GREAT LAKES AND ST. LAWRENCE RIVER COMMERCE: SAFETY, ENERGY AND ENVIRONMENTAL IMPLICATIONS OF MODAL SHIFTS

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GREAT LAKES AND ST. LAWRENCE RIVER COMMERCE: SAFETY, ENERGY AND ENVIRONMENTAL IMPLICATIONS OF MODAL SHIFTS

Executive Summary

INTRODUCTION

Transportation policy at all governmental levels must take into consideration energy, environmental and safety factors. Transportation is a major energy use sector in North America with a large impact on environmental quality. Safety, across all modes, has become a priority concern for both the public and government. In the last few years, media coverage of the transportation-environment connection has expanded in response to particular events and growing public awareness. Related legislative and regulatory action in Canada and the U.S. has also kept pace.

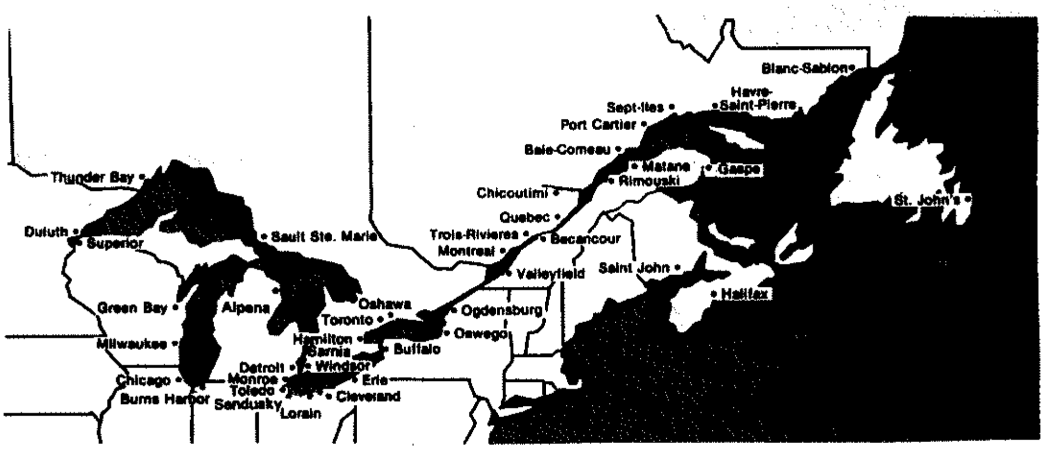
The Great Lakes Commission has undertaken a "modal shift" study for the Great Lakes-St. Lawrence River commercial navigation system. Through a method of shifting selected waterborne commodity movements to alternative surface modes, the study was designed to assess the comparative energy usage, emission impacts and safety risks of one transportation mode in relation to others. The study was funded by several regional maritime organizations along with the Canadian and U.S. Seaway agencies.

FINDINGS

The findings of this study show that vessel transport on the Great Lakes and St. Lawrence River is safer, uses less fuel and produces fewer emissions than either rail or truck when compared with equivalent commodity hauls. The study also addressed noise and congestion issues, and for these factors, the marine mode performed the best. Fuel use for the various commodity movements reveals substantially higher fuel efficiency for vessel movements on a ton-mile per gallon or tonne-kilometer per liter basis which also results in lower air pollutant emissions.

- For the eleven commodity movement scenarios, the shifting of 24.7 million tons/22.4 million metric tons of cargo from vessel to rail would result in the additional consumption of 14 million gallons/53.4 liters of fuel and the generation of an extra 4,321 tons/3,996 metric tons of carbon monoxide, hydrocarbon and nitrogen oxides pollutants.
- For the rail movements, total fuel use was 44 percent greater than for the marine movements. Vessel fuel efficiencies were considerably higher in some of the movement scenarios-ranging up to 100 percent greater than for rail.
- Total rail emissions were more than 47 percent greater than for the marine movements. For some movement scenarios, train trips generated much higher pollution amounts ranging to over 100 percent greater than for equivalent vessel hauls.
- In the three commodity movement scenarios where truck transportation was considered, the shifting of less than 1 million tons of waterborne cargo to highway would, compared to vessels, increase fuel use by 3.4 million gallons/12.88 million liters and result in an additional 570 tons/517 metric tons of air pollutants.
- With respect to safety issues, a vessel-to-rail shift could result in 36 crossing accidents, 14 derailments and one train collision. A shift to truck would add 1446 trucks a week to the region's traffic load and thereby annually generate 21 million additional vehicle miles. These truck movements could result in 141 more accidents with a quarter of them involving the potential for fatalities or serious injuries.
- Vessels operating on the Great Lakes and St. Lawrence River are quieter than rail and truck operations and generate less bothersome noise because most related sound is far from shore or away from residential areas.

GREAT LAKES ST. LAWRENCE RIVER SYSTEM



MOVEMENT SCENARIOS

The methodology for *Great Lakes and St. Lawrence River Commerce: Safety, Energy and Environmental Implications of Modal Shifts* made use of movement scenarios for several commodity flows representing a range of products and raw materials moving throughout the Great Lakes-St. Lawrence system. These eleven origin-destination movements are widespread and diverse, and represent more than 10 percent of the average annual tonnage moving on the system.

Annual waterborne tonnages for the study commodities were translated into an equivalent movement by surface mode. In all modal shift scenarios, rail movement alternatives were analyzed. The motor carrier option was used in three scenarios. A shift to truck was determined to be unrealistic in most cases because of transport costs, the length of the substitute haul, and the amount of tonnage involved. Fuel use, air pollutant emissions, and accident potential for each of the scenarios were developed permitting a comparison among the alternative movements.

1) Potash from Thunder Bay, Ontario to Toledo, Ohio;
2) Coal from Superior, Wisconsin to St. Clair, Michigan;
3) Taconite from the Minnesota North Shore to Lorain, Ohio;
4) Cement from Alpena, Michigan to Detroit, Michigan (truck);
5) Petroleum products from Sarnia, Ontario to Montreal, Quebec;
6) Petrochemical products from Sarnia, Ontario to Chicago, Illinois;
7) Grain from Thunder Bay to Quebec City;
8) Paper, wood pulp, and other products from Thunder Bay to Superior (truck);
9) Iron ore from Pointe Noire/Sept Iles, Quebec to Hamilton, Ontario, with combined vessel/rail alternative through Quebec City;
10) Coal from Sandusky, Ohio to Hamilton;
11) Steel from northern Europe (Rotterdam) to Cleveland, Ohio, with truck/rail alternative through Baltimore, Maryland (truck).

FREIGHT TRANSPORTATION AND THE REGIONAL ECONOMY

Transportation was an important factor in the development of the Great Lakes-St. Lawrence region. The combination of an in-place water transport infrastructure and a strong natural resource base promoted population settlement and a manufacturing economy. It was water transportation that was the foundation of shore-based manufacturing and related activities. In many cases, the waterborne shipment option for raw material delivery and movement of products was a major locational determinant for industrial operations.

Today, the region's binational transportation sstem is characterized by a well-developed multiple mode infrastructure with strong intermodal connections. Among the principal vehicle freight modes, a competitive and yet complementary relationship has evolved. The region's relatively high freight generation level is, in part, linked to the system's transport efficiencies. Particular modal patterns are evident in commodity movement and route structure. Historically, east-west freight routes have had more capacity and volume compared to north-south links. However, in recent years, partly attributable to the U.S. Canada Free Trade Agreement, north-south commodity flows have been increasing and the infrastructure to support this trend is receiving increased attention.

Freight movements in the binational region serve both domestic markets and international trade. Canada and the U.S. have the world's largest trade relationship and are each other's most important trading partners. Much of this trade is tied to the Great Lakes region. U.S. exports to Canada constitute more than one-fifth of total exports, and three-fourths of Canadian exports are to the U.S. Motor vehicles and parts, machinery and equipment contribute the most in terms of value to U.S.-Canada regional trade. Paper, pulp and lumber, along with coal, natural gas, oil and petroleum products, agricultural products and electricity are among other principal products that move across the border. Overseas exports of manufactured and agricultural products also represent a high value contribution to the regional economy. These goods are transported by rail, truck, barge and Great Lakes vessels to tidewater transshipment points. There are also direct overseas shipments from Great Lakes and St. Lawrence River ports.

The Great Lakes-St. Lawrence transportation system, stretching more than 2,300 miles/3,700 kilometers from the Gulf of St. Lawrence to the lakehead ports of Duluth-Superior and Thunder Bay, is a unique deep draft navigation route unlike any other in the world. System movements are dominated by bulk commodities. Total annual U.S. and Canadian tonnage (shipments and receipts) for the 145 ports and major terminals in the system has averaged around 200 million tons/181 million metric tons in recent years. Grain flows have been quite variable as the world grain market is continually adjusting in terms of supply and demand. North American steel production and related raw materials movement have been affected by recession periods and fluctuating levels of imported steel. Coal shipments, particularly those to electricity generating stations are more stable but utility decisions on fuel contracts have dramatically altered some supply patterns. Salt, which is used primarily for road de-icing, represents five to eight percent of Canadian Great Lakes tonnage. Petroleum products movement is significant for St. Lawrence River ports and Sarnia, Ontario, a major Great Lakes refinery center. Movement of general cargoes (higher value containerized, palletized and other processed or manufactured goods) is declining on the Great Lakes and such traffic now constitutes only a small percentage of St. Lawrence Seaway tonnage. Montreal, though, originates substantial vessel shipments of containers delivered mostly by rail.

Rail and motor carrier freight transportation complement waterborne commerce in the Great Lakes-St. Lawrence region but both maintain well-established service profiles while engaging in intermodal operations and head-to-head competition in some instances. Rail and motor carrier operations together account for more than two-thirds of intercity freight tonnage in the U.S.. From 1980 to 1990, mode share for rail and truck ton-miles combined has increased from 60 to 63.4 percent. In Canada, the two modes represent about 58 percent of total freight tonnage and nearly 75 percent of ton-kilometers, excluding pipelines. The binational region, because of its manufacturing and agricultural production strengths, is a major freight generating area for all the modes; six Great Lakes states are ranked in the top thirteen nationally and Ontario clearly dominates in Canada.

ENERGY USE AND FUEL EFFICIENCY

Transportation runs on energy. The transportation sector currently accounts for about 27 percent of total U.S. energy use and about 28 percent in Canada. The sector's almost total dependence on petroleum-based fuels raises serious questions about related pollution and future availability as well as cost. Nearly two-thirds of petroleum use in the U.S. and Canada is for transportation purposes. This level of petroleum consumption is likely to grow because of increasing use by the transportation sector, coupled with decreasing use in other sectors.

Truck

The fuel efficiency of tractor-trailer trucks, as measured by ton-miles per gallon(TM/gallon), reveals a substantial range with route characteristics, type of equipment and load as major variables. In this study, the truck figures for one-way trips ranged between 117 TM/gallon for the steel and paper movements to 223 TM/gallon for the cement movement using double trailers.

Rail

Railroad fuel efficiency has been improving with the introduction of new locomotives, reduction of empty car miles, optimal routings and speed control but it is still substantially less than the more efficient bulk carriers that ply the Great Lakes and St. Lawrence River. For the purpose of this study, most of the rail haul scenarios were developed as unit train movements engaged in dedicated service with long trains and level terrain. As a rule, unit train operations with the lowest horsepower per trailing ton ratios have the highest fuel efficiencies. The 3,000 horsepower SD-40 locomotive, the most common locomotive used in line-haul North American operations, was the standard locomotive used to calculate fuel use per locomotive mile. The number of locomotives per train ranged from one to three depending on train tonnage and other operational factors. On a ton-mile per gallon basis, the one-way movements in the eleven case studies ranged between 467 in the movement of petroleum products to Montreal from Sarnia, to 877 for taconite pellets from Minnesota to Lorain, Ohio. On a metric ton-kilometer per liter basis these figures were 180 and 338 respectively.

Marine

Among rail, truck and water modes, waterborne transport is generally the most energy efficient for large tonnage movements. Large cargo capacity relative to engine size and operating characteristics make Great Lakes bulk carriers, ocean-going ships and tug-barge combinations relatively fuel efficient on a straight ton-mile per gallon basis. The greater circuity of many navigable waterways compared with rail and road networks can reduce the fuel efficiency difference. However, with Great Lakes waterborne movements compared with alternative surface routes, circuity is usually not a major factor because the vast water bodies are barriers to more direct land routings.

Great Lakes dry bulk carriers, whether diesel or steam-powered, are mostly high block coefficient vessels designed to maximize cargo at normal 26-foot operating drafts. Fuel efficiency varies among the

Annual Fuel Use and Emissions (CO, HC, NOx) for Modal Shift Scenarios

	MARINE		RAIL		TRUCK	
	Fuel Use (million U.S. gallons)	Total Emissions (net tons)	Fuel Use	Total Emissions	Fuel Use	Total Emissions
1	.816	259.08	1.219	351.2		
2	7.215	2,290.6	14.498	4,175.3		
3	9.587	1,983.33	14.044	4,044.6		
4	.216	7.86	.160	46.28	.543	95.21
5	1.048	332.82	.479	138.05		
6	1.519	482.33	.582	167.63		
7	3.930	1,248.06	5.560	1,601.41		
8	.264	83.9	.460	132.69	.998	174.7
9*	4.413	1,401.16	5.835	1,730.85		
10	1.745	554.15	1.805	520.37		
11*	1.635	519.19	1.841	575.03	3.979	911.13
TOTAL	32.388	9,162.5	46.483	13,483.4	5.52	1181.04

NOTE: For the #9 scenario, rail fuel use and emissions include those from the marine leg of the complete movement from Quebec ore ports to Hamilton, Ontario through Quebec City.

For the #11 scenario, marine emissions and fuel use represent only one-way movements from Europe to the United States. Rail and truck figures include Europe to Baltimore marine figures..

vessels of the Great Lakes fleet. For the U.S. dry bulk carriers assessed in this study, the range is 520 TM/gallon (200 metric ton-kilometers/liter) for one-way trips from Alpena, Michigan to Detroit by cement carriers, to an average 1,426 TM/gallon (550 metric ton-kilometers/liter) for coal movements from Superior, Wisconsin to St. Clair, Michigan, aboard 1000-foot vessels. Propulsion fuel consumption also varies according to route/operation characteristics. For example, transits through the Welland Canal and the Great Lakes connecting channels involve reduced speeds and lower fuel use for those segments compared to open lake movements, and vessels operating in ballast save some fuel compared to loaded trips. Vessel fuel use for the eleven scenarios was 32.39 million gallons/122.55 million liters, or only 69.6 percent of that for the rail movements.

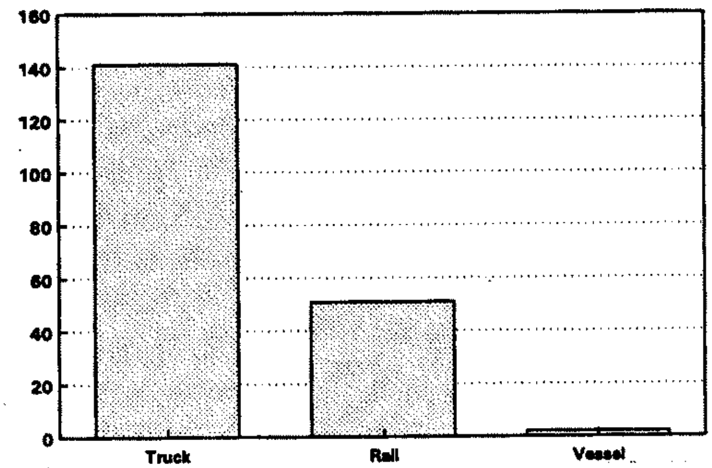
SAFETY, NOISE AND CONGESTION IMPACTS

Safety issues are focusing increasing public and government attention on the movement of commodities. Canada and the United States identify safety as their chief federal transportation program priority. Safe operation of vehicles, proper equipment inspections, and the handling of hazardous materials are the major areas of current policy interest. As recent examples of freight transportation accidents and related problems illustrate, human life, the natural environment, and property can all be at risk when an accident occurs.

In this study, the shifting of commodities from vessels to either rail or truck would increase the number of transportation-related accidents based on statistical accident probability. With such a shift there would be the potential for an additional 141 truck and 51 train accidents with many of them resulting in death or serious injury and substantial property damage and environmental harm.

Based on data from the Transportation Safety Board of Canada and the U.S. Coast Guard, serious accidents involving large cargo vessels operating on the Great Lakes St. Lawrence River entailing such mishaps as vessel collisions, founderings/sinkings, explosions or fire are quite rare. The study's determination of an annual accident rate of one accident per 8 billion vessel ton-miles indicates the possibility for only 2 such accidents for the existing waterborne cargo movements.

TRANSPORTATION ACCIDENTS FOR SELECTED COMMODITY MOVEMENTS



Transportation-related noise is a problem in modern society. With respect to freight transportation, increasing tonnage levels have generated higher noise exposure levels. Diesel trucks, idling diesel locomotives and freight trains generally produce noise levels sufficient to cause auditory fatigue, and prolonged exposure can cause hearing loss. Road traffic is considered the most serious noise problem where exposure levels are higher for the greatest number of persons. Noise problems associated with commercial navigation on the Great Lakes-St. Lawrence system are not perceived as a significant problem, since most related noise is far from shore.

Congestion and related capacity constraints can affect all transport modes. Rail yards are notorious bottlenecks and navigation locks have the potential to create delays, but road congestion is a leading transportation problem and it is rapidly getting worse. The alarming increase in congestion is reducing economic productivity, adding to vehicle emissions and fuel use, and raising safety risks. The consequences of a modal shift to truck in the Great Lakes St. Lawrence region where a large tonnage amount is involved would be especially troublesome. The substantial increase in truck traffic to accommodate tonnage volumes previously moved by rail or vessel would overwhelm highway routes and exacerbate capacity problems.

AIR POLLUTION AND EMISSIONS

Air pollution worldwide is a growing threat to human health and the natural environment. Fuel combustion is the largest contributor to human-caused air pollutant emissions with stationary and mobile sources responsible for approximately equal amounts. The most prevalent air pollutants from transportation sources are: carbon monoxide (CO); nitrogen oxides (NOx); hydrocarbons (HC) or volatile organic compounds (VOC); and particulates. According to the Organization for Economic Cooperation and Development, the transport sector (passenger and freight) in Canada and the United States accounts for the following percentages of total North American emissions: 71 percent of CO; 47 percent of NOx; 39 percent of HC and 14 percent of particulates. Transportation vehicles contribute only a small percentage of another important pollutant, sulfur dioxide, and the amount varies greatly depending on the sulfur content of a particular fuel. For the principal air pollutants, gasoline-fueled automobiles are the major sources and urban areas the most heavily affected places. However, freight transportation, dependent on diesel fuel, makes a significant contribution to pollution levels but the impacts vary according to mode and operations.

Diesel fuel or distillate represents only one-fifth of U.S. transportation energy consumption, but it is the principal fuel used by heavy trucks and the other major freight modes. Air pollutants from diesel vehicles compared with those from gasoline combustion have both favorable and undesirable characteristics. For example, because of better combustion efficiencies and lower temperatures, diesel CO, HC and NOx emissions are at lower rates. However, fine particulates as well as formaldehyde, are higher, and sulfur dioxide is higher due to the higher sulfur content of diesel fuel. Sulfur content of diesel fuels varies considerably depending on crude characteristics and refining practices.

Heavy duty trucks account for about three-fifths of total diesel fuel use in the U.S. In the study, truck emissions were substantially higher than for rail or marine. This result is attributable to the large number of vehicle trips and miles involved in the carriage of nearly a million tons. In the Great Lakes-St. Lawrence River system, emissions from commercial marine vessels, as with other large vessels, vary by type of engine and propulsion (steam or diesel motor) and kind of fuel (distillate or residual bunker.) Vessel emissions usually represent a small fraction of total transportation emissions for port communities particularly those with larger populations. Marine emissions in the study scenarios totaled 9,162.5 tons/8,312 metric tons or 4,321 tons/3,996 metric tons less than for the comparable rail movements. Railroad emissions vary according to throttle notch position on locomotives, with higher fuel use and higher emission levels generally occurring at the high end of running speeds, but idling locomotives particularly in railyards also entail significant pollution problems. In the modal shift study, a rail emissions total of 13, 483 tons/12,308 metric tons were nearly 50 percent greater than those for the marine movements.

CONCLUSION

The Great Lakes-St. Lawrence region, with freight transportation service by all modes solidly in place, is not confronted by the prospect of immediate, broadscale modal shifts induced by either energy or environmental factors. However, some shifts are occurring in the ordinary course of business and, over time, energy, safety and environmental evaluation of all forms of transportation will begin to drive investment decisions as well as regulatory policy.

In the United States and Canada as well as in Europe, the safety and environmental-energy impacts of transportation activity have become major concerns. The integration of environmental and transportation issues has taken place in response to rising public interest, as well as the critical need for viable solutions to transportation and environmental protection problems. It is now recognized that a comprehensive multimodal approach to transportation and environmental-energy policy is required.

Introduction

In 1991, the Minnesota Department of Transportation released a study that described certain environmental impacts which would occur should certain Minnesota-based cargo movements shift from the waterborne mode to land transportation. The study, "Environmental Impacts of a Modal Shift" conducted by MN/DOT's Ports and Waterways Section, focused primarily on river movements, but did include a cargo movement through a port on Lake Superior. Analysis of the projected modal shifts indicated substantial increases in such factors as fuel use, exhaust emissions and probable accidents as well as increased traffic congestion if vessels were replaced by trucks or trains.

Regional maritime interests asked the Great Lakes Commission to conduct a similar study for the Great Lakes-St. Lawrence Seaway system. The Great Lakes Commission is an eight-state compact agency that guides, protects and advances the common interests of its membership in areas of regional environmental quality, resource management and economic development. Five organizations and government agencies based in Canada and the United States agreed to fund the study. They are:

- International Association of Great Lakes Ports (binational)
- Lake Carriers' Association (Cleveland, Ohio)
- Canadian Shipowners Association (Ottawa, Ontario)
- Saint Lawrence Seaway Development Corporation, U.S. Department of Transportation (Washington D.C.)
- The St. Lawrence Seaway Authority (Ottawa, Ontario)

At a time when Great Lakes-St. Lawrence commercial navigation has come under increasing scrutiny for potential risks from oil and hazardous materials spills, as well as dredging and dredged material disposal, the results of a modal shift study will be valuable in understanding the comparative risks and impacts of one transportation mode in relation to another. Although economic and logistic factors are often pivotal in mode choice decision, the environmental and safety consequences of the use of certain modes are becoming more important in governmental policy.

Transportation policy at all governmental levels must take into consideration environmental factors. Transportation is the leading energy use sector in North America and has a major impact on environmental quality. Within the last few years, media coverage of the transportation/environmental connection has expanded in response to particular events and growing public awareness of the issues. Related legislative and regulatory action in Canada and the U.S. has also kept pace. With transportation arrangements and environmental information changing continually, a new dynamic situation for government and private sector decision-making has arrived.

The basic methodology for *Great Lakes and St. Lawrence River Commerce: Safety, Energy and Environmental Implications of Modal Shifts* made use of hypothetical scenarios for several commodity flows representing a range of products and raw materials moving on the Great Lakes-St. Lawrence system. Modal shift scenarios for eleven commodity movements were assessed. The commodity movements are:

1) Potash from Thunder Bay, Ontario to Toledo, Ohio;
2) Coal from Superior, Wisconsin to St. Clair, Michigan;
3) Taconite from the Minnesota North Shore to Lorain, Ohio;
4) Cement from Alpena, Michigan to Detroit, Michigan;
5) Petroleum products from Sarnia, Ontario to Montreal, Quebec;
6) Petrochemical products from Sarnia to Chicago, Illinois;
7) Grain from Thunder Bay to Quebec City;
8) Paper, wood pulp, and other products from Thunder Bay to Superior;
9) Iron ore from Pointe Noire/Sept Iles, Quebec, to Hamilton, Ontario, with combined vessel/rail alternative through Quebec City;
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11) Steel from northern Europe (Rotterdam) to Cleveland, Ohio with truck/rail alternative through Baltimore, Maryland.

For the purpose of this study, waterborne tonnages for the selected study commodities were translated into an equivalent movement by surface mode. In all commodity shift scenarios, rail movement alternatives were analyzed. The motor carrier option was used in three scenarios. A shift to truck was determined to be unrealistic in all cases except three because of transport costs, the length of the substitute haul, and the amount of tonnage involved.

The selection of the eleven commodity movements or "case studies" is intended to capture the basic elements of Great Lakes and St. Lawrence freight transportation. These particular origin-destination movements represent more than ten percent of the average annual tonnage moving on the system. The movement patterns are widespread and diverse. For example, grain from Thunder Bay, Ontario, to Quebec City, moves 1,380 miles (2200 kilometers) by water. In comparison, the cement haul from Alpena, Michigan, to Detroit travels only 219 miles (352 km). The prevalence of bulk commodities in the commodity selections mirrors their respective tonnage dominance in the Great Lakes-St. Lawrence system. Most of the major commodity movement patterns present today in Great Lakes and St. Lawrence River have been in place for years but they are part of an evolving system that changes over time. Delivery schedules and equipment needs are adjusted to accommodate changes in product demand and requirements. Volumes fluctuate from year to year and some trades disappear while new shipping arrangements come about. Continued flexibility in responding to new transportation challenges will be needed if the Great Lakes-St. Lawrence system is to build upon its great historical legacy.

