Environmental and Social Impacts of Marine Transport

in the Great Lakes-St. Lawrence Seaway Region

Executive Summary

Prepared by:

Research and Traffic Group

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About the Study Authors and Acknowledgements

For more than two decades **Research and Traffic Group** has provided advice and assistance to clients, and undertaken important studies, particularly in transportation. Brief resumes of the qualifications and experience of the Partners are provided below:

Gordon English (B.Sc., M.B.A., P.Eng.)

Gordon English has been a partner at Research and Traffic Group since 1999, and an active associate since 1994, leading projects focused on energy, safety and techno-economic feasibility evaluations, including five climate change evaluations, two energy/emissions modal comparison projects, several transportation safety impact assessments and a discussion paper on internalizing social costs in the transportation sector. English has more than 37 years' experience conducting transportation-related research. He is also currently the President of TranSys Research Ltd, which has focused on safety and techno-economic analyses for projects such as the economic viability of railway operations in an asset devolution assessment for the St. Lawrence Seaway and recommendations to the Republic of China on proposals for high-speed rail passenger service between Taipei and Kaohsiung. He also previously worked as the Director of Research for the Canadian Transportation Safety Board Act Review Commission and in various positions at the Canadian Institute of Guided Ground Transport at Queen's University.

David C. Hackston (B.Comm., B.Arts, FCILT)

David Hackston has been a partner at Research and Traffic Group since 1988, assisting clients with analyses related to rail transportation, intermodal and Great Lakes-Seaway issues. He has more than 40 years' experience in the transportation sector, including providing the *Canada Transportation Act Review* with expert advice on rail freight and passenger (intercity and urban) issues. From 1974 to 1987, he served with the Canadian Transport Commission as Executive Director, Traffic and Tariffs, advising on rates and public interest issues for rail, motor vehicle and marine (Great Lakes and Northern resupply). As chairman of the Ad Hoc Rates Committee and of the Sub Committee on Data, he advised on the drafting of the Western Grain Transportation Act and represented the CTC on the Steering Committee overseeing Transport Canada's review of the Atlantic Region Freight Assistance program. He also managed and conducted studies into various aspects of Canadian transportation flowing from initiatives agreed upon at the Western Economic Opportunities Conference, as well as the relationship between transportation and various Canadian industries. This followed a nine-year career in the marketing and sales department of CP Rail.

Acknowledgements

The study, *Environmental and Social Impacts of Marine Transport in the Great Lakes-St. Lawrence Seaway Region*, was commissioned and produced in collaboration with the Chamber of Marine Commerce, the Canadian Shipowners Association, the St. Lawrence Seaway Management Corporation and the Saint Lawrence Seaway Development Corporation.

The authors would like to thank the following participating marine carriers for providing confidential operating data and project steering committee members for the guidance and valuable feedback provided in the preparation of this report:

- Algoma Central Corporation
- American Great Lakes Ports Association
- American Steamship Company
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- Canadian Shipowners Association
- Chamber of Marine Commerce
- Fednav Limited
- Great Lakes Fleet / Key Lakes Inc.
- Interlake Steamship Company
- Lake Carriers Association
- Saint Lawrence Seaway Development Corporation
- St. Lawrence Seaway Management Corporation
- Transport Canada
- World Wildlife Fund (Canada)

We commend the steering committee members for setting the guiding principles for this study — to make modal comparisons in as accurate and equitable a way as was possible within the limitations of data and analytic tools available. There have been many previous modal comparison studies. Those dealing with the fleets operating in the Great Lakes-Seaway System have suffered from the lack of publicly available data on fuel and operational activity for the vessels operating on the system. Most modal comparison studies involving the Great Lakes-Seaway System and other marine segments have drawn comparisons between modes based on system average performance of each mode carrying its own mix of cargo, rather than making a like-for-like comparison based on each mode carrying the same cargo mix. We commend the Great Lakes-Seaway marine carriers and the study sponsors for their search for a like-for-like comparison and their commitment to accept the results — whether the results placed marine at higher or lower performance ratios than prior modal comparison studies.

Finally, we thank the three peer reviewers of the draft final report. Valuable comments were made and specific comments and suggested improvements were either incorporated into this final report or responded to.

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Executive Summary

1. Introduction

For more than 200 years, the marine shipping industry has been an integral part of the Great Lakes economy.

The Great Lakes and the St. Lawrence River combine to form the longest deep-draft navigation system in the world, extending 3,700 kilometers (2,300 miles) into the North American heartland (see Figure ES1). The system includes the five Great Lakes and their connecting channels, as well as the St. Lawrence River to the Gulf of St. Lawrence. A series of locks either lift or lower vessels to overcome elevation changes. These include:

- Seven locks on the Montreal-Lake Ontario (MLO) section of the St. Lawrence Seaway, which lift/lower ships 68.8 meters (226 feet);
- Eight locks on the Welland Canal (Welland) section of the St. Lawrence Seaway, which lift/lower ships 99.4 meters (326 feet):
- One lock at Sault Ste. Marie, Michigan, which lifts/lowers ships 9.2 meters (30 feet).

Three distinct vessel-operator groups serve the waterway. These include American and Canadian domestic carriers transporting cargo between ports within the system, and international ocean-going vessel operators that operate between ports within the system and ports located overseas.

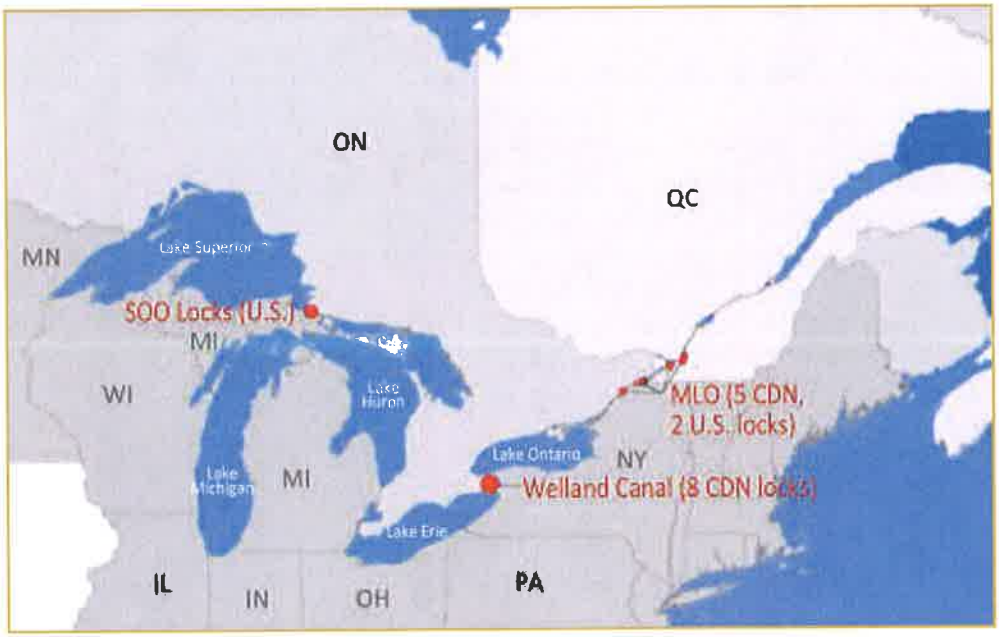


Figure ES1. Great Lakes-Seaway System

Source: RTG with data from U.S. DOT-NTAD and NRCan-Geogratis.

Every year, more than 160 million metric tons of raw materials, agricultural commodities and manufactured products are moved on the Great Lakes-St. Lawrence Seaway System. Dominant cargoes include iron ore for steel production, coal for power generation, limestone and cement for construction, and grain for both domestic consumption and export.

This marine highway supports the activities of more than 100 ports and commercial docks located in each of the eight Great Lakes states, and the provinces of Ontario and Quebec. It is also a crucial transportation network for commerce moving between North America and more than 59 overseas markets.

