PREPARED FOR:

Maritime Administration,
U.S. Department of Transportation / Transport Canada

GREAT LAKES-ST. LAWRENCE SEAWAY NEW CARGOES/NEW VESSELS MARKET ASSESSMENT REPORT

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1 INTRODUCTION

The Great Lakes and St. Lawrence Seaway System (GLSLS) has long played a key role in North America's transportation system by providing a vital transportation link for the movement of bulk traffic. The success of the GLSLS System in moving bulk cargo but not container traffic raises the important questions of whether or not it is fulfilling its potential and whether or not there are additional roles that it might play as part of the North American transportation system.

1.1 BACKGROUND

The Great Lakes and St. Lawrence Seaway System (GLSLS) provides a 2,300-mile system stretching from the Gulf of the St. Lawrence River to both the industrial heartland of the Midwest/Central Canada and the agricultural and natural resource areas of the Great Plains and Prairies. The region has developed as both one of the world's leading manufacturing and industrial areas and a provider of industrial raw materials such as timber, coal, iron ore and steel, as well as agricultural products such as wheat, corn and cattle.

As a result, the Great Lakes and St. Lawrence Seaway has long played a role as a vital transportation link for this region's rapidly expanding and dynamic economy. However, since the development of the railroads and more recently the trucking industry the GLSLS has largely been focused on bulk traffic such as grain, coal and ores. While the GLSLS moves over 200 million tons of traffic each year, more than 90 percent of its cargo is bulk traffic and most of the rest is neobulk traffic such as steel. Very little container traffic moves on the GLSLS.

Given that in Europe and elsewhere considerable container traffic moves by water (e.g., on the Rhine) the question arises as to whether or not the GLSLS system is fulfilling its potential and whether or not there are additional roles that it might play as part of the North American Transportation System?

1.2 STUDY CONTEXT

In 2003, a joint Canada/United States study was formally initiated to investigate the future infrastructure needs of the GLSLS System, including the engineering, economic, and environmental factors of those needs as they pertain to commercial navigation.

Transport Canada is leading the economic aspects of the study, which includes three principal components –

- Data Collection and Integration
- Policy Research and Data Analysis/Forecasting
- Economic Modeling and Policy Analysis

A key area of research is an evaluation of the GLSLS System's role as part of the integrated transportation network, incorporating "New Cargoes and New Vessels" into future economic viability and efficiency. The U.S. Department of Transportation through the Maritime Administration (MARAD) has commissioned this study of New Cargoes/New Vessels (NCNV) for the Great Lakes and St. Lawrence Seaway System. The NCNV Study will assess the economic significance and evolving transportation needs of the GLSLS bi-national region as a basis for projecting new cargo traffic, identifying its economic viability, and determining the cost-effectiveness of new vessel technologies.

Transportation Economics & Management Systems, Inc. (TEMS) and the RAND Corporation were asked to undertake the New Cargoes/New Vessels Study. The role of each firm was to provide insight into each of the two key questions to be answered in the New Cargoes/New Vessels (NCNV) Study. TEMS was to evaluate the size and scale of the potential New Cargoes that might use the GLSLS system given the results of the RAND evaluation of the potential water technologies that might be available on the GLSLS system over the study period.

1.3 Study Objectives

The specific intent of the NCNV Study is to evaluate the potential for new vessel technology to allow the GLSLS system to provide an effective and competitive alternative to rail and highway modes in the movement of container and neobulk traffic. This analysis will be made in the context of increasing congestion and capacity limitations for existing highway, rail and port facilities.

As a result, the objective of the New Cargoes/New Vessels Scoping Study will be to assess new cargoes in relation to both shippers' demand requirements and the potential for carriers to meet those requirements using the GLSLS. Key areas to be addressed include the nature of the existing competitive environment, the potential offered by New Vessels and the impact on existing highway and rail modes of increased congestion and tightening capacity.

The ability of the GLSLS System to attract new cargo, however, is determined by its ability to meet the needs of shippers in terms of the level of service required for each type of cargo. Where the service profile fits the needs of shippers, the GLSLS System can be competitive and attract new cargo. Two types of cargo should be considered – new neo-bulk commodities, such as waste, coil and rolled steel, vehicles and assembled engineering equipment and containerized traffic for typical manufacturing products, food, raw materials, finished and semi-finished goods.

1.4 Intended Use

The results of the Great Lakes and St. Lawrence Seaway New Cargoes/New Vessels Study is to provide baseline and sensitivity assessments of the impact of developing the GLSLS as a new mode for moving both container and neobulk traffic. This data will be combined with projected bulk traffic to provide an overall market assessment of GLSLS capabilities. This input will be compared with the costs of building and developing the GLSLS system and provide policy assessments of the value and potential role of the GLSLS system.

1.5 Report Layout

The report is structured to provide the logical steps by which the "interactive analysis" of the NCNV study was performed. The analysis process consisted of the following steps –

Step 1: Economic Potential of GLSLS Region - Establish the Economic Base of the GLSLS regions economy and develop economic scenarios of its potential growth and change over the next 50 years.

Step 2: New Vessel Potential - Assess the potential of New Vessels technologies as providers of competitive service with existing rail and highway service.

Step 3: Long Term Transportation Capacity Issues - Evaluate the likely changes in the competitiveness of rail, highway and port operations over the next 50 years.

Step 4: GLSLS Demand and Market Analysis - Assess the GLSLS market for New Cargoes (container and neobulk) given the levels of service offered by the new water technologies and the reduced capacity and increased costs of operation of existing rail, highway, and ports.

Step 5: Conclusions - Present the results and findings of the analysis.

2 Analytical Issues and the Evaluation Framework

2.1 The Critical Issues and Concerns

In recent decades, the character of the bi-national GLSLS economy has been changed by the impact of economic globalization on U.S. and Canadian east-west trade patterns, particularly with Asia, Europe, and the former Soviet Union. In addition, the North American Free Trade Agreement (NAFTA) has led to an acceleration of growth in north-south trade (extending to Mexico) and a major restructuring of industries in the GLSLS region as well as elsewhere in North America. GLSLS trade has also been dramatically affected by significant increases in the import of manufactured products and the region has followed the North American economy in diversifying into expanding service and high-tech sectors (including computers, telecommunications, and biotech). These changes along with continued economic growth throughout North America, as well as the GLSLS region, have led to a tremendous expansion in the movement of industrial and consumer freight on the continent's highway and rail systems. In coming decades, the North American transportation network is facing projections of greatly increased congestion in many highway, rail, and port facilities. These facilities are already reaching capacity in many modal segments due to domestic traffic growth and are encountering difficulty in boosting capacity due to high costs, physical constraints, and environmental concerns. They are already straining to move today's international and domestic trade through critical chokepoints and overburdened corridors.

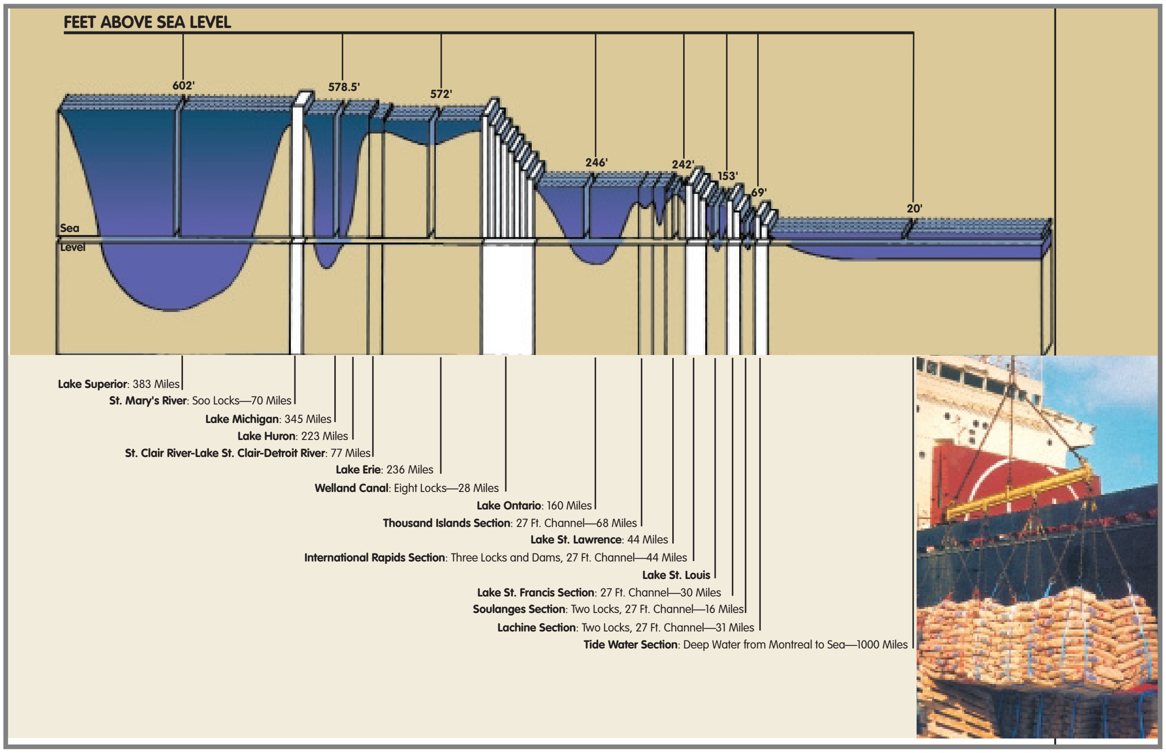
As a result, Canadian and U.S. government concerns have grown about the ability of the existing transport system to cope with continuing trade as well as vehicular traffic growth. Increases in both travel times and costs can be expected for both freight and passenger travel, as they are increasingly moving on over burdened transportation infrastructure.

One option to help deal with the increase is the potential offered by the GLSLS system. If competitive with rail and highway, water can offer considerable capacity to help move both container and neobulk traffic. This study is focused on identifying the potential that water might offer in trying to overcome the limitations of the existing system.

2.1.1 GLSLS System

The GLSLS System is over 2,300 miles (3,700 km) long, serves more than 30 ports between the gulf of the St. Lawrence River and Duluth, and moves over 200 million tons of cargo a year. It provides easy access to the largest manufacturing regions of Canada and the U.S. and, with its rail/water connections, the agricultural regions of the Prairies and Great Plains. The GLSLS System has six canals incorporating nineteen major sets of locks. These locks, however, limit the size and speed of vessels that can use the GLSLS System. The maximum size of vessels that can use the locks is 740 ft. (225.5 m) long, 78 ft. (23.8 m) wide and with a draft of 30 ft (9.1 m). A lock typically takes 45 minutes to fill with water and, over the full length of the system, vessels are raised a total of 180 meters above sea level.

Exhibit 2-1: GLSLS System



In terms of performance, there are a number of issues associated with the GLSLS System. Two of the most critical are the reliability of the locks and the scheduling of vessels through the locks. In competing for new cargo such as container traffic, transit times and the reliability of service are critical to any shipper who uses just-in-time inventory management. Improvements to lock reliability and scheduling will be important factors in getting shippers to use the GLSLS System. In this regard, the Seaway AIS network is a big step forward in facilitating the scheduling of vessels as well as providing information on trip costs, cargo matching, online transactions and account information and rules and regulation data. For the purposes of this study, it is assumed that the systems locks will be reliable and that vessel scheduling is possible.

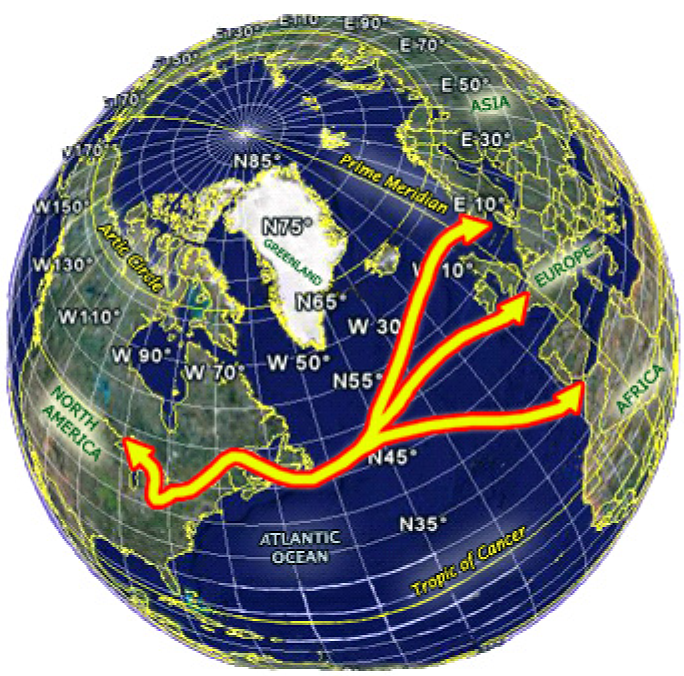
2.1.2 GEOGRAPHIC REGION

The New Cargoes/New Vessels study explores the container market potential for the 2,300-mile inland waterway stretching from the Gulf of the St. Lawrence River to inland cities such as Thunder Bay, Duluth-Superior and Chicago and the Port of Indiana-Burns Harbor. The GLSLS System includes 15 major ports and some 50 regional ports that are connected to more than 40 provincial and interstate highways, as well as 30 rail lines.

As a result, the GLSLS System connects the manufacturing, agricultural, and mining areas of Central Canada, the Midwest, the Prairies and the Great Plains. See Exhibit 2-2. Each area while different is both a producer and consumer of goods and services and therefore a candidate service of container traffic.

Exhibit 2-2: Study Area

Exhibit 2-3: North American Ports and European Destinations



Not only does the GLSLS region cover over 20 percent of North America, but it is itself both the largest production and consumer market areas of the continent. As will be discussed later, vessels are able to use GLSLS waterways to connect the region's producers and consumers via the Atlantic Ocean and through the Suez Canal into the Indian and Pacific oceans to major markets and producers worldwide. As a result, the GLSLS economy is, but can be more effectively, linked by trade to traditional as well as emerging trading partners in Europe, Latin American, Africa, Middle East and South and Southeast Asia.

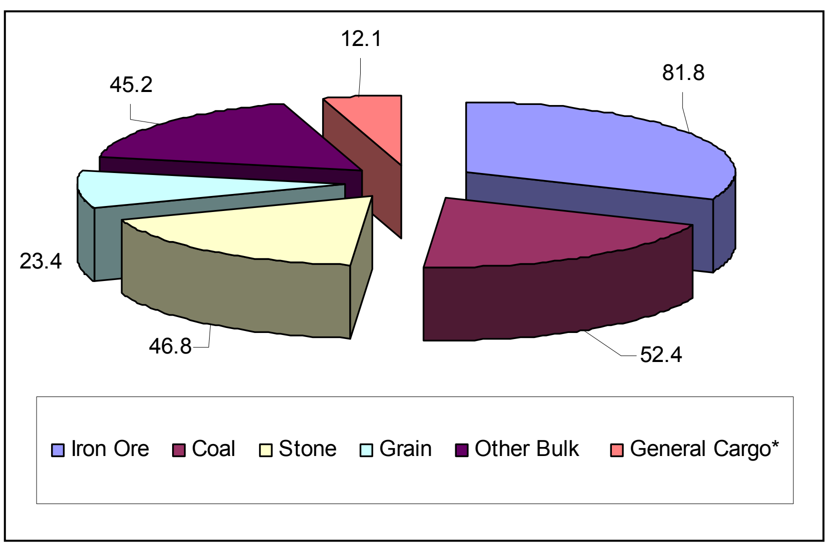
As shown in Exhibit 2-3 the distances between the North American ports on the GLSLS System to other parts of the world are highly competitive via direct ocean routes. For example, Baltimore, Maryland is closer to Liverpool, England via Detroit, Michigan and the GLSLS System at 3,673 miles (5,911 km) than by a direct ocean route, which is 3,936 miles (6,334 km). New York is closer to Rotterdam via Montreal and the GLSLS System at 3,612 miles (5,813 km) than by a direct ocean route at 3,824 miles (6,154 km). As a result, the GLSLS System provides an alternative for central Canada and the central U.S. that can compete with a wide range of rail, road, and port options stretching from Halifax, Nova Scotia, to northeastern U.S. ports such as Boston, New York, Baltimore, and Norfolk, Virginia. In each case, the GLSLS System's capability to compete with rail and highway for access to the widespread markets of Milwaukee, Chicago, Detroit, Cleveland, Toronto, Montreal and Quebec as well as the U.S. Northeast and Mid-Atlantic provide a positive basis for evaluating the potential for new cargoes on the GLSLS System. Therefore, the study area should encompass the following regions (See Exhibit 2-2)–

- Agriculture hinterlands (Prairies, Great Plains)
- Mining areas (Prairies, Great Plains)
- Manufacturing areas (Midwest, Ohio, Central Canada, Northeast and Mid-Atlantic)
- Market areas (Midwest, Ohio, Central Canada, Northeast and Mid-Atlantic)

2.1.3 CARGOES

The GLSLS System has demonstrated its ability to attract bulk cargo both in terms of domestic and international trade, see Exhibit 2-4.

Exhibit 2-4: Products Moved on the GLSLS System – 2004
(Millions of Metric Tonnes, Per Year)



*Includes steel slabs and containerized freight.

There is little doubt that for the long-distance movement of bulk commodities such as ore, grain and coal, the GLSLS System provides transit times and costs that make it attractive to shippers.

It can be seen that grain, iron ore, coal and other bulk commodities account for 95 percent of total cargo on the GLSLS System while container traffic (including the neo-bulk steel traffic) at 12.1 million metric tonnes, is only 5 percent of total cargo.[1] This cargo profile is similar to the cargo profiles for the Mississippi and Ohio River systems where well over 90 percent of the cargo on both systems is bulk products.[2]

The ability of the GLSLS System to attract new cargo, however, is determined by its ability to meet the needs of shippers in terms of the level of service required for each type of cargo. Where the service profile fits the needs of shippers, the GLSLS System can be competitive and attract new cargo. Two types of cargo should be considered – new neo-bulk commodities, such as waste, coil and rolled steel, vehicles and assembled engineering equipment and containerized traffic for typical manufacturing products, food, finished and semi-finished goods.

Neo-bulk cargo markets can be developed particularly if its rail and truck competitors continue to face higher capacity restrictions, increasing delays due to congestion and increasing costs due to higher energy prices and labor costs. Water transportation is capable of moving bulk cargo at the lowest cost per ton, lowest labor hours per ton-mile and lowest energy consumption per ton-mile.

The lack of rail and truck capacity in critical locations such as the U.S./Canadian border crossings on both sides of Lake Erie has also created an opportunity for new cargo flows across the GLSLS System. An example of this would be new ferry services on Lake Erie that provide an alternative means for moving hazardous and bulk materials by water rather than the conventional rail and truck modes. This hazardous cargo is increasingly barred from using tunnels and bridges and thus seeks an alternative mode of transport.

Critical features of this type of cargo are its specificity and the potential for water transportation to provide a direct service when the competition is forced, by regulation or capacity restrictions, to look for an alternative. In the case of the proposed Lake Erie (Nanticoke, Ontario-Erie and Pennsylvania) and Windsor-Detroit ferries, it is regulation and lack of capacity that have generated both of these opportunities. In the case of the Lake Erie ferry, it is truck weight restrictions, while, in the case of the Windsor-Detroit ferry, it is safety regulations.

2.1.3.1. CONTAINER CARGO FLOWS

The key development in container traffic transportation since the 1950's has been containerization. Container traffic has emerged from a largely agricultural and raw materials base that dominated early transportation to a highly diversified and high value added cargo that reflects the modern consumer goods industry. Containers move finished or semi-finished products in a "just-in-time" environment, which has made container traffic a highly time-sensitive payload that will be attracted to the GLSLS System only if it offers competitive rates and transit times.

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[1] "The St Lawrence Seaway 2004 Traffic Report", http://greatlakes-seaway.com/en/pdf/TrafficReport2004-EN.pdf and "Waterborne Commerce of the United States". Calender Year 2004. Part 3 - Waterways and Harbors Great Lakes. Institute for Water Resources, U.S. army Corps of Engineers. http://www.iwr.usace.army.mil/NDC/wcsc/pdf/wcusgl04.pdf

[2] "Waterborne Commerce of the United States". Navigation Data Center. 2001. Institute for Water Resources, U.S. Army Corps of Engineers. 20 Mar. 2005. http://www.iwr.usace.army.mil/ndc/wcsc/pdf/wcusnat101.pdf

One area where container traffic might be able to expand rapidly under the current conditions of the GLSLS System is where, as in the case of bulk cargo, the capacity limitations of the existing rail and truck networks have become problematic. In this environment, an improved GLSLS System would generate new opportunities along the Ontario, New York and Michigan borders. These could take the form of short ferry services carrying Ro/Ro (Roll on/Roll off) and Lo/Lo (Load on/Load off) cargo and freight ferry services similar to those proposed for Lake Erie and Lake Ontario. In terms of the current markets, the products that might move today by Ro/Ro and Lo/Lo between the U.S. and Canada include just-in-time, bonded and high-value shipments. This includes, for example, alcoholic beverages, machinery and precision goods via Ro/Ro freight ferry service.

2.1.3.2. Traffic and Revenue Potential

In terms of long-term growth, container traffic also offers the greatest opportunity in that it is growing very rapidly while the demand for bulk cargo (except perhaps in periods of rapid expansion such that recently experienced by China), is much lower. The projected annual growth rates for container traffic range between 4 and 6 percent and even higher whereas it is only 1 or 2 percent for bulk cargo. While the movement of bulk cargo grew quite strongly in the 1980's, it has been slowing down in recent years. The Mississippi river system, for example, carried in 2001 the same cargo it carried in 1995.

While bulk cargo provides the highest volume for the GLSLS System, it generates a much lower return than container traffic. For example, charges for grain, coal, and ores generate between 50 cents and 1 dollar (Canadian) per metric tonne, while containers, steel slab and container traffic generate from 1 to 2 dollars (Canadian) per metric tonne. Given the higher growth rate and the increased "value added" of container traffic, container traffic clearly offers the greatest opportunity for increasing revenues and improving the economics of the GLSLS System.

2.1.4 Vessel Operations and Technologies

As part of the overall analysis, consideration has been given to the potential incorporation of new vessel technologies to increase opportunities for new cargoes on the GLSLS System. Currently, Container on Barge (COB) is being developed on a number of North American waterways following the success of this technology on the Rhine/Danube river system. In addition, new high speed river and coastal vessel technologies capable of speeds greater than barges are currently being researched in Europe.

In addition, new small and large container ships are being built that are capable of up to 20 knots. These vessels have relatively low energy costs and large payloads. The potential of these modern vessel technologies has been considered in terms of their ability to change the pricing, service levels, and transit times for container cargo on the GLSLS System. The issues that were considered include allowable speed limits and the suitability of new technologies in relation to the locks and other infrastructure issues of the GLSLS System.

Potential new vessels on the GLSLS System evaluated in this study include —

2.1.4.1. Existing Technologies

COB Service: Tug/Barge

Today tug/barge vessels are providing service on a number of waterways in North America and Europe. This concept was developed for the Rhine/Danube river system as a way of moving containers, as well as bulk cargo, by making barge rates competitive with rail and truck. In many ways, this was achieved because of the less competitive character of rail and truck service in Europe. Lower productivity and high fuel and labor costs for trucks and rail in Europe have made barges more attractive to industry.

