

Greening North American Transportation Corridors

Challenges and Opportunities

Texas Transportation Institute
Texas A&M University System
College Station, Texas

Commission for Environmental Cooperation



ABSTRACT

This paper presents a case study determining the air-related environmental impact, including emissions of criteria pollutants and greenhouse gases, of truck and rail freight movement along a corridor stretching from Mexico City to Montreal. Network and freight activity data were assembled for the corridor for a base case (corresponding to the year 2010) and a future case (corresponding to 2035). Emission rates for the case study were obtained from the US Environmental Protection Agency's MOBILE6.2 emissions model, using US average parameters such as vehicle age distribution, from vehicle registration data. Rail emissions calculations are based on US average emissions and fuel consumption rates and were revised to reflect the ongoing improvements in locomotive engine standards.

The results show that freight movement will continue to cause substantial amounts of carbon dioxide (CO₂) emissions. Current levels of rail emissions are not significant relative to the contribution from trucking; proportionally, however, the share of rail emissions for some pollutants will increase over time. This is due to the projected increase in rail freight movement, coupled with a significant reduction in criteria pollutants from trucks as the result of more stringent emission standards and improved engine designs.

An expert panel was convened to discuss the findings and make further recommendations. Because of the vast differences between truck and rail operations in terms of routing and operational practices, it is recommended that rail and truck analyses be performed separately to gauge environmental and air quality impacts. It was also determined that the emerging sources of data such as GPS and engine loggers can lead to improved monitoring accuracy; however, making use of these potential resources requires cooperation between the freight industry and transportation and environmental agencies.

This background paper was prepared by the Texas Transportation Institute and the Texas A&M University System, College Station, Texas, for the Secretariat of the Commission for Environmental Cooperation. The information contained herein does not necessarily reflect the views of the CEC, or the governments of Canada, Mexico or the United States of America.

Reproduction of this document in whole or in part and in any form for educational or non-profit purposes may be made without special permission from the CEC Secretariat, provided acknowledgment of the source is made.

Except where otherwise noted, this work is protected under a Creative Commons Attribution-Noncommercial-No Derivative Works License.



Commission for Environmental Cooperation, 2010

Publication Details

Publication type: *Background paper*

Publication date: *December 2010*

Original language: *English*

Review and quality assurance

procedures:

First Party review: 28 May–25 June 2010

QA09.23

Disponible en español

Disponible en français

For more information:

Commission for Environmental Cooperation

393, rue St-Jacques ouest

Bureau 200

Montreal (Quebec) Canada H2Y 1N9

t 514.350.4300 f 514.350.4372

info@cec.org / www.cec.org



TABLE OF CONTENTS

List of Figures.....	iii
List of Tables.....	iii
Introduction.....	1
Background and Literature Review.....	2
Environmental Impacts of Freight Movement	2
Criteria Pollutant Emissions.....	2
GHG Emissions and Inventories.....	2
Freight Impacts – Future Scenario.....	3
Estimation of GHG and Air Quality Impacts.....	3
Congestion of Freight Corridors	5
Causes of Delay and Congestion.....	5
Impacts and Mitigation.....	5
Performance Measurement and Freight Data.....	6
Transportation Performance Measures	6
Performance Measures for Freight.....	7
Data Sources and Availability	7
Air Quality Mitigation Measures	8
Case Study: Mexico City to Montreal Corridor.....	10
Study Approach and Data Sources	11
Emissions Estimation Methodology	14
Estimation of Truck Freight Emissions.....	14
Estimation of Rail Freight Emissions.....	17
Analysis Results	19
Estimation of Emissions Due to Freight Activity at Border Crossings.....	31
Issues, Challenges, and Opportunities	33
Analysis Scope and Air Pollutants.....	33
Estimation Methodologies	34
Data Requirements and Data Sources.....	34
Data Sources.....	35
Trucking Activity	36
Network and Routing Data	36
Truck Emission Rates	37
Rail Freight Movement and Emissions.....	37
Performance Measures	38
Mitigation Strategies	38
Concluding Remarks	38
Appendix A: CO₂ Emission Projections to 2035	40
Appendix B: MOVES and MOBILE6.2	40

LIST OF FIGURES

Figure 1. Mexico City to Montreal Highway and Rail Corridor	12
Figure 2. Analysis Process for Annual Truck Emissions along Mexico City to Montreal Corridor	16
Figure 3. Analysis Process for Annual Rail Emissions along Mexico City to Montreal Corridor	18
Figure 4. Estimated CO ₂ Emissions from Trucks along the Corridor in 2010 versus 2035	21
Figure 5. Estimated CO Emissions from Trucks along the Corridor in 2010 versus 2035	22
Figure 6. Estimated NO _x Emissions from Trucks along the Corridor in 2010 versus 2035	23
Figure 7. Estimated Total HC (Total Hydrocarbon) Emissions from Trucks along the Corridor in 2010 versus 2035	24
Figure 8. Estimated PM ₁₀ Emissions from Trucks along the Corridor in 2010 versus 2035	25
Figure 9. Estimated Freight Railroad CO ₂ Emissions along the Corridor in 2010 versus 2035	26
Figure 10. Estimated Freight Railroad CO Emissions along the Corridor in 2010 versus 2035	27
Figure 11. Estimated Freight Railroad NO _x Emissions along the Corridor in 2010 versus 2035	28
Figure 12. Estimated Freight Railroad Total HC Emissions along the Corridor in 2010 versus 2035.....	29
Figure 13. Estimated Freight Railroad PM ₁₀ Emissions along the Corridor in 2010 versus 2035	30
Figure 14. Annual Volumes of Truck Border Crossings into the United States at Laredo, TX.....	31
Figure 15. Drayage Truck Model Year Frequency Based on 2006 TTI Survey.....	32
Figure 16. Annual Emissions at Laredo Port of Entry.....	33

LIST OF TABLES

Table 1. Emissions Reduction Strategies for Trucking and Rail	9
Table 2. Study Corridor Distance by Country and Mode	11
Table 3. Data Required for Corridor Level Air Quality Analysis of Freight Movement	13
Table 4. Fleet Average Locomotive Emission Factors.....	17
Table 5. Total Annual Amount of Emissions Due to Freight Movement on the Mexico City to Montreal Corridor.....	20
Table 6. Impact Scope and Data Accuracy for Transportation Air Pollutants.....	34

INTRODUCTION

The Commission for Environmental Cooperation's (CEC's) framework for assessing the environmental effects of the North American Free Trade Agreement (NAFTA)¹ addresses a wide variety of environmental concerns. These include air quality, water quality, land resources, biodiversity, and global climate change. Some of these are affected by freight transportation, which can have other significant impacts, including noise pollution, degradation of natural resources, socio-economic impacts, and hazardous waste contamination.

The majority of freight in North America is hauled by diesel-powered trucks and locomotives, which are major sources of greenhouse gases (GHG) emissions as well as other emissions that are harmful to human health, including nitrogen oxides (NO_x) and particulate matter (PM). Thus, the air quality impact of freight movement is a significant issue, both in terms of climate change/GHG emissions and also the emissions of other harmful pollutants.

The purpose of this study is to create an approach by which the air quality implications of major freight corridors can be studied, with a view to reducing environmental impacts. Corridors, because they concentrate traffic flow, are the most congested parts of the surface freight transportation system, and thus require specific attention in environmental assessment of freight movement. A few studies have examined GHG impacts of freight movement on a corridor, but there has not been an attempt to examine these impacts from a performance-monitoring perspective. The research team addressed the overall project goals through the following steps:

- conducting a comprehensive review of the literature on environmental impacts of freight movement, the applicability of performance measurement, data needs and availability, and other relevant topics;
- developing an approach to assessing air quality and greenhouse gas emissions of freight movement at the corridor level;
- applying this methodology to a case study of a major freight corridor from Mexico City to Montreal to determine the air quality impact of rail and truck movement; and
- discussing the findings with an expert advisory group comprising transportation professionals with freight and transportation sustainability expertise.

This study is intended to fill a void in the current understanding of GHG impacts and other air quality impacts of surface freight transportation at the corridor level. Together, these resources provided a context for determining issues, opportunities, and challenges related to conducting a corridor-level air quality analysis of freight movement. The following sections of this report cover the background and literature review, the case study findings, and a review of issues, challenges, and opportunities relating to freight movement and air quality impact analyses.

¹ Commission for Environmental Cooperation (1999). *Assessing Environmental Effects of the North American Free Trade Agreement (NAFTA): An Analytic Framework (Phase II) and Issue Studies*. Environment and Trade Series, No. 6. Montreal: Commission for Environmental Cooperation.

BACKGROUND AND LITERATURE REVIEW

This background section covers the environmental impacts of surface freight transportation, the impact of congestion on freight corridors and bottlenecks, performance measurement and freight data used for performance measures, and the various air quality mitigation measures that are available to reduce air quality impacts along freight corridors.

Environmental Impacts of Freight Movement

Criteria Pollutant Emissions

Trucks and locomotives powered by diesel engines move the majority of freight in North America. Diesel engines are major emitters of NO_x, PM, and volatile organic compounds (VOCs). NO_x and VOCs are precursors to ground-level ozone, which can trigger a variety of health problems, including serious respiratory illnesses. Ozone is also associated with other adverse environmental impacts such as damage to crops and plants in natural ecosystems. Exposure to PM is also linked to serious health conditions, such as aggravated asthma, respiratory difficulties, and cardiovascular illnesses, and can even cause premature death. PM is also the major source of haze that reduces visibility and creates unsafe conditions for airplanes and other modes of transportation. In the United States, NO_x, CO, and VOC are among the seven criteria pollutants and are regulated by standards set by the US Environmental Protection Agency (EPA).

All three NAFTA member countries (Canada, Mexico, and the United States) monitor atmospheric concentration levels of VOC, NO_x, ground-level ozone, and PM. Each country also has additional standards for other specific pollutants, such as lead (Pb), and sulfur dioxide (SO₂). Air pollution monitoring in the United States is based on a centralized system, with the EPA being responsible for these tasks. In Canada, the Department of the Environment maintains a centralized monitoring system whilst a number of Provinces, notably Quebec, also monitor air pollution and have established legislative policies on GHG. In Mexico, on the other hand, the monitoring of air quality is semi-centralized: performed by local governments with the coordination of the National Institute of Ecology (INE) under the National Information System for Environmental Quality (*Sistema Nacional de Información de la Calidad del Aire—Sinaica*).^{2,3}

GHG Emissions and Inventories

Freight transportation is also a major source of carbon dioxide (CO₂) emissions. In terms of quantity, CO₂ is the most important GHG contributing to global climate change. Unlike the criteria pollutants from point sources, whose levels can be reduced by emissions reduction technologies, trade-related GHG emissions are more diffuse in their origins and cannot be reduced easily. Although CO₂ emissions of freight movement activities are not regulated by the governments of the NAFTA countries, transportation is seen as a possible source of significant future GHG reductions.

² Sierra Club (2000). NAFTA Transportation Corridors: Approaches to Assessing Environmental Impacts and Alternatives, Washington, DC.

http://www.cec.org/programs_projects/trade_environ_econ/pdfs/sierra.pdf.

³ Asia-Pacific Economic Cooperation (2009). Mexico: Report of Air Pollution Control Equipment and Services, <http://egs.apec.org/more-articles/133-mexico-report-of-air-pollution-control-equipment-and-services>

GHG emissions quantification, also referred to as a GHG emissions inventory, is often the first step to taking action on GHG gases. Inventories are often used in regulatory settings to provide a sense of scale to emission levels. They are also often the foundation needed for action plans to set quantifiable goals and targets. The US EPA creates an annual national GHG emissions inventory. Currently, at least 40 US states have also developed GHG emissions inventories. Some states have also developed GHG action plans while others have specifically addressed transportation-related CO₂ emissions in their state energy plans or state environmental regulations.

Freight Impacts – Future Scenario

Freight transportation's relative contribution to air pollution is expected to grow in the future, as the share from the passenger transportation sector decreases because of more fuel-efficient and cleaner operating vehicles. Besides the health concerns due to pollutant emissions, there is also a heightened concern about global climate change and GHG sources. According to EPA's inventory of GHG emissions,⁴ US freight-related GHG emissions increased by 74 percent from 1990 to 2008 while over the same period, passenger transportation GHG emissions increased by 33 percent. Meanwhile, the increase in GHGs during this period from all US sources was 14 percent.

Since 1990, the CO₂ intensity of freight movement, measured in tons of CO₂-equivalent (CO₂eq) emissions per ton-mile of cargo, has increased significantly. This trend is mainly the result of the increasing utilization of energy-intensive freight modes, especially freight trucks, which provide faster and more reliable service at the expense of energy efficiency, and much greater reliance on on-demand freight delivery. The EPA GHG inventory shows that freight trucks account for 21 percent of total transportation GHG emissions in the United States. The trucking industry's share of total ton-miles of freight in the United States has increased from 19 percent in 1980 to 29 percent in 2007.⁵ Based on the energy consumption projections from 2008 to 2035, the *Annual Energy Outlook 2010* shows a 52-percent increase in CO₂ emissions from freight trucking transportation between 2010 and 2035.⁶ A 2001 report prepared for the CEC⁷ demonstrates that under the baseline 2020 growth scenario, CO₂ emissions from NAFTA trade would increase by up to four times over the 1999 levels in the five corridors that were studied.

Estimation of GHG and Air Quality Impacts

There are various approaches to developing GHG emissions inventories and estimates of pollutant emissions. The methodologies used for developing GHG emissions inventories are divided into three broad categories: top-down approaches, where data are aggregated and estimates are based on amount of fuel sold; bottom-up approaches that rely on end-use data and use activity data to estimate amount of fuel used for the studies activity; and hybrid approaches that are combination of top-down and bottom-up approaches. Because of the high accuracy of fuel data used for tax purposes, overall, top-down inventories tend to be more

⁴ EPA (2010). Inventory of US Greenhouse Gas Emissions and Sinks: 1990–2008. Washington, DC. <http://www.epa.gov/climatechange/emissions/usinventoryreport.html>.

⁵ US Bureau of Transportation Statistics
<http://www.bts.gov/publications/national_transportation_statistics/html/table_01_46b.html>.

⁶ US Energy Information Administration (2010). Table 67. Freight Transportation Energy Use http://www.eia.doe.gov/oiaf/aeo/supplement/suptab_67.xls. For calculations, see Appendix A. April.

⁷ ICF International (2001). North American Trade and Transportation Corridors: Environmental Impacts and Mitigation Strategies.

accurate but often lack some of the detail provided by bottom-up approaches, as they tend to be less sensitive to internal changes, which may limit analysis of mitigation measures.⁸ The accuracy of the top-down approach diminishes at more detailed levels of analysis (e.g., by sectors) because many assumptions must be made to break down the system-wide estimates.