2. Scope

This report is designed to provide marine stakeholders, transportation planners and government policy makers with an assessment of the potential environmental and social impacts that could occur, if cargo carried by marine vessels on the Great Lakes-St. Lawrence Seaway navigation system shifted to road and/or rail modes of transport.

The study examines the external impacts that can be compared between rail, truck and vessel, including the following:

- Fuel efficiency;
- Greenhouse Gas (GHG) emissions;
- Criteria Air Contaminant (CAC) emissions;
- Traffic congestion;
- Infrastructure impacts;
- Noise impacts.

The external impacts included in this study are not intended to be an exhaustive list, but rather, represent key impacts common to each of the three surface transportation modes, enabling comparison. All modes have had historic impacts that are not included in a marginal impact assessment of future traffic shifts. For example, the marine mode's past impacts related to invasive aquatic species were significant and are being addressed to prevent future occurrences. Similarly, the impacts of road and rail infrastructure on wildlife habitats were significant historic influences but are not significant marginal impacts for future traffic changes and are not included in this study. The ongoing loss of animal life on roads and railways, the infrequent instigation of forest fires from rail activity and the uncertain impact of marine activity on shore erosion are examples of external impacts that are related to changes in traffic but are not quantified in this study due to data limitations and/or scientific uncertainty.

To accomplish this analysis, a bi-national consortium of public and private sector Great Lakes-Seaway System stakeholders retained transportation consultants Research and Traffic Group of Ontario, Canada. Research and Traffic Group has conducted numerous safety and environmental studies related to rail, road and marine on behalf of Canadian federal and provincial government agencies, as well as governments abroad. The project was overseen by a steering committee of stakeholders, including WWF-Canada and Transport Canada.

3. Methodology — Current Conditions Comparison

Within the limitations of data and analytic models, the three freight transport modes are compared using 2010 characteristics that are representative of each mode's current operations in the Great Lakes-St. Lawrence region when carrying the existing mix of marine cargo.

The geographic focus was on cargo movements on the Great Lakes, including travel through the Seaway locks system to/from St. Lawrence River ports and overseas locations. All cargo movements handled by Canadian domestic, U.S. domestic, and international ocean-going vessels within the Great Lakes-Seaway System are included in the study; movements on the lower St. Lawrence River are only included if the vessel transits the MLO section of the Seaway.

The data used for marine analysis was compiled from a sample of U.S., Canadian and international carriers representing 79% of the 2010 cargo carried on the Great Lakes-Seaway System. To provide the most meaningful analysis of the marine mode, findings are presented for three categories:

- ***Seaway-size Fleet*** — the Seaway-size fleet consists of Canadian domestic carriers and Seaway-sized international vessels, which can navigate the narrower and shorter Seaway locks (the Welland Canal between Lake Erie and Lake Ontario, and the Montreal-Lake Ontario (MLO) locks between Lake Ontario and the lower St. Lawrence River.)
- ***U.S. Fleet*** — the U.S. domestic fleet predominantly operates in the Upper Great Lakes (above or west of the Welland Canal). The modal comparisons are based on the cargo that the U.S. Fleet carries and recognize the operational characteristics of the three modes in the U.S.
- ***Combined Great Lakes-Seaway Fleet*** — the Combined Great Lakes-Seaway Fleet includes all categories of vessels operating within the Great Lakes-Seaway System, i.e., Canadian domestic carriers, U.S. domestic carriers and international vessels.

This is the first time a study has examined the external impacts of the U.S., Canadian and international fleets operating on the navigation system, using actual data from all three categories of shipowners.

The rail and truck characterizations are based on publicly available data and simulation models developed by Research and Traffic Group to assess the specific performance in transporting cargo.

Where possible, the modal comparisons were based on the equipment type actually used in transporting cargo. Energy consumption associated with engine idling and vessel hotel power was included, but adjustments were made to attain a like-for-like comparison. Wayside energy associated with loading/unloading was excluded for all modes and auxiliary energy used by self-unloading vessels to unload cargo was also excluded. In addition, 10% of every vessel's hotel power (i.e., power used for crew accommodation) used while at port was excluded, in recognition of the absence of data about the wayside energy used by the ground modes for similar purposes. The other 90% of hotel power used while at port and 100% used by vessels while underway are included.

The rail network included in the study area involves CN and Canadian Pacific (CP) on both sides of the border, and CSX Transportation (CSXT) and Norfolk Southern Railway (NS) more principally within the U.S. but also with short border crossings into Canada. Due to data availability, rail mode characterization is based on the complete rail networks of these railways, not just those rail segments located in the Great Lakes-Seaway region.

The highway network included in the study area involves the Interstate Highway System in the states bordering the Great Lakes and the strategic highway network in Ontario and Quebec. Unlike the rail mode, truck operations differ significantly between the U.S. and Canada. The related truck performance analyses were segmented by country due to differences mainly in truck axle load limits and body-style configurations.

4. Methodology — Future Conditions Comparison

An additional assessment of long-term modal potential was provided by comparing marine, rail and truck energy efficiency after meeting the regulatory conditions, and the technology and fuel-use improvements that would be economically available over the time frame 2012–2025. The technologies used in the year 2010 baseline comparison can be expected to change over time for each of the modes. However, the magnitude of change will be much greater for the marine mode than for the two ground modes.

Domestic vessels in the Great Lakes-Seaway Fleet are over 30 years old, whereas the rail mode's mainline locomotive fleet and the truck mode's long-haul tractor fleet are newer than 20 years old. The delay in renewal of the domestic marine fleet has been influenced by the 25% duty on foreign-built vessels brought into Canadian domestic trade, and the *Jones Act* restrictions prohibiting foreign-built vessels in the U.S. domestic trade. The recent repeal of the Canadian 25% import duty and the introduction of the Environmental Protection Agency's (EPA's) assistance program for new power plants on existing U.S. vessels are stimulating fleet and power plant renewal that will significantly improve the efficiency of both Canadian and U.S. domestic fleets.

Current EPA and Canadian government regulatory initiatives will also lead to reductions in CAC emissions intensity for marine over the interval 2012 to 2025 and for rail by 2016. As the least emissions-efficient mode, trucking was the target of early CAC regulatory initiatives and is not expected to see further reduction in CAC emissions intensity on a gram-emitted per liter of fuel basis. However, there are regulatory initiatives to reduce truck GHG emissions over the 2014 to 2017 timeframe. Energy-efficiency improvements made to meet these regulations will have an equivalent reduction for the truck mode's engine-based CAC emissions.

Similarly, there are longer-term efficiency improvements in proposed regulations for the marine mode. International Marine Organization (IMO) initiatives for ocean vessels built after 2013 will lead to further opportunities (and in some jurisdictions, requirements) for efficiency advances in ship design/operations. If Canada and the U.S. extend the IMO regulations to the domestic fleets, efficiency improvements of 30% over 2010 baseline technology will be required for newly purchased vessels.

In order to assess the long-term potential performance of each mode, a "post-renewal" scenario has been developed for each mode, under the assumption that 100% of each mode's fleet is comprised of equipment that meets circa-2016 regulations.

Marine Mode's Post-renewal Framework

The basic post-renewal comparison is based on the following assumed conditions for the fleets operating on the Great Lakes-Seaway System:

- The Canadian Fleet is renewed (engine and vessel-design) at an estimated 36.5% average improvement from the present technology being used on newly ordered vessels (with 2013/2014 deliveries).
- The U.S. Fleet is repowered to attain the performance exhibited by the "Best-in-Fleet" vessel in the U.S. carriers' data, but with a 90% effectiveness ratio to account for trade-specific differences (e.g., shorter distances, smaller vessels). This results in a 33.4% average improvement for the U.S. Fleet.
- The International Fleet sees an average 10% efficiency improvement and meets Emission Control Area (ECA)-2015 emissions requirements while in the Great Lakes-Seaway.
- All Fleets use 100% marine diesel oil (MDO) fuel — with auxiliary engines meeting EPA-C2 regulations and propulsion engines meeting EPA-C3 regulations for ECA-2015 (involving a phase-in of sulfur dioxide (SO2) reductions by 2020 to 2025).