Exhibit 2-5: Container on Barge

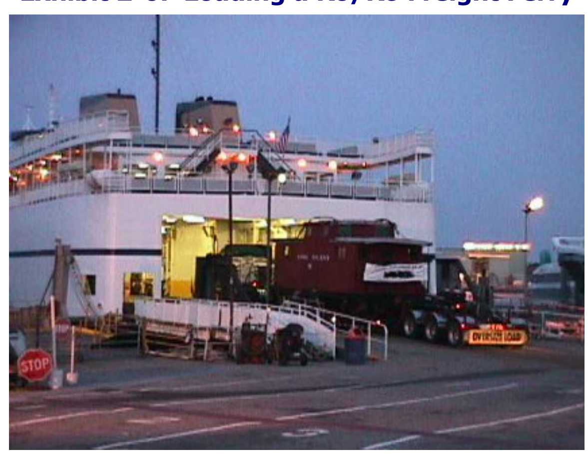
Specifically, the prohibition of trucks on German roads on weekends significantly improved barge competitiveness. Also, much European industry is located where barge service and barge cargo can be easily accessed compared to the industrial structure around the GLSLS System. Important factors in the success of the Rhine/Danube barge service include scheduled movements, current information systems and an ability to provide a wide range of options such as Lo/Lo and Ro/Ro.

Barges are typically 110 meters long and 11.4 meters wide with a draft of only 2.5 meters and the ability to carry 72 TEU with containers stacked three high on a single barge.[3]

Ro/Ro and Lo/Lo Freight Ferry Service

The development of ferry and short-distance shipping operations are largely a product of border congestion, regulations and safety concerns as evidenced by those ferry services that are either currently operational or being planned on the St. Lawrence River and Lakes Erie, Ontario and Michigan. However, in the future – as shown by the proposed Nanticoke-Erie freight ferry – the economics of Ro/Ro and Lo/Lo freight ferries are such that only a relatively small level of dislocation in the logistic supply chains of the steel, engineering, chemical or agricultural industries will produce conditions in which short-distance ferry operations can become viable.[4]

Exhibit 2-6: Loading a Ro/Ro Freight Ferry



Experience shows that the level of traffic congestion at the U.S./Canadian border crossings, where delays of 2-12 hours are frequent, is sufficient to make cross-border ferry operations viable.

[3] Great Lakes and St. Lawrence Seaway-New Cargoes/New Vessels Scoping Study. Transportation Economics & Management Systems, Inc. 2005

[4] "Lake Erie Freight Ferry Feasibility Study", Transportation Economics & Management Systems, Inc. 2003.

2.1.5 HIGH SPEED TECHNOLOGY

In the last twenty years, the character of shortsea operations has changed by the introduction of high speed technology that has revolutionized the nature of ferry operations around the world. This new technology offers the capability of running ferry services at 30 to 40 knots compared to the 15 to 20 knots of conventional ferries. For example, the introduction by Stena Lines of the HSS 1500 between Dun Laoghaire in Southern Ireland to Holyhead in Wales, a 70-mile route across the St. Georges Channel with some of the roughest waters around Britain, resulted in a two-hour service rather than the old four-hour service when the route used conventional ferries. This allowed Stena Lines to use only one vessel rather than two and dramatically improved the economics of operation. The HSS 1500 is capable of carrying some 900 meters of cars and trucks (or 350 TEU) as well as accommodate some 1500 passengers.[5] The major issues with this particular vessel are its width, which at 40 meters wide would make it too wide for the GLSLS System locks and its wake, which might be too severe for river and canal operation.

However, the European Union has been working on developing this type of technology for river work and in particular, the Rhine and Danube Rivers.

PACSCAT

The PACSCAT is a "Partial Air Cushion Support" Catamaran that is currently being developed as a viable vessel for carrying freight on inland waters. It is a fast, slender hull catamaran, with a beam of 22.8 meters and a length of 135 meters. It can carry up to 2,200 metric tonnes with a cargo capacity of 240 TEUs for Lo/Lo or Ro/Ro configuration. Using the Partial Air Cushion Support, the PACSCAT has a draft of 2.7 meters (with cushion) and 4.8 meters (off cushion).

Exhibit 2-7:
Rendering of PACSCAT with Containers Onboard

The PACSCAT is designed to produce a minimal wake while achieving speeds up to 20 knots well in excess of existing maximum speed of 8-12 knots currently permitted on GLSLS system.

In a river/sea version of the PACSCAT, it is considered that speed can be increased to 40 knots in open waters (such as on the Great Lakes) under conditions of up to Sea State 4.[6] The PACSCAT, therefore, offers a vessel capable of operating within the existing infrastructure of the GLSLS System, at speeds of twice as fast or more as those of existing vessels.

The European Union report in May 2001 concluded, "The technical and market feasibility studies (for PACSCAT) have been confirmed to a preliminary level through testing and analysis under a European Union Exploratory Project..." This type of vessel can clearly reduce transit times on the GLSLS System provided wash conditions meet environmental and engineering requirements.[7]

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[5] "The Rhine-Maine-Danube Waterway." Deutscher Wasserstrassen-und Schiffahrtsverein. 4 Apr. 2005. http://www.schiffahrtsverein.de/waterw.htm
[6] Sudar, Ann.
[7] "Stena Explorer/Technical Facts." Our Vessels. Stena Line. 4 Apr 2005.
http://www7stenaline.co.uk/servlet/se.ementor.econgero.servlet.presentation.Main?data.node.id=20274&data.languate.id=11&data.document.id=13872

CONTAINER SHIP

Although not strictly a high speed technology, incremental improvements in container ship design have transformed it from a 10-15 knot vessel to a 22-23 knot vessel. These new vessels are comparable with the PACSCAT river technology, which achieves 22-24 knots, but are much more efficient in terms of payload. The modern container ship can carry any where from 400-1,400 (TEU) containers and has a draft of only 7.9 meters, which can easily be used on the GLSLS navigation system.

Exhibit 2-8: Container Ship

2.2 ANALYTICAL ISSUES

The New Cargoes/New Vessels Study requires a comprehensive review of existing and potential cargoes and vessel technologies that might move on the GLSLS System. It identifies the potential new markets and assesses their critical thresholds in terms of price, service levels, and transit time together with any other relevant service needs (e.g., seasonality). The analysis reviews the nature of the competition in existing as well as potential new markets and considers the role of rail and highway modes in both the short- and long-term. The analysis also considers the role of the capacity issues in relation to the GLSLS System and the competitive modes, routes and ports. Concern exists about the ability of existing East and West Coast ports and their connecting railroads and highways to sustain their current levels of efficiency. In this environment, the development of new port facilities, new vessels and new uses of inland waterways might be possible, particularly in relation to the transport needs of the evolving Great Lakes/Seaway region economy, trade growth, and changing markets.

In evaluating the character of the GLSLS System's future, the emergence of new and niche markets and products available for transportation on the GLSLS System, as well as the development of new vessels has been explored. These options include investigating the use of container vessel technology that has not been previously used extensively on the GLSLS System. New vessels could well revolutionize the inland waterway markets by providing improved performance and more competitive pricing structures.

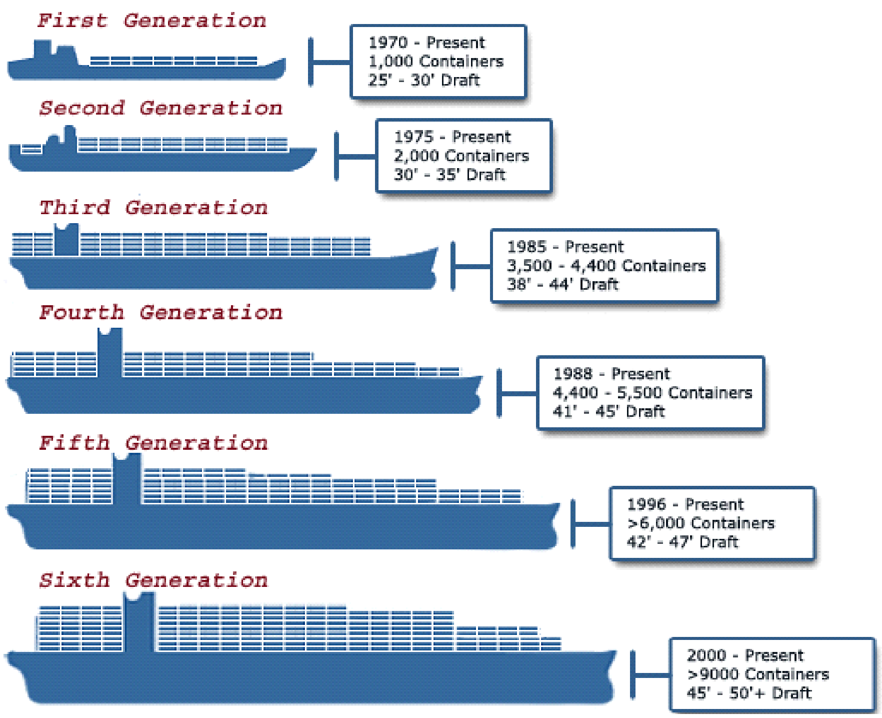
The evaluation of these issues has been completed within a framework that provides the ability to model the interaction of the competitive mode networks along the full length of the GLSLS System. The analysis provides the ability to show how specific transportation investment and improvements changes the GLSLS' competitiveness for existing and new cargoes; how changes in vessel technology will change the GLSLS' competitiveness; and how changes in capacity will affect price and level of service and, in turn, the competitive performance of the GLSLS System. The demand and supply model that has been developed is capable of evaluating –

- Competitive environment and issues
- Type of cargo
- Vessel operations and technology

COMPETITIVE ENVIRONMENT: THE BACKGROUND

Since the early 16th century when the French explorer Jacques Cartier was turned back by the Lachine Rapids just outside Montreal, there has been a desire to develop the Great Lakes and St. Lawrence Seaway as a trade route between the Atlantic and the interior of North America. However, as with the building of the Erie Canal, which in the 19th century spurred the development of the Great Lakes and St. Lawrence Seaway System, competition with the railroads initially and more recently with trucks, has meant that both waterways have had to specialize in slow moving (8-12 knots) bulk traffic and have found it hard to compete for faster moving container traffic. Even when the GLSLS System opened in the late 1950's, relatively long transit times meant that its traffic was heavily oriented to the movement of bulk commodities. While from the earliest times rail (and more recently truck) costs are higher than those of water, their transit times have typically been significantly less than those of the GLSLS System. As a result container traffic which emerged since the 1970's as the most cost effective way of moving manufactured goods has typically been unloaded at east and west coast ports and transferred to rail or truck.

Exhibit 2-9: The Evolution of the Container Ship



This emphasis on the use of rail and truck rather than water for inland distribution has been reinforced since the 1960's by the increased integration of container handling systems in ports and inland transportation centers. Containerization required special port handling facilities (i.e., cranes and container tugs) and encouraged the building of larger and larger vessels for the major ocean trade routes requiring channel depths greater than the 8.2 meters provided by the GLSLS System[8], see Exhibit 2-9.

[8] Great Lakes St. Lawrence Seaway System. Seaway Facts. 4 Apr. 2005. http://www.greatlakesseaway.com/en/aboutus/seawayfacts.html

Downstream ports like Montreal and Halifax invested in the new container infrastructure as they had the water depth and offered fast inland access, initially by rail and later by both rail and truck that attracted container traffic. Ports on the Great Lakes and St. Lawrence lacking these investments and the ability to attract ocean vessel calls increasingly concentrated on bulk goods.

Today, the GLSLS System cargo is over 80 percent bulk traffic, which is attracted by the highly cost effective, if relatively lengthy, transit times. It takes about ten days for a ship to go from one end of the System to the other, while it only takes rail or truck no more than three or four days. In addition, rail operators have improved their competitive position in the last ten years by introducing intermodal double stack train operations.

However, the continued expansion of world trade and the increasing globalism of world markets have implications for the existing port and inland waterway supply chain and logistics system of the current port and inland distribution systems. Not only are some ports reaching capacity and finding themselves unable to deal with the increasing size of container ships, but the inland distribution systems feeding from the ports are also reaching capacity. In this environment, it might well be difficult for the current system to provide for all the needs of trade growth. The question is raised as to whether the GLSLS System can provide an effective transportation option that will help maintain and allow for the expansion of trade. To assess this issue, the competitive environment needs to be explored to understand how demand and supply is affected by changes in the performance of the ports, modes, and routes that make up the supply chain. Additionally, the willingness of markets to adopt the potential price, service levels and shipping times that can be offered by the GLSLS System should be assessed. Exhibit 2-10 shows the range of factors considered in the study.

Exhibit 2-10: Supply and Demand Side Issues

Supply	Demand
Price	Economic Growth
Transit Time	Market Accessibility
Drayage/Access-Egress	Modal Competition
Dwell Time	Route Competition
Frequency of Service	Capacity Constraints
Reliability of Service	
Security of Shipment	
Shipment Characteristics	
Capacity	
Seasonality	

2.2.1 Supply Side Issues

To provide an effective assessment of supply side information, a micro-economic demand model was developed that properly represents the market's responses to supply conditions. The supply conditions were formulated as a metric containing all of the critical factors that motivate shippers and carriers to use a particular route, mode and shipment type.

Price

A key feature of any supply chain is price. Typically, water transportation has been able to offer the lowest price. The issue, however, is that while price dominates bulk transportation it is far less important in the movement of container traffic in which transit time and a wide range of other service variables play a major role.

In the case of bulk traffic, given the volumes involved, shipper concerns focus on the lowest rate per ton. In the case of container traffic, the focus is on transit times and the ability to reach certain markets by a given deadline. Faster transit times would allow a higher price to be charged for use on the GLSLS System. Clearly, faster transit times that are competitive with rail and truck can attract a price similar to that of rail and truck and dramatically increase the revenues per ton-mile. For water options that offer longer transit times than rail or truck, the ability to offer lower prices is critical to their success. As a result, for container vessels whose transit times are slower than truck and rail, it will be important to obtain the maximum economies of scale possible by boosting capacity as much as possible to minimize the average cost per container moved by water.

Transit Time

In a just-in-time economy, transit time has become the prime factor in shippers' decisions for container traffic. Improved transit time, therefore, has a strong relationship with the ability of the GLSLS System to attract container traffic. This can happen in several ways: water transit time can be improved relative to other modes because of the improved operation of the GLSLS System itself, by the use of new and faster vessels or as a result of increased time for other modes as they face congestion and capacity delays. In each case, the relative difference between water transit times and its competitors' transit time must be significantly reduced for the System to become an effective option. Today it takes about ten days for a ship to go from one end of the GLSLS System to the other. Critical bottlenecks include the Montreal-Lake Ontario section, which has a 22- to 24-hour average transit time and the Welland Canal with an 11-hour transit time. For products such as grain, iron ore, coal and steel, these times are both reasonable and competitive given the volume of cargo involved. However, for container or palletized products – the typical way to move manufactured products – these time scales are generally unacceptable. The gap between water and its competitors is currently three to four days of transit time; it would probably need to be improved to within one or two days, at the most, to become an effective shipping option.

Drayage/Access/Egress/Dwell Time

The experience of water transportation providers is that access, egress and dwell time along with drayage are very expensive components of total travel time and can rapidly reduce the viability of service. The reason for the development of the Alameda Corridor in California was the need to reduce dwell time, access/egress and drayage times for the San Pedro ports. The congestion and delays associated with getting from the ports across Los Angeles was such that shippers were willing to pay as much as $17 per box for improved service[9].

[9] "Expanded Preliminary Model – Alameda Corridor". Transportation Economics & Management Systems, Inc. March 1993.

Frequency of Service

The frequency of service is often a critical factor in a shipper's decision to use a particular transportation system. On Europe's Rhine/Danube River System, container traffic barges are being scheduled to ensure that required frequencies are being met and their reliability is improved. It is likely that frequency will be a critical factor on the GLSLS System and a minimum daily service level will be essential to attracting shippers and new cargoes.

Seasonality

A key issue for any waterway transportation system is seasonality. Over the last quarter century the GLSLS System has typically opened in late March and closed in late December, a period of 274 days, or more than 9 months. While the months of January to March are typically some of the slowest for manufacturing and, in particular, the retail industry, the inability to offer service at this time is a major limitation.

The impact of closing the GLSLS System for three months is that shippers and carriers will look for other alternatives. Once they find those alternatives, build relationships, negotiate contracts, and develop a dependable logistics chain it is difficult to see why they would return to the GLSLS. To evaluate the impact of seasonality, specific shipper and carrier input is required that shows the "disruptiveness" of the seasonality issue, how it affects costs and the penalty associated with forcing shippers to use alternative rail and truck options. Shippers and carriers are looking for seamless logistic systems negotiated for a given business cycle. One possible alternative is for the GLSLS to develop partnership arrangements to mitigate this issue as will be proposed in this report.

Reliability

The new economy of the 21st century is entirely dependent upon reliable transportation service to support the just-in-time manufacturing and processing of modern industry. Improving reliability significantly improves the ability of a facility such as the GLSLS to support container traffic. Reliability needs, therefore, to be built into the supply model.

Security of Shipment

Before containerization, pilferage from all forms of transportation was a problem. As a result, of containerization, a much more secure mechanism for moving goods was available and the level of pilferage diminished. The use of containers has enhanced shipment security, however, the level of security between different modes might not be the same, and this could be a significant factor to the shipper. Water transportation is regarded by shippers as being a safer mode than rail and truck. This could be an advantage in the movement of, for example, hazardous and waste material.

Shipment Characteristics

Cargoes have special characteristics that make them more or less subject to transportation restrictions on certain modes. Hazardous materials or cargo requiring refrigeration often have both handling cost implications and modal restrictions. Hazardous materials might be banned from critical bridges and tunnels.

Capacity Capabilities

An increasingly important factor in shipping decisions in the future will be system capacity. It is anticipated that supply side limitations including labor (trucking industry) and infrastructure will make existing distribution systems less cost effective and physically limited in what they can carry. As a result, capacity issues need to be considered for their impact on transit times and their effect on shipper usage decisions. The aim is to assess both types of issues with shippers.

CONCLUSION: The supply side model needs to be able to faithfully replicate these factors and to show the impact of changing any one of the factors on the supply chain and overall modal efficiency.

2.2.2 DEMAND SIDE ISSUES

On the demand side, a number of market issues need to be assessed in the analysis. These include –

CHANGES IN MARKET SIZE DUE TO ECONOMIC GROWTH

Over the next twenty to thirty years, if current trends continue, the freight volumes will increase by at least 70 to 100 percent. Recent Statistics Canada, U.S. Bureau of Commerce, and OECD data show trade volumes increasing rapidly from the early 1980's as the level of integration of the world economy increased. For example, U.S. exports increased 63 percent in the ten years from 1992-2002, while U.S. imports grew 138 percent in the same time period according to the U.S. Bureau of Economic Analysis.[10] The existing infrastructure will find this difficult to handle due to capacity limitations and once existing modes reach full capacity, cargo will seek new opportunities to reach markets. At this point, the GLSLS System will become more competitive and more attractive for container traffic. As a result, the demand model has been made responsive to both the growth in demand and the supply side capacity restrictions.

IMPACT OF MARKET ACCESSIBILITY ON TOTAL DEMAND

As existing freight options reach capacity, new routes will open. If these new routes prove not to be as competitive as existing routes, this will impact (reduce) the size of the overall market. Significant distributional impacts might follow. Conversely, once the minimum volume threshold required to support a GLSLS vessel service has been attained, shippers will have additional competitive options for transporting their goods. While the demand for transportation services is largely a derived demand dependent on the requirements of agricultural, manufacturing and service industries, a less competitive transportation market reduces the total demand for products while a more competitive transportation market makes the total market for products larger. This is due to the impact the competition has on the costs of transportation and the overall pricing of products. The demand model in conjunction with the supply model must be capable of determining the appropriate level of demand at equilibrium (i.e., the balance of market price and supply costs).

LEVEL OF MODAL AND ROUTE COMPETITION

The competition between modes and routes is assessed by a comparison of their relative performance as measured by transit time, price, frequency, etc. Changes in the relative performance of a mode or route will make it more or less competitive. The size of a given mode's market share is proportional to its relative competitiveness as measured by its performance compared to other modes. In evaluating route options the study has considered the changes in trade with Asia, the increasing role of south and west Asia and the potential for Asian traffic to the Midwest and central Canada to divert to an Atlantic route.

[10] U.S. Bureau of Economic Analysis of Current Business. April 2003.

Capacity Constraints and Traffic Shifts

The impact of mode, route, or port capacity constraints on ports, railroad, and trucks can cause a fundamental shift in the competitive advantage of the GLSLS System. If the relative performance of today's port and inland transportation distribution system worsens, the GLSLS System could become an overflow option for the truck and rail operations.

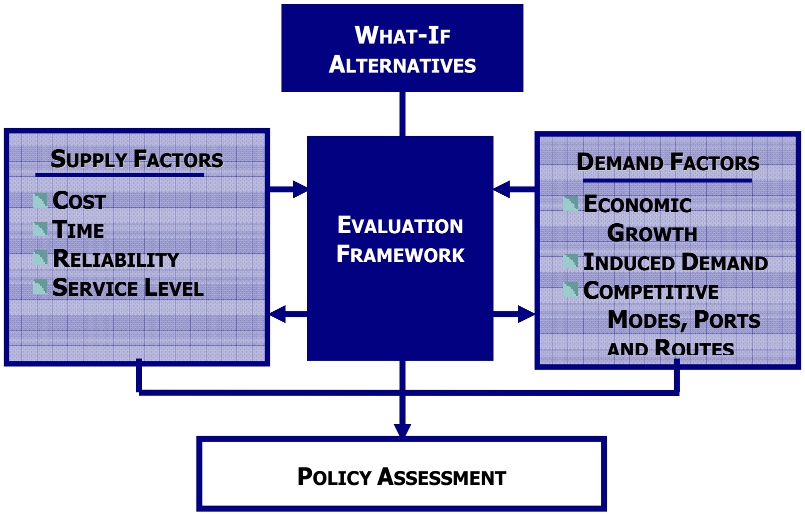
Conclusion: The analysis of the demand side factors needs to be undertaken using models that provide a mechanism for evaluating the full supply chain of each mode and set of modal service options. This will show the relevance of each component of the supply chain to a shipper or carrier's decision-making process. This decision making process was assessed by conducting stated preference surveys that allow the strengths and weaknesses of each service/supply chain option to be evaluated. This analysis showed not only how competitive the existing GLSLS System is, but also how it needs to change in order to attract new cargo. In this way, the thresholds that the GLSLS System needs to reach to achieve market share were identified and the actual potential of achieving the threshold defined.

2.3 Evaluation Frameworks

The purpose of the micro-economic evaluation framework is to provide a basis for assessing the "elasticities" associated with providing different levels of service on the GLSLS System. To define elasticities, a supply and demand analysis is required that shows the equilibrium response of demand to any given set of supply conditions. It is critical to measure elasticities at equilibrium since elasticities can change dramatically for quite small changes in the levels of service provided by any mode. For example, frequency elasticities change dramatically as water service increases from one service per week to eight services per week (-0.95 to –0.1). As well, different elasticities apply to either increasing or decreasing services or costs. As a result, the final form of the structure depended on the final corridor and route definitions, the evaluation framework should provide a basis for comparing alternative logistic structures for the GLSLS System and its ability to provide a competitive service. To meet this requirement, both the supply side and demand side factors need to be evaluated within a "what-if" framework. The what-if framework contains three major components –

- Economic scenarios and transportation strategies – what-if alternatives
- Demand model factors and systems
- Supply model factors and systems

Exhibit 2-11: Evaluation Frameworks



2.3.1 Economic Scenarios and Transportation Strategies

The economic scenarios and transportation strategies provide the what-if questions for the model framework to evaluate. They include –

Economic Growth Scenarios

This analysis shows how the economic growth impacts total cargo volumes by SIC class/type and the rates of change in the market. The range of options should include central, optimistic, and pessimistic growth rates.

Competitive Mode Route Investments

This analysis shows how investments or disinvestments in a mode's infrastructure will affect its performance and efficiency. This would include changes in price, transit time, reliability, and capacity.

Resource Costs Strategies

This analysis shows how changes in resource costs (e.g., oil price increases in real terms) will affect the performance of different modes/routes and options.

GLSLS Infrastructure Improvement Strategies

This analysis shows how any planned improvements for the GLSLS System, such as the reliability of locks, will affect its performance and efficiency.