Although this study was designed to simulate hypothetical modal shifts for comparative purposes, the effort was based on real possibilities for modal shifts in particular commodity movement cases and under certain circumstances. In fact, during preparation of this report, the railcar ferry carrying newsprint, wood pulp and other products from Thunder Bay to Superior, Wisconsin permanently ceased its Lake Superior operations and a complete modal shift is now likely. The 116-meter *Incan Superior* with a capacity of 26 to 32 rail cars had been used in a dedicated shuttle movement since February 28, 1974. The vessel connected CPRail at Thunder Bay with the Burlington Northern Railroad at Superior. Throughout its operation, the vessel, with its 11-member crews, carried approximately 5.7 million tons on 2,386 voyages. The ending of this service brings to a closure open lake railcar ferry operations on the Great Lakes. Competitive inroads from all-rail routings, a downturn in paper demand, coupled with the $155,000 annual cost for U.S.-imposed harbor maintenance taxes are cited as reasons for suspending service. Assuming that rail and occasional truck movements will take up where the *Incan* service left off, perhaps at lower tonnage levels, this commodity movement example serves to illustrate a "real world" modal shift.

Other modal shifts among the selected commodity movements in this study are possible. For example, the high volume western coal flows from the Powder River basin in Wyoming and Montana by rail to Superior and from there by vessel to Detroit Edison electric generating plants in Michigan could switch to all-rail. The railroads that originate traffic in the coal region would like to maximize their rail hauls. As a result, rail rates for delivery to Michigan points are inching closer to those for the innovative and efficient transshipment option. Another example is potash. Great Lakes movements, which were near 2 million metric tons in the 1980s, have declined substantially. At Thunder Bay, the dominant shipping port of potash originating in Saskatchewan, potash shipments were 1,095,061 metric tons in 1991, a 20 percent decline from a year earlier. All-rail shipments, particularly to Ontario points, have contributed to the decline as have reduced agricultural demand and product degradation concerns resulting from extra handling in the rail-vessel-rail/truck movements. These factors, coupled with more direct rail connections to interior U.S. distribution points have challenged lower-cost vessel delivery and could result in increased diversion of business to the railroads. These examples underline the potential of modal diversions for particular Great Lakes-St. Lawrence commodity movements.

The modal split characterizing historical transportation arrangements in the region is subject to continual adjustment. Rates and service factors usually influence the mode shift decisions of shippers. Some changes may last only over the short-term whereas others can persist. In addition to the basic economic outcomes of a particular split for a region's transportation activity, there are specific safety, energy and environmental impacts. These issues all entail financial considerations for transportation companies, but the health, welfare and safety of the public at large are also becoming important factors in the conduct of transportation business.

CHAPTER 1

Freight Transportation and the Regional Economy

Transportation was a pivotal factor in the development of the Great Lakes-St. Lawrence region. The combination of an in-place water transport infrastructure and a strong natural resource base promoted population settlement and a manufacturing economy. As a trade route among native peoples and a corridor of discovery and commerce for the Europeans, the Great Lakes-St. Lawrence River system and tributaries along with other rivers were an established transport system long before the United States and Canada became nations. The natural water routes and canal links channeled territorial expansion and with it came the underpinnings of economic development. The passenger and freight network distributed people and goods throughout the waterway system. Localized services for shore communities gradually expanded to support larger markets and hinterlands. The first major "gateway" cities in the region began as ports, such as Montreal, Cincinnati, Toronto, Pittsburgh, Buffalo, Cleveland, Detroit, Chicago, Milwaukee, and Minneapolis-St. Paul. When the railroads came, they connected the cities of the water-based transport system.

The major settlement period of the Great Lakes region coincided with the rapid development of industrial technologies and processes. Proximity to productive agricultural land and access to important raw materials, coupled with an available labor force, gave the region an unparalleled advantage in domestic and overseas markets. It was water transportation that was the foundation of shore-based manufacturing and related activities. In many cases, the waterborne shipment option for raw material delivery and movement of finished goods was a major locational determinant for industrial operations.

One of the first major industries to make use of the Great Lakes was logging and sawmilling. Gigantic log rafts were moved around the system. The lumber, in turn, nurtured a construction boom. Coal made its way overland to the eastern Great Lakes ports and from there was distributed by vessel for heating and, later, steelmaking and electricity generation. Massive movements of iron ore from northern Minnesota and Michigan to lower lakes steel mills, and grain flows to eastern flour mills, made the Great Lakes transportation system the busiest in the world for many years. These commodity movements materialized in response to the industrial base that was concentrating in the Great Lakes region.

The regional steel industry illustrates the role transportation has in a major industrial activity. The Great lakes proximity to the major supplies of iron ore, coal and limestone--the raw materials of the steelmaking process--was the major reason for the steel industry's concentration in the region. The high volume of these low value inputs favored maximum use of efficient lake vessels. The rail mode for some coal and ore movements played a complementary transshipment role. From mines adjacent to or near company-owned harbors, large shipments of low unit value limestone are primarily wedded to self-unloading lake delivery. Lakefront steel complexes were established at Buffalo, Cleveland, Detroit, Hamilton, Sault Ste. Marie and along the Lake Michigan shoreline in Illinois and Indiana. Several inland plants also rely on lake-hauled materials. Current Great Lakes and St. Lawrence River shipments of raw materials for both the U.S. and Canadian steel industries are more than 100 million net tons annually. With more than 70 percent of U.S. and 90 percent of Canadian steel production and half of each nation's steel consumption concentrated in the Great Lakes states, Ontario and Quebec, the regional economy is, without doubt, steel intensive.

Today, the region's binational transportation system is characterized by a well-developed multiple mode infrastructure with strong intermodal connections. Among the principal vehicle freight modes, a competitive and yet complementary relationship has evolved. The region's relatively high freight generation level is, in part, attributable to the system's transport efficiencies. Particular modal patterns are evident in commodity movement and route structure. Historically, east-west freight routes have had more capacity and volume compared to north-south links. However, in recent years, partly attributable to the U.S. Canada Free Trade Agreement, north-south commodity flows have been increasing and the infrastructure to support this trend is receiving increased attention. This regional north-south axis may be greatly expanded if a concept that U.S. DOT is exploring comes to fruition. Called "The Avenue of the Americas" or "Maritime System of the Americas," it envisions direct waterway transport links from the Great Lakes-St. Lawrence River through the Illinois-Mississippi Rivers system to the Gulf Intracoastal Waterway and Gulf of Mexico. The Great Lakes,their connecting rivers, and the St. Lawrence system not only demark an international boundary in the region but confine cross-border freight transportation by rail and truck at widely separated bridges and tunnels. The waterborne commerce connection, however, has always been there, providing cross-lake and inter-lake service. The region's east-west commodity movement patterns developed not only in response to geography and the orientation of population settlement but also from government policy. National goals for transportation sufficiency and economic development have fostered regulatory regimes and subsidy programs for various commodities and the transport modes themselves. This welter of rules and practices has undeniably shaped the flow of goods throughout the region.

Freight movements in the binational region serve both the domestic markets and international trade. Canada and the U.S. have the world's largest trade relationship and are each other's most important trading partners. Much of this trade is tied to the Great Lakes region. U.S. exports to Canada constitute more than one-fifth of total exports, and three-fourths of Canadian exports are to the U.S. The eight Great Lakes states accounted for 57% of total U.S./Canada trade in 1989, which was valued at $191 billion. Ontario accounts for more than a third of this binational trade with Michigan the largest partner. In the region, New York state has the strongest trade ties to Quebec. Motor vehicles and parts, machinery and equipment contribute the most in terms of value to U.S.-Canada regional trade. Paper, pulp and lumber, along with coal, natural gas, oil and petroleum products and electricity are among other principal products that move across the border. Overseas exports of manufactured and agricultural products also represent a high value contribution to the regional economy. These goods are transported by rail, truck, barge and Great Lakes vessels to tidewater transshipment points. There are also direct overseas shipments from Great Lakes and St. Lawrence River ports.

Great Lakes and St. Lawrence River commodity movements are dominated by relatively low value bulk commodities. Table 1-1 shows ranking system ports in cargo tonnage. Total annual U.S. and Canadian tonnage (shipments and receipts) for the 145 ports and terminals in the system has averaged around 200 million tons (181 million metric tons) in recent years. Grain flows have been quite variable as the world grain market is continually adjusting in terms of supply and demand. North American steel production and related raw materials movement have been affected by recession periods and fluctuating levels of imported steel. Coal shipments, particularly those to electricity generating stations are more stable but utility decisions on fuel contracts have dramatically altered some supply patterns. Salt, which is used primarily for road de-icing, represents five to eight percent of Canadian Great Lakes tonnage. Petroleum products movement is significant for St. Lawrence River ports and Sarnia, Ontario, a major Great Lakes refinery center. Movement of general cargoes, higher value containerized, palletized and other processed or manufactured goods is declining on the Great Lakes and such traffic now constitutes only a small percentage of St. Lawrence Seaway tonnage. Montreal, though, originates substantial vessel shipments of containers delivered mostly by rail. For 1991, 300,744 containers or 52 percent of Montreal's container traffic moved overseas.

The Great Lakes-St. Lawrence transportation system, stretching more than 2300 miles/3700 kilometers from the Gulf of St. Lawrence to the lakehead ports of Duluth-Superior and Thunder Bay is a unique deep draft navigation route unlike any other in the world. Recent studies of the system's economic impact indicate that more than 60,000 Canadian and U.S. jobs are dependent on the cargo

TABLE 1-1
RANKING GREAT LAKES AND ST.LAWRENCE RIVER PORTS IN CARGO TONNAGE
(net/metric tons)

U.S. PORTS (1989)	TONNAGE (Million net/metric tons)	LEADING COMMODITY
Duluth-Superior, MN/WI	40.8/37	ore
Detroit, Michigan	20.7/18.77	ore
Indiana Harbor, Indiana	15/13.6	ore
Toledo, Ohio	14.8/13.42	coal
Cleveland, Ohio	14.68/13.31	ore
Lorain, Ohio	14.56/13.20	ore
Marquette, Michigan	12.92/11.72	ore
Chicago, Illinois (Lakes)	11.05/10	ore
Two Harbors, Minnesota	10.53/9.55	ore
Ashtabula, Ohio	10.32/9.36	ore
Calcite, Michigan	9.23/8.37	limestone
Taconite Harbor, Minnesota	8.99/8.15	ore
Stoneport, Michigan	8.88/8.06	limestone
Conneaut, Ohio	8.89/8.06	coal
Burns Harbor, Indiana	8.69/7.88	ore
Gary, Indiana	8.3/7.53	ore
Escanaba, Michigan	6.76/6.13	ore
St. Clair, Michigan	5.75/5.21	coal
CANADA PORTS (1990)	**TONNAGE (Million net/metric tons)**	**LEADING COMMODITY**
Sept Iles/Pte. Noire, Quebec	23.51/21.34	ore
Montreal/Contrecoeur, Quebec	23.27/21.12	petroleum products
Port Cartier, Quebec	22.68/20.58	ore
Quebec/Levis, Quebec	18.86/17.12	crude petroleum
Thunder Bay, Ontario	15.34/13.93	grain
Hamilton, Ontario	13.06/11.86	ore
Nanticoke, Ontario	8.33/7.56	coal
Baie Comeau, Quebec	7.68/6.97	grain
Sorel, Quebec	5.87/5.33	titanium ore
Sarnia, Ontario	5.45/4.95	coal (power plant)
Sault Ste. Marie, Ontario	4.59/4.17	ore
Windsor, Ontario	3.36/3.05	salt
Clarkson, Ontario	3.10/2.82	limestone

Sources: Waterborne Commerce of the United States - 1989, Part 3, Waterways and Harbors, Great Lakes. U.S. Army Corps of Engineers (1991). Statistics Canada - Surface and Marine Transportation Section, Transportation Division.

movements and these activities generate more than $3 billion in business revenue and personal income. Since 1959, the modern Seaway with its seven river locks coupled with the older Welland Canal has transitted more than 1.3 billion metric tons with an estimated value of $200 billion. With few exceptions, annual tonnage for the Montreal-Lake Ontario section increased until the peak year of 1977, when over 57 million tons were reported. While there have been year-to-year fluctuations, the 34.9 million tons in 1991 indicate the substantial decline in average Seaway tonnage. A nine-month navigation season for through traffic, vessel size limits, Canadian tolls and the cumulative impact of pilotage costs for long-distance system movements have all combined to dampen growth prospects for Seaway general cargo shipping. Bulk cargoes, prone to much annual variability, also face long-term threats from increasing tolls, various government cost recovery initiatives, rail competition and changes in supply sources.

Rail and motor carrier freight transportation complement waterborne commerce in the Great Lakes-St. Lawrence region but both maintain well-established service profiles while engaging in intermodal operations and head-to-head competition in some instances. Rail and motor carrier operations together account for more than two-thirds of intercity freight tonnage in the U.S. From 1980 to 1990, mode share for rail and truck ton-miles combined has increased from 60 to 63.4 percent. In Canada, the two modes represent about 58 percent of total freight tonnage and nearly 75 percent of ton-kilometers, excluding pipelines. The binational region, because of its manufacturing and agricultural production strengths, is a major freight generating area for all the modes; six Great Lakes states are ranked in the top thirteen nationally and Ontario clearly dominates in Canada.

Over the past decade, one of the most important developments affecting the region's surface transportation industry has been economic deregulation through the Staggers Rail Act of 1980 and the 1980 Motor Carrier Act, as well as Canada's National Transportation Act in 1987, and the Motor Vehicle Transport Act in 1988. In the U.S. and Canada, significant transport inefficiencies caused by federal rate and entry/exit regulation for both modes gave impetus to regulatory reform. It has been estimated that the annual cost to the American economy of rail and motor carrier regulation was $4 to $5 billion. In Canada, the government has a major financial stake in supporting essential rail services and the existing regulatory environment is less uniform.

Total major U.S. railroad (Class I, representing 91 percent of all rail freight revenue) tonnage fluctuated during the 1980s, from a recession-low in 1982 of 1.26 billion to 1.42 billion in 1990. Revenue ton-miles have been increasing, indicating a trend toward longer hauls, which averaged 726 miles in 1990. During the 1980s, relaxed exit rules permitted Class I railroads in the Great Lakes states to abandon a quarter of their route system or more than 10,000 miles of unprofitable branchline track. For the Great Lakes states, the region's share of carloadings is about a third of the U.S. total of more than 21.4 million carloads. As for commodity mix in the Great Lakes area, motor vehicle and equipment rail shipments have been increasing but food product shipments have been losing ground to trucks. The heavy taconite (iron ore) shipments in Northern Minnesota and Michigan have given these two states a more than 90 percent share of total U.S. metallic ore rail shipments. With respect to grain/farm product shipments, the Great Lakes states have more than 30 percent of the total.

The major U.S. railroads, as a whole, have rebounded impressively from their pre-deregulation doldrums but vulnerabilities persist. The dependence on relatively few bulk commodities with nearly 60 percent of traffic tied to coal, grain, and chemicals has subjected many carriers to the vagaries of the marketplace, both domestic and overseas. Labor accounts for half of the industry's costs, which has helped the nonunion trucking sector capture an increasing share of the higher value merchandise business. Between 1980 and 1987, long-haul truckload volume increased 76 percent whereas rail movement of manufactured goods declined by 14 percent. Paralleling the growth of truck competition are intermodal operations. More than six million trailers and containers were carried in 1990, amounting to about a quarter of all U.S. carloadings.

Canadian rail tonnage averaged 278 million metric tons for the period 1985 through 1990 with the two main carriers, Canadian National (CN) and Canadian Pacific (CP), representing more than two-thirds of the total. In contrast to the U.S., revenue ton-kilometers have decreased since 1987. The average length of haul among the two major carriers in 1990 was 1,205 km (747 miles) or slightly more than in the U.S. Ontario, with more than a third of mainline trackage in Canada, accounts for the largest percentage of rail revenues among the provinces. The transborder integration of the regional/binational rail network is evidenced by the substantial amount of Canadian carrier-owned line located in the Great Lakes states and the fact that half of Canadian rail revenues derived from movements between Canada and the U.S. has an Ontario or Quebec connection. Transborder rail traffic is growing, now accounting for 18 percent of total Canada-U.S. merchandise trade value and representing 23 percent of total Canadian rail tonnage.

In Canada, as in the U.S., rail is losing tonnage to trucking operations. This trend has been particularly evident during the past decade in transborder traffic of motor vehicle parts, lumber and newsprint. On the other hand, piggyback and container operations increased by about 30 percent from 1984 to 1989. New investment in intermodal operations for CN and CP will strengthen freight revenues during the 1990s and may also enhance the carriers' U.S. connections. For example, CN is building a second rail tunnel at Sarnia-Port Huron under the St. Clair River. This $128 million tunnel, when completed in 1994, will accommodate double-stack cars, thereby eliminating the car ferry for such equipment and keeping the route competitive with trucks in the Chicago-Ontario corridor. In another case, the Detroit-Windsor rail tunnel, which is jointly owned by CP and CN is being enlarged to handle tri-level auto carriers. The two major carriers are also improving their Canadian transcontinental routes with mountain tunnel enlargement and through a new initiative called "Advantage Canada," emphasizing a coordinated and seamless transport system involving shippers, ports and vessel lines.

Trucking in Canada and the U.S. is a versatile mode providing tailored service for all kinds of goods ranging from gravel to computers. Timely delivery to points all over the road network assures the motor carriers a service advantage particularly for higher value products within a 500-mile range. U.S. intercity truck tonnage generally increased during the 1980's, reaching 2.6 billion tons in 1990. In Canada, the 1988 figure was 314 million tons with three quarters of the for-hire movements occurring within a province. For Ontario, 70 percent of manufactured goods are dependent on truck transport, and the trucking industry employs directly an estimated 60,000 people. In the less-than-truckload sector, regulatory reform in both countries has promoted network efficiency by reducing circuitry of routes and promoting backhaul opportunities in long distance hauls. Much state and provincial regulation and numerous fees persist though, resulting in less competition within jurisdictions. In Canada, interprovincial barriers have been reduced considerably through regulatory reform. The industry has also seen tremendous growth in nonunion high density corridor operations that take advantage of maximum vehicle use. Problems for the U.S. over-the-road trucking sector include the hodgepodge of state vehicle weight and safety laws and growing support for more vigilant weight enforcement and higher use taxes to offset the disproportionate share of pavement damage attributed to large trucks. Growing public concern about safe truck operation and relatively low fuel economy for tractor-trailer units, along with rising fuel prices have also created problems for the industry. Canadian truckers are particularly concerned about competitive disadvantages vis-a-vis their American counterparts in cross-border traffic. The Ontario-based trucking industry is especially vulnerable with one-quarter of all revenues tied to such traffic.

CHAPTER 2

Modal Shift Analysis and Public Policy

The region's transportation system operates in a dynamic environment. Its infrastructure allows goods and people to move among areas of economic importance matching demand with supply. Circumstances change and new transportation arrangements come into play. Public policy with respect to transportation has also undergone changes responding to historical and political developments. However, the vital connection between an efficient transportation system and a prosperous economy remains. In emphasizing the critical role of transportation in the economy, the U.S. Secretary of Transportation stated in 1990, "No industry in the nation is more important to U.S. economic growth and international competitiveness than transportation."

Transportation of goods in modern industrial societies is reliant on all modes. Multimodalism is based on the principle that each mode has unique characteristics conveying advantages for the movement of particular commodities. Intermodal operations build on this principle by recognizing that freight transportation is a blend of cost and service factors. Optimal routings often involve a combination of modes with each movement tailored to its set of unique requirements.

Government, at all levels, has a significant role in the freight transportation marketplace. Governments are users and occasional providers of transportation services. However, the thrust of current public policy regarding transportation is focused on three major areas: infrastructure investment, taxation and safety and environmental regulation. The substantial investment of public funds in roads, airports and commercial waterways carries with it the responsibility to assess the contribution to economic development as well as to maintain an efficient transportation system and competitive balance among the modes. Although the full spectrum of taxation policy affects transportation, it is fuel taxes and other kinds of user fees that are under increasing scrutiny by government for revenue generation. The transport industry is particularly concerned about the collective impact of such taxes and their effect on intermodal competition. Safety regulation is an area of active public policy. Hazardous materials transport and accident potential for a given mode or route have become major public concerns in recent years. Local and state officials are focusing increasing attention on risk assessment as a means to guide decisions bearing on safety issues. Environmental issues related to transportation have perhaps the greatest salience among the public. Pollution and land use impacts for proposed transportation projects, both public and private, are now a basic element of the government review process. The environment/transportation connection is strong and obvious and for this reason interrelated issues and problems are dealt with in a unified manner.

These three areas of public policy result in jurisdiction-specific actions but they also transcend political boundaries in the Great Lakes-St. Lawrence region. Canadian and U.S. residents have many common interests and concerns regarding transportation policy and how transportation affects their daily lives. The degree of interest among the public certainly varies according to how applicable an issue is to their local area and way of life. For example, the details of a nationwide highway investment program compared to the need for noise barriers along a stretch of nearby interstate highway compare quite differently in focusing residents' attention. Where private sector action or government policy poses a change in transportation activity, whether it is the level of such activity or how it manifests itself, the consequences are likely to be subject to public scrutiny. For goods movement, a change in mode share particularly if it is significant will translate into changed impacts with wide-ranging consequences. Such a "modal shift" can be assessed to determine what consequences are likely to result. These "impact analyses" often look at freight rate changes and shifting sector employment as well as access-to-service issues.

Modal shift analysis is also becoming an increasingly important tool to evaluate energy and related environmental impacts of transportation changes. Each mode has its own environmental and energy "profile." Transportation interest groups, trade associations, carriers, and shippers all have a vested interest in influencing public altitudes and government policy regarding modal issues. Modal shift studies can illuminate relevant issues and provide a basis for informed decision-making not only for government officials but also for private sector marketing activities.

FEDERAL POLICY

The U.S. and Canadian federal governments have shown recently a heightened awareness of the energy, environmental and safety implications of freight transportation. Policy development, comparative mode studies and a few operational initiatives have been the near-term outcomes. In 1990 the U.S. Department of Transportation (DOT) prepared a Statement of National Transportation Policy that included several broad themes and numerous "strategies for action." Safety across all modes was identified as the top priority for DOT. The Department's outreach hearings conducted in preparation for the new transportation policy revealed a deep reservoir of public interest in environmental issues. The effects of transportation activities on air and water quality and noise impacts were frequently addressed. Conservation of energy is considered a part of the broad environmental category for policy purposes. Specific actions include:

- Participate in national and international review of and research on transportation-related environmental issues, such as global climate change;
- Implement stronger measures to prevent oil spills and liability requirements that ensure that damages, including natural resource damages, are compensated;
- Ensure through close coordination between the U.S. Departments of Energy and Transportation that programs and actions are consistent;
- Foster development and use of more fuel-efficient vehicles and transportation operations.

- Develop regulations covering locomotive engineer qualifications, safety of employees working on railroad bridges, and maintenance of signals at railroad-highway grade crossings.

Within DOT, two recent examples of agency action illustrate how policy is translated into practice. The Saint Lawrence Seaway Development Corporation has incorporated satellite-based vessel tracking and automated weather monitoring technology into its operations to facilitate safe vessel movements. In 1991 a contract study funded by the Federal Railroad Administration compared rail and truck fuel efficiencies over a range of competing freight corridors.

In Canada, the government has also stated that its Department of Transport's primary responsibility is to ensure safety. Transport Canada in its 1992 Corporate Directions document integrates safety, environmental protection and sustainable development:

> "In the next decade, the environmental dimension of safety and the preservation of the environment are an integral part of our safety objectives.
>
> The reduction of negative environmental impact therefore becomes a key element of our decision-making, affecting all aspects of our operations, within the government's policy of sustainable development."

Current related initiatives of the agency include development and implementation of:

- regulations pursuant to the Railway Safety Act;
- amendments to the Canada Shipping Act to reflect recommendations of the Public Review Panel on Tanker Safety and Marine Spills Response Capability;
- amendments to the Motor Vehicle Safety Act to ensure the safety of vehicles is maintained and their environmental impact reduced;
- amendments to the Transportation of Dangerous Goods Act and regulations to enhance protection of the environment from dangerous goods transportation accidents, and to provide for court restitution for environmental damage;
- more stringent motor vehicle emission regulations; and
- environmental stewardship in Transport Canada operations.

Transport Canada's current agenda also includes funding for contract studies investigating fuel efficiency and environmental impacts for intercity freight modes. Two such studies have included modal shift scenarios.

Several examples of legislative and agency action illustrate the current governmental interest in the environmental aspects of freight transportation and connection to the Great Lakes St. Lawrence region. Government action is resulting in new regulations and may have an impact on future transportation funding. Also, the potential for modal shifts related to government action is present.