The study notes that the load capacity and related energy efficiency of the marine mode, and the deeper draft U.S. Fleet in particular, are sensitive to water-level variations on the Upper Great Lakes. The baseline data reflect the conditions of 2010, which was reasonably representative of the previous decade; however, the 2001-2010 decade was lower than the long-term average. There is no consensus forecast of future water levels; however, the performance of the marine mode, and the deeper draft U.S. Fleet in particular, could improve or worsen in the post-renewal scenario depending on future changes in water levels.

It should be noted that both the U.S. and Canadian fleets would see initial efficiency improvements much greater than the above fleet-wide averages, as the lowest efficiency vessels would be the first to be displaced by the newer vessels/engines.

Rail Mode's Post-renewal Framework

In recent years, rail has been renewing its long-haul fleet, while its local yard-switching fleet remains quite old. The study assumes that there is little scope for additional cost-effective rail engine efficiencies over the 2010 engine by 2015.

Rail mode engines will be subject to more stringent CAC emissions regulations in 2015 and sulfur content of railway diesel fuel will also be reduced in 2016. Post-renewal performance for rail is expected to exceed the 2010 performance as all locomotives in the 2010 fleet are replaced with engines that meet the circa-2016 regulations. The 2010 fleet had a distribution of ages, including many older, less efficient engines with higher emissions intensities. In the post-renewal scenario, the line-haul fleet is comprised of 100% new equipment meeting 2016 standards.

Investment opportunities to reduce fuel consumption exist for all modes and it is difficult to forecast how many will get adopted. For rail, it is assumed that the following operating efficiency improvements will be economical in the "post-renewal" scenario:

- Locomotive fleet updated to 100% new engines attaining 2016 emissions regulatory compliance and efficiency performance estimated by the EPA for the 2040 locomotive fleet;
- Coal car average load increased to 115 tons;
- Grain and other bulk cargo average load increased to 100 tons;
- Train length increased by 10%;
- Layover-idle decreased by 20%.

Truck Mode's Post-renewal Framework

All existing CAC regulations for trucks were in effect in 2010. While the EPA has not published notices of new CAC regulations for trucks, it has introduced a final rule requiring reductions of GHG emissions by 2014. Canada has proposed to adopt the same standards. As these reductions involve fuel-efficiency improvements to engines and tractors, CAC emissions from engines will see a reduction in proportion to the fuel reduction. The average reductions sought from tractor suppliers include the savings required by engine sub-suppliers, and the combined reductions vary by class of truck and cab style. The combined engine and tractor-body reductions required by 2014 range from 7% to 20%, and a further 3% reduction is required by 2017.

As with the other modes, the post-renewal scenario assumes 100% of the fleet is comprised of post-renewal (in this case post-2017) trucks. Since the regulatory reductions are related to a defined base vehicle, the actual service-specific performance will not necessarily result in the same savings. The post-renewal scenario for trucks assumes operators maintain the improvements required by the EPA for tractor manufacturers. The impacts of the GHG regulations are specific to the types of trucks and loads involved in this assessment.

5. Study Findings

All study results are presented in both metric and in United States customary units. For example, tonnage figures are presented in metric tonnes (2,204 pounds) and in net tons (2,000 pounds); liquid measures are presented in liters as well as in U.S. gallons.

Energy Efficiency

Current Conditions

A comparative analysis of the fuel used and engine technologies deployed in 2010 by each of the modes showed that marine vessels were able to carry one tonne of cargo significantly farther on one liter of fuel than both rail and trucks. The analysis related to the energy efficiency for each grouping of vessels shows the following results relative to rail and truck modes:

- The Seaway-size Fleet can move its cargo 24% farther (or is 24% more fuel-efficient) than rail and 531% farther (or is 531% more efficient) than truck.
- The U.S. Fleet can move its cargo 11% farther (or is 11% more fuel-efficient) than rail and 592% farther (or is 592% more efficient) than trucks.
- The Combined Great Lakes-Seaway Fleet can move its cargo 14% farther (or is 14% more fuel-efficient) than rail and 594% farther (or is 594% more efficient) than trucks (see Figure ES2).

Future Conditions

In addition to 2010 performances, energy and emissions performances are also derived for a post-renewal scenario — after each mode's upcoming regulatory changes are met and each mode's fleet (or the engines of the U.S. Fleet) is renewed. The results showed that the marine mode could significantly widen its fuel-economy advantage over rail and trucks.

Once all modal fleets are renewed:

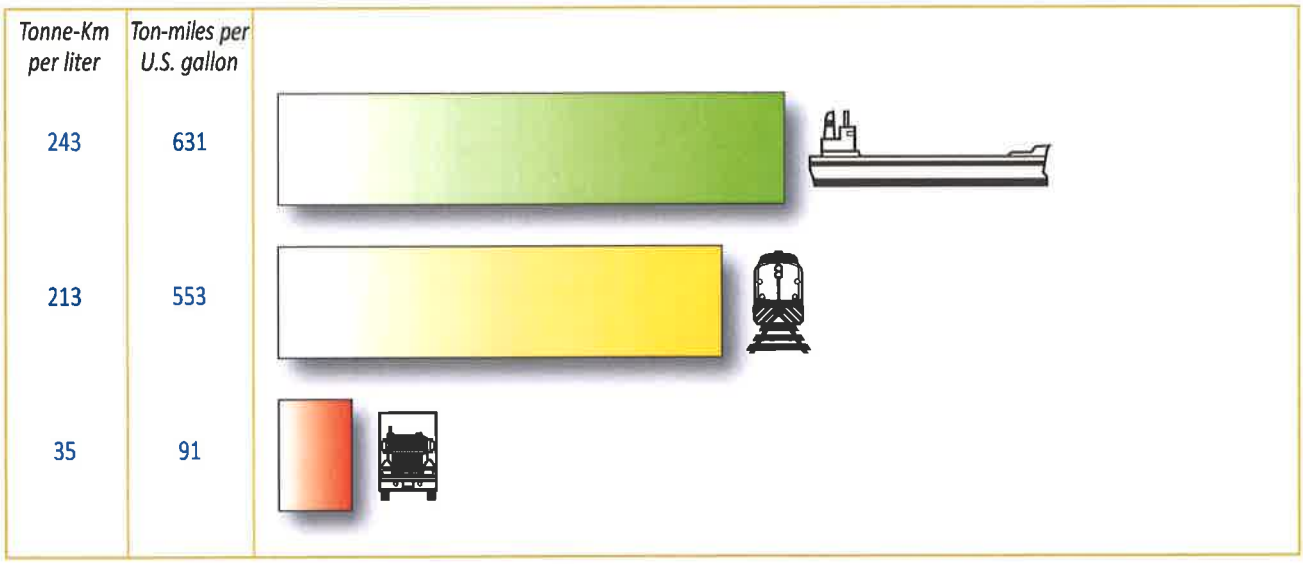
1. The Seaway-size Fleet will move its cargo 74% farther (or will be 74% more fuel-efficient) than rail and 704% farther (or will be 704% more efficient) than truck;
2. The U.S. Fleet will move its cargo 53% farther (or will be 53% more fuel-efficient) than rail and 754% farther (or will be 754% more efficient) than trucks; and
3. The Combined Great Lakes-Seaway Fleet can move its cargo 59% farther (or is 59% more fuel-efficient) than rail and 773% farther (or is 773% more efficient) than trucks (see Figure ES3).