New Vessel Technology Strategies

This analysis shows how both existing barge and high speed surface technologies will change the performance of the GLSLS System, its efficiency and its competitive position relative to truck and rail.

Regulatory Policy Strategies

This analysis shows how policies affect a mode's performance, market shares, and competitiveness.

2.3.2 DEMAND SIDE MODEL SYSTEMS

In evaluating the demand and market share implications for any economic scenario or transportation strategy for the GLSLS System, four specific demand model functions were used. These include –

TOTAL DEMAND MODEL

This model provides an understanding of how the total market will grow in terms of both bulk and container cargo. It is anticipated that the underlying macro-economic forecasts of trade and growth will be provided by the Policy Analysis Model (PAM).

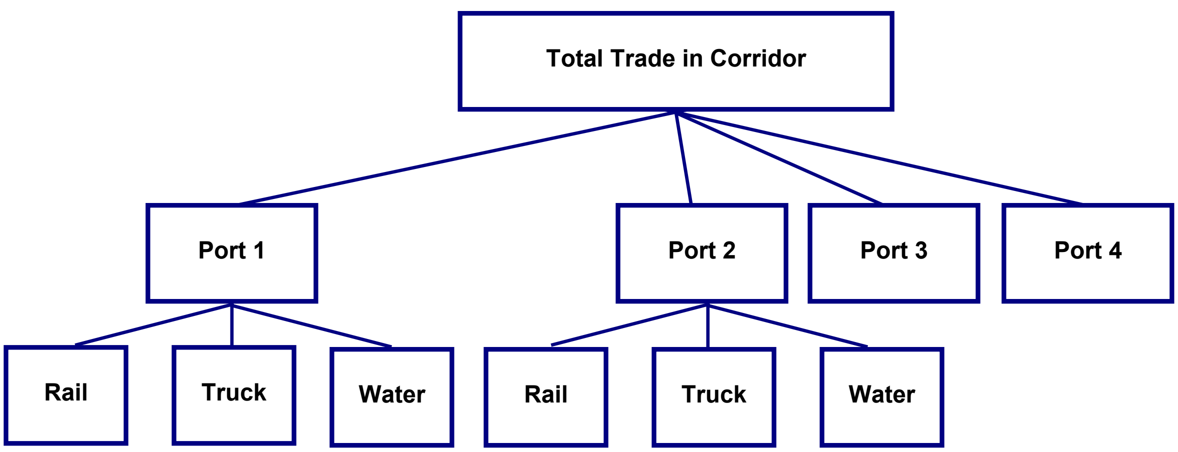
MARKET ACCESSIBILITY MODEL

This model shows how the transportation system performs in generating economic growth and traffic or discouraging economic growth and traffic. Improved transportation networks expand overall markets, while congested transportation networks reduce market size.

MODE AND ROUTE COMPETITION MODEL

The competitive character of each mode is assessed by comparison of their supply chain logistics. This includes details of transit times, prices, reliability, seasonality, access, and egress.
The hierarchical demand function for evaluating transportation strategies included –

Exhibit 2-12: Typical Hierarchical Demand Functions for Evaluating Transportation Strategies



CAPACITY CONSTRAINTS MODEL

An analysis was undertaken to show how the impact of increased congestion at ports or on the inland access and distribution networks affected the relative competitive structure of inland distribution and how such changes influence the relative market shares of each mode.

2.3.3 SUPPLY SIDE MODEL SYSTEMS

The supply side model was developed using a generalized cost metric. This provided the ability to evaluate changes in any of the supply side factors such as price, transit time, seasonality, frequency, reliability, etc. The importance to shippers of each factor was identified in the stated preference survey and included in the generalized cost metric as a weight on each factor.

Such a metric allows the supply side model to evaluate a wide range of transportation strategies and service options. These might include domestic services between the entry ports of Halifax, Quebec City and Montreal and potential inland distribution centers such as Toronto, Cleveland, Detroit, and Chicago. These services would of course compete with existing rail and truck systems and become an effective part of an intermodal network supporting the ports and inland distribution centers of the GLSLS System. The generalized cost metric also allows constraints on the system such as highway or port congestion and capacity constraints to be evaluated in the demand model.

The generalized cost of transportation is typically defined in travel time, i.e., minutes, rather than dollars. Costs are converted to time by applying appropriate conversion factors, as shown below. The generalized cost (GC) of travel between zones i and j for mode m and commodity p is calculated as follows:

$$GC_{ijmp} = TT_{ijm} + \frac{TC_{ijmp}}{VOT_{mp}} + \frac{VOF_{mp}\,OH}{VOT_{mp}\,F_{ijm}\,C_{ijm}} + \frac{VOR_{mp}\ \exp(-OTP_{ijm})}{VOT_{mp}}$$

Where

TT_{ijm}	=	Travel time between zones *i* and *j* for mode *m* (in-vehicle time + wait time + connection time + access/egress time + interchange penalty), with waiting, connect and access/egress time increased by an amount to account for the additional disutility associated with these activities
TC_{ijmp}	=	Travel cost between zones *i* and *j* for mode *m* and commodity *p* (tariff + access/egress cost, tolls, port charges, operating costs for each mode)
VOT_{mp}	=	Value of Time for mode *m* and commodity *p*
VOF_{mp}	=	Value of Frequency for mode *m* and commodity *p*
OH	=	Operating hours per week
F_{ijm}	=	Frequency in departures per week between zones *i* and *j* for mode *m*
C_{ijm}	=	Convenience factor of schedule times for travel between zones *i* and *j* for mode *m*
VOR_{mp}	=	Value of Reliability for mode *m* and commodity *p*
OTP_{ijm}	=	On-time performance for travel between zones *i* and *j* for mode *m*

2.4 Major Study Tasks and Activities

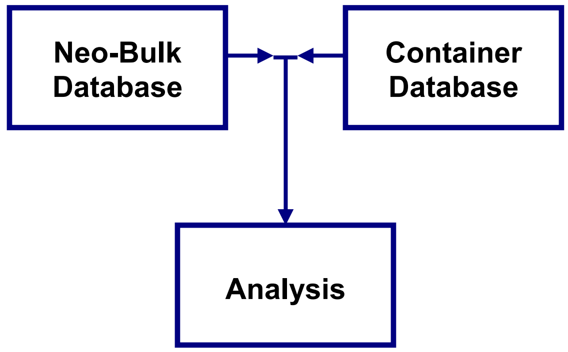
This section outlines the key work tasks completed during the course of the New Cargoes/New Vessels Study and the study deliverables to be provided to the GLSLS Economics Team. This work plan represents TEMS' and RAND's approach to the study. At the outset of the study, there was a detailed discussion of the work plan activities between the GLSLS Economics Team and the study team to ensure that the work plan exactly reflected the needs and goals of the GLSLS Economics Team.

Traffic Database

The development of the container and neobulk cargo database required a process that provided a comprehensive assessment of the study area, total volumes of traffic moving, and the disaggregation of traffic into bulk, neobulk, and container flows. The traffic flows were modeled using origin-destination databases derived from existing data sources. Furthermore, stated preference surveys were used to establish "preference utilities" and their "elasticities," for shippers. This work was completed by constructing specific industrial shipper and carrier surveys.

The approach adopted defined an integrated process for neo-bulk and container cargo database development –

Exhibit 2-13: Database Development



TASK 1: DEVELOP DATABASES

As a preliminary step in the development of the study databank, the consultant reviewed existing transportation data, including both Transport Canada and USDOT freight movement information in the Northeast and Midwest Corridors. This data will include AADT and ADT statistics and Statistics Canada and U.S. Bureau of Economic Analysis (BEA) commodity data. This review identified any new survey data that needed to be collected in order to ensure that the survey effort had maximum effectiveness.

TASK 2: DEFINE SURVEY NEEDS

Once the basic needs for data were established, the sampling frames, design of the questionnaires, development of survey procedures and actual surveys were completed. This was initiated after a pilot testing of questionnaires, survey instruments, and survey approach. A pilot survey was conducted to test the relevance of the proposed questions for each mode and trip purpose quota group. The results of this process were reviewed and the survey questionnaires and methods were adjusted as necessary.

TASK 3: SHIPPER/CARRIER SURVEYS

The surveys were carried out by a field force specially trained in attitudinal and transportation profile survey work. The survey framework was established with the support of the U.S.-based National Industrial Transportation League and Canadian Industrial Transportation Association. They provided membership lists, which were adopted as the survey framework. The Stated Preference Attitudinal Survey was carried out with shipping and carrier companies by means of a web survey. Where necessary, telephone screening and sampling were used in the attitudinal survey as an aid to the data collection process. The data collected was coded, edited, and expanded to provide a comprehensive database. This included the development of a seasonal structure to the database so that forecasts could be made on an annual and seasonal basis.

TASK 4: TRANSPORTATION SYSTEM NETWORK DATA

In addition to the development of demand data on traffic movements, an inventory of all study area systems was compiled to include modes, times, tariffs, tolls, frequencies, location of terminals, costs, etc. This information was obtained largely from departments of transportation and modal authorities (e.g., the St. Lawrence Seaway Management Corporation) and discussions with carriers to ensure that the information on service levels, costs and timetables was the most up-to-date available. The inventory was computerized and set up as part of the overall study database.

TASK 5: SYSTEM DATABANK

A databank was set up containing both demand and transportation systems data. All information was filed and subjected to a data verification assessment whereby crosschecks are made on the basic data to confirm its accuracy. The database was based on a 200-zone system reflecting Census tract and other statistical formats. The study area included a U.S. and Canadian corridor up to 200 miles wide in order to properly include all of the competitive transportation network options. The analysis included large cities such as Halifax, Montreal, Toronto, Hamilton, Boston, New York, Newark, Philadelphia, Baltimore and Washington, which are the key nexus points in the system. This analysis included evaluating service levels of the alternative rail and highway facilities.

TASK 6: TRADE-OFF ANALYSIS

Using the results of the Stated Preference Attitudinal Surveys, a trade-off analysis was carried out to identify the relative ranking and values of both system and mode appeal variables for each SIC/commodity type. For system variables, the analysis defined own mode and cross elasticities of demand for transit time, price and frequency for each mode and shipping purpose. The analysis was a two-stage process and used algorithms specially developed to provide preference utilities, own and cross elasticities and modal bias estimates. For the mode appeal variables, specific rankings, market share, and generalized cost values were derived.

TASK 7: MODEL SPECIFICATION

At the model specification stage, a range of possible modeling systems included various forms of the direct demand, induced demand, and modal/route choice and capacity restraint models for regional transportation were evaluated. A number of different model structures were tested in calibration. Year 2005 was used as the base year for calibration purposes. The agreed upon models were calibrated and the statistical validity of each tested using range, logic and consistency checks. In developing each model system, an interactive assessment was made of the potential role of the variables and the ability of the model to represent transportation behavior.

TASK 8: ECONOMIC SCENARIOS

In order to forecast the impact of regional economic growth on total traffic demand, economic scenarios were prepared on a zonal basis to identify the likely range of GNP, income, population and employment growth over the forecast period. The key input in developing the economic scenarios were the state, federal (Statistics Canada and the U.S. BEA) and commercial long-term forecasts. The results of each forecast were compared and three different long-term scenarios reflecting central, optimistic, and pessimistic growth rates were determined.

TASK 9: GLSLS SYSTEM STRATEGIES

A number of different GLSLS System strategies were developed in conjunction with the GLSLS Economics Team for evaluation in the models. The strategies considered a range of both system and mode appeal factors such as frequencies, speeds, loading times, and quality of service. The analysis considered the use of four vessel technologies. The stated preference mode appeal analysis included different types of services and reliability levels. By examining the impact of these facilities against tariff levels and transit times, evaluations can be made that identify the best GLSLS System strategies. Based on these strategies, the GLSLS forecasts were made. Alternative strategies for other transportation modes were also developed, so that the impact of investment (or disinvestment) in other modes such as changes in transportation time and services of other modes was also incorporated into the transit time forecasts and sensitivity analyses for the GLSLS forecasts. This task was undertaken in conjunction with the GLSLS Economics Team.

TASK 10: DEMAND FORECASTS

Using the economic scenarios and GLSLS System strategies, forecasts for the base year and ten-year intervals between 2005 and 2050 were prepared for new cargoes. For the GLSLS System, estimates were made in terms of freight volumes and revenues on an annual basis; these estimates were made on a route segment and city-pair basis. For other modes, overall cargo movements and market shares were estimated. Interpolation was used to derive forecasts for the five-year increments between 2005 and 2050.

TASK 11: ELASTICITY COMPARATIVE ANALYSIS

Using the elasticities estimated in the Trade-Off Analysis and equilibrium modeling, a comparative analysis was made with the elasticities derived by the consultant in previous studies. These studies provided a range of values against which the study estimates were compared and contrasted. There was a marked degree of comparability between elasticity values once income, trip length, and generalized cost differences are accounted for. Again, close consultation with the GLSLS Economics Team at this stage allowed a full discussion and assessment of the elasticity findings. This was particularly important in validating the forecasts and assuring the quality of the results.

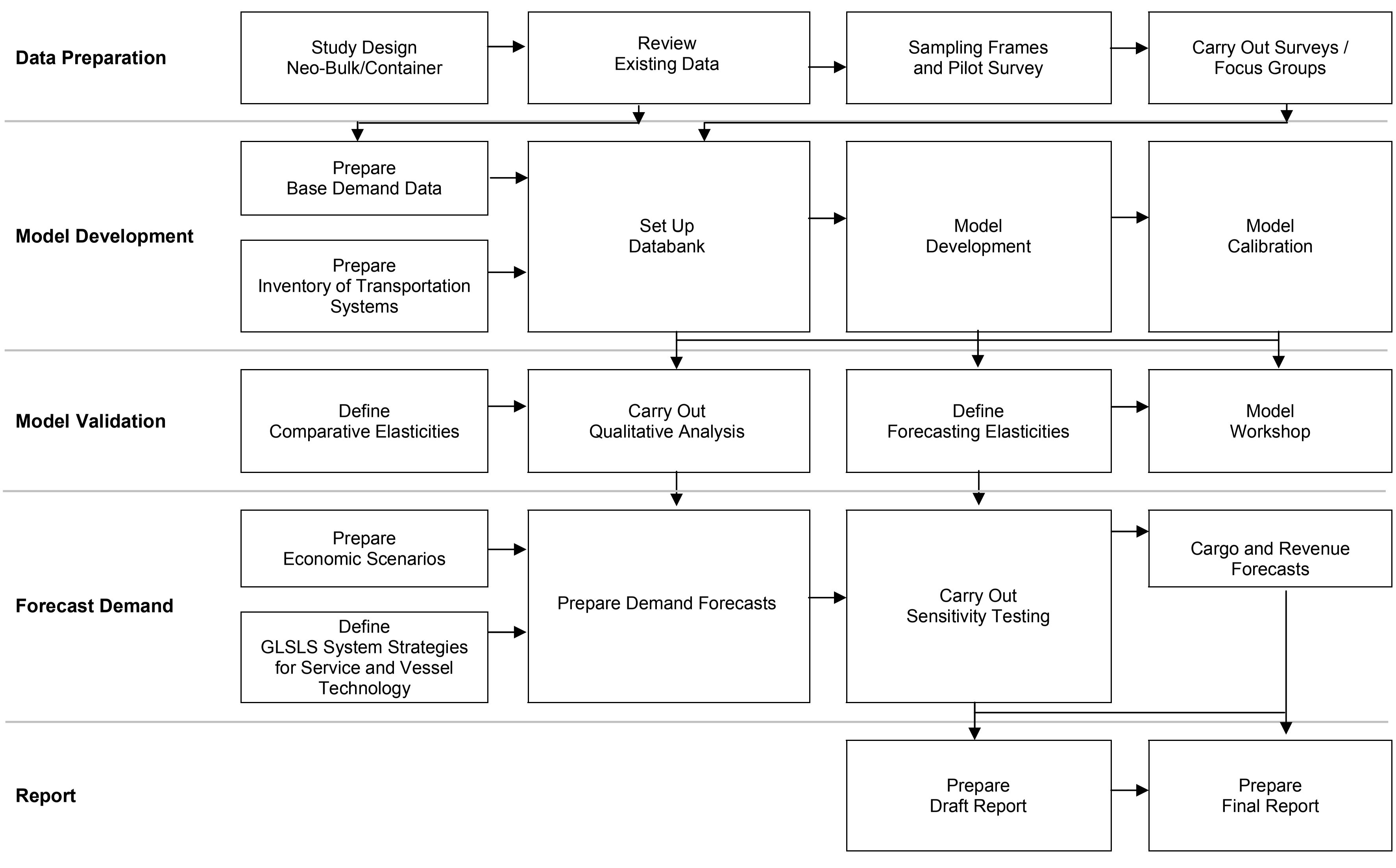
TASK 12: SENSITIVITY TESTS

Sensitivity tests were made for a range of what-if economic scenarios and competitive mode transportation strategies and trip characteristics. Following the completion of the initial forecasting sensitivities, the consultant, in conjunction with the GLSLS Economics Team, reviewed the results.

TASK 13: DRAFT AND FINAL REPORTS

A draft report was prepared, describing all aspects of the study and explained the methodology and findings of each step in the analysis. The draft report provided a comprehensive description of the study, its databases, methodologies used, model systems, results, and findings. In preparing the report, emphasis was placed on the use of graphics to illustrate complex concepts, ideas, and results. The draft report was submitted to the GLSLS Economics Team for review and approval. Upon notification, the final report will be prepared and submitted.

Exhibit 2-14: Generic Work Plan for the GLSLS System New Cargoes/New Vessels Study



2.5 KEY STUDY OUTPUTS

The study provided a wide range of data including the results of the stated preference surveys, the final model calibration estimates of the competitiveness of the GLSLS System for new cargoes (new neo-bulk and container) under different pricing structures, vessel technologies and infrastructure strategies. The market potential for new cargoes and new vessels was identified, projections of cargo volumes and revenue were developed, customer preferences were identified, and strategies to improve the GLSLS service and measures of its competitiveness were developed.

Study deliverables included –

- Cargo composition profiles for the GLSLS System showing variations in use. The profile identified volumes, values, and transportation characteristics of each cargo type by each traffic. This data was collected during the shipper profile analysis that was completed as part of the stated preference survey. The data was edited, coded, and stored in the demand model for use in the demand forecasting process. It was directly output from the model's databank and estimated market shares for the GLSLS System were produced as a result of calibrating the demand model.
- Base and forecast year networks specifying generalized times, costs and interchange penalties for cargo movements. These were suitably weighted by industrial distributions for each zone pair for the whole zone system. This is a direct output of the edited data files in the demand model.
- Base and forecast year equilibrium steady state market shares. These were given on an annual basis over the life of the project, drawn from the demand model. The forecasts and modal split estimates showed the growth in cargo and how long it will take to reach equilibrium or steady state conditions.
- Estimates of container markets in terms of current size, historic trends, and long-term annual forecasts through 2050.
- An analysis of the trends in movement costs and service levels for the period 2004 to 2050. This analysis was an integral part of the strategy formulation process, considered changes, or emerging trends (e.g., capacity limitations) in transportation conditions for each competitive mode of transportation analyzed and the potential impact on the GLSLS System.
- A composite set of cargo and revenue forecasts for all city-pairs and routes, incorporating sensitivity tests for each economic scenario and transportation strategy and including an analysis of truck and rail service options and a revenue maximizing analysis. The analysis also considered competitive responses in terms of lower rates and/or improved facilities. The forecasts were subject to a robustness analysis that checked, by model structure, weights, coefficients, functions, etc., the sensitivity of forecasts, market segments, and origin-destination movements.
- A set of model elasticities that show the likely variation of cargo, service levels, tariffs and other critical input variables was developed.

3 ECONOMIC SIGNIFICANCE OF THE GREAT LAKES AND ST. LAWRENCE SEAWAY

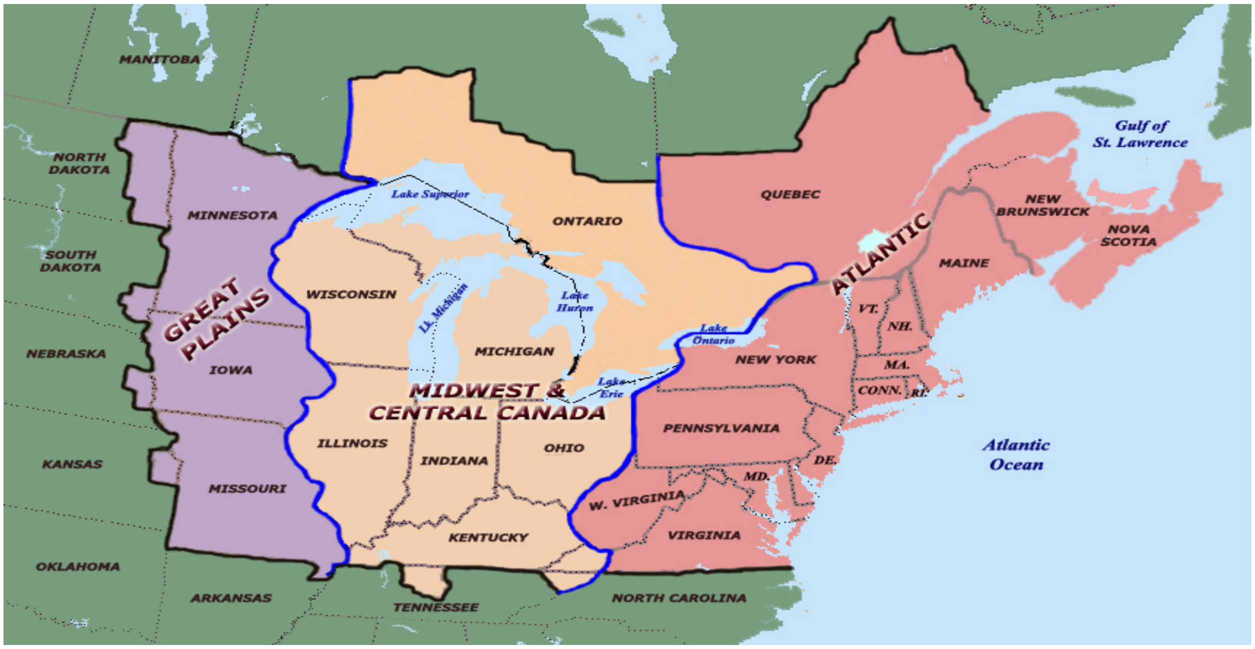
3.1 INTRODUCTION

The Great Lakes and St. Lawrence Seaway (GLSLS) runs through the heart of one of the most densely populated and leading economic regions of the U.S. and Canada. This 2,300-mile inland waterway stretches from the Gulf of St. Lawrence, along the St. Lawrence River and across the Great Lakes linking the U.S. and Canadian seaboard cities of the U.S. North East, Atlantic Canada, and Quebec with the Midwest and Central Canada and the Canadian and U.S. Prairies and Great Plains. As such, it links the trade and business oriented Atlantic seaboard cities, with the manufacturing and industrial heartland of the Midwest and Central Canada and the primary resource, agricultural and mining areas of the Canadian Prairies and Great Plains. It includes some of the largest cities of the U.S. and Canada such as Chicago, Cleveland, Columbus, Detroit and St. Louis, as well as Canada's two major cities of Montreal and Toronto.

The GLSLS is therefore a major trade corridor providing access to both the Atlantic Ocean and Europe and to the interior of North America. It is at the heart of what has become the world's largest manufacturing region supported by a transportation nexus that links the Atlantic coast "ports of entrée" with the agricultural, forestry, minerals and one with the resources of the Great Plains and Prairies. In its development, the Great Lakes and St. Lawrence Seaway region relied heavily on flows of goods, services, and labor from both the old colonial seaboard communities and the resources of the interior. As a result, the region's trade flows have always been both east and west and with the increasing globalization of the world economy these flows have been enhanced and overlaid by new flows that reflect the emerging 'new economy' of the region, as well as the growth of trade with Asia.