Several analytical tools are currently available to analyze the GHG impacts of transportation activities and each possess different capabilities and require different levels of data inputs. The selection of an analytical tool for GHG analysis of transportation activities depends on two factors: transportation modes investigated in the analysis, and the required level of detail and data availability. According to ICF, the recommended approaches for each level of analysis are:

- national and state level: a top-down approach based on EPA's State Inventory Tool (SIT) and a bottom-up approach based on EPA's Motor Vehicle Emission Simulator (MOVES) model;
- regional or local level: a combination of top-down and bottom-up approaches combining MOVES model and SIT results; similar to New York's transportation GHG inventory; and
- project level: depending on the type of the project, it is recommended to use either available specific tools such as EPA's MOVES and COMMUTER models and the Federal Highway Administration's (FHWA) IDAS model or perform a spreadsheet analysis combining data and results.⁹

MOBILE6.2, an emission factor model for predicting emissions of hydrocarbons (HC), carbon monoxide (CO), NO_x, CO₂, and PM produced by cars, trucks, and motorcycles under various conditions, is EPA's current emissions estimation model for mobile sources. The emission rates are calculated based on fixed drive cycles that represent different traffic conditions on different road types. For each class of vehicles, emission rates from MOBILE6.2 are expressed in gram/mile for different average speeds. MOBILE6.2 emission rates for CO₂ and PM are not sensitive to speed.

EPA's newest emissions model, MOVES, is intended to replace MOBILE6.2. The new model estimates air pollution emissions from highway vehicles and non-road equipment, providing analysis at multiple scales for additional pollutants and pollutant sources than the previous models. The first official version, called MOVES2010, was released in December 2009. MOVES2010 includes only on-road vehicles. The non-road capabilities will be added to future versions. The underlying running emissions information in MOVES is in the form of second-by-second emission rates divided into 23 operating modes, representing ranges of a vehicle's instantaneous speed and vehicle-specific power (VSP). VSP is a proxy variable for engine load that is correlated with emissions. As implemented in MOVES, VSP represents the vehicle's power normalized by the mass of vehicle. One of the major improvements of MOVES over MOBILE6.2 is that CO₂, fuel consumption, and PM emissions are sensitive to speed and model year, whereas in MOBILE6.2 these rates were only a function of vehicle classification. More details on data needs of MOVES and MOBILE6.2 models are provided in Appendix A.

⁸ US EPA. Transcript: "Greenhouse Gases Inventory 101: Creating an Inventory"
http://www.epa.gov/climatechange/emissions/downloads/ts1_transcript.pdf.

⁹ ICF International (2006). Assessment of Greenhouse Gas Analysis Techniques for Transportation Projects.

The research team recommends a bottom-up approach utilizing segment and node-level freight-related transportation activity data. Major activity data needed for this approach include freight truck volume and, for freight rail, ton-miles carried on each section of the study corridor. Appropriate emission rates from standard models and procedures such as MOBILE6, MOVES, and EPA Locomotive Emissions Standards¹⁰ were used to calculate freight-related CO₂ emissions for each section on the case study corridor.

Congestion of Freight Corridors

When analyzing environmental and air quality issues related to freight corridors, the issue of delay and congestion is of great significance. Delays are generally defined in terms of the additional time spent in transportation over and above the expected “free-flow” or unconstrained travel times. Freight delays continue to create negative environmental effects, especially air quality, for the freight industry. Currently, freight transportation contributes approximately one-half of the NO_x emissions from mobile sources and 36 percent of PM₁₀ (particles less than or equal to 10 microns in diameter) emissions from mobile sources.¹¹

Causes of Delay and Congestion

There is a positive correlation between freight bottlenecks (where delay/congestion occurs) and freight demand; as the demand for freight increases, so do the number and length of bottlenecks. Truck bottlenecks are usually measured by the ratio of traffic volumes to actual physical highway capacity. Recurring bottlenecks are most common at freight hubs, locations of general traffic congestion, and delivery locations. Freight hubs are defined as ports, airports, and border crossings. These locations produce congestion during major delivery times. General congestion can also occur at intersections with poor signal timing, steep grades, or single-track portions of railroads. Freight delivery locations can cause congestion when there is limited space at the final destination or lack of unloading facilities. Non-recurring congestion, which often exceeds recurring congestion, occurs during unpredictable situations such as traffic crashes, at work zones, or during bad weather. No matter what the cause, freight congestion influences trip duration, the number of trips, and environmental impacts from traffic tie-ups.^{11, 12}

Impacts and Mitigation

Bottlenecks create an increasingly negative impact on freight. Dense, urban interstate corridors are the most affected by congestion; however, without infrastructure improvements, these effects will spread to stretches of intercity highways in urban and rural areas. A majority of the truck delays in the United States occur at the top 10 highway interchanges—with an average rate of 1.5 million annual truck hours at each interchange. Other bottlenecks only account for 250,000 annual hours of truck delay each.^{11, 12}

Rail congestion will also increase if capacity and system improvements are not put in place. The Association of American Railroads suggests that, by 2035, the length of congested locations will increase from 108 miles to 16,000 miles and, without improvements to the

¹⁰ EPA (1998). *Locomotive Emissions Standards, Regulatory Support Document*. <www.epa.gov/oms/regs/nonroad/locomotv/frm/locorsd.pdf>.

¹¹ Schmitt, R., E. Strocko, and J. Sedor. 2008. Freight Story 2008. FHWA-HOP-08-051. http://www.ops.fhwa.dot.gov/freight/freight_analysis/freight_story/index.htm.

¹² Cambridge Systematics Inc. (2005). *An Initial Assessment of Freight Bottlenecks on Highways*. Prepared for Federal Highway Administration Office of Transportation Policy Studies. <http://www.fhwa.dot.gov/policy/otps/bottlenecks/index.htm>.

system, the 6,413 miles currently affected by service and incident disruptions will increase to over 12,000.¹¹

It is expected that reducing freight delays at the most congested international border crossings will significantly reduce emissions.^{11, 13, 14} Origin–destination surveys and border delay surveys are key inputs to air quality analysis of freight movement and should become regular features of data collection. In addition to monitoring environmental concerns, this would assist our ability to monitor border congestion.¹³

The US Department of Transportation suggests several improvements to freight operations and methods to address environmental concerns. It recommends improving the freight system by making changes in the management and operations of existing facilities, maintaining and preserving existing infrastructure, and exploring opportunities for privatization. Some environmental improvements it proposes include pursuing pollution reduction technologies, investments to mitigate environmental transportation impacts, energy conservation strategies, and alternative fuels in freight operations.^{12, 15}

These improvements to mitigate delays and congestion for freight are feasible with coordination between the FHWA and the states, metropolitan planning organizations, counties, and the freight industry to advance network bottleneck data collection and analysis.¹² Freight railroads have already begun to address system improvements and capital expenditures by investing (in 2006) \$8.5 billion on renewal of existing roadway, structures, equipment, and on additional traffic expansion.¹⁶

Performance Measurement and Freight Data

Transportation Performance Measures

Performance measurement originated in the private sector as a management tool to evaluate progress toward goals using measurable results or targets. Performance measures translate data and statistics into concise information that can be readily understood by stakeholders including engineers, administrators, politicians, and the general public. Performance measures can be used across all aspects of an organization to track system performance, evaluate alternatives for project selection, and use for internal and external communication. A comprehensive performance measure would provide information on the condition, trends over time, and the share attributed to the different agencies and/or actors.¹⁷ The terms “performance indicator” and “performance measure” both refer to variables that facilitate this progress.

For a transportation system, performance measurement provides the capability to understand how the system is currently performing and how it could perform in the future as

¹³ ICF Consulting (2001). North American Trade and Transportation Corridors: Environmental Impacts and Mitigation Strategies. Prepared for North American Commission for Environmental Cooperation.

¹⁴ Border Congestion Study: Study Findings and Methodology, Prepared for Western Governors' Association, Prepared by Parsons Transportation Group and Suma Sinergia, S.A. de C.V., June 9, 2000.

¹⁵ US Department of Transportation, Freight Transportation, www.freight.dot.gov/freight_framework.

¹⁶ US DOT, Federal Highway Administration. Freight Management and Operations. http://ops.fhwa.dot.gov/freight/freight_analysis/freight_story/congestion.htm.

¹⁷ Zietsman, J. and L.R. Rilett (2002). *Sustainable Transportation: Conceptualization and Performance Measures*, SWUTC/02/167403-1, Texas Transportation Institute, The Texas A&M University System, College Station, Texas.

the result of factors that could include anticipated population growth, today's investment strategies, land-use patterns, and economic conditions. A successful performance measurement system used by an organization must be established with a focus on its products, mission, or goals. The usual hierarchy in transportation planning and engineering involves goals, described by objectives that are clearly defined, and finally quantified with performance measures.¹⁸ This approach ensures that the changes in the value of a performance measure are adequately representing progress toward the completion of an objective.

Performance Measures for Freight

According to FHWA¹⁹ "freight-specific performance measures help to identify needed transportation improvements and monitor their effectiveness. They also serve as indicators of economic health and traffic congestion." With ever-increasing global shipping of commercial and industrial goods, the flow of freight is more and more dependent on infrastructures of varying quality and sophistication as well as on the operational and logistical characteristics of the transportation systems. The stakeholders need performance measures to determine if these transportation systems are capable of moving freight effectively, safely, and in an environmentally conscious manner.

Currently, the majority of freight performance measures used or proposed by transportation agencies cover the efficiency and safety aspects of freight movements, but no freight transportation emission measurements are used or proposed.

Data Sources and Availability

Data are the "raw materials" for establishing a performance measure. Data availability is a key component of a performance measurement system and obtaining the data required for a performance measurement system can be costly and difficult. Data availability must be examined for each potential performance measure as one of the main selection criteria. Another aspect of data availability is whether data are collectable even if they are available. Addressing the data requirement aspect of performance measurement includes answering to the following questions:

- Are data available in currently available databases?
- If data are available, are they easy to collect, or is obtaining them difficult?
- Are there new ways to develop or collect the data?
- What is the cost of collecting the appropriate data?

Freight data are available from many public and private sources. They vary by collection method, timeframe, format, and quality. Data held by private companies may be very useful; however, they are usually very expensive to obtain or are kept commercially confidential. US Inland Trade Monitor (USITM) and Transearch by Global Insight²⁰ are examples of privately held data that are costly to obtain.

¹⁸ R. Harrison et al. (2006). *Developing Freight Highway Corridor Performance Measure Strategies in Texas*, CTR Technical Report, FHWA/TX-07/0-5410-1, Austin, Texas.

¹⁹ FHWA, Freight Performance Measurement, http://ops.fhwa.dot.gov/freight/freight_analysis/perform_meas.htm.

²⁰ Global Insight, North American Commerce & Transport Data <http://www.globalinsight.com/ProductsServices/ProductDetail1024.htm>.

The North American Transborder Freight Database is the major publicly available information source for trade flow data in North America.²¹ It contains freight flow data by commodity type and by mode of transportation (rail, truck, pipeline, air, vessel, and other) for US trade flow to/from Canada and Mexico since the signing of the North American Free Trade Agreement (NAFTA). The database provides freight movement based on either commodity type or geographical details. The database includes data from 1994 to the current year and is used for trade corridor studies, transportation infrastructure planning, marketing and logistics plans, and other purposes.

The information from the North American Transborder Freight Database is aggregated data, providing information on a state-to-state or state-to-province level. Although this level of aggregation might be appropriate for application in large-scale planning and corridor studies, it poses a challenge for more detailed analyses, such as detailed air quality analysis.

In North America, the only publicly available information that provides geographically disaggregated freight flow information is the Federal Highway Administration (FHWA) Freight Analysis Framework (FAF). The FAF is a commodity Origin-Destination (O-D) database and analytical framework that provides estimates of tonnage and values of goods shipped according to origin, destination, commodity, and mode.²² Mexico and Canada have been developing similar tools but the information is not available to the public.

Air Quality Mitigation Measures

The focus of this research is on analyzing the air quality impacts of freight movement on transportation corridors, in order to develop or recommend mitigation strategies. There are many different pollutant reduction strategies for the freight sector. **Table 1** summarizes a variety of options and strategies found in the literature.

Fuel-saving strategies directly translate into reductions of GHG gases and other air pollutants. Vehicle and rail modifications that reduce the amount of energy used per ton-mile can often pay for themselves in time with fuel savings. A 10 percent improvement in fuel economy can be gained by reducing aerodynamic drag by 20 percent.²³ EPA's SmartWay Transport program estimates that low rolling resistance tires can result in fuel savings of three percent, or more. Aerodynamic devices such as trailer gap reducers and trailer fairings and skirts can individually reduce fuel usage by one to seven percent, or more.²⁴

Similarly, idle reduction technologies can also reduce emissions while paying for themselves through fuel savings. US regulations mandate that truck drivers rest 10 hours for every 14 hours of driving. During these rest periods it is common for truck drivers to idle their engines to create a comfortable cab environment and generate electricity to power various devices. In the United States, extended idling is estimated to waste an average of 13 million gallons of fuel daily.²⁵ Bunker heaters and auxiliary power units (APUs) provide comfortable cab

²¹ North American Transborder Freight Database, see <http://www.bts.gov/programs/international/transborder/>

²² US Federal Highway Administration (2009). Freight Analysis Framework (FAF). Office of Freight Management and Operations. Washington, DC. http://ops.fhwa.dot.gov/freight/freight_analysis/faf/

²³ Blank, S. (2009). *Greening Trade Corridors*, New York, March.

²⁴ US EPA. SmartWay Transport Partnership Verified Technologies, <http://www.epa.gov/smartway/transport/what-smartway/verified-technologies.htm>, accessed May 2009.

²⁵ Stodolsky, F., L. Gains, and A. Vyas (2000). Analysis of Technology Options to Reduce the Fuel Consumption of Idling Trucks. Center for Transportation Research, Argonne National Library for the US Department of Energy, June.

environments while allowing drivers to shut down engines. Truck stop electrification centers and electrified parking spaces allow truckers to connect their vehicles to amenities in exchange for a small fee. In the rail sector, the use of idle controls has been shown to reduce switcher idling by 80 percent and pay for themselves in two and one-half years, or less.²⁶

Table 1. Emissions Reduction Strategies for Trucking and Rail

Strategy	Truck Examples	Rail Examples
Vehicle and rail modifications for efficient movement	<ul style="list-style-type: none"> • Auto-tire inflation systems • Low-rolling and single-wide tires • Aerodynamic improvements • Low-viscosity lubricants • Lighter tractors and trailers 	<ul style="list-style-type: none"> • Track lubricants • Low-friction bearings • Lightweight cars
Idle reduction technologies	<ul style="list-style-type: none"> • Bunk heaters • Auxiliary power units • Automatic shutdown/start-up systems • Electrified truck stops • Idle reduction policies 	<ul style="list-style-type: none"> • Auxiliary power units • Automatic shutdown and start-up systems
Retrofit and replacement strategies	<ul style="list-style-type: none"> • Diesel oxidation catalysts • Diesel particulate filters • Selective catalytic reduction systems • Engine upgrades and replacements • Used truck replacement with newer or hybrid vehicles 	<ul style="list-style-type: none"> • Locomotive replacement with newer cleaner units • Hybrid rail yard switchers
Fuel strategies	<ul style="list-style-type: none"> • Biodiesel • Compressed natural gas (in limited applications) 	<ul style="list-style-type: none"> • Ultra-low sulfur diesel • Electrification • Biodiesel • Compressed natural gas
Activity reduction	<ul style="list-style-type: none"> • Double- or triple-stacked trailers • Improved trucking logistics to maximize loads, reduce empty backhaul miles • Mode shifting to rail 	<ul style="list-style-type: none"> • Longer trains • Double stacked trains
System operation	<ul style="list-style-type: none"> • Congestion mitigation measures and avoiding congested roadways • Route optimization • Driver education for eco-driving and speed reduction • Driver fuel efficiency incentive programs 	<ul style="list-style-type: none"> • Rail congestion mitigation measures

Typically, newer vehicles and engines are significantly cleaner than their older counterparts due to increasingly stringent emissions standards. Therefore, the retirement of older engines and replacement with newer models can significantly reduce emissions. Retrofit and after-market technologies are available as a cheaper alternative to vehicle or engine replacements.

