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GENIVAR

TP 15000E

EVALUATION OF ENVIRONMENTAL AND SOCIAL IMPACTS AND BENEFITS OF SHORTSEA SHIPPING IN CANADA

Prepared for
Transport Canada

December 2008

5355 Des Gradins Blvd. ~ Quebec (Quebec) CANADA G2J 1C8

Tel.: (418) 623-2254 ~ Fax: (418) 624-1857 ~ www.genivar.com

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Prepared by:

Christian Couette, MBA
Jean-Philippe Brosseau, M.Sc.
Jessica Beauguitte, Jr. Eng.

GENIVAR Limited Partnership

December 2008

NOTICES

This report reflects the views of the authors and not necessarily those of Transport Canada.

Since some of the accepted measures in the industry are imperial, metric measures are not always used in this report.

Un sommaire français se trouve avant la table des matières.

WORK TEAM

GENIVAR Limited Partnership

Project Director:	Christian Couette, M.B.A.
Project Manager:	Jean-Philippe Brosseau, M.Sc.
Analyst:	Jessica Beauguitte, Jr. Eng.

Innovation Maritime

General Director:	Nicolas Parent
Analyst:	Guy Redah

Hanam Canada Corporation

President:	Helmut Burke, P.Eng. M.B.A

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16. Abstract

The purpose of this study was to evaluate the environmental and social impacts of shortsea shipping in Canada and to compare the outcome with the rail and road modes. The environmental impacts considered were fuel consumption efficiency, criteria air contaminants, greenhouse gases and other non-quantifiable environmental impacts. The social impacts considered were accidents, congestion and noise.

A model incorporating the best approaches assessing the environmental and social impacts was developed to compare the three transportation modes on an economic basis. The results of the modal comparison should be used with care, given the general and specific limitations of the model developed for the study.

The study demonstrated the potential that shortsea shipping has in terms of helping the government of Canada reach its sustainable development objectives. The model showed that the environmental and social costs of shortsea shipping are generally lower than the rail and road transportation modes, when a port-to-port comparison is considered.

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16. Résumé

Cette étude avait pour but d'évaluer les impacts environnementaux et sociaux du transport maritime à courte distance au Canada et de comparer les impacts de ce type de transport avec ceux du transport ferroviaire et du transport routier. Les impacts environnementaux pris en compte étaient la consommation de carburant, les principaux contaminants atmosphériques, les gaz à effet de serre, ainsi que d'autres impacts environnementaux non quantifiables. Au nombre des impacts sociaux étudiés figuraient les accidents, la congestion et le bruit.

L'étude a comporté le développement d'un modèle incorporant des méthodes optimales d'évaluation des impacts environnementaux et sociaux pour permettre une comparaison économique des trois modes de transport. Il convient d'utiliser avec prudence les résultats de cette comparaison intermodale, en tenant compte des limites générales et particulières de ce modèle, développé expressément pour l'étude.

L'étude a démontré que le transport maritime à courte distance peut aider le gouvernement du Canada à atteindre ses objectifs en matière de développement durable. Le modèle a en effet révélé que les coûts environnementaux et sociaux du transport maritime à courte distance sont généralement inférieurs à ceux du transport ferroviaire et du transport routier, lorsque l'on compare des mouvements de port à port.

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EXECUTIVE SUMMARY

The purpose of this study, commissioned by Transport Canada (TC), is to evaluate the environmental and social impacts of shortsea shipping in Canada and to compare the outcome with the rail and road modes. In this context, a model incorporating the best approaches for the assessment of environmental and social impacts was developed so as to compare the three transportation modes on an economic basis. The results of the modal comparison should be used with care, given the general and specific limitations of the model developed for the study.

Environmental and Social Impacts

The environmental impacts considered in this study are fuel consumption efficiency, criteria air contaminants (CAC), greenhouse gases (GHG) and other non-quantifiable environmental impacts, while the social costs considered are accidents, congestion and noise.

The fuel consumption efficiency of the marine, rail and road modes are considered in a context of energy efficiency. The fuel consumption of each mode is measured in litres.

The CAC (SOx, NOx, PM) and GHG (CO_2, CH_4, N_2O) emissions are calculated in grams per tonne of freight per kilometre of freight movement, in order to compare them between the three transportation modes. The economic values of the emissions are then calculated, in the case of CAC, by applying unit costs of air pollution by pollutant emitted by province, and, in the case of greenhouse gases, by applying a unit cost for one tonne of CO_2-equivalent.

Other environmental issues, such as operational water pollution, non-indigenous aquatic species, anti-fouling paint and waste management, are not incorporated in the model, given that no methodologies are proposed in the literature for their quantification. Therefore, these impacts are discussed qualitatively in the study.

Moreover, accident cost valuation is based on a methodology that estimates the unit costs of accidents for the three transportation modes. A Statistical Life Value as well as a major injury value are used to calculate the accident unit costs.

Congestion costs are also considered in the model, as time saving and congestion are significant types of social costs. Marginal public costs of highway use by trucks in terms of cents per vehicle – kilometre are used in the model. Given the absence of methodologies in the literature to evaluate congestion costs for the marine and rail modes, the study does not consider congestion costs for those two modes.

Finally, noise costs are considered in the model. Noise costs generally consist of costs for annoyance and health. Marginal costs per province, in terms of dollars per vehicle – kilometre, are used in the model. No noise costs are considered for the marine mode.

The Scenarios

The model used in the study is based on realistic transportation case studies on main Canadian seaways. The four scenarios considered are located on the Great Lakes, the St. Lawrence system, the East Coast and the West Coast.

	Scenario 1	**Scenario 2**	**Scenario 3**	**Scenario 4**
	Great Lakes	**St. Lawrence System**	**East Coast**	**West Coast**
Origin	Superior (WI)	Halifax (NS)	Saint John (NB)	Prince Rupert (BC)
Destination	Nanticoke (ON)	Montreal (QC)	Boston (MA)	Richmond (BC)
Cargo weight (tonnes)	25,000	10,000	35,000	25,000
Type of products	Solid bulk	Truck trailers and containers	Petroleum products	Containers
Ship type	Seaway (Bulker 25,000)	Ro-Ro's - Lo-Lo's	Product tanker (35,000)	Ro-Ro's
Distance (km)				
Rail	1,514	1,226	1,616	1,513
Road	1,466	1,251	665	1,505
Marine	1,510	1,950	550	704

Notes regarding distances:
- Distances presented are approximate.
- Sources: CN, Innovation Maritime and GENIVAR.

For each scenario, the transportation modes are compared on a 2008-dollar basis. Thus, the model allows for identification of the transportation mode having the lowest environmental and social costs. The results are presented in the following table.

Total Environmental and Social Costs ($2008)	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**
	Great Lakes	**St. Lawrence System**	**East Coast**	**West Coast**
Rail	$144,391	**$29,665**	$97,285	$47,305
Road	$350,151	$97,655	$175,645	$174,556
Marine	**$29,674**	$30,170	**$4,781**	**$10,420**

Modelling results show that the shortsea shipping transportation mode has the lowest environmental and social costs for three of the four scenarios, while the rail mode has a slightly lower cost compared to the marine mode for the remaining scenarios.

Those results demonstrate that the marine mode seems to gain an advantage in terms of environmental and social costs when the total distance to cover is equal or lower than the distance to cover with the rail or road modes. In the case of the St. Lawrence system scenario, for which the rail mode has lower environmental and social costs, the distance to cover for the marine mode is about 50% higher than those to cover by the two other transportation modes.

Limitations of the Model

The model developed for this study has limitations that limit the scope of the results regarding modal comparison of environmental and social impacts and should be used with care. The following table summarizes the general and specific limitations. They can be considered as suggestions for improving the model.

General Limitations
1. The model assumes the tonnage to be shipped is equivalent to one trip with the chosen marine vessel. The shipping possibilities that can be studied with the model are limited to the weight capacity of the twelve types of vessels presented in the study.
2. The model examines routes between given port pairings. The whole transportation chain is not considered. Consequently, the model tends to favour shortsea shipping, as the overall impacts of all the components in the goods movement chain from origin to destination are not considered.
3. The model is making a comparison on a one-way trip basis. Return trips are not considered for any modes. This may be a disadvantage for railways or trucking companies, as it may be argued that these transportation modes may have more backhaul opportunities.
4. Choosing tonne-km as the transportation service measurement unit has limitation when trucking is considered, given that the vast majority of trucked shipments are volume constrained rather than weight constrained, while it is the opposite for train and ships. This introduces a bias against trucking performance in the mode comparison.
Specific Limitations
1. Energy efficiency: An update of CO_2e unit costs should be considered in a future version of the model considering that a Canadian Carbon market should be structured in the next few years.
2. Accidents: The marine mode enjoys an advantage over the other modes regarding accident costs. Given the impact this parameter has on the results from the model, a quantification of “property damage collisions” for the marine mode should be considered in a further study once this data has become available.
3. Congestion: Canadian congestion due to freight transportation must be further studied. Unit cost evaluation was studied in the last few years, but only in a passenger context. Unit costs considered in this model come from a US study. This is a limitation to the model given that these unit costs do not reflect the Canadian road transportation system. Moreover, the model assumes that all trucks will encounter some level of congestion in urban areas, whereas this might not be the case depending on the itinerary and traffic fluidity patterns. The model also assumes that there is no congestion for the marine and rail modes.
4. Noise: Gillen (2007) road noise estimates must be used with care. The cover note of the Gillen study indicates that the figures are an order of magnitude of costs of noise from transportation activities. The model also assumes that rail transportation effects can be calculated with the same unit costs as road transportation. This assumption is a limitation of the model. It comes from Gaudry et al. (2006) that states that the noise unit costs for heavy trucks and rail are equivalent.

Shortsea Shipping and Sustainable Development

The results of the study demonstrate the potential that shortsea shipping has in terms of helping the government of Canada reach its sustainable development objectives. The model developed for the study shows that the environmental and social costs of shortsea shipping are generally lower than the rail and road transportation modes, when a port-to-port comparison is considered.

The following recommendations are made regarding the fostering of the development of shortsea shipping activities in a context of sustainable development (SD). Three basic principles are generally applied when developing sustainable development strategies: developing knowledge, promoting responsible action and fostering commitment.

1. Developing knowledge
    - The Government should foster knowledge development in support of better decisions, legislation and policies on sustainable development as well as to better inform stakeholders of its actions.

2. Promoting responsible actions
    - The Government should enhance promotion of shortsea shipping, but not to the exclusion of railway and truck modes. Shortsea shipping is part of an integrated system.
    - The Government should focus on a well-integrated intermodal transportation system by planning for the fluidity of goods' movement between modes and improving port facilities. SD strategies will in that context have to support competitive logistics systems.

3. Fostering commitments
    - The Government's policies, regulations and legislation concerning environmental issues should consider the ongoing economic viability of the marine industry.
    - The Government, in cooperation with industry representatives, should identify measures to encourage ship-owners to upgrade or renew their fleets.
    - The Government should set clear and realistic SD targets.
    - The Government should increase cooperation with Canadian Port Authorities to ensure their understanding and interests regarding SD issues.

SOMMAIRE

Cette étude, commandée par Transports Canada (TC), avait pour but d'évaluer les impacts environnementaux et sociaux du transport maritime à courte distance au Canada, et de comparer les impacts de ce type de transport avec ceux du transport ferroviaire et du transport routier. Un modèle a été développé à cette fin. Celui-ci utilise des méthodes optimales d'évaluation des impacts environnementaux et sociaux pour permettre une comparaison économique des trois modes de transport. Il convient d'utiliser avec prudence les résultats de cette comparaison intermodale, en tenant compte des limites générales et particulières de ce modèle, développé expressément pour l'étude.

Impacts environnementaux et sociaux

Les impacts environnementaux étudiés sont la consommation de carburant, les principaux contaminants atmosphériques (PCA), les gaz à effet de serre (GES), ainsi que d'autres impacts environnementaux non quantifiables; les coûts sociaux englobent les accidents, la congestion et le bruit.

La consommation de carburant dans les trois modes, maritime, ferroviaire et routier, est examinée sous l'angle de l'efficacité énergétique, et elle est mesurée en litres.

Les émissions de PCA (SO_x, NO_x, PM) et de GES (CO_2, CH_4, N_2O) sont calculées en grammes par tonne de marchandises transportée sur un kilomètre, rapport qui constitue une base de comparaison commune aux trois modes de transport. Ces émissions sont ensuite chiffrées en coût. À cette fin on utilise, dans le cas des PCA, le coût unitaire de la pollution atmosphérique par matière polluante émise, par province, et dans le cas des gaz à effet de serre, le coût unitaire associé à une tonne d'équivalent CO_2.

D'autres impacts environnementaux, comme la pollution de l'eau, l'introduction d'espèces aquatiques non indigènes, la peinture antisalissure et la gestion des déchets, ne sont pas intégrés au modèle, car on n'a trouvé dans la littérature aucune méthode pour les quantifier. Ces impacts sont donc examinés uniquement sous un angle qualitatif.

Par ailleurs, l'évaluation du coût des accidents est fondée sur une méthode qui établit le coût d'un accident pour les trois modes de transport. Cette méthode utilise la valeur statistique de la vie humaine, ainsi que la valeur attribuée à une blessure grave.

Le modèle incorpore en outre les coûts de congestion, car le gain de temps et la congestion sont des aspects importants des impacts sociaux. Les coûts marginaux pour le secteur public associés à l'utilisation des routes par les camions, en cents par véhicule-kilomètre, font aussi partie du modèle. Comme il n'existe pas, dans la littérature, de méthode pour évaluer les coûts de congestion dans le transport maritime et le transport ferroviaire, l'étude n'a pas examiné les coûts de la congestion dans ces deux modes.

Finalement, le modèle intègre les coûts engendrés par le bruit, lesquels comprennent généralement les coûts associés à la nuisance et aux problèmes de santé dus au bruit. Le modèle utilise les coûts marginaux par province, en dollars par véhicule-kilomètre. Aucun coût associé au bruit n'est pris en compte pour le transport maritime.

Les scénarios

Le modèle mis au point pour l'étude est fondé sur des études de cas réalistes de transport maritime sur quatre grandes voies maritimes du Canada, soit les Grands Lacs, le système du Saint-Laurent, la Côte Est et la Côte Ouest.

	Scénario 1	**Scénario 2**	**Scénario 3**	**Scénario 4**
	Grands Lacs	**Système du Saint-Laurent**	**Côte Est**	**Côte Ouest**
Origine	Superior (WI)	Halifax (N.-É.)	Saint John (N.-B.)	Prince Rupert (C.-B.)
Destination	Nanticoke (Ont.)	Montréal (Qc)	Boston (MA)	Richmond (C.-B.)
Poids de marchandises (tonnes)	25 000	10 000	35 000	25 000
Type de chargement	Vrac solide	Remorques et conteneurs	Produits pétroliers	Conteneurs
Type de navire	Vraquier de la Voie maritime (25 000)	Ro-Ro* - Lo-Lo**	Transporteur de produits raffinés (35 000)	Ro-Ro
Distance (km)				
Ferroviaire	1 514	1 226	1 616	1 513
Routier	1 466	1 251	665	1 505
Maritime	1 510	1 950	550	704

Notes concernant les distances :
- Les distances sont approximatives.
- Sources : CN, Innovation Maritime et GENIVAR.

* Porte-conteneurs à manutention horizontale
** Porte-conteneurs à manutention verticale

Pour chaque scénario, les modes de transport sont comparés sur la base de dollars de 2008. Le modèle permet donc de déterminer le mode de transport qui engendre les coûts sociaux et environnementaux les plus faibles. Les résultats sont présentés dans le tableau ci-après.

Coûts totaux, impacts environnementaux et sociaux ($ 2008)	Scénario 1	Scénario 2	Scénario 3	Scénario 4
	Grands Lacs	Système du Saint-Laurent	Côte Est	Côte Ouest
Ferroviaire	144 391 $	**29 665 $**	97 285 $	47 305 $
Routier	350 151 $	97 655 $	175 645 $	174 556 $
Maritime	**29 674 $**	30 170 $	**4 781 $**	**10 420 $**

Les résultats montrent que le transport maritime à courte distance est celui qui entraîne les coûts environnementaux et sociaux les plus bas, dans trois scénarios sur quatre; les coûts associés au transport ferroviaire sont légèrement inférieurs à ceux du transport maritime dans le scénario restant.

Il semble donc que le transport maritime s'avère avantageux, pour ce qui est des coûts environnementaux et sociaux, lorsque la distance totale à franchir est égale ou inférieure à celle qu'il faut franchir par train ou par camion. Ainsi, dans le cas du système du Saint-Laurent, où le transport ferroviaire affiche des coûts environnementaux et sociaux plus faibles que le transport maritime, la distance à parcourir par eau est d'environ 50 % de plus que par le rail ou la route.

Limites du modèle

Le modèle développé aux fins de la présente étude comporte des limites qui restreignent la portée des résultats de la comparaison, ce qui invite à la prudence dans l'interprétation de ceux-ci. Le tableau ci-après résume ces limites, générales et spécifiques. Celles-ci peuvent être considérées comme des suggestions pour améliorer le modèle.

Limites générales
1. Selon le modèle, le tonnage transporté par train ou par camion est équivalent à celui transporté par le navire choisi, en un seul voyage. Le modèle ne peut donc tenir compte que des capacités d'emport des douze types de navires présentés dans l'étude.
2. Le modèle examine des trajets entre ports, sans tenir compte de toute la chaîne de transport. Il a donc tendance à être favorable au transport maritime à courte distance, car il laisse dans l'ombre les impacts associés à toute la chaîne de transport des marchandises, de l'origine à la destination.
3. Le modèle établit des comparaisons entre voyages aller seulement, ne prenant jamais en compte les voyages de retour. Or, cela peut être défavorable aux entreprises de transport ferroviaire ou routier, car on peut penser que les trains et les camions ont davantage d'occasions que les navires de rentabiliser leurs voyages de retour.
4. Le choix des tonnes-km en tant qu'unité de mesure du service de transport comporte des limites pour le camionnage, car, contrairement aux expéditions par train et par navire, la grande majorité des expéditions par camion sont mesurées selon leur volume et non selon leur poids. Cela introduit un biais défavorable au transport par camion dans la comparaison intermodale.

Limites spécifiques
1. Efficacité énergétique : une version future du modèle devrait comporter une mise à jour des coûts unitaires par équivalent CO_2, pour tenir compte de la bourse du carbone qui devrait être mise en place au Canada dans les prochaines années.
2. Accidents : le transport maritime jouit d'un avantage par rapport aux autres modes de transport en ce qui a trait au coût des accidents. Étant donné l'effet de ce paramètre sur les résultats du modèle, il importera d'établir le coût des « accidents avec dommages matériels » dans le transport maritime, lors d'une étude subséquente, quand ces données seront disponibles.
3. Congestion : il y a lieu de se pencher plus avant sur la congestion due au transport de marchandises au Canada. On a établi des coûts unitaires de la congestion ces dernières années, mais seulement pour les passagers. Les coûts unitaires utilisés dans le présent modèle proviennent d'une étude menée aux États-Unis. Cela représente une limite, car ces coûts unitaires ne reflètent pas la situation canadienne. De plus, le modèle suppose que tous les camions font face à un certain niveau de congestion dans les zones urbaines, mais tel n'est pas nécessairement le cas, selon l'itinéraire et la fluidité du trafic. Le modèle suppose en outre l'absence de congestion dans le transport maritime et le transport ferroviaire.
4. Bruit : les estimations de Gillen (2007) concernant le bruit engendré par le transport routier doivent être envisagées avec un certain recul. En effet, la note de couverture de l'étude de Gillen indique que les chiffres représentent un ordre de grandeur des coûts associés au bruit engendré par les activités de transport. Aussi, le modèle suppose que les effets du transport ferroviaire peuvent être calculés à l'aide des mêmes coûts unitaires que ceux associés au transport routier. Cette hypothèse constitue une limite du modèle. Elle découle de l'étude de Gaudry et coll. (2001), selon laquelle les coûts unitaires associés au bruit des camions lourds et au bruit des trains sont équivalents.

Transport maritime à courte distance et développement durable

L'étude a démontré que le transport maritime à courte distance peut aider le gouvernement du Canada à atteindre ses objectifs en matière de développement durable. Le modèle a en effet révélé que les coûts environnementaux et sociaux du transport maritime à courte distance sont généralement inférieurs à ceux du transport ferroviaire et du transport routier, lorsque l'on compare des mouvements de port à port.

Les recommandations ci-après concernent la promotion du transport maritime de marchandises dans un contexte de développement durable. L'élaboration de stratégies de développement durable s'appuie généralement sur trois principes de base : le développement du savoir, la promotion des gestes responsables et l'engagement des parties intéressées.

1. Développement du savoir
   - Le gouvernement doit encourager le développement du savoir, afin de pouvoir prendre les meilleures décisions et élaborer des lois et des politiques optimales en matière de développement durable, et de mieux informer les parties intéressées de ses actions.

2. Promotion de gestes responsables
    - Le gouvernement doit davantage promouvoir le transport maritime à courte distance, mais sans exclure le transport ferroviaire et le transport routier. Le transport maritime à courte distance doit constituer un élément d'un système intégré.
    - Le gouvernement doit doter le pays d'un système de transport intermodal bien intégré, en prenant des mesures pour garantir la fluidité des mouvements de marchandises entre les divers modes de transport, et en améliorant les installations portuaires. Dans ce contexte, les stratégies de développement durable doivent appuyer des systèmes logistiques compétitifs.

3. Engagement des parties intéressée
    - Les politiques, règlements et lois du gouvernement en matière environnementale doivent faire en sorte de maintenir la viabilité économique du secteur maritime.
    - Le gouvernement, en coopération avec des représentants de l'industrie, doit trouver des façons d'encourager les propriétaires de navires à améliorer ou renouveler leurs flottes.
    - Le gouvernement doit établir des cibles claires et réalistes en matière de développement durable.
    - Le gouvernement doit accroître sa coopération avec les administrations portuaires canadiennes afin de les rendre plus sensibles et plus intéressées aux enjeux du développement durable.

