriate planning and design choices – as noted under Task 1 and Task 2 in the body of this Guide. It is important to note that avoiding air quality and GHG emission impacts by judicial project planning and design is often much more effective than mitigation. However, in those instances where impacts remain unacceptably high, MTO will consider mitigation options and mitigate adverse impacts using those tools within its control.

Although this document is intended for individual EA and select Group A and B projects, local mitigation options discussed here may also apply to Group C projects

There are a spectrum of mitigation options – direct or indirect measures to alleviate the negative impacts of the project. Local impacts are best mitigated by reducing local emissions and/or exposure. Provincial and global impacts can only be influenced through net reductions in pollutant and GHG emissions across the province. These net reductions are primarily derived from broader air quality programs (discussed under Broad Regional Air Quality Programs, below). In some cases they may be achieved through the project's influence on regional transportation activity or through unrelated measures such as the adoption of stringent vehicle emission and fuel consumption standards.

The need for project-specific mitigation is determined on a case-by-case basis. This process involves a degree of subjectivity due to the absence of clear regulatory requirements with the air quality and GHG emission impacts of mobile sources. The document at hand stipulates a need to consider mitigation of local impacts, especially where the local air quality impact assessment predicts exceedances of the provincial AAQC or the federal CAAQS for criteria air contaminants over a significant period of time per year at a significant number of receptors. The need to mitigate provincial impacts may arise if the provincial air quality and GHG emission impact assessments predict a significant net addition to the provincial air pollution and GHG burden.

Broad Regional Air Quality Programs – Background

To date, the most effective mechanism to reduce transportation air quality impacts has been through regulation of new vehicle emissions with gradually tightening federal emission standards. Regulations establishing exhaust emission limits for on-road vehicles were first enacted in 1971 under the Motor Vehicle Safety Act, which is administered by Transport Canada. The legislative authority for controlling on-road vehicle emissions was transferred from Transport Canada to Environment Canada in 2000 under the Canadian Environmental Protection Act, 1999.

The federal On-Road Vehicle and Engine Emission Regulations (SOR/2003-2) introduced more stringent emission standards for on-road vehicles and engines, including passenger cars, light-duty trucks, and heavy-duty vehicles. The subsequent Regulations Amending the On-Road Vehicle and Engine Emission Regulations and Other Regulations Made Under the Canadian Environmental Protection Act, 1999 (SOR/2015-186), introduced stricter limits on air pollutant emissions from new passenger cars, light-duty trucks, and certain heavy-duty vehicles beginning with the 2017 model year in alignment with the EPA Tier 3 vehicle standards.

Canada started to regulate fuel quality through the Sulphur in Gasoline Regulations (SOR/99-236) and Sulphur in Diesel Fuel Regulations (SOR/2002-254). Specifically, the sulphur content of gasoline and diesel fuel is now subject to strict standards, which have contributed directly to a reduction in PM emissions. The regulations have also enabled reductions in gaseous pollutants by ensuring that the level of sulphur in gasoline and diesel fuel does not impair the effective operation of advanced emission control technologies. Fuel quality standards are very effective since they immediately affect emissions of all vehicles in the region.

Broad Regional GHG Programs – Background

There are also a number of provincial and federal actions in place or proposed to reduce vehicle GHG emissions. The federal Passenger Automobile and Light Truck Greenhouse Gas Emission Regulations (SOR/2010-201) established mandatory GHG emission standards for new vehicles covering model years 2011–2016. The subsequent Regulations Amending the Passenger Automobile and Light Truck Greenhouse Gas Emission Regulations (SOR/2014-207) covers model years 2017–2025. Both regulations were developed in collaboration with the EPA to ensure alignment of standards. They establish progressively more stringent annual fleet-average GHG emission standards, while providing companies with flexibility mechanisms to allow them to comply in a cost-effective manner.

The federal Heavy-duty Vehicle and Engine Greenhouse Gas Emission Regulations (SOR/2013-24) established mandatory GHG emission standards for new on-road heavy-duty vehicles and engines covering 2014 and later model years. The regulations are aligned with U.S. national standards and include provisions that establish compliance flexibilities, which include a system for generating, banking, and trading emission credits.

More recently, the federal Regulations Amending the Heavy-duty Vehicle and Engine Greenhouse Gas Emission Regulations and Other Regulations Made Under the Canadian Environmental Protection Act, 1999 (SOR/2018-98) introduced more stringent GHG emission standards that begin with the 2021 model year for on-road heavy-duty vehicles and engines.

Ontario has a number of GHG reduction initiatives of its own. The Ethanol in Gasoline regulation requires fuel suppliers to provide an average annual content of at least 5% ethanol in gasoline sold in the province. Ontario's Greener Diesel regulation requires fuel suppliers to provide bio-based diesel fuels that meet specific GHG performance targets.

Local Air Quality Impacts

MTO Experience with Local Air Quality Impacts

Experience with MTO air quality impact assessments over more than a decade suggests that the principal local air quality issue regarding major highways is with PM concentrations. Specifically, $PM_{2.5}$ concentrations may exceed the 24-hour CAAQS of 28 $\mu g/m^3$ on a number of days in a typical year when highly unfavourable meteorological conditions persist. Exceedances are, however, limited to $PM_{2.5}$ and PM_{10} and to locations within 100 metres from the edge of highways.