Table ES1. Fuel efficiency to move Great Lakes-Seaway cargo

Distance in kilometers to move one tonne of cargo with 1 liter of fuel	Base year 2010			Post renewal of all modes		
	Marine	*Rail*	*Truck*	*Marine*	*Rail*	*Truck*
Seaway-size Fleet	265	213	42	394	226	49
U.S. Fleet	235	212	34	342	224	40
Combined Great Lakes-Seaway Fleet	243	213	35	358	225	41
Distance in miles to move one ton of cargo with 1 U.S. gallon of fuel	**Base year 2010**			**Post renewal of all modes**		
	Marine	*Rail*	*Truck*	*Marine*	*Rail*	*Truck*
Seaway-size Fleet	688	553	109	1,022	586	127
U.S. Fleet	610	550	88	887	581	104
Combined Great Lakes-Seaway Fleet	631	553	91	929	584	106

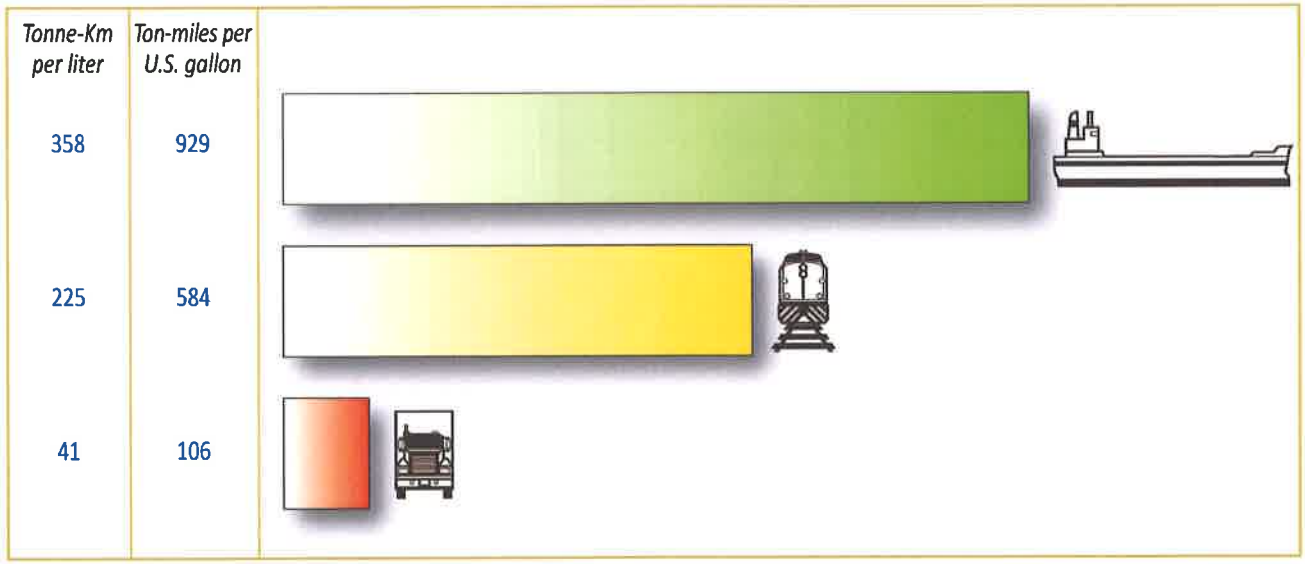
Source: RTG analysis of confidential marine carrier data.

Figure ES2. Energy Efficiency Comparison – Combined Great Lakes-Seaway System Fleet (2010)



Source: RTG analysis based on each mode carrying Great Lakes-Seaway traffic an equal distance.

Figure ES3. Energy Efficiency Comparison – Combined Great Lakes-Seaway System Fleet (Post Renewal of All Modes)



Source: RTG analysis based on each mode carrying Great Lakes-Seaway traffic an equal distance.

These results reflect the fact that the magnitude of technological change will be much greater for the marine mode than for the two ground modes. Domestic vessels in the Great Lakes-Seaway Fleet are over 30 years old, whereas the rail mode's mainline locomotive fleet and truck mode's long-haul tractor fleet are newer than 20 years, with much of the fleets newer than 10 years. As noted earlier, the repeal of the Canadian import duty and the introduction of the EPA assistance program for new power plants on existing U.S. vessels are stimulating fleet and power plant renewal that is expected to significantly improve the Great Lakes-Seaway Fleet's overall efficiency.

Greenhouse Gas (GHG) Emissions

Current Conditions

Once energy efficiency was determined, a comparison of GHG emissions was made based on total equivalent carbon dioxide (CO_2-e) emitted by each mode in carrying the same cargo an equal distance. The results show that marine produces fewer greenhouse gas emissions per tonne/kilometer (or thousand-cargo-ton/miles) than both the rail and truck modes.

In terms of incremental GHG emissions:

1. Compared to the Seaway-size Fleet carrying one tonne of cargo one kilometer, rail would produce 22% higher GHG emissions, and the truck mode 450% higher GHG emissions than marine.
2. Compared to the U.S. Fleet carrying one ton of cargo one mile, rail would emit 15% more GHG, and the truck mode 534% more GHG than marine.
3. Compared to the Combined Great Lakes-Seaway Fleet carrying one tonne of cargo one kilometer, rail would emit 19% more GHG, and the truck mode 533% more GHG than marine.

Table ES2 provides more detailed data and includes a column that shows the relative intensity when indexed to the marine fleet. The indexed columns indicate what each mode produces in emissions relative to marine. For example, for each tonne of GHG emissions from the Seaway-size Fleet in carrying a tonne of Seaway cargo one kilometer in 2010, the rail mode would produce 1.22 tonnes and trucks would produce 5.5 tonnes of GHG emissions.

Future Conditions

The truck is the only mode to have regulatory standards for GHG emissions requiring the use of fuel-saving technologies by highway tractor manufacturers over the 2014-2019 timeframe.

Table ES2. GHG Emissions Intensity Comparisons

GHG Emissions Intensity for the Seaway-size Fleet						
	2010			Post Renewal		
	g/CTK	lb/kCTM	Index	g/CTK	lb/kCTM	Index
Marine	11.5	37.0	1.00	7.7	24.9	1.00
Rail	14.1	45.1	1.22	13.3	42.7	1.72
Truck	63.4	203.5	5.50	55.1	177.0	7.12
GHG Emissions Intensity for the U.S. Fleet						
	2010			Post Renewal		
	g/CTK	lb/kCTM	Index	g/CTK	lb/kCTM	Index
Marine	12.4	39.6	1.00	8.5	27.3	1.00
Rail	14.2	45.7	1.15	13.4	43.0	1.57
Truck	78.3	251.2	6.34	67.9	217.9	7.98
GHG Emissions Intensity for the Combined Great Lakes-Seaway Fleet						
	2010			Post Renewal		
	g/CTK	lb/kCTM	Index	g/CTK	lb/kCTM	Index
Marine	11.9	38.3	1.00	8.1	26.1	1.00
Rail	14.2	45.5	1.19	13.3	42.9	1.64
Truck	75.5	242.4	6.33	65.5	210.3	8.07

g/CTK = grams emitted per cargo-tonne-kilometer.
lb/kCTM = pounds emitted per thousand cargo-ton-miles.

Source: RTG analysis.

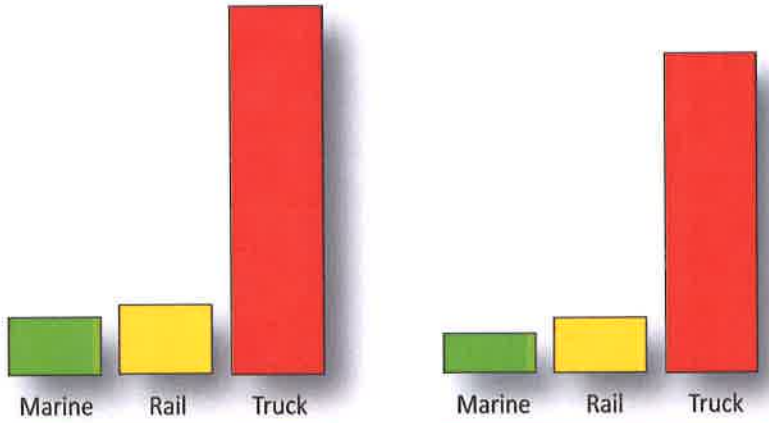
Table ES2 illustrates post-renewal comparisons that show it is expected that the marine mode will considerably improve its GHG performance relative to rail and trucks. Again, this is a reflection of fleet renewal and engine-replacement programs currently underway in the Canadian and U.S. Fleets.