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GLOSSARY

BC	British Columbia
BTS	US Bureau of Transportation Statistics
CAC	Criteria air contaminants
Cd	Cadmium
CH_4	Methane
CN Rail	Canadian National Railway
CO	Carbon monoxide
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
DWT	Deadweight
EPA	Environmental Protection Agency
FEU	Forty foot equivalent units
GHG	Greenhouse gas
GWP	Global warming potential
HC	Hydrocarbon
HFO	Heavy fuel oil
Hg	Mercury
HM	Heavy metals
INFRAS	Zurich consulting group
IMO	International Maritime Organization
IWW	University of Karlsruhe Institute for Economic Policy Research
Lo-Lo	Lift on / lift off
MA	Massachusetts
MCeX	Montréal Climate Exchange
MDO	Marine diesel oil
MTO	Ministry of Transportation of Ontario
N_2O	Nitrous oxide
NB	New Brunswick
NFL	Newfoundland and Labrador
NH_3	Ammonia
NOx	Oxides of nitrogen
NRTEE	National Round Table on the Environment and the Economy

NS	Nova Scotia
O_3	Ozone
OECD	Organisation for Economic Co-operation and Development
ON	Ontario
Pb	Lead
PEI	Prince Edward Island
PM_{10}	Particulate matter (particle size 10 micrometres or less)
$PM_{2.5}$	Particulate matter (particle size of less than 2.5 micrometres)
POP	Persistent organic pollutants
QC	Quebec
Ro-Ro	Roll on / roll off
RTK	Revenue tonne kilometre
SD	Sustainable development
SDS	Sustainable development strategies
SFC	Specific fuel consumption
SO_2	Sulphur dioxide
SOx	Oxides of sulphur
TBT	Tributyltin
TC	Transport Canada
TEU	Twenty foot equivalent units
UNCTAD	United Nations Conference on Trade and Development
US	United States
USEC Middle	US East Coast middle states (Delaware, District of Columbia, Maryland, New Jersey, Pennsylvania, Virginia, West Virginia)
USEC North	US East Coast northern states (Connecticut, Maine, Massachusetts, New Hampshire, New York, Rhode Island, Vermont)
USEC South	US East Coast southern states (Florida, Georgia, North Carolina, South Carolina)
USGL	US Great Lakes states (Illinois, Indiana, Michigan, Minnesota, Ohio, Wisconsin)
VKT	Vehicle-kilometre travelled
VOC	Volatile Organic Compounds
WI	Wisconsin
WTP	Willingness to pay

1. INTRODUCTION

1.1 Background

Since 2003, TC has placed great emphasis on the possibilities of enhancing shortsea shipping. It defines shortsea shipping as follows:

> *"Shortsea shipping involves the movement of cargo or passengers by water over relatively short distances. It can occur within lakes and river systems and along coast lines. It consists of mainly domestic shipping but can also include cross-border traffic (Canada–US–Mexico). It does not consist of shipping across the world's major oceans."*

The federal government has confirmed the importance of the analysis and promotion of this under-used form of transportation. With a better use of Canadian seaway capabilities, shortsea shipping could contribute to the decrease of congestion, to the enhancement of trade, to the reduction of air emissions such as greenhouse gases (GHG) and criteria air contaminants (CAC), and finally to increased transportation network efficiency.

The purpose of this study, commissioned by TC, is to evaluate the potential of shortsea shipping regarding environmental and social impacts, as compared to trucking and rail. These impacts include environmental impacts, such as air emissions, as well as social impacts, such as congestion, accidents or noise. The impacts are compared on an economic value basis.

After preparing four realistic case studies on main Canadian seaways, namely the West Coast, the Great Lakes, the St. Lawrence River and the East Coast, the environmental impacts and benefits of shortsea shipping vis-à-vis road and rail transportation are analyzed with a model using best approaches taken from the most recent literature.

1.2 Scope of Work

This final report includes the following parts:

- <u>LITERATURE REVIEW</u>: identification of parameters to consider, analysis of methodologies for quantifying and monetizing those parameters (marine, road and rail transport) and identification of the optimal methodology for each;
- <u>DEFINITION OF THE SCENARIOS</u>: description of four scenarios - Great Lakes, St. Lawrence River, East Coast and West Coast − Shortsea shipping vis-à-vis road and rail transportation modes, relevance and viability of the shortsea shipping project and presentation of available references.

- DEFINITION OF THE MODEL: description of the model to evaluate the impacts of CAC, GHG, accidents, noise and congestion.
- EVALUATION OF THE ENVIRONMENTAL IMPACTS AND BENEFITS OF THE SCENARIOS: evaluation of the impacts and benefits of the four scenarios with the model.
- EVALUATION OF STRATEGIC IMPACTS OF SHORTSEA SHIPPING AND SUSTAINABLE DEVELOPMENT.

2. LITERATURE REVIEW

Many components have to be considered in order to obtain an exhaustive portrait of the environmental and social impacts coming from different transportation modes. Externalities are costs or benefits arising from an economic activity that affect somebody other than the people engaged in the economic activity and are not reflected fully in prices. Some of these effects are imposed on society at large, such as air pollution. Others are more subjective, for example noise and congestion.

Several methodological approaches have to be considered when estimating transportation environmental and social impacts. In 2007, TC completed the Full Cost Investigation of Transportation in Canada, which includes social and environmental cost estimates. This investigation considered congestion and moving time value, noise, accidents, air pollution and greenhouse gases. Other reports have also been submitted to TC to address environmental issues.

This section consists of a review of literature on environmental and social impacts of freight transportation. To prepare this section, recent reports, mainly written in a Canadian context, but also in American and European documents, were consulted.

First, each parameter considered in the study is presented, namely air emissions, energy efficiency, freight transportation, time saving and congestion, accidents, noise and other environmental impacts. Then, approaches frequently used to quantify these parameters are presented. Finally, recognized methods of estimating the cost of these externalities are provided.

2.1 Fuel Consumption Efficiency

2.1.1 Context

Energy efficiency is a criterion to be considered when improving transportation strategies. It is often assumed that marine transportation is the most energy-efficient mode. Benefits of energy efficiency are mainly related to air emission reductions. Results in Eastman (1980) confirm the fuel efficiency of marine freight transportation: barge and towing transportation is the most fuel-efficient method of moving raw materials and semi-finished products in the American context. Moreover, all bulk transport modes make significant contributions to the US distribution system regarding fuel-efficiency.

Fuel efficiency of water transportation and land-based modes are brought out in this reference (Table 2.1).

Furthermore, in Texas Transportation Institute 2007 (TTI, 2007), the energy intensities of domestic transportation modes are estimated. On a US national industry-wide basis, inland towing by towboats and cargo barges is nearly four times more efficient than the truck mode and nearly 1.5 times more efficient than railroads (Table 2.1).

Table 2.1 Multimodal Freight Fuel Efficiency Comparison

Transportation Mode	Eastman 1980 (tonne-miles/gallon)	TTI 2007 (tonne-miles/gallon)
Cargo Barge	514	576
Railroads	202	413
Truck	59.2	155

Source: TTI (2007)

Energy efficiency is based on fuel consumption. Thus, an economic value, which is the fuel cost, can be calculated by combining fuel consumption with fuel price. However, since fuel cost cannot be considered an environmental impact, the energy efficiency parameter will be left aside in the model. For reference, total fuel costs will nevertheless be presented for each transportation mode.

2.1.2 Fuel Consumption

As mentioned in Railway Association of Canada, 2008 (RAC, 2008), the freight traffic fuel consumption observed in 2006 was 5.93 L per 1,000 Tonne-km (RTK). The tonnes of goods carried refer to the total weight of the goods in the cars of the train handled over the distance moved and excludes the tonne-kilometres involved in the movement of railway materials or any other non-revenue movement. This rate was 0.7% lower than the 2005 level and 24.3% lower than in 1990.

For the road transportation mode, Transportation Research Board, 2007 (TRB, 2007) suggests an estimate of fuel use rate for trucks of 75 tonne-kilometres per Litre of Fuel, i.e., 13.3 litres per 1,000 tonne-kilometres.

In Office of Energy Efficiency, 2007 (OEE, 2007), on-road fuel consumption averages are provided. They have decreased from 37.8 L per 100 km in 2000 to 34.7 L per 100 km in 2005. This leads to an average heavy-truck fuel efficiency for the 2000-2005 period of 36.2 L per 100 km.

For the marine mode, the approach proposed to estimate fuel consumption is based on the specific fuel consumption (SFC) rate for main engines. This SFC is expressed in g/kWh and is about 213 g/kWh for all main engines. These figures must be converted into grams per tonne-kilometres, using the following equation:

$$\boxed{\frac{\text{kW Main Engine * Main Load Factor *Main engine SFC}}{\text{Average Speed Sailing (km/h) * Average Freight Tonnage}} \qquad (1)}$$

Those data are provided in Table 2.5 with air emission factors, in Section 2.2.

To be able to compare with other transportation modes, this result must be converted in L per tonne-kilometres. According to Levelton (2006a), density for heavy fuel oil (HFO) fuel is about 965 grams per litre whereas marine diesel oil (MDO) density is about 900 grams per litre. These figures must be used as indicators since the density of fuel depends on the temperature.

2.2 Air Emissions

2.2.1 Description

The main environmental effects of transportation are related to air emissions. As mentioned in Innovation Maritime (2008), pollutants can be classified into four groups:

- CAC;
- Heavy metals (HM);
- Persistent organic pollutants (POP);
- GHG.

Air pollutant (CAC, HM, and POP) emission sources and effects are briefly summarized in Table 2.2. GHG sources and effects are summarized in Table 2.3.

As mentioned in Marbek (2007), NO_x, SO_2 and direct $PM_{2.5}$ emissions are primary pollutants. They represent more than 93% of total costs of human health effects and agro-environmental impacts measured in that study. They must be considered in the model.

Moreover, ozone (O_3) and secondary $PM_{2,5}$ are secondary pollutants. As NO_x and Volatile Organic Compounds (VOCs) are the key precursor pollutants for ground-level ozone, VOCs must also be taken into account in the model.

GHG emissions are also important pollutants to be considered. Carbon dioxide (CO_2), methane (CH_4) and Nitrous oxide (N_2O) are the main GHG components (Table 2.3). Hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride are also GHG, but they are not present in diesel fuel (RAC, 2008) and therefore will not be considered in the model.

Table 2.2 Air Emissions Sources and Effects

Pollutants		**Sources**	**Effects**
Criteria Air Contaminants (CAC)	Carbon monoxide (CO)	Partial combustion of carbon-containing compounds, notably in internal combustion engines.	Impact on human health: toxic effects on blood and tissues, and effects on organ functions, inadequate oxygen supply to the heart, circulatory, nervous system. Impact on global climate change: Indirect through ozone formation.
	Nitrogen oxides (NO_x)	Produced during combustion, especially at high temperatures Oxidation of N_2 and N-compounds in fuel.	Ozone, formed by photochemical oxidation with NO_x and HC (hydrocarbons), causes significant economic damage to organic materials (paints, plastics, rubber, textiles) and vegetation (risk of leaf and root damage, lower crop yields) Directly injurious to human health: respiratory irritation and other problems. Strong role in long-range transboundary air pollution and acid rain.
	Sulphur oxides (SO_x)	Function of the sulphur content of the fuel and the amount of fuel consumed. Sulphur content of marine gas oil (MGO) was 0.5%, marine diesel oil (MDO) was 1.0% and residual oil (RO) was 2.7% (ENTEC, 2002)	Major cause of the acidification of soil and water. Directly adverse effects on human health (i.e., an increase in respiratory problems) and corrosion of buildings and other materials. Major contributor to ambient $PM_{2.5}$
	VOCs	Consequence of incomplete fuel combustion.	Can damage soil and groundwater Some VOCs are considered as toxic compound. Benzene, toluene, acetaldehyde, formaldehyde and acrolein are suspected carcinogens and may lead to leukemia through prolonged exposure. At acute high exposure of 1.3-Butadiene, damage to the central nervous system will start to occur.
	Particulate matter (PM)	Diesel engines burning low quality fuel emit significantly more particulate matter than those burning clean fuels, such as gas	Strong impact on human morbidity as well as contributing to atmospheric haze. Smoke and dust lead to respiratory damage such as asthma.
	Ammonia (NH_3)	Ammonia is a colourless gas with a pungent odor that is noticeable at concentrations above 50 ppm. Most of the NH_3 emitted is generated from livestock waste management and fertilizer production. In transportation, NH_3 is mainly produced by gasoline fuelled cars and trucks.	NH_3 is poisonous if inhaled in great quantities and is irritating to the eyes, nose, and throat in lesser amounts. It combines in the atmosphere with sulphates and nitrates to form secondary fine particulate matter ($PM_{2.5}$). $PM_{2.5}$ is known to have harmful effects on human health and the environment. NH_3 can also contribute to the nitrification and eutrophication of aquatic systems.
Main Heavy Metal	Lead (Pb)	Marine and rail transportation	Wide range of biological effects (e.g. synthesis of haemoglobin, chronic damage to the nervous system).
	Cadmium (Cd)	Marine and rail transportation	Long-terms exposure is associated with renal dysfunction. High exposure leads to obstructive lung disease and bone defects (e.g. osteoporosis)
	Mercury (Hg)	Road transportation	Tremors, gingivitis, minor psychological changes, spontaneous abortion, congenital malformation
Persistent Organic Pollutant	Dioxins and Furans	Road transportation Semi-volatile chemicals	The grasshopper effect process allows POPs to travel great distances quickly. Some of them are toxic cancer-causing chemicals.
	Benzo(a)Pyrene	ND	
	Benzo(b)Flouranthene Benzo(k)Flouranthene Indeno(1,2,3-cd)pyrene	All transportation modes	

Sources: Environnement Canada (2008), Innovation Maritime (2008), Envirochem (2007), Lenntech (2008)

Table 2.3 GHG Sources and Effects

	Pollutants	Sources	Effects
Greenhouse Gases (GHG)	Carbon dioxide (CO_2)	Function of the quantity of fuel burnt, but are also a function of the composition of the fuel being burnt.	Components of the atmosphere that contribute to the greenhouse effect. Amplified greenhouse effect would make the Earth uninhabitable.
	Methane (CH_4)		Not toxic, but highly flammable and may form explosive mixtures with air asphyxiants and may displace oxygen in an enclosed space. Leads to ozone formation.
	Nitrous oxide (N_2O)		Contributing to troposphere ozone production during smog formation. Supercharging global warming at a rate that many species, including humans, will find it difficult to adapt.

Sources: Environnement Canada (2008), Innovation Maritime (2008), Envirochem (2007), Lenntech (2008)

Finally, few studies consider ammonia, heavy metals or persistent organic pollutants in a transportation context. In Innovation Maritime (2008), releases were studied for ten ports. However, the importance given to those products is generally low, since their impact is minimal compared to other air pollutants. Nevertheless, SENES (2002) gives details about emission factors of toxic pollutants from marine engines. The US Environmental Protection Agency (EPA) also provides a methodology to estimate these emissions.

2.2.2 Emission Levels

2.2.2.1 Equations

Two methodologies are mainly used in the literature to calculate baseline emissions for CAC and GHG, namely the Energy-based and Fuel-based approaches (Table 2.4).

They can both be applied to marine, rail and road modes.

In theory, both approaches are equivalent. The fuel-based approach uses fuel consumption and normalized emission factors. Emission factors can be converted from g/kWh to g/tonne fuel burned by dividing the factors, expressed in g/kWh, by specific fuel consumption rates for each engine and fuel combination (Levelton, 2006a). In practice, limitations in available fuel data for marine activities do not favour the fuel-based approach.

Indeed, the energy-based approach is used in most references and inventories studying marine emissions (Section 2.2.2.2) and is mentioned as the best practice in Levelton (2006a). As a bottom-up methodology, it uses averaged operational characteristics of marine vessels. This approach is useful from shipper or policy analyst’s perspective because information needed to apply this approach, such as distance travelled, freight tonnages and vessel type used, is usually known.

In the model, the fuel-based approach is used for road and rail modes (Section 2.2.2.3).

Table 2.4 Equations to Quantify Air Emissions

	Energy-Based Approach	Fuel-Based Approach
Formula	E (tonne) = Sum $(P \times LF \times A \times EF/10^6)_{mode}$	E (tonne) = FC x EF
Variables	• P: Maximum continuous rated power of main and auxiliary engines (kW); • LF: Load factor of main or auxiliary engines by mode of operation, as a fraction; • A: Activity in hours by mode of operation (h); • EF: Emission factor for main and auxiliary engines by mode of operation (g/kWh).	• FC: Fuel Consumption (L); • EF: Normalized Emission Factors (g/L).
Marine References	Envirochem (2007); Innovation Maritime (2008); Levelton (2006a); Senes (2004)	Innovation Maritime (2008)

Note: For rail transportation, the number of locomotives per train for freight operations must be taken into account

Otherwise, “gram of emissions per tonne of freight per kilometre of freight movement” is the unit recommended by Envirochem (2007) to compare emissions between different modes of transportation. Baseline air emissions input in the model of this study will thus be expressed in grams of emissions per tonne of freight per kilometre of freight movement.

2.2.2.2 Marine Air Emissions

As emissions are a function of engine type and fuel type, baseline air emissions accuracy directly depends on input data of characteristics of power systems and inherent variability of vessel movement and energy used.

It is important to take into account several vessel categories and their characteristics. Here are some basics about these parameters.

Five principal vessel categories have been selected for this study, namely bulk, general cargo/break-bulk, container ships, product tankers and Ro-Ro’s. A brief description of each vessel type is provided in Annex A.

The type and the size of ship influences the emission factors in grams per tonne-km. Economies of scale are made as ships get larger. In general, the power needed to deadweight (DWT) ratio follows a logarithmic relationship. It means that, as the ship capacity increases, the emissions per unit of cargo decrease for ships sailing at the same speed. Several sizes of ships have been used to estimate emission factors in grams per tonne-km (Table 2.5).

Ship types are mainly based on ship construction and configuration. These types can be based on the type of propulsion such as self-propelled ships and tug and barge combinations, or by the way the cargo is loaded. Indeed, the cargo can be rolled in, pumped in or loaded from the top with cranes of conveyors belts through side-doors.

All these configurations influence the loading space available and the ship lightweight. When space is wasted by tweendecks of trailer wheels or when the DWT decreases by loading gear, the ship energy efficiency (measured by the amount of energy needed to move one tonne by one km) decreases.

Finally, propulsion configuration also influences the energy efficiency. Most modern ships are equipped with a diesel engine. Gas turbines, nuclear propulsion, diesel electric and steam propulsion are now reserved to very specific uses such as ice breakers and military ships. They won’t be considered in the model.

The main technical characteristics of these ships are summarized in Table 2.5. These figures represent vessels mainly observed in the Great Lakes, St. Lawrence River and East Coast waters.

Table 2.5 Parameters of Candidate Vessels for Shortsea Shipping

Vessel Type	**DWT**[b]	**Underway Service Speed**[a]		**Main Engine Characteristics**		**Auxiliary Engine Characteristics**	
		kn	**km/h**	**Power (kW)**	**Load factor (Underway)**	**Power (kW)**	**Load factor (Underway)**
Bulk/General Cargo	5,000	12.0	22.2	1,950	75%	500	17%
	15,000	14.0	25.9	4,900	75%	750	17%
Seaway	25,000	14.0	25.9	7,000	80%	1,800	17%
Ro/Ro	10,000	17.5	32.4	5,900	80%	5,108	15%
	15,000	19.5	36.1	10,500	80%	5,108	15%
Product Tankers	10,000	12.5	23.2	4,400	75%	1,000	13%
	17,000	14.0	25.9	6,400	75%	1,400	13%
	35,000	16.0	29.6	8,000	75%	1,465	13%
Container	10,000	17.0	31.5	7,100	80%	750	13%
	15,000	18.5	34.3	10,500	80%	1,000	13%
	5,000	14.0	25.9	3,000	80%	500	13%
	3,000	13.5	25.0	2,200	80%	500	13%

Source: Maritime Innovation compilation (2008)
a: Service speeds in km/h come from speed knots value multiplied by 1.852.
b: DWT: Deadweight.

An engine factor can thus be calculated, using the equation below to apply the energy-based approach (Table 2.6).

Equation: (2)

Main Engine factor = Main Engine Power* Main Load Factor / (Freight Tonnage*Service Speed)

Table 2.6 Shortsea Shipping Main and Auxiliary Underway Engines Factors (kWh/tonne-km)

Vessel Type	DWT	Underway Main Engine Factor (1,000kWh/tonne-km)	Underway Aux. Engine Factor (1,000kWh/tonne-km)
Bulk/General Cargo	5,000	13.16	0.76
	15,000	9.45	0.33
Seaway	25,000	8.64	0.47
Ro/Ro	10,000	14.56	2.36
	15,000	15.51	1.41
Product Tankers	10,000	14.25	0.56
	17,000	10.89	0.41
	35,000	5.79	0.18
Container	10,000	18.04	0.31
	15,000	16.34	0.25
	5,000	18.51	0.50
	3,000	23.46	0.87

Source: GENIVAR compilation

Baseline air emissions in grams per tonne-km will be available by multiplying the engine factor, expressed in kWh/tonne-km, with composite ocean-going vessels emission factors, expressed in g/kWh (Annex B), extracted from Levelton (2006a).

As the fuel used has an impact on the sulphur content, and SO_x emission factors vary in proportion to the sulphur content of the marine fuel burned, Levelton Marine SO_x emission factors are appropriate to our study, because the observed proportion of International HFO and Domestic Intermediary Fuel Oil used have been taken into account.

In Envirochem (2007), main baseline air emission ratios for Canadian ocean-going vessels in grams per tonne-km are then provided. These ratios include emissions for main and auxiliary engines for each vessel type, considering underway mode at low and medium speed. Manoeuvring and dockside modes are also taken into account in these results, because an emission prorate ratio corresponding to the ratio between total vessel emissions and vessel underway emission has been applied.

Using this methodology, Table 2.7.a provides CAC emission ratios in shortsea shipping context, whereas Table 2.7.b provides GHG emission ratios, including CO_2-equivalent ratio. Emission prorate ratio is also included in this table.