²⁶ US EPA (2004). Case Study: Chicago Locomotive Idle Reduction Project. Report 420-R-04-003, March.

Diesel particulate filters can reduce emissions of particulate matter by 90 percent or more and come standard on post-2007 model year trucks. Diesel oxidation catalysts replace traditional mufflers and can reduce PM emissions by more than 25 percent and often reduce HC emissions by 50 percent.²⁷ Selective catalytic reduction (SCR) systems can reduce NO_x by an estimated 65 percent, while significantly slashing HC and CO emissions.²⁸ Tighter NO_x emissions standards for 2010 model year vehicles are expected to reduce emissions by 90 percent, a significant portion of which can be attributed to SCR systems.

Alternative fuels, such as biodiesel, propane, and natural gas, can reduce GHGs by replacing high-carbon diesel with cleaner fuels. Moderate levels of biodiesel (such as B20) can be readily used in engines without major modifications or special conditions for use. Natural gas, hydrogen, and other “boutique” fuels require their own infrastructure, often have storage and handling issues, and require a dedicated engine. Alternative fuels will vary in their emission-reduction effectiveness, depending on their source (such as feedstock), production, and refining processes. They can also have unexpected impacts on the environment compared to traditional fuels. For example, biodiesel production can result in land use changes that have the effect of converting natural landscapes that sequester carbon into a carbon-emitting source. However, biofuels created from waste or biomass residues can significantly reduce greenhouse gases.

Activity-reduction strategies cut emissions by reducing the need for transport. These can include giving priority to the use of local goods, employing smaller packaging that stacks more efficiently, and/or reducing the number of trips needed by transporting more cargo per trip. Good transportation logistics can reduce the number of trips by eliminating empty backhauls or combining different loads going to the same area to avoid underutilized trucks. Shifting cargo from trucks to rail can also reduce emissions significantly, since rail uses 90 percent less energy than trucking.²⁹

Finally, operational strategies to reduce trip inefficiencies can also reduce fuel and emissions. Eco-driving techniques that include progressive shifting, speed moderation, and the avoidance of rapid accelerations and unnecessary stops can result in truck fuel economy gains of five percent or more.³⁰ The Intelligent Transportation System (ITS) can reduce emissions and fuel use by preventing delays at border crossings and checkpoints and enabling firms to monitor and track driving performance.

CASE STUDY: MEXICO CITY TO MONTREAL CORRIDOR

The selection of the transportation corridor that would serve as the object of the present study was the result of a number of factors, including the availability of existing research and data for estimating the emissions of GHGs and other pollutants caused by freight movement on it. There are a number of important transportation corridors and gateways in North

²⁷ US EPA. “Diesel Retrofit Technology Verification Program: Verified Technologies,” <http://www.epa.gov/otaq/retrofit/verif-list.htm>, accessed May 2009.

²⁸ US EPA. *Emerging Technology List*, <http://www.epa.gov/otaq/diesel/prgemerglist.htm>, accessed May 2009.

²⁹ Davis, J., C. Facanha, and J. Aamidor (2007). *Greenhouse Gas Emissions from US Freight Sources: Using Activity Data to Interpret Trends and Reduce Uncertainty*. 2008 Transportation Research Record, November 15.

³⁰ US EPA. SmartWay Transport Partnership, *Drivers Training*, <http://www.epa.gov/smartway/transport/documents/tech/driverstraining.pdf>, accessed May 2009.

America. For the purposes of the present study, we are defining "trade and transportation corridors" to mean the designated principal trading "routes" between Mexico, Canada and the United States: in other words, the major North-South transportation routes (either highway or rail) supporting freight movements between the three countries. Gateways refer to East-West transportation routes such as those identified in Canada's designated "Gateways" programs and policies.³¹

For the purpose of the present study, Interstate 35, already an established and important avenue for freight transportation between Mexico and the southern and central United States, was chosen as the principal southern arm of the model corridor in the US, linked in Mexico to Federal Highway 85 through Monterrey to Mexico City. To the north, the corridor departs from I-35 at Dallas and follows I-30 and then I-40 through Little Rock (AR) and Memphis (TN) to Nashville, where it veers northward again on I-65 to Louisville (KY). Skirting northeastward along the edge of Kentucky-Indiana line on I-71, the corridor turns northward on I-75 just below Cincinnati (OH) and continues on up to Detroit (MI). Crossing into Canada at the Detroit-Windsor (ON) Crossing, it follows the TransCanada Highway (401 in Ontario, 40 in Quebec) to Montreal, Quebec, thus including parts of the Ontario-Quebec Continental Gateway (**Figure 1**). We have selected a rail corridor that parallels as nearly as possible the highway corridor and then, for the purposes of developing the methodology for the study, estimated the rail freight tonnage from the Federal Highway Administration Freight Analysis Framework. This highway corridor and the paralleling rail facilities represent a very important transportation lane for the movement of freight in North America. **Table 2** provides information of distances in each country by mode and the total corridor length.

Since there are no official North American corridors, the route we have selected as a model corridor nonetheless enables us to examine, based on freight flow information, the impact of freight movements by truck and rail in North America. The data and methodology used in this study can be applied to other corridors and/or gateways to improve the efficiency of freight movement and hopefully lessen the impact of freight transportation in them.

Table 2. Study Corridor Distance by Country and Mode

Mode	Canada	United States	Mexico	Total
Truck	531 mi (850 km)	1,624 mi (2598 km)	693 mi (1108 km)	2,847 mi (4555 km)
Rail	575 mi (920 km)	1,903 mi (3045 km)	717 mi (1147 km)	3,194 mi (5110 km)

Study Approach and Data Sources

The air quality impact analysis utilized existing data sources on truck and rail movement along the Mexico City to Montreal Corridor, as well as border crossing information. The data were assembled from different sources along the corridor. The major data source for truck and rail freight movement used in this effort was the FHWA's Freight Analysis Framework (FAF and FAF²). In Canada, the information that was used for the estimation came from Transport Canada truck flows and from the Canadian National Railway Company. In Mexico, information included truck flow data from the *Secretaría de Comunicaciones y Transportes* (SCT) and the *Instituto Mexicano de Transporte* (IMT). Other data sources were the Bureau of Transportation Statistics (BTS), National Transportation Atlas Database (NTAD), North American Transborder Freight Data (NATFD), and other rail and freight databases.

³¹ Canada's Gateways: <http://www.canadagateways.gc.ca/index2.html>.



Figure 1. Mexico City to Montreal Highway and Railway Corridor

Two years were selected for analysis: 2010 was selected as the base case and the year 2035 was selected for the future case, based largely on data availability. For the base year, 2010

was preferred rather than current data (2008/2009) because of the ongoing economic downturn and recession, which may have an effect on freight activity.

To begin, the key characteristics of truck and rail emissions estimation methodologies were identified. In general, quantifying the air quality impacts of freight activities requires information on freight movements and emission rates per unit of activity; however, the estimation methods for each mode demand different data. Most significantly, the available data on truck freight movement and emission rates are significantly more detailed and accurate. **Table 3** shows the major data required for corridor-level air quality analysis of freight movement by truck and rail.

Table 3. Data Required for Corridor Level Air Quality Analysis of Freight Movement

Truck	Rail
Freight Activity <ul style="list-style-type: none"> - Annual truck vehicle-miles traveled for each link (VMT), estimated from annual volume - Annual truck numbers and volumes at ports of entry - Fleet characteristics, including trucks' age distribution and share of VMT - Speed profile for trucks passing through ports of entry into the United States 	Freight Activity <ul style="list-style-type: none"> - Annual commodity flow between each major origin-destination pair, in ton-miles
Emission Rates <ul style="list-style-type: none"> - Aggregated exhaust emission rates, based on vehicle registration data and MOBILE6.2 model - PEMS measurements 	Emission Rates <ul style="list-style-type: none"> - Exhaust emission rates based on national average rates

The data were aggregated to document freight flows along the corridor from Mexico City, Mexico to Montreal, Canada. FHWA's FAF data was used for the US portion of the corridor for truck and rail freight flows. The highway and railway network information in FAF are available in the form of Geographical Information System (GIS) datasets. FAF contains the two following major datasets:³²

- Highway Link and Truck Data, and
- Commodity Origin-Destination Data.

The current version of FAF Highway Link and Truck Data is known as FAF² Highway Link and Truck Data and contains commodity flow estimates for 2002, 2007, and for 2010 to 2035 in five-year increments; however, it only has highway link truck flow estimates for 2002 and 2035. The research team obtained these data for the 2010 base year from the previous versions of the FAF database. The Highway Link and Truck database contains length and freight volume and non-freight truck volumes for each specific highway link, as well as such additional information as section capacity, congestion speed, and estimated delays for each

³² FHWA, FAF². Highway Link and Truck Data and Documentation: 2002 and 2035, Freight Analysis Framework, <http://www.ops.fhwa.dot.gov/freight/freight_analysis/faf/faf2_high.htm>.

link of a highway. The truck volumes and length were used to estimate the total truck-related VMT for about 1,200 links of the study corridor in the United States.

Rail freight movement data among major cities in the United States were obtained from FAF and FAF² Commodity Origin-Destination Data. This database incorporates estimated weight and value of goods shipped by commodity type and transportation modes among and within 114 urban areas in the United States. It also contains commodity flow to and from the 114 areas and 17 international gateways from 7 international trading regions.³³ The rail tonnage and length were used to compute total tonnage per unit distance for each section of the rail corridor in the United States.³⁴

The Texas Transportation Institute (TTI) routinely obtains vehicle registration data for Texas. These data are used to develop regional emission inventories. In addition to number of registered vehicles by class of vehicle, these data also include the estimated average mileage driven by each model year and class of vehicles. Because the majority of non-freight volumes in the FAF are associated with regional and local services, it is assumed that they are all Class 6 heavy-duty diesel trucks (defined as those with a gross vehicle weight rating [GVWR] between 19,501 and 26,000 lb). All of the freight truck volumes are considered as Class 8b heavy-duty diesel trucks (GVWR of 33,000 lb and heavier). It is further assumed that all the trucks on the study corridor share the characteristics of Texas trucks in terms of the vehicle fleet mix. In addition, annual freight movement growth rates between 2002 and 2010 and projections for 2002 to 2035 were calculated for truck and rail freight activity using FAF database. They were then applied to estimate future long-haul truck volume and rail freight tonnage for both Canadian and Mexican corridors, while assuming that freight movements by truck and rail modes grow in the same degree along the study corridor throughout Canada, the United States, and Mexico.

Emissions Estimation Methodology

Estimation of Truck Freight Emissions

Figure 2 provides a flowchart describing the process of estimating truck emissions along the study corridor. EPA's MOBILE6.2 model was utilized to obtain emissions factors for the freight and non-freight truck categories. NO_x, Total HC (total hydrocarbons), CO, PM₁₀, and CO₂ emissions are included in this analysis. Since the corridor crosses urban areas, two operating speeds were assumed for the analysis: 55 mph for urban areas and 65 mph for rural areas, and the emission rates were considered to vary accordingly. While these assumptions fail to explicitly include the impact of extended idling and local congestion, they produce results at the required resolution for a corridor study. The classification of the areas as urban and rural was determined from FAF's Geographical Information System dataset. Detailed emission rates in grams per mile (g/mi) for these two speeds were obtained for all model years using the following assumptions:

- analysis years: 2010 and 2035;
- default ambient conditions; and

³³ FHWA, FAF² Commodity Origin-Destination Data and Documentation: 2002–2035, Freight Analysis Framework, <http://www.ops.fhwa.dot.gov/freight/freight_analysis/faf/faf2_com.htm>.

³⁴ In the original version of this report, TTI used metric tonnage per mile for these emission maps. However, because of the trilingual audience for this release of the report, CEC has converted the data to metric tons per kilometer.

- all trucks in this analysis are powered by ultra-low sulfur diesel fuel with maximum 15 parts per million (ppm) sulfur content.

The detailed emission rates from the MOBILE6.2 model were aggregated to obtain a set of average fleet emission rates for the truck fleet operating on the Mexico City to Montreal corridor. The emission rates were weighted based on the age distribution and corresponding estimated annual driven miles to obtain aggregate emission rates. These aggregate rates were applied to the freight VMT values to obtain total emissions per mile for each section of the corridor. The results were then transformed into GIS map formats for presentation.

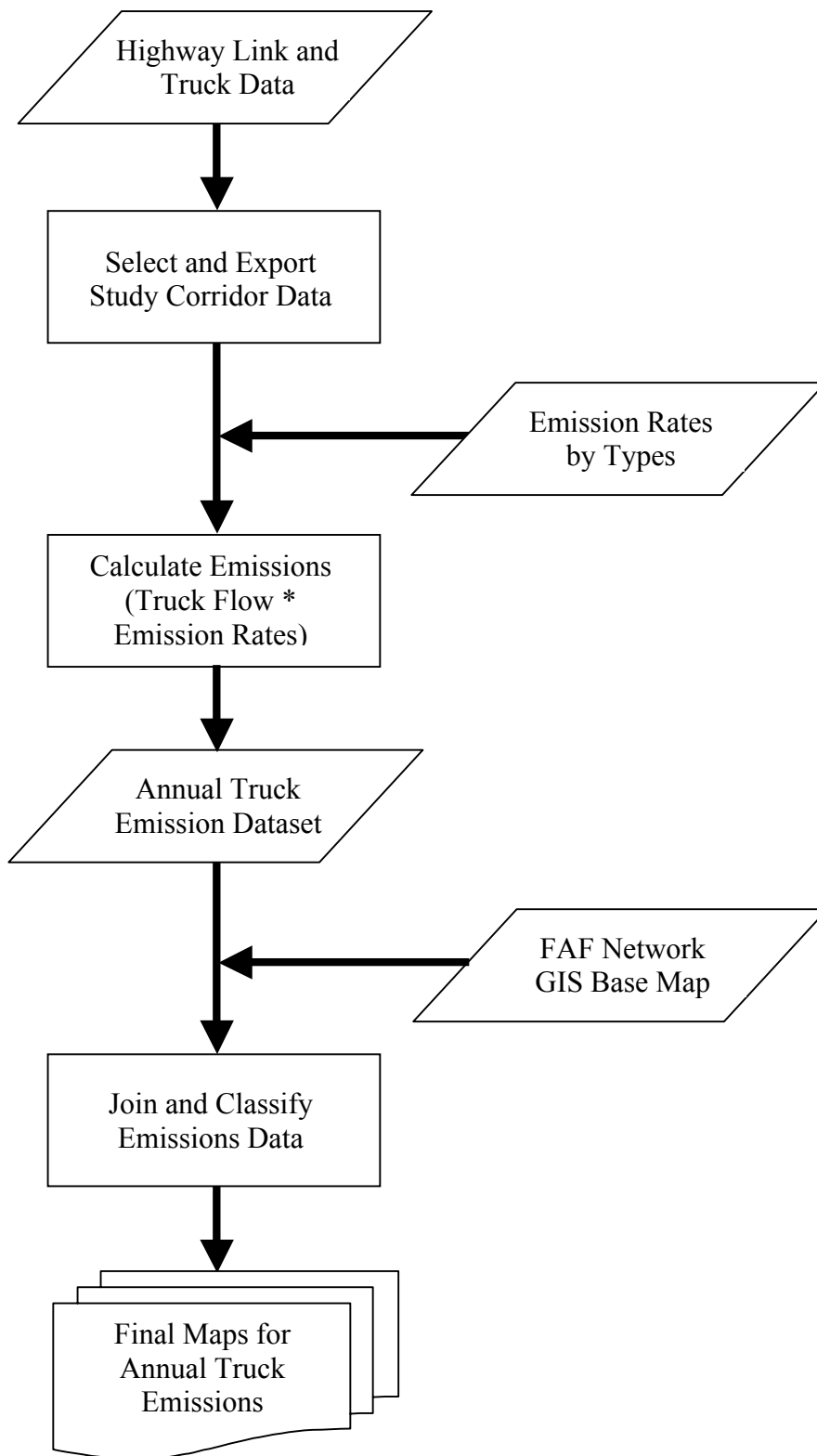


Figure 2. Analysis Process for Annual Truck Emissions along Mexico City to Montreal Corridor

Estimation of Rail Freight Emissions

Figure 3 provides a flowchart describing the process of estimating rail emissions along the study corridor. The activity data for rail freight movement was obtained from the FAF² Commodity Origin-Destination Data for the United States. Rail volumes for the Mexican and Canadian sections of the corridor were estimated based on the available information and calibrated with border crossing total figures. Canadian National Railway Company³⁵ and the SCT and IMT estimates for Mexico were used as the base data.