MARINE SPILLS AND EMERGENCY RESPONSE

The massive oil spill that occurred when the supertanker *Exxon Valdez* ran aground off Alaska caused a public furor and prompted Congress to pass the Oil Pollution Act of 1990. The law provides for the establishment of emergency response centers (including one on the Great Lakes) to handle oil and hazardous materials spills. OPA also addresses, among many specific provisions, the need for tank vessel spill prevention and response plans coupled with appropriate on-board equipment.

In Canada, the federal government also took initiatives following the Alaskan spill. Environment Canada reviewed marine spill prevention and response capabilities and a Public Review Panel was established. Among the panel's recommendations is the phasing-in of double-hulled tankers to replace the existing Canadian fleet of mostly single-hull vessels and a tanker cargo levy to help pay for government implementation costs. In December 1990, Canada released its environmental action plan or "Green Plan." Although this broad initiative was not directly related to the Alaskan spill, it specifically addressed the need for marine spill contingency planning along with research on prevention and clean-up technology. The Ontario Ministry of Transportation commissioned a study (released in December 1991) to assess the impact of such proposals on Ontario-based oil and petroleum product movements on the Great Lakes. The prospect of diversions of such shipments to other modes was a key question for the study.

AIR QUALITY

Canada and the U.S. have undertaken major air pollution control programs aimed at both stationary and mobile sources. With respect to freight transportation, Canada's federal-provincial Management Plan for Nitrogen Oxides (NOx) and Volatile Organic Compounds (VOCs) adopted in 1990, sets more stringent emission standards for heavy duty trucks and off-road diesel engines as well as a cap on NOx emissions for locomotives. On March 13, 1991, the United States/Canada Air Quality Agreement was signed committing the two counties to reducing transboundary air pollution. Although much of the initial effort is aimed at acid deposition precursors and unilateral control measures, the agreement encourages cooperative action on air pollutant monitoring activities and research on measures for controlling emissions. Canada's Green Plan ties the goal of reducing CO_2 and other transport emissions to improvements in transportation energy efficiency, with the Ministry of Energy, Mines and Resources having lead responsibility for policy development.

The U.S., with 1990 amendments to the Clean Air Act (CAA-90), also established tougher emission standards for trucks and addressed many aspects of fuel quality and alternative fuels as measures to improve air quality. The CAA-90 provides for an assessment of the contributions of non-road engines and vehicles to certain air pollutant levels with the prospect of regulatory action if such sources are determined to make a significant contribution or otherwise "endanger public health or welfare." The new law provides for a continuous transportation-air quality planning process that encourages state and local implementation of transportation control measures to reduce air pollutants of concern. Title II of the CAA-90, which deals with mobile sources, concludes with the following statement: "It is the sense of the Congress that Federal transportation policy should reflect environmental policy and concerns."

INFRASTRUCTURE INVESTMENT

Concern about the level of investment in public works infrastructure such as roads, sewer and water supply systems has become a major public policy issue. An aging infrastructure coupled with tightening governmental budgets has produced a widening gap between needs and the adequacy of existing facilities. With attention focused on infrastructure investment because of its economic importance including job creation, environmental issues have added a new dimension to the discussion, particularly as it relates to transportation. The expenditure of vast sums carries with it an obligation that the environment be protected in the process.

In December 1991 a landmark transportation bill was signed into U.S. law. The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) not only authorized more than $151 billion for highway and transit projects over six years but provided for a national intermodal transportation plan and transportation technology research. A major thrust of the new legislation is to establish new policy linking transportation improvements to environmental compatibility. From the law's policy section, two provisions clearly indicate this new direction:

> *The National Intermodal Transportation System shall consist of all forms of transportation in a unified, interconnected manner, including the transportation systems of the future, to reduce energy consumption and air pollution while promoting economic development and supporting the nation's pre-eminent position in international commerce.*

> *The National Intermodal Transportation System shall give special emphasis to the contributions of the transportation sectors to increased productivity growth. Social benefits must be considered with particular attention to the external benefits of reduced air pollution, reduced traffic congestion and other aspects of the quality of life in the United States.*

The ISTEA requires that transportation planning on a statewide basis and for metropolitan areas consider the economic, energy, environmental and social effects of transportation decisions. State and local transportation officials have been given more flexibility in using federal money to achieve ISTEA's goals. With respect to air quality, more funding will be available to ensure that local and state transportation plans, programs and projects conform with State Implementation Plans established in the Clean Air Act Amendments of 1990.

According to the Transportation Research Board (part of the National Research Council), a major thrust of the ISTEA "is to encourage transportation alternatives that mitigate traffic and air quality problems." This new direction in federal transportation policy with its focus on transportation and related environmental impact planning at the local and regional levels signals a major turning point in public policy. The integration of environmental and transportation issues was necessitated by rising public interest as well as the critical need for viable solutions to transportation and environmental protection problems. Much of the initial efforts in states and metropolitan areas will be to improve transit, increase vehicle occupancy and implement traffic management strategies. Truck use and routings will also be evaluated as will impacts of rail yards and airports. A comprehensive multimodal approach involving both people and goods movement is required. Throughout the U.S., metropolitan planning agencies are currently wrestling with these issues. At the state and provincial levels, the fusion of environmental and transportation planning is also taking hold. For example, the Southeast Michigan Council of Governments has recently adopted a new transportation improvement program for 1993-95 that will result in a 10 to 15 percent reduction in hydrocarbon emissions consistent with CAA-90 requirements. In another example, the Ontario Ministry of Transportation has begun a series of studies on long-term transportation needs through a process that emphasizes public input and squarely places transportation solutions in their economic, environmental and social context. The Niagara-Lake Erie area is one region for which this process is underway. The area is a key goods movement corridor with associated congestion and environmental impacts and therefore, prospects for modal shifts as a mitigation strategy will be analyzed.

EUROPE AND MODAL SHIFT ISSUES

During the past several years, government officials and industry experts in Europe have together acknowledged an impending crisis for Europe's transportation system. Insufficient capacity to accommodate projected growth in people and goods movement coupled with a serious lack of coordination among the freight modes have placed transportation issues high on the policy agenda. At the same time, the development of an environmental policy for the European Community (EC) has resulted in new transportation-related initiatives including the use of "biofuels" such as ethanol and tax measures to drive freight from roads to the "greener" modes of rail and waterways.

In the twelve-nation European Community, the transport sector accounts for 7 percent of gross national product, 7 percent of jobs, 40 percent of public investment and 30 percent of energy consumption. With Europe implementing its 1993 Single Market status and current efforts to integrate Eastern European country economies with the existing EC, transportation's role in the economy is receiving maximum attention. European leaders fear that congestion, pollution impacts and other network inefficiencies will hamper the area's global competitiveness and quality of life. In January 1991, a special task force set up by the Transport Commissioner for the European Commission, released a report titled "Transport in a Fast Changing Europe." This report was the product of consultations with more than 200 experts and its basic message was that a major change was needed in current transport policies, one that would result in significant modal shifts. The report recognized that strong measures were needed to arrest the continuing decline in freight mode shares for water and rail. It was recommended that government rail monopolies should be abolished opening up opportunities for new carriers and more cross-border rail service. Coastal shipping with its large capacity potential and relatively benign environmental impact was identified for future investment.

Subsidies for road transport should be redetermined so that the external costs of energy consumption and environmental impact could be addressed.

A Pan-European transport policy is envisioned for the Continent. However, its implementation as with other aspects of European political and economic integration is beset by fractious political issues among EC countries and its projected large costs. In June 1992 the European Community Commission unveiled its ambitious plan for transportation development. Part of the plan would entail major new road building in the poorest EC countries (Greece, Spain, Portugal and Ireland). Elsewhere, the emphasis will be on non-road projects with a near term goal of doubling the share of intermodal cross-border traffic to 8 percent. Recommended waterway system investments include improving links to major seaports, increasing barge traffic on the Rhine-Main-Danube system and constructing a canal between the Rhine and Rhone Rivers. Increased intermodal movements will likely be focused on the longer distance hauls that a Pan-Europe transport network will encourage. However, with 12 percent of the land mass of the U.S. and a much higher population density (324 million people are within a 500 mile radius), much of the European system is tailored to short-hauls. The real challenge for the transport industry and government officials in moving traffic away from roads and on to rail and waterways is to develop a logistics system that is responsive and service-oriented so as to accommodate established just-in-time inventory/delivery practices.

During the 1980s, the inland waterways share of European freight movement declined from 12.5 to 9 percent. Nevertheless, recent governmental and industry initiatives are beginning to reverse the trend. For example, the Port of Paris, which handles 22 million metric tons, 80 percent of which are building materials, is aggressively recruiting companies to locate at sites along the River Seine. There are 300 such places, both occupied and vacant, on the 500 kilometers of waterway in the Greater Paris area. In Britain, where relatively short distances may not justify an expansion of rail freight capacity, short-sea or coastal shipping is under investigation for reducing road congestion and related environmental impacts. Rail freight will be upgraded, though, in southeast England when the Channel-Tunnel is opened for through service to Europe. The North Sea-Black Sea connection through the Rhine-Danube has tremendous potential for expanding European waterway traffic. Large barge convoys will be used in the mid-90s with container shipments likely to be an important part of the tonnage. Already, at Rotterdam, 20 percent of its large volume container business is tied to barge movement on the Rhine. According to one analyst, the "Rhine barges have the potential to become the double stack trains of Europe." Government policy throughout the EC with new taxes on road transport along with increasing noise and safety restrictions is facilitating a transition toward "greener" modes. Rail has serious infrastructure problems and investment needs and therefore will have difficulty accommodating a near-term shift. The waterways system in Europe is set for a period of growth. These developments in Europe may have application in North America and particularly in the Great Lakes-St. Lawrence region where the coastal shipping option is readily available.

MODAL SHIFT ISSUES AND THE GREAT LAKES-ST. LAWRENCE REGION

During 1991 and 1992, modal shift analysis and its relation to regional public policy gained new attention. The Minnesota Department of Transportation's study, "Environmental Impacts of a Modal Shift" coupled with the Ontario Ministry of Transportation's report on possible modal shifts resulting from tank vessel safety proposals have thrust the issue into the limelight. Now, Transport Canada's study and this one are extending the geographic and commodity scope of modal shift analysis to provide decision-makers with additional research to support possible policy action. In another related effort, the U.S. Maritime Administration, in cooperation with inland waterway interests, is preparing a public information brochure tentatively titled "Environmental Advantages of Waterway Transportation."

For more than two decades, environmentalists, government officials and industry representatives have been addressing the issue of modal shifts. When the President signed the National Environmental

Policy Act on January 1, 1970, the groundwork was laid for a comprehensive environmental review process where proposed transportation projects among others would be scrutinized. The first Earth Day in 1970 followed by the "energy crisis"/oil shortfalls and pioneering clean water and air legislation all combined to create heightened awareness of energy and environmental issues and their relation to transportation. The relative merits of one mode compared to others in terms of energy consumption and/or environmental impact became a topic of interest particularly for water transportation advocates. In 1972, the International Association of Great Lakes Ports Engineering Committee undertook a comparative study of air and noise pollution from truck, train and ship. In conclusion, the report stated:

> "While railways contribute less sustained noise and air pollution to our environment than airplane jets and highway vehicles, results of our studies show that the transporting of goods by ship produce by far the lowest overall effect on our environment when based on per ton mile of goods moved."

Other studies in the late Seventies and early Eighties commissioned by the National Waterways Foundation, the National Environmental Development Association and the American Waterways Operators, Inc. addressed modal energy consumption. These studies also made a case for navigation project investment. During this time, federal policy interest in energy independence prompted several freight transportation energy studies. In 1980, the Great Lakes Basin Commission (established under the Water Resources Planning Act of 1967 and dissolved in 1981 by Executive Order) undertook a study that specifically addressed the prospect of modal shifts within the region resulting from energy price increases.

The Great Lakes-St. Lawrence region, with freight transportation service by all modes solidly in-place, is not confronted by the prospect of immediate, broadscale modal shifts induced by either energy or environmental factors. However, some shifts are occurring in the ordinary course of business and, over time, energy, safety and environmental evaluation of all forms of transportation will begin to drive investment decisions as well as regulatory policy.

Modal shifts can have wide-ranging effects. From the local to national/continental levels, energy, safety and environmental implications vary considerably. Government and industry also respond at various levels. Local officials are more focused on environmental, safety and congestion impacts whereas energy issues are often dealt with on the regional or national level. The Great Lakes St. Lawrence Mayors' Conference at their 1992 Annual Meeting in Thunder Bay, Ontario adopted a resolution that exemplifies this perspective. The resolved clause states:

> "That the policies and programs for future economic growth in the Great Lakes St. Lawrence region include consideration of using maritime transport, where appropriate, for carriage of goods with greatest protection for the environment, safety, and avoidance of congestive impact on land traffic."

At their 1993 conference the region's shoreline mayors expanded on their earlier position by adopting a resolution requesting "that governments promote marine transport as an economical means of transportation with the least environmental impact."

CHAPTER 3

Safety, Noise and Congestion Issues

When modal shifts occur among rail, truck and marine modes, safety as well as noise, congestion, and other environmental impacts may change reflecting mode-specific differences. In this section of the report these impacts will be generally addressed and specific assessments will be developed, where feasible, for the study's identified commodity movement patterns.

SAFETY

Safety issues are focusing increasing public and government attention on the movement of commodities. Canada and the U.S. identify safety as their chief transportation program priority. Safe operation of vehicles, proper equipment inspections, and the handling of hazardous materials are the major areas of current policy interest. As the preceding examples of freight transportation accidents and related problems illustrate, human life, the physical environment, and property can all be at risk when an accident occurs.

In this section, general mode safety issues are addressed and a comparative representation of accident risk is developed.

October 5, 1992 – A twin trailer truck carrying a load of steel from Michigan to northern New York went out of control on an interstate highway near Buffalo, N.Y. and crashed, hitting a car. The accident resulted in four fatalities and one injury.

September 21, 1992 – A car-freight train accident at a crossing near Flint, Michigan killed a family of three. At this same crossing, three other people were killed a year earlier. The crossing did not have light/sound warning signals or gates.

June 30, 1992 – Fourteen cars of a freight train en route from Alberta to Chicago, Illinois, derailed near Duluth, Minnesota and Superior, Wisconsin. A tank car fell from a trestle into the Nemadji River, releasing approximately 26,000 gallons of a benzene-based chemical. Although no serious injuries resulted from the derailment or the toxic spill, more than 25,000 persons were evacuated and the long-term effects of the spill on fish and wildlife remain unknown.

September 16, 1990 – The 384-foot tank vessel *Jupiter* exploded and burned in the Saginaw River near Bay City, Michigan. One seaman was killed and several million dollars of damage resulted. Hundreds of people were involved in the emergency response and cleanup. The conflagration consumed most of the estimated 860,000 gallons of gasoline aboard the vessel, but thousands of gallons of product/water mixture were recovered from the vessel and nearby waters.

February 12, 1990 – An arsonist set fire to a 12-acre pile of tires near Hagersville, Ontario, 75 miles west of Buffalo, New York. The site was a storage area for 13 million tires from all kinds of motor vehicles. The difficult fire required weeks of attention from many fire and pollution control personnel. The burning and melting tires, which produced tons of toxic gasses and liquids, caused the evacuation of 500 residents.

Truck

In the U.S. about 4,000 persons die every year as a result of approximately 349,000 truck accidents. In Canada, truck accidents claimed 597 lives in 1990. Driver training, truck maintenance and size (number and length of trailers) are the major safety issues. Driver error and not equipment malfunction is the leading cause of accidents. The National Transportation Safety Board (NTSB) recently estimated that about half of the heavy trucks currently operating in the U.S. have brake problems usually relating to adjustment. The NTSB has recommended that the trucking industry develop uniform, model guidelines for maintenance and inspections. The industry has been particularly interested in expanding use of heavier trucks and longer combination vehicles (LCVs). Since 1982, twin trailers or "doubles" have operated legally on an interstate basis. About twenty states permit triples and/or other longer and heavier trucks to use certain roads. The 1991 transportation authorization law (ISTEA) made no change in the status quo. Concern about pavement damage and the competitive impact on railroads were lobbying issues. Several studies have produced conflicting results concerning the safety aspects of LCVs. However, many studies indicate that heavier vehicle weights, whether multiple trailer configuration or not, cause considerable damage to roads and bridges.

tractors was 6.79 per million vehicle-miles for single trailer configurations and 5.69 for double trailer trucks. Rates for accidents where fatalities or serious injuries resulted were very similar for the trailer number: single-1.51 and double-1.61 per million vehicle-miles. Table 3-1 shows the potential truck accidents for the three commodity movements in this study where a modal shift to truck was assessed. See Table 3-7 for truck tonnages and related movements. Accident rate calculations for the example movements show that a shift of nearly one million tons of cargo from vessel haul to truck transport in the region could result in 141 truck accidents per year. Also, with these accidents, there is the potential for 32 fatalities or serious injuries.

TABLE 3-1
ACCIDENT POTENTIAL FOR TRUCK MOVEMENTS

COMMODITY MOVEMENT	ANNUAL ROUND-TRIPS*	MILEAGE (ONE-WAY)	VEHICLE MILES	POTENTIAL ACCIDENTS PER YEAR
Thunder Bay, Ont. to Superior, WI (paper & wood pulp)	13,636	194	5,290,768	36
Alpena, MI to Detroit, MI (cement)	5,833 (double trailers)	233	2,718,178	15.5
Baltimore, MD to Cleveland, OH (imported steel products)	18,182	361	13,127,404	89

* Includes empty backhaul movements.

NOTE: Accident rate calculations are based on 6.79 per million vehicle miles for single tractor-trailers and 5.69 for double trailers. Rates are derived from *Differential Truck Accident Rates for Michigan*, Richard W. Lyles, Kenneth L. Campbell, Daniel F. Blower, and Polichronis Stamatiadis, Transportation Research Record 1322, Transportation Research Board, 1991.

A comprehensive study of Michigan truck accident rates by Michigan State University's Department of Civil and Environmental Engineering and the University of Michigan's Transportation Research Institute has provided reliable data that will be used in this modal shift study. The Michigan study covered the period from May 1987 to May 1988. For the state, the number of truck accidents increased 64 percent from 1982 to 1988 compared with a 40 percent increase for all motor vehicles. During the study year, accidents for trucks larger than pickups and panel trucks numbered 21,827 or 5.3 percent of all motor vehicle accidents. These truck accidents, compared with non-truck-involved accidents were more likely to be multiple-vehicle accidents and had double the fatality rate. The study revealed that the rates for all accidents involving Michigan-registered

Rail

Accidents involving freight trains can have a devastating effect at the crash site and beyond. Train personnel can be injured or killed and for road-rail impacts and track trespassers, fatalities often result. Also, train accidents can cause widespread, serious pollution problems through water or the air. According to the Federal Railroad Administration, 1,405 people were killed and 4,937 were injured in public road crossing accidents in the U.S. during 1989 and 1990. For the same period in Canada, public crossing fatalities were 112 and injuries amounted to 415. The great majority of the crossing casualties occur at public crossings as opposed to private crossings, and most involve motor vehicle occupants. Crossing accidents usually account for a substantial percentage of total rail-related accident deaths: for 1990, in Canada - 46.5 percent and in the United States - 53.8 percent. On a positive note, these kinds of accidents have been declining in recent years. In the U.S. a third of the 176,572 road-rail crossings have automated warnings systems and in Canada the figure is 30 percent. Train-activated signals cost more than $100,000 per crossing and U.S. federal funding assistance can cover only a small percentage of crossings without active warning devices each year. Table 3-2 shows crossing accidents and related casualties for selected states and provinces where a Great Lakes-St. Lawrence modal shift could result in increased rail movements.

TABLE 3-2
ROAD-RAIL CROSSING ACCIDENTS AND CASUALTIES IN 1990: SELECTED STATES AND PROVINCES

STATE/PROVINCE	PUBLIC AND PRIVATE CROSSINGS	ACCIDENTS	FATALITIES	INJURIES
Illinois	16,639	344	57	132
Indiana	10,866	313	38	106
Maryland	1,528	21	2	9
Michigan	9,131	231	19	97
Minnesota	9,190	121	20	50
Montana	3,724	30	14	5
North Dakota	7,246	24	5	7
Ohio	12,346	324	58	147
Pennsylvania	9,517	144	7	44
Wisconsin	8,542	185	5	74
UNITED STATES	292,839	5,691	694	2,400
Manitoba	2,948	24	1	12
Ontario	5,425	138	21	75
Quebec	2,607	59	9	38
Saskatchewan	6,206	52	7	26
CANADA	23,518	386	47	202

Sources: Rail-Highway Crossing Accident/Incident and Inventory Bulletin, No. 13, 1990. Federal Railroad Administration, U.S. Dept. of Transportation, 1991. Railway/Commodity Pipeline Occurrences: 1990, Transportation Safety Board of Canada, 1992.

Rail accidents other than those at crossings are also serious situations. Track trespassers or persons illegally on a section of track make up another large category of rail-related deaths. In Canada 54 people were killed and 38 injured in 1990 after being struck by rolling stock. In the U.S. 521 such trespassers were killed in 1990 representing about 40 percent of all fatalities. Train collisions and derailments claim a relatively small portion of total rail accident deaths compared with crossing and trespasser situations. For example, there were only two such deaths in Canada from 1987 through 1990. In the U.S. in 1990, 22 deaths were reported in this category. Since the beginning of U.S. rail deregulation in 1980, total reportable rail accidents (those meeting a dollar and/or casualty threshold) have declined by about two-thirds. In the eighties, Canadian railway accidents also dropped, but by 38 percent. The 1990 figure was an all-time low. On the other hand, rail incidents and accidents involving hazardous/dangerous materials have been relatively constant during the latter half of the decade in both countries. In Canada, about a third of rail accidents involve trains carrying dangerous/hazardous goods. In the United States the figure was only about 16 percent in 1990, and averaged 22 percent during the eighties. As with truck accidents, human error is a major contributing factor to rail accidents. Before 1980, track defects were the primary accident factor. In Canada during the 1980s, track and equipment problems contributed to an average of 70 percent of derailments but operational or other human factors accounted for nearly 8 out of 10 rail collision accidents.

For purposes of this study, accident rates on a million train-mile basis were developed for three kinds of accidents: derailments, collisions and crossing impacts. Carrier-specific information, where available, is used (see Table 3-3). For each rail movement example where two or more carriers would split a substantial share of total train miles, the respective accident rates are averaged.

TABLE 3-3
1990 RAIL ACCIDENT RATES: CARRIER, TYPE OF ACCIDENT, AND NATIONAL SYSTEM
(Per million train miles)

CARRIER	DERAILMENTS*	COLLISIONS*	CROSSING ACCIDENTS
Canadian National Railways	1.48	.05	5.1
Canadian Pacific Ltd.	1.32	.11	6.2
Burlington Northern Railroad	3.46	.18	5.6
Conrail	2.53	.39	9.6
Grand Trunk Western Railroad Co.	6.54	.34	13.2
Soo Line Railroad Co.	8.69	3.0	12.51
Class II Railroads	5.28	.35	NA
ALL RAILROADS:			
United States	3.52	.52	.27
Canada	1.46	.09	5.5

*Derailments and collisions for Canadian Pacific and Canadian National are main track occurrences.
Sources:Rail-Highway Crossing Accident/Incident and Inventory Bulletin, No. 13, 1990. Accident/Incident bulletin No. 159, 1990, Federal Railroad Administration, U.S. Dept. of Transportation, 1991. Railway/Commodity Pipeline Occurrences: 1990, Transportation Safety Board of Canada, 1992.

In establishing a Great Lakes St. Lawrence marine accident rate for this study, Canadian and American accident data is combined. Ton-mileage for 1990 systemwide operations is estimated at 128 billion ton-miles or about 173 billion metric tonne-kilometers. Using these figures and a 28 serious accident season, an estimated annual accident rate of 1 accident per 4.57 billion ton-miles or 1 accident per 6.17 billion metric tonne-kilometers is determined. With the exclusion of tugs and barges, the accident rate is 1 accident per 8 billion ton-miles. For the specific waterborne movements assessed in this study, the number of possible accidents based on the 1 per 8 billion ton-mile rate is 2.

Marine

Serious accidents involving large cargo vessels operating on the Great Lakes and St. Lawrence River are unusual. However, the consequences of such vessel accidents, particularly for those carrying chemical or other hazardous material cargoes can be extremely serious. Based on data from the Transportation Safety Board of Canada and the U.S. Coast Guard, Great Lakes commercial vessel accidents entailing such serious mishaps as vessel collisions, founderings/sinkings, explosions, or fire are quite rare (see Table 3-4). Other kinds of accidents such as groundings and contact with objects without substantial damage occur more frequently. Also, vessel mishaps involving the Seaway locks and those at Sault Ste. Marie, Michigan, pose special problems for lock operations. Because of the "tight quarters" in and near the locks, vessel contact with structures does occur and some of it results in damage. Canadian marine accident data indicate that the number of reportable accidents nationwide has averaged less than 1,100 per year over the past decade. Fishing vessels make up approximately half of these accidents and harbor locations account for more than a third. The human factor is linked to about half of all accidents.