Table 2.7.a Shortsea Shipping Vessels CAC Emission Ratios (grams per tonne-km)

Vessel Type	DWT	Specific Fuel Consumption (g/tonne-km)	Emission Ratios in Grams per Tonne-Km						
			SO_x	NO_x	VOC	PM	PM_{10}	$PM_{2.5}$	CO
Bulk/Gen Cargo	5,000	2.553	0.157	0.287	0.009	0.033	0.026	0.022	0.009
	15,000	2.388	0.110	0.202	0.006	0.023	0.018	0.015	0.006
Seaway	25,000	2.354	0.103	0.188	0.006	0.022	0.017	0.014	0.006
Ro/Ro	10,000	6.783	0.190	0.341	0.011	0.039	0.030	0.026	0.011
	15,000	5.944	0.190	0.346	0.011	0.040	0.031	0.026	0.011
Product Tankers	10,000	3.875	0.157	0.306	0.010	0.036	0.028	0.023	0.009
	17,000	3.026	0.120	0.234	0.007	0.027	0.021	0.018	0.007
	35,000	1.616	0.063	0.124	0.004	0.014	0.011	0.009	0.004
Container	10,000	4.307	0.211	0.381	0.012	0.044	0.035	0.029	0.011
	15,000	3.908	0.191	0.345	0.011	0.040	0.032	0.027	0.010
	5,000	4.556	0.219	0.394	0.012	0.046	0.036	0.030	0.012
	3,000	6.058	0.280	0.503	0.016	0.058	0.046	0.039	0.015
Emission Prorate Ratio	-	-	*1.106*	*1.087*	*1.085*	*1.062*	*1.066*	*1.071*	*1.187*

Source: GENIVAR compilation (2008)

Table 2.7.b Shortsea Shipping Vessels GHG Emission Ratios (grams per tonne-km)

Vessel Type	DWT	CO_2	CH_4	N_2O	CO_2-equivalent
Bulk/Gen Cargo	5,000	9.864	0.0011	0.0003	9.980
	15,000	6.904	0.0007	0.0002	6.986
Seaway	25,000	6.451	0.0007	0.0002	6.527
Ro/Ro	10,000	12.136	0.0013	0.0004	12.277
	15,000	12.685	0.0014	0.0004	12.834
Product Tankers	10,000	10.469	0.0011	0.0003	10.593
	17,000	7.985	0.0009	0.0002	8.079
	35,000	4.213	0.0005	0.0001	4.263
Container	10,000	12.927	0.0014	0.0004	13.080
	15,000	11.690	0.0013	0.0004	11.828
	5,000	13.413	0.0014	0.0004	13.571
	3,000	17.187	0.0018	0.0005	17.389
Emission Prorate Ratio		*1.128*	*1.085*	*1.087*	-

Source: GENIVAR compilation (2008)

CO_2-equivalent emission factors are proposed for CH_4 and N_2O emissions. Those factors are based on their respective global warming potential values (GWP) (Table 2.8), given in the Canadian GHG Challenge Registry Guide to Entity & Facility-Based Reporting, Version 4.3, 2005 and used in Transport Canada (2008).

Table 2.8 Global Warming Potential Values (CO_2-equivalent emission factors)

GHG	CO_2	CH_4	N_2O
GWP	1	21	310

Source: Transport Canada (2008)

2.2.2.3 Land-based Mode Emissions

Baseline air emission ratios for rail and truck modes can be found in several reports. As mentioned earlier, the fuel-based approach is mostly used in these documents.

In the rail context, ratios provided below come from RAC (2008) and in fact, are specific to the Canadian fleet. They are appropriate to use in the model of the present study, except for SO_x which is a function of sulphur content of the diesel fuel. Emission factors for CAC are specific to individual engine and locomotive types. They are obtained from test measurements. Table 2.9 provides air emissions based on observed data from 2003 to 2006.

RAC (2008) is proposing a Hydrocarbon (HC) emission factor. As proposed in Jansen (1992), HC emissions for locomotives, as well as heavy-duty vehicles can be converted to VOC emissions with a conversion factor of 1.005.

As Canadian railways continue to replace their fleet with new locomotives and to pursue fuel consumption reduction strategies, the trend of lower GHG and CAC emissions will continue in the future, particularly the NO_x.

Table 2.9 Rail Air Emissions Ratios, 2003-2006 (kg per 1,000 RTK)

		Locomotive Air Emissions (kg / 1,000 RTK)			
		2003	2004	2005	2006
CAC	NO_x	0.33	0.32	0.31	0.3
	CO	0.07	0.05	0.04	0.04
	HC	0.02	0.02	0.02	0.01
	VOC[a]	*0.02*	*0.02*	*0.02*	*0.01*
	PM	0.01	0.01	0.01	0.01
	SO_2	0.01	0.01	0.01	0.01
GHG	CO_2	16.6	16.58	16.31	16.18
	CH_4	0.02	0.02	0.02	0.02
	N_2O	2.07	2.07	2.04	2.02
	$CO_{2\text{ equivalent}}$	18.69	18.67	18.37	18.22

Source: Extracted from Railway Association of Canada (2006), Table 10 p. 15 and Table 12 p. 19

a: Converted from HC emission factor, with 1.005 factor conversion

In the road context, CAC and GHG emission factors can be found in the Urban Transportation Emissions Calculator inputs of Transport Canada (2008). GHG emission factors used in this calculator are based on the Canada's GHG Inventory Report 1990-2005 (Environment Canada, 2007). They are expressed in grams per km travelled and not in grams per tonne-km (Table 2.10).

Table 2.10 Heavy-Duty Commercial Vehicle Air Emission Ratios

	Diesel	
	g/L	g/km
NO_x		7.01
SO_2	-	0.090
VOC	-	0.267
CO	-	1.49
$PM_{2.5}$	-	0.163
PM_{10}	-	0.192
CO_2	2730	754.14
CH_4	0.124	0.034
N_2O	0.08	0.022
$CO_{2\ \text{equivalent}}$	2758	761.88

Source: Transport Canada 2008
Conversion from g/L to g/km for GHG is based on 2000-2005 average diesel consumption for heavy-truck equal to 36.2 L/100 km (see Section 2.1.2).

2.2.3 Evaluating Economic Value

2.2.3.1 CAC Unit Costs

The comparison of air pollution costs between different transportation modes is based on the evaluation of health damages, agriculture (changes in crop yields from ozone) and visibility (reduced with PM increased) costs, due to CAC emissions. This is called the damage function approach (description available in page six of Marbek (2007)).

Marbek (2007) generates unit costs for CAC (NOx, SO_2, $PM_{2.5}$, VOCs) emissions. The combination of different models taking into account the impacts of these emissions provides two tables presenting air pollution unit costs. Only significant CAC pollutant costs are defined.

Marginal cost values (unit costs in $/tonne of emissions) are provided in terms of avoided air pollution costs of reducing a unit of pollution for any transportation-related activity, by province (Table 2.11). Only one variable is needed to use this table and estimate cost of emissions in a scenario. This is the quantity of emissions, discussed previously.

As the Marbek methodology takes into account health damages, agriculture and visibility impacts, unit costs in each province can vary depending on activity levels.

Prince Edward Island (PEI) does not have any costs associated because no concentration changes were predicted for PEI since no suitable stations were available to estimate concentration changes (Marbek, 2007).

Finally, Marbek (2007) assumes that the release of emissions does not necessarily occur in the same location where health, agricultural and visibility impacts occur. For Maritime Provinces, all upwind emissions are assumed to originate in the United States (US). As the effects of changes in transportation emissions from the US have not been assessed in the Marbek study, there are no predicted upwind impacts for these provinces. That's why VOC emission costs have not been allocated for these provinces.

Table 2.11 Unit Costs of Air Pollution by Pollutant Emitted and by Province (2000 C$ / tonne of emissions)

Province	$PM_{2,5}$	$PM_{2,5}$ (including Paved Road Dust)	SO_2	NO_2	VOC
Newfoundland and Labrador	2,900	2,900	2,020	456	0
PEI	0	0	0	0	0
Nova Scotia	561	533	176	468	0
New Brunswick	7,150	7,150	2,450	1,060	0
Quebec	13,200	13,000	4,680	5,590	594
Ontario	29,100	28,600	6,520	5,940	877
Manitoba	2,710	2,690	9,860	1,740	86
Saskatchewan	7,750	9,150	3,790	1,070	116
Alberta	4,080	4,050	617	1,630	213
British Columbia	5,200	5,150	2,110	2,010	87

Source: Marbek (2007)

As mentioned in Marbek (2007), there is a very large uncertainty associated with the calculation of $PM_{2.5}$ emissions from paved road dust. The model proposed in Section 4 of this report will not use this unit cost.

Table 2.12 provides unit costs of air pollution by pollutant emitted and by province, in $/million tonne-km travelled. This one proposes a unit cost including quantities of emissions by transportation mode. For each transportation mode, variables to input in the model would be cargo weight, travel distance and province. These ratios are not engine type specific.

Furthermore, a ratio expressed in dollars per tonne of emission units may be more adapted to our model. Combined with the quantity of emissions calculated as discussed previously, results may be more accurate.

Table 2.12 Unit Costs of Air Pollution by Pollutant and by Province (2000 C$ / million tonne-km travelled)

Freight Marine Transportation				
Province	**$PM_{2,5}$**	**SO_2**	**NO_2**	**VOC**
Newfoundland and Labrador	26.91	26.71	10.61	0
PEI	-	-	-	0
Nova Scotia	4.39	11.41	67.21	0
New Brunswick	99.78	297.33	290.29	0
Quebec	477.48	975.16	4,019.90	35.99
Ontario	908.96	1,508.46	3,690.38	66.56
Manitoba	-	-	-	-
Saskatchewan	-	-	-	-
Alberta	-	-	-	-
British Columbia	184.48	361.89	1,723.98	1.61
Freight Rail Transportation				
Province	**$PM_{2,5}$**	**SO_2**	**NO_2**	**VOC**
Newfoundland and Labrador	-	-	-	0
PEI	-	-	-	0
Nova Scotia	3.22	2.38	132.79	0
New Brunswick	28.33	22.75	215.15	0
Quebec	80.60	67.00	1,742.90	8.74
Ontario	326.54	172.90	3,404.66	23.63
Manitoba	33.75	282.11	1,128.54	2.59
Saskatchewan	97.92	109.41	672.51	3.50
Alberta	15.25	5.42	311.43	1.91
British Columbia	48.48	35.66	955.31	1.95
Freight Heavy-Duty Diesel Transportation				
Province	**$PM_{2,5}$**	**SO_2**	**NO_2**	**VOC**
Newfoundland and Labrador	-	-	-	0
PEI	-	-	-	0
Nova Scotia	34.69	7.19	988.95	0
New Brunswick	422.16	101.17	2,433.11	0
Quebec	709.98	178.91	10,352.11	38.60
Ontario	1,208.26	209.74	10,349.58	47.06
Manitoba	344.63	475.74	7,283.35	13.94
Saskatchewan	1,181.53	197.71	4,856.49	22.24
Alberta	261.80	17.84	3,801.69	18.46
British Columbia	302.02	47.07	4,043.05	6.78

Source: Marbek 2007 – Appendix C

2.2.3.2 CO_2-Equivalent Unit Costs

As climate warming has been accelerating globally, it has become one of the major environmental challenges facing humanity.

In fact, the first Canadian carbon market was launched on May 30, 2008 by the Montréal Climate Exchange (MCeX). As the federal government published in 2008 mandatory reduction targets starting in 2010, MCeX offers through futures contracts. This new system for Canada is based on the allocation of units to a company for exceeding its intensity-based GHG emissions reduction targets (MCeX, 2008). As this market is quite young, the GHG unit cost used in the model of this study will not reflect the MCeX value.

Three other references were studied to determine which unit cost to use in the model (Table 2.13), namely:

- Transport Canada (2007a), Full Cost Investigation Project, GHG cost estimations for Canada for the year 2000 (Feb. 2007);
- National Round Table on the Environment and the Economy (NRTEE)- Interim Report to the Minister of the Environment (June 2007);
- BC Utilities Commission (VIEC, 2003), Vancouver Island Generation Project (Sept. 2003).

The first determines a unit cost for 1 tonne of CO_2-equivalent based on the European carbon market price[1] (Table 2.13). This methodology offers a good perspective of CO_2-equivalent values, since the European market has been operating since April 2005. Furthermore, it is easy to get up-to-date values. However, carbon prices are higher than those presented in other Canadian studies.

The second reference examines the implications for Canada of long-term GHG emissions reductions of 45% to 65% below 2003 levels by 2050. CO_2 costs are estimated based on these two targets. In 2003 C$, the price in 2010 is estimated at $10/tonne CO_2, while in 2015, it is targeted at $15/tonne CO_2.

The third reference notes that:

> *BC Hydro has developed a $3/MWh price adjustment for proposals with near-zero GHG emissions that are submitted in response to its Green Energy and CBG programs. Vancouver Island Energy Corporation stated that $3/MWh equates to approximately $10/tonne CO_2 equivalent, assuming a CCGT GHG emission factor of 0.36 tonnes/MWh*."

Table 2.13 Unit Cost for 1 Tonne CO_2-Equivalent

Unit Cost for 1 Tonne CO_2-Equivalent		
Transport Canada (2007a)	NRTEE (2007)	BC Utilities Commission (VIEC, 2003)
$28.03/tonne CO_2 (2000 C$)	$10/tonne CO_2 (2003 C$)	$10/tonne CO_2 (2003 C$)

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[1] www.europeanclimateexchange.com

As reports prepared by and for TC suggest using a unit cost based on the European Carbon market price, this option will be used in the model. An updated value will be integrated in the model. The average CO_2 price for 2008 is 25.33€ per tonne.

Hence, to estimate GHG cost of a scenario, by transportation mode, the quantity of GHG emitted in tonne CO_2 equivalent is the only variable needed.

2.2.4 Air Emission Methodology to be Used in Model

General equation to find the economic value of CAC and GHG emissions in a given scenario can be expressed as followed:

$$\text{Cost}_{i,\ \text{mode},\ \text{province}} = (\text{Annual Emissions for the scenario})_{i,\text{mode}} \times (\text{Unit cost})_{i,\ \text{province}} \qquad (3)$$

Where: i: species of air emission pollutants (CAC or GHG)
Mode: transportation mode

The inputs needed to evaluate the impacts are:

- Cargo weight per vehicle (tonne);
- Annual cargo weight (tonne);
- Province(s) crossed;
- Distance - One way trip in each crossed province;
- Ship type;
- Emission factors in grams per tonne-km (Table 2.7 for marine mode, Table 2.8 for rail mode and Table 2.9 for road mode);
- Unit cost in dollars per tonne of emissions of specific pollutant (CAC and GHG) and per province (CAC only, Table 2.12).

2.3 Accidents

The number of accidents is a parameter to consider in a multimodal comparison. Accidents have social and environmental impacts and are an important part of transportation operations.

2.3.1 Social and Private Impacts of Accidents

2.3.1.1 Definition and General Approaches

In Delft (2008), two approaches are summarized, namely the top-down and bottom-up approaches.

The first approach estimates total and average accident costs considering national accident statistics and insurance systems. Values of national statistics are usually higher than the second approach. The total cost of an accident is the sum of various components, namely the direct, indirect and intangible costs. Human health effects, material damage, time as well as resources invested must be taken into account when accidents occur (TC, 2007b). The largest cost component is the loss of human life.

Another interesting way to define accident costs is the Delucchi approach in UCD (2005). Four categories of accident costs are provided, namely monetary versus non-monetary and social versus private, and are presented in Table 2.14.

Table 2.14 Definition of Accident Costs

	Monetary	**Non-monetary**
Private	Repair and damage for self-inflicted crashes, insurance premiums for liability costs inflicted by others	Pain and suffering costs of self inflicted crashes
Social/External	Property damage costs inflicted in uninsured crashes	Pain and suffering, lost productivity inflicted on/by others and not covered by insurance payments

Source: Zhang (2004)

The Bottom-up approach estimates marginal costs. It is assumed that transport users are able to anticipate and consider their own risks. Only third-party damages are as external and only willingness-to-pay for relatives and friends has to be considered.

At a scientific level, there is still no consensus about which one to use. But, if the focus is on all types of accident externalities (not just infrastructure pricing), the top-down approach can be applied resulting in accident costs using this equation:

Accident costs = (4)

Accident figures x Unit Cost per accident x External Part

(*Statistics*) *(Unit value per type of damage)* *(Info on insurance system)*

Moreover, as mentioned in Zhang et al. (2004), the usual method of computing the cost of an accident is the top-down approach.

Finally, the external part for non-road modes is lower than the road transportation part. In Delft (2007), the European average external accident cost for rail is 0.08-0.03€ per train-km. Using European figures is not appropriate for Canada due to a number of factors such as traffic densities and accident rates that are different.

2.3.1.2 Unit Costs of Accidents in Canada

Zhang et al. (2004) provides unit costs of accidents, estimated in 2002 C$ (Table 2.15). These costs have been adjusted to a Canadian context. The accident costs presented in the Zhang study are based on a Statistical Life Value equal to $4.25 million and a major injury value of $330,875.

For road transportation, accident costs include medical and emergency services, property damage, lost productivity and quality of life losses.

For rail transportation, only fatalities and major injuries are considered. This figure underestimates the true cost, given that it is assumed that minor injuries have no cost.

For marine transportation, the cost includes fatalities and major injuries, but does not include property damage (only), hazardous materials, crash costs or emergency services.

All estimates include willingness-to-pay (WTP), health and legal for costs of victims injured, by severity, but do not include the cost of time delay due to accidents.

Table 2.15 Estimated Unit Costs of an Accident (2002 C$)

	Marine (freight only)[1]	Heavy-truck (freight)	Costs of Rail accidents (passenger and freight)
Unit	Cost per trip	Cost per 1,000 km	Cost per million main-track train – km
Cost	822	152.47	5,732,000,000

Source: Zhang et al. (2004)

2.3.1.3 Full Cost Investigation – TC (2007)

TC (2007b) aims to calculate the average accident costs for Canada in 2000. The methodology used is a top-down approach and is divided into four main steps, which are:

- Getting input, i.e., quantitative data about accidents (how many fatalities, how many injuries and how much material damage only occurred?);
- Getting human economic unit value for death, injury and material damage only in the context of accidents (Table 2.16);
- Combining quantitative data with unit costs to get whole costs in Canada;
- Computing unit accident costs.

In this study, cost element quantification and monetization are based on the Ministry of Transportation Ontario – Transport Canada study (MTO-TC, 2007). The MTO-TC study provides social costs of road accidents by province, based on WTP in a medium (basis) scenario.

Table 2.16 Estimated Human Impact Values (2000 C$)

	Death	Total Inability	Partial Inability	Major Injury	Minor Injury	Light Injury
Basis Scenario	4.05 M	259,627	129,813	23,275	4,674	249
Lower Scenario	3.05 M	195,521	97,761	17,528	3,520	188
Higher Scenario	5.05 M	323,732	161,866	29,022	5,828	311

Source: Transport Canada (2007b), p. 12

Then, TC (2007b) provides average unit costs for road accidents for three scenarios (Table 2.17). These costs include direct human health costs (Willingness-To-Pay to reduce the risk of death), as well as hospital/health care, fire, ambulance, tow trucks and out-of-pocket expenses. Property damage, police and court costs as well as traffic delays are not included. In these results, Statistical Life Value used is equal to $4.05 million (2000 C$).

These rates are also used to estimate rail, marine and aerial accident costs in TC (2007b).

Table 2.17 Average Unit Accident Costs (2000 C$)

	Death	Major injuries	Minor injuries	Light injuries	Material Damages only
Basis Scenario	$4.05 M	$55,500	$8,900	$2,700	$2,600
Lower Scenario	$3.05 M	$43,900	$7,300	$2,500	$2,600
Higher Scenario	$5.05 M	$67,000	$10,500	$3,000	$2,600

Source: Transport Canada (2007b), p. 24

These figures must be used with care given that accidents involving more than one transportation mode might be recorded twice or three times in total estimated costs. To avoid this problem, it is necessary to count the type of vehicles involved in the accident.

Statistics are needed about quantities of fatalities, injuries (major, minor and light) and material damage in each scenario as well as activity levels by mode to compute ratios per vehicle-kilometre for instance.

2.3.1.4 First Quebecer Freight Multimodal Statement, Gaudry et al. (2006)

Another methodology is proposed in First Quebecer Freight Multimodal Statement, Gaudry et al. (2006). Three cost types are calculated, namely the infrastructure, environmental (air emission and noise only) and accident costs. To estimate accident costs, Gaudry et al. (2006) takes into account losses due to accident and health costs paid by insurance companies (administration costs).

Costs paid by insurance companies for rail and marine modes are considered nil, because they are assumed in compensation programs.

Using several sources, a unit cost per victim and per accident is provided for each transportation mode (Table 2.18).

Table 2.18 Unit Accident Cost ($ per victim per accident)

Accident Categories	Marine	Road	Rail
Death[a]	1,363.64	391,919	39,007
Injuries	1,363.64	11,876	402,946
Material Damage Only	1,363.64	5,938	39,007

Source: Gaudry et al (2006)

a: Cost of human life must be added to proposed unit accident costs. Gaudry et al. uses the final report of the *Canada Transportation Act* Review Panel (1992). This value must be adjusted with consumer price index.

2.3.1.5 Accident Methodology to Be Used in the Model

The methodology to be used in the model is based on the Full Cost Investigation study of TC. Statistics about quantities of fatalities, injuries and material damage have been collected for each transportation mode studied. Vehicle – kilometres travelled data for the road and rail modes, and the number shipments for the marine mode have then allowed to compute accident unit costs using the cost per accident data provided in TC (2007b) (Table 2.19).

Table 2.19 Accident Unit Costs to Be Used in the Model

Transportation modes	Road	Rail	Marine
Number of accidents			
Number of fatal collisions	507.7	70.0	7.0
Number of injury collisions	9,130.8	60.0	24.2
Number of property damage collisions	40,563.8	1,249.0	N/A
Vehicle - kilometers travelled			
Unit	per million vehicle-kilometers	per million freight-train kilometers	number of shipments
Vehicle – kilometres travelled	24,329.7	111.8	95,444
Number of accidents per vehicle km			
Unit	per million kilometers	per million kilometers	number of accidents/shipment
Fatal collisions	0.021	0.626	0.000073
Injury collisions	0.375	0.536	0.000254
Property damage collisions	1.667	11.167	N/A

Table 2.19 (cont.)

Transportation modes	Road	Rail	Marine
Cost per accident (2000 C$) – Willingness to pay Method			
Fatal collisions	4,053,800	4,053,800	4,053,800
Injury collisions	55,500	55,500	55,500
Property damage collisions	2,600	2,600	2,600
Accident unit costs			
Unit	Unit cost of accident / veh. - km	Unit cost of accident / train - km	Unit cost of accident / vehicle shipment
Fatal collisions	0.08	2.54	297
Injury collisions	0.02	0.03	14
Property damage collisions	0.00	0.03	NA
Total	**0.11**	**2.60**	**311**

Sources: Road - Canadian Vehicle Survey, Table 4-3, http://www.tc.gc.ca/pol/en/aca/cvs/menu.htm
Rail - Transportation Safety Board of Canada, Rail Statistics, http://www.tsb.gc.ca/en/stats/rail/2008_aug/r08_2008_e.xls
Marine -Transportation Safety Board of Canada, Marine Statistics, http://www.tsb.gc.ca/en/stats/marine/2006/index.asp
Cost per accident data - Estimating the Total Costs of Accidents, Transport Canada, April 2007

2.3.2 Environmental Effects from Spills

TTI (2007) reports data on hazardous material incidents for truck, rail and inland towing transportation modes in the US. It reports only large spills and analyzes them with a four-year average. Rates of spills in gal/M tonne-miles are 6.06 for trucks, 3.86 for rail and 3.60 for inland marine.

Spill accidents clearly fit within an environmental impact assessment. Ship spills, in particular, have obvious impacts on ecosystems and wildlife. They frequently occur while loading or unloading in port. Moreover, accidental spills which occur when a boat runs aground or breaks up in bad weather can be potentially dangerous (OECD, 1997). Such disasters typically occur where there is little room for manoeuvre or going off course in case of bad weather.