Post renewal of all three modes:

1. Compared to the Seaway-size Fleet carrying one tonne of cargo a distance of one kilometer, rail would produce 72% higher GHG emissions, and the truck mode 612% higher GHG emissions;
2. Compared to the U.S. Fleet carrying one ton of cargo a distance of one mile, rail would emit 57% more GHG, and the truck mode 698% more GHG; and
3. Compared to the Combined Great Lakes-Seaway Fleet moving one tonne of cargo a distance of one kilometer, rail would emit 64% more GHG, and the truck mode 708% more GHG than marine.

Figure ES4 illustrates the GHG emissions intensity for the Combined Great Lakes-Seaway Fleet compared to the rail and truck modes.

Figure ES4. GHG Emissions Comparisons (2010 vs Post Renewal) Combined Great Lakes-Seaway Fleet



	2010			Post Renewal		
Grams per cargo-tonne-kilometer	11.9	14.2	75.5	8.1	13.3	65.6
Pounds per 1,000 cargo-ton-miles	38.3	45.5	242.4	26.1	42.9	210.3
Index	1.0	1.2	6.3	1.0	1.6	8.1

Source: RTG analysis.

Criteria Air Contaminants (CAC) Emissions

Criteria air contaminants (CACs) are a set of air pollutants that cause smog, acid rain and other health hazards. In the transportation industry, these emissions are related to the combustion of fuel to provide engine and auxiliary power.

The marine sector has been a later target for emissions regulations than the other modes. Criteria air contaminant (CAC) regulations were initially focused on the truck mode, then the rail mode and are now being introduced for the marine mode.

The truck mode was the focus of early regulatory standards and no further changes to the 2010 CAC regulations have been identified. The long-haul truck fleet is renewed more frequently than the other modes so regulatory changes work into the system performance quite quickly.

The rail mode was the second focus of CAC regulatory standards and partial advances were in place by 2010. Additional reductions of hydrocarbons (HC), nitrogen oxides (NO_X), particulate matter (PM) and sulfur dioxide (SO_2) are required by 2015.

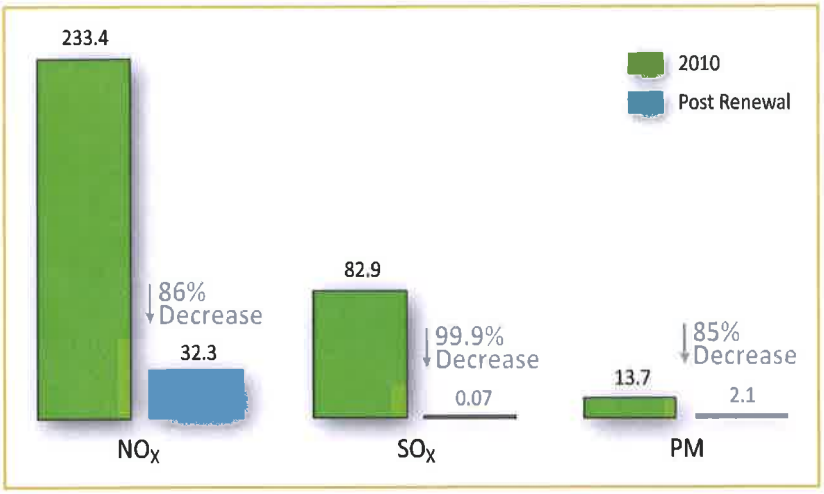
The marine mode has been the last mode to see CAC emissions regulations and all will take place over the 2012-2025 timeframe. The regulations will require significant reductions of NO_X and SO_2, and the reductions of SO_2 will produce reductions in PM. The marine fleet is also the oldest of the three modes. As a consequence, marine will see a much more dramatic improvement than the two ground modes in the future.

The study notes that in 2010, the marine mode overall was the lowest emitter for NO_X, but higher for sulfur oxides (SO_X) and PM compared to other modes. In the future, however, the fleets operating on the Great Lakes-Seaway System will realize significant reductions in CAC emissions. After meeting new regulatory conditions and achieving improvements with the use of new technology that would be economically available over the time frame 2012 to 2025, the Combined Great Lakes-Seaway Fleet would achieve significant decreases in emissions as follows:

- NO_X emission reductions of 86%
- SO_X emission reductions of 99.9%
- PM emission reductions of 85%

The emissions comparisons of NO_X, SO_X and PM for each mode are summarized in Table ES3 for the Seaway-size Fleet, Table ES4 for the U.S. Fleet and Table ES5 for the Combined Great Lakes-Seaway Fleet under current and future conditions.

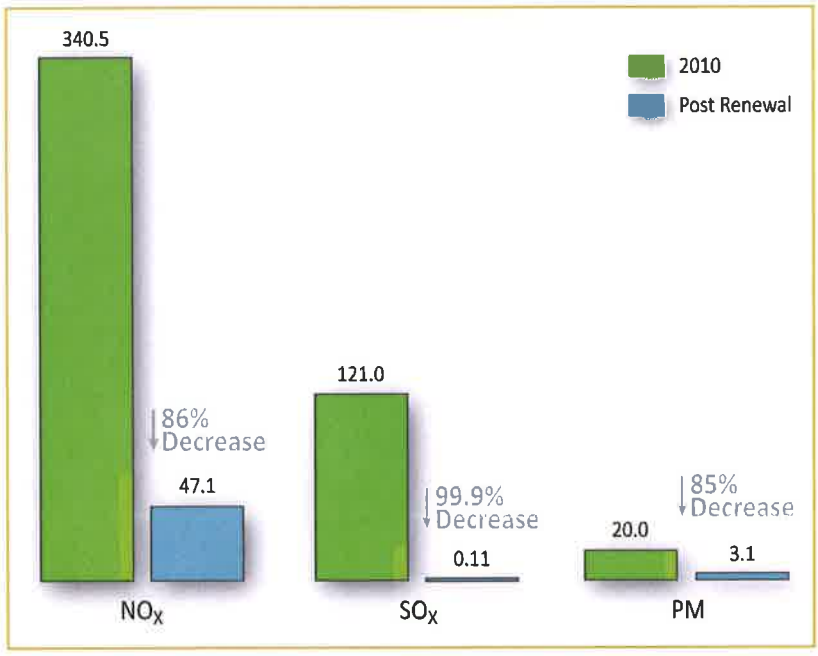
Figure ES5. CAC Comparison for Combined Great Lakes-Seaway Fleets (2010 vs Post Renewal)



g/kCTK = grams emitted per thousand-cargo-tonne-kilometers.

Source: RTG analysis.

Figure ES6. CAC Comparison for Combined Great Lakes-Seaway Fleets (2010 vs Post Renewal)



g/kCTM = grams emitted per thousand-cargo-ton-miles.

Source: RTG analysis.

Table ES3. Comparison of the Primary CAC Emissions for the Seaway-size Fleet

Year	Mode	NO_X		SO_X		PM	
		(g/kCTK)	(g/kCTM)	(g/kCTK)	(g/kCTM)	(g/kCTK)	(g/kCTM)
2010	Seaway-size Fleet	250.3	365.2	105.3	153.6	17.0	24.8
	Rail	237.1	346.2	0.8	1.2	6.1	9.0
	Truck	315.2	459.9	0.6	0.9	11.4	16.6
Post Renewal	Seaway-size Fleet	30.9	45.1	0.07	0.10	2.0	2.9
	Rail	33.4	48.8	0.108	0.158	0.5	0.7
	Truck	27.1	39.5	0.5	0.8	2.4	3.6

g/kCTK = grams emitted per thousand-cargo-tonne-kilometers.
g/kCTM = grams emitted per thousand-cargo-ton-miles.

Source: RTG analysis of confidential marine carrier data.