For the US section, only class I railroads are included in the analysis as they carry more than 90 percent of US railroad ton-miles and consume almost 95 percent of all railroad fuel combusted.³⁶ This database provides estimated tonnage and value of goods shipped by type of commodity and mode of transportation among and within 114 areas, as well as to-and-from seven international trading regions. These data were extracted for the base year (2010) and the future case year (2035) for all origin-destination pairs along the study corridor.

The standard method for estimating the emissions of rail locomotives is based on fuel consumption. The emission rates are expressed in grams of pollutants per gallon of fuel burned in the engine. The EPA standards for rail locomotives require a 59-percent reduction in NO_x for engines built in 2005 and later, compared to pre-2002 levels. The standards also require 40 percent lower HC and PM emissions for locomotives than their pre-2002 level. Current EPA standards do not include provisions for future CO and CO₂ emissions as reflected in their corresponding future rates as listed in **Table 4**. As with the truck emissions calculations, the results were calculated for sections on the corridor and then transformed into GIS map formats for presentation.

Table 4. Fleet Average Locomotive Emission Factors

Emission Factors (grams/gallon) [grams/liter]					
Year	HC	CO	NO _x	PM	CO ₂
2010	9.2 [2.43]	27.4 [7.238]	163.7 [43.245]	5.7 [1.51]	10,084 [2,663.91]
2035	6.42 [1.696]	27.4 [7.238]	102.254 [27.013]	4.08 [1.078]	10,084 [2,663.91]

Note: The base year emission rates were obtained from FHWA National Freight Transportation Trends and Emissions <http://www.fhwa.dot.gov/environment/freightaq/chapter2.htm#s2_3>. For the future year case (2035), it is assumed that all the in-service locomotive engines will be in compliant with the previously discussed standards.

³⁵ Canadian National, 2009 Investor Fact Book, <http://www.cn.ca/documents/Investor-Factbook-current/DensityMap.pdf>.

³⁶ North American Transborder Freight Database, www.bts.gov, accessed on August 5, 2007.

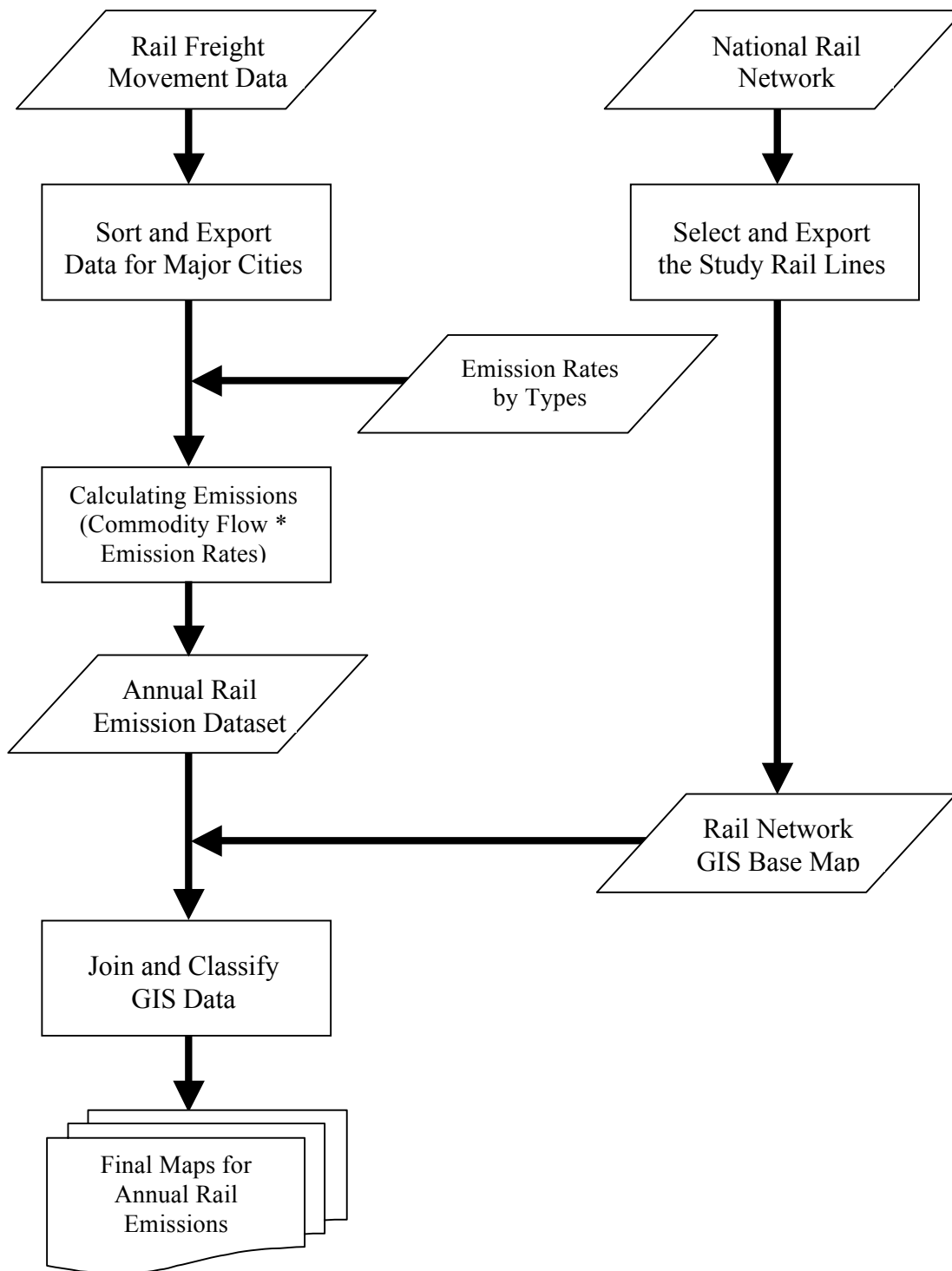


Figure 3. Analysis Process for Annual Rail Emissions along Mexico City to Montreal Corridor

Analysis Results

Figures 4 through 13 show the results of CO₂, CO, NO_x, Total HC, and PM emissions analyses in GIS map format for both the base year, 2010, and for 2035. The maps show salient features of the corridor, including urban areas. The levels of emissions are indicated through color-coding, with darker shades representing sections with higher levels of emissions. The CO₂ emissions values are two to three orders of magnitude higher than those of the other pollutants; therefore, a 'kilotonne per kilometer unit is adopted for CO₂ rather than 'metric ton per kilometer which is used for the CO, NO_x, Total HC, and PM.

Table 5 summarizes the total annual amount of pollutants for the base and future cases for truck and rail freight along the corridor. These results do not include Laredo trans-border short-haul (drayage) freight activity. Short-haul freight is addressed explicitly in the next section. The base case results indicate that trucks emit higher amounts of all pollutants. However, the share of some pollutant emissions (i.e., NO_x and PM) contributed by rail locomotives will increase in the future case. CO₂, though, should be an exception. Trucks emit more than 75 times as much CO₂ as freight locomotives in 2010 (the base case). While in 2035 the total CO₂ contribution of both modes will be higher than in the base year, the increase in the portion from trucks will be at a greater rate: it is expected that in 2035 trucks will emit more than 110 times the total CO₂ from freight locomotives. As CO₂ is the direct result of fuel combustion, fuel consumption would therefore follow the same trend. Due to limitations in the setup of available data, it is unclear what proportion of the relative increase in truck emissions and the reduction in rail emissions will be attributable to modal shifts, to technological improvements, and to an overall increase in freight, respectively. Detailed future research will doubtless provide more insight into these issues.

Overall, the results indicate that emissions reduction strategies used on trucks will result in considerable reduction of criteria pollutants (CO, NO_x, and PM). The rail emissions, however, generally increase for the future case. This is because of looser emissions standards expected for locomotives when compared to trucks and the long compliance/implementation periods for those standards.

**Table 5. Total Annual Amount of Emissions Due to Freight Movement
on the Mexico City to Montreal Corridor**

	Year	Annual Emissions				
		CO ₂ (kilotonnes, kt)	CO (metric tons)	NO _x (metric tons)	Total HC ³⁷ (metric tons)	PM (metric tons)
Truck	2010	13,508	10,746	76,733	2,231	713
	2035	32,218	4,209	17,015	3,730	217
Rail	2010	177	480	2,866	161	100
	2035	278	756	2,821	177	113

Note: The base year emission rates were obtained from FHWA National Freight Transportation Trends and Emissions <http://www.fhwa.dot.gov/environment/freightag/chapter2.htm#s2_3>. For the future year case (2035), it is assumed that all the in-service locomotive engines will be in compliant with the previously discussed standards.

Note that future emissions estimates for the criteria pollutants depend heavily on future engine standards, emissions reduction technologies, and their market penetration. It is expected that diesel will still be the main energy source for truck and rail freight activities and the advance in technology will marginally improve the fuel efficiency as it is modeled in MOBILE 6; therefore, future estimates for CO₂ emissions are considered fairly reliable and accurate.

³⁷ To be consistent with border crossing analysis, total hydrocarbon (Total HC) results are reported instead of volatile organic compounds (VOC) emissions. According to EPA, 95% of total VOCs for diesel engines are Total HC emissions (<http://www.epa.gov/OMS/models/nonrdmdl/nonrdmdl2005/420r05015.pdf>).

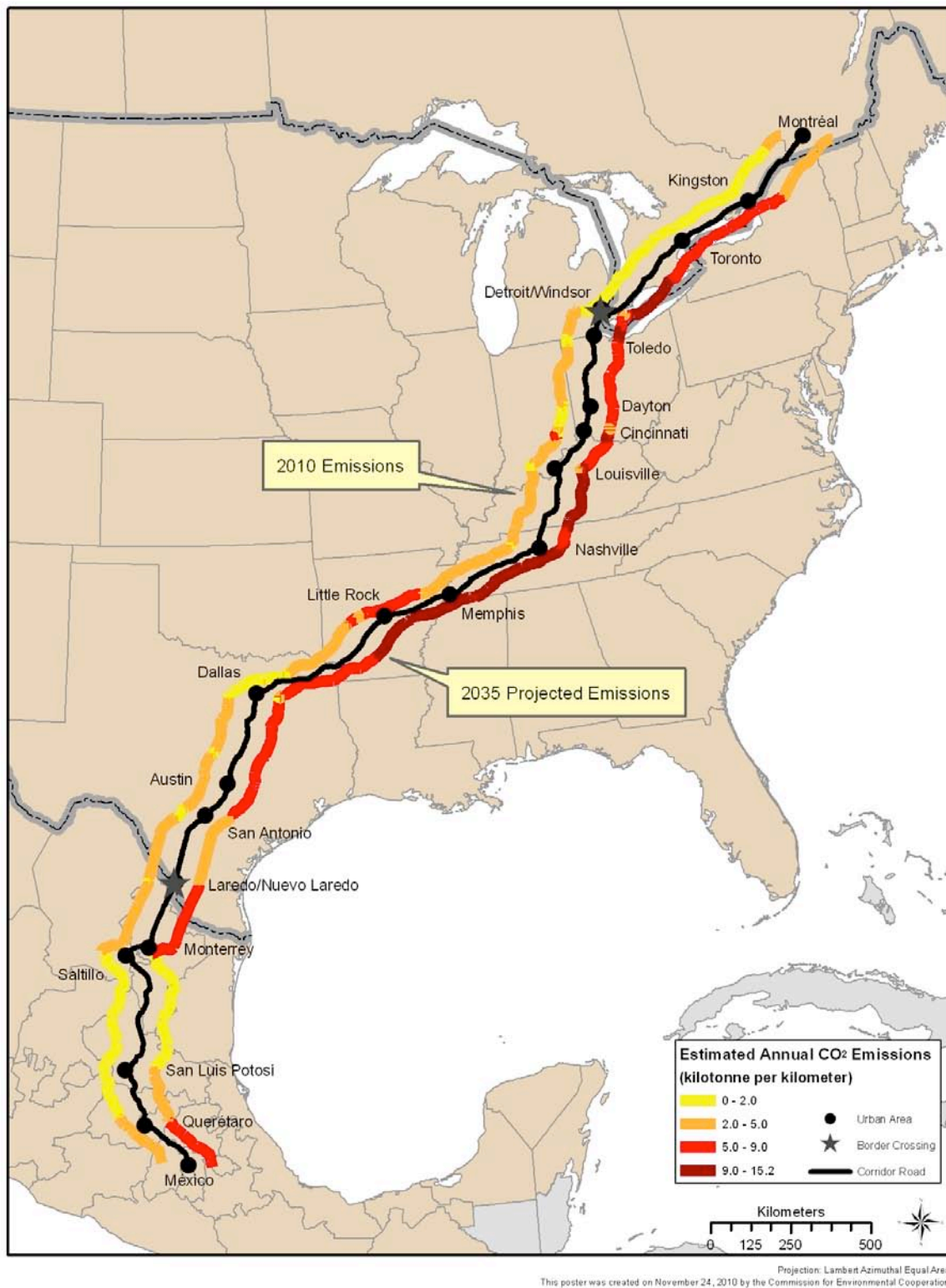


Figure 4. Estimated CO₂ Emissions from Trucks along the Corridor in 2010 versus 2035