Spills costs may be high. UNCTAD estimated in 1993 that the cost of cleaning spilled oil in European port is about US$7,000 for several cubic metres of spilled oil. Chemical spills are much more expensive to clean up, as are massive oil spills. For example, VPTI (2007) reports that in 1989, Chemick and Caverhill had estimated Exxon Valdez clean-up costs at US$728 per gallon of spilled oil (equivalent to US$193,000 per m^3).

Nevertheless, even with average spill costs for each transportation mode, it is difficult to predict an incident rate probability. Thus, no complete methodology has really been developed to estimate spills costs and their impact on the environment. Due to these data gaps, this issue cannot be addressed directly in the model.

2.4 Congestion

Time saving and congestion are significant types of social costs that a transportation strategy aims at changing into benefits. The costs of delays are borne collectively by transport users and are not imposed directly on society as a whole, but rather on transport users themselves.

2.4.1 General Concepts

2.4.1.1 Definitions

Various definitions for congestion costs can be found in the literature as mentioned in Zhang (2004). Hence, it is very important to identify issues in these definitions before comparing different congestion costs.

According to Delft (2007), different types of costs exist when talking about congestion, namely travel time increases, vehicle provision and operating costs, additional fuel costs, reliability and scarcity of slots. Basic definitions proposed below are important to keep in mind while estimating unit costs (Table 2.20).

As mentioned in Nash et al. (1999), additional users of road infrastructure may well impose externalities on other transport users, as well as experiencing congestion themselves. Indeed, even while motorists recognize the increased true cost they face when delayed by congestion, they do not recognize that they impose delay costs on others.

External congestion costs are then crucial components of the social cost. Resulting traffic slowdowns can have a wide range of negative effects on people and on the business economy.

Table 2.20 Basic Terms in Congestion Definition

Congestion	In the narrow sense, it denotes the social loss due to the fact that users do not care for the additional costs and inconvenience they cause to other users. This is relevant for non-scheduled road transport.
Delays	Additional journey times or increased travel costs are the effects of traffic congestion experienced by users. In scheduled transport, delays can be measured against arrival and departure times published in timetables, but it is not clear in how far timetables already consider usual delays.
Reliability	The higher valuation of delay time compared to standard in-vehicle time commonly relates to the unreliability of travel times caused by congestion. In particular in freight transport, this is considered much more of a problem than the pure increase of average travel times. The argument behind this concept is that the traveller or shipper needs to know with a particular level of certainty when the trip needs to start in order to arrive on time.
Scarcity	These costs denote the opportunity costs to service providers for the non-availability of desired departure or arrival times. The value of scarcity effects strongly depends on market conditions and internal cost structures of the service provider. Scarcity is a concept applied to scheduled public transport (essentially rail and air transport) using an infrastructure with strictly limited access. External part of cost is the difference of the willingness-to-pay for scarce slots and the existing slot charge.

Source: altered from Delft (2007) and Delft (2008)

2.4.1.2 Congestion over Different Transportation Modes

Even though congestion can occur anywhere and for any mode, it is mainly in large urban areas and on the road that such phenomena are observed. Recent reports, like Delft (2008), confirm that there are no best practice figures available for transportation other than road.

Congestion on roads remains the major issue in terms of social costs and public exposure. Moreover, this is a growing problem in many urban areas in all countries. Thus, many reports, like TTI (2007) or TRB (2007), are using social benefit values associated with truck diversion.

Literature on rail congestion is not common. As mentioned in Nash et al. (1999), the capacity should be never exceeded, as the volume of traffic is directly controlled by allocation of slots. Hence, a scarcity value is more appropriate in a rail context. According to Nash et al. (1999), the most efficient mechanism for estimating scarcity values is to allow the infrastructure manager to negotiate with the potential users about their WTP for alternative slots in determining that plan. In Europe, marginal costs are available, but the Canadian context is different from the European one, thus we are unable to use these scarcity values.

2.4.2 External Congestion Analysis

Four dimensions may be considered while analysing congestion levels, namely the spatial pattern (delay can be area-wide or location specific), the temporal pattern (delay can occur during morning or afternoon peak periods or off-peak periods), the stochastic element (predictability or sporadic delays as a result of traffic incident), as well as the mix of vehicles and traffic classes (local or through traffic) affected (TRB, 2007).

Hence, societal benefit values associated with truck diversion will vary greatly depending on local conditions, types of trucks diverted and time of the day the diverted freight movement could occur. Moreover, congestion in one urban centre may have a more dramatic impact on a local or short-distance delivery business than a coast-to-coast freight shipment business.

In the Canadian literature, mainly prepared for TC, the stochastic element, like predictability, is a key factor. Recurrent and incident (non-recurrent) are two main types of congestion. The first includes the day-to-day build-up of traffic on urban ways, whereas the second reflects delays caused by random incidents. It is important to understand recurrent congestion before analyzing incident congestion. However, non-recurrent congestion analysis is often confronted with a lack of coherent incident datasets.

In the Canadian context, ITrans (2006) reports that over 50% of total congestion is incident. This figure is for expressways and arterials for peak-periods only, and reflects delays for passengers only.

2.4.3 Monetary Value of Congestion

2.4.3.1 General Approach

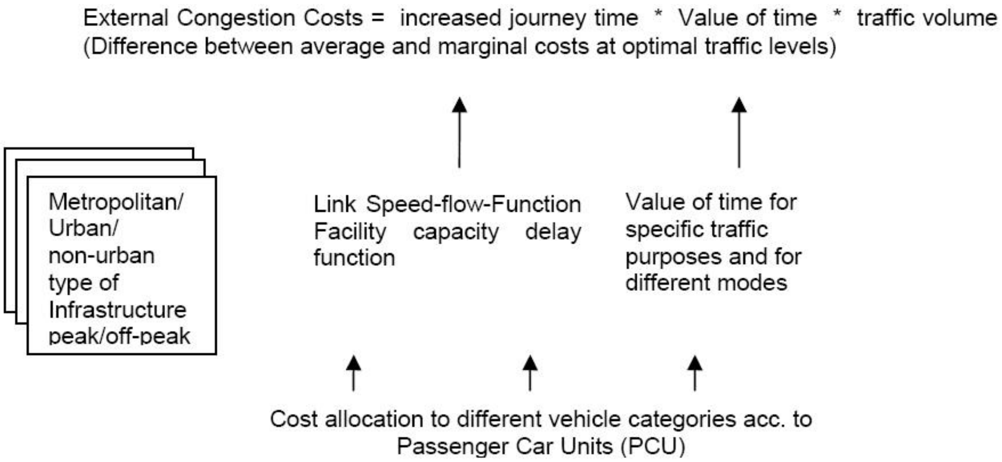
As congestion is a function of a reduction in speed, sources of monetary value can be listed, namely the value of delay, the value of fuel and the value of GHG emissions.

As mentioned in Zhang (2004), estimating the social cost of road congestion requires modes that allow investigation of the change in journey time and travel time reliability caused by a change in traffic on a particular mode.

The two main components of delay costs for road users are time losses and vehicle operating costs (very small compared to time costs). Hence, as external costs are dominated by time losses, value of time is extremely sensitive.

Delft (2008) provides a general approach scheme to get measurements of unit congestion costs (Figure 2.1).

Figure 2.1 Model to Measure External Congestion Costs



Source: Extracted from Delft (2008)

2.4.3.2 External Congestion Unit Costs Available in Literature Review

Some external congestion unit costs are available for road transportation in the literature from Europe, the US and Canada.

Europe

Delft (2007) developed marginal reliability costs for passenger and heavy-duty vehicles in Europe (Table 2.21). Those costs are divided according to the location, urban or interurban, and to the period of the day, peak or off-peak. Thus, in urban areas in peak periods, heavy-duty vehicle marginal costs are three times the cost for passengers.

Table 2.21 Marginal Reliability Cost (€ct / vehicle-km)

	Passenger		Heavy-Duty Vehicle	
	Min	Max	Min	Max
Urban	2.0	28	6.0	84
Interurban	0.0	15	0.0	7.0

Source: Delft (2007)
Note: Min means off-peak; Max means peak.

United States

TRB (2007) developed marginal public costs of highway use by trucks in terms of cents per vehicle – mile. A distinction is made between urban interstate and rural interstate highway (Table 2.22).

Table 2.22 Marginal Cost of Highway Use by Trucks (Cents per Mile – US$2000)

Vehicle Class / Highway Class	Congestion (US cents per mile)
Urban	
40 kip 4 axle S.U. Truck / Urban Interstate	24.48
60 kip 4 axle S.U. Truck / Urban Interstate	32.64
60 kip 5 axle Comb / Urban Interstate	18.39
80 kip 5 axle Comb / Urban Interstate	20.06
Rural	
40 kip 4 axle S.U. Truck / Rural Interstate	2.45
60 kip 4 axle S.U. Truck / Rural Interstate	3.27
60 kip 5 axle Comb / Rural Interstate	1.88
80 kip 5 axle Comb / Rural Interstate	2.23

Source: TRB (2007). Reproduced in part from Addendum to the 1997 Federal Highway Cost Allocation Study Final Report; US Department of Transportation Federal Highway Administration, May 2000, Table 13.

Note: S.U. = Single Use; Comb. = Combination

Canada

The ITrans (2006) report provides total congestion unit costs per vehicle-kilometre travelled (VKT), including value of delay, value of fuel and GHG emissions, for recurrent, non-recurrent and total congestion in nine main urban areas in Canada.

The threshold (50%, 60% and 70%) represents the point at which congestion becomes apparent and is deemed unacceptable. According to ITrans (2006), it is only against this quantifiable reference point that the socio-economic costs can be measured.

As previously mentioned, these figures are available for expressways and arterials for peak periods only and delays for auto drivers only (Table 2.23).

Table 2.23 Total Costs of Congestion (2000 C$ / vehicle per km per tonne)

	Threshold		
Location	**50%**	**60%**	**70%**
Vancouver	$0.53	$0.47	$0.45
Winnipeg	$0.49	$0.48	$0.42
Hamilton	$0.11	$0.12	$0.09
Hamilton (old)	$0.17	$0.11	$0.07
Toronto	$0.31	$0.29	$0.27
Ottawa-Gatineau	$0.22	$0.16	$0.15
Ottawa-Gatineau (no rural)	$0.22	$0.16	$0.18
Montréal	$0.47	$0.43	$0.39
Québec City	$0.32	$0.25	$0.21

Source: ITrans (2006). Including recurrent and non-recurrent congestion

Depending on fuel and GHG emissions earlier comparison, these factors might not be included in the model to avoid double-counting. Hence, only total unit costs of delays per VKT might be useful.

Moreover, the proportion of delay in total recurrent costs is about 92% when considering additional GHG emissions and fuel for passenger vehicles. This proportion will probably be lower while estimating heavy-duty truck external congestion costs (Table 2.24).

Table 2.24 Total Costs of Delays (2000 C$ / passenger vehicle per km per tonne)

	Threshold		
Location	**50%**	**60%**	**70%**
Vancouver	0.49	0.43	0.42
Winnipeg	0.45	0.43	0.39
Hamilton	0.10	0.10	0.09
Hamilton (old)	0.07	0.09	0.06
Toronto	0.28	0.27	0.25
Ottawa-Gatineau	0.19	0.14	0.14
Ottawa-Gatineau (no-rural)	0.18	0.14	0.16
Montréal	0.44	0.40	0.37
Québec City	0.28	0.22	0.19

Source: GENIVAR compilation, altered from ITrans (2006). Including recurrent and non-recurrent congestion.

2.4.4 Congestion Methodology to Be Used in Model

ITrans (2006) provides realistic congestion costs due to delays, for main urban areas in Canada. However, these costs are provided for passenger mode only (auto-driver) and cannot be directly used in our model.

Delft (2007) provides road congestion costs for passenger mode and also for heavy-duty trucks, in a European context. These costs cannot be directly used in a Canadian scenario, given the context difference.

Finally, the methodology to be used in the model is based on US unit costs provided in TRB (2007). These costs are proposed depending on the number of axles per truck (4 or 5) and on the location (urban or rural areas).

2.5 Noise

2.5.1 Noise Impact Variation between Traffic Modes

Traffic is a major source of noise, particularly in urban areas. Noise impacts occur when the noise level exceeds the normal level. This is a subjective externality because the noise externality is generated by the components of the transportation system, but paid for by agents outside the system. Thus, noise costs consist of costs for annoyance and health. Total costs per person exposed will vary between different traffic modes.

In the Delft (2008) European study, as roads and living areas are close together, noise from trucks are considered. Rail noise is usually considered, but at a lower level than other land-based modes. This depends on the time of day and the frequency of trains. As rail noise is intermittent, the noise nuisance posed by rail is generally considered to be less harmful than that posed by trucks (OECD, 1997).

According to Delft (2008), noise is not a major issue in water transportation. Envirochem (2007) adds that only a small fraction of the ship noise emitted will be close to inhabited areas. The economic value of this impact can be considered as negligible. Moreover, Gillen (2007) specifies that no research has been undertaken with respect to noise impact of marine transport. Therefore, Delft (2008), Gillen (2007) and Gaudry et al. (2006) consider noise impacts only for the rail and road transportation modes.

2.5.2 Best Practice Approaches

Delft (2007) provides an interesting summary of the two main approaches to estimate noise cost from transportation activities: the bottom-up approach and the top-down approach. Both approaches are considered valid. These approaches are also discussed in Zhang et al. (2004) and Gillen (2007).

The bottom-up approach is also called the “Impact Pathway Approach”. It refers to the difference in damage costs between a reference scenario, reflecting present scenario with traffic volume, speed distribution, vehicle technologies and other parameters, and a marginal scenario, which is based on the reference but includes one additional vehicle. This approach aims at estimating marginal external noise costs, which are considerably smaller for heavily frequented and loud roads.

The top-down approach is based on the WTP for more silence and the health effects. This method considers national data on noise exposure for different noise classes. It considers exposure rates for the whole country and thus produces averaged figures.

2.5.3 Estimating Unit Costs

Different methods can be applied to value the effects of transport noise, according to Delft (2007), namely the cost of illness (market prices), WTP-values, contingent valuation, hedonic pricing (quantification of amenity losses due to noise), abatement costs or avoidance costs.

2.5.3.1 European Costs

In Europe, Delft (2008) recommends unit costs for noise per person (Table 2.25). These costs are used in a top-down approach. However, these unit costs would be difficult to apply in our model, given the number of inputs needed.

Table 2.25 Unit Annual Cost per Person Exposed

Noise Level	Euros per Person Exposed per Year	
L_{den} [dB(A)]	Heavy-duty vehicle	Rail
>45	30	0
>50	90	30
>55	140	90
>60	200	140
>65	260	200
>70	370	260
>75	460	370

Source: Table extracted from Delft (2008)

INFRAS/IWW (2004), as reported in Delft (2007), provides unit values in €ct/vehicle-km (Table 2.26). These values are marginal noise costs for the rail and road modes based on a bottom-up approach.

Table 2.26 Noise Unit Values (2004 €ct / vehicle-km)

	Heavy-Duty Vehicle		Rail Freight	
	Min	Max	Min	Max
Urban	7.0	31	32	96
Interurban	0.1	0.2	1.8	5.5

Source: INFRAS/IWW (2004), reported in Delft (2007)

Note: "Min" corresponds to dense traffic situations during day time
"Max" corresponds to thin traffic situations during night time

2.5.3.2 Canadian studies

Gillen (2007) reports an estimate of annual noise costs in 2000 C$, based on a top-down approach. All required data were not available at the desired level of detail to produce the most precise estimates.

Hence, this report provides an order of magnitude of costs of noise from transportation activities. Estimated annual costs are provided below by transportation mode and for each Canadian province (Table 2.27).

Table 2.27 Annual Noise Costs by Province (2000 C$)

Province	Annual Noise Costs Rail	Annual Noise Costs Road
British Columbia	-	52,847,315
Ontario	2,197,680	101,861,986
Quebec	173,141	61,352,417
New Brunswick	-	165,118
Nova Scotia	-	636,690
NFL	-	526,777

Source: Gillen (2007)

By knowing the percentage of the total truck and train traffic replaced by shortsea shipping in each province, it is possible to estimate annual costs saved. To use this approach, input in the model must be:

- Traffic by mode (rail and road) that will be replaced by shortsea shipping in each scenario;
- Total traffic in each province by mode in 2000 and in the reference year for the model.

To get these results, marginal costs for road have been estimated (Table 2.28). Unfortunately, according to the authors, it is not possible due to data limitations to express rail noise costs in terms of dollars per tonne-km.

Table 2.28 Road Marginal Cost (2000 C$ / 1,000 vehicle-km)

Canada-Average	**0.5**
British Columbia	5.71
Alberta	0.29
Saskatchewan	0.01
Manitoba	0.1
Ontario	4.93
Quebec	2.35
New Brunswick	0.01
Nova Scotia	0.08
Newfoundland	0.05

Source: Gillen (2007), p. 19

Finally, Gaudry et al. (2006) refers to a unique unit cost for heavy trucks and trains, which is 11.14¢/veh-km (2001 C$). Thus, variables in this case are the travel distance and the quantity of vehicle.

2.5.4 Noise Methodology to Be Used in the Model

INFRAS/IWW values are provided in a European context. They are available for heavy-duty vehicle and rail traffic. As mentioned in Gillen (2007), the marginal costs of noise are calculated by principally taking into account traffic flow, housing density and house value. Hence, it will be more appropriated to use the Gillen (2007) average cost estimates by province, despite limitations mentioned in the cover note of this report (same value for all road transportation vehicles).

Moreover, given that no methodology specific to Canada was found in the literature reviewed, road marginal costs will be used to evaluate the noise impact of the rail mode. This is based on the assumption of Gaudry et al. (2006) stating that the noise unit cost for heavy trucks and train is the same. In this context, one rail car will be considered as one truck.

2.6 Other Environmental Impacts

OECD (1997) has defined the environmental effects of freight for shipping, air transport, trucking, rail and pipeline modes. Marine effects described below are extracted from this paper. This section is completed with Envirochem (2007) conclusions about specific environmental impacts coming from marine transportation, namely oily water, invasive species coming from ballast water, anti-fouling paint and waste disposal.

These issues increase with growth of shipping, but they are less directly linked to tonne-kilometres of freight than air pollution. As no methodology is proposed in the literature to quantify, in monetary value, these impacts, only definitions are provided in this section. Indeed, many guidelines measuring controls and technologies and aiming to reduce environmental impacts and risks can be found.

2.6.1 Operational Water Pollution

OECD (1997) reports that ships are designed to move safely through the water when filled with cargo. When empty, their tanks are filled with ballast water in order to weigh them down and thus stabilize them during a voyage. Before entering a port to load up, the ballast water is discharged. This discharged water is typically unclean, being contaminated with oil and possibly other waste, as well as non-native organisms (Section 2.6.2) within the ballast tanks. The discharge is therefore a source of water pollution.

Transport Canada issued, in June 2006, *Ballast Water Control and Management Regulations* that are harmonized with the US Coast Guard requirements and with the International Convention for the Control and Management of Ship's Ballast Water and Sediments from International Maritime Organization (IMO). Under the regulations, all ship operators must develop a ballast water management plan for each ship that must comply with the regulations.

OECD (1997) reports another similar source of pollution named bilge water. This is seepage that collects in the hold of a ship and must be discharged regularly. On oil tankers, the bilge water is typically contaminated with oil, which seeps out of the cargo tanks. Untreated bilge water discharge into Canadian waters is prohibited by "*Regulations for the Prevention of Pollution from Ships and for Dangerous Chemicals*" under the "*Canadian Shipping Act*".

Envirochem (2007) adds that the cumulative effect of small operational discharges, both accidental and deliberate, poses a bigger threat to seabirds and shorelines than large-scale accidents or spills.

2.6.2 Non-Indigenous Aquatic Species

Shipping is often a means of transporting aquatic species from one part of the world to another, especially in ballast water. They may also attach themselves to boat hulls or arrive within goods being transported. According to Envirochem (2007) over 60% of invasive species introductions in the St. Lawrence Seaway and Great Lakes system are attributed to marine vessel transportation. Most invaders do not survive in their new environment and so do not impose significant ecological or financial costs.

However, some of them can crowd out other species or change the balance of existing ecosystems, e.g. zebra mussels (*Dreissena polymorpha*) which have multiplied in the Great Lakes.

OECD (1997) adds that the link between increased freight and the growth of nuisance species problems is very approximate and that establishing a quantitative link is unrealistic.

However, in the study context, shortsea shipping is the mode studied that could replace trucking or rail. Therefore, ships will move in quite the same ecological system. Non-indigenous aquatic species are not likely to be transported with these ships.

Finally, guidelines, like "*Voluntary Management Practices to Reduce the Transfer of Aquatic Nuisance Species Within the Great Lakes by US and Canadian Domestic Shipping"*, from the St. Lawrence Seaway Corporation, and codes, like "*Code of Best Practices for Ballast Water Management*", from the Shipping Federation of Canada, have been issued in recent years.

2.6.3 Anti-Fouling Paint

Fouling control, needed to protect the hull from corrosion, reduce drag and save fuel, requires the use of biocidal anti-fouling coatings.

Some of these paints contain tributyltin (TBT). Envirochem (2007) describes how this compound causes shell deformation in sea oysters, reduces resistance to infection in fish, is absorbed throughout the food chain, and has been found to be highly toxic to humans. Canada has prohibited the use of TBTs since October 2002.

TBT-free paints are mainly used today. Most of these coatings are composed of copper or zinc as the active biocide. These paints are less effective and their longevity is shorter than TBT paints. Moreover, heavy metals used like copper can cause various problems for organisms residing in basins or harbours. For example, as mentioned in Roberts and al. (2006), copper contamination of macroalgae is a widespread phenomenon that has the potential for substantial negative consequences for associated invertebrate fauna.

Copper contamination greatly reduced the colonization of a variety of epifaunal taxa. Other effects like habitat preferences, feeding rates, survivorship or growth have also been studied and reported in this paper. In some areas, like in San Diego, these types of anti-fouling coatings are prohibited.

Finally, paint manufactures have been developing non-biocidal coatings using silicon-based coatings. These are more costly than the traditional coatings.

2.6.4 Waste Management

The remaining environmental issues can come from garbage, cargo residues and sewage discharges.

As mentioned in OECD (1997), discarded plastics and wood pose a threat to marine species and to coastal regions.

Here are some examples of observed environmental impacts:

- band-shaped packing materials can encircle marine mammals fish, or birds and strangle them;
- ingestion of plastics by marine organisms can kill them;
- wood used for dunnage, if not grated or pulped can, damage small boats.

However, the discharge of garbage into all waters under Canadian Jurisdiction is prohibited by the "*Regulations for the Prevention of Pollution from Ships and for Dangerous Chemicals*" under the "*Canadian Shipping Act*".