Table ES4. Comparison of the Primary CAC Emissions for the U.S. Fleet

Year	Mode	NO_X		SO_X		PM	
		(g/kCTK)	(g/kCTM)	(g/kCTK)	(g/kCTM)	(g/kCTK)	(g/kCTM)
2010	U.S. Fleet	215.2	313.9	58.9	85.9	10.1	14.7
	Rail	251.8	367.4	1.9	2.8	7.6	11.1
	Truck	391.6	571.4	0.7	1.1	13.7	20.0
Post Renewal	U.S. Fleet	33.8	49.3	0.08	0.11	2.2	3.2
	Rail	36.4	53.1	0.10	0.15	0.6	0.8
	Truck	38.5	56.2	0.6	0.9	2.7	4.0

g/kCTK = grams emitted per thousand-cargo-tonne-kilometers.
g/kCTM = grams emitted per thousand-cargo-ton-miles.

Source: RTG analysis of confidential marine carrier data.

Table ES5. Comparison of the Primary CAC Emissions for the Combined Great Lakes-Seaway Fleet

Year	Mode	NO_X		SO_X		PM	
		(g/kCTK)	(g/kCTM)	(g/kCTK)	(g/kCTM)	(g/kCTK)	(g/kCTM)
2010	Marine	233.4	340.5	82.9	121.0	13.7	20.0
	Rail	245.9	359.0	1.5	2.2	7.0	10.3
	Truck	392.0	572.0	0.7	1.0	13.3	19.4
Post Renewal	Marine	32.3	47.1	0.07	0.11	2.1	3.1
	Rail	35.2	51.4	0.10	0.15	0.53	0.77
	Truck	54.5	79.5	0.61	0.90	2.7	3.9

g/kCTK = grams emitted per thousand-cargo-tonne-kilometers.
g/kCTM = grams emitted per thousand-cargo-ton-miles.

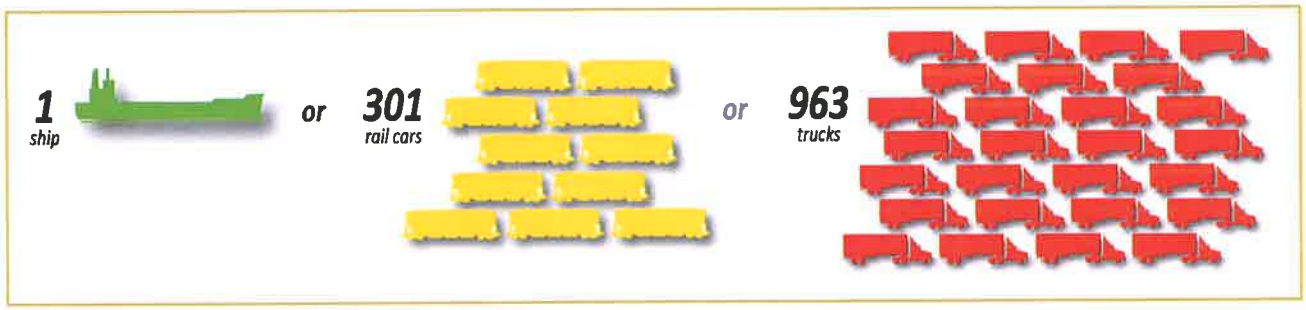
Source: RTG analysis of confidential marine carrier data.

The study authors note that marine's CAC emissions when on open water are comprised of emissions from propulsion engines and auxiliary engines, while emissions when docked at port are only from auxiliary engines. Criteria Air Contaminant (CAC) emissions consequences are dependent on the source location relative to areas of air-quality concern. Marine's CAC emissions on open water (as well as at many ports in remote areas) will have significantly different consequences than emissions at ports located in urban areas. Similarly, CAC emissions from the ground modes while traveling through remote areas will have significantly different consequences than their emissions when traveling through urban areas. The consequences of each mode's CAC emissions relative to each other, and the relative consequences of transportation's emissions relative to fixed-plant emissions are beyond the scope of this assignment. The authors believe that such a comparative evaluation would be in favor of the marine mode and recommend that such a comparative analysis be undertaken.

Modal Capacity

In the case of Seaway-size vessels carrying roughly 30,000 tonnes of cargo, it would take 963 trucks or 301 rail cars to carry the same load, as shown in Figure ES7.

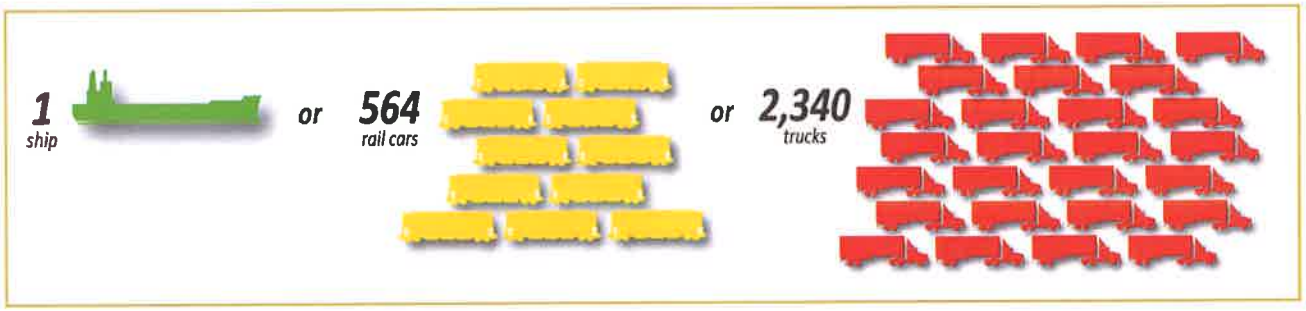
Figure ES7. To move 30,000 tonnes of cargo with a Seaway-size vessel



Source: RTG analysis.

The largest Great Lakes vessels, typically 1,000 feet in length, can carry 62,000 tons of cargo — equivalent to 2,340 trucks or 564 rail cars, as illustrated in Figure ES8.

Figure ES8. To move 62,000 tons of cargo with a Great Lakes 1,000-foot vessel



Source: RTG analysis.

The study calculates the potential traffic that would be created on highways or railways if the cargo transported by Great Lakes-Seaway vessels was shifted to trucks or rail and the resulting congestion and maintenance impacts.

- If the total cargo transported by the Combined Great Lakes-Seaway Fleet in 2010 was instead transported by truck, 7.1 million additional truck trips in the region would be required.
- An extra 1.9 million truck trips across the border would be required to move the cross-border cargo carried by the Combined Great Lakes-Seaway Fleet. To put this into perspective, the additional volume of trucks (equivalent to 8.8 million passenger car-equivalent traffic units) would be more than the total amount of annual traffic across the Ambassador Bridge in Detroit-Windsor — the busiest Canada-U.S. border crossing in terms of trade.
- One 1000-foot vessel carrying 62,000 tons (56,260 tonnes) passing under the Ambassador Bridge between Windsor and Detroit is equivalent to 2,340 trucks at a nominal 26.5 ton (24.1 tonne) load passing over the bridge. That is enough to fill a traffic lane for 50 kilometers (30 miles) back from the border inspection booths. While the number of trucks required to replace a single 1,000-foot vessel would not arrive at a border crossing at the same time, the comparison is still illustrative.
- The traffic moved by the combined Great Lakes-Seaway Fleet in 2010 would require about 3.0 million additional railcar trips throughout the region. This is equivalent to an additional 115 trains per day that would be distributed across the rail network. The increase for specific rail segments would represent as much as double the existing traffic on some rail lines in Canada and at least a 50% increase in traffic on some of the busiest lines in the U.S.

Traffic Congestion

The study notes that marine transport activities in the Great Lakes-Seaway region have a negligible impact on congestion delays for the traveling public. However, a shift of Great Lakes-Seaway traffic to the highway or rail modes would lead to increased levels of congestion and delays for the traveling public. The study attempts to quantify the costs of the delay impacts but notes that the impacts would be highly sensitive to the specific cargo movements that shifted, and to the values and time periods assumed for those delays.

Both of the ground modes have an impact on road traffic delays — trucks via direct interaction with other traffic and trains via delays incurred at road-rail at-grade crossings. Traffic congestion is mainly an urban issue. Nonetheless, a hypothetical shift of Great Lakes-Seaway traffic to the highway mode would decrease the available capacity of rural freeways by 5% to 15% (with the range covering level to rolling terrain). The capacity impacts would be higher for rural arterial highways with occasional passing lanes; however, capacity utilization is also lower on these highways.