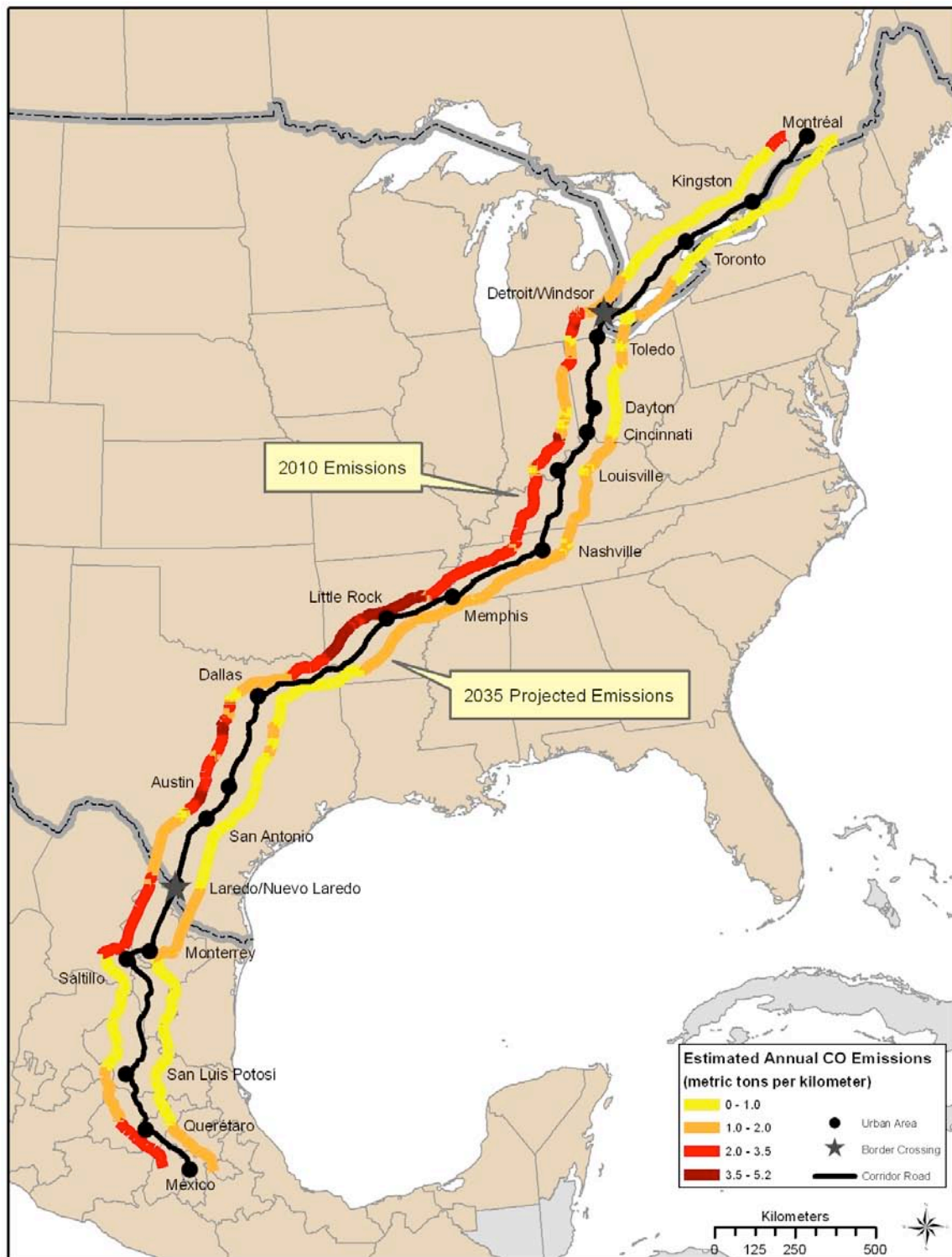


Figure 5. Estimated CO Emissions from Trucks along the Corridor in 2010 versus 2035

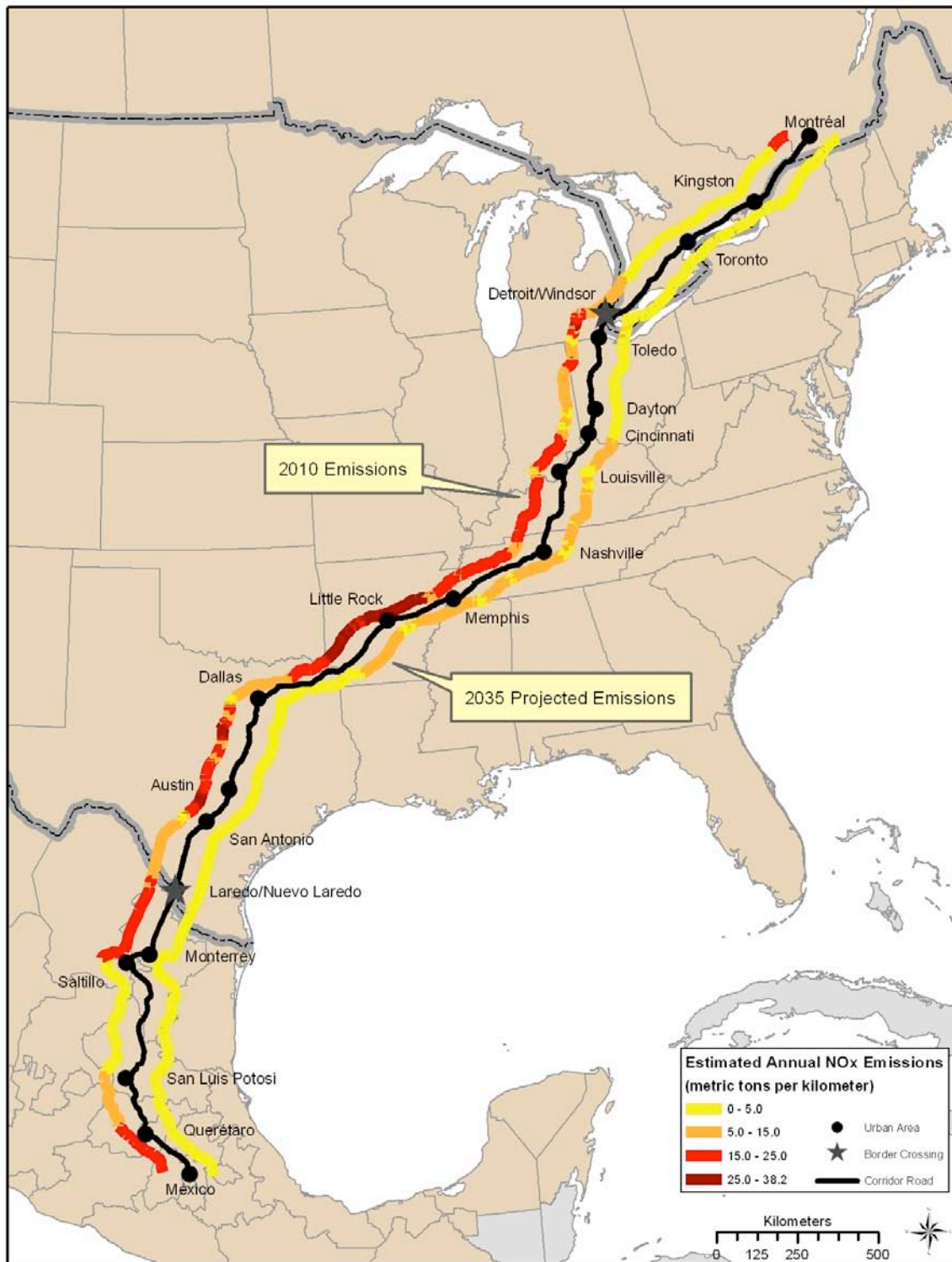


Figure 6. Estimated NO_x Emissions from Trucks along the Corridor in 2010 versus 2035

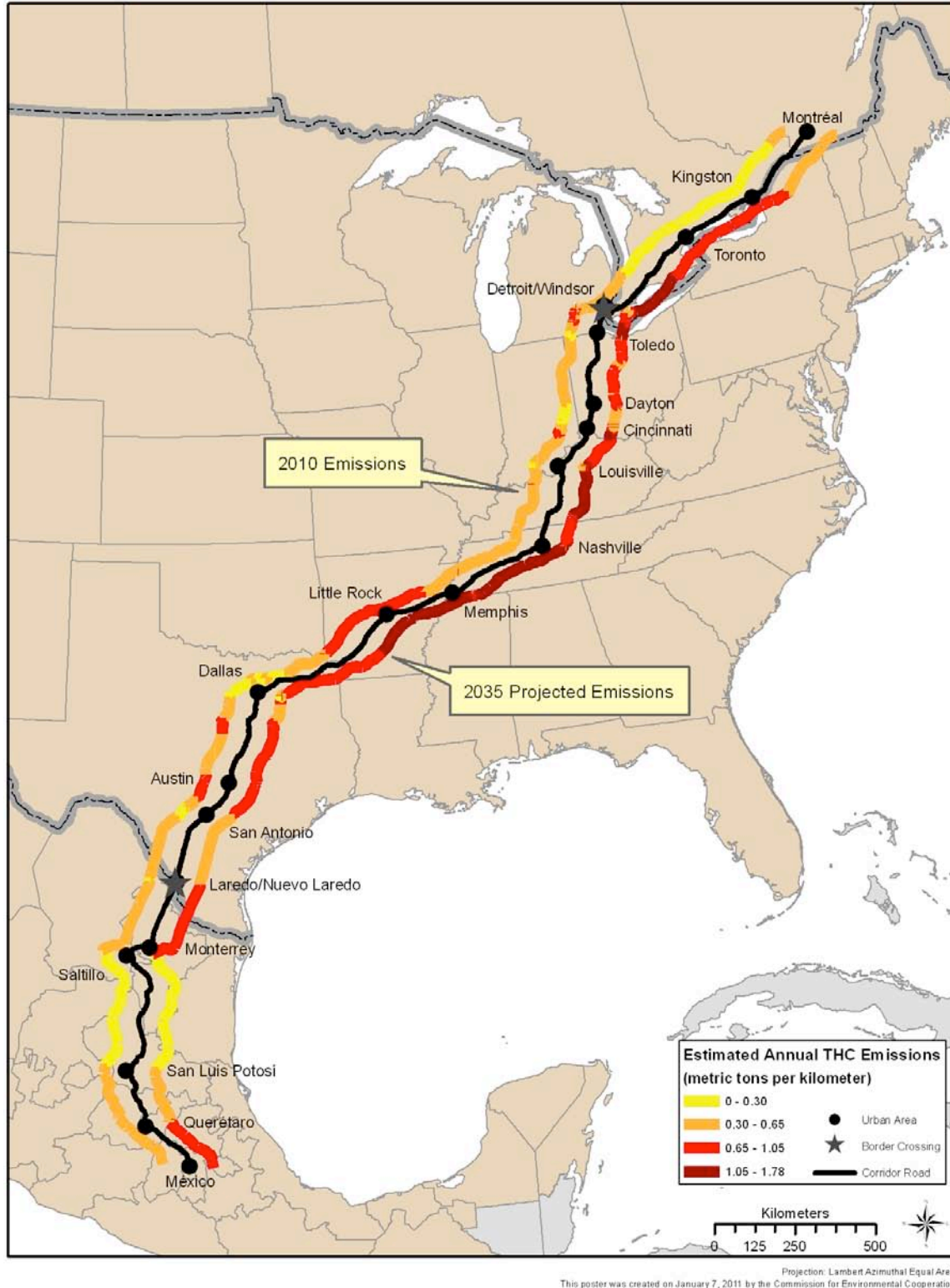


Figure 7. Estimated Total HC (Total Hydrocarbon) Emissions from Trucks along the Corridor in 2010 versus 2035

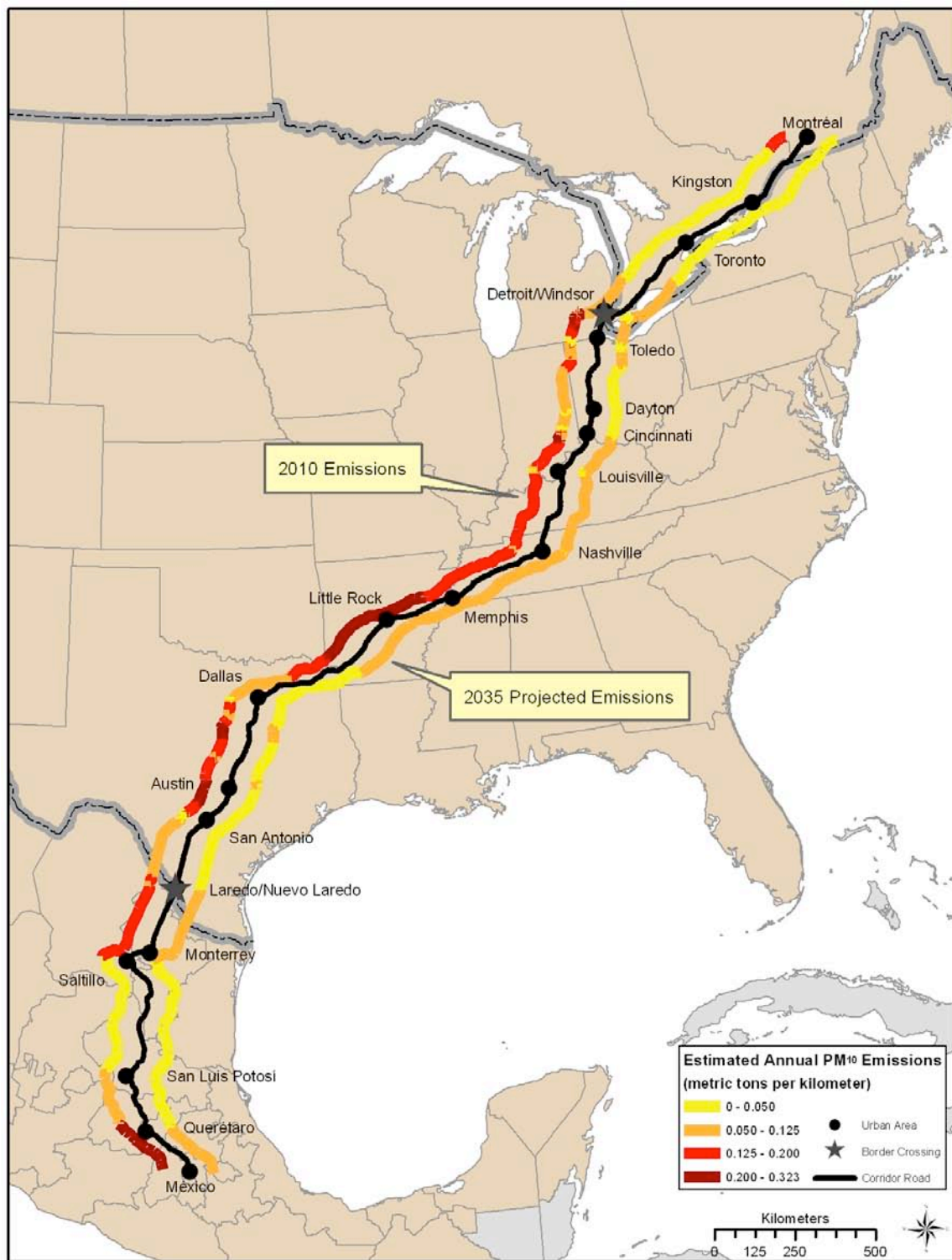


Figure 8. Estimated PM₁₀ Emissions from Trucks along the Corridor in 2010 versus 2035