To understand the existing and future role of the GLSLS, it is essential therefore to understand the region's trade relations with the Atlantic Seaboard "ports of entrée" as well as the resource flows from the interior and the increasing trade with Asia. As shown in Exhibit 3-1, in defining the study area for the New Cargoes and New Vessels Study, it was necessary to define a region that includes the major east coast ports of the U.S. and Canada and their highway and rail access routes to the Midwest and Central Canada. In addition, it was necessary to include as the part of the Great Plains and Prairies that provide access by rail and highway to the western Great Lakes ports. For comparative purposes, data is provided for the GLSLS Study Region as a whole, as well as the Atlantic Region, Midwest and Central Canada and the Prairies and Great Plains.

Exhibit 3-1: Great Lakes and St. Lawrence Seaway Study Area

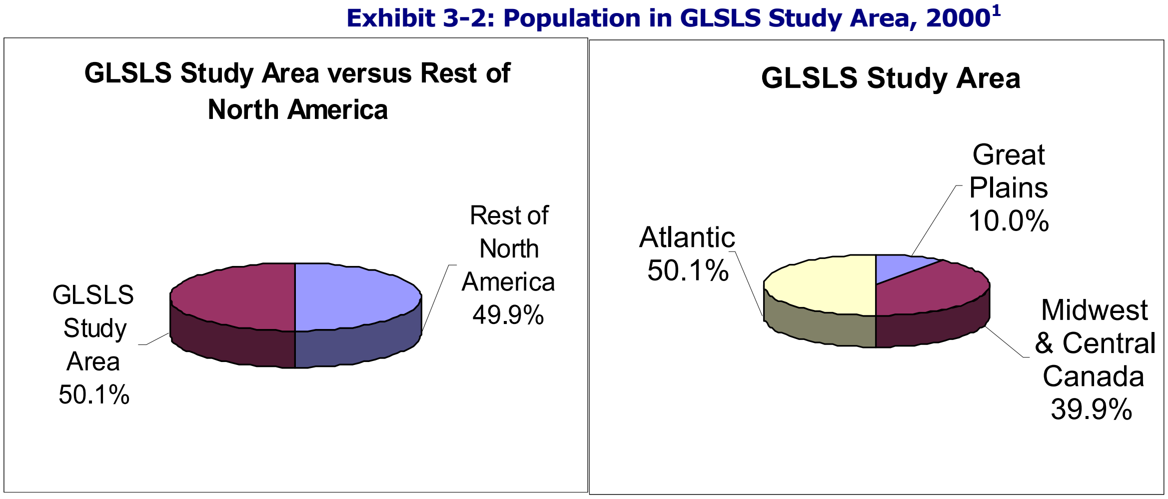


3.2 The Region's Development

Exhibit 3-2 shows that the year 2000 population of this region was almost 156 million or 50 percent of the U.S. and Canadian population. In terms of the distribution of population within the study area, 50% is in the Atlantic Seaboard and 40% is in the Midwest and Central Canada and 10 percent in the Great Plains.

The population is settled on less than 20 percent of the land mass of the U.S. and Canada. With the exception of certain West Coast cities (San Diego-Los Angeles, San Francisco-Oakland, Seattle and Vancouver) and the growing SMSA's of South Florida and Texas, the GLSLS region has the highest population density containing 60 percent of the urban population of Canada and U.S.

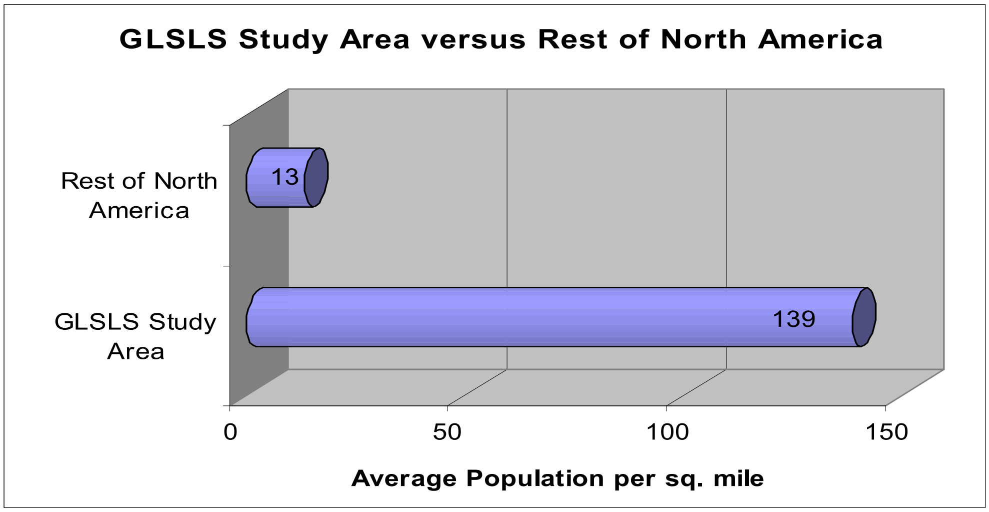
Exhibit 3-2: Population in GLSLS Study Area, 2000[1]



[1] US Population is 281.4 million, the Canadian Population is 29.8 million for year 2000.

Exhibit 3-3 shows that the population density of the GLSLS study area has an average of nearly 140 people per square mile compared with just under 15 people per square mile for the rest of North America.

Exhibit 3-3: Population Density in GLSLS Study Area, 2000



The concentrations in population in the region reflect the fact that the bi-national Atlantic Seaboard areas were the earliest areas developed by the flood of European immigration in the 18th and 19th Century, but grew as the great trade and service centers for the whole continent. As a result, cities like New York, Philadelphia, Boston, and Montreal still play a dominant role in the economy of the region and indeed all of North America. Further west the heartland of Central Canada and the Midwest grew as North America's premier manufacturing centers in the 19th and 20th Centuries. This development reflected the population's ingenuity, its new transportation nexus, and the resource base (agricultural products, coal, iron, steel, wood, and labor) that were the key to the industrial revolution in both Europe and North America. The transportation nexus of the Midwest reflected the flow of products from both the Atlantic seaboard and the flow of resources (agricultural, ores, coal, and wood) from the Great Plains and Prairies. The Midwest became in Chicago, Detroit, Cleveland, Buffalo, Toronto, and Hamilton and a mass of other smaller water ports a convenient break of bulk point. At these locations, steel and other metal manufacturing lead to vehicle assembly and building. Initially the region built boats (e.g. the ships for the 1812-14 war between the U.S. and Canada were built in Erie, Pennsylvania and Dover, Ontario) which led to trains and rail cars and finally to automobiles and trucks. The ready availability of needed raw materials, transportation, and labor spurred the development of the industrial complex that even today is the world's largest vehicle manufacturing center.

As its industrial and engineering base expanded and its work force developed, the region became a major market for products in its own right. While initially, the region's products were imported from Europe gradually they began to be produced locally. The market continued to grow, supported by a growing population and the expanding income of the region. This expansion of the market was accelerated in the early part of the 20th Century as Europe experienced two world wars and looked to North America for support and products. By the mid twentieth Century, the Midwest and Central Canada had become the largest manufacturing center in the world with a specialization in fundamental products like iron, steel and chemicals, as well as the manufacturer of every type of equipment, machine and, of course, vehicles.

To meet the needs of the Midwest and Central Canada, specialist transportation systems were developed to support the region's role as a transportation nexus and manufacturing center. Some of the key developments include –

- The early development of water, canal, and port systems for the movement of bulk commodities that in particular provided support for the basic industries of iron, steel and metal manufacturing, and agricultural processing across the Midwest and Central Canada.
- The development of railroads from the Atlantic Seaboard as well as the Prairies and Great Plains created critical hubs and yards in Chicago, St. Louis, Cleveland, Detroit, Toronto, and Montreal to interchange products. These transport hubs provided the focal point at which the needs of the region's manufacturing industry could be met and a location for manufacturing to grow and prosper particularly in the late 19th Century and early 20th Century.
- The development of the Interstate/expressway highway system and in particular the development of the New York, Pennsylvania, Ohio and Illinois toll roads and Canada's 401 provided the accessibility and cost efficiencies that were critical to the development of the light manufacturing facilities that grew so rapidly with increasing consumer needs in the second half of the 20th Century.

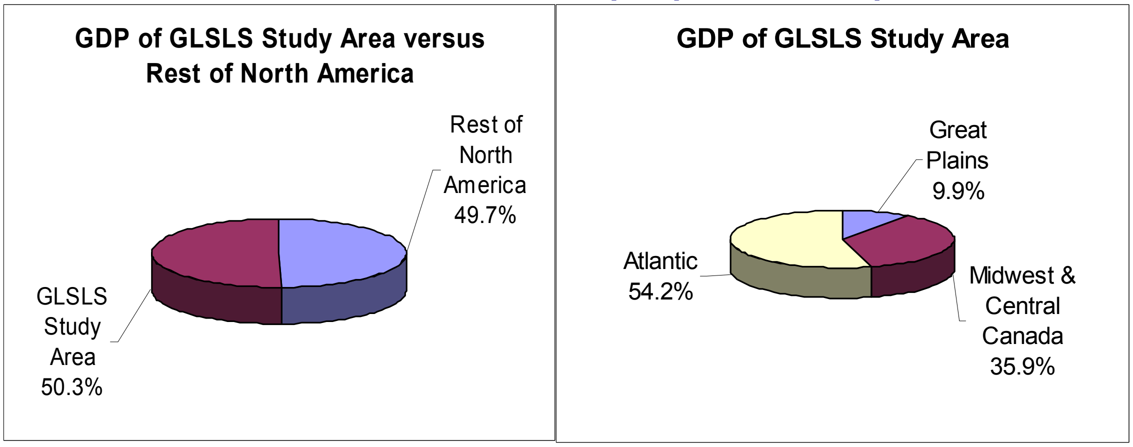
With this support the Midwest and Central Canada grew into one of the most diverse and comprehensive manufacturing regions in the world –

- The region had a powerful resource base in terms of primary products (agricultural, forestry and mining) to supply its factories.
- It had strong market in both the eastern seaboard communities but also in its own growing population.
- It had a productive labor force that was not only able to develop products but to reengineer them time and time again to make them even more attractive, efficient low cost, and diverse products.
- As a result, by the mid 20th Century the Midwest and Central Canada region came to be the leading manufacturing area in North America and across the world. Its key products include everything from basic iron, steel, and chemicals, to automobiles and washing machines, to pharmaceuticals and paints and consumer products of every kind.

3.3 The Region's Economy Today

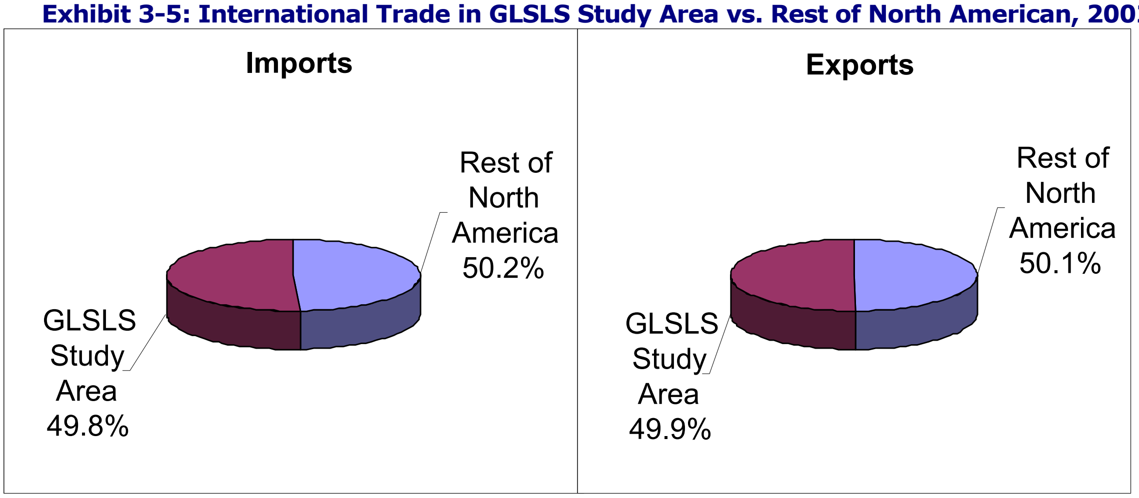
Today the Great Lakes and St. Lawrence Seaway region has one of the most diverse and vibrant economies of the world. It produces nearly 50% of North American Gross Domestic Product (see Exhibit 3-4). It not only dominates manufacturing and service industries of North America, but also reaches out across the world to the other major economies of the world in Europe and Asia. The economy's activities are globalized with trade flows east through the Atlantic ports and west across the continent to west coast Pacific ports.

Exhibit 3-4: Gross Domestic Product (GDP) in GLSLS Study Area, 2004.[2]



The Region has a highly significant share of international trade. Both imports and exports of the region account for more than 50% of the corresponding total North American imports and exports, see Exhibit 3-5[3].

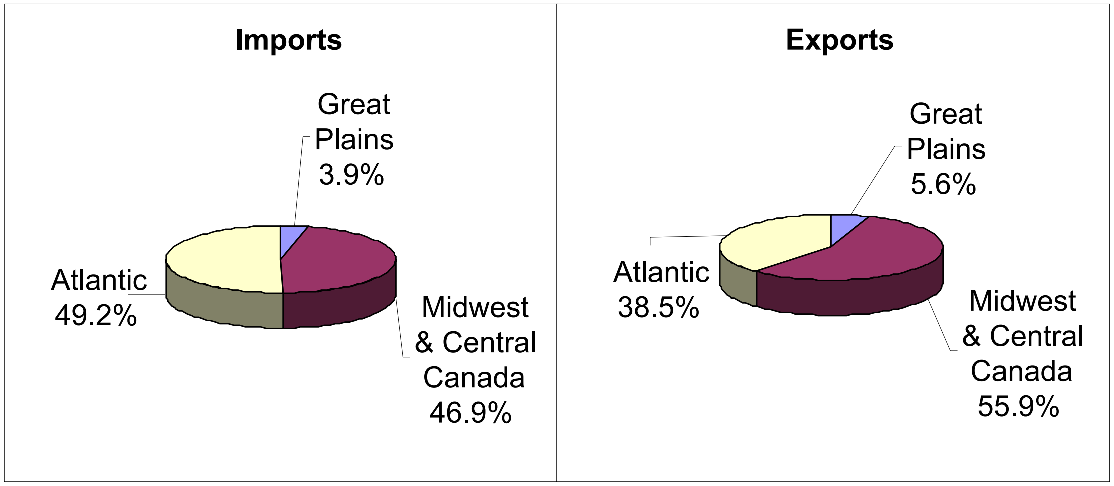
Exhibit 3-5: International Trade in GLSLS Study Area vs. Rest of North American, 2002[4].



The largest share (almost 56%) of GLSLS exports is from the Midwest of the U.S. and Ontario in Canada. Atlantic seaboard is the leader in import performance of the region. The major role here belongs to New York port. It accounts for more than 40% of Atlantic seaboard imports or 20% of overall GLSLS imports. Among other ports that play an especially significant role in the import activity of GLSLS region are the Canadian ports of Ontario and Quebec provinces (having 21% and 5% of the overall regional imports respectively) and the American ports of Detroit, Mi (14%), Chicago, Il (8%), Buffalo, NY and Cleveland, OH (5% each).

[2] U.S. GDP is 92 percent; Canadian GDP is 8 percent of the US$ 6,294 billion GLSLS region's GDP.
[3] These figures include U.S.- Canadian Trade.
[4] U.S. imports are 74 percent of US$ 688 billion GLSLS region's imports; U.S. exports are 61 percent of the US$ 471 billion GLSLS region's exports.

Exhibit 3-6: International Trade in GLSLS Study Area, 2002[5]



As a result of its economic strength, the region is the headquarters of more than half of the top in 2006 Fortune 500 companies in 2006. It has 30 firms in the top fifty Fortune 500 companies by revenue with combined revenues of more than 2 trillion dollars or 53 percent of the total revenue generated by these top firms. The largest of the region's firms are General Motors and Ford (ranked 3rd and 5th respectively) which are supported by a host of competitors and suppliers. The automotive assembly industry is distributed across the Midwest and Central Canada spreading out from Detroit and Windsor west to Chicago and Rockford, east to Toronto/Montreal and upper New York State. The region contains about 55 percent of North America's manufacturing and service industry.

The diversity of the region's service economy is phenomenal. It encompasses financial services and banking in the older Atlantic coast cities (e.g., Citigroup ranked 8th, J.P. Morgan Chase and Morgan Stanley ranked 17th and 30th respectively) to computer equipment, software and information services (IBM ranked 10th and AOL Time Warner ranked 40th), and Telecoms (Verizon ranked 18th and Sprint ranked 59th) through Consumer Products (Target and Sears ranked 29th and 33rd) to agricultural and resource companies (e.g. Archer Daniel Midland and DuPont ranked 56th and 73rd).

The area not only contains the largest assembly of manufacturing and service industries but also has substantial markets. The region is home to seven of the top twelve markets in North America and the region at a figure of over 1.7 trillion, has about 50 percent of total North American retail sales. These markets include New York, Philadelphia, Chicago, Detroit, and Toronto. Across the region, the urbanized population supports an ever expanding and growing market for retail goods and services.

In terms of the breakdown of the industrial structure, Exhibit 3-6 shows the composition of the region's industry. Finance, professional, and information services constitute 37% of the region's economy, with manufacturing and wholesale trades constituting another 18 percent of the region's activity. Primary industry (Agriculture, Forestry, Fishing, Hunting, and Mining) only represents 1-5 percent of industrial activity while transportation and retail trade each represents about 6%.

[5] Includes U.S. and Canadian trade.

The industrial composition of the GLSLS study area compared to the rest of North America shows that it is very much a reflection of the whole North American economy (see Exhibit 3-7).

However, it does exhibit lower primary industry and more manufacturing, finance and information industry. It has slightly higher education, health and social services, but slightly lower retail trade and public administration services as a percentage of the total. Within this framework, the Atlantic seaboard is higher in financial, professional and information service industry with slightly weaker manufacturing and wholesale trades and much weaker primary industry activities (see Exhibit 3-8). The Midwest and Central Canada are much stronger in manufacturing; slightly stronger in transportation and slightly lower in financial services (see Exhibit 3-9). As might be expected the Great Plains and Prairies are stronger in primary industry, construction, manufacturing and transportation industry, but slightly weaker in all forms of services, (see Exhibit 3-10).

Exhibit 3-7: Industrial Composition by 2004 GDP - GLSLS Study Area

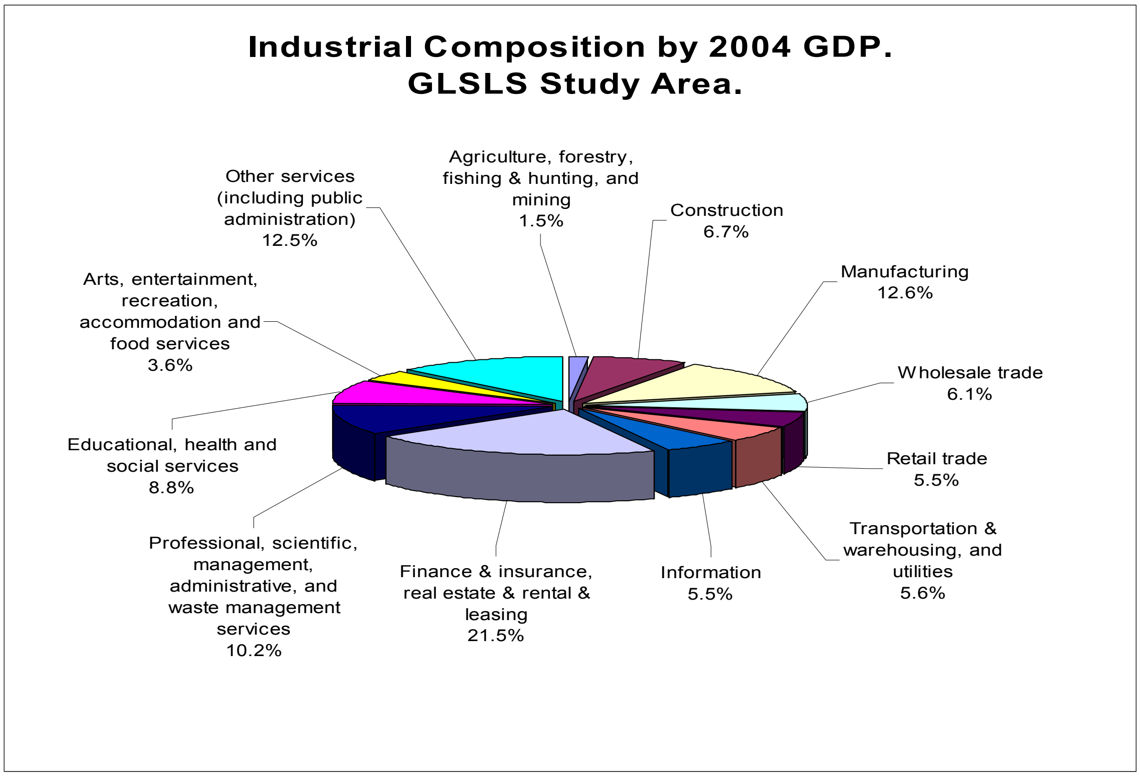


Exhibit 3-8: Industrial Composition by 2004 GDP - North America excluding GLSLS Study Area