The estimated cost of incremental urban congestion associated with shifting Great Lakes-Seaway traffic to trucks was in the range of $346 million to $380 million per year. The present value of this incremental cost would be $5.6 billion to $6.1 billion over a 24-year time period, assuming a 2.5% annual rate of growth in traffic.

The estimated cost of incremental delays at highway-railway grade crossings associated with shifting Great Lakes-Seaway traffic to rail was $46 million per year. The present value of this incremental cost would be approximately $750 million over a 24-year time period, assuming a 2.5% annual rate of growth in traffic.

Infrastructure Impacts

The study looks at the impacts on highway maintenance costs if the Great Lakes-Seaway cargo was shifted to trucks.

The trucking mode uses publicly maintained highway infrastructure with maintenance costs that are sensitive to traffic levels. Maintenance costs are a mix of recurring annual and longer-interval renewal investments. Pavement damage, which is the main traffic-sensitive component of the maintenance costs, is quite sensitive to axle loads. The Great Lakes-Seaway traffic is mostly bulk cargo, and involves truck configurations and axle loads that are much larger/heavier than the existing mix of intercity truck traffic. The incremental maintenance costs are derived on the basis of both the incremental traffic involved and the incremental axle loads utilized in hauling the traffic.

If Great Lakes-Seaway marine shipping cargo shifted to trucks permanently, it would lead to $4.6 billion in additional highway maintenance costs (calculated on a present-value basis over a 60-year period using a 6% discount rate).

The study did not undertake a full social cost analysis to determine the extent to which incremental fuel taxes generated by new truck traffic should be allocated to mitigate the maintenance costs.

Noise Impacts

Noise footprints for the three modes were developed on the basis of noise emitted during line-haul activity for each of the three modes.

The noise impacts of trains are a combination of the noise from air horns blown on approach to public highway-railway at-grade crossings and the noise from movement of trains that occurs everywhere. In the case of trucks, it is primarily the noise associated with the freeway and arterial highway systems that is relevant in determining noise impacts. Noise from trucks and trains related to loading and unloading activities at terminals and yards was not considered.

The noise footprint of the Great Lakes-Seaway Fleet is associated with the sounding of horns when vessels meet and when mooring lines are dropped in preparation for departure from locks and ports. As in the case of rail and trucks, noise emitted by vessels while at ports related to loading/unloading activity was not included.

On the basis of the analysis undertaken, the results show that:

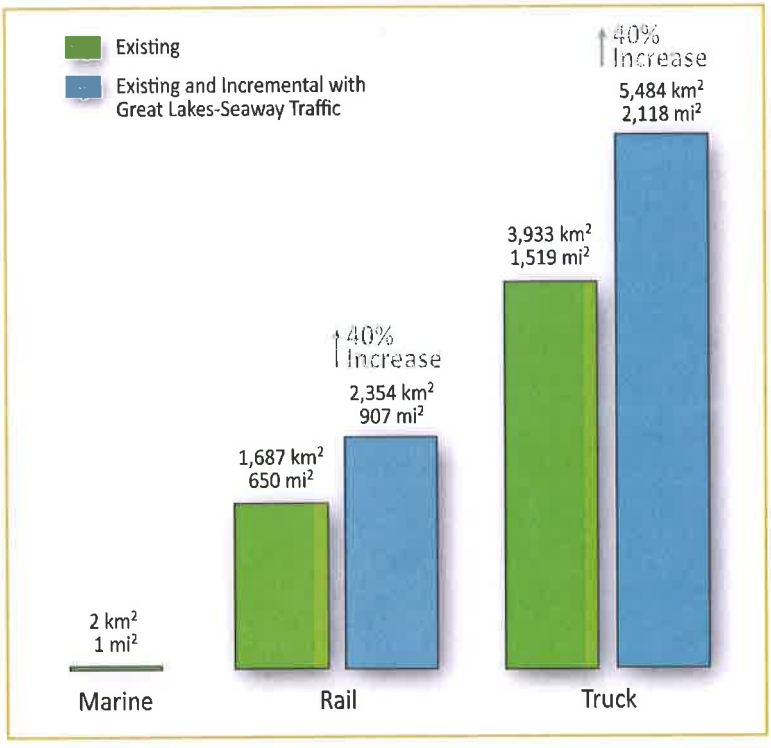
- The noise footprint of the Combined Great Lakes-Seaway fleet is negligible in comparison with that of the other modes; and
- The noise footprint for the rail and truck modes would increase by 40% if either mode were to transport the Great Lakes-Seaway cargo.

The noise footprints of the three modes illustrated in Figure ES9 show both the existing footprint and the marginal incremental footprint associated with a traffic shift from marine.

Figure ES9. Modal Noise Footprint Comparisons

Severe Ldn Footprint (sq. km.) / Severe Ldn Footprint (sq. mi.)

Source: RTG analysis.



6. Peer Review of Study

To ensure that the methodology used by Research and Traffic Group to measure and compare the impacts for marine, rail and trucking modes of transportation was sound and met generally accepted precepts of environmental analysis, a final draft version of this analysis was submitted to three Canadian and U.S. experts in transport logistics, economics and environmental sciences, for independent peer review. Research and Traffic Group responded in writing to all peer reviewer comments to the satisfaction of all three reviewers. Based on these comments, several minor adjustments were made to the analysis prior to final release. Letters from each of the three peer reviewers confirming their overall satisfaction with the analysis are included in the next section of this report.

Closing Comments from the Study Authors

This report, *The Environmental and Social Impacts of Marine Transport in the Great Lakes–St. Lawrence Seaway Region*, highlights that Great Lakes ships are more fuel-efficient and emit fewer greenhouse gases per tonne-kilometer than land-based alternatives. The analysis also shows that a shift of cargo carried by marine vessels on the Great Lakes-St. Lawrence Seaway navigation system to road and/or rail modes of transport would lead to increased levels of traffic congestion, higher infrastructure costs to maintain highways and significantly greater levels of noise.

New ship designs and engine technology being introduced to the Great Lakes fleet over the next few years will only serve to increase these benefits. In particular, the Great Lakes-Seaway fleet overall is expected to achieve significant reductions in emissions with a 32% decrease in GHG emissions, an 86% reduction in NO_X emissions, a 99% reduction in SO_X emissions and an 85% reduction in PM emissions.

With this report, the Great Lakes-Seaway shipping industry now has the latest information on its environmental and social performance compared to other modes. This bi-national data will allow the industry to measure its progress as a whole as it continues to reduce its environmental footprint in the coming years.

Gordon English, Partner
David Hackston, Partner
Research and Traffic Group

Study Peer Review

Introduction

A final draft version of this analysis was submitted to three Canadian and U.S. experts in transport logistics, economics and environmental sciences, for independent peer review. The review was intended to ensure that the methodology used by Research and Traffic Group to measure and compare the impacts for marine, rail and trucking modes of transportation was sound and met generally accepted precepts of environmental analysis. Research and Traffic Group responded in writing to all peer reviewer comments to the satisfaction of all three reviewers. Based on these comments, several minor adjustments were made to the analysis prior to final release. Letters from each of the three peer reviewers confirming their overall satisfaction with the analysis are included in this section.

Peer Reviewers

Dr. Bradley Z. Hull (B.S., M.S., Ph.D.)

Dr. Hull is Associate Professor and Reid Chair in the Department of Management Marketing and Logistics at John Carroll University (Cleveland, Ohio), where he teaches undergraduate and MBA courses in logistics and transportation. He researches transportation topics related to the Great Lakes and Seaway, and has hosted several conferences and given many presentations on opportunities for increased commercial use of this system. Dr. Hull has a business background that includes 28 years with British Petroleum with experience directing logistics operations for BP Oil Company and BP Chemicals, utilizing multiple transportation modes, including rail, truck, barge, pipeline and ship. With a PhD in Operations Research, Mr. Hull also directed and performed many quantitative supply chain analyses while working for BP.