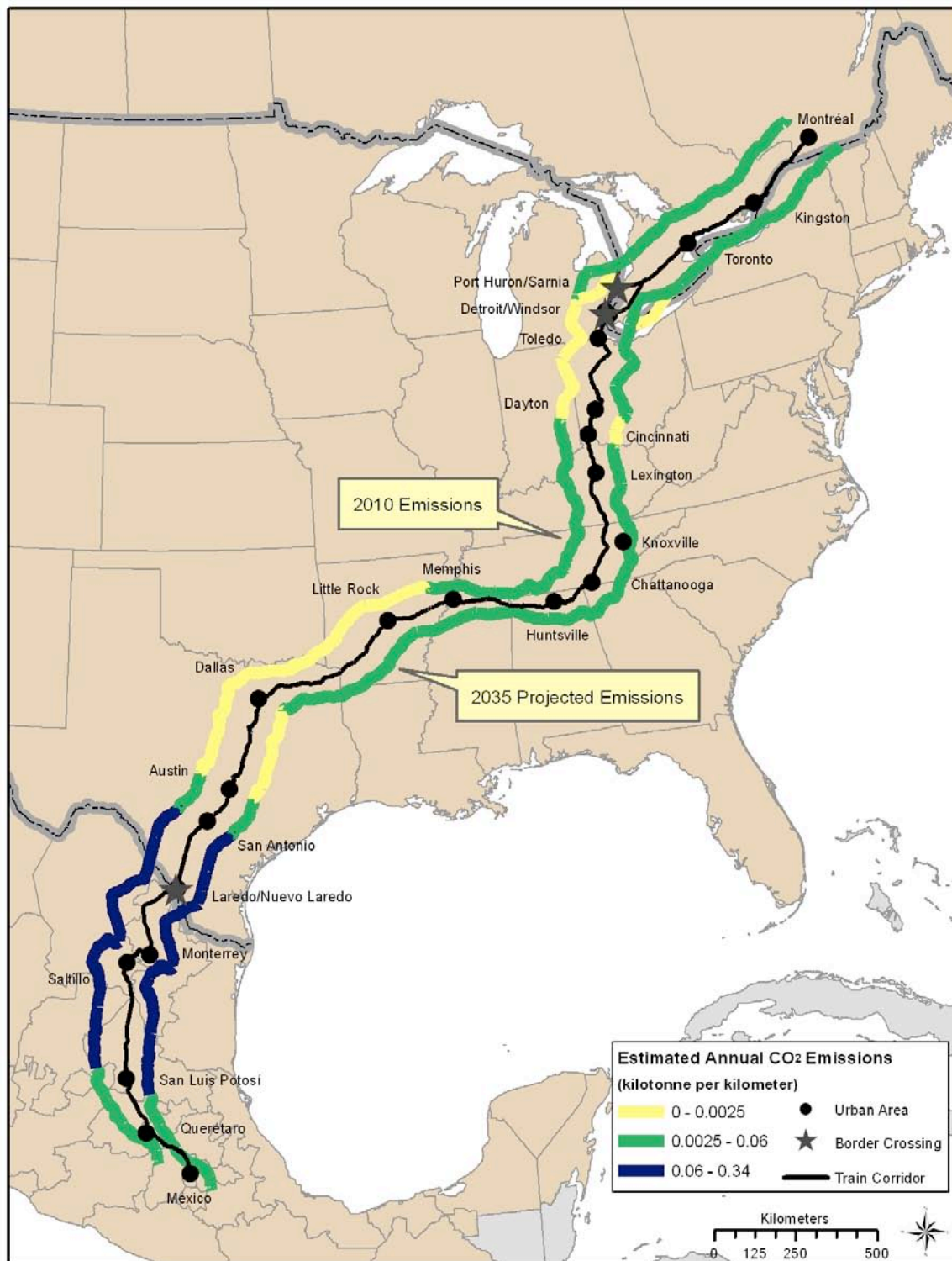
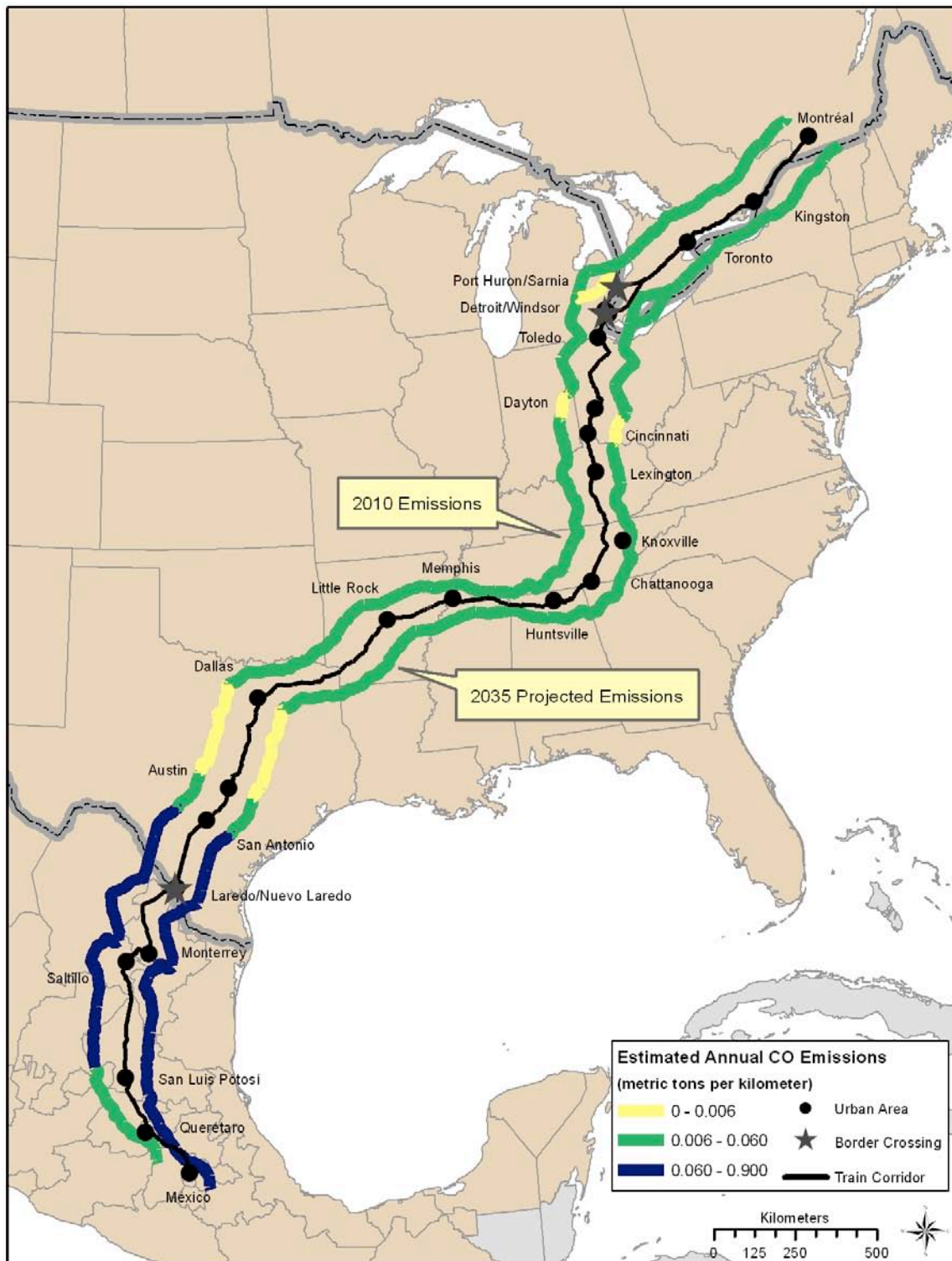


Figure 9. Estimated Freight Railroad CO₂ Emissions along the Corridor in 2010 versus 2035



Projection: Lambert Azimuthal Equal Area
This poster was created on January 10, 2011 by the Commission for Environmental Cooperation

Figure 10. Estimated Freight Railroad CO Emissions along the Corridor in 2010 versus 2035

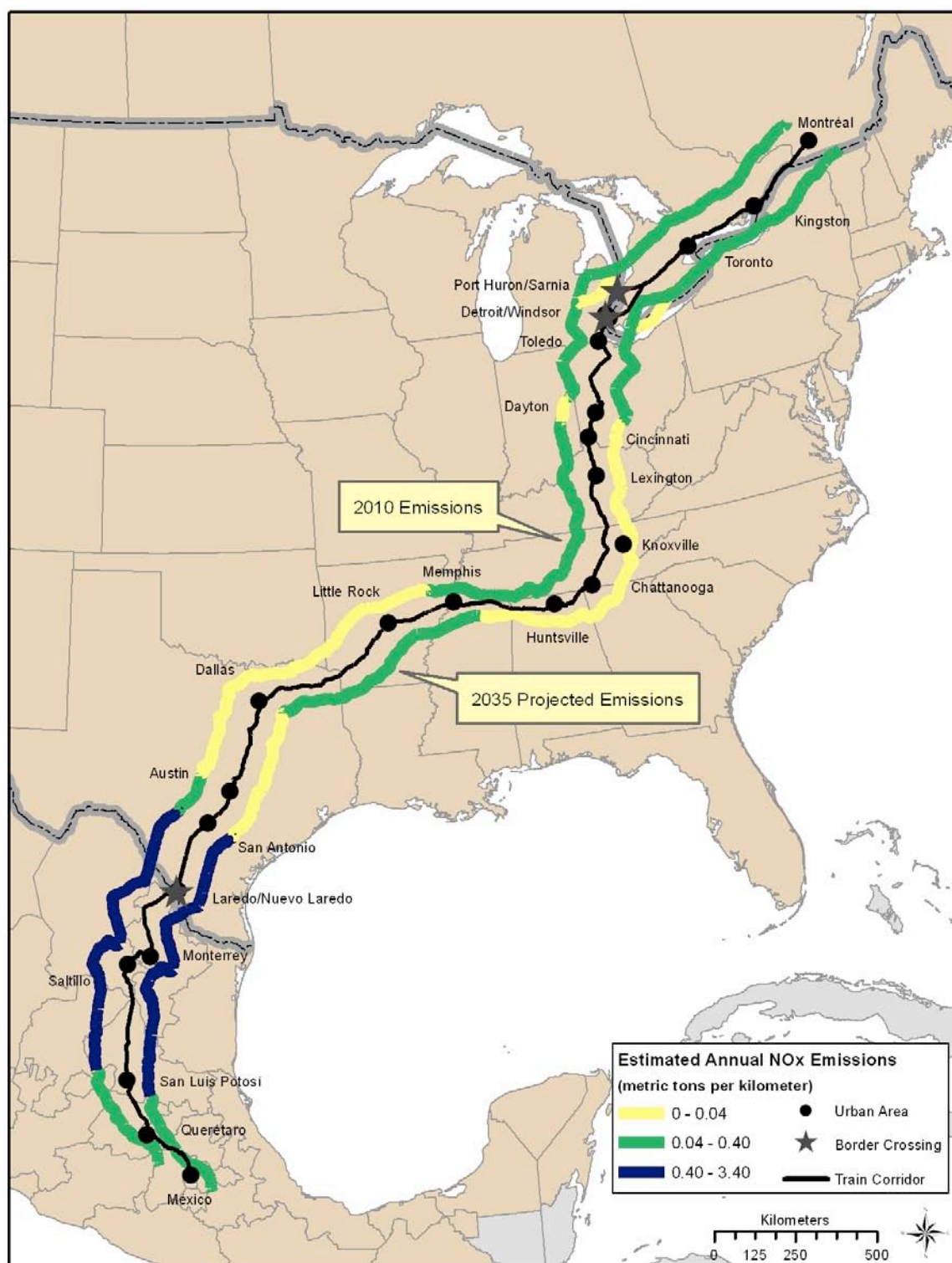


Figure 11. Estimated Freight Railroad NO_x Emissions along the Corridor in 2010 versus 2035

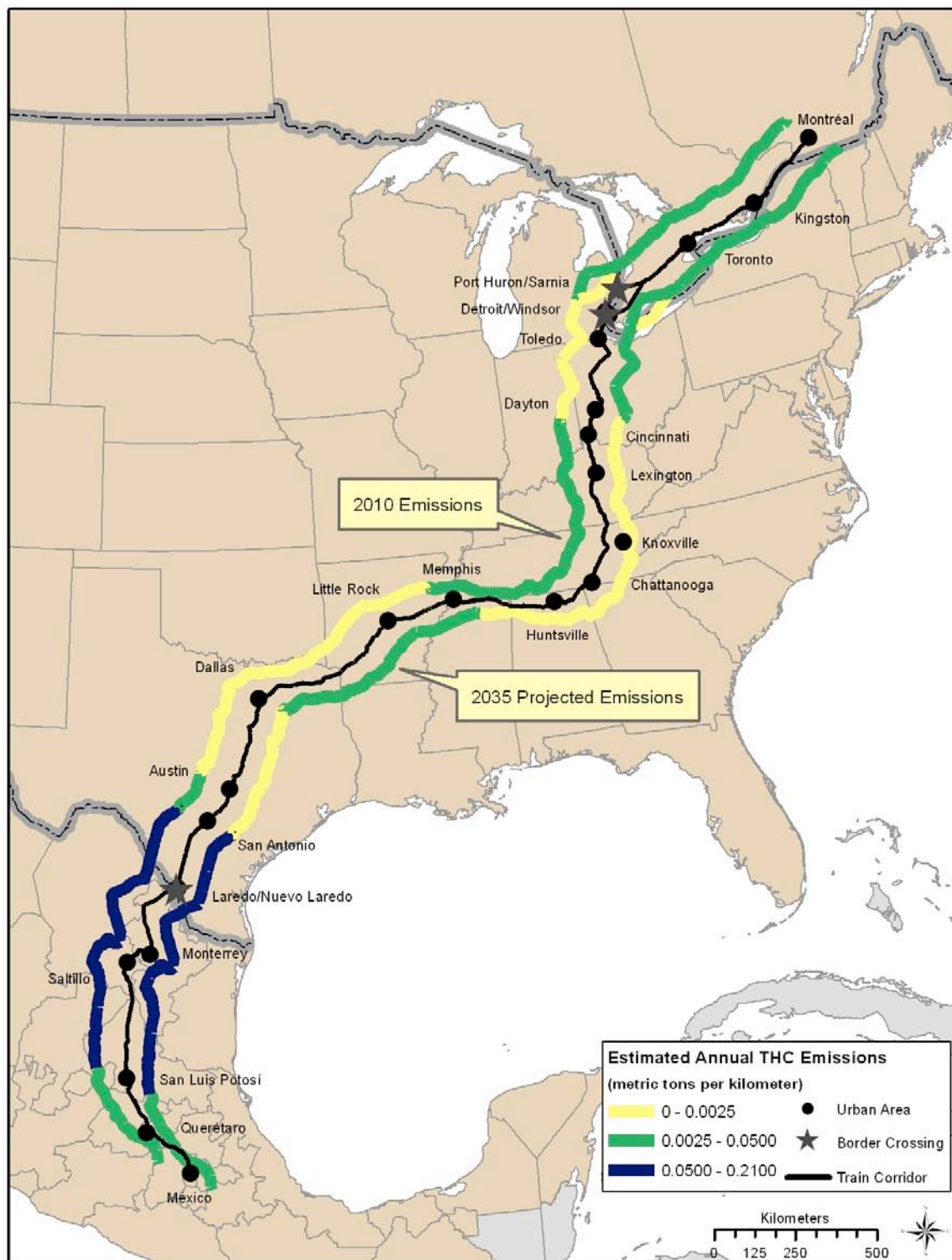


Figure 12. Estimated Freight Railroad Total HC Emissions along the Corridor in 2010 versus 2035