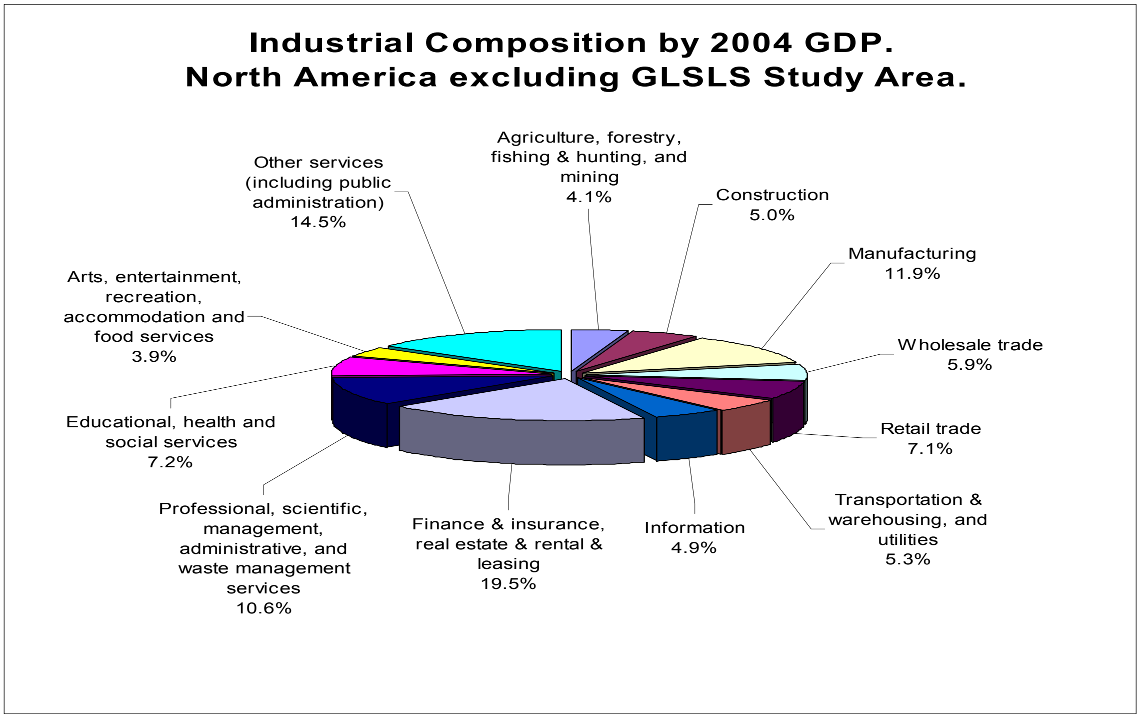


Exhibit 3-9: Industrial Composition by 2004 GDP - Atlantic

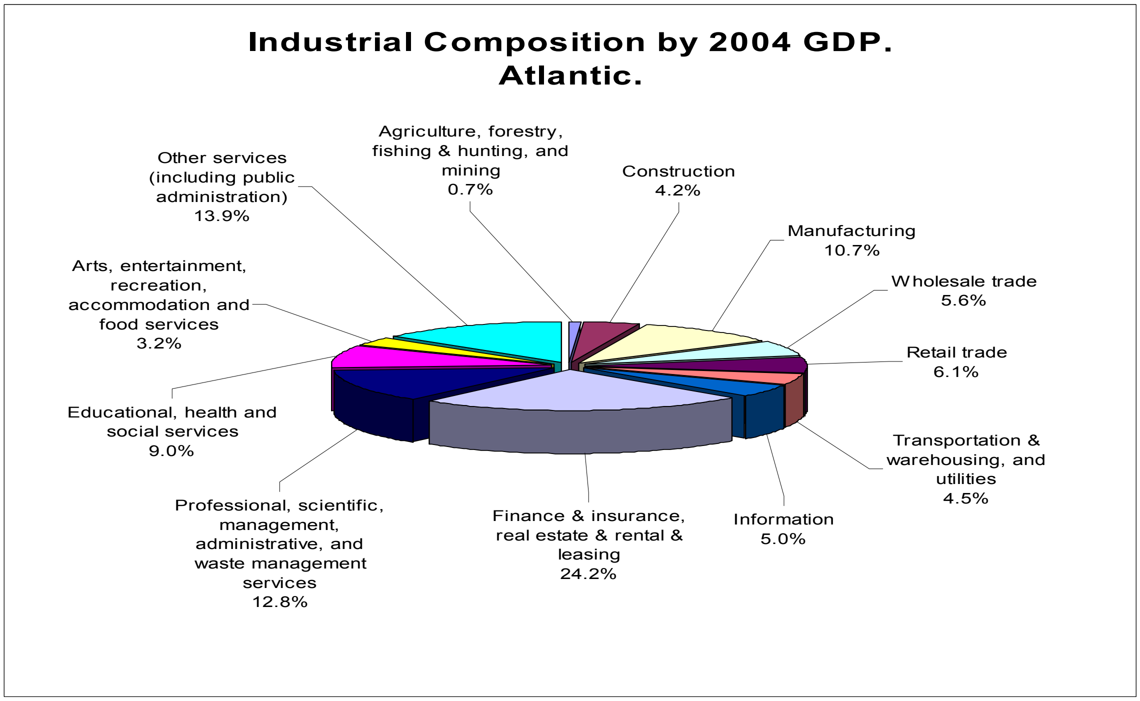


Exhibit 3-10: Industrial Composition by 2004 GDP - Midwest & Central Canada

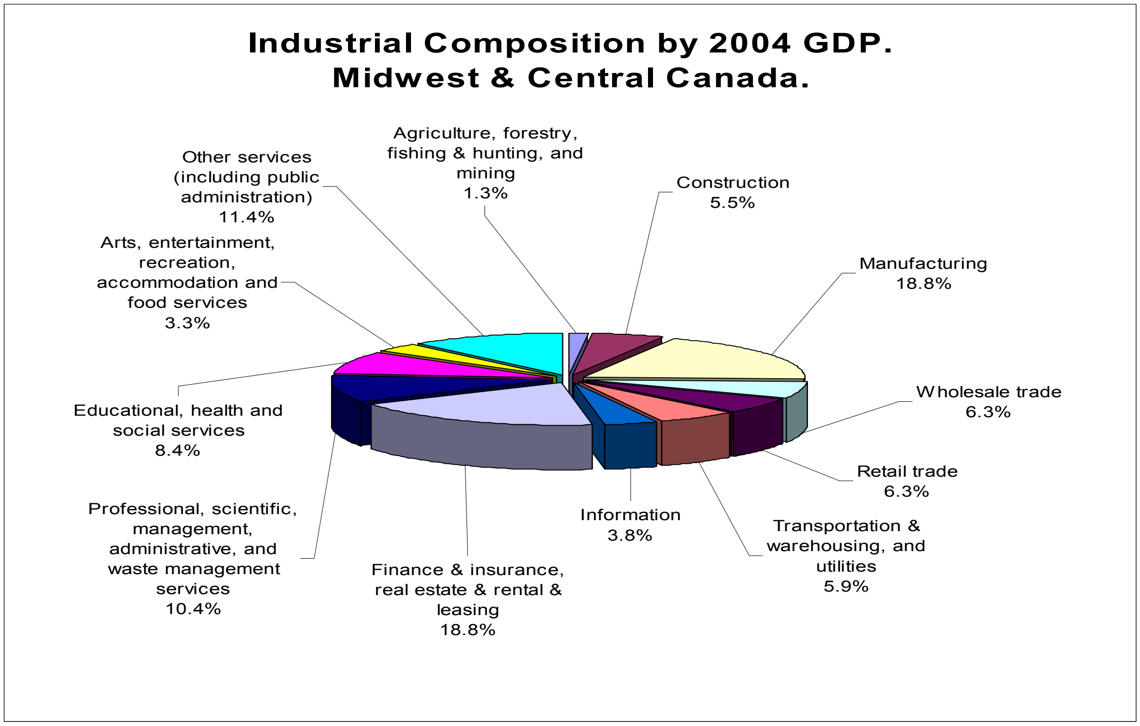
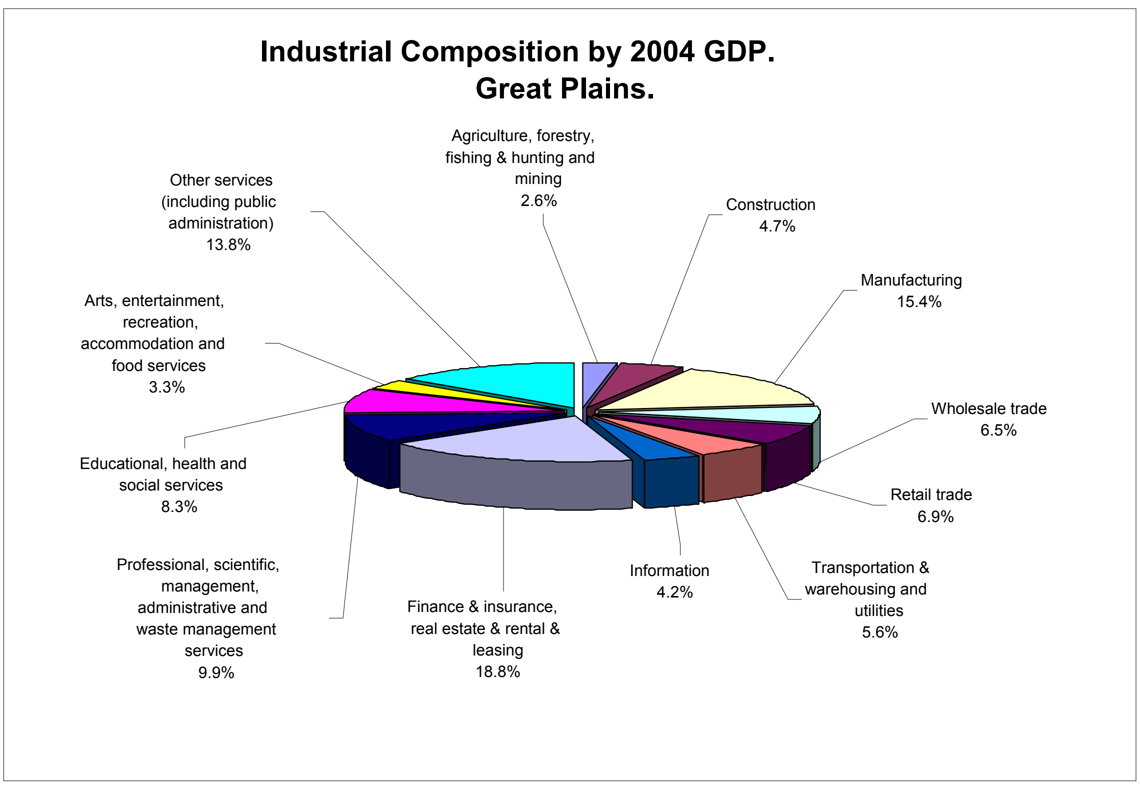


Exhibit 3-11 Industrial Composition by 2004 GDP - Great Plains



3.4 THE REGION'S HUMAN RESOURCES

A key factor in the success of the study region is the character of its 156 million population. As with the rest of North America 60 percent of the GLSLS population or 93 million people are of working age, see Exhibit 3-12.

Exhibit 3-12: Age Distribution - GLSLS Study Area vs. Rest of North America (2000)

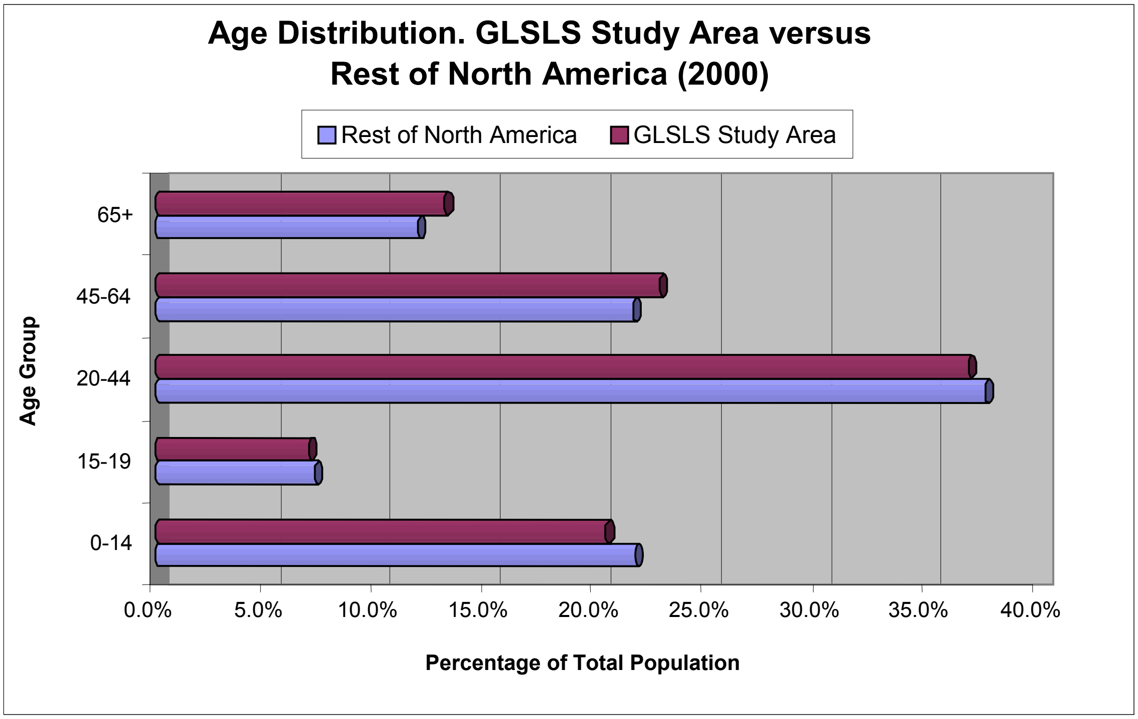
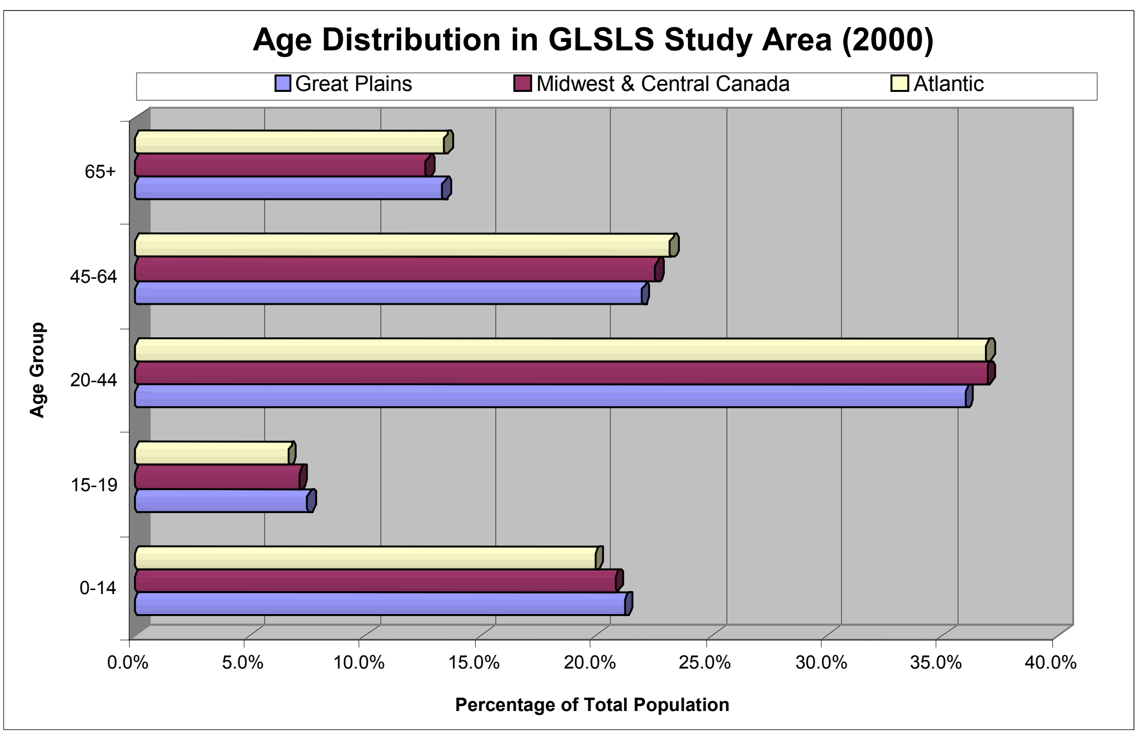


Exhibit 3-13: Age Distribution in GLSLS Study Area (2000)



This characteristic applies across the whole region, although the Atlantic region has slightly older population than the Midwest & Central Canada, which has slightly older population than the Great Plains and Prairies (see Exhibit 3-13).

In terms of education, more than 50 percent of the population has some form of higher education (see Exhibit 3-14). The percentage with Bachelors and higher degrees is greatest on the Atlantic seaboard, over 25 percent. However, the Midwest, Central Canada and the Great Plains and Prairies are not far behind at over 20 percent, particularly in Bachelor degrees (see Exhibit 3-15). The region therefore has a work force that is both able and educated.

Exhibit 3-14: Educational Attainment - GLSLS Study Area vs. Rest of North America (2000)

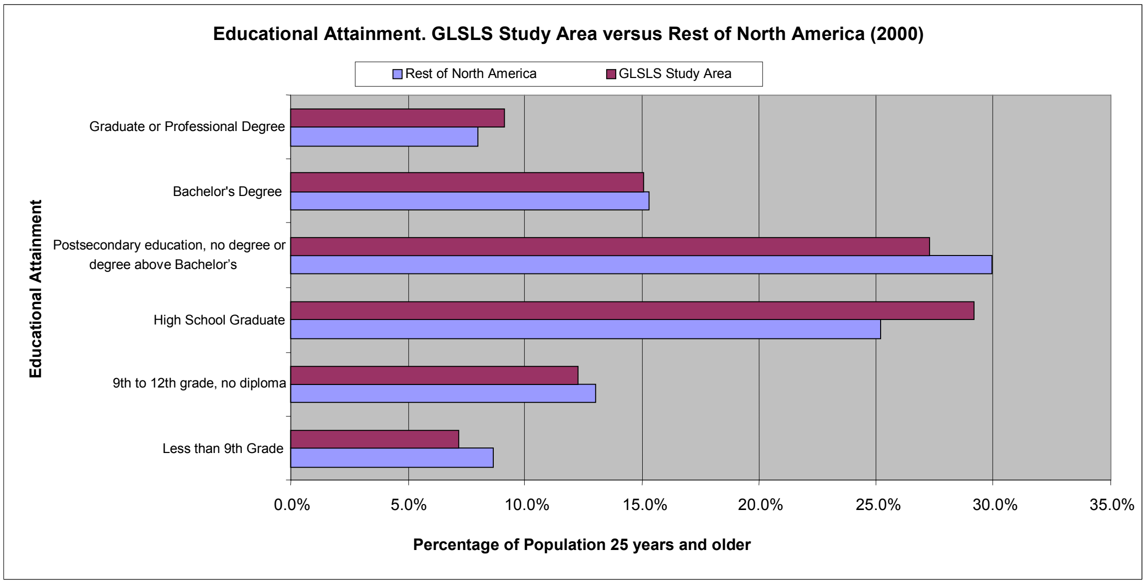
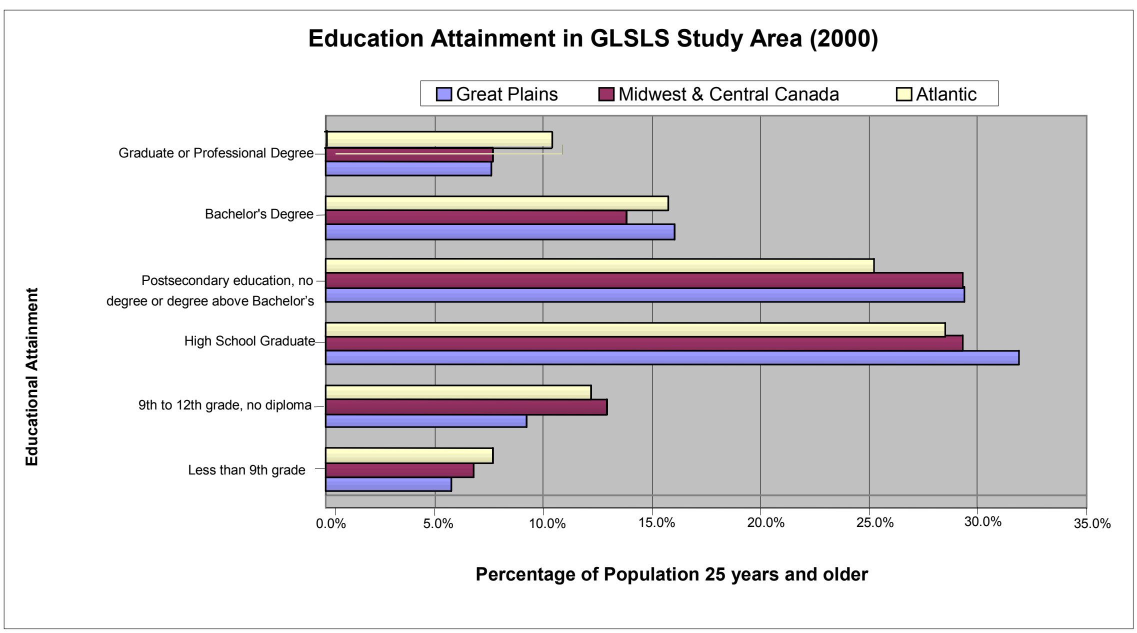
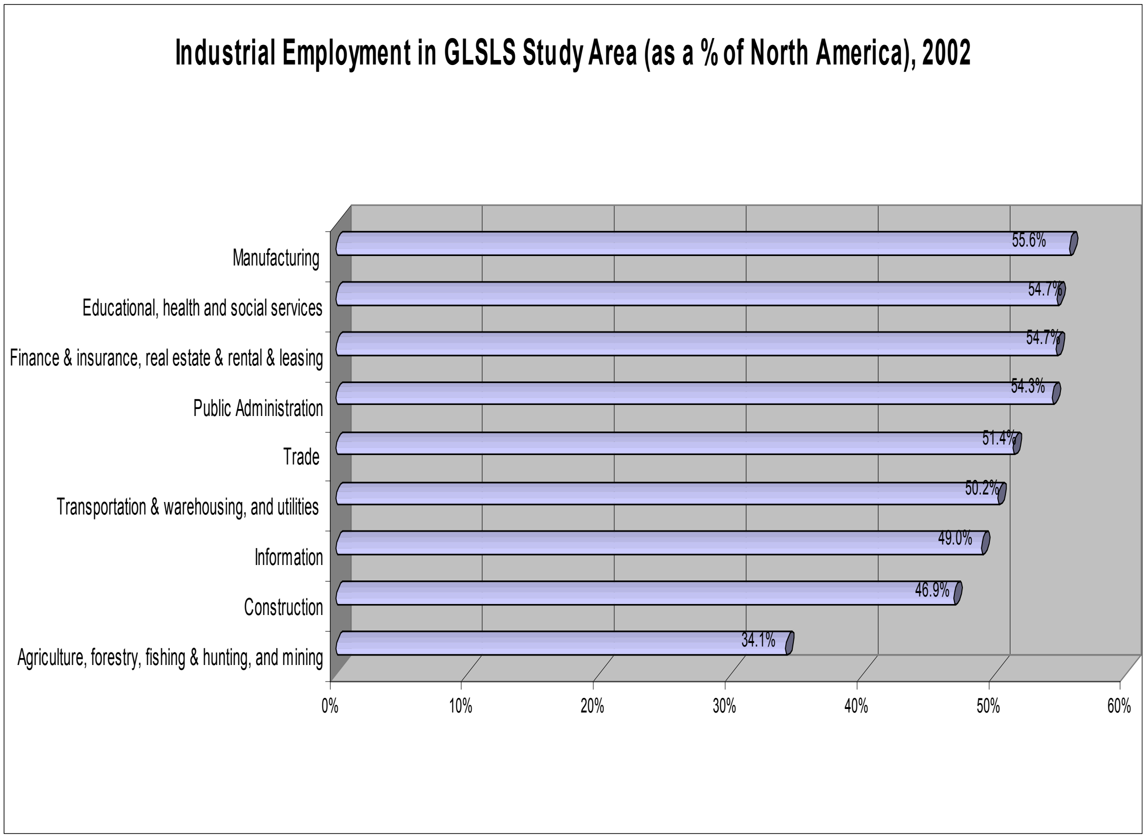


Exhibit 3-15: Education Attainment in GLSLS Study Area (2000)



Within the GLSLS region, more than 74 million people (or 80% of the region's population of working age) are employed. 64.4 million are in the U.S. and 9.6 million are in Canada. As can be seen from Exhibit 3-16, in terms of employment the GLSLS region plays the dominating role in North American manufacturing (57%), also in finance, insurance, real estate rental and leasing (55%) and public services such as education, health, social services and public administration services (54-55%). In comparison with the rest of North America, the GLSLS study area also has a slightly higher share of employment in trade (51%) and transportation & warehousing and utilities (50.2%). Exhibit 3-17 shows that Midwest & Central Canada is a working place for those occupied in manufacturing its share is more than 27% of the corresponding number in North America. We can see from the same Exhibit that Atlantic Seaboard has a high share of employed in service industries (22%-28% of North American employment in these finance) and in insurance & rental & leasing (almost 30% of the corresponding North American employment).

Exhibit 3-16: Industrial Employment in GLSLS Study Area (as a % of North America), 2002



If we look at the employment in the specific sub-industries of manufacturing, we can examine the special role of certain types of production in the region. From Exhibit 3-18 we can see that the region plays extremely significant role in motor vehicle manufacturing and primary metal manufacturing. The share of the regional employment in the overall employment in these industries in North America accounts for 74% and 70% correspondently. The highest share here belongs to iron & steel mills & ferroalloy manufacturing (79%). All these industries are located mainly in Midwest and Central Canada (see Exhibit 3-19).