Vessel accidents involving a discharge of cargo or fuel into the Great Lakes or St. Lawrence River are a serious problem for the environment. Contamination of part of the largest fresh water resource on earth can degrade a source of drinking water for more than 25 million people, foul industrial water supplies, and disrupt a fragile and irreplaceable ecosystem. Crude

TABLE 3-4
SERIOUS COMMERCIAL VESSEL ACCIDENTS: GREAT LAKES AND ST. LAWRENCE RIVER*
(1990 AND 1991)

	GREAT LAKES **			MONTREAL TO SEPT ISLES, QUEBEC	
	Canada		U.S.	Canada	
	1990	1991	1990	1990	1991
Cargo Vessel	4	4	3	7	10
Tanker	--	--	2	--	--
Barge	1	3	1	1	2
Tug	4	1	3	2	--
TOTALS	9	8	9	10	12

* Serious accidents include collisions with other vessels, foundering, sinking, fire and explosion. U.S. data is not available for 1991.
** Canadian "Great Lakes" data covers all Great Lakes and St. Lawrence River segment from Montreal to Lake Ontario.
Sources:Transportation Safety Board of Canada, Marine Statistics and Analysis. U.S. Coast Guard, Marine Safety Evaluation Branch (1992 correspondence).

petroleum, refined products/petrochemicals, chemicals, and in particular, those hazardous materials that are soluble, chemical suspensions or solutions, pose the most serious threat to human health and the environment. There is much concern about toxic contaminant levels and possible low thresholds for human health impacts. The ability of the Great Lakes to flush themselves is limited. For example, the retention time for Lake Michigan is 100 years. Clean up of an open lake spill would be very difficult, if not impossible. For these reasons, current public policy is focusing carefully on the waterborne transport of these kinds of commodities. The increasing emergency response and contingency planning activities at both federal and local levels reflects this heightened awareness. One such activity relating to the Great Lakes is the Joint U.S./Canada Marine Pollution Contingency Plan or "CANUSLAK" exercise held every other year. The September 1992 drill involved a collision scenario between a tanker and a railcar ferry in western Lake Superior. More than 200 people participated in the four-day event that involved several Coast Guard vessels, deployment of 4,000 feet of containment boom and a prototype skimming system.

Very little crude petroleum moves on the Great Lakes. Only 20,329 net tons of oil, all of which were imported from Canada, moved through U.S. Great Lakes ports in 1989. Most of the oil received at Great Lakes and St. Lawrence refineries is delivered via pipeline and not tanker although tanker deliveries are more substantial on the St. Lawrence River, particularly at Quebec City. Compared with crude oil, the tonnages for petroleum products transported from refineries to or from U.S. Great Lakes ports are much greater. In 1989 about 6.2 million tons of product including 2 million tons of petroleum coke, were shipped. Petrochemicals and chemical movement on the Great Lakes to both Canadian and U.S. terminals is substantially less than that of petroleum products. For example, Ontario-based vessel tonnages of petroleum products have averaged about three times that for petrochemicals and other chemical products. The marine mode though, carries much less of all tank products than do the other modes. Again, using Ontario as an example, vessels accounted for only about 10 percent of the total provincial movement in the 1980s, with rail at about 20 percent and truck and pipeline the balance.

Spill data for the Great Lakes compiled by the U.S. Coast Guard indicate that commercial vessels were responsible for about 16 percent of the known oil/product or hazardous material spills for the period 1989 through 1991. The great majority of such spills were near the shore. With respect to amounts, the three-year average was a little over 12 percent for the marine mode. In 1990, the amount attributed to commercial vessels was 6.6 percent and most of this resulted from the explosion of the tank vessel *Jupiter* at Bay City, Michigan. The Coast Guard spill statistics for 1990 also reveal that 319 of the total 332 spills were oil/petroleum products spills and that 45 percent were of land-origin. Appendix A displays this information according to U.S. Coast Guard Marine Safety Office jurisdictions. For the St. Lawrence River, Canadian Coast Guard data reveals that from 1979 to 1988 there were 307 accidental spills of pollutants from vessels. These spills were mostly petroleum products and 96 percent occurred in ports, with Montreal and Quebec accounting for more than half. Canada's Public Review Panel on Tanker Safety and Marine Spills Response Capability has estimated that 100 small spills (tanker-related) are likely to occur every year in Canada, along with three moderate ones and one major spill. The panel also said that eastern Canada had the highest risk for a spill, particularly Newfoundland.

Commercial vessels fare well when compared to other kinds of transportation. The Ontario Ministry of the Environment, through its Spills Action Centre, has categorized transportation-related spills for the province. Table 3-5 shows that most such spills, which include some gaseous discharges to the air, have involved motor vehicles, with heavy trucks accounting for nearly 50 percent of all transportation spills in 1990 and 1991. Vessel tankers and bulk carriers represented less than 2 percent of the transportation spills. The two-year comparison reveals a remarkable similarity in accident number for several of the vehicle categories. The total number of known spills from all sources was 5,686 for 1990 and transportation-related spills accounted for less than a quarter of all spills in the province.

Transportation safety, noise, and congestion also have land-use implications. Residential location is an obvious concern as is environmental protection. The

Hagersville, Ontario tire storage inferno illustrates how a non-vehicle safety incident can arise and the

TABLE 3-5
ONTARIO SPILLS IN 1990 AND 1991-TRANSPORTATION MODE

SOURCE	YEAR	
	1990	1991
Bulk Marine Carrier	11	11
Marine Tanker	14	10
Motor Vehicle	479	684
Other Watercraft	30	27
Pleasure Craft	28	29
Transport Truck	342	294
Train	57	59
Tanker Truck	388	387

Source: Spills Action Centre, Ontario Ministry of the Environment, 1992.

implications for future land use. Public policy at all government levels is wrestling with transportation land use issues. Freight transportation activity will be evaluated closely in the future regarding its impact on the human and natural environments. Emphasis on prevention, whether it is accomplished through better safety training and education or government-imposed routing and other operational requirements, or any number of other approaches, is here to stay.

NOISE

Transportation-related noise is a major source of noise in modern society. Although mostly a transient phenomenon, periods of sustained high noise levels emanating from highways, rail yards and airports have raised public concern. With respect to freight transportation, increasing tonnage levels have generated higher noise exposure levels for the population. Noise walls along freeways, special aircraft landing and take-off procedures and new engine designs are examples of mitigation measures required by an aggravated public.

Auditory fatigue can be caused by noise exceeding 75-80 dB(A) and prolonged exposure at this level can cause hearing loss. Noise emissions from diesel trucks range between 78 and 85dB(A) at fifty feet (15.2 meters). For rail, noise from standing diesel locomotives can range between 88 and 98 dB(A), whereas freight trains running at 30 mph (49 kmph) have been measured at 80-94 dB(A), both at fifty feet. There has been little research on commercial vessel noise impacts. One study undertaken in 1972 by the International Association of Great Lakes Ports, measured noise levels for six vessels transiting Lock 3 in the Welland Canal. Three downbound vessels averaged 58 dB(A) at 140 feet/42.6 meters from the instrument to center line of vessels. The upbound vessels averaged 66 dB(A), at an average of 57 feet. Figure 3-1 graphically shows the relative differences among the three modes represented in this study.

FIGURE 3-1
MODAL NOISE LEVELS

Noise Levels dB(A)	50	60	70	80	90	100
Vessels in the Welland Canal (at 57 to 140 ft.)		XXXXX				
Diesel trucks (at 50 feet)				XXXXX		
Diesel locomotives (at 50 feet)					XXXXXXX	
Freight trains (30 mph at 50 feet)				XXXXXXXXX		

Road traffic is considered the most serious noise problem where exposure levels are higher for the greatest number of persons. Most noise complaints originate in residential areas. Much of the problem is concentrated along heavily traveled truck routes, particularly in metropolitan areas. On the other hand, North American rail yards and main line trackage usually generate less sustained noise. In some European countries though, rail noise complaints are relatively common because of frequency of operations and dense settlement patterns. Noise problems associated with commercial navigation on the Great Lakes St. Lawrence system are not perceived as a significant problem, since most related noise is far from shore. There are instances of objectionable noise from waterfront loading/unloading activities and river operations but sound levels from most vessels underway compare favorably with that from trucks and trains.

TABLE 3-6
CONGESTION ON MAJOR URBAN ROADS IN THE GREAT LAKES STATES

STATE	TOTAL CONGESTED MILES*	CONGESTION PERCENTAGE OF MAJOR URBAN MILES	NATIONAL RANKING
Illinois	1,549	51.6	9
Indiana	549	31.5	26
Michigan	1,336	51.2	10
Minnesota	319	33.9	24
New York	2,049	53.9	5
Ohio	1,242	38.2	21
Pennsylvania	1,496	41.5	18
Wisconsin	319	23.9	37

*Includes interstate, freeway and principal arterial.
Source: 1992 State Highway Funding Methods, The Road Information Program, Washington, D.C. (Information derived from Federal Highway Administration data).

CONGESTION

Congestion and other capacity constraints can affect all transport modes. Rail yards are notorious bottlenecks and navigation locks have the potential to create delays, but road congestion is a leading transportation problem and it is rapidly getting worse. Such congestion occurs when the amount of traffic exceeds a road's design capacity, resulting in a decline in vehicle speeds.The alarming increase in congestion is reducing economic productivity, adding to vehicle emissions and fuel use, and raising safety risks. With nearly three-quarters of the nation's $300 billion freight transportation bill spent on motor carriage, roadway congestion has a direct impact on the business bottom line and the national economy. The Federal Highway Administration projects that the current levels of congestion on non-freeways will double by the year 2005 and more than triple on urban freeways. Table 3-6 shows the number of miles and percentage of congested major urban roadways for the Great Lakes states along with their national ranking.

Congestion has a deleterious effect on vehicle emissions. Slower speeds and longer travel times hike emission levels. In some places congestion alone accounts for upwards of 25 percent of total vehicle emissions. Heavy traffic also increases accident probabilities. Government officials, in cooperation with business, are exploring options to relieve congestion. More roadway capacity, in terms of lane space, has not been an effective solution for most places. Road building did increase capacity in the past but the much greater increase in vehicle-miles traveled and vehicle ownership helped neutralize the benefit. This path now is widely acknowledged as one of diminishing returns. Transit alternatives, high occupancy vehicle lanes, congestion fees/tolls, peak hour charges, parking restrictions and new technology to better manage traffic flow will get increasing attention in the years ahead.

As for existing truck traffic, it is certainly an aggravating congestion factor. The consequences of a modal shift to truck in the Great Lakes St. Lawrence region where a large tonnage amount is involved would be especially troublesome. The substantial increase in truck traffic to accommodate tonnage volumes previously moved by rail or vessel could overwhelm possible highway routes, further aggravating capacity problems. Table 3-7 shows the number of truck movements (including backhauls) that would be necessary to accommodate a complete modal shift from vessel to truck for those movement patterns in this study where the truck alternative was assessed.

Modal shifts from vessel to truck for the three selected commodity movements would add about 241 trucks a day (Monday through Saturday) and more than 21 million annual vehicle miles to the region's traffic load. The impact on particular routes and road segments would be significant. The Thunder Bay to Superior haul would travel for much of its distance on two-lane Highway 61 along the North Shore of Lake Superior. Summertime traffic, which is double that of the rest of the year, experiences periods and places of congestion, and 87 additional trucks per day would add to these problems. For other commodities shipped on the Great Lakes and St. Lawrence River, shifting all or some of the tonnage could create similar problems. Shorelines act to guide major highways and many origin/destination routings would, in effect, parallel the waterway system. This "channeling effect" could dramatically increase traffic and associated congestion along these water-parallel routes. Canada's Route 401 from Windsor, Ontario to Toronto and Montreal, is the kind of route that could be affected by a modal shift to trucks for particular commodities.

TABLE 3-7
MODAL SHIFT FROM VESSEL: INCREASED TRUCK MOVEMENTS

COMMODITY MOVEMENT	TONNAGE (short tons)	LOAD PER TRUCK (short tons)	ANNUAL MOVEMENTS ONE-WAY	MOVEMENTS PER DAY (six-day week)
Paper & Wood Pulp (Thunder Bay, Ont. to Superior, WI)	300,000	22	27,273	87.1
Cement (Alpena, MI to Detroit, MI)	262,500	45 (double trailer)	11,667	37.3
Import Steel (Baltimore, MD to Cleveland, OH)	400,000	22	36,364	116.2

CHAPTER 4

Transportation Energy Use and Air Pollution Consequences of Modal Shifts

TRANSPORTATION ENERGY USE

Transportation runs on energy. The transportation sector currently accounts for about 27 percent of total U.S. energy use and about 28 percent in Canada. The sector's almost total dependence on petroleum-based fuels raises serious questions about related pollution and future availability as well as cost. Nearly two-thirds of petroleum use in the U.S. and Canada is for transportation purposes. This level of petroleum consumption is likely to grow because of increasing use by the transportation sector, coupled with decreasing use in other sectors. Personal transportation represents the largest specific use of transportation energy, followed by motor carriers. Table 4-1 shows the percentage of total energy use for each mode in Canada and the U.S. for 1988. The similarities between the two countries, despite major differences in population and freight tonnages, underlines the highly-developed structure of the two economies.

TABLE 4-1
1988 TRANSPORTATION ENERGY USE: UNITED STATES AND CANADA
(Percentage share by mode)

MODE	Canada	U.S.*
Air	8.4	8.7
Marine	5.4	5.9
Pipelines	7.1	3.9
Road	74.5	72.9
Rail	4.6	2.3

*U.S. figures do not include off-highway use (2.9%) and military use (3.5%). Sources: Transportation Energy Data Book: Edition 11, Oak Ridge National Laboratory and Martin Marietta Energy Systems, Inc., U.S. Dept. of Energy, 1991, and Energy and Environmental Factors in Freight Transportation, Transport Canada, A.M. Khan, 1991.

Energy policy is driven by both energy efficiency and environmental concerns. Congress' Office of Technology Assessment (OTA) has identified energy efficiency as "an essential cornerstone to a comprehensive energy policy framework." The OTA, in its 1991 report titled *Energy Technology Choices: Shaping Our Future*, also indicated that with energy and environmental goals tightly linked, policies addressing either should not be developed, assessed or changed in isolation from the other. Freight transportation energy policy reflects overall energy policy goals. Conservation of energy resources and protection of the environment are not only compatible objectives butinterconnected for much of goods movement. Each mode and kind of transportation has specific energy use and environmental characteristics. Widely varying fuel efficiency levels, emissions and other environmental impacts among the freight modes adds complexity to public policy.

With respect to fuel efficiency, modal shift analysis compares the relative fuel efficiencies for selected commodity movements by alternative modes. Many studies of freight transportation fuel efficiency have been completed. Some studies have taken a "global' approach by looking at sector-wide tonnage and fuel consumption. This method, even though it does not take into account variability related to equipment, weight and route characteristics, does provide data useful for general analysis. Table 4-2 shows energy intensities and fuel efficiencies for the major freight modes. Some studies have developed fuel efficiency factors for specific kinds of equipment and movement scenarios and where specific fuel usage data is available, very accurate fuel efficiency information can be generated. Also, some energy efficiency studies have looked at indirect energy use such as that required for fuel production and transportation, vehicle manufacturing, and infrastructure construction, operation and maintenance. In this modal shift study, only direct energy usage or that involving vehicle propulsion is considered. For this study, a variety of sources for mode fuel efficiency were consulted. Industry sources provided fuel consumption data for marine movements. The truck fuel use figure is based on U.S. Department of Energy national data for heavy duty combination trucks. For rail movements, industry and government research findings were used to develop fuel efficiency figures for both mixed freight and unit train operations.

The following section provides information on modal fuel efficiencies and fuel use methodology used for the modal shift scenarios.

Truck

In 1989, 1.6 million combination (tractor-trailer) trucks and 4.1 million single-unit trucks were registered in the U.S.. The fleet of combination vehicles, because of their lower fuel economy and higher vehicle travel, use more than twice as much fuel annually as do single-unit trucks. The 1987 Truck Inventory and Use Survey undertaken as part of the Census of Transportation estimated fuel economy for trucks with gross vehicle weights of 26,000 lbs. or greater at 5.4 mpg for gasoline fuel and 5.3 mpg for diesel fuel. 1988 U.S. figures for combination trucks, based on total vehicle miles and fuel consumed, indicates a 5.27 mpg average.

Fuel efficiency as measured by ton-miles per gallon shows a substantial range, with route characteristics, type of equipment, and load as major variables. A 1991 study by the Abacus Technology Corporation for the U.S. Federal Railroad Administration compared fuel efficiency between truck and rail movements over a variety of corridors. The study indicated a truck range between 84 and 167 ton-miles per gallon with auto haulers at the low end. Higher payloads were a significant factor in higher ton-mile fuel efficiencies. Improvements in average truck fuel efficiencies over the past fifteen years can be attributed in part to better aerodynamic designs, use of radial tires, electronic fuel control, and better driving techniques. Continued development and future use of the adiabatic diesel engine may substantially improve fuel efficiencies in the future.

For the three commodity movements where a shift to truck was assessed, 5.3 miles per gallon of diesel fuel was used in each case to derive one-way and total annual fuel use for the movement. The resulting ton-miles per gallon (TM/gallon) figures for one-way movements ranged from 239 TM/gallon for the cement movement using double trailers, to 117 TM/gallon for both the steel and paper movements (see Chapter 5). Roundtrip movements with empty backhauls were half as fuel efficient.

TABLE 4-2
MODAL ENERGY INTENSITY AND FUEL EFFICIENCY

MODE	ENERGY INTENSITY BTU/ton mile (1990)[1]	FUEL EFFICIENCY Ton miles/U.S. gallon
Truck	3,357	131-163[2] (van trailer) 223[3] (double trailer)
Waterborne Commerce Inland Waterways Great Lakes	396	514[4] 271-1,426[5]
Crude Oil Pipeline Coal Slurry Pipeline	272 2,765	Not Applicable
Class I Railroads Unit Trains	411 226-359[7]	358[6] 414-1,179[2] (mixed freight) 196-327[2] (TOFC)

[1]U.S. Department of Energy
[2] Federal Railroad Administration - 1991.
[3]Industry sources, based on 45 tons and 233 mile movement at 5 mpg.
[4]Eastman - 1980.
[5]Industry sources. 271 ton-miles/gallon represents a tanker. 1,426 ton-miles/gallon represents a 1000-foot bulk carrier.
[6]Class I systemwide revenue ton-miles data for 1991.
[7]Railroad industry estimates and University of Illinois, 1974.

Sources: Fuel Efficiency in Freight Transportation, Samuel E. Eastman, 1980.

Rail vs. Truck Fuel Efficiency: The Relative Fuel Efficiency of Truck Competitive Rail Freight and Truck Operations Compared in a Range of Corridors, Prepared for the Federal Railroad Administration, U.S. Dept. of Transportation, by Abacus Technology Corporation, 1991.

Transportation Energy Data Book: Editions 13, Oak Ridge National Laboratory and Martin Marietta Energy Systems, Inc., U.S. Dept. of Energy, 1993.

Railroad Facts, Association of American Railroads, 1992.

Energy Intensity of Barge and Freight Hauling, Center for Advanced Computation, University of Illinois, 1974.

Marine

Among rail, truck and water modes, waterborne transport is generally the most energy efficient for large tonnage movements. Large cargo capacity relative to engine size and operating characteristics make Great Lakes bulk carriers, ocean-going ships and tug-barge configurations relatively fuel efficient on a straight ton-mile per gallon basis. However, because of greater circuity of navigable waterways compared with rail and road networks, the longer route distance for some water movements can reduce the fuel efficiency difference. Circuity, or the divergence from the Great Circle distance between origin and destination, varies considerably among modes for particular routes. Generally, there is greater correspondence between rail and road. But where these routes parallel rivers and coastlines, circuity is less pronounced. For most of this study's modal shift scenarios, circuity was not a major factor because the Great Lakes themselves are barriers to more direct land routings.

Great Lakes dry bulk carriers are mostly high block coefficient vessels intended to maximize cargo at normal 26-foot operating drafts. The vessels in the Canadian and U.S. Great Lakes fleets are either steam turbine or diesel-powered and use No. 2 diesel fuel (distillate fuel oil) as well as a distillate blend bunker fuel. For the U.S. fleet, an average of 100 million gallons of fuel is consumed annually, with a breakdown of 44 million gallons of diesel fuel for diesel ships, 21 million gallons of bunker fuel for diesel ships and 35 million gallons of bunker for steam-powered ships. With 58.3 billion ton-miles for U.S. flag operations recorded for 1989, the Great Lakes systemwide fuel efficiency figure is about 583 ton-miles per gallon. This figure incorporates vessel movements in ballast. For this study, specific propulsion fuel use for actual one-way vessel movements was provided by the Lake Carriers' Association (cement, coal and taconite); Algoma Central Marine (potash); FedNav (steel); EnerChem Shipmanagement Inc. (liquid bulk); Great Lakes Bulk Carriers Inc. (grain, iron ore); ULS Corporation; and Incan Ships Limited (paper). Fuel efficiency varies among the vessels of the Great Lakes fleet. For the dry bulk carriers assessed in this study, the range is 520 TM/gallon (200 tonne-kilometers per liter) for trips from Alpena, Michigan to Detroit by cement carriers to an average 1,426 TM/gallon (550 tonne-kilometers per liter) for coal movements from Superior, Wisconsin to St. Clair, Michigan, aboard 1000-foot vessels. Two separate tanker movements with 8,000 metric ton cargoes from Sarnia to Chicago and Montreal had relatively low fuel efficiencies averaging 287 ton-miles per gallon (111 tonne-kilometers per liter). Diesel fuel is used not just for vessel propulsion but also for auxiliary functions such as onboard electricity and heating, etc., while underway and in port. For Great Lakes-Seaway movements, this kind of fuel use can represent up to 15 percent of total vessel fuel use. Fuel consumption also varies according to route characteristics. For example, transits through the Welland Canal and the Great Lakes connecting channels entail reduced speeds and lower fuel use for those segments compared to open lake movements.

Rail

Rail fuel efficiency has been improving. According to the Association of American Railroads and as one measure of fuel efficiency, revenue ton-miles per gallon of fuel consumed in freight service for Class I railroads increased from 206 in 1975 to 358 in 1991, or 74 percent. From 1975 to 1990, system fuel consumption per year declined from 3.73 billion gallons to 3.13 or 16 percent. In Canada, rail freight fuel use decreased 13 percent to 2.1 billion litres (551 million U.S. gallons) between 1985 and 1990, while rail ton-kilometers increased slightly.

Fuel savings and energy efficiency gains can be attributed to changes in operations, capital investment and technological improvements. Deregulation has permitted the major railroads to concentrate on higher volume business and main line operations. The reduction of empty car miles, and heavier car loadings, coupled with optimal routings and speed control, have made significant contributions to fuel efficiency. The introduction of lighter-weight, larger-capacity cars and new locomotives along with track and signal improvements have also raised fuel efficiencies. One technological change that will significantly improve fuel efficiency is the use of alternating current motors instead of the standard direct current equipment. Expected to be gradually introduced beginning in the mid-1990s, the new line-haul locomotive power plants will increase horsepower and traction per unit. As an alternative fuel that may be gradually introduced in locomotive fleets, liquid natural gas may not result in significant energy efficiency improvement but it will dramatically reduce emissions, fuel costs and petroleum use for the railroads. At the current rate of rail fuel efficiency improvement, a one percent gain per year is expected. Use of systemwide rail fuel efficiency levels is not adequate for the purpose of this study. Actual fuel use for a particular train movement can give a precise measurement of fuel efficiency. This option is not available for evaluating hypothetical movement scenarios. Fuel usage rates for certain kinds of trains and operating conditions can be used for extrapolation to scenario cases where there are similarities. Another method for assessing fuel use for projected movements involves the use of the Train Performance Calculator or Simulator (TPC). This computer program involves a determination of fuel flows in response to car and locomotive characteristics, terrain, track structure, and speed, among other variables. However, it is recognized that TPC data is only a projection and may well understate fuel use under actual operating conditions.