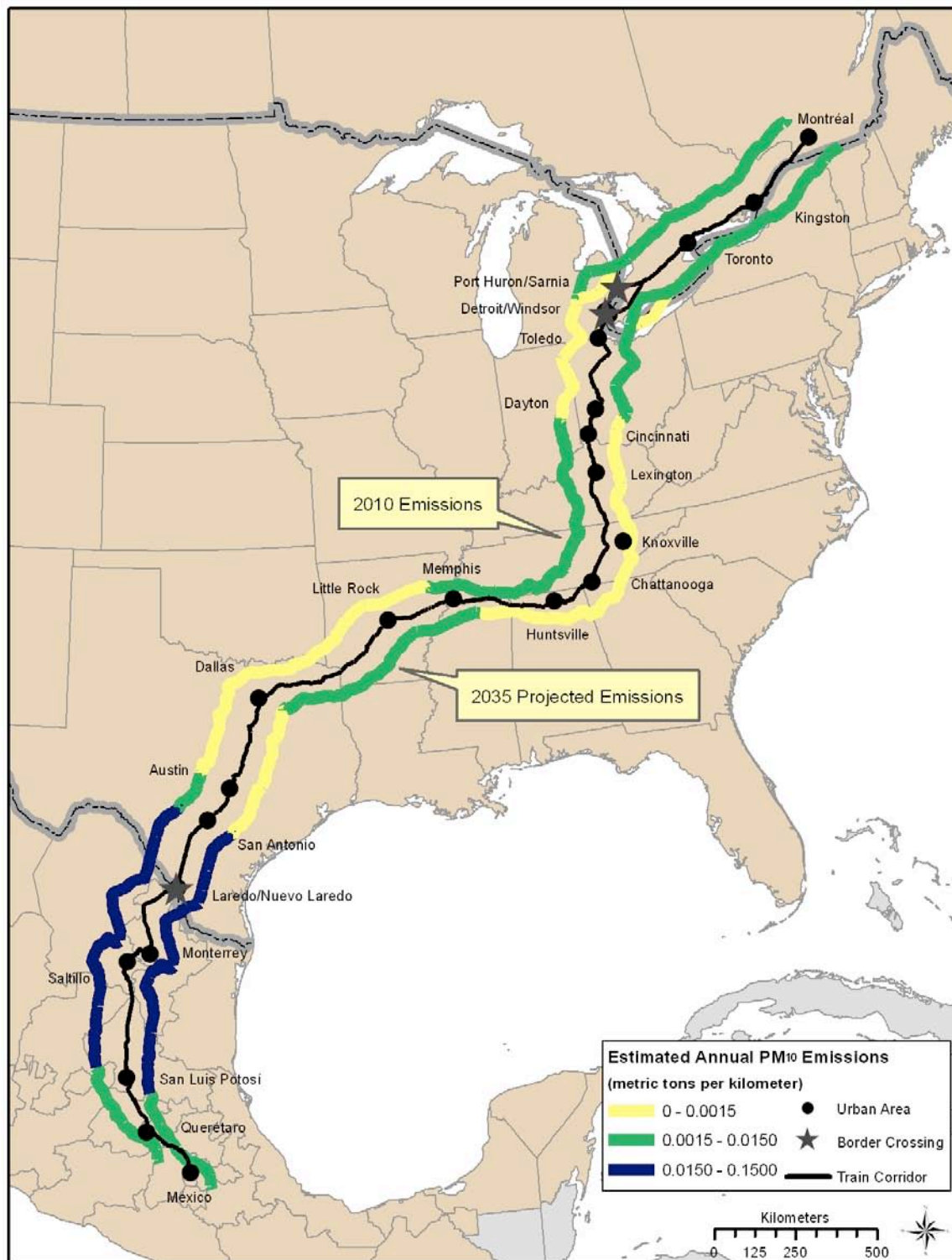


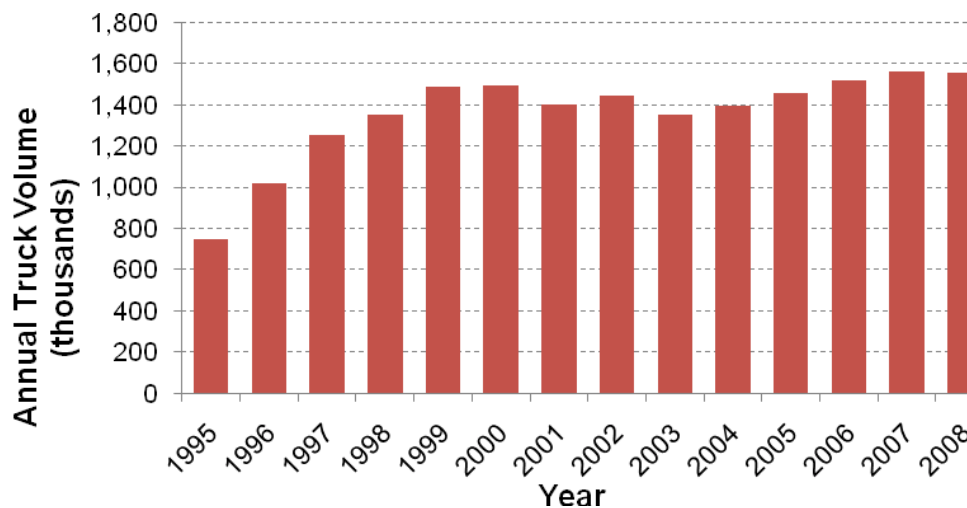
Figure 13. Estimated Freight Railroad PM₁₀ Emissions along the Corridor in 2010 versus 2035

Estimation of Emissions Due to Freight Activity at Border Crossings

The short-haul freight activity is mainly concentrated at border crossings and is commonly known as drayage trucking. In terms of the study corridor under consideration here, the emissions from truck activity at the Laredo border crossing is of great significance, as it is a major crossing, and the few border crossings available to Mexican trucks coming into the United States generates additional drayage and movement of empty trucks at those crossings. Even though there is truck congestion at the US/Canadian border, congestion levels at the US/Mexican crossing are much higher; therefore, this section deals solely with this border. However, the methodology presented in this section could be applied to all border crossings.

The majority of truck crossings from Mexico into the United States involve Mexican drayage trucks. Currently, the operation of Mexican motor carriers in the United States is confined to a narrow commercial zone that generally extends up to 20 miles beyond the border. Because of this, Mexican truck shipments into the United States are required to use a drayage or transfer tractor. Drayage trucks pick up northbound trailers on the Mexican side of the border and shuttle them into the US commercial zone. There, they are transferred to a US carrier that delivers them to the final destination.

Border crossing traffic data in total numbers of trucks crossing annually into the United States at each port of entry were obtained from the BTS website (see footnote 21). **Figure 14** gives these data for the port of entry at Laredo. The most recent full-year traffic data, for 2008, show a decrease in truck volume compared to 2007. The first two months of 2009 also maintained that trend because of the ongoing recession. It is assumed that the truck volume in base year 2010 will recover to approximately its 2007 level and we therefore used 2007 truck crossing volumes in the calculations. Truck volumes for 2035 were estimated by applying the growth rate of FHWA FAF² volumes between 2010 and 2035.



Source: US Bureau of Transportation Statistics.

Figure 14. Annual Volumes of Truck Border Crossings into the United States at Laredo, TX

The emissions estimation data and methodology used for this study were taken from a 2007 TTI study addressing air quality at US-Mexico border crossing. That methodology was constructed around the data collected for two TTI studies on Mexican trucks and general truck emission profiles. In the first of those studies, 10 Mexican trucks were selected as a sample for testing. Each truck was subjected to long-haul and drayage drive cycles while pulling a trailer that had been loaded to a specified weight. Emissions data were collected using PEMS equipment. In the second study, high-speed emissions testing was performed on the high-speed test track at the Pecos Research and Testing Center (RTC) near Pecos, Texas. The emissions data from this testing effort were used to develop a series of instantaneous, second-by-second emissions models.

The analytical method for estimating the total air quality impact of Mexican trucks was developed by combining these second-by-second emissions models with the Mexican trucks' emissions data. The developed methodology combined the observed emissions data from the sample of Mexican trucks, the results of the second-by-second emissions models, commercial trucking traffic data, activity-based driving patterns from a sample of GPS dataset, and truck age distribution in a systematic approach. **Figure 15** shows the age distribution for the drayage Mexican trucks in Laredo (as of 2006).

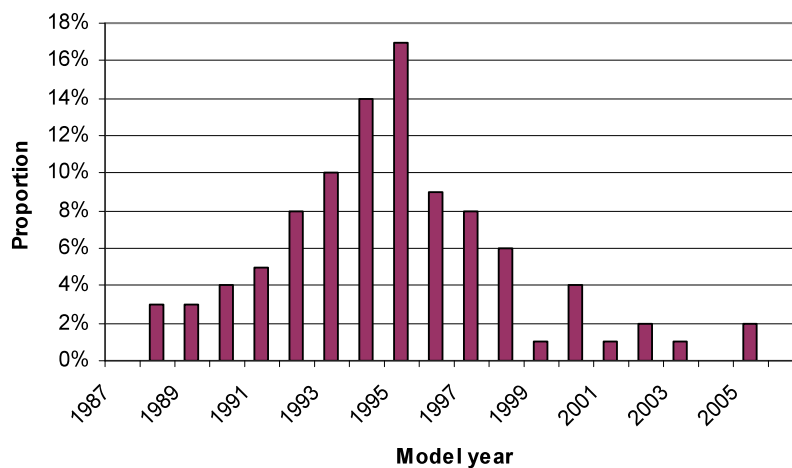


Figure 15. Drayage Truck Model Year Frequency Based on 2006 TTI Survey

The emission rates for 2035 were modified to reflect the projected changes in emissions standards for heavy-duty trucks. It was assumed that the percentage change in emissions of Mexican trucks would be the same as US trucks and attributable to improved engine technologies and a newer fleet. Using the estimated 2010 and 2035 truck volumes, this assumption was utilized to estimate the total air quality impact (**Figure 16**) of Mexican-domiciled commercial drayage trucks crossing at Laredo entry port.

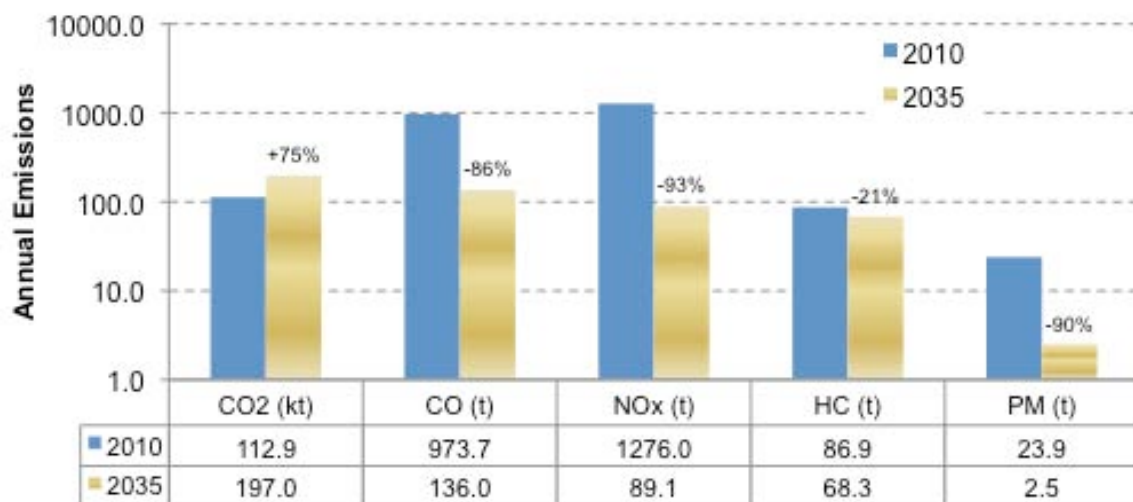


Figure 16. Annual Emissions at Laredo Port of Entry

The figure shows that the Laredo border crossing is a significant source of emissions, especially in comparison to the emissions due to freight movement along the entire corridor. Note that these emissions are in large part due to delays and congestion at the border and do not represent much contribution from actual freight movement. Thus, improving border crossing processes and infrastructure can significantly impact the overall emissions from freight movement along a corridor.

ISSUES, CHALLENGES, AND OPPORTUNITIES

Building on the findings from previous sections, this section will consider analysis scope, data requirements, and available data sources as they relate to determining air quality and climate change impacts of freight movement along major transportation corridors, and mitigation strategies for these impacts.

Analysis Scope and Air Pollutants

This study has focused on exhaust emissions from truck and rail freight movement along a corridor. The pollutants that were addressed in this work include CO₂, CO, NO_x, Total HC, and PM. Emissions of mobile source air toxic (MSAT) substances were not covered in this effort because current data regarding MSAT emissions have a high level of uncertainty; however, MSAT emissions are gaining more importance as more studies are conducted on their health impacts and estimation methodologies are improved.

Table 6 shows the different geographical levels of impact and the data accuracy for each of the pollutants. CO₂ is the major greenhouse gas that contributes to climate change and therefore has a global impact. Total HC, NO_x (mainly NO), and CO emissions are precursors to ground-level ozone, which is a regional problem. CO, NO_x (mainly NO₂), PM, and MSAT have negative health impacts and are therefore considered to have local impacts on the exposed population.

Table 6. Impact Scope and Data Accuracy for Transportation Air Pollutants

Pollutant	Impact Area	Data Accuracy
CO ₂	Global	Average to high
CO	Regional, Local	Average
NO _x	Regional, Local (NO ₂)	Average
Total HC	Regional	Average
PM	Local	Below average
MSAT	Local	Poor

Estimation Methodologies

CO₂ is the direct product of combustion of fossil fuels and can be easily estimated from the amount of fuel consumed by applying appropriate conversion factors. The fuel consumption data are generally collected and recorded by state and federal governments for tax purposes. These data are fairly accurate and provide a reliable source to analyze CO₂ emissions at the state and national levels. However, a finer-scale analysis (similar to what is performed in this analytical case study) requires estimating the fuel consumption of specific vehicles and equipment under study. This is similar to estimating other gaseous pollutant emissions (CO, Total HC, and NO_x). For this type of analysis, distance-based emission rates (g/mi) are applied to fleet activity data (e.g., VMT) to estimate the total air quality impact. The emission rates are developed by EPA based on emissions data collected from a limited sample of vehicles representing different types, makes, and model years. These rates reflect the average national fleet characteristics.

Historically, there has been greater uncertainty in the measurement of emissions and assessment of health impacts of PM than with gaseous criteria pollutants. Current emission rates are based on measurements from filter systems. Measurement methods for PM emissions have been improved substantially in the past decade and better data quality is expected to be available for use in future estimation models. The same issue also applies to MSAT emissions, where the relatively miniscule amounts of MSAT in tailpipe emissions cause the available data to have considerable uncertainty.