In the case of sewage, discharges can have detrimental impacts on both animal and human life. As explained in UKSAC (2008), when human waste is discharged into the water, bacteria feed on the organic matter within the sewage. As the organic substances are decomposed by the bacteria, dissolved oxygen in the water is consumed. If large quantities of waste are discharged into the water the bacteria's biochemical oxygen demand can seriously deplete dissolved oxygen levels in the water.

As outlined in EPA (2001), pathogens found in untreated sewage can cause extreme illness and even death when ingested by humans. Untreated sewage discharge from vessels can suffocate animals and plants living in the aquatic environment. Delicate coral reef communities and shellfish beds are particularly sensitive to untreated sewage.

In UKSAC (2008), potential effects of sewage are outlined. The effect of raw and treated sewage discharged from boats in fast flushing coastal areas is considered as negligible in the context of its diluted nature and in comparison to sewage discharge from water companies' treatment plants. However, boat sewage discharge in poor flushing estuarine areas, for example, inlets and bays, can have a significant localized impact on the environment. UKSAC (2008) adds that it is difficult to quantify this impact but it is likely to be greatest in areas which already suffer from environmental stresses from other sources such as agricultural run off. This fact is affirmed in Envirochem (2007), that sewage from ships is seen as having a smaller impact than sewage from municipal wastewater discharges for example.

To conclude this section, sewage discharge in Canadian waters is regulated by the "*Regulations for the Prevention of Pollution from Ships and for Dangerous Chemicals*".

2.7 Synthesis of Methodologies

2.7.1 Methodologies to Be Used in the Model

This section is a synthesis of information to be used in the model. Required equations are mentioned in Table 2.29, as well as variables to input into the model.

2.7.2 Relative Limitations of the Model

Some limitations have to be outlined before using the proposed model. They can be considered as suggestions for improving the model. They may be required to refine the model.

2.7.2.1 General Limitations of the Model

First, the model assumes the tonnage to be shipped is equivalent to one trip with the chosen marine vessel. It is assumed that a ship is available which has the exact capacity required to transport the tonnage required, i.e., 100% of the available capacity is used. In that context, the model does not allow loading factor variations. The shipping possibilities that can be studied with the model are limited to the weight capacity of the twelve types of vessels presented in the study.

Second, the model examines routes between given port pairings. In a rail and marine freight transportation context, the model only takes into account respective rail and marine segments. The whole transportation chain, including for example, segments between plants and port or road segment between rail station and final destination, is not considered. However, the origin and destination of cargo is very rarely a port or a business with port facilities. Consequently, the model favours shortsea shipping, as the overall impacts of all the components in the goods movement chain from origin to destination are not considered.

Table 2.29 Methodologies to Be Used in the Model to Evaluate Environmental Impacts of Shortsea Shipping in Canada

Equations	Inputs	Output
CAC and GHG Emissions Methodologies		
Cost $_{i,\ mode,\ province}$ = (Annual Emissions for the scenario)$_{i,mode}$ x (Unit cost)$_{i,\ province}$ ▪ i: species of air emission pollutants (CAC or GHG) ▪ Mode: transportation mode	▪ Cargo weight per vehicle (tonne) ▪ Annual cargo weight (tonne) ▪ Provinces crossed ▪ Distance (one-way trip) in each crossed province ▪ Ship type (Envirochem 2007 categories) ▪ Emission factors in grams per tonne-km (from Envirochem (2007) for marine transportation, and from Railway Association of Canada for rail and from Transport Canada for truck mode) ▪ Unit costs by province in $/tonne of emissions (from Marbek (2007))	▪ Cost of air emissions for studied scenario by transportation mode ($)
Accident Cost Methodology		
Marine Cost = (Cost per shipment) x (Number of shipments) *Road* Cost = (Unit cost per vehicle - km) x (Total distance in km) *Rail* Cost = (Unit cost per train – km) x (Total distance in km)	Marine mode ▪ Number of shipments, Innovation Maritime ▪ Number of accidents, Transportation Safety Board of Canada, Marine Statistics ▪ Cost per accident, Transport Canada (2007b) Road mode ▪ Total distance in kilometres, Transport Canada, Canadian Vehicle Survey (2008) ▪ Number of accidents, Transport Canada, Canadian Vehicle Survey (2008) ▪ Cost per accident, Transport Canada (2007b) Rail mode ▪ Total distance in kilometres, Transportation Safety Board of Canada, Rail Statistics ▪ Number of accidents, Transportation Safety Board of Canada, Rail Statistics ▪ Cost per accident, Transport Canada (2007b)	▪ Cost of accidents for studied scenario by transportation mode ($)
Congestion Cost Methodology (only road transportation mode)		
Cost $_{i,}$ = (Distance in urban conditions) x (Unit cost)$_{i,}$ + (Distance in rural conditions) x (Unit cost)$_{i,}$ ▪ i: type of truck (4 axles or 5 axles)	▪ Total distance in kilometres ▪ % of distance in urban conditions ▪ % of distance in rural conditions ▪ Unit cost of dollars per kilometre by urban and rural conditions	▪ Cost of congestion for studied scenario by transportation mode ($)
Noise Cost Methodology (marine mode is not considered)		
Road Cost $_{province}$ = (Vehicle - Kilometre)$_{i,}$ x (Marginal cost)$_{province}$ *Rail* Cost $_{province}$ = (Train car - Kilometre)$_{i,}$ x (Marginal cost)$_{province}$	Road ▪ Number of vehicle - kilometre ▪ Provinces crossed ▪ Marginal cost Rail ▪ Number of train car - kilometre ▪ Provinces crossed ▪ Marginal cost	▪ Cost of noise for studied scenario by transportation mode ($)

Third, the model compares on a one-way trip basis. Return trips are not considered for any of the modes. This may be a disadvantage for railways or trucking companies because these transportation modes may more easily find backhaul opportunities than the marine mode.

Fourth, choosing tonne-kilometre as the transportation service measurement unit has a clear limitation when trucking is considered, given that the vast majority of trucked shipments are volume constrained rather than weight constrained, which is the opposite for trains and ships. This introduces a bias against trucking performance, but more importantly limitations in the mode comparison.

Fifth, cargo handling and transloading activities usually generate environmental impacts, like air emissions. Innovation Maritime (2008) reports observations about this topic. Different air pollutants are emitted by different types of equipment used in port activities and air pollutants are released while handling bulk cargoes. These emissions are excluded in the modal comparison allowed with the proposed model.

If required in a refined version of the model, some emission factors needed to assess air emissions in port can be the same as those used in warehousing or rail switch yards. However, other factors may be developed to reflect emissions released by specific equipment such as gantry cranes, grain elevators or tank farms.

Finally, some environmental and social impacts of marine transportation are not incorporated into the model. As mentioned in Section 2.6, effects of operational oil waters, non-indigenous species or waste management can not be easily quantified. However, in Canada, regulations are in force to prohibit some discharges and countenance better practices.

2.7.2.2 Specific Limitations of the Model

Energy Efficiency (fuel consumption and air emissions)

An update of CO_2e unit cost should be considered in a future version of the model considering that a Canadian Carbon market should be structured in the next few years.

Accidents

The marine mode enjoys an advantage over the other two modes regarding accident costs. Given the impact this parameter has on the results from the model, a quantification of "property damage collisions" for the marine mode should be considered in a further study.

Congestion Issue

Canadian congestion due to freight transportation must be further studied. Unit cost evaluation was studied in the last few years, but only in a passenger context. In fact, unit costs coming from a US study will be used in the model. This is a limitation because these costs do not reflect the Canadian road transportation system and road congestion is much more severe in the US than in Canada.

Moreover, the model assumes that all trucks will encounter some level of congestion in urban areas. This might not be the case depending on the specific itinerary and traffic fluidity patterns.

Finally, the model assumes that there is no congestion on Canadian waterways and ports, as well as on the rail network. The model does not take into consideration potential port terminal congestion that can have an impact on cargo handling activities or urban traffic congestion caused by trucks delivering and/or picking up cargo. There are also some shortsea shipping routes that require roadways to be temporarily inaccessible. Furthermore, Canada’s rail network crosses many roadways, and the delays caused to those involved in both personal and commercial transport while waiting for the tracks to clear should also have an associated cost to society. Those factors may be added in a further version of the model where the whole transportation chain is evaluated.

Noise Issue

As mentioned in Section 2.5, Gillen (2007) estimates must be used with care. The cover note of the study indicates that the figures presented are “an order of magnitude of costs of noise from transportation activities”. Allocating the road transportation to noise costs among the different vehicles types is not possible.

However, the author mentions that its results would not distort modal comparisons, as noise related costs only represent a small share of the full environmental and social costs.

Finally, the model assumes that rail transportation effects can be calculated with the same unit costs as road transportation. This assumption is another limitation; it comes from Gaudry et al. (2006) that states that the noise unit costs for heavy trucks and rail are the same.

3. DEFINITION OF SCENARIOS

Four shortsea shipping scenarios are defined in this section: Great Lakes, St. Lawrence, East Coast and West Coast.

3.1 Canadian Shortsea Shipping Context

These shortsea shipping scenarios have a common point: the Canada / US trade patterns. They are determined according to the following criteria:

- The existence of shortsea shipping services in the area under consideration;
- The Canada / US trade patterns;
- The modal competition.

The first criterion demonstrates that the shortsea shipping service is economically viable. Indeed, many studies have been done in recent years to capture shortsea shipping opportunities. Unfortunately, very few of them were implemented. Actually, most marine transportation services are:

- Addressed to a single shipper on demand;
- Ferry services where most of them are subsidized;
- Connecting islands and isolated regions to the continent.

CSL, Groupe Desgagnés and McKeil Marine, to name a few, are involved in marine transportation for specific customers. They also move cargo on an occasional basis and their ships sail on the Great Lakes, the St. Lawrence and in the Atlantic. Other companies such as Oceanex, Marine Atlantic, and NFL Ferries operate regular services. These companies connect islands, isolated regions or offer significant short cuts compared to land transportation.

The second criterion demonstrates the importance of the shortsea shipping service within the trade patterns. This criterion is used to show that the selected shortsea shipping service has a role to play within the continental trade. Furthermore, to increase their chance of success, different studies stated that shortsea shipping projects must capture an important part of trade (Cambridge Systematics, Brooks & al, Innovation Maritime, MariNova Consulting Ltd.). Indeed, marine transportation commercial strength is related to economies of scale. To achieve this goal, marine transportation must then look at getting market share of the most important trade patterns within Canada and with the US. This criterion is then an indicator of the economic relevance of shortsea shipping.

The minimum tonnage to be considered as being viable for a shortsea shipping service depends on the ship capacity and the service frequency. Ship operating costs become viable when ships get to 2,500 tonnes of DWT and higher (Table 3.1). These rates are for modern boxed ships, sailing in Europe. Considering a weekly service, minimum tonnage should be around 130,000 tonnes of freight per year. The latter would reach 650,000 tonnes a year for a daily service if performed by a 2,500 tonnes DWT ship.

Table 3.1 Time Charter Rates (Euros)

DWT	Rate/day	Rate/tonne-day
1,250	1,950€	1.56€
1,750	2,100€	1.20€
2,500	2,600€	1.04€
3,500	3,550€	1.01€
6,500	5,400€	0.83€

Source: Scandinavian Shipping Gazette

From a commercial aspect, minimal service frequencies and marine freight rates obtained shall also be comparable to the ones offered by rail and road options. It does not exclude the use of a smaller ship but it is preferable to use larger ships. For a similar type of ship, the larger the ship, the lower is the unit transportation cost.

In 2006, trade between Canada and the US was $574,849 million, compared to $380,130 million in 1996. This represents a 51.22% rise during this period of time. The trade balance between Canada and the US is positive as Canada exports more than it imports.

Table 3.2 shows the percentage of goods transported by each means of transportation for commercial exchanges between the US and Canada during the years 1996, 2001 and 2006. It shows a decrease, expressed as a percentage, in road transportation and air transportation, and an increase in the railway and maritime sectors.

Table 3.2 Trade between Canada and the US by Means of Transportation, 1996, 2001, 2006

Years	Road	Railway	Maritime	Air	Other
1996	67.6%	16.9%	2.5%	6.4%	6.5%
2001	63.7%	16.6%	2.3%	7.5%	9.8%
2006	60.2%	17.0%	3.7%	5.8%	13.4%

Source: Statistics Canada

The last criterion renders the modal comparison relevant. If a shortsea shipping service is the only one which can be used, the socio-ecological comparison becomes irrelevant. This is the case for the Oceanex services to Newfoundland. Indeed, there is no rail service to Newfoundland and trucks must use marine transportation to reach the island.

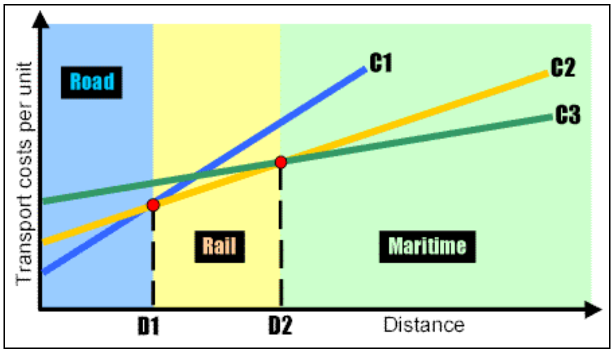
On the other hand, there are few corridors where marine and land transportation are comparable. The only corridor follows the St. Lawrence and the Great Lakes from Halifax up to Windsor. Other routes offer geographical shorts cuts to land or marine transportation. This is the case of shortsea shipping crossing Great Lakes or the ferry services across the Bay of Fundy. On the St. Lawrence, North/South trade patterns usually offer short cuts to land transportation. Indeed, ships must go around Nova Scotia to reach the USEC region from Quebec or Ontario.

Passenger scenarios were not considered as being relevant. Passengers moved by sea are mostly carried by regular ferry services. These services are mainly used as road shortcuts. Of course, there are ferries servicing islands, such as Newfoundland and Vancouver Island for example, but in every case there is not much modal competition.

MariNova Consulting Ltd observed that shortsea shipping services increase their chance when rail services are inadequate. However, adequate rail services are offered along the St. Lawrence Seaway corridor. The rail services become limited to the St. Lawrence south shore from Clermont. However, Baie Comeau has a rail ferry to Matane to connect with the continental rail network.

Distance is also a factor influencing modal competition. In Figure 3.1, C1 represents the road transportation costs, C2 the rail and C3 the marine costs. In general, road transportation is more economical on short distances and marine transportation on longer ones, while rail transportation falls somewhere between the two. Different studies in multimodal choice conclude that there is a minimal distance where one transportation mode is more competitive than another. According to the Université de Montréal, D_1 is generally about 750 km from the departure point and D_2 around 1,500 km from the departure point.

Figure 3.1 Distance, Modal Choice and Cost



Source: http://www.geog.umontreal.ca/geotrans/fr/ch3fr/conc3fr/ch3c5fr.html#1

The factors influencing it are the loading costs and the operating costs. Marine transportation has high loading costs compared to road transportation. On the other hand, cost per tonne-kilometre is smaller by sea than by road. It means that a marine transportation journey must be long enough to gain benefits from the lower unit operating cost.

To facilitate analysis, states have been grouped into different areas (see Annex B):

- USGL consists of the states having port facilities in at least one of the Great Lakes;
- USEC is divided into sub-regions such as the Northern, the Middle and the Southern. This is necessary because trade between the USEC and Canada is greater with the Northern region than with the Southern.

The states of New York and Pennsylvania were calculated in two different regions. Unfortunately, statistics on commerce do not provide information allowing us to determine if it concerns more the USGL region or the USEC region. All other states are gathered into one region. These states either do not provide marine access or trade with these states is not as significant as it is with the USGL and USEC regions.

3.2 Scenario 1 – Great Lakes System

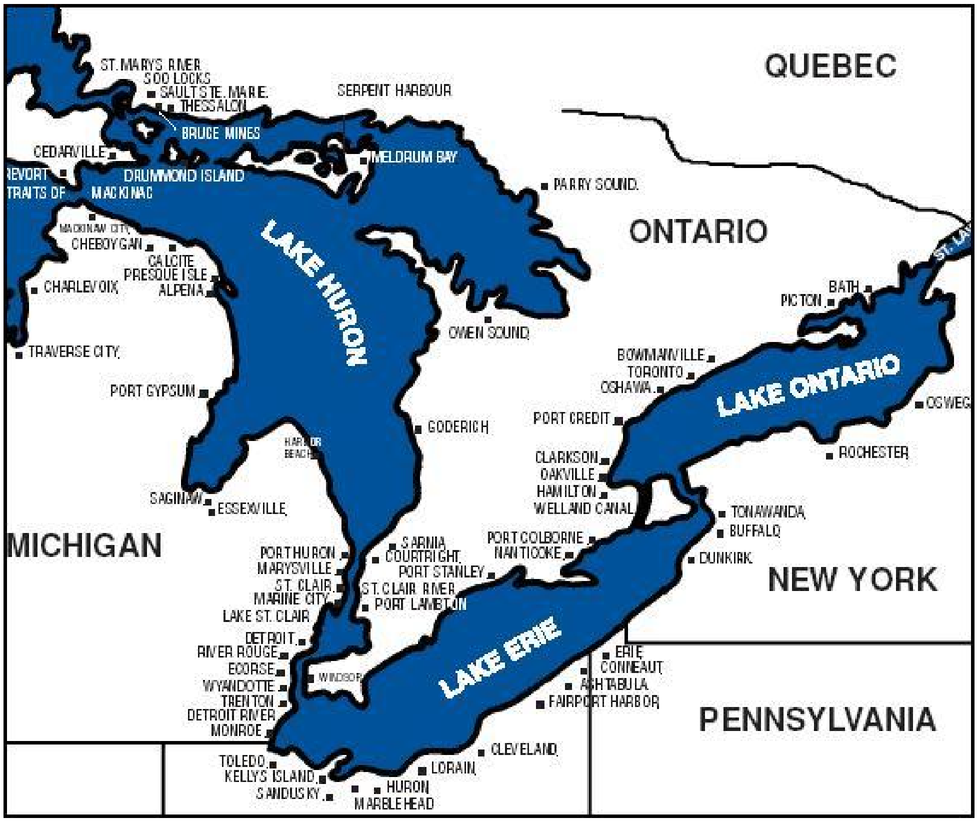
The major commodity moved by sea on the Great Lakes and the major trade route between Ontario and Great Lake States were defined in order to choose origin, destination and commodity type of this first scenario.

After that, this scenario definition will take into account the most common ship type and size used on Great Lakes and the St. Lawrence Seaway system.

3.2.1 Study Area Location

Most Great Lakes shortsea shipping scenarios involve Canada / US trade. Indeed, the Great Lakes are a natural barrier to land transportation. Lake Ontario, Huron and Erie crossing points are located at the head or the tail of each one (Figure 3.2). This forces rail and truck transportation to go around them. Road congestion is also a constant reality to deal with on the highways between Toronto and Detroit.

Figure 3.2 Great Lakes Map



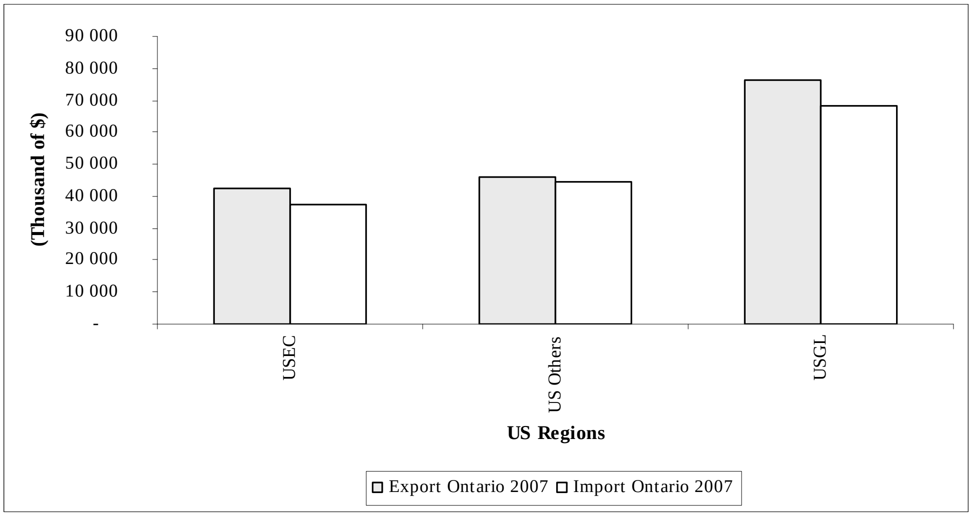
Source: Lake Carrier Association

Lake Erie would be the place where a shortsea shipping service would capture most trade between Ontario and USGL. Indeed, trucks must go through Buffalo or pass by Windsor or Sarnia.

3.2.2 Existing Trade Patterns

For the years 2006 and 2007, about 48% of trade between Canada and the US came from Ontario. Approximately 46% of this trade is via trucks. Figure 3.3 draws the portrait of Ontario transborder commercial exchanges. According to this figure, USGL region states were the main business partners of Ontario in 2007, followed by the USEC region. We can also note that the value of inbound and outbound shipments between Ontario and its major commercial partners are similar.

Figure 3.3 Trade between Ontario and the US, 2007



Sources: Transport Canada, Statistics Canada, Innovation Maritime

The portrait of commercial exchanges between Ontario and the USGL shows that the state of Michigan is by far the major partner, followed by Ohio and Illinois (Table 3.3).

Table 3.3 Trade between Ontario and US Great Lakes States, 2007 (in value)

USGL states	Import 2007	Export 2007
Michigan	36%	65%
Ohio	27%	12%
Illinois	14%	10%
Indiana	13%	6%
Wisconsin	6%	3%
Minnesota	4%	3%

Sources: Transport Canada, Statistics Canada, Innovation Maritime

Value-based data are more complete. However there are not very useful for determining the potential of a shortsea shipping service.

Michigan and Ohio are also the main Ontario trading partners in terms of cargo tonnage shipped from Ontario (Table 3.4). These states represent about 50% of land transportation tonnage.

The main cargo is solid bulk products and metallic products with respectively 6 million tonnes and 5.1 million tonnes. This cargo represents almost 50% of the land transportation tonnage transported from Ontario to the USGL region.