For this study, government and industry sources for rail fuel efficiency were consulted. The Association of American Railroads provided general unit train fuel efficiency data. Canadian National Railways agreed to provide unit train fuel efficiency figures for specific long-haul movements in Canada through the use of TPC data. Actual fuel use data for selected train movements and locomotive models was also considered, even though these data sources were extremely limited. Through the use of these general fuel use parameters, fuel use per locomotive-mile was developed for each rail-haul scenario. The 3,000 horsepower SD-40 locomotive, built by the Electro-Motive Division of General Motors and commonly used in line-haul operations, was the standard locomotive used for the fuel use calculations. Two different fuel use figures per locomotive mile/kilometer were used in the study, depending on whether the power units were either two or three locomotive configurations for the example train movements. On a per locomotive-mile/kilometer basis, the two figures were: 4 gallons/9.4 liters (two locomotives for lower weight trains), and 3.8 gallons/8.9 liters (three locomotives for higher weight trains). On a ton-mile per gallon/tonne-kilometer per liter basis, the rail movements in the eleven case studies ranged between 467/180 in the movement of petroleum products to Montreal from Sarnia, to 877/338 for taconite pellets from Minnesota to Lorain, Ohio. Unit train fuel efficiencies are calculated on a one-way, loaded basis. Generally, those

Highway vehicles, as mobile sources of air pollutants, are subject to increasingly stringent regulations by both Canada and the United States. The Clean Air Act Amendments of 1990 covered a broad range of transportation pollution issues including fuel quality, new emission standards, and pollutant reduction goals and the legislation focuses on nonattainment areas with graduated requirements for pollution control. For example, for the 32 areas with moderately severe ground-level ozone, the law mandates a 15 percent reduction in hydrocarbon emissions over a six-year period. A variety of transportation control measures will be needed to implement these requirements. Because of the severity of the ozone problem in Los Angeles, restrictions on the use of heavy duty trucks may even be necessary. With respect to freight transportation, the control of nitrogen oxides is the primary focus of Canada and U.S. regulation. The federal-provincial initiative, the NOx/VOC Management Plan (1990), sets forth new limits on NOx emissions for heavy duty trucks to be fully implemented by the 1998 model year (similar to U.S.) and it also caps NOx emissions from rail transport.

Air pollution from freight transportation was also addressed in the CAA-90. Section 213 provided for the study of non-road emission sources and their possible regulation. These sources include such categories as agricultural, logging and other construction/industrial equipment as well as locomotives and commercial marine vessels. Regarding possible emission standards, the legislation specifically provides:

> "Whenever the Administrator (EPA) determines that emissions from categories of non-road engines or vehicles contribute significantly to concentrations of ozone, carbon monoxide or to oxides of nitrogen or particulate levels or otherwisecontribute to air pollution that may reasonably be anticipated to endanger public health or welfare, the Administrator shall promulgate regulations applicable to emissions from new vehicles or engines is such categories. Such standards shall achieve the greatest degree of emission reduction achievable through the application of technology which the Administrator determines will be available for the engines or vehicles to which such standards apply, giving appropriate consideration to the cost of applying such technology within the period of time available to manufacturers and to noise, energy, and safety factors associated with the application of such technology."

Type of fuel and related emissions is an important issue for freight transportation. Even though diesel fuel or distillate represented only 20.5 percent of U.S. transportation energy consumption in 1989, it is the principal fuel used by heavy trucks and the other major freight modes. In 1990, diesel fuel accounted for 15.3 percent of the total U.S. motor gasoline and diesel fuel market. Air pollutants from diesel vehicles compared with those from gasoline combustion have both favorable and undesirable characteristics. For example, because of better combustion efficiencies and lower temperatures, diesel CO, HC and NOx emissions are at lower rates. However, fine particulates (solid carbonaceous compounds) as well as formaldehyde, are higher, and sulfur dioxide is higher due to the higher sulfur content of diesel fuel. Sulfur content of diesel fuels varies considerably depending on crude characteristics and refining practices. The CAA-90 requires an on-highway sulfur concentration of .05 percent by weight by October 1, 1993. Diesel sulfur levels are being reduced with proportionate SO_2 emissions reductions for the principal freight modes. Although bunker fuel, which accounts for about half of Great Lakes commercial fuel use, has a higher sulfur content than does diesel fuel, the variability of fuel sulfur content for the rail, truck and vessel modes makes SO_2 emission comparisons difficult. For this reason and the fact that diesel sulfur levels are being substantially reduced, SO_2 emissions will not be examined in this paper.

The following section provides brief background on mode emissions and the specific emission factors used in the study.

Truck

In 1987, heavy duty trucks accounted for about three-fifths of total diesel fuel use in the U.S.. These trucks with gross vehicle weights above 26,000 pounds represented 53 percent of all diesel-fuel trucks and 55 percent of their total annual travel miles. Emissions vary considerably by vehicle type, age and operating conditions. The U.S. Environmental Protection Agency and the Department of

Transportation have developed computer models to estimate average emission rates per mile of travel for a full range of vehicle types accounting for a number of variables. The current emission factor model is Mobile4, issued in March 1989, although Mobile5, which will incorporate new vehicle standards mandated by CAA-90 is expected soon. Emission rates used in this report were derived from the EPA report, Compilation of Air Pollutant Emission Factors, AP-42, Volume II: Mobile Sources, (Supplement A) January 1991.

Heavy duty diesel vehicle emission levels from the basic test condition of 19.6 mph were averaged with those resulting at 55 mph to more accurately portray intercity operating conditions for the three modal shift scenarios. A truck model year of 1988 was selected. The emission rates from the 19.6 mph table are those calculated for January 1, 1993. The 55 mph emission rate was based on fleet average age as of 1990. It should be noted that the temperature of 75 degrees Fahrenheit for the basic test condition is likely to produce emission levels slightly lower than would actually occur during year-round operations in the Great Lakes region. HC and NOx emissions are generally higher at lower ambient air temperatures. The emission rates as expressed in grams per mile and pounds per U.S. gallon (developed by using 5 or 5.3 mpg) are:

Carbon monoxide: 8.9 g/mile - .1039 lbs/gallon
Hydrocarbons: 1.7 g/mile - .0198 lbs/gallon
Nitrogen oxides: 19.4 g/mile - .2266 lbs/gallon

Marine

Emissions from marine engines as a non-road mobile source are coming under increasing scrutiny. These emissions represent usually a small fraction of total emissions for port communities but in some places, particularly those with large populations and substantial commercial vessel traffic, the problem is more significant. Where the marine mode represents a large part of transportation activity, air pollutants from shipping are proportionately larger. For example, NOx emissions from shipping in Norway are 40 percent of the country's total, whereas shipping represents 7 percent of the global total. In the Great Lakes-St. Lawrence River system, emissions from commercial marine vessels, as with other large vessels, vary by type of propulsion (steam or diesel motor) and kind of fuel (distillate or residual bunker). The diesel motor vessels have significantly higher CO, HC and NOx emissions than do the steam powered ships which usually burn a bunker fuel. However, the steamships tend to produce more particulate pollutants.

In response to the need for updated information on commercial vessel emissions, EPA contracted with Booz, Allen and Hamilton, Inc. to develop data. The final report was submitted in October 1991 and represents an effort to combine and integrate emission data from EPA's AP-42 emissions document, the Maritime Administration's 1986 Port Vessel Emissions Model and other relevant industry and government research. Although emission factors were developed for a broad range of ocean-going vessels, the data, based on pounds of pollutant per amount of fuel consumed, is reasonably applicable for use with Great Lakes bulk carriers. (See Appendix B for emission factor table.) In this study, for each scenario's vessel movement, an engine and fuel type is identified and corresponding emissions for CO, HC and NOx are calculated based on fuel usage. Fuel use for auxiliary purposes also produces emissions. For this study, only propulsion fuel usage at full power is assessed, which allows for appropriate fuel usage and emission comparisons among modes. The emission rates as expressed in pounds per thousand gallons of fuel consumed are:

Carbon monoxide - 7.27 (steam) and 61 (diesel motor)
Hydrocarbons - 1.72 and 24
Nitrogen oxides - 63.6 and 550

Rail

Studies of diesel-electric locomotive emissions have generally shown that NOx emissions are the exhaust pollutants of greatest concern. One study prepared by the Environmental Protection Agency assessed such emissions for five Air quality Control Regions (metro areas) and found that NOx pollution from rail operations ranged from 2.3 to 15 percent of total manmade emissions in the area. With respect to total CO and HC emissions, the rail contribution is less than one-half percent. Chicago, a major rail hub for the central U.S., with substantial railyard and switching activity, had the largest amount of emissions among the five areas. In the case of estimated NOx emissions, Chicago represented three-fifths (81.4 tons/year) of the five-city total. There are no federal emission regulations for diesel electric locomotives but this situation may change. As part of the CAA-90-required non-road emissions study, completed in November 1991, the Environmental Protection Agency has updated locomotive emission factor information in AP-42. The new emission factors, depending on engine type and accounting for newer equipment in locomotive fleets, indicate reduced levels for HC and CO but substantially higher levels for NOx. The emission factors have been developed for different engine types and two different operational modes: line-haul and yard. Emissions vary according to throttle notch position on locomotives, with higher fuel use and higher emission levels generally occurring at the high end of running speeds. The line-haul emission rates developed by EPA were based on duty cycle data (time in each throttle notch position) derived from a 1991 Booz, Allen and Hamilton report, *Locomotive Emission Study*. These rates are considered to reasonably represent national line-haul operations. For all of the rail movement scenarios in this study, the emission rates for two SD40 engine types, 16-64SE3 and E3B, were averaged. These two engine types represent about 40 percent of those currently in service in the country. The emission rates in pounds per thousand gallons of fuel consumed are:

Carbon monoxide - 59.05
Hydrocarbons - 17.90
Nitrogen oxides - 499.0

Emission totals for the individual scenarios as presented in this study are expressed in pounds or kilograms per amount of fuel consumed. Emissions can also be developed on a ton-mile basis. With each scenario, an emissions amount per number of ton-miles by mode is a function of fuel consumed for equivalent tonnage movement. When comparing rail with Great Lakes vessel hauls, the significant difference between one-way train and vessel tonnage means that a number of round trip train movements are needed to position the same amount of vessel cargo.

These multiple train round trips result in a proportionate increase in emissions with a corresponding effect on pollutants generated on a ton-mile basis. Emission rate differentials among modes and route circuity factors can also influence this method of comparing pollution generation potential among modes. Scenario #2 involving the movement of low-sulfur coal from Superior Wisconsin to St. Clair, Michigan illustrates these issues. A one-way vessel movement of 66,150 tons would require five round trips by train along with an additional one-way haul. This fact coupled with a one-way rail distance which is 131 miles longer than the vessel route translates into a big vessel advantage in fuel use and emissions. Total rail fuel use of 101,198 gallons would generate 58,285 lbs of pollutants compared with 31,359 gallons and 19,913 lbs. of pollutants for the one-way vessel haul. These figures translate into 2,246 ton-miles per pound of pollutant for the vessel compared to 923 ton-miles per pound for the total rail haul.

CHAPTER 5

Modal Shift Scenarios: Great Lakes-St. Lawrence Region

Table 5-1 tabulates the energy use and emission results of the eleven modal shift secnarios. For the rail movements, fuel use was 43.5 percent greater than that for the marine movements. Rail emissions were more than 47 percent greater than marine. If the two tanker movements are not considered, rail fuel use is 52 percent greater than for vessel use. For rail emissions, the figure is 58 percent greater. We would not expect the rail and marine figures to match because of different emission factors for the various pollutants by mode. Also, some of the difference is attributable to fuel use by steam-powered vessels found in two (#3 and #4) scenarios where the overall emissions were dramatically lower. The safety implications of a shift from the marine mode to truck or rail are also significant. For the three scenarios where the truck alternative was considered, the diversion of less than a million tons from the water route could result in 141 accidents per year with nearly a quarter of them having the potential for fatalities or serious injuries. For the rail movements, derailment, collision and crossing accident rates were developed using federal data for the individual railroads. As a result, for all eleven scenarios, a shift to rail could result in 14 derailments, one collision and 36 crossing accidents.

TABLE 5-1
Annual Fuel Use and Emissions (CO, HC, NOx) for Modal Shift Scenarios
(See TABLE 5-1A for metric equivalents)

	MARINE		RAIL		TRUCK	
	Fuel Use (million U.S. gallons)	Total Emissions (net tons)	Fuel Use	Total Emissions	Fuel Use	Total Emissions
1	.816	259.08	1.219	351.2		
2	7.215	2,290.6	14.498	4,175.3		
3	9.587	1,983.33	14.044	4,044.6		
4	.216	7.86	.160	46.28	.543	95.21
5	1.048	332.82	.479	138.05		
6	1.519	482.33	.582	167.63		
7	3.930	1,248.06	5.560	1,601.41		
8	.264	83.9	.460	132.69	.998	174.7
9*	4.413	1,401.16	5.835	1,730.85		
10	1.745	554.15	1.805	520.37		
11*	1.635	519.19	1.841	575.03	3.979	911.13
TOTAL	32.388	9,162.5	46.483	13,483.4	5.52	1181.04

NOTE: For the #9 scenario, rail fuel use and emissions include those from the marine leg of the complete movement from Quebec ore ports to Hamilton, Ontario through Quebec City.

For the #11 scenario, marine emissions and fuel use represent only one-way movements from Europe to the United States. Rail and truck figures include Europe to Baltimore marine figures.

TABLE 5-1A
Annual Fuel Use and Emissions (CO, HC, NOx) for Modal Shift Scenarios

	MARINE		RAIL		TRUCK	
	Fuel Use (million liters)	Total Emissions (metric tonnes)	Fuel Use	Total Emissions	Fuel Use	Total Emissions
1	3.08	235.06	4.61	318.7		
2	27.31	2078.	54.87	3,847.8		
3	36.28	1,799.3	53.16	3,669.2		
4	.82	7.13	.68	41.98	2.05	86.37
5	3.96	301.93	1.82	125.23		
6	5.75	437.57	2.20	152.07		
7	14.87	1,132.26	21.04	1,452.8		
8	1.0	76.11	1.74	120.38	3.77	158.48
9*	16.70	1,271.14	22.09	1,586.77		
10	6.60	502.73	6.83	471.69		
11*	6.18	471.02	6.97	521.68	15.06	826.51
TOTAL	122.55	8,312.25	178.01	12,308.3	20.88	1,071.36

NOTE: For the #9 scenario, rail fuel use and emissions include those from the marine leg of the complete movement from Quebec ore ports to Hamilton, Ontario through Quebec City.

For the #11 scenario, marine emissions and fuel use represent only one-way movements from Europe to the United States. Rail and truck figures include Europe to Baltimore marine figures.

NO. 1 POTASH FROM THUNDER BAY, ONTARIO TO TOLEDO, OHIO

Annual Tonnage: 360,000 net tons

Marine: 658 miles; diesel-powered self-unloader; 20,000 tons of cargo; 566 TM/GAL (loaded, one-way); 18 annual roundtrips; 23,688 vessel miles

Rail: 1,059 miles from Thunder Bay via Canadian National, Class II carriers and Conrail; 72 trains per year, each with two SD-40 locomotives and 50 100-ton covered hopper cars; 4 gallons of fuel per locomotive mile; 152,496 roundtrip train miles

1,395 miles from Kalium, Saskatchewan via Canadian Pacific, Soo Line and Conrail; 72 trains per year, each with two SD-40 locomotives and 50 100-ton covered hopper cars; 4 gallons of fuel per locomotive mile; 200,880 roundtrip train miles

	MARINE			RAIL FROM THUNDER BAY			RAIL FROM KALIUM, SASKATCHEWAN		
FUEL USE (U.S. gal.) One-Way	23,251			8,472			11,160		
Annual	816,102			1,219,968			1,607,040		
EMISSIONS	CO	HC	NOx	CO	HC	NOx	CO	HC	NOx
One-Way (lbs.)	1,418	558	12,788	500.3	151.6	4,227.5	658.9	199.7	5,541.9
Annual (net tons)	24.89	9.79	224.4	36	10.9	304.3	47.4	14.38	400.9
POTENTIAL ACCIDENTS Annual	.028			Derailments: .47 Collisions: .04 Crossing Accidents: 1.1			Derailments: 1.0 Collisions: .23 Crossing Accidents: 1.9		

COMMENTS: In 1990 and 1991, total potash vessel shipments from Thunder Bay were 1,279,907 and 1,206,757 net tons respectively. Of these amounts, nearly 75 percent was delivered to U.S. ports with Great Lakes ports handling most of the commodity. Toledo, in 1990, was the largest Great Lakes receiving port with 390,568 net tons representing 42 percent of U.S. Great Lakes receipts.

Vessel tonnage of potash has been declining in recent years. All-rail movements from Saskatchewan mining areas have been increasing even though rates are usually higher than for rail-to-vessel transportation. Product degradation concerns resulting from extra handling along with more direct access to interior fertilizer distribution points partly explain the trend. Also, the fact that spring peak demand in the U.S. occurs before the opening of navigation gives rail an advantage with inventory-conscious buyers.

Two different rail movements were considered in this scenario to more accurately portray shipment alternatives. The movement from Thunder Bay is intended to match up with the vessel movement--even though it entails substantial circuity because of an absence of more direct rail connections in the western Lake Superior area. However, this movement would also require a prior rail haul from Saskatchewan. In contrast to this lengthy and therefore unlikely rail movement, a more direct rail route from Kalium, Saskatchewan (near Regina) to Toledo, is possible. Even though it is longer than the Thunder Bay origin movement, it is about 500 miles shorter than the Kalium-Thunder Bay-Toledo rail route.

NO. 1 POTASH FROM THUNDER BAY, ONTARIO TO TOLEDO, OHIO

Annual Tonnage: 326,592 metric tonnes

Marine: 1,059 km; diesel-powered self-unloader; 18,144 tonnes of cargo; 218 Tkm/liter (loaded, one-way); 18 annual roundtrips; 38,114 vessel km

Rail: 1,704 km from Thunder Bay via Canadian National, Class II carriers and Conrail; 72 trains per year, each with two SD-40 locomotives and 50 100-ton (90.7 tonnes) covered hopper cars; 9.4 liters of fuel per locomotive km; 245,366 roundtrip train km

2,245 km from Kalium, Saskatchewan via Canadian Pacific, Soo Line and Conrail; 72 trains per year, each with two SD-40 locomotives and 50 100-ton (90.7 tonnes) covered hopper cars; 9.4 liters of fuel per locomotive km; 323,216 roundtrip train km

	MARINE			RAIL FROM THUNDER BAY			RAIL FROM KALIUM, SASKATCHEWAN		
FUEL USE (liters) One-Way / Annual	88,005 3,088,946			32,067 4,617,579			42,241 6,082,646		
EMISSIONS	CO	HC	NOx	CO	HC	NOx	CO	HC	NOx
One-Way (kgs)	643	253	5,801	226.9	68.8	1,917.6	298.9	90.6	2,513.8
Annual (tonnes)	22.58	8.88	203.6	32.7	9.9	276.1	43	13	363.7
POTENTIAL ACCIDENTS Annual	.028			Derailments: .47 Collisions: .04 Crossing Accidents: 1.1			Derailments: 1.0 Collisions: .23 Crossing Accidents: 1.9		

COMMENTS: In 1990 and 1991, total potash vessel shipments from Thunder Bay were 1,161,440 and 1,095,061 metric tonnes respectively. Of these amounts, nearly 75 percent was delivered to U.S. ports with Great Lakes ports handling most of the commodity. Toledo, in 1990, was the largest Great Lakes receiving port with 354,323 metric tonnes, representing 42 percent of U.S. Great Lakes receipts.

Vessel tonnage of potash has been declining in recent years. All-rail movements from Saskatchewan mining areas have been increasing even though rates are usually higher than for rail-to-vessel transportation. Product degradation concerns resulting from extra handling along with more direct access to interior fertilizer distribution points partly explain the trend. Also, the fact that spring peak demand in the U.S. occurs before the opening of navigation gives rail an advantage with inventory-conscious buyers.

Two different rail movements were considered in this scenario to more accurately portray shipment alternatives. The movement from Thunder Bay is intended to match up with the vessel movement--even though it entails substantial circuity because of an absence of more direct rail connections in the western Lake Superior area. However, this movement would also require a prior rail haul from Saskatchewan. In contrast to this lengthy and therefore unlikely rail movement, a more direct rail route from Kalium, Saskatchewan (near Regina) to Toledo, is possible. Even though it is longer than the Thunder Bay origin movement, it is about 805 km shorter than the Kalium-Thunder Bay-Toledo rail route.

NO. 2 COAL FROM SUPERIOR, WISCONSIN TO ST. CLAIR, MICHIGAN

Annual Tonnage: 7,805,700 net tons

Marine: 676 miles; 1000-foot diesel-powered self-unloader; 66,150 tons of cargo; 1,426 TM/GAL (loaded, one-way); 118 annual roundtrips; 159,536 vessel miles

Rail: 807 miles from Superior via Class II carrier, Conrail and Grand Trunk Western; 788 trains per year, each with three SD-40 locomotives and 90 110-ton hopper cars; 3.8 gallons per locomotive mile; 1,271,832 roundtrip train miles

1,385 miles from Powder River Basin (Wyoming/Montana) via Burlington Northern, Conrail and Grand Trunk Western; 788 trains per year, each with three SD-40 locomotives and 90 110-ton hopper cars; 3.8 gallons of fuel per locomotive mile; 2,182,760 roundtrip train miles

	MARINE			RAIL FROM SUPERIOR			RAIL FROM WYOMING/MONTANA		
FUEL USE (U.S. gals.) One-Way / Annual	31,359 7,215,700			9,200 14,498,884			15,789 24,883,464		
EMISSIONS	CO	HC	NOx	CO	HC	NOx	CO	HC	NOx
One-Way (lbs.)	1,913	752.6	17,247	543	164.7	4,590.8	932.3	282.6	7,878.7
Annual (net tons)	220	86.6	1,984	428	129.8	3,617.5	734.7	222.7	6,208.4
POTENTIAL ACCIDENTS Annual	.66			Derailments: 6.07 Collisions: .45 Crossing Accidents: 14.5			Derailments: 6.5 Collisions: .62 Crossing Accidents: 16.6		

COMMENTS: The vessel shipment of low-sulfur western coal at Superior, Wisconsin, began in 1976 with the opening of the Superior Midwest Energy Terminal (SMET). Shipments from this facility have steadily increased in response to implementation of Clean Air Act restrictions on power plant sulfur emissions. Detroit Edison is a major customer of SMET coal, with its St. Clair generating stations accounting for more than two-thirds of the 11.4 million tons shipped in 1991.

SMET receives an average of three 115-car unit trains a day from the Powder River Basin strip mines in Wyoming and Montana. For this scenario, a 20 percent shorter train was used to accommodate track and delivery conditions for eastern operations. One of the world's largest shiploading conveyors, rated at 10,500 tons per hour, transfers the coal to lake vessels. Several 1000-foot "supercarriers" figure prominently in these coal shipments, handling nearly three-quarters of the tonnage.

The coal terminal is exploring the potential for increased capacity beyond its 13 to 13.5 million ton capacity. With new sulfur emission reductions required by the Clean Air Act Amendments of 1990, many midwest utilities are planning for new western coal deliveries, and the rail-to-vessel transshipment option may play a role. Also under consideration are all-rail routings, inland coal terminals where western and other coals are blended for subsequent reshipment, and overseas exports through the St. Lawrence Seaway.

NO. 2 COAL FROM SUPERIOR, WISCONSIN TO ST. CLAIR, MICHIGAN

Annual Tonnage: 7,081,331 metric tonnes

Marine: 1,088 km; 1000-foot diesel-powered self-unloader; 60,011 tonnes of cargo; 550 Tkm/liter (loaded, one-way); 118 annual roundtrips; 256,693 vessel km

Rail: 1,298 km from Superior via Class II carrier, Conrail and Grand Trunk Western; 788 trains per year, each with three SD-40 locomotives and 90 110-ton (99.8 tonnes) hopper cars; 8.9 liters of fuel per locomotive km; 2,046,378 roundtrip train km

2,228 km from Powder River Basin (Wyoming/Montana) via Burlington Northern, Conrail and Grand Trunk Western; 788 trains per year, each with three SD-40 locomotives and 90 110-ton (99.8 tonnes) hopper cars; 8.9 liters of fuel per locomotive km; 3,512,061 roundtrip train km

	MARINE			RAIL FROM SUPERIOR			RAIL WYOMING/MONTANA		
FUEL USE (liters) One-Way	118,694			34,821			59,761		
Annual	27,311,424			54,878,275			94,183,911		
EMISSIONS	CO	HC	NOx	CO	HC	NOx	CO	HC	NOx
One-Way (kgs)	868	341	7,823	246.4	74.7	2,082.4	422.9	128.2	3,573.8
Annual (tonnes)	199.6	78.5	1,799.9	388.3	177.7	3,281.8	666.5	202	5,632.3
POTENTIAL ACCIDENTS Annual	.66			Derailments: 6.07 Collisions: .45 Crossing Accidents: 14.5			Derailments: 6.5 Collisions: .62 Crossing Accidents: 16.6		

COMMENTS: The vessel shipment of low-sulfur western coal at Superior, Wisconsin, began in 1976 with the opening of the Superior Midwest Energy Terminal (SMET). Shipments from this facility have steadily increased in response to implementation of Clean Air Act restrictions on power plant sulfur emissions. Detroit Edison is a major customer of SMET coal, with its St. Clair generating stations accounting for more than two-thirds of the 10.3 million metric tonnes shipped in 1991.

SMET receives an average of three 115-car unit trains a day from the Powder River Basin strip mines in Wyoming and Montana. For this scenario, a 20 percent shorter train was used to accommodate track and delivery conditions for eastern operations. One of the world's largest shiploading conveyors, rated at 9,525.6 metric tonnes per hour, transfers the coal to lake vessels. Several 1000-foot (305 meters) "supercarriers" figure prominently in these coal shipments, handling nearly three-quarters of the tonnage.