The role of highway traffic on local air quality, and specifically PM concentrations, is a strong function of distance from the highway. At very short range (30 metres or less), large highway traffic volumes (i.e., over 100,000 vehicles per day) typically contribute 80% of the ambient $PM_{2.5}$ concentrations. This fraction drops to approximately 50% at 100 metres from the edge of the highway. With PM_{10}, concentrations drop even faster due to faster loss to deposition. The principal source of $PM_{2.5}$ from highway traffic is vehicle exhaust, particularly diesel-engine exhaust. The primary source of the coarse fraction of PM_{10} around highways is re-entrained road dust.

Local Mitigation Opportunities and Considerations

Mitigation is best planned based on the scientific findings of the air quality impact assessment and the specifics of the project and its social and natural environments. MTO experience suggests that the need for mitigation with major highways will depend, in part, on whether any critical receptors or a large number of sensitive receptors are located very close (less than approximately 30 metres) to the highway. Experience also suggests that mitigation should be aimed at minimizing emissions of and exposure to PM.

The following mitigation options are available for consideration around transportation, particularly highway transportation projects. The potential benefits of these options should be assessed, where feasible, by dispersion modelling prior to implementation.

Dust Control

Re-entrained road dust, which is the primary source of traffic-related PM_{10}, can be controlled where problematic by reducing the amount of dust precursors on the road. This may be achieved by minimizing tracking of mud and other debris onto the highways and by sweeping and washing any issue areas more frequently and thoroughly.

Limiting Vehicle Speed

The rate at which dust is re-entrained is a function of vehicle size and speed. Larger vehicles travelling at higher speeds contribute more to dust re-entrainment and to the PM_{10} level in the atmosphere near highways. Hence, where PM_{10} levels are expected to exceed AAQC for significant periods of time and affect a significant number of sensitive and/or critical receptors, the project team may consider the potential effects of speed limits.

This option is however not available for freeways (controlled-access highways) and is practical only on new roads.

Vegetation

Vegetation, such as grasses, shrubs, and trees, along highways can enhance gravitational deposition of particles through agglomeration, impaction, and interception. In particular, planted windbreaks (shrubs or rows of trees) can reduce PM concentrations by several distinct mechanisms. Particle-laden air is filtered as it flows through the windbreak. This process contributes significantly to a decrease in airborne particulate matter, especially larger-diameter particles.

There is a considerable volume of scientific literature on particle deposition to help design effective windbreaks or other means to enhance particle deposition. This literature suggests that there is an optimum windbreak density for a given particle size to achieve maximal deposition. Some field experiments may, however, be needed to develop more specific guidance on the best means for typical highway settings in Ontario.

Mitigation of Provincial Air Pollutant and GHG Emission Impacts

Provincial Mitigation Opportunities and Considerations

The scope for project-level mitigation of provincial air quality and GHG emission impacts is limited and consists mainly of the measures suggested in Section 2. Most of these measures help reduce or trap emissions and will provide both local and provincial benefits.

Broader measures that target emissions from entire transportation sectors such as emission and fuel consumption standards can have a profound effect. Many such measures are already being implemented or close to being implemented by the three tiers of government, the private sector, and the public at large. They are described in the Introduction to this Appendix and will not be repeated here, unless they can be part of an individual project.

The remainder of this section is devoted to potential measures with a regional reach that can be considered within the context of an individual project. Most of these options (alternative transportation modes, HOV lanes, road pricing, and geometric design) are applicable to MTO’s Individual and Group A projects during the early stages of the planning process.

Provision of Transportation Modes with Low Emission Rates

Certain transportation modes, such as commuter and freight rail, can incur potentially less emissions per passenger-kilometre or tonne-kilometre travelled. Preference can be given to these modes over highways, where they can adequately serve transportation needs and are economically viable. The pollutant and GHG emission benefits of these rail-based modes are in part due to their inherent energy efficiency advantage. They also have other advantages such as higher load factors and thus lower emissions per unit of transportation service. This is particularly true in the comparison of a single-occupant vehicle with commuter rail.

Provision of HOV Lanes

On new highways, continuous and extensive HOV lanes can contribute significantly to the reduction of total VKT and emissions generated in the province. This potential is a function of the level of service on the highway. Under free-flow conditions, the full potential of HOV lanes cannot be realized. Conversely, under severely congested conditions, HOV lanes may not succeed. The full potential is realized with marginally-congested highways, where the use of HOV lanes by ridesharing provides significant time savings.

Road Pricing

Road pricing through electronic tolling or other means may result in a net reduction of total VKT and emissions generated in the province. The potential of this measure will, in part, depend on the availability of alternatives to the corridor and can be estimated with transportation demand models.

Highway Geometric Design

Highways that provide the most direct and shortest route between prevalent origins and destinations will help reduce VKT and emissions. Other geometric measures that minimize the need for acceleration and braking will also help reduce emissions.

Vegetation

Vegetation along highways such as grasses, shrubs, and trees remove CO_2 from the atmosphere through photosynthesis, where carbon dioxide is incorporated into the roots, stems, trunks, branches, and leaves of the vegetation. Properly managed, carbon is accumulated and stored throughout the life of vegetation serving as a carbon sink. Several factors such as tree size, age, and species, affect how much trees can absorb and should also be considered when using vegetation as a GHG mitigation option.

Vegetation as a means to absorb CO_2 for a project should consider the effect on contaminant dispersion and concentrations in the local area as discussed in Section 2 of Appendix 5.