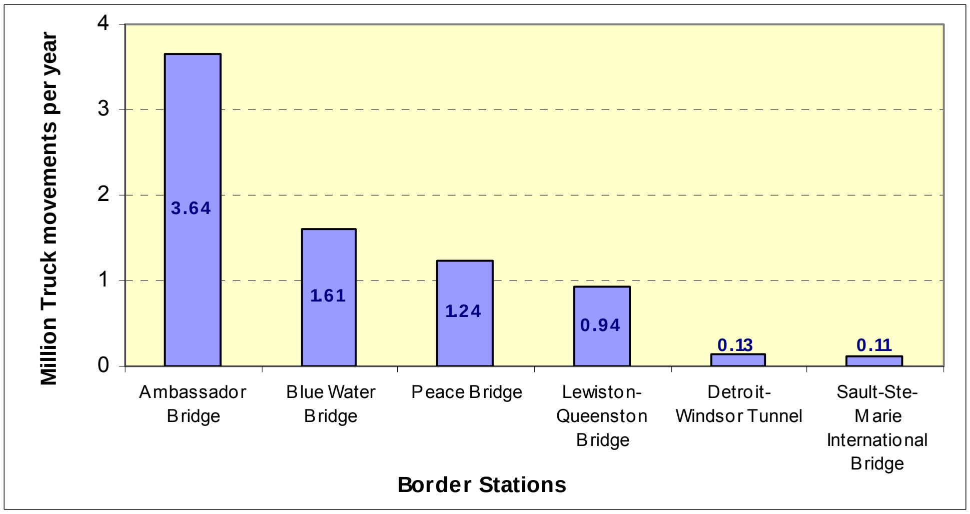
Table 3.4 Land Transportation from Ontario to USGL States, 2007 (tonnes)

	Illinois	**Indiana**	**Michigan**	**Minnesota**	**Ohio**	**Wisconsin**	**Total**
Chemical Products	183,351	37,958	107,770	8,532	188,239	39,118	563,968
Food Products	327,968	73,167	252,860	23,052	181,770	69,035	927,852
Forest Products	160,934	196,115	790,500	161,661	223,720	559,600	2,092,531
General Cargo	507,436	252,967	555,505	87,419	640,456	161,95	2,205,759
Grain	184,812	32,943	128,615	41,877	363,162	66,479	817,887
Machinery	26,003	25,533	41,160	4,739	23,508	9,347	130,290
Metallic Products	521,429	681,084	1,750,326	301,237	1,719,891	137,749	5,111,805
Ore / Concentrates	20	51,810	525,260		304,662	35	881,788
Others	156,333	193,482	692,583	28,962	267,052	58,636	1,396,775
Petroleum Products	154,905	62,662	677,040	23,651	320,502	37,557	1,276,318
Pulp / Paper	406,545	95,165	128,487	114,393	202,757	138,408	1,085,766
Solid bulk	917,608	425,433	820,862	447,896	1,913,494	1,469,161	5,994,454
Textile Products	21,555	4,426	18,162	1,345	5,773	3,263	54,524
Vehicles / Parts	240,216	328,153	32,222	35,768	506,241	89,621	1,233,131
Total	3,808,026	2,460,898	6,460,898	1,280,622	6,861,237	2,839,711	23,772,846

Sources: Bureau of Transportation Statistics, Innovation Maritime

This situation leads us to identify the main border stations used by trucks in Ontario. The Ambassador Bridge is the busiest border station crossing in Ontario, with nearly four million truck movements per year (Figure 3.4).

Figure 3.4 Principal Border Stations Crossed by Trucks in Ontario



Sources: Transport Canada, Statistics Canada, Innovation Maritime

The US Bureau of Transportation Statistics (BTS) publishes different data concerning transportation. Most of the traffic goes from Ontario to USGL states with 23,772,846 tonnes of cargo (Table 3.5). Whether the data are compiled by Statistics Canada or by the BTS, there are important gaps especially for weight data in land-mode transportation statistics.

Table 3.5 Tonnage per Year between Ontario and USGL (tonnes)

Origin / Destination	**Land Transportation 2007**	**Marine Transportation Average 2001-2005**
Ontario / USGL	23,772,846	13,966,826
Ontario / Ontario	ND	8,997,825
USGL / Ontario	3,353,049	29,140,890
Total tonnage	**27,125,895**	**52,105,541**

Sources: Bureau of Transportation Statistics, Statistics Canada, Innovation Maritime

Marine transportation is very active on the Great Lakes. The majority of trade took place between the US and Ontario. Looking in further detail at marine trade patterns, the most important marine transportation route on the Great Lakes between 2001 and 2005 was from Superior (WI) to Nanticoke (ON). According to Statistics Canada, in this period, there has been above 5.6M tonnes of cargo moved from Superior (WI) to Nanticoke (ON). This cargo was mainly composed of coal, with 5.3M tonnes.

Considering that there is major trade between Ontario and Great Lake States, it is therefore recommended to use Superior (WI) - Nanticoke (ON) route in the Great Lakes scenario of this study.

3.2.3. Choice of Commodity and Marine Vessel Type for of Great Lakes Scenario

Trade by marine transportation between Ontario and the US was mainly for solid bulk products such as iron ore, coal, minerals and grain (Table 3.6).

Table 3.6 Marine Trade between the US and Ontario by Type of Product, 2001 to 2005

	Year					
Products	**2001**	**2002**	**2003**	**2004**	**2005**	**Total**
Grain and food products	1,724,790	1,255,574	1,254,897	1,572,619	1,407,321	7,215,201
Manufactured goods	46,924	27,530	4,570	933,269	941,598	1,953,891
Petroleum and chemical products	3,045,958	2,673,509	2,469,096	3,042,037	2,145,850	13,376,450
Coal	22,688,047	20,237,536	19,750,456	16,969,044	18,124,345	97,769,428
Machinery and transportation equipments	345	167	15,764	3,102	315	19,693
Minerals, ore and concentrates	26,592,821	26,613,333	27,170,425	29,224,358	29,525,142	139,126,079
Forest products	113,611	114,095	58,316	2,528	65,146	353,696
Metallic Products	50,532	254,518	195,769	105,723	106,724	713,266
Total	54,263,028	51,176,262	50,919,293	51,852,680	52,316,441	260,527,704

Sources: Innovation Maritime, Statistics Canada

This will be the commodity type used for this first scenario.

Regarding ship type, gearless and geared bulk carriers are consequently the main ships used on the Great Lakes. These ships were built to optimize the Seaway. Indeed, there are different locks on the St. Lawrence / Great Lakes system.

3.2.4 Scenario General Inputs

Table 3.7 summarizes general inputs of the Great Lakes scenario. The distance to be crossed in each transportation mode has also been calculated.

Table 3.7 General Inputs of Great Lakes Scenario

Origin	Superior (WI)	**Destination**	Nanticoke (ON)
Cargo weight	25,000 tonnes	**Commodity type**	Solid bulk (coal, minerals …)
Ship type	Seaway (Bulker 25 000)		

Transportation mode	**Rail**	**Road**	**Marine**
One way trip Distance (km)	1,514	1,466	1,510
Urban proportion (%)	10	10	1

3.3 Scenario 2 – St. Lawrence System

3.3.1 Study Area Location

Figure 3.5 St. Lawrence System Area

Source: St. Lawrence Seaway Management Corporation, http://www.greatlakes-seaway.com

3.3.2 Existing Trade Patterns

Traffic from Quebec to the US and Mexico accounts for 46% of all traffic originating from the province. In 2006, paper and forest products were the main commodities transported from Quebec to the US and Mexico.

The USEC is the major trade partner with Quebec. The northern part of the USEC is the main sub-region with $23 billion worth of total trade (Table 3.8).

Table 3.8 Quebec – US Trade, 2007 (C$)

US Region	Export	Import	Total
USGL	19,833,688,259	9,575,768,367	29,409,456,626
Other[a]	15,963,080,491	9,618,382,172	25,554,462,663
USEC-North	16,174,244,011	7,283,826,869	23,464,070,880
USEC-Middle	5,814,909,693	1,767,556,443	7,582,466,136
USEC-South	4,175,717,061	1,934,548,952	6,110,266,013

Sources: Institut de la statistique du Québec, Innovation Maritime
a: States of New York and Pennsylvania

The trade data in tonnes obtained from the Bureau of transportation statistics confirm that the northern states of the USEC are also considered to be important trading partners (Table 3.9).

Table 3.9 Land Transportation, 2007 (tonnes)

	Import	Export	Total
USEC-Middle	485,121	5,500,457	5,985,579
USEC-North	291,999	9,756,979	10,048,978
USEC-South	312,118	2,301,898	2,614,016
USGL	633,535	6,898,342	7,531,877

Sources: Bureau of Transportation Statistics, Innovation Maritime

The Quebec / Atlantic region is also a major rail corridor with 24 million tonnes of freight moved in 2006 (Table 3.10). Iron ore and concentrates represent 20 million tonnes of this trade. This commodity comes from Labrador City and it is moved to Sept-Îles. It means that only four million tonnes of freight are moved by rail along the Montréal / Halifax corridor.

Table 3.10 Quebec Rail Traffic, 2006 (tonnes)

	Import	Export	Total
Atlantic	21,696,271	2,354,204	24,050,475
US	5,358,093	13,488,698	18,846,791
Ontario	5,364,821	5,758,718	11,123,539
British Columbia	2,914,806	1,605,818	4,520,624
Alberta	1,064,266	951,273	2,015,539
Saskatchewan	1,308,638	124,267	1,432,905
Manitoba	610,584	265,970	976,554
Mexico	24,318	199,645	223,963

Sources: Statistics Canada, Innovation Maritime

The second most important rail corridor is with the US, and the third is between Quebec and Ontario. However, truck traffic must also be considered.

According to the results of the study carried out in 1999 on truck traffic,[2] there were 1,900 weekly truck movements between Ontario and the Maritimes compared to 5,300 movements between Quebec and the Maritimes.

For Quebec, three principal areas generate these displacements: Chaudière-Appalaches, Montréal and Bas-Saint-Laurent, representing more than half of road displacements between these two regions. Figure 3.6 shows the distribution of these movements between the different Maritime Provinces.

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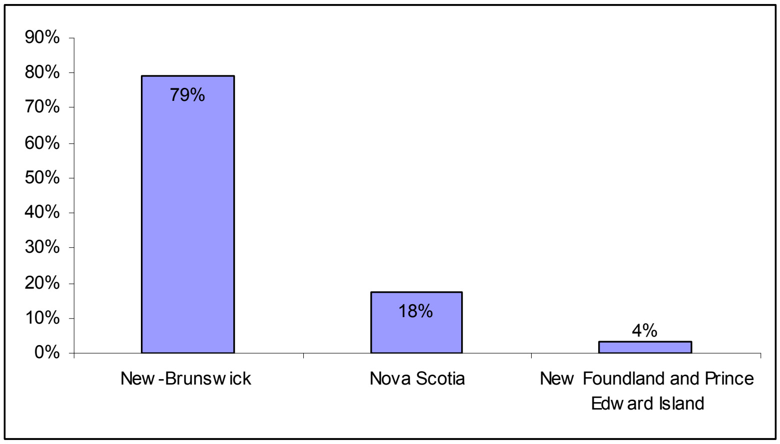
[2] Les déplacements interurbains de véhicules lourds au Québec - Enquête sur le camionnage de 1999, 2003, Transports Québec.

Figure 3.6 Contributions of the Maritime Provinces to Quebec Haulage Flows



Sources: Transport Canada, Statistics Canada, Innovation Maritime

It is geographically and economically very constraining to set a shortsea shipping service between Quebec and New Brunswick even though it is the major trade corridor.

Indeed, a ship must travel a much longer journey to get to New Brunswick compared to a truck. Furthermore, travel can be done within a day for truck drivers.

In addition to this domestic cargo, the opportunity of linking with international cargo, which in turn links with deep sea carriers calling at the Port of Halifax, should be also explored in order to develop shortsea shipping scenarios in the St. Lawrence. Despite its smaller volume of containers handled compared to Montreal, Halifax offers more liner services to more world ports than any other port in Eastern Canada. In 2004, about 46% of the containers handled in the Port of Halifax were from or for inland Canada.[3] Approximately 20% of it involved Quebec.

3.3.3 Shortsea Shipping Scenarios in the St. Lawrence

There are different shortsea shipping projects servicing Quebec. Most of these scenarios concern a unique shipper to different destinations.

Even though the economic feasibility of a shortsea shipping service between Halifax and Montréal is not yet proven, it would be a representative one for this study since it would be offered to different shippers and there is modal competition along the St. Lawrence Seaway trade corridor.

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[3] Marinova Consulting Ltd, 2005, Shortsea Shipping Market Study.

3.2.4 General Inputs for St. Lawrence System Scenario

Table 3.11 summarizes general inputs of the St. Lawrence System scenario. The distance to be crossed in each transportation mode has also been calculated.

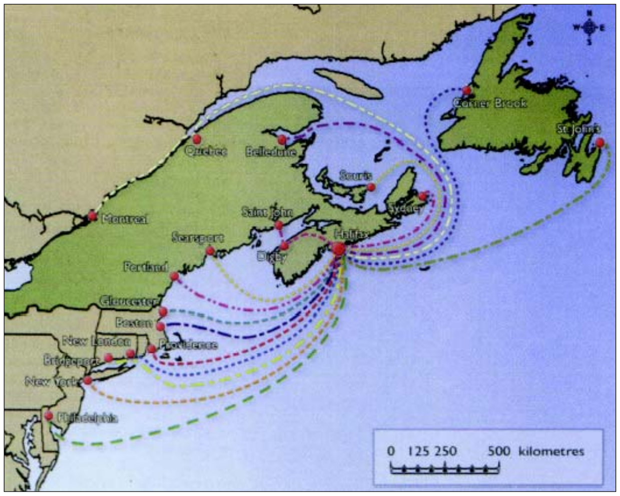
Table 3.11 General Inputs of St. Lawrence System Scenario

Origin	Halifax (NS)	**Destination**	Montreal (QC)
Cargo weight	10,000 tonnes	**Commodity type**	Truck trailers and containers
Ship type	Ro-Ro's / Lo-Lo's		
Transportation mode	**Rail**	**Road**	**Marine**
One way trip Distance (km)	1,226	1,251	2,950
Urban proportion (%)	2	2	1

3.4 Scenario 3 – East Coast

3.4.1 Study Area Location

Figure 3.7 East Coast Area



3.4.2 Existing Trade Patterns

Atlantic trade with the US is mostly done with the northern part of the USEC region. More than half of the trade from Atlantic Canada is made with USEC-North and it is mainly exportation.

In 2007, $15 billion worth of petroleum products represented the main commodity exported to the USEC (Table 3.12). Seafood and forestry products come second at about $3 billion. Surprisingly, Atlantic Canada imported $300 million worth of seafood and wood products from New England.

Table 3.12 Atlantic - US Trade, 2007 (US$)

	Export	Import	Total
Other	3,074,661,513	795,107,462	3,869,768,975
USEC-Middle	3,115,408,563	346,735,538	3,462,144,101
USEC-North	14,750,648,369	823,775,638	15,574,424,007
USEC-South	1,515,184,626	387,566,916	1,902,751,542
USGL	3,445,680,429	685,027,181	4,130,707,610

Notes:

USEC Middle:	Delaware, District of Columbia, Maryland, New Jersey, Pennsylvania, Virginia, West Virginia
USEC North:	Connecticut, Maine, Massachusetts, New Hampshire, New York, Rhode Island, Vermont
USEC South:	Florida, Georgia, North Carolina, South Carolina
USGL:	Illinois, Indiana, Michigan, Minnesota, Ohio, Wisconsin

Sources: Strategis, Innovation Maritime

The majority of Newfoundland trade is shipped by vessel (Table 3.13). Truck is the main mode used inbound to New Brunswick (85%), outbound from Nova Scotia (52%) and Prince Edward Island (92%).

Table 3.13 US-Canada Atlantic Trade by Transportation Mode for Each Province, 2007

	Air		Maritime		Other		Rail		Truck	
	Import	Export	Import	Export	Import	Export	Import	Export	Import	Export
New Brunswick	0.17%	0.03%	7.83%	72.51%	0.01%	4.47%	7.13%	5.80%	84.86%	17.20%
Newfoundland	12.83%	0.16%	84.55%	88.87%	0.05%	0.00%	0.00%	0.12%	2.57%	10.84%
Nova Scotia	12.43%	1.62%	74.01%	7.19%	0.37%	28.38%	5.12%	10.98%	8.07%	51.83%
Prince Edward Island	0.92%	6.62%	70.88%	0.95%	0.00%	0.00%	0.00%	0.40%	22.18%	92.02%

Sources: Bureau of Transportation Statistics, Innovation Maritime

In terms of tonnage, Atlantic Canada trade with the US regions is unbalanced. USEC-North is the main trading region with eight million tonnes of commodities shipped by rail or by truck (Table 3.14).

Table 3.14 Atlantic Canada – US Land Transportation, 2007 (tonnes)

	Import	Export	Total
USEC-Middle	1,393,265	4,594,187	5,987,452
USEC-North	247,647	7,976,314	8,223,962
USEC-South	144,255	5,478,264	5,622,519
USGL	142,427	1,113,499	1,255,925
Others	335,528	2,793,367	3,128,895
Total	**2,263,122**	**21,955,631**	**24,218,753**

Sources: Bureau of Transportation Statistics, Innovation Maritime

Nova Scotia and New Brunswick are the main provinces where land transportation is used to move cargo to the US. The states of New York, Massachusetts and Maine are the principal destination of the shipments made by rail or by truck (Table 3.15).

Table 3.15 Land Transportation Origin / Destination Matrix, 2007 (in metric tonnes)

	Connecticut	**Maine**	**Massachusetts**	**New Brunswick**	**New Hampshire**	**New York**	**Nova Scotia**	**Rhode Island**	**Vermont**	**Total**
Connecticut							10			10
Maine				1,621			14			1,635
Massachusetts				1			104			105
New Brunswick	492,002	1,183,202	1,849,631		107,224	715,193		201,012	26,394	4,574,678
New Hampshire				8						8
New York							43,370			43,370
Nova Scotia	52,713	104,444	255,791		88,834	1,244,883		2,806	17,264	1,766,735
Rhode Island										
Vermont				0						
Total	**544,715**	**1,287,647**	**2,105,422**	**1,630**	**196,078**	**1,960,076**	**43,498**	**203,818**	**43,657**	**6,386,541**

Sources: Bureau of Transportation Statistics, Innovation Maritime

Marine transportation in the Atlantic region is also important. There were more than 63 M tonnes of cargo on average loaded per year in Atlantic ports to different continental destinations during the 2001 to 2005 period (Table 3.16), and about 23 million tonnes of cargo unloaded. The major trade pattern over this period was 35 million tonnes of cargo shipped to USEC destinations by ship.

Table 3.16 Cargo Loaded in Atlantic Ports, 2001 to 2005 (tonnes)

	Unloaded	**Loaded**
Atlantic	18,109,745	18,109,745
Ontario	295,068	507,584
Others	199,710	301,037
Quebec	835,452	2,269,281
US East Coast	1,085,224	35,450,874
US Gulf	1,994,528	2,491,765
USGL	289,248	4,528,048
Total	**22,808,975**	**63,658,333**

Sources: Innovation Maritime, Statistics Canada

As a major trade route between Atlantic Canada and the US, the scenario route will consider a destination in northern USEC region. This trade route has modal competition against rail and trucks.

3.4.3 Commodity Type and Vessel Type

Petroleum products are the main commodities shipped by land transportation to the northern states on the East Coast (Table 3.17).

Table 3.17 Tonnage Shipped by Land Transportation between Nova Scotia, New Brunswick and the USEC – North Region, 2007

	Connecticut	**Maine**	**Massachusetts**	**New Hampshire**	**New York**	**Rhode Island**	**Vermont**	**Total**
Chemical Products		366	37	326	423			1,151
Food Products	30,323	86,450	79,812	5,762	42,347	4,096	847	249,637
Forest Products	54,574	335,348	162,842	41,380	96,229	5,895	11,251	707,519
General Cargo	12,242	50,938	40,405	15,780	21,205	644	9,303	150,516
Grain	41	4,771	1,738	551	1,042		84	8,228
Machinery	151	75	63	22	36	1	19	367
Metallic Products	1,457	7,825	5,361	243	11,678	96	67	26,726
Ore / Concentrates	2,722							2,722
Others	607	13,714	1,765	1,455	1,087	45	380	19,052
Petroleum Products	387,783	683,718	1,541,330	55,708	355,420	188,787	17,813	3,230,560
Pulp / Paper	54,587	32,209	87,104	5,440	76,069	4,027	3,796	263,230
Solid bulk	61	72,540	182,336	69,218	1,397,240	177	95	1,721,667
Textile Products	39	455	1,645	106	247	31	3	2,524
Vehicles / Parts	139	875	1,090	96	424	19	0	2,643
Total	**544,725**	**1,289,282**	**2,105,527**	**196,086**	**2,003,446**	**203,818**	**43,657**	**6,386,541**

Source: Bureau of Transportation Statistics, Innovation Maritime

Looking at marine transportation in greater detail, ships carried, on average between 2001 and 2005, 4.1 M tonnes per year of petroleum and chemical products between Saint-John (NB) and Boston (MA).

There are also different shortsea shipping services and projects related to general cargo. Most shortsea shipping projects involving Atlantic Canada are with the northern part of the USEC. Figure 3.8 shows different possible routes.

Considering that petroleum products constitute the main cargo within the major trade route, it would make a representative scenario. Knowing that Saint John to Boston is the busiest route for this kind of trade, it would then be an ideal scenario. This scenario involves product and chemical tankers, which makes it unique compared to the others scenarios.

3.4.4 General Input for East Coast Scenario

Table 3.18 summarizes general inputs of the East Coast scenario. The distance to be crossed in each transportation mode has also been calculated.

Table 3.18 General Inputs of East Coast Scenario

Origin	Saint John (NB)	**Destination**	Boston (MA)
Cargo weight	35,000 tonnes	**Commodity type**	Petroleum products
Ship type	Product Tanker		
Transportation mode	**Rail**	**Road**	**Marine**
One way trip Distance (km)	1,616	665	550
Urban proportion (%)	8	8	2

3.5 Scenario 4 – West Coast

The West Coast scenario is to move containers within British Columbia between Prince Rupert and Richmond, situated in the Lower Mainland along the Fraser River.

3.5.1 Study Area Location

Figure 3.8 West Coast Area

Source: British Columbia Ports Strategy, FINAL, March 2005

3.5.2 Existing Trade Patterns

The most significant trend on the Pacific Coast is the rapid growth of container trade with Asia, especially Shanghai and Shenzhen (China).

Table 3.19 Top 15 Container Ports in Asia Pacific Region, 2005

	PORT	THROUGHOUT MILLION EUs PER YEAR	5-YEAR GROWTH TREND (%)
1	Singapore	23.2	6
2	Hong Kong, China	22.4	4
3	Shanghai, China	18.1	26
4	Shenzhen, China	16.2	32
5	Busan, Korea	11.8	9
6	Kaohsiung, Taiwan	9.5	7
7	Qingdao, China	6.3	24
8	Klang, Malaysia	5.5	11
9	Ningbo, China	5.2	42
10	Tianjin, Korea	4.8	23
11	Pelepas, Malaysia	4.2	58
12	Laem Chebang, Thailand	3.8	12
13	Tokyo, Japan	3.6	4
14	Priok, Malaysia	3.2	7
15	Yokohama, Japan	2.9	4

Source: Clarkson Research Ltd.