The coal terminal is exploring the potential for increased capacity beyond its 11.8 to 12.25 million metric tonne capacity. With new sulfur emission reductions required by the Clean Air Act Amendments of 1990, many midwest utilities are planning for new western coal deliveries, and the rail-to-vessel transshipment option may play a role. Also under consideration are all-rail routings, inland coal terminals where western and other coals are blended for subsequent reshipment, and overseas exports through the St. Lawrence Seaway.

NO. 3 TACONITE FROM MINNESOTA'S LAKE SUPERIOR ORE LOADING PORTS TO LORAIN, OHIO

Annual Tonnage: 7,699,995 net tons

Marine: Average of 775 miles; steam-powered self-unloader; 28,154 tons of cargo; 994 TM/GAL (loaded, one-way); 88 annual roundtrips; 136,400 vessel miles; and

1000-foot diesel-powered self-unloader; 62,921 tons of cargo; 1,356 TM/GAL; 83 annual roundtrips; 128,650 vessel miles

Rail: Average of 800 miles from Minnesota's ore loading ports via Class II carriers and Conrail; 770 trains per year, each with three SD-40 locomotives and 100 100-ton hopper cars; 3.8 gallons of fuel per locomotive mile; 1,232,000 roundtrip train miles

	MARINE (steam-powered)			MARINE (diesel-powered)			RAIL		
FUEL USE (U.S. gallons) One-Way / Annual	21,951 3,766,796			35,961 5,820,288			9,120 14,044,800		
EMISSIONS	CO	HC	NOx	CO	HC	NOx	CO	HC	NOx
One-Way (lbs.)	159.6	37.75	1,396	2,19-3.6	863	19,-778.5	538.5	163.2	4,550.8
Annual (net tons)	13.69	3.24	118.6	177.5	69.84	1,600.5	414.7	125.7	3,504.2
POTENTIAL ACCIDENTS Annual	.38			.35			Derailments: 4.8 Collisions: .46 Crossing Accidents: 11.8		

COMMENTS: Iron ore and taconite pellets are currently shipped from ten ports on the Great Lakes and St. Lawrence River. The seven U.S. ports, six of which are on Lake Superior, averaged 55.7 million tons over the five-year period, 1987 through 1991. During this period, Superior, Wisconsin, was the leading taconite tonnage port with Two Harbors, Minnesota, close behind. Lorain, Ohio, is a major transshipment port for iron ore/taconite with nearly 8 million tons recorded for 1989, 97 percent of which originated at Minnesota's Lake Superior ore loading ports. In 1989, 68 percent of the Minnesota ports-to-Lorain ore was carried in 1000-foot self-unloaders, all of this amount originating at Taconite Harbor.

NO. 3 TACONITE FROM MINNESOTA'S LAKE SUPERIOR ORE LOADING PORTS TO LORAIN, OHIO

Annual Tonnage: 6,985,435 metric tonnes

Marine: Average of 1,247 km; steam-powered self-unloader; 25,541 tonnes of cargo; 383 Tkm/liter (loaded, one-way); 88 annual roundtrips; 219,446 vessel km; and

1000-foot (305 meters) diesel-powered self-unloader; 57,082 tonnes of cargo; 523 Tkm/liter (loaded, one-way); 83 annual roundtrips; 206,998 vessel km

Rail: Average of 1,287 km from Minnesota's ore loading ports via Class II carriers and Conrail; 770 trains per year, each with three SD-40 locomotives and 100 100-ton (90.7 tonnes) hopper cars; 8.9 liters of fuel per locomotive km; 1,982,288 roundtrip train km

	MARINE (steam-powered)			MARINE (diesel-powered)			RAIL		
FUEL USE (liters) One-Way Annual	83,084 14,257,322			136,114 22,029,789			34,519 53,159,568		
EMISSIONS	CO	HC	NOx	CO	HC	NOx	CO	HC	NOx
One-Way (kgs)	72.4	17.1	633.2	995	391.4	8,971.5	244.3	74	2,064.3
Annual (tonnes)	12.42	2.93	107.6	161	63.36	1,452	376.2	114	3,179
POTENTIAL ACCIDENTS Annual	.38			.35			Derailments: 4.8 Collisions: .46 Crossing Accidents: 11.8		

COMMENTS: Iron ore and taconite pellets are currently shipped from ten ports on the Great Lakes and St. Lawrence River. The seven U.S. ports, six of which are on Lake Superior, averaged 50.53 metric tonnes over the five-year period, 1987 through 1991. During this period, Superior, Wisconsin, was the leading taconite tonnage port with Two Harbors, Minnesota, close behind. Lorain, Ohio, is a major transshipment port for iron ore/taconite with nearly 7.26 million metric tonnes recorded for 1989, 97 percent of which originated at Minnesota's Lake Superior ore loading ports. In 1989, 68 percent of the Minnesota ports-to-Lorain ore was carried in 1000-foot self-unloaders, all of this amount originating at Taconite Harbor.

NO. 4 CEMENT TO DETROIT, MICHIGAN FROM ALPENA, MICHIGAN

Annual Tonnage: 262,500 net tons

Marine: 219 miles; steam-powered self-unloader; 12,000 tons of cargo; 520 TM/GAL (loaded, one-way); 22 annual roundtrips; 9,636 vessel miles

Rail: 245 miles via Class II carrier and Grand Trunk; 82 trains per year, each with one SD-40 locomotive and 32 100-ton covered hopper cars; 4 gallons of fuel per locomotive mile; 40,180 roundtrip train miles

Truck: 233 miles; 45 tons per double trailer; 5 mpg (loaded, one-way); 5,833 annual roundtrips; 2,718,178 truck miles

	MARINE			RAIL			TRUCK		
FUEL USE (U.S. gallons) One-Way / Annual	5,050 / 216,645			980 / 160,720			47 / 543,636		
EMISSIONS	CO	HC	NOx	CO	HC	NOx	CO	HC	NOx
One-Way (lbs.)	36.7	8.68	321.1	57.87	17.54	489	4.84	.92	10.56
Annual (net tons)	.787	.186	6.89	4.745	1.44	40.09	28.24	5.38	61.59
POTENTIAL ACCIDENTS Annual	.005			Derailments: .237 Collisions: .014 Crossing Accidents: .53			15.5		

COMMENTS: With 542,866 tons in 1989, Detroit was the largest U.S. Great Lakes receiving port for cement. Nearly 90 percent of the Detroit tonnage was shipped from U.S. points with the balance from Canadian terminals. Lafarge Corporation's cement plant in Alpena is a major supplier to Detroit, with nearly all of the amount in recent years shipped by vessel. However, occasional truck (double-trailer) and rail (carload) movements do take place each year, mostly during the winter. Rail movements are expected to increase in future years.

Cement is transported throughout the Great Lakes St. Lawrence system usually in relatively small self-unloaders and barges. One company based in Alpena, Inland Lakes Management, Inc., owns seven cement carriers, six of which are steam-powered. All are under 520 feet in length. Its "newest" vessel is the Str. *Alpena*, which was converted in 1991 from an ore carrier. The *Alpena* is an historic first--first major Great Lakes vessel shortened (by 120 feet) in order to navigate smaller system ports.

The modal shift scenario clearly shows the advantage for the marine mode in every emission assessment category, reflecting the fact that the example movements are steam-powered and not diesel-powered.

NO. 4 CEMENT TO DETROIT, MICHIGAN FROM ALPENA, MICHIGAN

Annual Tonnage: 238,140 metric tonnes

Marine: 352 km; steam-powered self-unloader; 10,886.4 tonnes of cargo; 200 Tkm/liter (loaded, one-way); 22 annual roundtrips; 15,504 vessel km

Rail: 394 km via Class II carrier and Grand Trunk; 82 trains per year, each with one SD-40 locomotive and 32 100-ton (90.7 tonnes) covered hopper cars; 9.4 liters of fuel per locomotive km; 64,650 roundtrip train km

Truck: 375 km; 40.8 tonnes per double trailer; 2.13 km/liter (loaded, one-way); 5,833 annual roundtrips; 4,373,548 truck km

	MARINE			RAIL			TRUCK		
FUEL USE (liters) One-Way	19,114			3,709			176		
Annual	820,001			608,325			2,057,661		
EMISSIONS	CO	HC	NOx	CO	HC	NOx	CO	HC	NOx
One-Way (kgs)	16.6	3.93	145.6	26.25	7.96	221.8	2.19	.42	4.79
Annual (tonnes)	.714	.169	6.25	4.3	1.3	36.38	25.62	4.88	55.87
POTENTIAL ACCIDENTS Annual	.005			Derailments: .237 Collisions: .014 Crossing Accidents: .53			15.5		

COMMENTS: With 492,488 metric tonnes in 1989, Detroit was the largest U.S. Great Lakes receiving port for cement. Nearly 90 percent of the Detroit tonnage was shipped from U.S. points with the balance from Canadian terminals. Lafarge Corporation's cement plant in Alpena is a major supplier to Detroit, with nearly all of the amount in recent years shipped by vessel. However, occasional truck (double-trailer) and rail (carload) movements do take place each year, mostly during the winter. Rail movements are expected to increase in future years.

Cement is transported throughout the Great Lakes St. Lawrence system usually in relatively small self-unloaders and barges. One company based in Alpena, Inland Lakes Management, Inc., owns seven cement carriers, six of which are steam-powered. All are under 158.5 meters in length. Its "newest" vessel is the Str. *Alpena*, which was converted in 1991 from an ore carrier. The *Alpena* is an historic first--first major Great Lakes vessel shortened (by 36.6 meters) in order to navigate smaller system ports.

The modal shift scenario clearly shows the advantage for the marine mode in every emission assessment category, reflecting the fact that the example movements are steam-powered and not diesel-powered.

NO. 5 PETROLEUM PRODUCTS FROM SARNIA, ONTARIO TO MONTREAL, QUEBEC

Annual Tonnage: 220,400 net tons

Marine: 661 miles; diesel-powered tanker; 8,816 tons of cargo; 271 TM/GAL (loaded, one-way); 25 annual roundtrips; 33,050 vessel miles

Rail: 508 miles via Canadian Pacific; 59 trains per year, each with two SD-40 locomotives and 50 jumbo tank cars each at 74.71 tons; 4 gallons of fuel per locomotive mile; 59,944 roundtrip train miles

	MARINE			RAIL		
FUEL USE (U.S. gallons) One-Way	21,503			4,064		
Annual	1,048,271			479,552		
EMISSIONS	CO	HC	NOx	CO	HC	NOx
One-Way (lbs.)	1,312	516	11,827	239.9	72.74	2,027.9
Annual (net tons)	31.97	12.58	288.27	14.16	4.29	119.6
POTENTIAL ACCIDENTS Annual	.017			Derailments: .07 Collisions: .006 Crossing Accidents: .36		

COMMENTS: Ontario's petroleum refining industry is the largest among the Canadian provinces, representing 27 percent of total national capacity. Pipeline dominates delivery of crude supplies to refineries and also plays an important role in movements from refineries to terminals in major population areas. The other surface modes also have important niches in the distribution market, with vessel tankers and rail serving more distant higher-volume markets and tank trucks capturing nearly all of the distribution to retail points.

Vessel tanker movement of petroleum products from Ontario refineries is mostly to Ontario ports but a substantial amount of product (around 551,000 net tons), is shipped each year to Montreal. The 25 Canadian-flag tankers that ply the Great Lakes-St. Lawrence and Atlantic Coast trade are dominant in the region's waterborne petroleum product movement. With relatively low freight rates and product demand growth, the Canadian tanker companies have not launched a new vessel since 1982. Fifty percent of the fleet is more than 20 years old. Compared with new tankers, existing vessels are significantly less fuel efficient, have slower navigation speeds, and higher manning requirements.

NO. 5 PETROLEUM PRODUCTS FROM SARNIA, ONTARIO TO MONTREAL, QUEBEC

Annual Tonnage: 199,947 metric tonnes

Marine: 1,064 km; diesel-powered tanker; 7,997.8 metric tonnes of cargo; 105 Tkm/liter (loaded, one-way); 25 annual roundtrips; 53,177.4 vessel km

Rail: 817.4 km via Canadian Pacific; 59 trains per year, each with two SD-40 locomotives and 50 jumbo tank cars each at 67.78 metric tonnes; 9.4 liters of fuel per locomotive km; 96,500 roundtrip train km

	MARINE			RAIL		
FUEL USE (liters) One-Way	81,390			15,382		
Annual	3,967,706			1,815,104		
EMISSIONS	CO	HC	NOx	CO	HC	NOx
One-Way (kgs)	594.9	234	5,364.5	108.85	32.99	919.9
Annual (tonnes)	29	11.41	261.52	12.84	3.89	108.5
POTENTIAL ACCIDENTS Annual	.017			Derailments: .07 Collisions: .006 Crossing Accidents: .36		

COMMENTS: Ontario's petroleum refining industry is the largest among the Canadian provinces, representing 27 percent of total national capacity. Pipeline dominates delivery of crude supplies to refineries and also plays an important role in movements from refineries to terminals in major population areas. The other surface modes also have important niches in the distribution market, with vessel tankers and rail serving more distant higher-volume markets and tank trucks capturing nearly all of the distribution to retail points.

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NO. 6 PETROCHEMICAL PRODUCTS FROM SARNIA, ONTARIO TO CHICAGO, ILLINOIS

Annual Tonnage: 385,700 net tons

Marine: 610 miles; diesel-powered tanker; 8766 tons of cargo; 302 TM/GAL (loaded, one-way); 44 annual roundtrips; 53,680 vessel miles

Rail: 379 miles via Canadian Pacific and Conrail; 96 trains per year, each with two SD-40 locomotives and 50 or 51 jumbo tank cars each at 80 tons; 4 gallons of fuel per locomotive mile; 72,768 roundtrip train miles

	MARINE			RAIL		
FUEL USE (U.S. gallons) One-Way Annual	17,706 1,519,175			3,032 582,144		
EMISSIONS	CO	HC	NOx	CO	HC	NOx
One-Way (lbs.)	1,080	424.9	9,738.3	179	54.27	1,512.9
Annual (net tons)	46.33	18.23	417.77	17.18	5.21	145.24
POTENTIAL ACCIDENTS Annual	.028			Derailments: .14 Collisions: .02 Crossing Accidents: .57		

COMMENTS: Ontario has thirty percent of Canada's petrochemical production capacity. Much of this is based in Sarnia, where six major companies produce an array of chemicals from petroleum feedstock. Vessel chemical shipments from Sarnia average around 809,970 net tons annually with exports to the U.S. (principally to lower Lake Michigan) accounting for more than half of the total. The major chemical cargoes to U.S. ports include caustic soda (used in paper/pulp mills); benzene and toluene (used in other chemical processing).

NO. 6 PETROCHEMICAL PRODUCTS FROM SARNIA, ONTARIO TO CHICAGO, ILLINOIS

Annual Tonnage: 349,907 metric tonnes

Marine: 981.5 km; diesel-powered tanker; 7,952.4 tonnes of cargo; 116 Tkm/liter (loaded, one-way); 44 annual roundtrips; 86,371 vessel km

Rail: 609.8 km via Canadian Pacific and Conrail; 96 trains per year, each with two SD-40 locomotives and 50 or 51 jumbo tank cars each at 72.57 tonnes; 9.4 liters of fuel per locomotive km; 117,084 roundtrip train km

	MARINE			RAIL		
FUEL USE (liters) One-Way Annual	67,018 5,750,077			11,476 2,203,415		
EMISSIONS	CO	HC	NOx	CO	HC	NOx
One-Way (kgs)	490	192.73	4,417.3	81.2	24.62	686.28
Annual (tonnes)	42.03	16.54	379	15.59	4.72	131.76
POTENTIAL ACCIDENTS Annual	.028			Derailments: .14 Collisions: .02 Crossing Accidents: .57		

COMMENTS: Ontario has thirty percent of Canada's petrochemical production capacity. Much of this is based in Sarnia, where six major companies produce an array of chemicals from petroleum feedstock. Vessel chemical shipments from Sarnia average around 735,000 metric tonnes annually with exports to the U.S. (principally to lower Lake Michigan) accounting for more than half of the total. The major chemical cargoes to U.S. ports include caustic soda (used in paper/pulp mills); benzene and toluene (used in other chemical processing).

NO. 7 GRAIN FROM THUNDER BAY, ONTARIO TO QUEBEC CITY, QUEBEC

Annual Tonnage: 1,944,420 net tons

Marine:	**1,382 miles; diesel-powered straight deck bulk carrier; 28,180 tons of cargo; 1,333 TM/GAL (loaded, one-way); 69 annual roundtrips; 190,716 vessel miles**
Rail:	**Average of 1,167 miles via Canadian National or Canadian Pacific; 209 trains per year, each with three SD-40 locomotives and 93 100-ton covered hopper cars; 3.8 gallons of fuel per locomotive mile; 487,806 roundtrip train miles**

	MARINE			RAIL		
FUEL USE (U.S. gallons) One-Way	29,216			13,304		
Annual	3,930,996			5,560,988		
EMISSIONS	CO	HC	NOx	CO	HC	NOx
One-Way (lbs.)	1,782	701	16,068.7	784.9	238.1	6,638.6
Annual (net tons)	119.89	47.17	1,081	164.18	49.77	1,387.46
POTENTIAL ACCIDENTS Annual	.33			Derailments: .68 Collisions: .04 Crossing Accidents: 2.75		

COMMENTS: Since the opening of the modern St. Lawrence Seaway in 1959, downbound agricultural cargoes have represented from one-third to nearly three-fifths of annual Seaway cargo tonnage. Wheat shipped from Thunder Bay to lower St. Lawrence River export terminals has been the principal commodity and originating port. Direct shipments of wheat aboard foreign-flag ocean vessels do occur, but most of the Lakes-Seaway tonnage is moved by Canadian lakers. Historically, 80 percent of Canadian wheat production has been exported, much of it through the Seaway. However, during the last several years, a substantial share of Canadian grain exports has shifted to West Coast outlets. The previous pattern of 60 percent of exports eastward bound has now been reversed as the Pacific Rim countries have become major markets.

All rail movement of Canadian grain to St. Lawrence River terminals does occur, particularly during the winter shutdown of the Seaway. The lack of adequate federally-required grain cleaning capacity at St. Lawrence terminals, and the fact that a few of the elevators do not have rail service, coupled with favorable vessel rates, have prevented a substantial modal shift from taking place. However, more rail-delivered grain for the Port of Quebec is likely beyond the 10,000 annual car average with the recent construction of a grain cleaning facility and silo repairs at the large Bunge elevator.

NO. 7 GRAIN FROM THUNDER BAY, ONTARIO TO QUEBEC CITY, QUEBEC

Annual Tonnage: 1,763,978 metric tonnes

Marine: 2,224 km; diesel-powered straight deck bulk carrier; 25,565 tonnes of cargo; 514 Tkm/liter (loaded, one-way); 69 annual roundtrips; 306,862 vessel km

Rail: Average of 1,878 km via Canadian National or Canadian Pacific; 209 trains per year, each with three SD-40 locomotives and 93 100-ton (90.7 tonnes) covered hopper cars; 8.9 liters of fuel per locomotive km; 784,880 rouondtrip train km

	MARINE			RAIL		
FUEL USE (liters) One-Way Annual	110,582 14,878,818			50,355 21,048,341		
EMISSIONS	CO	HC	NOx	CO	HC	NOx
One-Way (kgs)	808.3	318	7,288.7	356	108	3,011.3
Annual (tonnes)	108.77	42.79	980.7	148.95	45.15	1,258.7
POTENTIAL ACCIDENTS Annual	.33			Derailments: .68 Collisions: .04 Crossing Accidents: 2.75		

COMMENTS: Since the opening of the modern St. Lawrence Seaway in 1959, downbound agricultural cargoes have represented from one-third to nearly three-fifths of annual Seaway cargo tonnage. Wheat shipped from Thunder Bay to lower St. Lawrence River export terminals has been the principal commodity and originating port. Direct shipments of wheat aboard foreign-flag ocean vessels do occur, but most of the Lakes-Seaway tonnage is moved by Canadian lakers. Historically, 80 percent of Canadian wheat production has been exported, much of it through the Seaway. However, during the last several years, a substantial share of Canadian grain exports has shifted to West Coast outlets. The previous pattern of 60 percent of exports eastward bound has now been reversed as the Pacific Rim countries have become major markets.

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NO. 8 PAPER, WOOD PULP AND OTHER PRODUCTS FROM THUNDER BAY, ONTARIO TO SUPERIOR, WISCONSIN

Annual Tonnage: 300,300 net tons

Marine: 200 miles; railcar ferry; 26 boxcars per trip; 2600 tons including 650 tons of boxcar weight; 606 TM/GAL (loaded, one-way); 154 annual roundtrips; 61,600 vessel miles

Rail: 360 miles via Canadian National and Class II carrier; 80 trains per year, each with two SD-40 locomotives and 50 boxcars, each at 75 cargo tons and 20 empty cars; 4 gallons of fuel per locomotive mile; 57,600 roundtrip train miles

Truck: 194 miles; 22 tons per trailer; 5.3 mpg; 13,636 annual roundtrips; 5,290,768 truck miles

	MARINE			RAIL			TRUCK		
FUEL USE (U.S. gals.) One-Way / Annual	858 264,264			2,880 460,800			36.6 998,295		
EMISSIONS	CO	HC	NOx	CO	HC	NOx	CO	HC	NOx
One-Way (lbs.)	52.3	20.6	471.9	170	51.55	1,437.1	3.8	.72	8.3
Annual (net tons)	8.06	3.17	72.67	13.6	4.12	114.97	51.8	9.8	113.1
POTENTIAL ACCIDENTS Annual	.005			Derailments: .19 Collisions: .001 Crossing Accidents: .29			36		

COMMENTS: A permanent modal shift from vessel to rail and truck is no longer a possibility. As of November 20, 1992, the Canadian-flag railcar ferry *Incan Superior* ceased operations, a victim of the current downturn in demand for newsprint, competitive inroads from all-rail hauls and the burden of $155,000 (U.S.) annual U.S. harbor maintenance tax. This unique intermodal operation had operated for 18 years and was the last open lake railcar ferry in the Great Lakes.

For mode comparison purposes, roundtrip routings are evaluated. Ferry and truck operations are considered to be dedicated service operations. However, the rail service would likely blend dedicated and other service, thus total roundtrip fuel use and related emissions would not be assignable to the particular commodity movement.

NO. 8 PAPER, WOOD PULP AND OTHER PRODUCTS FROM THUNDER BAY, ONTARIO TO SUPERIOR, WISCONSIN

Annual Tonnage: 272,432 metric tonnes

Marine: 322 km; railcar ferry; 26 boxcars per trip; 2,359 tonnes including 590 tonnes of boxcar weight; 234 Tkm/liter (loaded, one-way); 154 annual roundtrips; 99,114 vessel km

Rail: 579 km via Canadian National and Class II carrier; 80 trains per year, each with two SD-40 locomotives and 50 boxcars each at 68 cargo tonnes and 20 empty cars; 9.4 liters of fuel per locomotive km; 92,678 roundtrip train km

Truck: 312 km; 20 tonnes per trailer; 2.25 km/liter; 13,636 annual roundtrips; 8,512,846 truck km

	MARINE			RAIL			TRUCK		
FUEL USE (liters) One-Way Annual	3,248 1,000,239			10,901 1,744,128			138.53 3,778,547		
EMISSIONS	CO	HC	NOx	CO	HC	NOx	CO	HC	NOx
One-Way (kgs)	23.7	9.34	214	77.1	23.38	651.87	1.72	.33	3.76
Annual (tonnes)	7.31	2.875	65.93	12.34	3.74	104.30	46.99	8.89	102.6
POTENTIAL ACCIDENTS Annual	.005			Derailments: .19 Collisions: .001 Crossing Accidents: .29			36		

COMMENTS: A permanent modal shift from vessel to rail and truck is no longer a possibility. As of November 20, 1992, the Canadian-flag railcar ferry *Incan Superior* ceased operations, a victim of the current downturn in demand for newsprint, competitive inroads from all-rail hauls and the burden of $155,000 (U.S.) annual U.S. harbor maintenance tax. This unique intermodal operation had operated for 18 years and was the last open lake railcar ferry in the Great Lakes.

For mode comparison purposes, roundtrip routings are evaluated. Ferry and truck operations are considered to be dedicated service operations. However, the rail service would likely blend dedicated and other service, thus total roundtrip fuel use and related emissions would not be assignable to the particular commodity movement.