Exhibit 3-17: Industrial Employment, 2002 - Parts of GLSLS Study Area as a % of North America

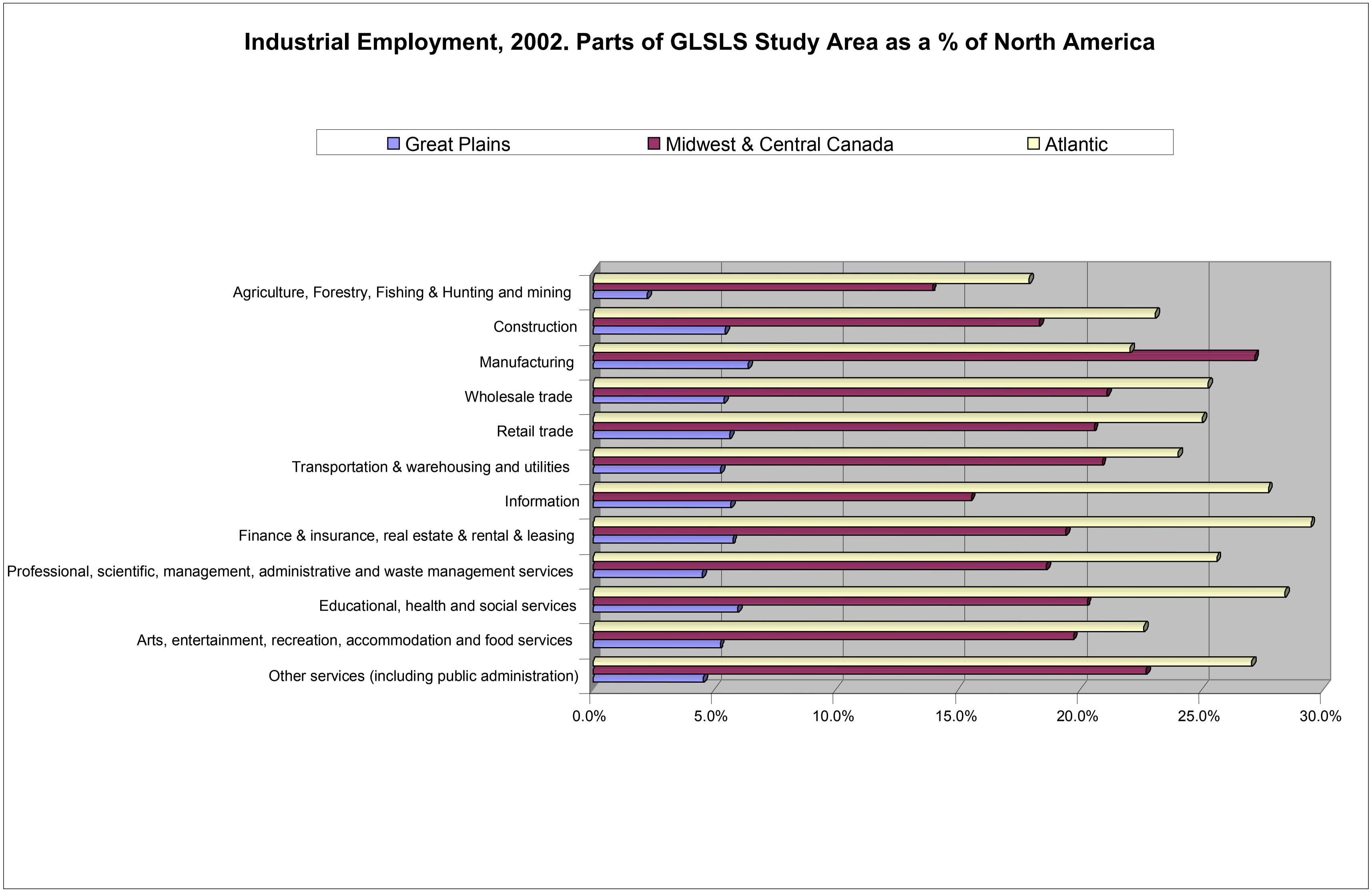


Exhibit 3-18: Employment in Manufacturing - GLSLS Study Area vs. North America (2002)

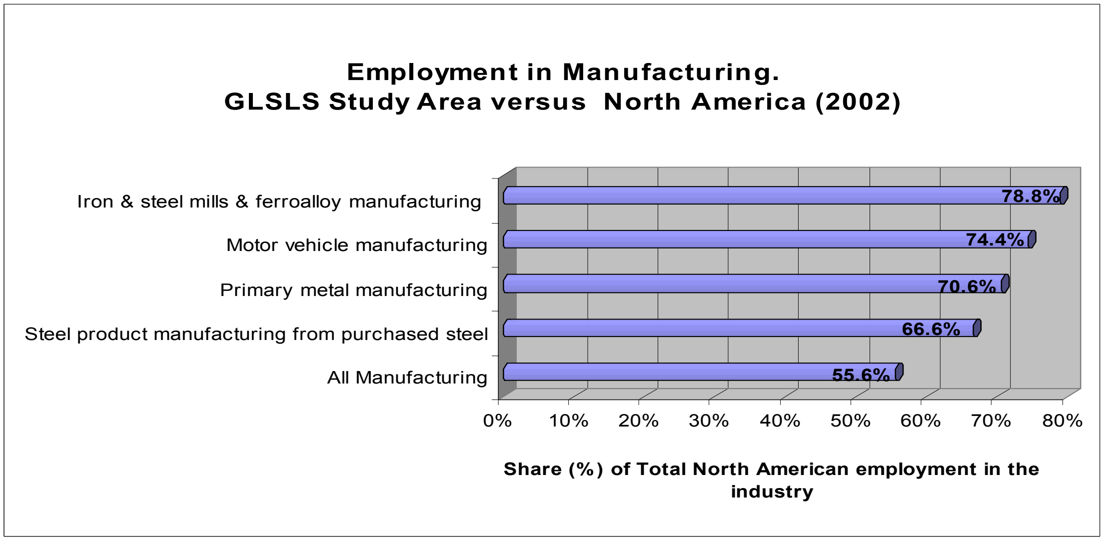
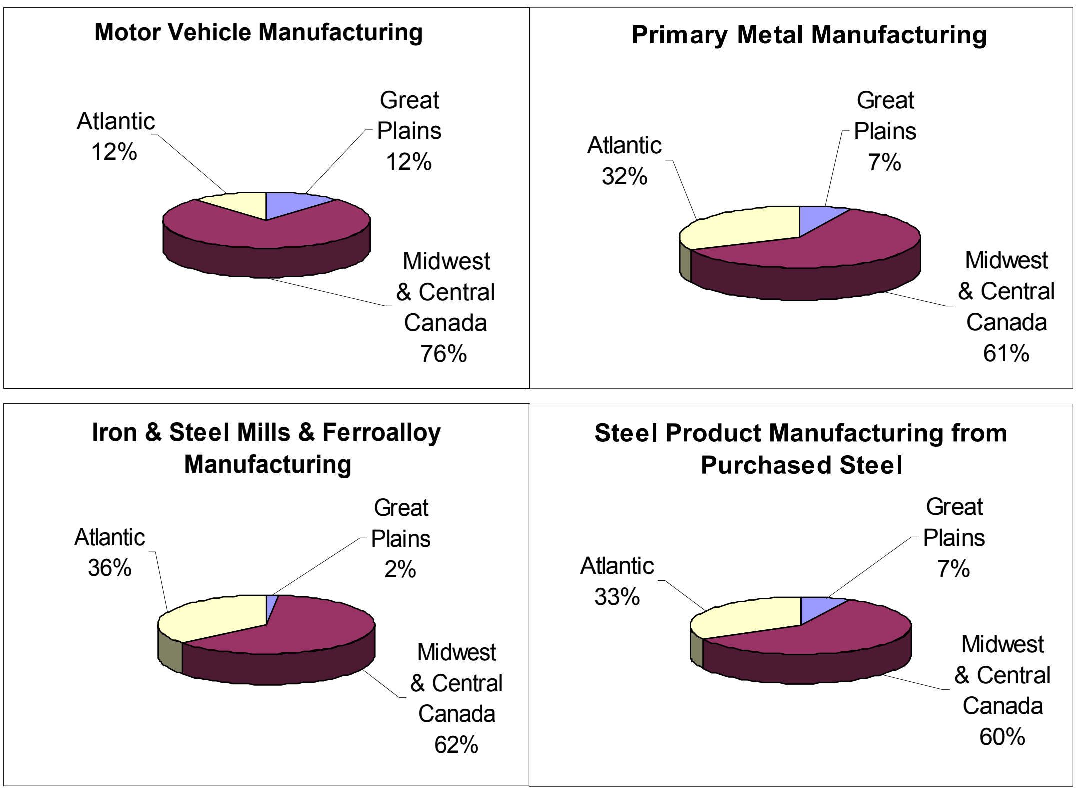


Exhibit 3-19: Employment in Selected Manufacturing Industries - GLSLS Study Area, 2002



In terms of income and the reward, the region gives its workforce, the region has 50 percent of its adult population earning over $25,000 per year and 15-20 percent making over $50,000 per year (see Exhibit 3-20). In Exhibit 3-21, it can be seen that the Atlantic region has a higher percentage earning over $50,000, but that the Midwest & Central Canada and Great Plains are not far behind. This creates strong purchasing power and makes this region the world's strongest market place.

Exhibit 3-20: Income Stratification - GLSLS Study Area vs. Rest of North America (2000)[6]

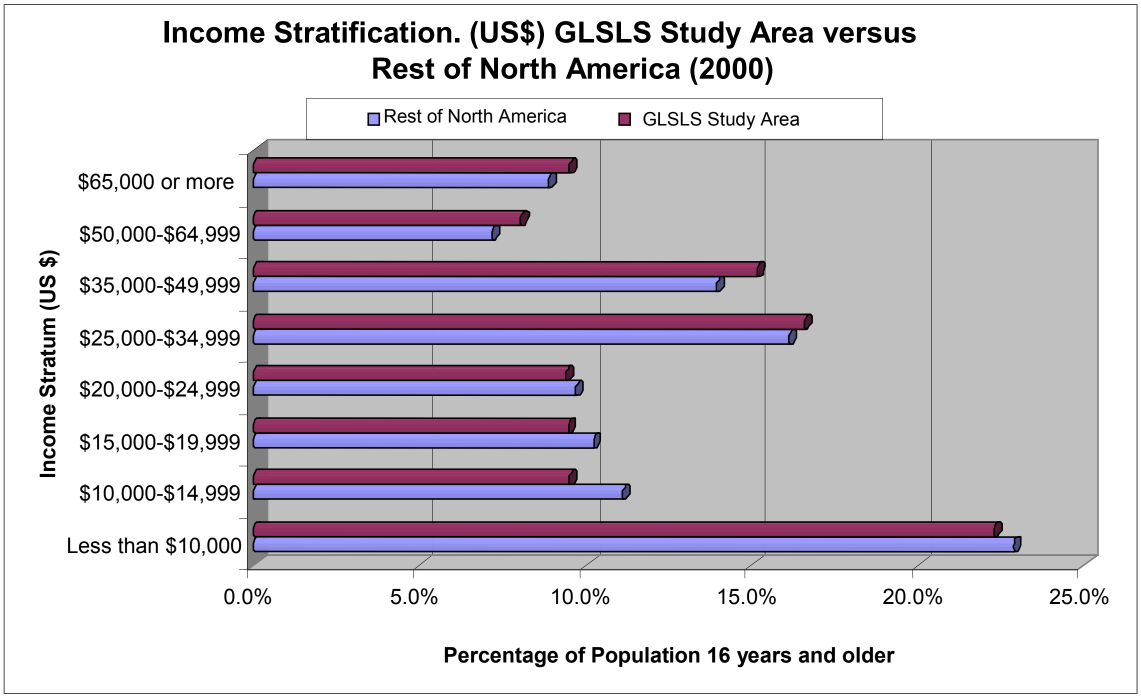
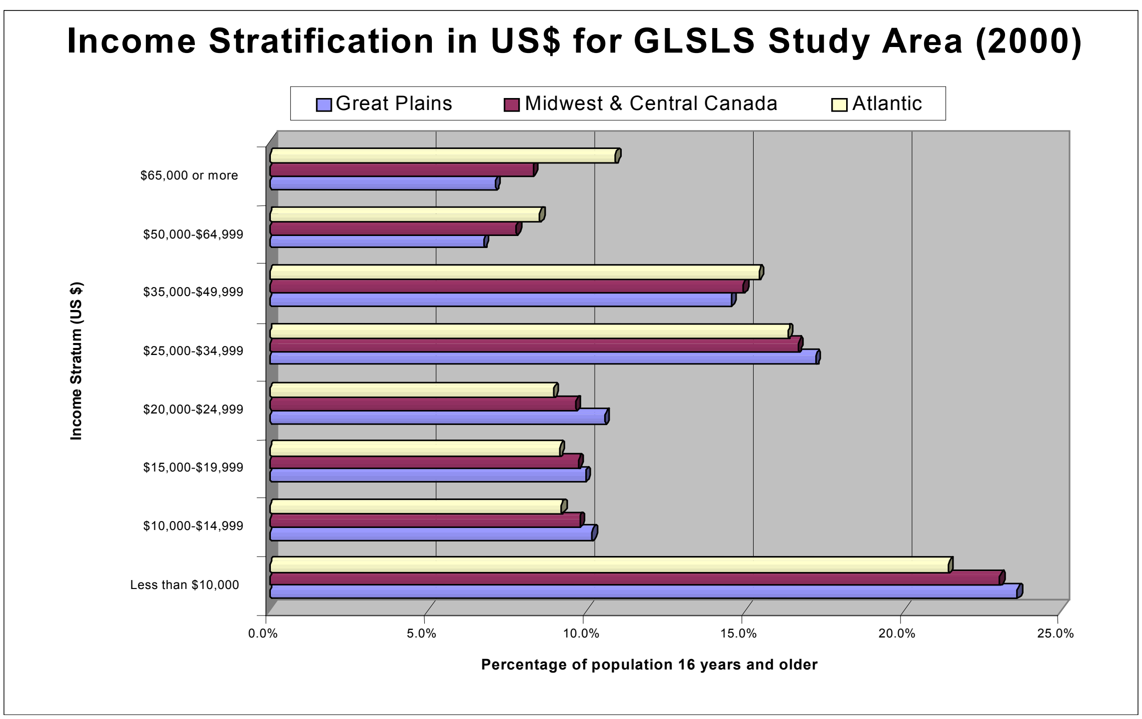


Exhibit 3-21: Income Stratification in GLSLS Study Area (2000)[6]



[6] US/Canada purchasing power was derived from OECD estimates for year 2000.

3.5 Economic Future and Scenarios

The development of long-term traffic forecasts is dependent on the projection of long-term socioeconomic trends. The most important of these socioeconomic factors are population, employment, income, gross domestic product (GDP) and trade factors such as the growth of import and export traffic. In order to be able to compare the likely impact of growth in the future not only was a central case developed for each of these factors but a high (aggressive) and low (conservative) estimate was also developed. This provides an envelope of the full range of potential economic change that might occur in the GLSLS study area.

The high growth case assumes higher than average historical growth rates for population, non-farm employment, and productivity and would be accompanied by comparatively low interest rates and inflation. On the other hand, low growth cases assumed lower growth rates for population, non-farm employment, and productivity, resulting in higher prices and interest rates as well as lower industrial output growth[7].

In developing the socioeconomic scenarios, a wide range of data was collected and assembled from a variety of sources. A statistical database on population and employment was assembled from U.S. Census 2000 (U.S. Census Bureau)[8] and 2001 Census of Canada (Statistics Canada)[9]. Data on employment in the selected types of industry[10] (such as Agricultural, Forestry, Fishing and Hunting (NAICS – 11), Construction (NAICS – 23) and Manufacturing (NAICS – 33)) was obtained by using data from additional sources: CenStats databases for the United States[11] and Canadian Business Patterns (for Canada)[12]. Data for the base-year 2005 was obtained using statistical data where available along with estimates and short-term projections on population and employment for this year.

The data was disaggregated to the 200 GLSLS study zonal system (including 12 port zones) as shown in Exhibit 3-22. The data for each zone was derived from country data in the U.S. and census division data in Canada. Projections on population and employment were made for each of 150 U.S. zones and 38 Canadian zones of the GLSLS region. Socioeconomic projections were derived by governmental or authoritative research organizations projections. For the U.S., Woods & Poole, Inc.[13] and U.S. Census Bureau[14] projections were used. For each Canadian province in the GLSLS region, population and employment forecasts were obtained from government and research organizations[15] and adjusted to the zone level of the study area.

7 About three long-term growth scenarios in the U.S. see in more details; Energy Information Administration/Annual Energy Outlook 2006. Trends in Economic Activity. http://www.eia.doe.gov/oiaf/aeo/pdf/0383(2006).pdf

8 Census 2000 Summary File 3. http://factfinder.census.gov/

9 2001 Census of Canada, Statistics Canada. http://www.12.statcan.ca/english/census01/home/index.cfm

10 Here we selected industries producing products that are usually shipped in containers.

11 County Business Patterns Data (2000-2004), USA Counties. http://censtats.census.gov/

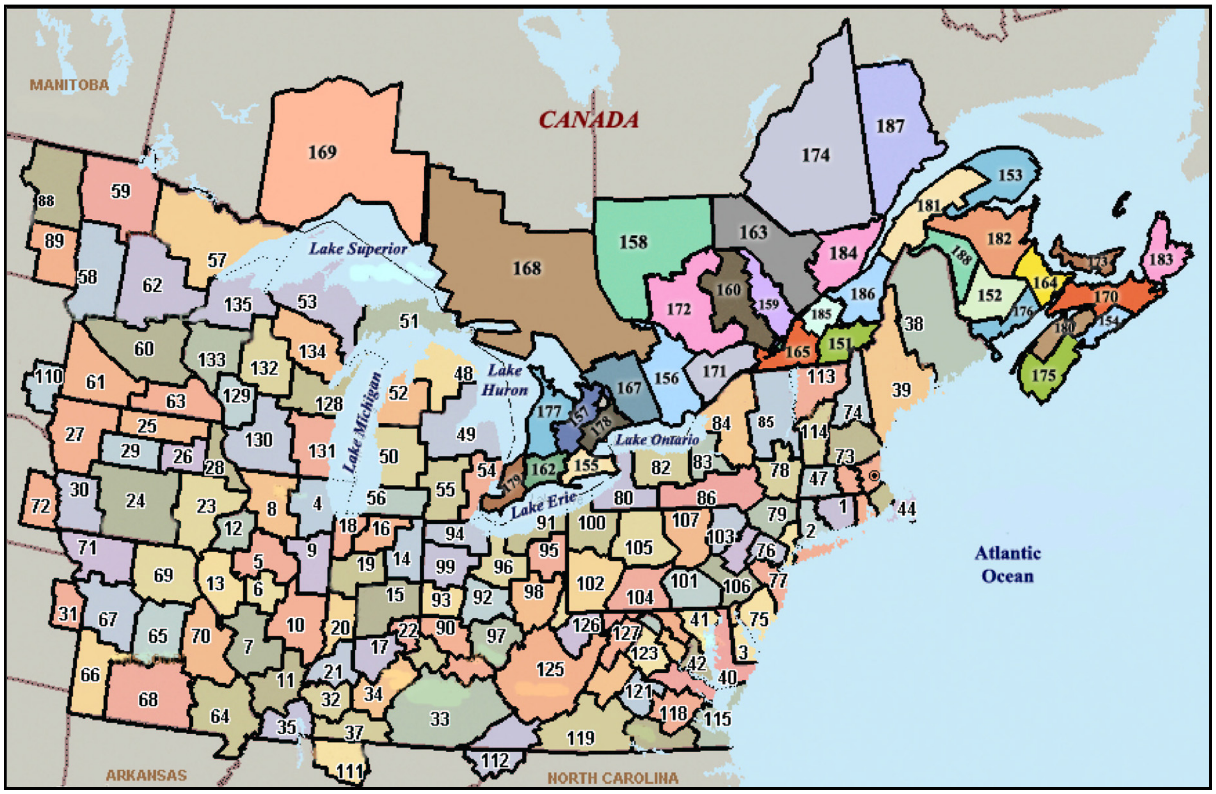
12 Canadian Industry Statistics. Industry Canada. http://strategis.ic.gc.ca/sc_ecnmy/sio/ciseste.html

13 Woods & Poole Economics, Inc is an independent firm that has been making long-term county economic and demographic projections since 1983.

14 U.S. Census Bureau. State Interim Population Projections by Age and Sex; 2004-2030. Table 6. Total population for region's, divisions and states: 2000 to 2030. http://www.census.gov/population/www/projections/projectionsagesex.html

15 Long-term forecasts on population for Quebec province, for example were prepared by Quebec Institute de la Statistique, see: http://www.stat.gouv.qc.ca/ . The forecasts on population for Ontario province were obtained from Ontario Ministry of Finance website http://www.fin.gov.on.ca/english/index.html and then adjusted for study purposes.

Exhibit 3-22: GLSLS Zone System



For developing trade forecasts, projections on Gross Domestic Product (GDP) play an especially significant role. According to the recent research on container trade growth made by UNESCAP[16] there is a very close relationship between GDP growth and trade volumes (including container volumes)[17]. Historical data on GDP (for both U.S. and Canada) for 1980-2005 was obtained from International Energy Information Administration database[18]. Historical data on container traffic by each North American port for the same 25-year period was taken from American Association of Port Authorities (AAPA) database[19].

In order to establish the relationship between GDP and container traffic (for the U.S. and Canada separately) the study team performed regression analysis using historic data for the last 25 years. The results of regression analysis and T-tests, presented in Exhibits 3-23 and 3-24 show a very high correlation coefficient (R2) and highly significant 't' values. Application of regression model identified very strong relationship between container traffic and GDP both in the U.S. and Canada. Following UNESCAP methodology and using the derived regression equations, TEMS developed forecasts of trade and container traffic based on projected data on GDP in accordance with three economic scenarios[20] (upper, central and lower).

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[16] UNRSCAP – United Nations Economic and Social Commission for Asia and the Pacific.

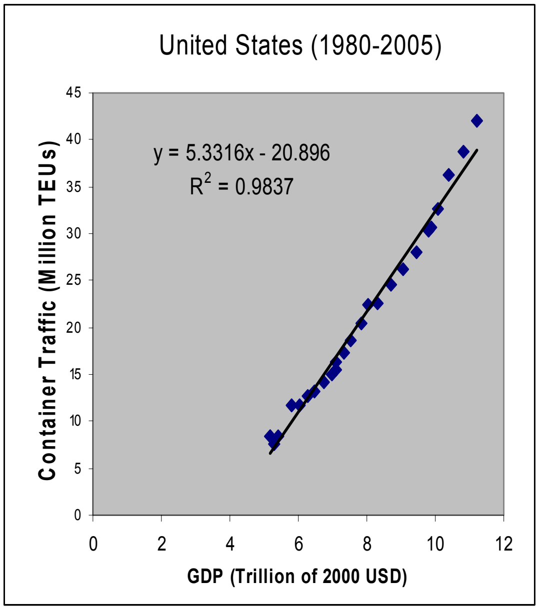
[17] Regional Shipping and Port Development Strategies (Container Traffic Forecast). United Nations Economic and Social Commission for Asia and the Pacific. United Nations, New York, 2005, Chapter 3. http://www.unescap.org/

[18] World Gross Domestic Product Using Market Exchange Rates (Billions of 2000 U.S. Dollars), 1980-2003. International Energy Annual 2003. Energy Information Administration. http://www.eia.doe.gov/iea/popgdp.html

[19] AAPA online Port Industry Statistics.
http://www.aapa-ports.org/pdf/CONTAINER_TRAFFIC_CANADA_US.xls

[20] Projections made by Global Insight, Inc are available in: International Energy Outlook 2006. Energy Information Administration. http://www.eia.doe.gov/oiaf/ieo/index.html

Exhibit 3-23: Container Traffic as a function of GDP



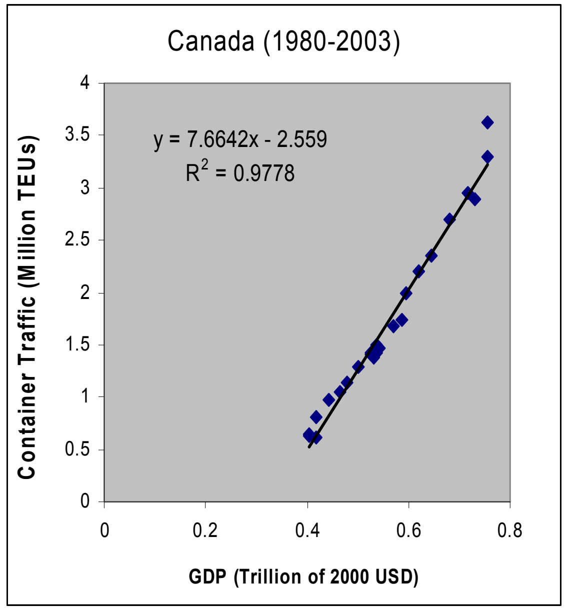


Exhibit 3-24: Regression Coefficients and Statistics

	B_0	B_1	T-value for β_1	T-value for β_0	R^2
United States	5.3316	-20.896	-18.7075	38.1121	0.9837
Canada	7.6642	-2.559	-18.2857	31.1220	0.9778

Forecasts of the port container traffic for the U.S. and Canada were adjusted for the level of North American ports included in the Demand Forecasting model[21]. Containerized cargo handled in each selected North American port was divided into three groups in accordance with the region of destination/origin of this cargo[22] - Asian, European, and other traffic.