Five years ago, the main source of imports was Japan, but China now accounts for almost half of imports. Of the 26 million twenty foot equivalent units (TEUs) handled on the Pacific Coast in 2006, about two thirds originated from Hong Kong, Taiwan and Mainland China.[4] Container shipments from Chinese ports are growing at a rate of 29% per year.

Trade from more established suppliers including Busan (Korea), Kaohsiung (Taiwan), and Tokyo (Japan) also continues to expand in both volume and value.

The main destination for containers from Asia is the major distribution centres in Chicago and Toronto. The rapid growth in trade with China supports the suggestion by shipping company representatives for a high-speed direct shuttle to better serve their import customers in Toronto and Chicago.

However, more containerized exports are required in order to balance traffic. In 2005, Canada imported $30 billion worth of goods but exported only $7 billion to China.[5] Canada, the US and Mexico each import about five times more in dollar value from China as they export. This imbalance has an adverse impact on the economic feasibility of our Pacific Coast shortsea shipping scenario. For example, much of the export traffic from Prince Rupert comes from the US rather than Canada.

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[4] Norman Stark, President, TSI Terminal Systems Inc., Port Days, Halifax, Sept. 27, 2005.

[5] CBC News, April, 3, 2006. www.cbc.ca

3.5.3 Commodities

In Vancouver, 68% of the import containers are for destinations outside British Columbia and are moved by rail. A breakdown of the main commodities imported is provided in Table 3.19. Furniture and bedding account for more than one third of containerized imports by volume. Machinery and parts including motorcycles account for 16%, toys, games and sports equipment 11% and home & building products, 9%.

Furthermore, about one million TEU containers were exported from Vancouver Fraser Port in 2007 (Table 3.20). Forest products are the leading containerized exports.

Table 3.20 Containerized Imports through Vancouver, 2006

COMMODITY	VALUE[a] $/TEU	% BY VALUE	% BY VOLUME	VANCOUVER
Furniture & Bedding	10,600	14	34	380
Machinery And Parts	25,800	16	16	180
Toys, Games & Sports Eq.	21,200	6	11	120
Home & Building Products	16,900	6	9	100
Electronic & Electrical Eq.	47,900	10	5	60
Textiles & Clothing	46,100	7	4	40
Ceramic Goods	10,700	2	4	40
Footwear	31,200	4	3	40
Food & Beverage	30,000	3	3	30
Other	26,000	29	10	110
TOTAL		**100**	**100**	**1,100**

Source: Calculated from port data

a: Robert Leachman, University of California at Berkeley, “Port and Modal Elasticity Study”, 2005

Table 3.21 Containerized Exports through Vancouver, 2007

COMMODITY	VALUE ($1,000/TEU)	VANCOUVER FRASER (TEUS/YEAR)
Pulp, Paper & Waste Paper	8	340,000
Lumber, Panels & Wood Products	8	190,000
Agri Crops (Peas, Beans, Barley)	4	90,000
Animal Feed- Hay, Alfalfa Pellets	2	70,000
Metals (Lead, Zinc, Copper, Aluminium)	40	30,000
Metal Scrap	5	50,000
Chemicals	12	20,000
Machinery & Equipment	26	40,000
Food, Drinks, Meat & Fish	30	50,000
Other		70,000
TOTAL		**950,000**

Source: Calculated from Port data 2007

Crop exports have more than doubled in the past four years and have the most potential to balance imports through Fairview Terminal. In the 2006-2007 crop year, 2.1 million tonnes of crops, about 13% of the total crops, were exported in containers from Vancouver and Delta. This volume means that about 46,000 TEU per year of peas, lentils and beans are shipped from Vancouver. Specialty crop exports from Canada were valued at $1 billion per year in 2007 and are growing at a rate of 7% per year with stable prices.

Malt barley is the second leading containerized agricultural export from Vancouver, with about 33,000 TEUs per year. Finally, metal concentrates, chemicals and scrap metal are three other exports that have changed from bulk shipments to a significant proportion of containers. It seems likely that these products will follow the rapid growth trend of containerized forest product and agricultural crop exports.

3.5.4 Scenario Description

Prince Rupert was selected as the incoming site. The Port of Prince Rupert offers an alternative for exporters such as Canfor, West Fraser, Catalyst Paper and Teck Cominco. There is an opportunity to export specialty wood products from British Columbia and polyethylene, potash, sulphur, from Alberta and Saskatchewan. CN Rail recently started up a forest products container terminal in Prince George for lumber, pulp, and paper exports from six pulp mills, two paper mills, and about a dozen sawmills in the area. One of the fast growing containerized exports is pallet wood for China.

Exporters of farm crops such as malt, barley, beans, lentils, and peas may also benefit from the service. More than half of Canada’s crop exports from the west coast now go to the Port of Prince Rupert, but Canada greatly lags behind the US in containerized exports. The Port of Prince Rupert currently handles containerized crops from the US mid west but little from Canada.

3.5.5 Ship Description

One possibility for the feeder service is to offload the Vancouver bound containers in Prince Rupert and to reload them onto a subsequent ship going on to Vancouver. However, this would mean handling containers twice in relatively high cost international container terminals. There would be no significant change in emissions.

The smaller ships used by local carriers could be loaded and unloaded on the Fraser River at domestic terminals. This would reduce truck traffic and related emissions. The ideal ship size would match the Metro Vancouver portion of a weekly container ship shuttle service between North China and Prince Rupert. Cosco representatives estimate the size of such a shuttle would be about 3,000 TEUs. If the Vancouver portion of the business is about 25%, then the shuttle between Prince Rupert and Richmond should be 380 FEU.

This size is similar to the container ships presently shuttling between Tacoma and Alaska. For example, Totem Ocean Trailer Express' MV Midnight Sun (Figure 3.11), and North Star have a capacity of 600 FEU,[6] and Totem's Westward Venture has a capacity of 380 FEU. A sister ship, the 380 FEU Greatland, is soon returning from duty in Iraq and could be deployed on the Prince Rupert - Richmond - Tacoma route.

The Totem ships have multiple decks and containers are rolled on or off the ship without the use of cranes. They can be taken directly to the customer's warehouse. This system of handling containers on chassis matches the competitive terminal service in Los Angeles and Long Beach. It gives the Richmond terminal a competitive advantage over the local terminals that do not have space for chassis.

Figure 3.9 Shortsea Ships

Source: Totem Ocean Trailer Express Inc.

Barges for container shipments were also considered (Figure 3.12). The barges are used on the weekly services between Seattle and Alaska with connections to Whitehorse, Yukon. Northland's barges are 60 metres wide, 122 metres long and require 5.5 metres

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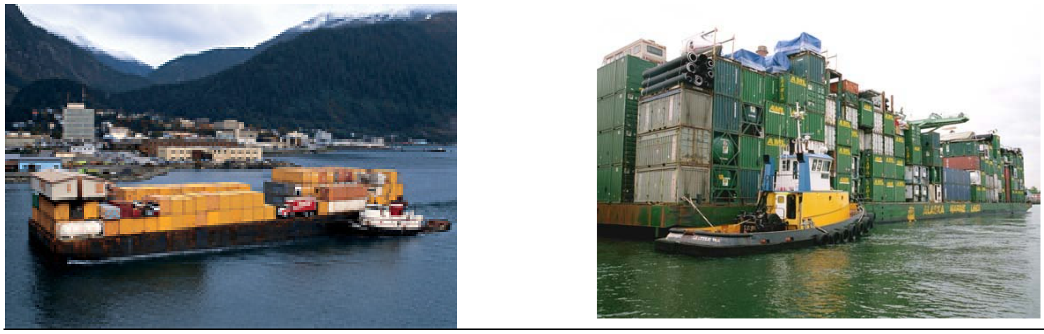
[6] FEU : Ocean-freight term meaning containerized cargo equal to one forty-foot (40 x 8 x 8 feet) or two twenty-foot (20 x 8 x 8 feet) containers. One FEU equals about 25 metric tons or 72 cubic meters.

draft. The barge companies have the potential to add a Canadian barge to their existing barges and provide a tandem tow. Since they already pass by Prince Rupert twice a week their shortsea service is very competitive. Two challenges for a barge service are that the high 8.2 metres tide changes at the Prince Rupert terminal may make loading difficult and poor winter weather could make the schedule less reliable than for ships.

Figure 3.10 Container Barges



Source: Northland Services, Seattle

Source: Alaska Marine Lines, Lynden

3.5.6 General Input for West Coast Scenario

Table 3.22 summarizes general inputs of the West Coast scenario. Distance to be crossed in each transportation mode has also been calculated.

Table 3.22 General Inputs of West Coast Scenario

Origin	Prince Rupert (BC)	**Destination**	Richmond (BC)
Cargo weight	15 000 tonnes (600 FEU)[a]	**Commodity type**	Containers
Ship type	Ro-Ro's		
Transportation mode	**Rail**	**Road**	**Marine**
One way trip Distance (km)	1,505	1,505	704
Urban proportion (%)	5	5	1

a: One FEU equals about 25 metric tons or 72 cubic metres

4. MODEL RESULTS

4.1 Input of Scenarios

Table 4.1 presents data for each of the four scenarios to be used as input in the Excel model developed for this study. An instruction sheet describes the steps to follow to obtain the comparison between the three transportation modes (rail, road and marine) for one scenario.

Table 4.1 Input to the Model

	Scenario 1 **Great Lakes**	**Scenario 2** **St. Lawrence system**	**Scenario 3** **East Coast**	**Scenario 4** **West Coast**
Origin	Superior (WI)	Halifax (NS)	Saint-John (NB)	Prince Rupert (BC)
Destination	Nanticoke (ON)	Montréal (QC)	Boston (MA)	Richmond (BC)
Cargo weight (tonnes)	25,000	10,000	35,000	15,000
Type of products	Solid bulk (coal, minerals, ore and concentrates)	Truck trailers and containers	Petroleum products	Containers
Ship type	Seaway (Bulker 25,000)	Ro-Ro's - Lo-Lo's	Product tanker (35,000)	Ro-Ro's
Total distance (km)				
Rail	1,514	1,226	1,616	1,513
Road	1,466	1,251	665	1,505
Marine	1,510	1,950	550	704
Province 1	Ontario	Nova Scotia	New Brunswick	British Columbia
Rail				
Distance (km) One way trip in Province 1	1,514	196	1,616	1,513
Urban proportion (%)	10	5	8	5
Road				
Distance (km) One way trip in Province 1	1,466	200	665	1,505
Urban proportion (%)	10	5	8	5
Marine				
Distance (km) One way trip in Province 1	1,510	800	550	704
Urban proportion (%)	1	1	2	1
Province 2 (if applicable)		New Brunswick		
Rail				
Distance (km) One way trip in Province 2		500		
Urban proportion (%)		1		
Road				
Distance (km) One way trip in Province 2		510		
Urban proportion (%)		1		
Marine				
Distance (km) One way trip in Province 2		150		
Urban proportion (%)		3		
Province 3 (if applicable)		Quebec		
Rail				
Distance (km) One way trip in Province 3		530		
Urban proportion (%)		2		
Road				
Distance (km) One way trip in Province 3		541		
Urban proportion (%)		2		
Marine				
Distance (km) One way trip in Province 3		1,000		
Urban proportion (%)		2		

Note 1: Road mode is defined by Heavy-Duty Commercial Vehicle, running with Diesel.

Note 2: Data from the province crossed (to be crossed) is used when origin (destination) of the scenario is in US.

Note 3: A train is here defined with 1 locomotive and 79 wagons per locomotive. A wagon can approximately handled 73 tonnes of freight (Source : 2007 Railway Trends, The Railway Association of Canada).

Note 4 The sources of distance data are CN for Rail, Google for Road and Innovation Maritime for Marine.

4.2 Results

Table 4.2 summarizes the modelling results for the four scenarios considered in this study, which are Scenario 1 – Great Lakes, Scenario 2 – St. Lawrence System, Scenario 3 – East Coast and Scenario 4 – West Coast. The results of the modal comparison should be used with care, given the general and specific limitations of the model described in Section 2.7.2. The results presented hereafter are based on a port to port comparison and do not consider the entire transportation chain.

Modelling results show the shortsea shipping transportation mode has the lowest environmental and social costs for three of the four scenarios, while the rail mode has a slightly lower cost compared to the marine mode for the remaining scenario.

Those results demonstrate that the marine mode seems to gain an advantage in terms of environmental and social costs when the total distance to cover is equal or lower than the distance to cover with the rail or road modes. In the case of the St. Lawrence system scenario, for which the rail mode has lower environmental and social costs, the distance to cover for the marine mode is about 50% higher than those to cover by the two other transportation modes.

Table 4.2 Modelling Results of the Four Scenarios

	Scenario 1 Great Lakes	**Scenario 2** St. Lawrence system	**Scenario 3** East Coast	**Scenario 4** West Coast
Origin	Superior (WI)	Halifax (NS)	Saint John (NB)	Prince Rupert (BC)
Destination	Nanticoke (ON)	Montréal (QC)	Boston (MA)	Richmond (BC)
Cargo weight (tonnes)	25,000	10,000	35,000	15,000
Type of products	Solid bulk (coal, minerals, ore and concentrates)	Truck trailers and containers	Petroleum products	Containers
Ship type	Seaway (Bulker 25,000)	Ro-Ro's - Lo-Lo's	Product tanker (35,000)	Ro-Ro's
Total distance (km)				
Rail	1,514	1,226	1,616	1,513
Road	1,466	1,251	665	1,505
Marine	1,510	1,950	550	704
Total Cost (C$2008)				
Rail	$144,391	**$29,665**	$97,285	$47,305
Road	$350,151	$97,655	$175,645	$174,556
Marine	**$29,674**	$30,170	**$4,781**	**$10,420**

Tables 4.3 to 4.6 present the detailed modelling results for each scenario.

Table 4.3 Results of Scenario 1 – Great Lakes

Summary sheet

1/2

1) Description of the scenario

Origin: Superior (WI)
Destination: Nanticoke (ON)
Cargo weight (tonnes): 25,000

2) General inputs for scenario

Type of products: Solid bulk (coal, minerals, ore and concentrates)
Ship type: Seaway (25,000)
Truck type: 5 axle Comb.

		Rail	Road	Marine
Cargo weight per vehicle (tonne)		5 767	28	5 000
Cargo weight (tonne)		25 000	25 000	25 000
No of vehicle		4	910	1
Province 1		Ontario		
Distance (km) One way trip in Prov. 1		1 514	1 466	1 510
Urban proportion (%)		0	0	0
Total distance in Province 1		6 563	1 334 060	1 510
Province 2		Ontario		
Distance (km) One way trip in Prov. 2		0	0	0
Urban proportion (%)		0	0	0
Total distance in Province 2		0	0	0
Province 3		Ontario		
Distance (km) One way trip in Prov. 3		0	0	0
Urban proportion (%)		0	0	0
Total distance in Province 3		0	0	0
Total scenario trip		-		
Total Distance (km) One way trip		1 514	1 466	1 510
Urban proportion (%)		0	0	0
Total distance		6 563	1 334 060	1 510

Summary sheet

2/2

3) Quantity results for the scenario

	Rail	Truck	Marine
Fuel consumption (litres)	224 451	482 930	66 241
CAC and GHG Emissions (tonnes)			
$PM_{2,5}$	0.38	0.22	0.11
PM_{10}	0.38	0.26	0.13
SO_2	0.38	0.12	0.77
NO_x	11.36	9.35	1.42
VOC	0.38	0.36	0.04
CO	1.51	1.99	0.04
CO_2	612.41	1 006.07	243.53
CH_4	0.76	0.05	0.03
N_2O	76.46	0.03	0.01
$CO_{2\ equivalent}$	689.63	1 016.39	246.39

4) Cost results for the scenario (C$2008)

Reference year for comparison **2008**

	Year	Rail	Road	Marine
CAC Costs	2000	$80 931	$62 662	$16 660
	2008	*$96 184*	*$74 472*	*$19 800*
GHG Costs	2008	$26 229	$38 656	$9 371
	2008	*$26 229*	*$38 656*	*$9 371*
Accidents	2000	$17 037	$146 414	$423
	2008	*$20 248*	*$174 008*	*$503*
Noise	2001	$1 493	$6 774	ND
	2008	*$1 730*	*$7 853*	*ND*
Congestion	2000	ND	$46 414	ND
	2008	*ND*	*$55 161*	*ND*
Total Considered Costs	**2008**	**$144 391**	**$350 151**	**$29 674**

5) Comparative Table

(Line - Column)	Rail	Road	Marine
Rail	$0	-$205 760	$114 717
Road	$205 760	$0	$320 477
Marine	-$114 717	-$320 477	$0

Table 4.4 Results of Scenario 2 – St. Lawrence System

Summary sheet

1/2

1) Description of the scenario

Origin: Halifax (NS)
Destination: Montreal (QC)
Cargo weight (tonnes): 10,000

2) General inputs for scenario

Type of products: Truck trailers and containers
Ship type: Ro/Ro (10,000)
Truck type: 5 axle Comb.

		Rail	Road	Marine
Cargo weight per vehicle (tonne)		5 767	28	5 000
Cargo weight (tonne)		10 000	10 000	10 000
No of vehicle		2	364	1
Province 1		Nova-Scotia		
Distance (km) One way trip in Prov. 1		196	200	800
Urban proportion (%)		0	0	0
Total distance in Province 1		340	72 800	800
Province 2		New-Brunswick		
Distance (km) One way trip in Prov. 2		500	510	150
Urban proportion (%)		0	0	0
Total distance in Province 2		867	185 640	150
Province 3		Quebec		
Distance (km) One way trip in Prov. 3		530	541	1 000
Urban proportion (%)		0	0	0
Total distance in Province 3		919	196 924	1 000
Total scenario trip		-		
Total Distance (km) One way trip		1 226	1 251	1 950
Urban proportion (%)		0	0	0
Total distance		2 126	455 364	1 950

Summary sheet

2/2

3) Quantity results for the scenario

	Rail	Truck	Marine
Fuel consumption (litres)	72 702	164 842	57 680
CAC and GHG Emission (tonnes)			
$PM_{2,5}$	0.12	0.07	0.25
PM_{10}	0.12	0.09	0.30
SO_2	0.12	0.04	1.85
NO_x	3.68	3.19	3.33
VOC	0.12	0.12	0.10
CO	0.49	0.68	0.11
CO_2	198.37	343.41	236.65
CH_4	0.25	0.02	0.03
N_2O	24.77	0.01	0.01
$CO_{2\ equivalent}$	223.38	346.93	239.40

4) Cost results for the scenario (C$2008)

Reference year for comparison **2008**

	Year	Rail	Road	Marine
CAC Costs	2000	$12 195	$10 107	$17 301
	2008	*$14 494*	*$12 012*	*$20 562*
GHG Costs	2008	$8 496	$13 195	$9 105
	2008	*$8 496*	*$13 195*	*$9 105*
Accidents	2000	$5 518	$49 977	$423
	2008	*$6 559*	*$59 396*	*$503*
Noise	2001	$101	$879	ND
	2008	*$117*	*$1 019*	*ND*
Congestion	2000	ND	$10 125	ND
	2008	*ND*	*$12 034*	*ND*
Total Considered Costs	**2008**	**$29 665**	**$97 655**	**$30 170**

5) Comparative Table

(Line - Column)	Rail	Road	Marine
Rail	$0	-$67 990	-$505
Road	$67 990	$0	$67 485
Marine	$505	-$67 485	$0

Table 4.5 Results of Scenario 3 – East Coast

Summary sheet

1/2

1) Description of the scenario

Origin: Saint-John (NB)
Destination: Boston (MA)
Cargo weight (tonnes): 35,000

2) General inputs for scenario

Type of products: Petroleum Products
Ship type: Product Tankers (35,000)
Truck type: 5 axle Comb.

		Rail	Road	Marine
Cargo weight per vehicle (tonne)		5 767	28	5 000
Cargo weight (tonne)		35 000	35 000	35 000
No of vehicle		6	1 273	1
Province 1		New-Brunswick		
Distance (km) One way trip in Prov. 1		1 616	665	550
Urban proportion (%)		0	0	0
Total distance in Province 1		9 808	846 545	550
Province 2		New-Brunswick		
Distance (km) One way trip in Prov. 2		0	0	0
Urban proportion (%)		0	0	0
Total distance in Province 2		0	0	0
Province 3		New-Brunswick		
Distance (km) One way trip in Prov. 3		0	0	0
Urban proportion (%)		0	0	0
Total distance in Province 3		0	0	0
Total scenario trip		-		
Total Distance (km) One way trip		1 616	665	550
Urban proportion (%)		0	0	0
Total distance		9 808	846 545	550

Summary sheet

3) Quantity results for the scenario

	Rail	Truck	Marine
Fuel consumption (litres)	335 401	306 449	22 619
CAC and GHG Emission (tonnes)			
$PM_{2,5}$	0.57	0.14	0.03
PM_{10}	0.57	0.16	0.03
SO_2	0.57	0.08	0.17
NO_x	16.97	5.93	0.34
VOC	0.57	0.23	0.01
CO	2.26	1.26	0.01
CO_2	915.14	638.41	81.10
CH_4	1.13	0.03	0.01
N_2O	114.25	0.02	0.00
$CO_{2\ equivalent}$	1 030.52	644.97	82.06

4) Cost results for the scenario (C$2008)

Reference year for comparison **2008**

	Year	Rail	Road	Marine
CAC Costs	2000	$23 416	$7 464	$973
	2008	*$27 829*	*$8 871*	*$1 156*
GHG Costs	2008	$39 194	$24 530	$3 121
	2008	*$39 194*	*$24 530*	*$3 121*
Accidents	2000	$25 459	$92 909	$423
	2008	*$30 257*	*$110 419*	*$503*
Noise	2001	$5	$7	ND
	2008	*$5*	*$8*	*ND*
Congestion	2000	ND	$26 771	ND
	2008	*ND*	*$31 817*	*ND*
Total Considered Costs	**2008**	**$97 285**	**$175 645**	**$4 781**

5) Comparative Table

(Line - Column)	Rail	Road	Marine
Rail	$0	-$78 360	$92 504
Road	$78 360	$0	$170 864
Marine	-$92 504	-$170 864	$0

Table 4.6 Results of Scenario 4 – West Coast

Summary sheet

1/2

1) Description of the scenario

Origin: Prince Rupert (BC)
Destination: Fraser River (BC)
Cargo weight (tonnes): 15,000

2) General inputs for scenario

Type of products: Petroleum Products
Ship type: Container (15,000)
Truck type: 5 axle Comb.