NO. 9 IRON ORE FROM POINTE NOIRE/SEPT ILES, QUEBEC TO HAMILTON, ONTARIO, WITH VESSEL/RAIL ALTERNATIVE THROUGH QUEBEC CITY, QUEBEC

Annual Tonnage: 3,217,500 net tons

Marine: 861 miles to Hamilton; diesel-powered straight deck bulk carrier; 27,500 tons of cargo; 1,224 TM/GAL (loaded, one-way); 117 annual roundtrips; 201,474 vessel miles

331 miles to Quebec City; diesel powered straight deck bulk carrier; 27,500 tons of cargo; 1,224 TM/GAL (loaded, one-way); 117 annual roundtrips; 77,454 vessel miles

Rail: 542 miles from Quebec City via Canadian National; 335 trains per year, each with three SD-40 locomotives and 96 100-ton hopper cars; 3.8 gallons of fuel per locomotive mile; 363,140 roundtrip train miles

	MARINE (Pointe Noire/Sept-Iles to Hamilton)			MARINE (Pointe Noire/Sept Isles to Quebec)			RAIL (Quebec to Hamilton)		
FUEL USE (U.S. gallons) One-Way Annual	19,344 4,413,334			7,437 1,696,751			6,179 4,139,796		
EMISSIONS One-Way (lbs.) Annual (net tons)	CO 1,180 134.6	HC 464.2 52.96	NOx 10,639 1,213.6	CO 453.6 51.75	HC 178.5 20.36	NOx 4,090.3 466.6	CO 364.8 122.22	HC 110.6 37.05	NOx 3,083.3 1,032.87
POTENTIAL ACCIDENTS Annual	.34			.13			Derailments: .53 Collisions: .01 Crossing Accidents: 1.83		

COMMENTS: In 1991, iron ore shipments through the St. Lawrence Seaway totaled 11.3 million tons with 82 percent of the amount westbound. Overseas origin ore accounted for only 6 percent of the Seaway total and most of this was transhipped from Quebec City to the Bethlehem Steel plant at Burns Harbor, Indiana. In April 1992, a record iron ore cargo from overseas was unloaded in Quebec City - 128,000 tons from Brazil. Canada's principal iron ore shipment ports are all in Quebec: Pointe Noire, Sept-Iles, and Port Cartier. These ports originated 328 vessel cargoes in 1991 with 181 cargoes (5.06 million tons) destined for steel mills in Hamilton, Ontario.

Grain cargoes downbound through the Seaway support the upbound movement of iron ore by providing a regular backhaul. As a result of this efficient two-way shipment system, grain and ore vessel rates have been more moderate than they would have been with only one or the other commodity. The annual fluctuations in iron ore and grain shipments cause difficulty in maximizing vessel usage and, in particular, the trend of less overall grain may result in rate increases for ore.

NO. 9 IRON ORE FROM POINTE NOIRE/SEPT ILES, QUEBEC TO HAMILTON, ONTARIO, WITH VESSEL/RAIL ALTERNATIVE THROUGH QUEBEC CITY, QUEBEC

Annual Tonnage: 2,918,916 metric tonnes

Marine: 1,385 km to Hamilton; diesel-powered straight deck bulk carrier; 24,948 tonnes of cargo; 472 Tkm/liter (loaded, one-way); 117 annual roundtrips; 324,172 vessel km

533 km to Quebec City; diesel powered straight deck bulk carrier; 24,948 tonnes of cargo; 472 Tkm/liter (loaded, one-way); 117 annual roundtrips; 124,623 vessel km

Rail: 872 km from Quebec City via Canadian National; 335 trains per year, each with three SD-40 locomotives and 96 100-ton (90.7 tonnes) hopper cars; 8.9 liters of fuel per locomotive km; 584,292 roundtrip train km

	MARINE (Pointe Noire/Sept-Iles to Hamilton)			MARINE (Pointe Noire/Sept Isles to Quebec)			RAIL (Quebec to Hamilton)		
FUEL USE (liters) One-Way Annual	73,218 16,704,469			28,147 6,422,202			23,387 15,669,127		
EMISSIONS One-Way (kgs) Annual (tonnes)	CO 535.2 122.1	HC 210.6 48.04	NOx 4,825.85 1,101	CO 205.75 46.94	HC 80.96 18.47	NOx 1,858 423.29	CO 165.5 110.88	HC 37.05 50.17	NOx 1,398.5 937.02
POTENTIAL ACCIDENTS Annual	.34			.13			Derailments: .53 Collisions: .01 Crossing Accidents: 1.83		

COMMENTS: In 1991, iron ore shipments through the St. Lawrence Seaway totaled 10.26 million metric tonnes with 82 percent of the amount westbound. Overseas origin ore accounted for only 6 percent of the Seaway total and most of this was transhipped from Quebec City to the Bethlehem Steel plant at Burns Harbor, Indiana. In April 1992, a record iron ore cargo from overseas was unloaded in Quebec City - 128,000 tons from Brazil. Canada's principal iron ore shipment ports are all in Quebec: Pointe Noire, Sept-Iles, and Port Cartier. These ports originated 328 vessel cargoes in 1991 with 181 cargoes (4.59 million metric tonnes) destined for steel mills in Hamilton, Ontario.

Grain cargoes downbound through the Seaway support the upbound movement of iron ore by providing a regular backhaul. As a result of this efficient two-way shipment system, grain and ore vessel rates have been more moderate than they would have been with only one or the other commodity. The annual fluctuations in iron ore and grain shipments cause difficulty in maximizing vessel usage and, in particular, the trend of less overall grain may result in rate increases for ore.

NO. 10	**COAL FROM SANDUSKY, OHIO TO HAMILTON, ONTARIO**
	Annual Tonnage: 2,100,000 net tons
Marine:	260 miles; diesel-powered self-unloader; 28,000 tons of cargo; 610 TM/GAL (loaded, one-way); 75 annual roundtrips; 39,000 vessel miles
Rail:	313 miles via Conrail and Canadian National; 253 trains per year, each with three SD-40 locomotives and 83 100-ton hopper cars; 3.8 gallons of fuel per locomotive mile; 158,378 roundtrip train miles

	MARINE			RAIL		
FUEL USE (U.S. gallons) One-Way Annual	11,934 1,745,410			3,568 1,805,509		
EMISSIONS	CO	HC	NOx	CO	HC	NOx
One-Way (lbs.)	727.99	286.4	6,563.9	210.7	63.86	1,780.4
Annual (net tons)	53.23	20.94	479.98	53.3	16.16	450.47
POTENTIAL ACCIDENTS Annual	.062			Derailments: .32 Collisions: .034 Crossing Accidents: 1.16		

COMMENTS: Four U.S. Lake Erie ports account for nearly all of the "cross-lake" coal movements to steel mills and electric generating stations in Ontario. These ports--Ashtabula, Conneaut, Sandusky and Toledo (all in Ohio)--shipped 11,140,924 tons of coal in 1990. Hamilton received thirty percent of this amount, all of it destined for Dofasco and Stelco steel mills. Sandusky shipments to Hamilton were 2,125,596 tons, representing three-fifths of U.S. vessel shipments to Canada's steel center in 1990.

Competitive Canadian vessel rates, coupled with attractive U.S. steam and metallurgical coal prices have supported this high-volume transborder commodity movement pattern. However, tonnages have fluctuated, but with a downward trend, for various reasons. Canadian steel production is lower following industry restructuring, and annual output corresponds with cycles in the U.S. and Canadian economies. Also, electricity generation varies with the economy and year-to-year climate conditions. Ontario Hydro's increasing reliance on nuclear generating capacity and its commitment to use some western Canadian coal for blending purposes is dampening coal shipping prospects from Lake Erie ports.

NO. 10	**COAL FROM SANDUSKY, OHIO TO HAMILTON, ONTARIO**
	Annual Tonnage: 1,905,120 metric tonnes
Marine:	418 km; diesel-powered self-unloader; 25,402 tonnes of cargo; 232 Tkm/liter; 75 annual roundtrips; 62,751 vessel km
Rail:	504 km via Conrail and Canadian National; 253 trains per year, each with three SD-40 locomotives and 83 100-ton (90.7 tonnes) hopper cars; 8.9 liters of fuel per locomotive km; 254,830 roundtrip train km

	MARINE			RAIL		
FUEL USE (liters) One-Way / Annual	45,712 / 6,606,376			13,506 / 6,833,852		
EMISSIONS	CO	HC	NOx	CO	HC	NOx
One-Way (kgs)	330.2	129.9	2,977.4	95.57	28.97	807.6
Annual (tonnes)	48.29	19	435.44	48.36	14.66	408.67
POTENTIAL ACCIDENTS Annual	.062			Derailments: .32 Collisions: .034 Crossing Accidents: 1.16		

COMMENTS: Four U.S. Lake Erie ports account for nearly all of the "cross-lake" coal movements to steel mills and electric generating stations in Ontario. These ports–Ashtabula, Conneaut, Sandusky and Toledo (all in Ohio)–shipped 10,107,046 tonnes of coal in 1990. Hamilton received thirty percent of this amount, all of it destined for Dofasco and Stelco steel mills. Sandusky shipments to Hamilton were 1,928,341 tonnes, representing three-fifths of U.S. vessel shipments to Canada's steel center in 1990.

Competitive Canadian vessel rates, coupled with attractive U.S. steam and metallurgical coal prices have supported this high-volume transborder commodity movement pattern. However, tonnages have fluctuated, but with a downward trend, for various reasons. Canadian steel production is lower following industry restructuring, and annual output corresponds with cycles in the U.S. and Canadian economies. Also, electricity generation varies with the economy and year-to-year climate conditions. Ontario Hydro's increasing reliance on nuclear generating capacity and its commitment to use some western Canadian coal for blending purposes is dampening coal shipping prospects from Lake Erie ports.

NO. 11	**STEEL FROM NORTHERN EUROPE (ROTTERDAM) TO CLEVELAND, OHIO, WITH VESSEL-TRUCK/RAIL ALTERNATIVE THROUGH BALTIMORE, MARYLAND**		
	Annual Tonnage: 400,000 net tons		
Marine:	4,215 miles to Cleveland; diesel powered, ocean-going vessel; 25,000 tons of cargo; 1,031 TM/GAL (loaded, one-way); 16 annual trips; 67,440 vessel miles one-way 4,376 miles to Baltimore; diesel-powered, ocean-going vessel; 25,000 tons of cargo; 1,164 TM/GAL (loaded, one-way); 16 annual trips; 70,016 vessel miles one-way		
Rail:	487 miles via Conrail; 87 trains per year, each with two SD-40 locomotives and 54 gondolas/flatcars each at 85 cargo tons; 4 gallons of fuel per locomotive mile; 38,960 roundtrip train miles and 22,889 one-way train miles		
Truck:	361 miles; 22 tons per trailer; 5.3 mpg; 18,182 round trips; 13,127,404 truck miles		

	MARINE			MARINE			RAIL			TRUCK		
FUEL USE (U.S. gallons) One-Way Annual	CLEVELAND 102,207 1,635,305			BALTIMORE 93,986 1,503,780			3,896 338,952			68.1 2,476,869		
EMISSIONS One-Way (lbs.) Annual (net tons)	CO 6234. 6 49.87	HC 2,45- 2.9 19.62	NOx 56,- 214 449.7	CO 5,73- 3.1 45.86	HC 2,25- 5.6 18.04	NOx 51,692 413.53	CO 23 0 10	HC 69.7 3 3.03	NOx 194- 4.1 84.57	CO 7.07 128. 6	HC 1.3 4 24. 5	NOx 15.43 280.6
POTENTIAL ACCIDENTS Annual	Not Available			Not Available			Derailments: .15 Collisions: .02 Crossing Accidents: .59			89		

COMMENTS: In recent years, steel has been the leading commodity moved across the docks at the port of Cleveland. Ninety percent of the 443,320 net tons of steel for 1991 was imported from overseas, with The Netherlands as the top originating country. This higher value cargo, which supports many waterfront jobs, is destined for the scores of industrial metal bending and using operations in Ohio, including eleven truck, bus and auto assembly plants.

This modal shift example shows that direct shipment to Cleveland from Rotterdam has a large advantage in total fuel use and emissions over shipment through Baltimore, with a continuing movement by rail or truck to Cleveland. Only one-way vessel movements were considered because of little likelihood of empty backhauls compared with either rail or truck. For the rail movements, 47 were considered to be one-way hauls and 40 were considered roundtrips operating in a quasi-shuttle system.

In this example, even though vessel miles are fewer for the Cleveland scenario, fuel usage is higher. This situation results from the longer transit time for the Cleveland shipment because of slower movement through the St. Lawrence River and Seaway section.

NO. 11	**STEEL FROM NORTHERN EUROPE (ROTTERDAM) TO CLEVELAND, OHIO, WITH VESSEL-TRUCK/RAIL ALTERNATIVE THROUGH BALTIMORE, MARYLAND**
	Annual Tonnage: 362,880 metric tonnes
Marine:	6,781.9 km to Cleveland; diesel powered, ocean-going vessel; 22,680 tonnes of cargo; 398 Tkm/liter (loaded, one-way); 16 annual trips; 108,511 vessel km one-way
	7,041 km to Baltimore; diesel-powered, ocean-going vessel; 22,680 tonnes of cargo; 449 Tkm/liter (loaded, one-way); 16 annual trips; 112,656 vessel km one-way
Rail:	784 km via Conrail; 87 trains per year, each with two SD-40 locomotives and 54 gondolas/flatcars each at 77.1 tonnes; 9.4 liters of fuel per locomotive km; 62,687 roundtrip train km and 36,828 one-way train km
Truck:	581 km; 20 tonnes per trailer; 2.25 Tkm/liter; 5.3 mpg; 18,182 roundtrips; 21,121,993 truck km

	MARINE			MARINE			RAIL			TRUCK		
FUEL USE (liters)	CLEVELAND			BALTIMORE								
One-Way	386,852			355,738			14,746			257.76		
Annual	6,189,629			5,691,807			1,282,933			9,374,949		
EMISSIONS	CO	HC	NOx	CO	HC	NOx	CO	HC	NOx	CO	HC	NOx
One-Way (kg)	2,828	1,112.6	25,499	2,600.5	1,023.2	23,448	104.35	31.63	8818	3.2	.6	6.99
Annual (tonnes)	45.25	17.8	407.97	41.60	16.37	375.16	9.08	2.75	76.72	116.6	22.22	254.56
POTENTIAL ACCIDENTS Annual	Not Available			Not Available			Derailments: .15 Collisions: .02 Crossing Accidents: .59			89		

COMMENTS: In recent years, steel has been the leading commodity moved across the docks at the port of Cleveland. Ninety percent of the 402,287 metric tons of steel for 1991 was imported from overseas, with The Netherlands as the top originating country. This higher value cargo, which supports many waterfront jobs, is destined for the scores of industrial metal bending and using operations in Ohio, including eleven truck, bus and auto assembly plants.

This modal shift example shows that direct shipment to Cleveland from Rotterdam has a large advantage in total fuel use and emissions over shipment through Baltimore, with a continuing movement by rail or truck to Cleveland. Only one-way vessel movements were considered because of little likelihood of empty backhauls compared with either rail or truck. For the rail movements, 47 were considered to be one-way hauls and 40 were considered roundtrips operating in a quasi-shuttle system.

In this example, even though vessel miles are fewer for the Cleveland scenario, fuel usage is higher. This situation results from the longer transit time for the Cleveland shipment because of slower movement through the St. Lawrence River and Seaway section.

CONCLUSION

The Great Lakes-St. Lawrence region, with freight transportation service by all modes solidly in place, is not confronted by the prospect of immediate, broadscale modal shifts induced by either energy or environmental factors. However, some shifts are occurring in the ordinary course of business and, over time, energy, safety and environmental evaluation of all forms of transportation will begin to drive investment decisions as well as regulatory policy.

The findings of this study, ***Great Lakes and St. Lawrence River Commerce: Safety, Energy and Environmental Implications of Modal Shifts,*** show that vessel transport on the Great Lakes and St. Lawrence River is safer, uses less fuel and produces fewer emissions than either rail or truck when compared with equivalent commodity hauls. The study also addressed noise and congestion issues, and for these factors, the marine mode performed the best. Fuel use for the various commodity movements reveals substantially higher fuel efficiency for vessel movements on a ton-mile per gallon or tonne-kilometer per liter basis which also results in lower air pollutant emissions.

- For the eleven commodity movement scenarios, the shifting of 24.7 million tons/22.4 million metric tons of cargo from vessel to rail would result in the additional consumption of 14 million gallons/53.4 liters of fuel and the generation of an extra 4,321 tons/3,996 metric tons of carbon monoxide, hydrocarbon and nitrogen oxides pollutants.

- For the rail movements, total fuel use was 44 percent greater than for the marine movements. Vessel fuel efficiencies were considerably higher in some of the movement scenarios-ranging up to 100 percent greater than for rail.

- Total rail emissions were more than 47 percent greater than for the marine movements. For some movement scenarios, train trips generated much higher pollution amounts ranging to over 100 percent greater than for equivalent vessel hauls.

- In the three commodity movement scenarios where truck transportation was considered, the shifting of less than 1 million tons of waterborne cargo to highway would, compared to vessels, increase fuel use by 3.4 million gallons/12.88 million liters and result in an additional 570 tons/517 metric tons of air pollutants.
- With respect to safety issues, a vessel-to-rail shift could result in 36 crossing accidents, 14 derailments and one train collision. The shift to truck would add 1,446 trucks a week to the region's traffic load and thereby annually generate 21 million additional vehicle sites. These truck movements could result in 141 more accidents with a quarter of them having the potential for fatalities or serious injuries.

- Vessels operating on the Great Lakes and St. Lawrence River are quieter than rail and truck operations and generate less bothersome noise because most related sound is far from shore or removed from residential areas.

In the United States and Canada as well as in Europe, the safety and environmental-energy impacts of transportation activity have become major concerns. The integration of environmental and transportation issues has taken place in response to rising public interest, as well as the critical need for viable solutions to transportation and environmental protection problems. It is now recognized that a comprehensive multimodal approach to transportation and environmental-energy policy is required.

The modal split characterizing historical transportation arrangements in the region is subject to continual adjustment. Some changes may last only over the short term, whereas others can persist. In addition to the basic economic outcomes of a particular split for a region's transportation activity, there are specific safety, energy and environmental impacts. These issues all entail financial considerations for transportation companies, but the health, welfare and safety of the public at large are also becoming important factors in the conduct of transportation business.

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Spill Statistics - 1990

	Total Spills	Oil Spills	Hazmat Spills	Amount Oil Spilled	Amount Hazmat Spilled	No. Of Cleanups	No. From Comm. Vessels	No. From Recreat. Vessels	No. From Land-Based	No. From Unknown Source	Amount Oil From Comm. Vessels (Gal.)
Buffalo	56	53	3	1,456	25,600	11	2	11	12	31	15
Cleveland	33	33	0	2,698	0	25	1	3	14	15	2
Toledo	39	37	2	663	1,112	23	5	8	17	9	33
Detroit	81	79	2	15,223	670	44	6	4	51	20	10,113
Chicago	37	35	2	112,105	Unknown	12	4	2	21	10	31
Milwuakee	31	30	1	1,125	35	7	2	3	18	8	3
Duluth	23	23	0	586	0	14	10	0	6	7	568
Soo	15	15	0	1,212	0	6	5	3	5	2	9
Grand Haven	17	14	3	223	110*	4	0	3	6	8	0
Totals	332	319	13	135,291	27,527 gals. 15,600 lbs.	146	35	37	150	110	10,774
Percent							11%	11%	45%	33%	7%

*There was 15,600 lbs. of hazardous material in addition to the 110 gallons discharged.

Prepared by Lake Carriers' Association

AVERAGE EMISSION FACTORS
FOR
OCEAN-GOING COMMERCIAL VESSELS

POUNDS OF POLLUTANT PER THOUSAND GALLONS OF FUEL CONSUMED

OPERATING PLANT Operating Mode/Rated Output	POLLUTANT NOx	HC	CO	SOx	PM
STEAM PROPULSION					
Full power	63.6	1.72	7.27	159x(%S)	56.5
Maneuver/Cruise	55.8	0.682	3.45	159x(%S)	20
Hotelling					
- Burning residual bunker fuel	36.4	3.2	*	159x(%S)	10
- Burning distillate oil	22.2	3	4	142x(%S)	15
MOTOR PROPULSION					
All underway operating modes	550	24	61	157x(%S)	33
AUXILIARY DIESEL GENERATORS					
- 20 KW (50% Load)	477	144	53.4	27	17
- 40 KW (50% Load)	226	285	67.6	27	17
- 200 KW (50% Load)	140	17.8	62.3	27	17
- 500 KW (50% Load)	293	81.9	48.1	27	17

Notes:
1. Emission factors showing an asterisk (*) are considered negligible for these operating modes.
2. Average sulfur concentrations used are 0.8 percent for marine diesel, and 2.0 percent for bunker fuel oil.

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1. U.S. Environmental Protection Agency, Compilation of Air Pollutant Emission Factors, 1985
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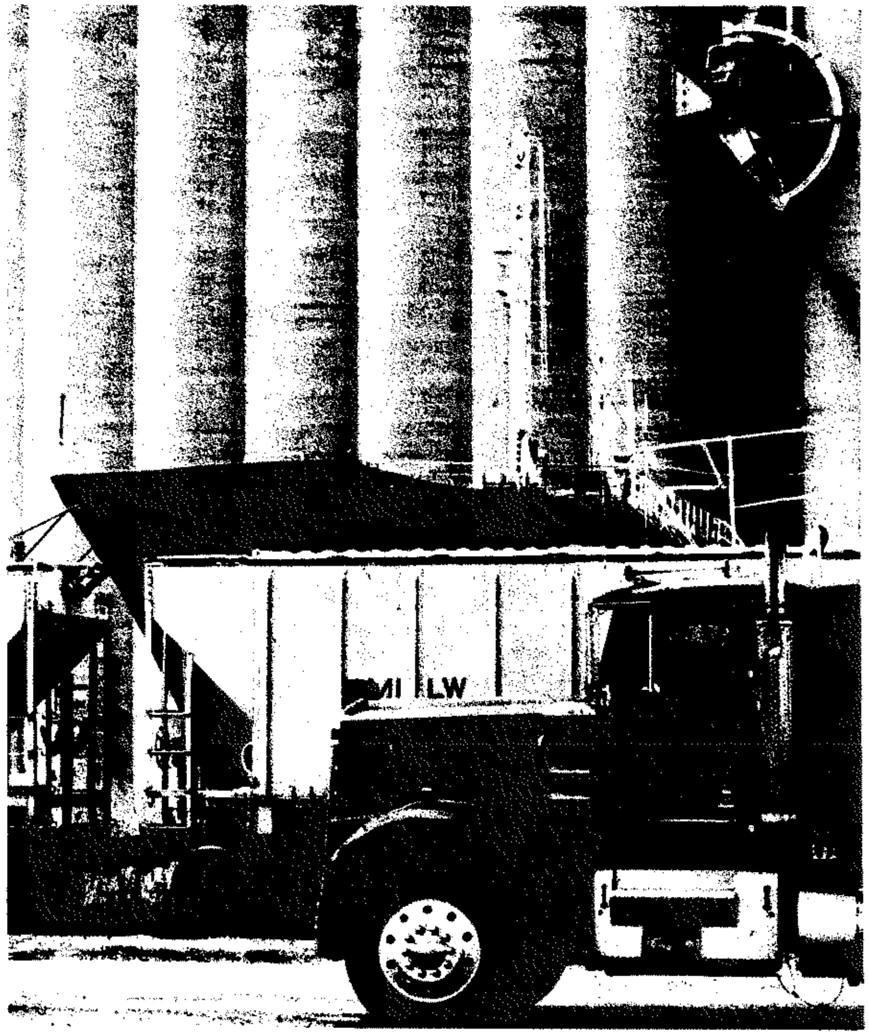
Modal Shift

Safety, energy and environmental implications for Great Lakes-St. Lawrence River commerce

July/August 1993

Environment, energy use and safety

Transportation considerations move beyond economics



If you had a large amount of goods that needed to get from one place to another, would you choose train, truck or vessel to move them?

Some things you'd probably consider are the cost and the logistics to transport the cargo. But other factors are involved, including energy use, the environment and safety. These factors should be considered not only by individual companies, but more importantly, they should be reflected in transportation policy at all governmental levels.

Transportation is a major energy-use sector in North America, accounting for more than a quarter of the energy used in the United States and Canada. This vast industry has a large impact on environmental quality. For example, transportation in the United States and Canada accounts for 71 percent of carbon monoxide emissions. In addition, safety across all transportation modes has become a priority concern for both the public and government. In the last few years, media coverage of the transportation-environment connection has expanded in response to particular events and growing public awareness. Related legislative and regulatory action in Canada and the United States also has kept pace. The *Exxon Valdez* incident prompted some sectors of the Great Lakes community to examine maritime transportation practices on the Great Lakes-St. Lawrence Seaway system. How could shifting cargo movements from the waterborne to truck or rail modes affect risk from safety, energy and environmental standpoints?

To better understand such impacts of various modes of transportation, the Great Lakes Commission conducted a "modal shift" study of the Great Lakes-St. Lawrence River commercial navigation system titled *Great Lakes and St. Lawrence River Commerce: Safety, Energy and Environmental Implications of Modal Shifts*. The study was funded by several regional organizations: International Association of Great Lakes Ports, Saint Lawrence Seaway Development Corp., St. Lawrence Seaway Authority, Lake Carriers' Association and Canadian Shipowners Association.

At a time when Great Lakes-St. Lawrence commercial navigation has come under increasing scrutiny for potential risks from oil and hazardous materials spills, as well as dredging and dredged materials disposal, the results of a modal shift study will be valuable in understanding the risks and impacts of one transportation mode compared to another. Although economic and logistics factors often are pivotal in determing which mode to use, the environmental and safety consequences of certain modes are becoming more important in government policy.