Different annual growth rates projected in the UNESCAP study[23] were applied to each part of container traffic for each port (central scenario). In accordance with UNESCAP, container traffic forecast annual growth rate for Trans-Atlantic container traffic (i.e., Europe- and Asia-North America) share will be 6.5%. Average annual growth rate of container traffic between North America and other regions was assumed at the conservative level of 2%. The results of the TEMS analysis were found to be consistent with other long-term forecasts of North American containerized trade such as those made by NJTPA[24]. The projected socioeconomic factors are shown as Exhibit 3-25 - 3-29.

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[21] We made the selection of North American ports by making use of overall data on container traffic volumes for each port and information on origin/destination of the traffic as well.

[22] Data used in the calculations were obtained from multiple sources such as: U.S. Waterborne Container Trade by U.S. Custom Ports, 1997-2005 MARAD database, http://www.marad.dot.gov/; Doug O'Keefe The Future for Canada-U.S. Container Port Rivalries. June 2003. Statistics Canada. http://dsp-psd.pwgsc.gc.ca/Collection.Statcan/54F0001X/54F0001XIE2003.pdf; the Port of Halifax website: http://www.portofhalifax.ca. etc.

[23] Regional Shipping and Port Development Strategies (Container Traffic Forecast). United Nations Economic and Social Commission for Asia and the Pacific. United Nations, New York, 2005, Chapter 4. http://www.unescap.org/

[24] NJTPA – New Jersey Transportation Planning Authorities, Inc. Forecasts of Containerized Trade (1999-up to 2040 was prepared by Moffat & Nichol Engineers bases on adjusted PIERS and other data and presented in: BER-1 Market Analysis Final Report. Chapter 6. Shift Dynamics and Cargo Forecast, 2000-2040. Table 6.1 http://njtpa.org/planning/brownfields/documents_brownfields/6-Shift_Dynamics.pdf

Exhibit 3-25: GLSLS Area Employment Forecast

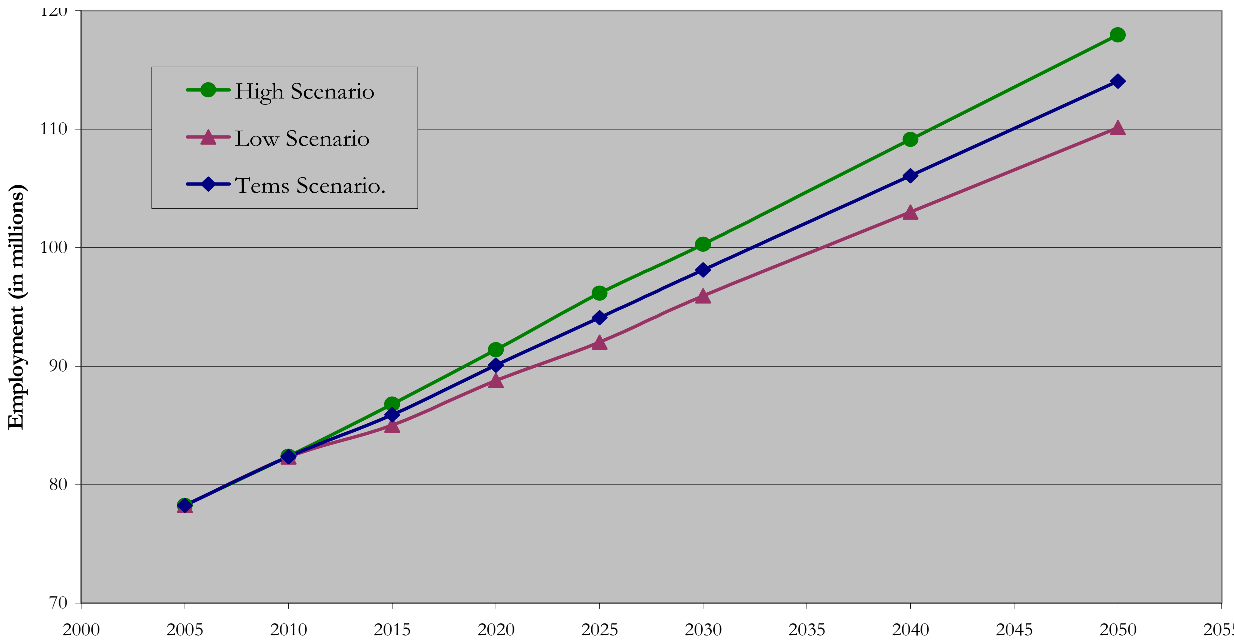


Exhibit 3-26: GLSLS Area Gross Domestic Product Forecast

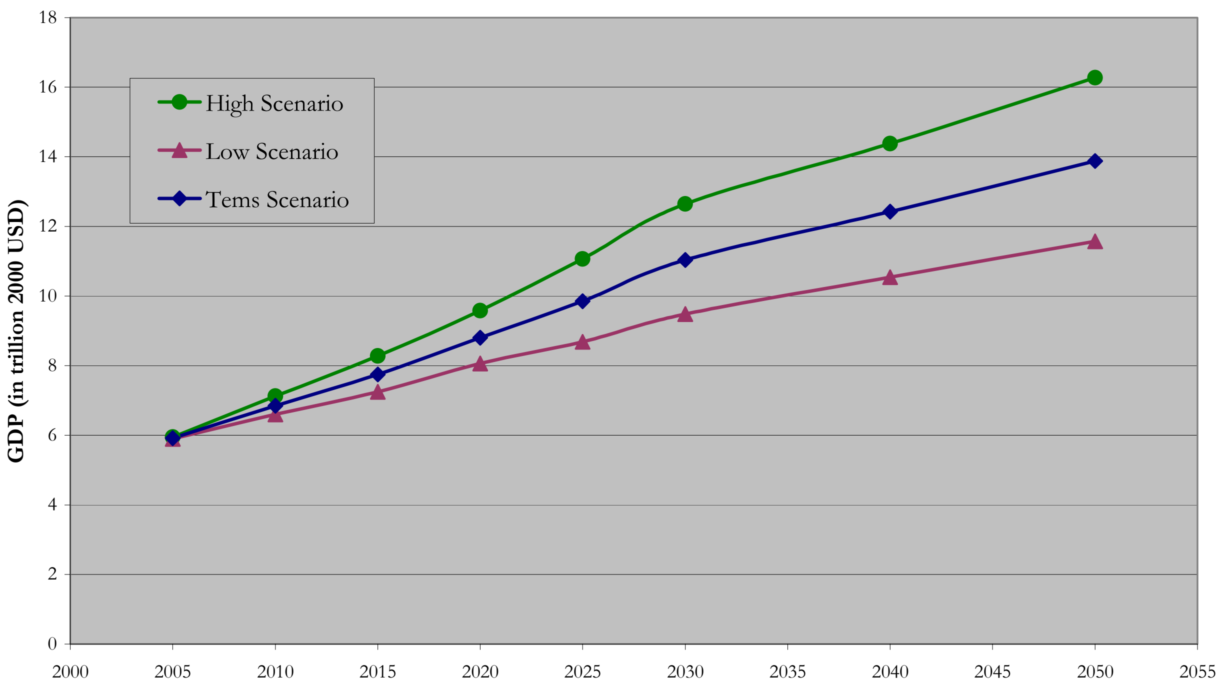


Exhibit 3-27: GLSLS Population

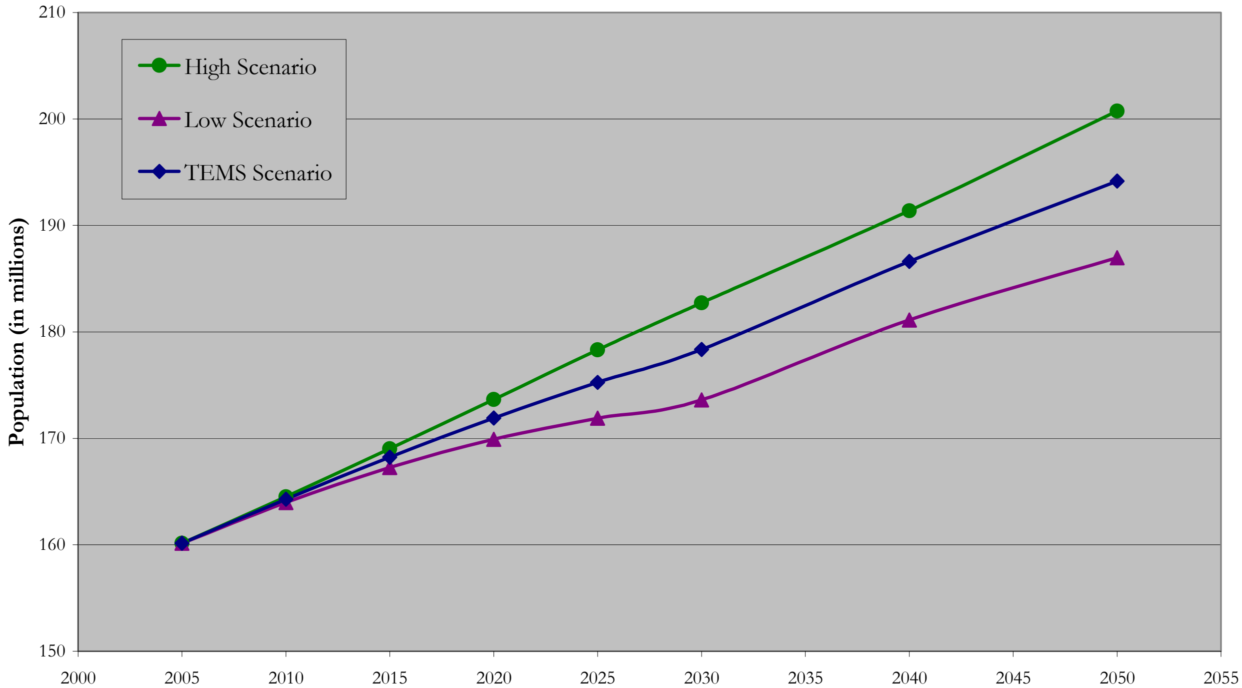


Exhibit 3-28: United States Container Traffic Forecast

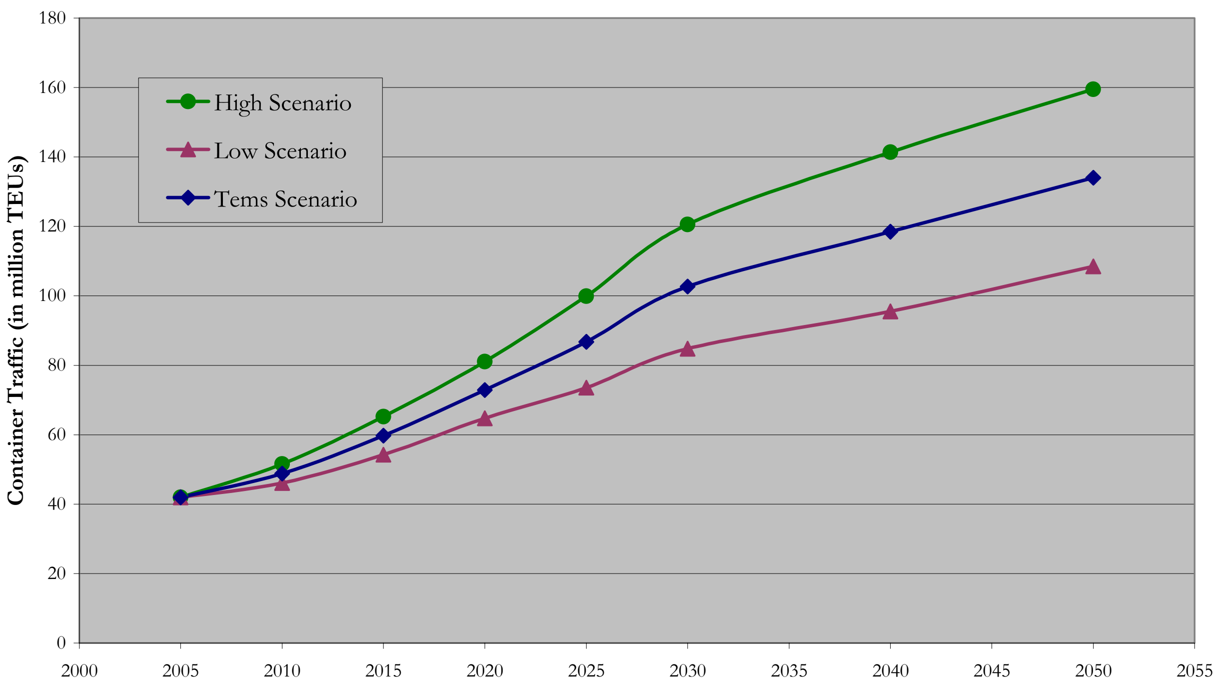
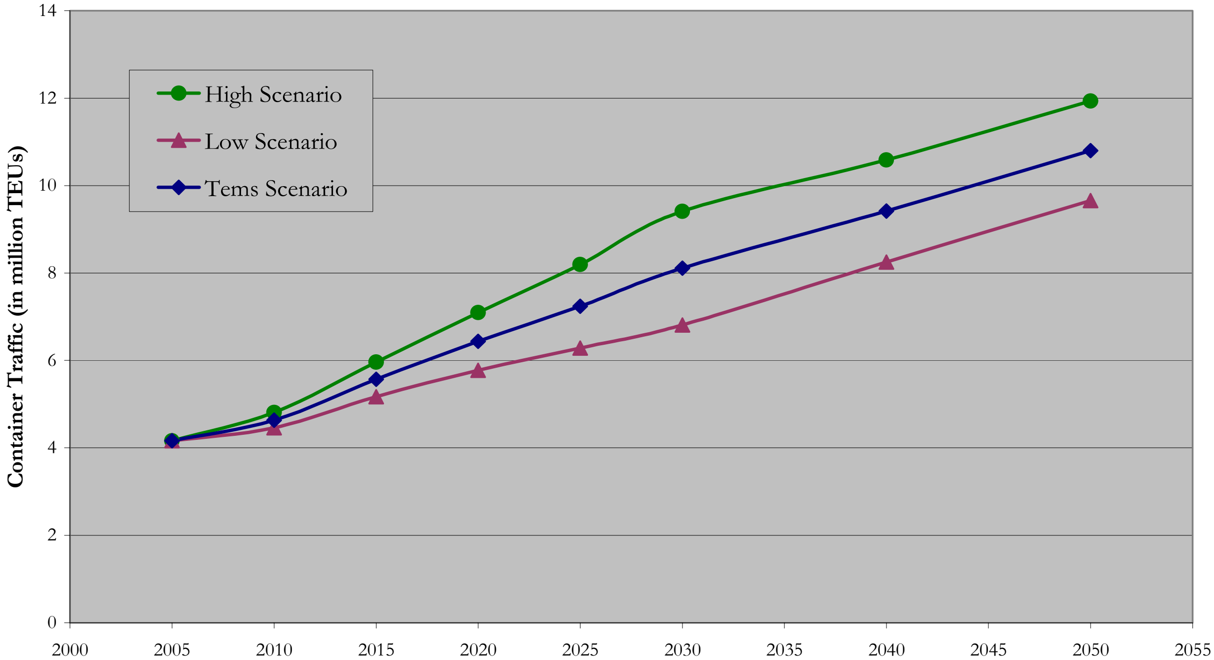


Exhibit 3-29: Canadian Container Traffic Forecast



4 TECHNOLOGY ASSESSMENT

4.1 INTRODUCTION AND METHODOLOGY

In this chapter the "new vessels" component of the New Cargoes/New Vessels study, characterizes four classes of generic vessels that could be used on the Great Lakes -St. Lawrence Seaway (GLSLS) to transport containerized cargo. These classes are Container on Barge (COB), a GLSLS containership, a roll-on/roll-off (Ro/Ro) fast ferry and the partial air-cushion support catamaran (PACSCAT). All of the vessels are based on existing technology. Each technology has different speed, cargo, and operating characteristics. The performance characteristics of the vessels shall be an input to the economic analysis that determines which, if any, of the vessel technologies presents a viable economic case for use in the GLSLS.

The first task is the characterization of the GLSLS itself. The St. Lawrence Seaway Development and Management Corporation imposes speed restrictions based on the width and depth of the channels and the currents present in them. The locks that connect portions of the GLSLS have size restrictions that constrain the maximum dimensions of each vessel type. Finally, the vessels must call on the ports within the GLSLS, which impose their own constraints on the vessels. An analysis of port infrastructure requirements and investments is beyond the scope of this analysis.[1]

The vessels are characterized in terms of their dimensions, cargo handling capabilities, and operational performance. All prototype vessels are constrained by the dimensions of the locks that connect portions of the GLSLS. For the COB, fast ferry and PACSCAT vessels, we presume the use of currently available designs. For the GLSLS containership, we derive a prototype vessel based on currently operational bulk freighters and container "feeder" vessels. The capacity of a vessel in twenty-foot equivalent units (TEU) is a function of the cargo deadweight, which is the maximum load that the vessel can carry. The operational performance includes the fuel consumption and crew requirements of each vessel.

4.2 GREAT LAKES-ST. LAWRENCE SEAWAY OPERATING CHARACTERISTICS

4.2.1 OPERATING SPEEDS IN THE GREAT LAKES-ST. LAWRENCE SEAWAY

Speed limits exist in the GLSLS to prevent erosion, protect riparian habitat and promote safety[2]. Exhibit 4-1 lists the maximum speeds allowed along the GLSLS. Speed limits are indicated for segments of the GLSLS between the major ports or waypoint locations. The distance and estimated travel time of the segments at maximum speed are also listed[3].

There are several segments of the GLSLS system that constrain the flow of vessels. The table lists the speed limits for vessels originating where the Atlantic Ocean meets the Gulf of St. Lawrence near Halifax, Nova Scotia and continues until the GLSLS terminus in Duluth, Minnesota. Along the over 4,000 km of the GLSLS, there are 6 short canals over a total of less than 110 km. These canals account for approximately three percent of the length of the GLSLS but approximately 10 percent of the best case travel time. The Detroit, St. Clair and St Mary's Rivers compose an additional 10 percent of the length of the GLSLS and an

[1] There are also environmental restrictions for vessels operating within the GLSLS. These include requirements for ballast exchange, among others. We shall assume that all vessel types comply with these restrictions.
[2] Burgess, Peter. Interview Regarding Speed Limits along the St. Lawrence Seaway. Arlington, Virginia, March 3, 2006.
[3] The Seaway Handbook. Cornwall, Ontario: The St. Lawrence Seaway Management Corporation, 2002

additional 10 percent of best case vessel travel time.[4] The remaining 2,895 km are classified as open water including Lakes Ontario, Erie, Huron, and Superior. The open water segments of the GLSLS compose 87 percent of the distance and typically, 80 percent of the best case travel time.

In general, there are three types of waterways along the GLSLS: canals and locks, channels and open water. In locks and canals, the speed limit is 11.1 km/h. In channels, the speed limit varies from 14.8 km/h in the leg from Port Robinson to Buffalo, to 24.1 km/h in the channel entering Lake Ontario. In less restricted, non-open water sections of the GLSLS, such as Lake St. Louis, the speed limit is 29.6 km/h. For the Detroit, St. Clair, and St. Mary's Rivers, we assume a speed limit of 19.4 km/h, which is the same as in similar channels elsewhere in the GLSLS. In the Detroit and St. Clair rivers, the maximum speed of vessels operating in non-displacement mode is 64.4 km/h; we will assume that non-displacement vessels may operate at this speed in certain sections of the Canadian-managed portion of the GLSLS.[5] In the open water of the Great Lakes, there is no regulated speed limit: as an example, the recently discontinued ferry service from Rochester, New York, to Toronto, Ontario, cruised at over 74 km/h[6]. In addition, maximum speeds occasionally vary depending on whether or not the GLSLS is in a high water or normal water state.[7]

The speed limits are motivated by several factors. Some factors are environmental: the speed limits seek to minimize wake, preventing erosion and protecting habitat. The speed limits also promote safe use of the system. Large vessels share the GLSLS with commercial and private vessels of varying size and agility. Thirteen percent of the length of the GLSLS is composed of locks, canals, and rivers. These sections require more precise navigation by vessels, especially through canals and locks that are often only just wide enough to accommodate the largest vessels. Furthermore, there are several sections of the GLSLS in which the navigable channel is only 300 feet wide, leaving little space to separate two passing vessels of maximum size. The maximum navigable depth of the GLSLS is 8.23 m.[8]

[4] All traveling times are for ideal conditions absent delays including backups and technical problems at the locks.

[5] Vessels operating in non-displacement mode may operate at 64.4 km/h, "except when required for the safety of the vessel or any other vessel. Vessels 20 meters or more in length but under 100 gross tons operating in the nondisplacement mode and meeting the requirements set out in paragraph (c) of this section, may operate at a speed not exceeding 40 miles per hour (34.8 knots)-- (i) During daylight hours (sunrise to sunset); (ii) When conditions otherwise safely allow; and (iii) When approval has been granted by the Coast Guard Captain of the Port…. In this section, 'nondisplacement mode' means a mode of operation in which the vessel is supported by hydrodynamic forces, rather than displacement of its weight in the water, to an extent such that the wake which would otherwise be generated by the vessel is significantly reduced" (33CFR162.138).

[6] *New U.S.-Canada ferry link 2006*. MarineLog 2002 [cited March 6 2006]. Available from http://www.marinelog.com/DOCS/NEWSMMIIb/MMIISep06.html

[7] During high water conditions, waves and currents increase, which makes navigation more difficult.

[8] The Seaway Handbook. Cornwall, Ontario: The St. Lawrence Seaway Management Corporation, 2002

Exhibit 4-1: Segments of the GLSLS and legal operating speeds.