John Lawson (B.A., M.A.)

Mr. Lawson is a recognized transport economist with nearly 40 years' experience, initially with the UK Department of Transport in the early 1970s, then from the mid-1970s to 2005 at Transport Canada. As Transport Canada's Director for Economic Analysis and Research, Mr. Lawson was responsible for analysis of policy issues, development of analytical methods and data. Retired from Transport Canada in 2005, Mr. Lawson is now an independent transport economics researcher and consultant, and Research Associate of the University of British Columbia Centre for Transport Studies. He consults for public and private sectors, in Canada and internationally, particularly on transport energy and emissions.

Captain James R. Parsons (MM, BMS, BEd, MSc, FCIP, PhD)

Capt. Parsons is the academic director for an online Masters of Maritime Management program at the Marine Institute of Memorial University in Newfoundland. He consults for the public and private sectors, most recently with WWF Canada, Transport Canada and NATO. His company Global Marine Solutions also provides marine consultancy, logistics, risk management and formal safety assessments for vessels, ports and terminals among other services. Capt. Parsons is a Master Mariner with extensive experience working in the Western, Central, and Eastern Canadian Arctic.

Peer Review Endorsement Letter from Dr. Bradley Hull

John Carroll University

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November 18, 2012

Mr. Raymond Johnston
President
Chamber of Marine Commerce
350 Sparks Street, Suite 700
Ottawa, Ontario, K1R 7S8

Re: Peer Review of "A Social/Environmental Impacts Comparison of the Surface Freight Transport Modes in the Great Lakes-Seaway Region" conducted by the Research and Traffic Group

Dear Mr. Johnston:

The RTG study is a detailed multi-tiered analysis that compares Great Lakes St. Lawrence Seaway transportation by ship, with the rail and truck alternatives. The comparison focuses on fuel efficiency and emissions generation, but also includes comparisons of modal capacity, congestion, and infrastructure. The study is based on confidential information provided by many waterborne carriers, data for specific Great Lakes Seaway railroads, and RTG simulations of rail and truck operations. It examines the impact of potentially transferring Great Lakes/Seaway cargos from water to rail and truck – both at present and in the future.

Per your request, I have spent considerable time reviewing the RTG study. Due to confidentiality of the waterborne data and the simulations, I cannot validate the results of the study. However, the methodology behind the study appears sound. The authors have detailed knowledge of the rail, truck and Great Lakes/Seaway shipping industries, and spent a great deal of time and effort developing data sources and structuring their analysis. During my review, I found the authors responsive at addressing my observations and suggestions, and incorporating the results into the study.

Respectfully,

Bradley Hull

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Peer Review Endorsement Letter from John Lawson

LAWSON ECONOMICS RESEARCH INC.
Independent Transport and Economics Research, Ottawa, Canada

Mr Raymond Johnston
President
Chamber of Marine Commerce
350 Sparks Street, Suite 700
Ottawa, Ontario
K1R 7S8

Dear Mr. Johnston:

Re: Peer Review of "A Social/Environmental Impacts Comparison of the Surface Freight Transport Modes in the Great Lakes-Seaway Region: Draft Final Report," prepared for The Chamber of Marine Commerce by the Research and Traffic Group, September 2012.

As requested, I undertook and reported on my "Peer Review" of the above report, interpreting my task as primarily to comment on the validity of the methods and results based on my experience as a transport economist and my knowledge of North American transportation, and also to make editorial suggestions about the clarity and accuracy of the text. As I had provided some of the material used in the safety comparisons as a minor sub-contractor to the Research & Traffic Group, I excused myself from commenting on the safety component of the report.

My overall assessment is that the study offers a substantial improvement over previous comparisons of the impacts of freight modes, through its use of improved information and its application of improved engineering models and simulations to estimate activities in the three modes, and to examine the marginal impacts if GL-S marine freight were shifted to the competing modes of rail or truck. Major improvements were achieved particularly through RTG's access to new information on marine movements and fuel consumption, also to RTG's new model of truck energy use and emissions, and simulation model of rail energy use and emissions.

The study provides more information on the particular GL-S traffic, and a more appropriate comparison of the modal characteristics of the traffic, than any previously published, either in Canada or the US. Comparisons of modal freight traffic impacts have often been attempted, but typically use nationally-reported statistics with important limitations on their comparability among the modes, and on the consistency between different dimensions of impacts. The basic traffic measures, of tonnes of cargo shifted and trip distances, and therefore freight tonne-kilometres, are not reported nationally in Canada for trucks or marine vessels; and while national statistics are reported in the US, they rely to some extent on assumption and inference. Calculations combining those tonne-km estimates with national statistics of system-wide fuel consumption, emissions, accidents, spills etc, to produce rates per tonne-kilometre for comparisons among the modes therefore suffer from those uncertainties. Researchers (and even Government departments) have in fact unknowingly calculated incorrect rates, using tonne-km estimates from only a segment of national traffic that happened to be reported in national statistics (in Canada, for example, estimates of tonne-km in domestic marine freight and in for-hire trucking have been compared respectively to total marine fuel and total truck fuel refinery sales, producing gross overestimates of fuel use per tonne-km in both cases).

Furthermore, even if such problems could be avoided, it has normally been possible using published statistics to make estimates of average rates of freight impacts only at the national, network-wide levels. Traffic diversity means such estimates are hardly appropriate for any region, and certainly not for the GL-S region with its particular mix of commodities, trip O-Ds and equipment types. Attempts in previous studies to adjust available statistics to represent GL-S traffic have relied on assumptions to provide rough approximations. The current study is I believe unique particularly in describing the marine mode traffic impacts, and considering the marginal effects if that traffic were diverted to the competing rail or truck modes.

The report correctly spends most effort and space on fuel consumption and emissions of GHGs and CACs as the impacts of most current interest and debate, and the greatest research challenges due to the data and modelling requirements. The study is impressive in its development of consistent measures of activity in freight movements in the three modes, including tonne-kilometres, and comparable estimates of fuel consumption, to enable estimation of rates of GHG and CAC emissions. Comparisons of those rates are the major achievement of the study, but it also provides valuable information on the effects on congestion, infrastructure requirements, and noise from hypothetical transfers of freight from marine to the other two modes.

In my review I provided a number of comments and questions for clarification, which were all addressed in the finalized report.

Sincerely,

John Lawson

John Lawson
President and Principal of Lawson Economics Research, Inc.

2012-11-13

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17 November 2012

Mr. Raymond Johnston
President
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Ottawa, Ontario, K1R 7S8

RE: A Peer Review of "A Social/Environmental Impacts Comparison of the Surface Freight Transport Modes in the Great Lakes-Seaway Region" conducted by Research and Traffic Group

Dear Mr. Johnston:

As per your request, I have reviewed the RTG report with great interest, paying particular attention to the validity of the methodology employed. As the various freight carriers had provided confidential data to RTG, it was not possible to validate the findings of the report.

Overall the report does a very fair, rigorous, and thorough examination and comparison of three unique modes of transport with respect to the external impacts of a mode shift of GL-S cargo to or from marine carriage relative to rail and road carriage. A direct comparison of three unique modes of transport occurring within and throughout several states and provinces of two different countries, each with its own restrictions, is not straightforward. In many cases were data sets were not collected, complied and presented in similar fashion, the report takes a very fair, honest, and open approach at making like-for-like comparisons. Simulation and sensitivity analysis are undertaken where data is absent, vague, or inconsistent so as to provide scientific rigour to the report. With respect to the social and environmental impacts of the three modes of carriage, the report is thorough in the selection of the areas of focus ranging from greenhouse gas emissions to the provision and maintenance of infrastructure. The methodological approach to the study is valid and reliable.

During my careful examination of the draft report I did note several minor and major observations, all of which were satisfactorily addressed by the RTG in the final report. In light of data limitations, scientific uncertainty and a lack of consensus from the scientific community on matters such as futuristic water levels and impacts on infrastructure, RTG delivered as per their project scope.

Respectfully Submitted,

Captain James R. Parsons, PhD
Global Marine Solutions