		Rail	Road	Marine
Cargo weight per vehicle (tonne)		5 767	28	5 000
Cargo weight (tonne)		15 000	15 000	15 000
No of vehicle		3	546	1
Province 1		British Columbia		
Distance (km) One way trip in Prov. 1		1 513	1 505	704
Urban proportion (%)		0	0	0
Total distance in Province 1		3 935	821 730	704
Province 2		British Columbia		
Distance (km) One way trip in Prov. 2		0	0	0
Urban proportion (%)		0	0	0
Total distance in Province 2		0	0	0
Province 3		British Columbia		
Distance (km) One way trip in Prov. 3		0	0	0
Urban proportion (%)		0	0	0
Total distance in Province 3		0	0	0
Total scenario trip		-		
Total Distance (km) One way trip		1 513	1 505	704
Urban proportion (%)		0	0	0
Total distance		3 935	821 730	704

Summary sheet

2/2

3) Quantity results for the scenario

	Rail	Truck	Marine
Fuel consumption (litres)	134 581	297 466	35 056
CAC and GHG Emission (tonnes)			
$PM_{2,5}$	0.23	0.13	0.09
PM_{10}	0.23	0.16	0.11
SO_2	0.23	0.07	0.67
NO_x	6.81	5.76	1.21
VOC	0.23	0.22	0.04
CO	0.91	1.22	0.04
CO_2	367.21	619.70	123.45
CH_4	0.45	0.03	0.01
N_2O	45.84	0.02	0.00
$CO_{2\ equivalent}$	413.50	626.06	124.90

4) Cost results for the scenario (C$2008)

Reference year for comparison **2008**

	Year	Rail	Road	Marine
CAC Costs	2000	$15 344	$12 431	$4 347
	2008	*$18 236*	*$14 774*	*$5 167*
GHG Costs	2008	$15 727	$23 811	$4 750
	2008	*$15 727*	*$23 811*	*$4 750*
Accidents	2000	$10 215	$90 186	$423
	2008	*$12 141*	*$107 183*	*$503*
Noise	2001	$1 037	$2 195	ND
	2008	*$1 202*	*$2 544*	*ND*
Congestion	2000	ND	$22 082	ND
	2008	*ND*	*$26 244*	*ND*
Total Considered Costs	**2008**	**$47 305**	**$174 556**	**$10 420**

5) Comparative Table

(Line - Column)	Rail	Road	Marine
Rail	$0	-$127 251	$36 885
Road	$127 251	$0	$164 135
Marine	-$36 885	-$164 135	$0

5. STRATEGIC IMPACTS OF SHORTSEA SHIPPING

5.1 Sustainable Development

The Government of Canada has recognized sustainable development (SD) in various pieces of legislation over the last two decades. Between 1995 and 2007, a distributed departmental approach was used. Responsibility for SD, laid out in the *Auditor General Act*, was assigned to twenty-five government departments and agencies and, thus, individual SD strategies (SDS) were not coordinated. The Fourth round of departmental SDS (2007-2009) is framed under a new working approach, which is government wide. Three new components have been determined, namely a set of common federal SD goals, a consolidated reporting on federal SD goals and linkages to federal planning and reporting processes, and an inclusion of guidance for greening government operations.

Since 2005, through Environment Canada leadership, the federal government has renewed its support for the integration of environmental sustainability with economic competitiveness, productivity and social equity. The set of common federal SD goals is divided into two groups: environmental quality-related goals and sustainable development management.

The first group is composed of three specific objectives, namely:

- clean and secure water for people, marine and freshwater ecosystems;
- clean air for people to breathe and ecosystems to function well;
- reduction of greenhouse gas emissions.

The second group also presents three objectives, namely:

- Communities enjoy a prosperous economy, a vibrant and equitable society, and a healthy environment for current and future generations;
- SD and use of natural resources;
- Strengthen federal governance and decision making to support SD.

This last objective indicates the federal government's willingness to enhance its own practices regarding SD. The Government aims at strengthening accountability of all departments and agencies with a common reporting format. SD remains a key priority for federal government departments, as they are still responsible for identifying issues of relevance to their mandate, and in developing policies, regulations and other instruments for achieving specific SD objectives.

5.2 Sustainable Transportation System

Apart from its strategic role, the size of the Canadian transportation service industry is significant. Transportation in Canada has significant impacts in terms of energy, material resource use, environmental pollution, noise and land use at the local, regional and global levels (Yevdokimov, 2007).

In March 1996, a national round table composed of Canadian transportation stakeholders was held during an OECD International Conference in Vancouver. One of the problems identified was that the Canadian transportation system was not on a sustainable path. This statement implied that the main challenge for TC was to find ways of meeting transportation needs that are environmentally sound, socially equitable and economically viable. This challenge remains today.

Hence, as mentioned in the Centre for Sustainable Transportation, 2005 (CST, 2005), a sustainable transportation system can be defined as one that:

- allows the basic access needs of individuals and societies to be met safely and in a manner consistent with human and ecosystem health, and with equity within and between generations.
- is affordable, operates efficiently, offers a choice of transport modes, and supports a vibrant economy.
- limits emissions and waste within the planet's ability to absorb them, minimizes consumption of non-renewable resources, limits consumption of renewable resources to the sustainable yield level, reuses and recycles its components, and minimizes the use of land and the production of noise.

For some years now, road and rail carriers have been fiercely competing with maritime shipping on certain continental routes, particularly for transportation of goods, such as aluminum, paper and gasoline.

In 1995, the federal government announced that it was abandoning its traditional responsibilities as owner, operator, manager and financial supporter of port infrastructure throughout Canada. This withdrawal, which also extends to navigational services, has had a significant impact on the industry and affected the competitiveness of several areas of the marine transportation system (MTQ, 2001).

As impacts are local, regional and global, the federal government must work with all levels of government to align policies and also with concerned industries. Future policies must increase cooperation between the various economic and political organizations concerned with environmental issues.

For example, as the governments of British Columbia and Quebec have recently become more active with respect to the marine transportation issue, the federal government must closely work with them, as well as other provincial and local governments, to propose coherent and adapted policies.

5.3 Shortsea Shipping and SD

5.3.1 SD Issues of Shortsea Shipping

The transportation industry has a clear impact on the environment. The maritime shipping industry is however one of the most energy-efficient modes of transportation. Studies have shown that marine transportation has superior safety performance in terms of accidents and loss of life, requires less fuel, and produces fewer emissions per tonne-kilometre of cargo than rail or truck. It also lowers noise levels on roads and railways. The possibilities of relieving road congestion by transferring some goods movements to the marine system are a key potential of shortsea shipping. The results of the present study tend to confirm these statements.

In that context, at the continental level, marine transportation could contribute to a decrease in the social and environmental impacts of transportation. It could also help reduce socio-economic costs that the population has to bear, such as the deterioration of roads, rise of noise levels, congestion and air pollution as well as decreased road safety. However, the federal government must be aware of certain challenges where economic objectives are in conflict with environmental objectives.

Furthermore, the Government will have to consider the economic and environmental advantages of Canada's domestic fleet when it comes to public policies and legislative deliberations. Since the federal government has provided a high degree of commercial management autonomy to the main ports, the adoption of federal environmental initiatives may need regulatory intervention.

Finally, the Government will have to keep addressing the remaining environmental effects of marine transportation, as presented in Chapter 2 of this study. The minimization of the potential for damage to the environment will also have to take into account the presence of ships themselves.

Figure 5.1 SD and Shortsea Shipping

Canadian SD Objectives (Environment Canada, 2007b)

Environmental Quality Related Objectives

- Clean and secure water for people, marine and freshwater ecosystems;
- Clean air for people to breathe and ecosystems to function well;
- Reduce GHG emissions.

SD Management Objectives

- Communities enjoy a prosperous economy, a vibrant and equitable society, and a healthy environment for current and future generations;
- Sustainable development and use of natural resources;
- Strengthen federal governance and decision making to support SD.

Sustainable Transport System Objectives (CST, 2005)

- Allows the basic access of individuals and societies to be met safely and in a manner consistent with human and ecosystem health, and with equity within and between generations;
- Affordable, operates efficiently, offers choice of transportation mode, and supports a vibrant economy.
- Limits emissions and waste within the planet's ability to absorb them, minimizes consumption of non-renewable resources, limits consumption of renewable resources to the sustainable yield level, reuses and recycles its components, and minimizes the use of land and the production of noise.

Shortsea Shipping and SD Development

- One of the most energy-efficient transportation mode;
- Maritime transportation has superior performance compared to other transportation modes in terms of lower ratios of emissions per tonne-km as well as a lower number of accidents and loss of life.
- Possibility of relieving road congestion by transferring goods movement to the marine system.

5.3.2 Recommendations

5.3.2.1 Fundamental Issues

Three fundamental issues must be applied in the development of SD strategies (GovQC, 2007):

- developing knowledge;
- promoting responsible action; and
- fostering commitment.

The first fundamental issue encourages endorsement of SD values and principles, and makes possible enlightened decisions. Awareness either by the public or the marine industry itself will enable better actions and better understanding on the part of all stakeholders regarding government decisions, legislation and policies.

The second fundamental issue is to adopt practices that are both socially and ecologically responsible, and economically viable to be able to contribute to development and prosperity.

As a consequence, government SDS should enhance promotion of shortsea shipping, but not exclude railway and truck modes. It may be dangerous to establish a long-term imbalance for the whole transportation system. Shortsea shipping is one of the keys of the system, but it is only a part of the global system. It depends upon the provision of efficient land-mode movements at both ends and transload facilities. Government should focus on a well-articulated intermodal transportation system by planning fluidity of goods movements between modes and improvement of port facilities. SD Strategies, in that context, should support competitive logistics systems.

Moreover, the actual performance of a competing modally integrated service involving a shortsea shipping service leg must be made sufficiently attractive to cargo shippers to stimulate both substantive cargo diversion from truck routes and new market development. For example, there must be enough cargo moving (preferably in both directions) on chosen and promoted shortsea shipping routes.

The third fundamental issue is to foster the commitment of all stakeholders. To foster the commitment of the marine industry, government policies, regulations and legislation concerning environmental issues will need to ensure the economic viability of the marine industry. Cooperation between all levels of government and industry is then a key issue. Various measures that might encourage ship-owners to upgrade or renew their fleets might be identified in cooperation with industry representatives. Hence, the implementation of research and development strategies regarding best environmental practices of the last few years may be discussed with the marine industry.

From the industry’s point of view, clear and realistic targets must be set. The Canadian merchant fleet has faced economic and financial difficulties over the last few years. As mentioned in Envirochem (2007), financial government incentives, such as the reduction of fees, fuel tax rebates, or the introduction of a port dues component related to environmental protection, as the Port of Vancouver did in January 2007, may be implemented to support green carrier’s initiatives or efforts. Carrier performance measure system must also be applicable to other modes for comparison’s sake.

Finally, port and transport infrastructure must be adequate and efficient to support the increase in freight marine transportation and to encourage the process of continuous improvement and use of best environmental practices by carriers. Government must continually increase cooperation with Canadian Port Authorities to ensure their understanding and interest regarding SD issues.

5.3.2.1 Recommendations by SD Fundamental Issues

1. Developing knowledge
    - The Government should foster knowledge development in support of better decisions, legislation and policies on sustainable development as well as to better inform stakeholders of its actions.

2. Promoting responsible actions
    - The Government should enhance promotion of shortsea shipping, but not to the exclusion of railway and truck modes. Shortsea shipping is part of an integrated system.
    - The Government should focus on a well-integrated intermodal transportation system by planning for the fluidity of goods' movement between modes and improving port facilities. SD strategies will in that context have to support competitive logistics systems.

3. Fostering commitments
    - The Government's policies, regulations and legislation concerning environmental issues should consider the ongoing economic viability of the marine industry.
    - The Government, in cooperation with industry representatives, should identify measures to encourage ship-owners to upgrade or renew their fleets.
    - The Government should set clear and realistic SD targets.
    - The Government should increase cooperation with Canadian Port Authorities to ensure their understanding and interests regarding SD issues.

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ANNEX A

Main Ocean-Going Vessels Description

GENERAL CARGO, BULK-CARRIER

Break-bulk was the most common form of cargo for most of the history of shipping. Break-bulk cargo, also called general cargo, is a term that covers a great variety of goods that must be loaded individually, and not in shipping containers, nor in bulk as with oil or grain. These goods may be in bags, cases, crates, drums, barrels, or they may be kept together by baling or loaded onto pallets.

Bulk-carriers are merchant ships specially designed to transport unpackaged bulk cargo, such as grains, coal, ore, and cement.

Loading and unloading the cargo is difficult, dangerous, and can take up to 120 hours on larger ships, but bulkers are designed to be easy to build and to store cargo efficiently, which increases energy efficiency.

Break-bulk, general cargo, bulkers and to some extent container ships are all built on the same mode. The most energy wise ship has no gear and no tweendecks.

CONTAINER SHIPS

Container ships carry all of their loads in truck-size containers. They form a common means of commercial intermodal freight transport.

These vessels are designed so that no space is wasted. They do not have tweendecks but recent ships have cells to ease the loading and the lashing of the containers. These cells, combined with the weight of the containers, decrease the energy efficiency of this type of ship.

Furthermore, container ships tend to go faster than regular general cargo and bulk carriers. The power needed to push the ship at 20 or 25 knots exponentially increases the amount of fuel needed. Faster ships therefore mean less energy efficiency per tonne of cargo.

ROLL ON – ROLL OFF SHIPS

Roll on and roll off (RO-RO) ships and ferries are the least efficient self-propelled ships. RO-RO ships are designed to carry wheeled cargo such as automobiles, trucks, semi-trailer trucks, trailers or railroad cars. This is in contrast to LO-LO (lift on-lift off) vessels which use a crane to load and unload cargo

Several tweendecks are needed to load trailers, as well as elevators and loading ramps.

Combined with the wasted space due to the trailers' wheels, Ro-Ro ships energy efficiency is very low compared to the other types of ships.

Furthermore, Ro/Ro ships also tend to go as fast as a container ship, which decreases their energy efficiency even more.

TUG AND BARGES

Today, ships are self-propelled or tugs are used to move barges.

Barges used to be pulled by a tug. Now, tugs are pushing and they are coupled with the barge. This configuration allows a speed increase of 25 % and a fuel consumption reduction of up to 33 % compared to pulled barges (Lloyds, 2003).

However, tugs and barges are less fuel-efficient compared to self-propelled ships. The space between the tug and barge increases the hydrodynamic drag and the use of a smaller propeller explains the difference.

TANKERS

Tankers are the most efficient ship. There are two basic types of oil tanker: the crude tanker and the product tanker.

Crude tankers move large quantities of unrefined crude oil from its point of extraction to refineries.
Product tankers, generally much smaller, are designed to move petrochemicals from refineries to points near consuming markets.

The ship is a tank onto which a bow, an engine room and a wheelhouse have been fitted. The liquid allows for maximizing the use of the space. Even with the introduction of double-hull tanker, the space available for cargo remains optimal. Furthermore, the gain of weight from the inner skin is not large enough to significantly increase the ship's lightweight.

ANNEX B

Marine Emission Factors for Main and Auxiliary Engines by Mode

Engine Type	Source	Weighting Factor	Fuel Type	Sulphur Content*	SFC g/kWh	NOx g/kWh	SOx g/kWh	HC g/kWh	VOC g/kWh	PM g/kWh	PM10 g/kWh	PM2.5 g/kWh	CO g/kWh	CO2 g/kWh
Ocean-Going Vessels														
Main Engine														
Underway														
Slow speed	1,2,4	0.95	HFO	2.7	195	19.5	10.5	0.6	0.6	2.4	1.9	1.5	0.5	620
Medium speed	1,2	0.05	HFO	2.7	213	14	11.5	0.5	0.5	0.8	0.6	0.5	1.1	677
Composite			Avg	2.7	196	19.2	10.6	0.6	0.6	2.3	1.8	1.5	0.5	623
Manoeuvring														
Slow speed	1,2	0.95	HFO	2.7	215	14.5	11.6	1.8	1.8	2.4	1.9	1.5	1	682
Medium speed	1,2	0.05	HFO	2.7	234	11.2	12.7	1.5	1.5	1.5	1.2	1	2.2	745
Composite			Avg	2.7	216	14.3	11.7	1.8	1.8	2.4	1.9	1.5	1.1	685
Auxiliary Engines														
All modes														
Medium speed	1,2	0.75	HFO	2.7	227	14.7	12.3	0.4	0.4	1.5	1.2	1	0.9	722
Medium speed	1,2,3	0.25	MDO	1.0	217	13.9	4.3	0.4	0.4	0.4	0.4	0.4	0.9	690
Medium speed	1,2,3	0.0	MDO	0.5	217	13.9	1.1	0.4	0.4	0.3	0.2	0.2	0.9	690
Composite			Avg	2.3	224	14.5	10.3	0.4	0.4	1.2	1	0.9	0.9	713
Ferries														
Main Engine														
Underway														
Medium speed	1,2	0.76	MDO	0.17	203	13.2	0.7	0.2	0.2	0.2	0.2	0.2	1.1	645
High speed	1,2	0.24	MDO	0.17	203	12	0.7	0.2	0.2	0.2	0.2	0.2	1.1	645
Composite				0.17	203	12.9	0.7	0.2	0.2	0.2	0.2	0.2	1.1	645
Manoeuvring														
Medium speed	1,2	0.76	MDO	0.17	223	10.6	0.8	0.4	0.4	0.2	0.2	0.2	2.2	710
High speed	1,2	0.24	MDO	0.17	223	9.6	0.8	0.4	0.4	0.2	0.2	0.2	2.2	710
Composite				0.17	223	10.4	0.8	0.4	0.4	0.2	0.2	0.2	2.2	710
Aux Engines -All modes														
Medium speed	1,2	0.76	MDO	0.17	217	13.9	0.7	0.4	0.4	0.2	0.2	0.2	0.9	690
High speed	1,2	0.24	MDO	0.17	217	10.9	0.7	0.4	0.4	0.2	0.2	0.2	0.8	690
Composite				0.17	217	13.2	0.7	0.4	0.4	0.2	0.2	0.2	0.9	690

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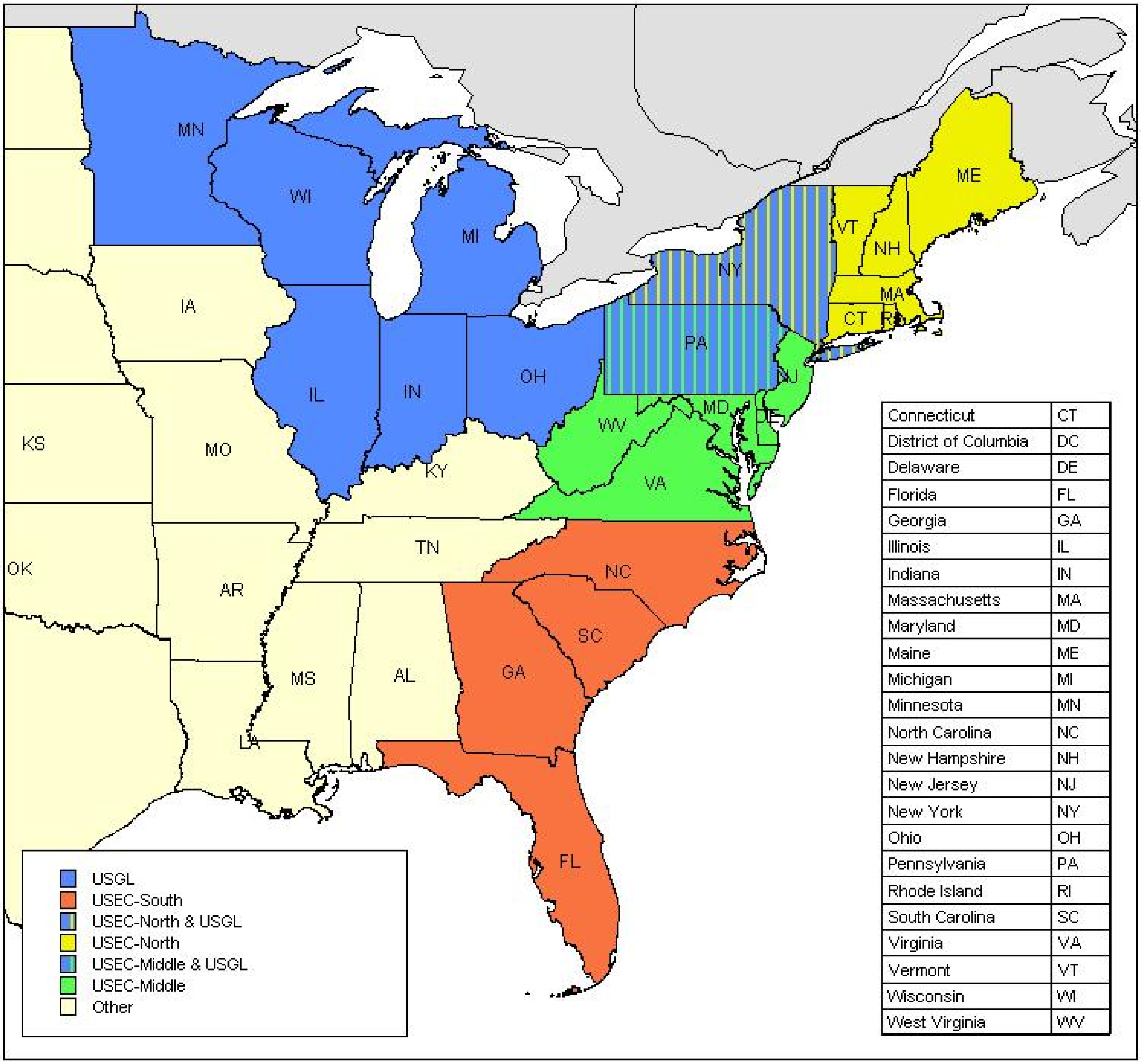
* For sulphur content shown. These were adjusted to reflect the fraction of vessels using North American and international fuel sources.

Sources: 1. ENTEC, 2002 – Fuel type, SFC, NOx, SOx, HC, PM, PM10, CO2.; 2. SMED, 2004 – PM2.5, CO; 3. Starcrest, 2004 – PM2.5/PM10

ANNEX C

United States Regions



Connecticut	CT
District of Columbia	DC
Delaware	DE
Florida	FL
Georgia	GA
Illinois	IL
Indiana	IN
Massachusetts	MA
Maryland	MD
Maine	ME
Michigan	MI
Minnesota	MN
North Carolina	NC
New Hampshire	NH
New Jersey	NJ
New York	NY
Ohio	OH
Pennsylvania	PA
Rhode Island	RI
South Carolina	SC
Virginia	VA
Vermont	VT
Wisconsin	WI
West Virginia	WV

Source: Innovation Maritime