Freight transportation and the regional economy

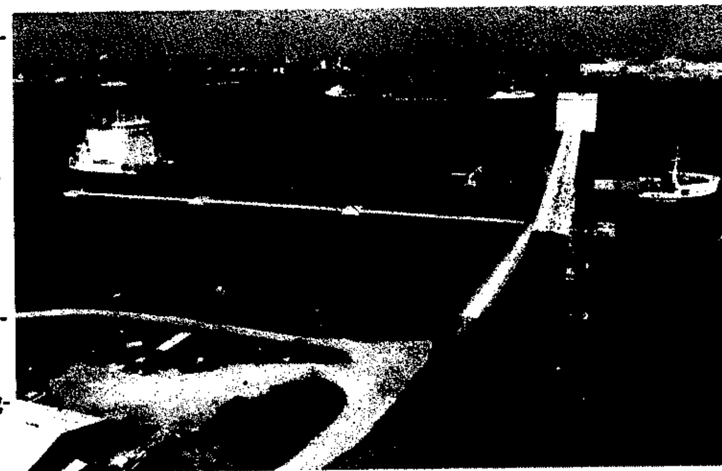
An historical background

Transportation played an important role in the development of the Great Lakes-St. Lawrence region. The combination of an in-place water transport infrastructure and a strong natural resource base promoted population settlement and a manufacturing economy. It was water transportation that provided the foundation for shore-based manufacturing and related activities. In many cases, the waterborne shipment option for raw material delivery and movement of products was a major factor in determining where industry located.

Today, the region's binational transportation system is characterized by a well-developed multiple-mode infrastructure with strong intermodal connections. Among the principal vehicle freight modes, a competitive and yet complementary relationship has evolved. The region's relatively high freight generation level is, in part, linked to the system's transport efficiencies. Particular modal patterns are evident in commodity movement and route structure. Historically, east-west freight routes have had more capacity and volume compared to north-south links. However, in recent years, partly attributable to the U.S. Canada Free Trade Agreement, north-south commodity flows have been increasing and the infrastructure to support this trend is receiving increased attention.

U.S.-Canada trade

Freight movements in the binational region serve both domestic markets and international trade. Canada and the United States have the world's largest trade relationship and are each other's most important trading partners. Much of this trade is tied to the Great Lakes region. U.S. exports to Canada constitute more than one-fifth of total exports, and three-fourths of Canadian exports are to the United States. Motor vehicles and parts, machinery and equipment add the greatest economic value to U.S.-Canada regional trade. Paper, pulp and lumber, along with coal, natural gas, oil and petroleum products, agricultural products and electricity are among other principal products that move across the border. Overseas exports of manufactured and agricultural products also represent a high value contribution to the regional economy. These goods are transported by rail, truck, barge and Great Lakes vessels to transshipment points. In addition, direct overseas shipments originate at Great Lakes and St. Lawrence River ports.



The *M. V. Paterson*, a Canadian laker, loads grain in Windsor, Ontario.

Great Lakes-St. Lawrence Transportation

The Great Lakes-St. Lawrence transportation system, stretching more than 2,300 miles (3,700 kilometers) from the Gulf of St. Lawrence to the lakehead ports of Duluth-Superior and Thunder Bay, is a deep-draft navigation route unlike any other in the world. System movements are dominated by bulk commodities. Total annual U.S. and Canadian tonnage (shipments and receipts) for the 145 ports and major terminals in the system has averaged around 200 million tons (181 million metric tons) in recent years. Grain flows have been quite variable as world grain supply and demand continually adjusts. North American steel production and related raw materials movement have been affected by recession periods and fluctuating levels of imported steel. Coal shipments, particularly those related to electricity-generating stations, are more stable, but utility decisions on fuel contracts have dramatically altered some supply patterns. Salt, which is used primarily for road de-icing, represents five to eight percent of Canadian Great Lakes tonnage. Petroleum products movement is significant for St. Lawrence River ports and Sarnia, Ontario, a major Great Lakes refinery center. Movement of general cargoes (higher value containerized, palletized and other processed or manufactured goods) is declining on the Great Lakes and such traffic now constitutes only a small percentage of St. Lawrence Seaway tonnage. Montreal, though, originates substantial vessel shipments of containers delivered mostly by rail.

Regional rail and truck freight

Rail and motor carrier freight transportation complement waterborne commerce in the Great Lakes-St. Lawrence region, but both maintain well-established service profiles while engaging in intermodal operations and head-to-head competition in some instances. Rail and motor carrier operations together account for more than two-thirds of intercity freight tonnage in the United States. From 1980 to 1990, mode share for rail and truck ton-miles combined has increased from 60 to 63.4 percent. In Canada, the two modes represent about 58 percent of total freight tonnage and nearly 75 percent of ton-kilometers, excluding pipelines. The binational region, because of its manufacturing and agricultural production strengths, is a major freight-generating area for all the modes; six Great Lakes states are ranked in the top 13 nationally and Ontario clearly dominates in Canada.

Using movement scenarios to study commodity flows

The study explored movement scenarios for several commodity flows chosen to represent a range of products and raw materials moving throughout the Great Lakes-St. Lawrence system. These 11 origin-destination movements are widespread and diverse, and represent more than 10 percent of the average annual tonnage moving on the system. These scenarios are indicated in the accompanying list.

Annual waterborne tonnages for the study commodities were translated into an equivalent movement by surface mode. In all modal shift scenarios, rail movement alternatives were analyzed. However, the truck option was used in only three scenarios. A shift to truck was determined to be unrealistic in most cases because of transport costs, the length of the substitute haul, and the amount of tonnage involved.

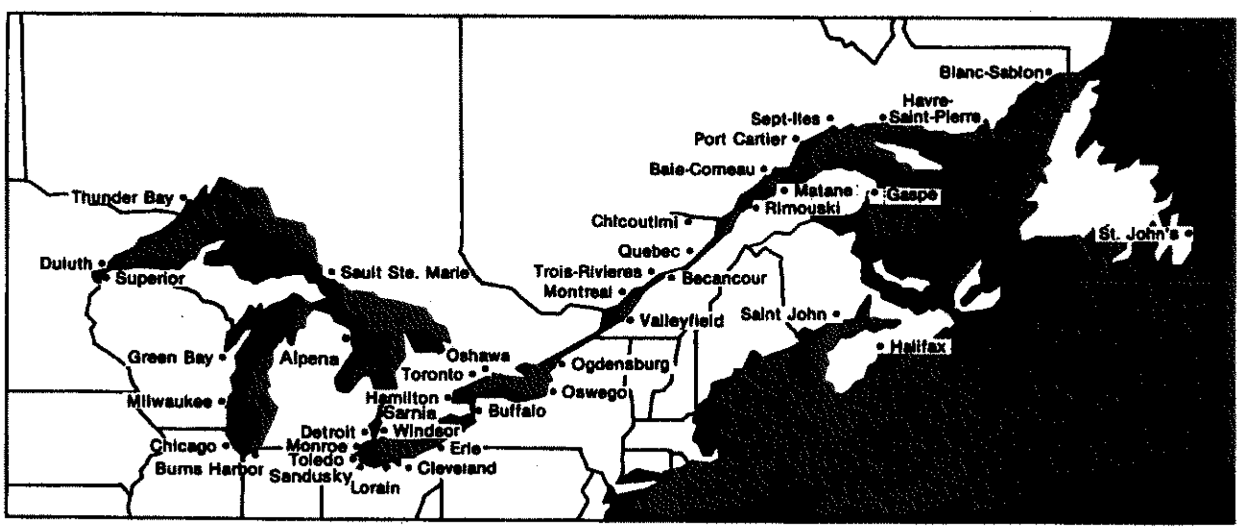
Fuel use, air pollutant emissions, and accident potential for each of the scenarios were determined, permitting a comparison among the alternative movements.

Movement scenarios

1) Potash from Thunder Bay, Ontario, to Toledo, Ohio
2) Coal from Superior, Wisconsin, to St. Clair, Michigan
3) Taconite from the Minnesota North Shore to Lorain, Ohio
4) Cement from Alpena, Michigan, to Detroit, Michigan (truck)
5) Petroleum products from Sarnia, Ontario, to Montreal, Quebec
6) Petrochemical products from Sarnia, Ontario, to Chicago, Illinois
7) Grain from Thunder Bay to Quebec City, Quebec
8) Paper, wood pulp, and other products from Thunder Bay to Superior (truck)
9) Iron ore from Pointe Noire/Sept Iles, Quebec, to Hamilton, Ontario, with combined vessel/rail alternative through Quebec City
10) Coal from Sandusky, Ohio, to Hamilton
11) Steel from northern Europe (Rotterdam) to Cleveland, Ohio, with truck/rail alternative through Baltimore, Maryland (truck)

Each scenario explored marine and rail transport. Scenarios 4, 8 and 11 also analyzed the truck alternative.

Great Lakes and St. Lawrence River maritime system



Highlights

Vessel transport has clear benefits over train or truck

The findings of this study show that vessel transport on the Great Lakes and St. Lawrence River is safer, uses less fuel and produces fewer emissions than either rail or truck when compared with equivalent commodity hauls.

The study also addressed noise and congestion issues and, for these factors, the marine mode performed the best. Fuel use for the various commodity movements reveals substantially higher fuel efficiency for vessel movements on a ton-miles per gallon or metric ton-kilometers per liter basis, which also results in lower air pollutant emissions.

Key results from the study are summarized here.

Energy efficient 1,000-foot laker upbound through the Soo Locks.

Key findings

- For the 11 commodity movement scenarios studied, the shifting of 24.7 million tons (22.4 million metric tons) of cargo from vessel to rail would result in the additional consumption of 14 million gallons (53.4 liters) of fuel and the generation of an extra 4,321 tons (3,996 metric tons) of carbon monoxide, hydrocarbon and nitrogen oxides pollutants.
- For the rail movements, total fuel use was 44 percent greater than for the marine movements. Vessel fuel efficiencies were considerably higher in some of the movement scenarios, ranging up to 100 percent greater than for rail.
- Total rail emissions were more than 47 percent greater than for marine emissions. For some movement scenarios, train trips generated much higher pollution amounts ranging to more than 100 percent greater than for equivalent vessel hauls.
- In the three commodity movement scenarios where truck transportation was considered, the shifting of less than 1 million tons of waterborne cargo to highway would, compared to vessels, increase fuel use by 3.4 million gallons (12.88 million liters) and result in an additional 570 tons (517 metric tons) of air pollutants.
- With respect to safety issues, a vessel-to-rail shift could result in 36 crossing accidents, 14 derailments and one train collision. A shift to truck would add 1,446 trucks a week to the region's traffic load and thereby annually generate 21 million additional vehicle miles. These truck movements could result in 141 more accidents with a quarter of them involving the potential for fatalities or serious injuries.
- Vessels operating on the Great Lakes and St. Lawrence River are quieter than rail and truck operations and generate less bothersome noise because most related sound is far from shore or away from residential areas.

Energy use and fuel efficiency

Transportation runs on energy. The transportation sector currently accounts for about 27 percent of total U.S. energy use and about 28 percent in Canada. The sector's almost total dependence on petroleum-based fuels raises serious questions about related pollution and future availability, as well as cost. Nearly two-thirds of petroleum use in the United States and Canada is for transportation purposes. This level of petroleum consumption is likely to grow because of increasing use by the transportation sector, coupled with decreasing use in other sectors.

The fuel used by each mode of transport in the 11 scenarios is presented in the table below.

Truck

The fuel efficiency of tractor-trailer trucks, as measured by ton-miles per gallon (TM/gallon), reveals a substantial range, with route characteristics, type of equipment and load as major variables. In this study, the truck figures for one-way trips ranged between 117 TM/gallon for the steel and paper movements to 223 TM/gallon for the cement movement using double trailers.

Rail

Railroad fuel efficiency has been improving with the introduction of new locomotives, reduction of empty car miles, optimal routings and speed control, but it is still substantially less than the more efficient bulk carriers that ply the Great Lakes and St. Lawrence River. For the purpose of this study, most of the rail haul scenarios were developed as unit train movements engaged in dedicated service with long trains and level terrain. As a rule, unit train operations with the lowest horsepower per trailing ton ratios have the highest fuel efficiencies. The 3,000 horsepower SD-40 locomotive, the most common locomotive used in line-haul North American operations, was the standard locomotive used to calculate fuel use per locomotive mile. The number of locomotives per train ranged from one to three depending on train tonnage and other operational factors. On a ton-miles per gallon basis, the one-way movements in the 11 case studies ranged between 467 in the movement of petroleum products to Montreal from Sarnia, to 877 for taconite pellets from Minnesota to Lorain, Ohio. On a metric ton-kilometers per liter basis these figures were 180 and 338 respectively.

Marine

Among rail, truck and marine modes, waterborne transport is generally the most energy efficient for large tonnage movements. Large cargo capacity relative to engine size and operating characteristics make Great Lakes bulk carriers, ocean-going ships and tug-barge combinations relatively fuel efficient on a straight ton-miles per gallon basis. The fact that many navigable waterways are more circuitous than rail and road networks can reduce the fuel efficiency difference. However, for Great Lakes waterborne movements compared with alternative surface routes, this is usually not a major factor because the vast water bodies are barriers to more direct land routings.

Great Lakes dry bulk carriers, whether diesel or steam-powered, are mostly high block coefficient vessels designed to maximize cargo at normal 26-foot operating drafts. Fuel efficiency varies among the vessels of the Great Lakes fleet. For the U.S. dry bulk carriers assessed in this study, the range is 520 TM/gallon (200 metric ton-kilometers/liter) for one-way trips from Alpena, Michigan, to Detroit, Michigan, by cement carriers, to an average 1,426 TM/gallon (550 metric ton-kilometers/liter) for coal movements from Superior, Wisconsin, to St. Clair, Michigan, aboard 1,000-foot vessels. Propulsion fuel consumption also varies according to route/operation characteristics. For example, transits through the Welland Canal and the Great Lakes connecting channels involve reduced speeds and lower fuel use for those segments compared to open lake movements, and vessels operating in ballast save some fuel compared to loaded trips. Vessel fuel use for the 11 scenarios was 32.39 million gallons (122.55 million liters), or only 69.6 percent of that for the rail movements.

Annual fuel use for modal shift scenarios (in million U.S. gallons)

Scenario	Marine	Rail	Truck
1	0.816	1.219	
2	7.215	14.498	
3	9.587	14.044	
4	0.216	0.160	0.543
5	1.048	0.479	
6	1.519	0.582	
7	3.930	5.560	
8	0.264	0.460	0.998
9*	4.413	5.835	
10	1.745	1.805	
11*	1.635	1.841	3.979
Total	32.388	46.483	5.520

Note: For the #9 scenario, rail fuel use and emissions include those from the marine leg of the complete movement from Quebec ore ports to Hamilton, Ontario, through Quebec City.
For the #11 scenario, marine emissions and fuel use represent only one-way movements from Europe to the United States. Rail and truck figures include Europe-to-Baltimore marine figures.

Safety, noise and congestion impacts

Safety

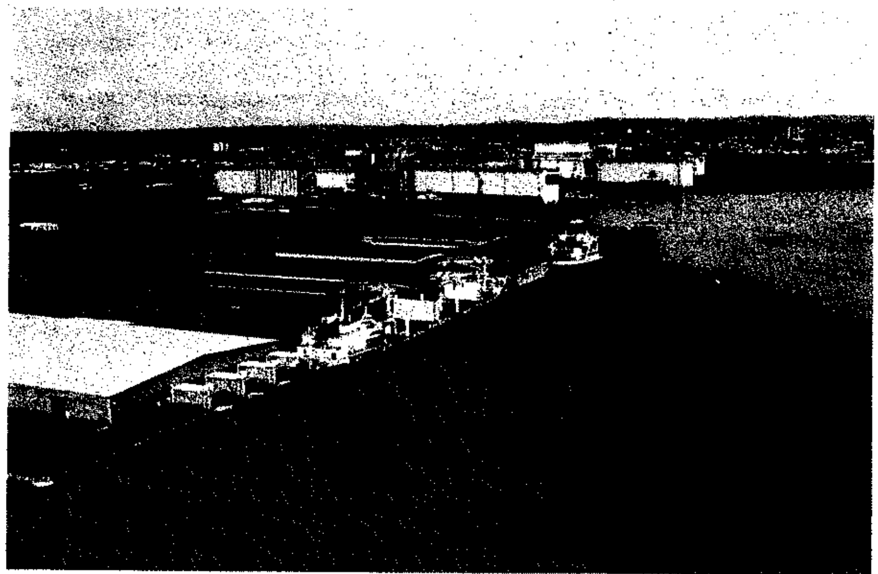
Safety issues are focusing increasing public and government attention on the movement of commodities. Canada and the United States identify safety as their chief federal transportation program priority. Safe operation of vehicles, proper equipment inspections, and the handling of hazardous materials are the major areas of current policy interest. As recent examples of freight transportation accidents and related problems illustrate, human life, the natural environment, and property can all be at risk when an accident occurs.

In this study, the shifting of commodities from vessels to either rail or truck would increase the number of transportation-related accidents based on statistical accident probability. With such a shift there would be the potential for an additional 141 truck and 51 train accidents with many of them resulting in death or serious injury and substantial property damage and environmental harm.

Based on data from the Transportation Safety Board of Canada and the U.S. Coast Guard, serious accidents involving large cargo vessels operating on the Great Lakes-St. Lawrence River entailing such mishaps as vessel collisions, founderings/sinkings, explosions or fire are quite rare. However, the consequences of such vessel accidents, particularly for those involving an open-lake spill of chemical or other hazardous cargoes, can be extremely serious. The study's determination of an annual accident rate of one accident per 8 billion vessel ton-miles indicates the possibility for only two such accidents for the existing waterborne cargo movements.

Noise

Transportation-related noise is a problem in modern society. With respect to freight transportation, increasing tonnage levels have generated higher noise exposure levels. Diesel trucks, idling diesel locomotives and freight trains generally produce noise levels sufficient to cause auditory fatigue, and prolonged exposure can cause hearing loss. Road traffic is considered the most serious noise problem where exposure levels are higher for the greatest number of people. Noise problems associated with commercial navigation on the Great Lakes-St. Lawrence system are not perceived as a significant problem, since most related noise is far from shore.

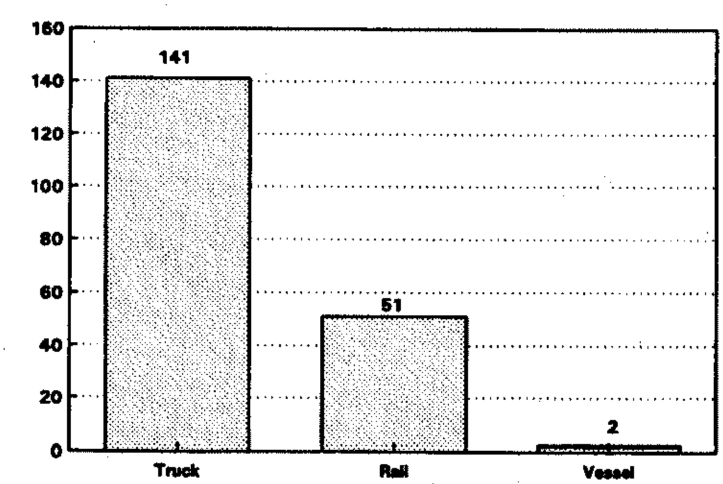


Port of Thunder Bay, Ontario.

Congestion

Congestion and related capacity constraints can affect all transport modes. Rail yards are notorious bottlenecks and navigation locks have the potential to create delays, but road congestion is a leading transportation problem and is rapidly getting worse. The alarming increase in congestion is reducing economic productivity, adding to vehicle emissions and fuel use and raising safety risks. The consequences of a modal shift to truck in the Great Lakes-St. Lawrence region where a large tonnage amount is involved would be especially troublesome. The substantial increase in truck traffic to accommodate tonnage volumes previously moved by rail or vessel would overwhelm highway routes and exacerbate capacity problems.

Transportation accidents for selected commodity movements



Air pollution and emissions

Air pollution worldwide is a growing threat to human health and the natural environment. Fuel combustion is the largest contributor to human-caused air pollutant emissions, with stationary and mobile sources responsible for approximately equal amounts. The most prevalent air pollutants from transportation sources are carbon monoxide (CO), nitrogen oxides (NOx), hydrocarbons (HC) or volatile organic compounds (VOC), and particulates. According to the Organization for Economic Cooperation and Development, established by convention in 1960 by 20 member countries, the transport sector (passenger and freight) in Canada and the United States accounts for the following percentages of total North American emissions: 71 percent of CO; 47 percent of NOx; 39 percent of HC and 14 percent of particulates. Transportation vehicles contribute only a small percentage of another important pollutant, sulfur dioxide, and the amount varies greatly depending on the sulfur content of a particular fuel. For the principal air pollutants, gasoline-fueled automobiles are the major sources and urban areas the most heavily affected places. However, freight transportation, dependent on diesel fuel, makes a significant contribution to pollution levels; yet the impacts vary according to mode and operations.

Diesel fuel or distillate represents only one-fifth of U.S. transportation energy consumption, but it is the principal fuel used by heavy trucks and the other major freight modes. Air pollutants from diesel vehicles compared with those from gasoline combustion have both favorable and undesirable characteristics. For example, because of better combustion efficiencies and lower temperatures, diesel CO, HC and NOx emissions are at lower rates. However, emissions of fine particulates, as well as formaldehyde, are higher, as are levels of sulfur dioxide due to the higher sulfur content of diesel fuel. Sulfur content of diesel fuels varies considerably depending on crude characteristics and refining practices.

Heavy duty trucks account for about three-fifths of total diesel fuel use in the United States. In the study, truck emissions were substantially higher than for rail or marine. This result is attributable to the large number of vehicle trips and miles involved in the carriage of nearly a million tons. In the Great Lakes-St. Lawrence River system, emissions from commercial marine vessels, as with other large vessels, vary by type of engine and propulsion (steam or diesel motor) and kind of fuel (distillate or residual bunker). Vessel emissions usually represent a small fraction of total transportation emissions for port communities particularly those with larger populations. Marine emissions in the study scenarios totaled 9,162.5 tons (8,312 metric tons) or 4,321 tons (3,996 metric tons) less than for the comparable rail movements. Railroad emissions vary according to throttle notch position on locomotives, with higher fuel use and higher emission levels generally occurring at the high end of running speeds, but idling locomotives, particularly in railyards, also cause significant pollution problems. In the modal shift study, a rail emissions total of 13,483 tons (12,308 metric tons) was nearly 50 percent greater than those for the marine movements.

Low-sulfur, western coal being loaded at Superior, Wisconsin.

Annual emissions (CO, HC, NOx) for modal shift scenarios (in net tons)

Scenario	Marine	Rail	Truck
1	259.08	351.2	
2	2,290.60	4,175.30	
3	1,983.33	4,044.60	
4	7.86	46.28	95.21
5	332.82	138.05	
6	482.33	167.63	
7	1,248.06	1,601.41	
8	83.90	132.69	174.70
9*	1,401.16	1,730.85	
10	554.15	520.37	
11*	519.19	575.03	911.13
Total	9,162.50	13,483.40	1,181.04

Note: For the #9 scenario, rail fuel use and emissions include those from the marine leg of the complete movement from Quebec ore ports to Hamilton, Ontario, through Quebec City.
For the #11 scenario, marine emissions and fuel use represent only one-way movements from Europe to the United States. Rail and truck figures include Europe-to-Baltimore marine figures.

The need for a multimodal transportation approach

The Great Lakes-St. Lawrence region, with freight transportation service by all modes solidly in place, is not confronted by the prospect of immediate, broadscale modal shifts induced by either energy or environmental factors. However, some shifts are occurring in the ordinary course of business and, over time, energy, safety and environmental evaluation of all forms of transportation will begin to drive investment decisions as well as regulatory policy.

The integration of environmental and transportation issues has taken place in response to rising public interest, as well as the critical need for viable solutions to transportation and environmental protection problems.

In the United States and Canada, as well as in Europe, the safety, environment and energy impacts of transportation activity have become major concerns. The integration of environmental and transportation issues has taken place in response to rising public interest, as well as the critical need for viable solutions to transportation and environmental protection problems. It is now recognized that a comprehensive, multimodal approach to transportation, environment and energy policy is required.

The modal split characterizing historical transportation arrangements in the region is subject to continual adjustment. Rates and service factors usually influence the mode-shift decisions of shippers. Some changes may last only over the short term whereas others can persist. In addition to the basic economic outcomes of a particular split for a region's transportation activity, there are specific safety, energy and environmental impacts. These issues all entail financial considerations for transportation companies, but the health, welfare and safety of the public at large also are becoming important factors in the conduct of transportation business.

Steel is an important cargo at Burns International Harbor in Indiana.

Funders

The modal shift study was funded by the following regional maritime interests, from both the U.S. and Canada:

International Association of Great Lakes Ports

Saint Lawrence Seaway Development Corp.

St. Lawrence Seaway Authority

Lake Carriers' Association

Canadian Shipowners Association

For more information

If you'd like to learn more about the Great Lakes Commission's modal shift study or receive a copy of the full study report, please contact:

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