The analysis conducted in this study focused on tail-pipe running emissions, which constitute the majority of truck emissions in a freight transportation corridor. While other modes of operation, such as extended idling and border crossing activities, do sometimes result in significant emissions, these usually have more impact on local-level health and environmental analyses than at the corridor level. The methods utilized in this research provide only direct emission impacts of freight movement and do not consider petroleum life-cycle or “well-to-pump” energy and emissions implications. These types of analyses require extensive additional data, which are not nearly as accurate or readily available as direct emissions measurements.

Data Requirements and Data Sources

The process of analyzing the environmental impacts of freight movement along a corridor revealed a number of areas where necessary information is highly uncertain, or even non-existent. It is important that these deficiencies be addressed as trade-related environmental

issues become more prominent. Four specific areas are discussed below, along with several examples of ways to improve information collection and environmental monitoring.

Data Sources

Available data sources can generally be classified either as publicly available data that are collected and maintained by local, state, and federal governments, or as private databases that are developed and maintained by private companies. Private databases often combine publicly available datasets with additional data obtained from freight companies. Private data are often proprietary and are therefore expensive to obtain. Such data are considered to be beyond the scope of the type of analysis conducted in this research.

FHWA's Freight Analysis Framework (FAF) databases and the Bureau of Transportation Statistics (BTS) were found to be the most reliable sources of freight data required for the analysis performed in this study. Specifically, the FAF and the National Transportation Atlas Database (NTAD) from the FHWA and port of entry freight data from the BTS provided the required information at an acceptable level of accuracy.

As there is no single freight database for all three North American countries with the level of information that is required for analyses of freight corridors, it is necessary to identify data sources in each country. Canadian and Mexican sources of freight data were difficult to obtain. Data collection efforts vary in each country and the level of granularity could be different. Due to data sharing rules in Canada, the information that is collected by Transport Canada is difficult to obtain. In Mexico, the *Secretaría de Comunicaciones y Transportes* (SCT) and the *Instituto Mexicano de Transporte* (IMT) are collecting and analyzing freight transportation information. However, the information is limited and not up-to-date in most cases. Another potential issue is the selection of a base year for the data, as all three countries do not necessarily keep information updated with the same regularity: in some cases certain available information may become available only with a lag of several years. Rail information is also difficult to obtain in Canada and Mexico, as the operating companies are private entities that do not report information with the level of disaggregation that is required for this type of analysis.

Some of these data sources also contain projections for future freight activity. As with any projection, there is a high degree of uncertainty involved in predicting long-range freight activity data. Since the projections provided in these databases often show very general future trends, care must be taken when deriving emissions estimates based on these data.

The limitations of data sources are generally due to two factors: availability and collectability. The integration of new data collection technologies to freight movement has increased the amount of data that is collected; however, not all of it is available to the public and the government. The majority of data collected and recorded by the freight industry is proprietary and sometimes even considered a "trade secret." However, improvements in technology will continue to enable the collection of more data, more frequently. But the real benefit would lie in making the data available to the public in an appropriate form. This requires serious coordination and cooperation between all the stakeholders—ranging from shippers to port operators and from local governments to national transportation agencies.

Standard methods and tools will open up new opportunities for data sharing between the three countries. Freight data shared along the North American supply chain could be used both by policy makers to plan programs and projects for maximum effectiveness, and by logistics firms to optimize freight operations, modal shifts and incentivize efficiency improvements in the marketplace. It is recognized that the current trend toward greater

carbon disclosure and transparency provides opportunity for governments to work with the market to provide incentive and recognition programs to stimulate the demand for more sustainable freight transportation. It is anticipated that given the right incentives and opportunities, business will be more inclined to share their data publicly. Thus, it is strongly recommended that the three governmental transport and environmental agencies work to achieve this common goal.

In addition to the technical aspect of data requirement and data sources, implementing air quality performance monitoring on a corridor level raises questions of governance and accountability. The following are sample issues related to such corridor-level environmental impact studies:

- Who would be responsible for collecting data and who would use them to monitor performance?
- Who would be responsible for making adjustments to operations and infrastructure to improve performance?

Trucking Activity

Trucking freight activity is usually described in volume of trucks, or total volume/weight/value of cargo. Volume of the trucks is the main input for estimating the running emissions on a corridor. FAF, for example, provides freight and non-freight (local service) truck volumes for each section of major interstate highways in the United States. This information does not include weight and loading conditions of trucks. This can cause uncertainty in the emissions estimation process, as the emission rates of empty trucks might be underestimated in the process.

Truck volume is the main activity parameter used for the emissions estimation. If these data are not available, freight origin-destination volume/weight data can be converted to truck volumes using an average conversion factor; however, this will reduce the accuracy of the results. The average speed of trucks on a highway link is another parameter that affects the emissions of moving trucks. The current practice for estimating emissions is based on average speed limits for different road types, e.g., rural freeway versus urban freeway. This practice provides satisfactory accuracy for a corridor-level analysis; however, a local analysis would require actual speed information for specific links and these data are more difficult to collect. More detailed analysis such as project-level analyses requires finer-scale data, such as second-by-second speed profiles. New technologies, such as GPS and engine data-loggers, can provide such information, though the accuracy and reliability of such data for air quality impact analysis purposes have not been sufficiently investigated. Furthermore, there are high levels of uncertainty surrounding the collection methods of these data for air quality emissions analysis because there are no standards and guides on data collection and processing procedures.

Network and Routing Data

Network data exist in GIS format for highways and railways. Freight movement data are determined from publicly accessible information such as truck volumes and the reliability of such data is generally high. Rail routing and movement data, on the other hand, are considered business-sensitive data and are not usually shared publicly. This results in greater uncertainty.

Note that freight railways often do not follow highway corridors. This means that the assumption of parallel freight movement on rail between an origin-destination pair has higher uncertainty than trucks moving between the same pair. Truck activity can be

determined on many sections independently. However, rail freight activity is mainly determined from estimated total cargo movement between each origin-destination pair. Because the rail lines are owned and operated privately, there is very little public information on activity in each section. Furthermore, different rules determine freight movement routing by truck and rail. Rail freight movement has less flexibility and needs to follow major routes to distribution centers, whereas trucks enjoy high levels of flexibility in choice of route. An additional aspect that complicates the analysis of rail flows is that a more efficient movement by rail is obtained when it is handled by the same operator. However, single-operator rail routes can be more circuitous between origin-destination pairs than a more direct route with several operator interchanges.

The research team therefore recommends that any analysis of freight movement involving different modes should analyze each mode separately and include the specific routing and network characteristics. An exception to this is large-scale corridor analyses, such as with south-north corridors, in which an assumption of parallel movement provides a satisfactory level of accuracy.

Truck Emission Rates

Currently, emission rates for trucks are mainly obtained from the MOBILE6.2 model and aggregate distance-based rates for different average speeds. These rates are suitable for medium- and large-scale analyses, as they are not sensitive to changes in driving conditions as long as the average speed does not change. Furthermore, CO₂ and PM rates from the MOBILE model are not sensitive to speed and therefore not very helpful when conducting a link-by-link investigation.

EPA's newest model, MOVES, is capable of fine-scale analyses; however, it requires disaggregated activity data to conduct such analyses. These data are not currently available and no standard procedures have been developed for collecting them. Both MOVES and MOBILE base their emission rates for future vehicle model years on the expected future emission standards. These rates provide the general direction, but care must be taken when using these rates for the purposes of comparison, alternative selection, and decision-making.

Rail Freight Movement and Emissions

As discussed previously, high levels of uncertainty are inherent in rail freight movement data. In addition, the available methods for estimating emissions are aggregate procedures based on national average values that consider the total weight of hauled cargo to obtain fuel consumption and emissions. These two factors result in a very large uncertainty for estimated railroad emissions. The current emissions estimation methodology clearly underestimates the impact of having a large number of empty cars and other rail-related issues. Furthermore, the current rates are based on old data and newer locomotive emission measurements are required to improve these rates.

Although the current air pollutant contribution of freight rail is small compared to that of truck freight, this study indicates that the PM and NO_x emission contributions of railroad locomotives will be proportionally more significant in the future. This possibility argues that better analytical tools and estimation methodologies are required for determining railroads' fuel consumption and pollutant emissions levels. This will not occur without a coordinated effort between the rail industry and relevant government agencies such as the EPA.

Performance Measures

Performance measurement is a powerful tool to use in quantifying the impacts of freight movement and systematically monitoring its progress toward sustainability goals. However, current freight performance measures focus on freight logistics and fail to provide information on other aspects, such as the environmental and socio-economic impacts of freight movement. As a result, performance measures have not been fully adapted to provide a comprehensive picture of freight movement and gauge the success of various transportation sustainability programs throughout the nation.

This study recommends the development of a corridor-level performance monitoring system for freight movement. Such a system should combine different aspects of a sustainable freight transportation system, including qualitative measures by system operators and users of the system's ability to move freight and of the freight movement's broader impacts on society and the environment. A successful sustainable freight monitoring system depends on two factors: 1) goals and objectives that support "freight sustainability" in the corridor, and 2) establishment of performance measures that express a full view of the freight corridor's elements. A possible approach is to create a performance measurement system that results in some form of a "freight sustainability index" that combines multiple performance measures. The outputs of the system should be integrated into the planning process as well as strategy selection and system monitoring to track the progress toward the established goals.

Mitigation Strategies

A matrix of available mitigation strategies to reduce the air quality impact of freight movement was presented in **Table 1**. These mitigation strategies can be divided into two broad categories: improvements affecting a single vehicle, and strategies that target freight movement as a whole. The majority of strategies falling in first category are technologies that reduce emissions while those in the second focus on reducing the negative air quality impact of freight movement through improved efficiency and reduced delay and congestion. Strategies such as the use of biodiesel can fall into either category, depending on their deployment scope.

Since the deployment of the strategies in the first category is a business decision, policymakers cannot directly influence their deployment. Indirect influence can be exerted through taxes, regulations, and incentives. On the other hand, larger-scale improvements (typically in the second category, such as building assigned truck corridors or investment in reducing freight bottlenecks, are directly related to policy making.

Concluding Remarks

This research examined the effects on the air quality of major freight corridors from various pollutant and GHG emissions. The following are the main findings and implications of this research.

- Background information on the environmental impacts of freight, the effect of congestion, the need for performance measurement, and data availability and requirements were assembled and presented.
- A methodology was proposed to estimate the emissions impacts from truck and rail freight movement at the transportation corridor level and was tested in a case study of the Mexico City to Montreal corridor. An analysis of border crossing emissions for trucks was also included.

- The paper discussed the various issues, challenges, and opportunities linked to the estimation of air quality impacts of freight transport, as well as mitigation strategies and methods to improve performance measurements incorporating environmental and sustainability concerns.

APPENDIX A: CO₂ EMISSION PROJECTIONS TO 2035

Based on energy use projections from 2010 to 2035, the following CO₂eq emissions and percentage increase can be projected over the period.

				2010	2035
		2010	2035	CO ₂ eq	CO ₂ eq
lbs/10 ⁶ Btu		trillion Btu	trillion Btu	mMT	mMT
161	Diesel	3900.87	5939.21	284.8740497	433.7310101
156	Motor Gasoline	318.66	407.21	22.54852971	28.81462439
139	Liquefied Petroleum Gases	15.96	27.78	1.006430251	1.751381398
117	Compressed Natural Gas	7.03	83.89	0.373088081	4.451844122
	Total	4242.521066	6458.09006	308.8020978	468.74886
				% Change	51.80%

Source: US Energy Information Administration. *Annual Energy Outlook 2010*. April 2010.

Table 67. Freight Transportation Energy.

<http://www.eia.doe.gov/oiaf/aeo/supplement/suptab_67.xls>.

APPENDIX B: MOVES AND MOBILE6.2

The following excerpts from EPA compare MOVES and MOBILE6.2.³⁸

“In MOBILE6, emissions were calculated from default information in block data, supplemented with information provided by the user in input text files. In MOVES, default information is contained in a default input database. Hypothetically, users can run MOVES using all default data, all new data, or anything in-between. In reality, the inputs that users bring to the model will depend on the situation being modeled and the purpose of the modeling.”

“Many of user inputs expected by MOVES are similar to those previously used in MOBILE6. For example, information on age distributions, local fuels, and local temperatures are essential inputs for any accurate estimate of emissions. MOVES differs, however, in that the categories for these inputs have changed. For example, MOBILE6 has 28 vehicle categories, generally based on vehicle weight ratings, while MOVES has only 13 categories, based on observable characteristics (e.g., combination vs. single unit trucks) and typical use (e.g., long haul versus short haul). The EPA is developing converters to allow users to automatically convert MOBILE6 inputs into MOVES formats.”

“MOVES’ new capabilities also require new inputs. In particular, because MOVES can calculate inventories as well as gram per mile emission rates, [the model] relies on input of Vehicle Miles Travelled (VMT). The MOVES design also recognizes that vehicle starts and evaporative activity may not be well correlated with VMT, and thus relies on vehicle population estimates to calculate these emissions.”

³⁸ Taken from M. Beardsley et al. (n.d.). Air Pollution Emissions from Highway Vehicles: What MOVES Tells Us. EPA, Ann Arbor, MI.

<<http://www.epa.gov/ttn/chief/conference/ei18/session6/beardsley.pdf>>.

“In another example of how new capabilities require new inputs, MOBILE6 allowed users to enter a speed distribution or an average speed for a run. MOVES also allows input of a speed distribution, but it can also accept specific driving cycles or operating mode distributions, allowing the user to model emissions resulting from changes in driving behavior.”

Major Inputs and Outputs of MOVES and MOBILE6.2 Models

MOVES	MOBILE6.2
Main Outputs	
gram/mile emission rates – gram/time for some processes	gram/mile emission rates – fixed format
Total emissions – inventory for specific period and area	N/A
Different levels of aggregation/disaggregation – second-by-second activity is captured by the model	Aggregate
Local Analysis Data Needs	
Fuel characteristics	Fuel characteristics
Meteorology	Meteorology
I/M program	I/M program
Age distribution – registration data	Age distribution – registration data
Population of MOVES vehicle types	Population of MOBILE vehicle types
Total VMT of vehicle types	N/A
VMT fraction across road types	VMT fraction across road types
Local speed profiles (drive cycles) for each vehicle types and road types *	N/A

* Optional input – major improvement over MOBILE6.2

Major Features of MOVES and Comparison with MOBILE6.2 ³⁹

MOVES Major Features	MOVES Vs. MOBILE6
Geography	Jurisdiction, regional or state level aggregation possible.
Time Spans	No change. Energy /emission output available by hour of the day, and month for calendar years 1990 and 1999 through 2050, with options to run at more aggregate day, month or year levels. Same as ozone & winter day and seasonal (annual)
Sources	Requires conversion from 28 to 13 vehicle types.
Outputs and Pollutant Emissions	MOBILE6 pollutants VOC, CO, NOx, PM2.5 & PM10, N2O, CH4, CO2, toxics; Plus new pollutants added (e.g., CO2 equivalent, individual components of PM2.5 & PM10, total energy consumption).
Emission Processes	Some change. Running, start, extended idle (e.g. heavy-duty truck ("hoteling"), well-to-pump, brakewear, tirewear, evaporative permeation, evaporative fuel vapor venting, and evaporative fuel leaks. Evaporative emissions characterized differently.

³⁹ Kumar, S. and E. Lucas (2009). MOBILE6 to MOVES,
<http://www.mwcog.org/uploads/committee-documents/kV5bXltb20090612161006.pdf>