Segment Number	Origin	Origin Waypoint	Destination	Destination Waypoint	Speed Limit in Normal Water (km/h) (dspl./non. displ.)	Speed Limit in High Water (km/h) (dspl./non. displ.)	Distance (km)	Time Traveling at Normal Speed Limit (h) (dspl./non. displ.)	Cumulative Distance (Km)
1	Halifax		Quebec		No limit	No limit	1514.9	NA	1514.9
2	Quebec		Montreal		29.6/64.4	29.6/64.4	260	8.8/4.0	1774.9
3	Montreal			Upper Entrance South Shore Canal	19.4	19.4	0.9	0	1775.8
4		Upper Entrance South Shore Canal		Lake St. Louis	19.4	19.4	26.2	1.3	1802
5		Lake St. Louis		Lower Entrance Beauharnois Lock	29.6/64.4	29.6/64.4	19.6	0.7/0.3	1821.6
6		Lower Entrance Beauharnois Lock		Upper Entrance Beauharnois Lock	11.1	11.1	1.7	0.2	1823.3
7		Upper Entrance Beauharnois Lock		Lake St. Francis	18.5	18.5	21.2	1.1	1844.5
8		Lake St. Francis		Lake St. Francis	23.2/64.4	23.2/64.4	49	2.1/0.8	1893.5
9		Lake St. Francis		`	17.6	17.6	3.8	0.2	1897.3
10		Snell Lock		Eisenhower Lock	11.1	11.1	6.6	0.6	1903.9
11		Eisenhower Lock		Iroquois Lock	21.3	19.4	41.9	1.9	1945.8
12		Iroquois Lock		McNair Island Light Buoy	24.1	19.4	44.9	1.8	1990.7
13		McNair Island Light Buoy		Deer Island	21.3	19.4	23.9	1.1	2014.6
14		Deer Island		Bartlett Point	17.6	17.6	24.6	1.4	2039.2
15		Bartlett Point		Tibetts Point	24.1	19.4	25.9	1.1	2065.1
16a	Kingston		Welland Canal Entrance		No limit	No limit	244.4	NA	2309.5
16b	Kingston		Toronto		No limit	No limit	297	NA	2362.1
16c	Kingston		Hamilton		No limit	No limit	300.8	NA	2662.9

17		Welland Canal Entrance		Welland Canal Exit	11.1	11.1	43.4	3.2	2352.9
18		Port Robinson	Buffalo		14.8	14.8	13.6	0.9	2366.5
19a	Buffalo		Toledo		No limit	No limit	412.5	NA	2779
19b	Buffalo		Erie		No limit	No limit	133.5	NA	2500
20	Erie		Toledo		No limit	No limit	278.2	NA	2778.2
21	Toledo			Start - Detroit River	No limit	No limit	66.1	NA	2844.3
22		Start - Detroit River	Detroit		16.7	16.7	34.6	2.1	2878.9
23	Detroit		Lake St Claire		16.7	16.7	10	0.6	2888.9
24	Lake St. Claire		Lake St. Claire		No limit	No limit	35.2	NA	2924.1
25	Lake St. Clair		Port Huron		16.7	16.7	55.4	3.3	2979.5
26	Port Huron			De Tour Passage	No limit	No limit	368	NA	3347.5
27a		De Tour Passage	Soo Locks Entry		16.7	16.7	73	4.4	3420.5
27b		De Tour Passage	Chicago		No limit	No limit	592	NA	3939.5
28	Soo Locks Entry		Soo Locks Exit		11.1	11.1	3.2	.3	3423.7
29	Soo Locks Exit		Lake Superior		16.7	16.7	9.7	.6	3433.4
30a	Lake Superior		Thunder bay		No limit	No limit	364.3	NA	3797.7
30b	Lake Superior		Duluth		No limit	No limit	639.9	NA	4073.3

4.2.2 Canals and Locks of the Great Lakes-St. Lawrence Seaway

The GLSLS extends from the Gulf of St. Lawrence to Duluth, Minnesota. Six short canals and 19 locks with a total length of less than 110 km connect major sections of the system. Exhibit 4-2 lists the locks and their dimensions, age, operator.

The Montreal/Lake Ontario section of the GLSLS includes a series of seven locks over a distance of 300 km from Montreal, Quebec to Iroquois, Ontario enabling ships to navigate from the St. Lawrence River to Lake Ontario. The first canal is the South Shore Canal, which includes two locks, the St. Lambert and Côte Ste. Catherine; the South Shore Canal is 26 km long and extends from the Port of Montreal to Lake St. Louis. Next, the Beauharnois Canal is 21 km long and links Lake St. Louis to Lake St. Francis through two locks. The Wiley-Dondero Canal is 15 km long and provides access to Lake St. Lawrence via the Snell and Eisenhower Locks. The last canal in the Montreal/Lake Ontario section of the GLSLS is the Iroquois Canal, which is 600 m long and includes one lock.[9] All of the seven locks of the Montreal/Lake Ontario section of the GLSLS are 233.5 m long, 24.4 m wide and 9.1 m deep.

The Welland Canal links Lake Ontario and Lake Erie with a series of eight locks, all Canadian-operated, over a distance of 43.4 km. The Welland Canal lifts vessels from a height of 75 m above sea level to 99 m above sea level. Counting from the north, three of the first seven locks (locks 4, 5 and 6) are twinned and contiguous.[10] The eighth lock, at the south end, is a guard lock.[11] All of the locks in the Welland Canal are the same size: 233.5 m long, 24.3 m wide and 9.1 m deep.

The final canal in the GLSLS, the St. Mary's Canal, links Lake Huron to Lake Superior and has four twinned locks of various dimensions at Sault Ste. Marie. These are also known as the Soo Locks. The locks on the St. Mary's Canal are administered by the U.S. Army Corps of Engineers. The Poe lock is 366 m long, 33.5 m wide and 9.8 m deep. The MacArthur lock is 244 m long, 24.4 m wide and 9.4 m deep. The Canadian lock is 250.8 m long, 16.1 m wide and 9.9 m deep and the Sabin lock is 411.5 m long, 24.3 m wide and 7.0 m deep. [12]

The speeds and times listed in Exhibit 4-1 account for the time required to traverse locks and canals assuming no delay. Transit through locks includes a queuing time to enter the lock and the time to perform the locking procedure. Additional delays sometimes occur due to mechanical causes related to lock operation and maintenance.[13] The St. Lawrence Seaway Management Corporation claims that the average transit time for the Welland Canal (eight locks) is 12 hours.[14] Rodrigue, Jean-Paul claims[15] that the average transit time for the Welland Canal is 11 hours. The lockage time for the seven locks from Montreal to Lake Ontario is claimed to take five hours giving an overall transit time of 24 hours upbound and 22 hours downbound, this difference being primarily due to river currents.[16] Queuing delays in the South Shore, Beauharnois, Wiley Dondero, and Iroquois Canals average 0.35 hours.

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9 The Seaway Handbook. Cornwall, Ontario: The St. Lawrence Seaway Management Corporation, 2002

10 Twinned locks are arranged in pairs to allow simultaneous locking of ships in both directions.

11 A guard lock or tide lock is a canal lock located between a canal and a body of water of varying depth such as a harbor or a river. When the canal is at a different level than the open body, such a lock allows ships and boats to pass into and out of the canal regardless of the water level or tide.

12 The Seaway Handbook. Cornwall, Ontario: The St. Lawrence Seaway Management Corporation, 2002

13 We do not consider such delays in this analysis.

14 *Great Lakes St. Lawrence Seaway System: Seaway Facts 2006*. St. Lawrence Seaway Management Corporation 2006 [cited May 30 2006]. Available from http://www.reawtlakes-seaway.com/en/aboutus/seawayfacts.html.

15 Rodrigue, Jean-Paul. 2006. *The St. Lawrence Seaway and Regional Development*. Hofstra University, May 27 2003 [cited April10 2006]. Available from http://people.hofstra.edu/geotrans/eng/ch7en/appl7en/ch7a2en.html.

In the Soo Locks, vessel queuing delays of 0.25 hours and 0.56 hours per vessel per lock for the MacArthur and Poe Locks respectively.[17]

Exhibit 4-2: Canals and locks of the GLSLS and their characteristics.

Canal	Lock Name	Length (m)	Width (m)	Depth (m)	Year of Construction	Operator
South Shore Canal	St. Lambert	233.5	24.3	9.1	1959	Canada
	Côte Ste. Catherine	233.5	24.3	9.1		
Beauharnois Canal	Lower Beauharnois	233.5	24.3	9.1	1959	Canada
	Upper Beauharnois	233.5	24.3	9.1		
Wiley Dondero Canal	Snell	233.5	24.3	9.1	1959	U.S.
	Eisenhower	233.5	24.3	9.1		
Iroquois Canal	Iroquois	233.5	24.3	9.1	1959	Canada
Welland Canal	Lock 1	233.5	24.3	9.1	Construction occurred: 1913 to 1932	Canada
	Lock 2	233.5	24.3	9.1		
	Lock 3	233.5	24.3	9.1		
	Lock 4	233.5	24.3	9.1		
	Lock 5	233.5	24.3	9.1		
	Lock 6	233.5	24.3	9.1		
	Lock 7	233.5	24.3	9.1		
	Lock 8	233.5	24.3	9.1		
St. Mary's Canal	MacArthur Lock	243.8	24.3	9.3	1943	U.S.
	Poe Lock	365.8	33.5	9.8	1968	

4.2.3 PORTS IN THE GREAT LAKES-ST. LAWRENCE SEAWAY

Exhibit 4-3 lists the 19 largest U.S. and Canadian ports along the GLSLS. The data in the table were compiled from online sources presented by the St. Lawrence Seaway Management Corporation (Canada), the St. Lawrence Seaway Development Corporation (United States)[18] and the U.S. Army Corps of Engineers.[19]

Predictably, the ports are built to accommodate vessels that can traverse the GLSLS. The data show that most of the ports along the Seaway can accommodate vessels with a maximum draft of 8.2 m, length of 233.5 m and beam of 24 m. The ports at Quebec, Windsor, Ontario, Monroe, Michigan and Milwaukee and Green Bay, Wisconsin would require dredging to accommodate "Seaway-max" vessels.

Currently, the ports along the GLSLS do not have the required infrastructure to support large-scale containerized operations. The ports do have rail connections that could facilitate the development of intermodal trade. For the purpose of this analysis, we will assume that all ports contain appropriate infrastructure to handle containerized trade. A complete analysis would require site-specific surveys of available infrastructure, construction requirements, and financing.

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16 *Great Lakes St. Lawrence Seaway System: Seaway Facts* 2006. St. Lawrence Seaway Management Corporation 2006 [cited May 30 2006]. Available from http://www.reawtlakes-seaway.com/en/aboutus/seawayfacts.html.
17 NDC Publications and U.S. Waterway Data CD, Volume 9. 2003. Alexandria, Virginia: U.S. Army Corps of Engineers.
18 The Seaway Handbook. Cornwall, Ontario: The St. Lawrence Seaway Management Corporation, 2002
19 NDC Publications and U.S. Waterway Data CD, Volume 9. 2003. Alexandria, Virginia: U.S. Army Corps of Engineers.

Exhibit 4-3: Characteristics of ports of the GLSLS.

Port Name	City	State/Province	Rail Connections	Depth (m)	Berth Length (m)	Equipment
Quebec Port Authority	Quebec	Quebec	Yes	11.3	341 – 1366	4 cranes, conveyor, ship loader
Montreal Port Authority	Montreal	Quebec	Yes	8.2	144 – 1620	
Ogdensburg Bridge and Port Authority	Ogdensburg	New York	Yes	8.2	381	
Port of Oswego Authority	Oswego	New York	Yes	8.2	229	
Toronto Port Authority	Toronto	Ontario	Yes	8.2	1829	Ro/Ro berth
Hamilton Port Authority	Hamilton	Ontario	Yes	8.8	128 – 2300	
Port of Buffalo	Buffalo	New York	Yes	8.8	229	2 Crawler Cranes 2 - 46 m ship loading conveyors and related highlifts
Erie-Western Pennsylvania Port Authority	Erie	New York	Yes	8.8	396	272 * 10^3 kg stiff-legged crane
Cleveland-Cuyahoga County Port	Cleveland	Ohio	Yes	8.2	191 – 1524	
Toledo-Lucas County Port Authority	Toledo	Ohio	Yes	8.2	244 – 1250	One 163 * 10^3 kg crawling crane, one 100 * 10^3 kg, one 66 * 10^3 kg, three 32 * 10^3 kg cranes for break bulk
Windsor Port Authority	Windsor	Ontario	Yes	8.0	96 – 732	
Port of Monroe	Monroe	Michigan	Yes	6.4	457	
Detroit/Wayne County Port Authority	Detroit	Michigan	Yes	8.5	274 – 1036	All general cargo, heavy lift and Ro/Ro
Ports of Indiana	Burns Harbor	Indiana	Yes	8.2	1676	Cranes - one 318 * 10^3 kg, one 272 * 10^3 kg, eight 209 * 10^3 kg, three 181 * 10^3 kg, one 159 * 10^3 kg, four 91 * 10^3 kg
Illinois International Port District	Chicago	Illinois	Yes	8.2	305	
Port of Milwaukee	Milwaukee	Wisconsin	Yes	7.9	122 – 1067	
Brown County Port and Solid Waste Department Port of Green Bay	Green Bay	Wisconsin	Yes	7.9	213 – 457	
Thunder Bay Port Authority	Thunder Bay	Ontario	Yes	8.2	201	
Duluth	Duluth	Minnesota	Yes	8.2	192 – 1524	

4.3 CANDIDATE VESSEL TECHNOLOGIES

A critical component of this Great Lakes and St. Lawrence Seaway Study is an assessment of the different water transport technologies that can be used to move containers on the GLSLS system. Two novel technologies, Fast Freighter and PACSCAT (as described below) have also been included in this assessment. These vessel technologies span a full range of cost/performance tradeoffs for the GLSLS. For conducting the assessment, specific representative vessels of each type were selected by the RAND Corporation, as reported here, for quantification of performance factors. We provide performance data for four vessel technologies for use for containerized trade on the GLSLS. These candidates represent a range of speeds and cargo-handling capabilities. The dimensions of each vessel are such that it may traverse the complete GLSLS and call at all ports of the system.

A review of the full range of water technology options and an assessment of the potential performance of each option included the following vessel types as study options –

- **Container on Barge (COB):** The simplest and slowest technology is COB, which consists of several barges configured to handle containers towed by a towboat.
- **GLSLS Container Ship:** The trend in the construction of containerships has been to larger and larger vessels; the containership we consider is a moderate-size but comparatively fast vessel built especially for use in the GLSLS.
- **Fast Freighter:** The so-called "fast ferry" is a catamaran configured to handle "roll on roll off" (Ro/Ro) cargo; Ro/Ro vessels often have built-in ramps, or use land-based ramps, to load and unload the vessel by "rolling on" and "rolling off" the cargo. These vessels are capable of high-speeds at the expense of cargo deadweight and fuel economy.
- **Partial Air Cushion Support Catamaran (PACSCAT):** The final technology is the partial air-cushion support catamaran (PACSCAT). Vessels using aerostatic support with rigid hulls are not new: the U.S. Navy experimented with such vessels in the 1980s.[20] In commercial operation, these vessels promise increase cargo-handling capability over standard multihull vessels and improved fuel efficiency.[21]

For each of the candidate technologies, a vessel could be designed to optimize parameters such as displacement, deadweight, maximum speed, crew requirements and wake, among others. We have not attempted to perform this task, rather we report on the general parameters that distinguish the candidates, basing them on existing vessels. However, there is actually some overlap in the performance ranges of different vessel types. For example, the performance of a large seagoing Container Barge is not too much different than a small container ship. Similarly, PACSCAT technology spans a range from that of a small container ship up to the Fast Freighter. In order to assess the performance capabilities of the vessel technologies, two variants of the GLSLS Container Ship and two variants of PACSCAT have been evaluated. By varying the size, configuration, and propulsion power of the vessels, a full range of deployment options has been developed for each vessel type.

The remainder of the section is organized as follows. First, we discuss assumptions we make regarding cargo, crew, and propulsion that we will apply to all vessels. Then we discuss each technology in turn, accounting for their technical and operational characteristics. The following sections will outline the basic performance parameters for each vessel type that have been included in this study. An exhibit summarizing all vessels appears in the following section.

[20] Gillmer, Thomas C. and Bruce Johnson. 1982. *Introduction to Naval Architecture.* Annapolis, Maryland: Naval Institute Press.

[21] Both the fast ferry and the PACSCAT operate in non-displacement mode and are able to operate at higher speeds than displacement vessels when in the open water of the lakes. The speed limit for these vessels is 64.4 km/h whereas the speed limit for displacement vessels is 29.6 km/h.

4.3.1 Parameters Used for Estimating Vessel Performance[22]

The choice of a propulsion method for vessels is particular to the application. A large cargo vessel may have a directly coupled propeller turning at a relatively low rate. A light and fast vessel may choose a water-jet propulsion system and employ engines that operate at relatively high revolutions per minute (RPM). One of our candidate technologies is a "fast freighter" concept designed by the Australian firm Austal; it has four 9,000 kW engines.[23] At 90 percent output, Austal claims that the fuel consumption of the vessel is 6,500 kg/hour, yielding a specific fuel consumption of 0.201 kg/kW-hr of marine diesel oil (MDO). Similar engines have a specific fuel consumption of 0.201 kg/kW-hr of MDO.[24] The engines are optimized for peak power production, so the specific fuel consumption increases by approximately 10 percent at lower power. We shall assume that the specific fuel consumption of all vessels is constant at all power ratings and is 0.201 kg/kW-hr. The density of MDO is 836 kg/m^3. The assumed values of parameters appear in Exhibit 4-4.
We make several additional assumptions regarding vessel and their operation –

- Crew requirements. For vessels with a registered displacement over 907 * 10^3 kg, the management of the GLSLS requires a minimum crew of three certified deck officers and two engineers.[25] Additional crewmembers are required to man mooring lines and tend cargo. We will derive estimates for crew based on this baseline and on the amount of cargo the ship handles.
- Starting and stopping. We assume that the time/distance to full speed/stop under normal operating conditions to be 5 minutes and 2 km.26
- Ballast exchange. We assume that all vessels are configured to comply with ballast exchange requirements of the GLSLS.
- Port infrastructure requirements. We assume that all ports have the appropriate facilities and equipment to handle containerized cargo operations.
- To compare vessel economics on a consistent basis, average line-haul unit costs have been calculated per Forty-Foot Equivalent Unit (FEU) mile. The FEU rather than TEU has been chosen as the basis for comparison, because it more closely corresponds to one truckload and therefore supports a comparison to trucking and rail costs as well as between vessel types.

22 All unites are metric and all figures are reported to three significant digits.
23 Fast Freighter Outline Spec 1. 2004. Henderson, Australia: Austal.
24 3618 Marine Propulsion Engine, LEHM1875-01. 2002. Peoria, Illinois: Caterpillar, Inc.
25 The Seaway Handbook. Cornwall, Ontario: The St. Lawrence Seaway Management Corporation, 2002
26 This assumption standardizes the operation of the vessels near ports. The assumption should not have an effect on the analysis of the four vessel technologies. The assumption does not hold in the case when a route requires frequent docking of the vessel and the amount of time the vessel spends stopping and starting is a significant fraction of the overall transit time.

Exhibit 4-4: List of assumed parameters for calculation of vessel performance and operating characteristics

Parameter	Value
TEU empty mass	1,810 kg
TEU revenue tonnage	12,700 kg
TEU loaded mass	14,500 kg
Specific fuel consumption	0.201 kg/kW-hr
Density of MDO	836 kg/m³
Crew requirements	5 for navigation; 4 to 9 additional
Start/stop time/distance	5 minutes over 2 km

4.3.2 Container on Barge

The first technology considered is COB. A barge is a flat-bottomed boat built mainly for river and canal transport of heavy goods. Most barges are not self-propelled and need to be moved by tugboats or towboats. Each barge has a relatively small cargo capacity, but is typically towed as a member of a group. The drawback of COB is its relatively slow speed.

Container on Barge

We base the prototype COB on vessels currently operating in the GLSLS. McKeil Marine Limited operates a fleet of more than 45 tugs and 60 barges[27]. As a model, we choose the tug *Evans McKeil* and barge *Labrador Spirit,* as a vessel to develop our prototype. We maximize the allotted lock and canal dimensions by linking the tug and two *Labrador Spirit* barges together. We assume that the number of crewmembers is 9, which is the same as on (larger) Mississippi tow-barge combinations.[28] Estimating the fuel consumption of the towboat-barge combination is particularly difficult. The hydrodynamics of the vessels is difficult to analyze, because the frequent changes in configuration cause fuel consumption to vary. Based on a ton-km estimate of fuel consumption, we can estimate the fuel consumption of the loaded COB to be 560 kg/hr at cruise and 370 kg/hr at 11.1 km/h,

[27] McKeil Marine Limited is a Canadian company. McKeil Marine Limited is headquartered in Hamilton and has commercial offices and operational facilities in several cities including Toronto, Montreal and St. John's. McKeil Marine specializes in the transportation of dry and liquid bulk, oversized project cargoes, heavy equipment and general cargo on the Great Lakes, St. Lawrence River, the eastern seaboard and in the Canadian Arctic. The acquisition of larger, ocean-going tugs and barges has also enabled them to expand into the international trade market. Both the tug Evans McKeil and the barge Labrador Spirit are Canadian-flag (similar to all of McKeil's tugs, barges and vessels). Details on McKeil's fleet can be found at http://www.mckeilmarine.com/fleet1.html.

[28] Coatney, Mark. 2006. *Down the Mississippi: The Pulse of America*. Time.com 2000 [cited 8 March 2006]. Available from http://www.time.com/time/reports/mississippi/day5.html

which is a common slower operating speed along the GLSLS.[29] The fuel efficiency at 14.8 km/h for COB is 0.061 kg/TEU-km.

Acquisition costs of a COB unit comprise the costs of a towboat and two barges. Marcon International, Inc., a vessel brokerage firm, estimates the total acquisition cost of the COB unit described in this section to be $11 million.[30] Each barge costs $1 million; the towboat costs approximately $9 million. The estimate for the cost of the towboat is based on a rule-of-thumb cost of $1.5 million per 1000 hp (746 kW) of installed power. Based on the speed/fuel consumption estimates above, the installed power of the towboat is approximately 3,000 kW, or 4,000 hp.

Exhibit 4-5: Summary of the characteristics of the tug Evans McKeil and barge Labrador Spirit and a prototype vessel combining the tug and two barges for use in the GLSLS.

Parameter	*Evans McKeil*	*Labrador Spirit*	Prototype Vessel
Length Overall (m)	33.5	73.15	179.8
Beam (m)	7.7	21.9	21.9
Draft (m)	3.5	3.7	3.7
Cargo deadweight (kg)		$4.50 * 10^6$	$9.00 * 10^6$
Loaded TEU		310	620

Exhibit 4-6: Fuel consumption at common operating speeds in the GLSLS for the COB.

Speed (km/h)	Fuel consumption (kg/hr)	Fuel economy (kg/TEU-km)
11.1	370	0.054
14.8	560	0.061
19.4	NA	NA
29.6	NA	NA

Exhibit 4-7: Container on Barge Performance Parameters

Performance Parameter	Prototype Vessel
Cruise Speed (km/h)	14.8
Fuel consumption at cruise speed (kg/hr)	560
Fuel economy at cruise speed (kg/TEU-km)	.061
Loaded TEU/FEU capacity	620 / 310
Crew	9

COB service is generally limited to 8-10 knots due to the barge hullform. Streamlined hulls for lake or ocean service can go up to 15 knots and deployment of these is under consideration by some GLSLS ports. COB service is energy efficient, but it is very slow.[31] New technologies, such as Germany's "Futura Carrier" use bubble-lubrication technology to make COB service even more efficient but unfortunately, without improving the speed by very much. For a best-case evaluation of the transit time of COB service, it is assumed that

[29] Prozzi, et al. (2002) state that a gallon of fuel can move one ton of cargo 514 miles. Applying conversions and assuming that the movement is at the cruise speed of 14.8 km/h, we estimate the fuel consumption of a loaded combination of towboat and barges to be 560 kg/hr. Using this value as a data point, it is possible to fit a quadratic equation to the speed/fuel consumption curve to derive the estimate of 370 kg/h at a speed of 11.1 km/h, since hydrodynamic drag rises roughly with the square of the velocity of the vessel.

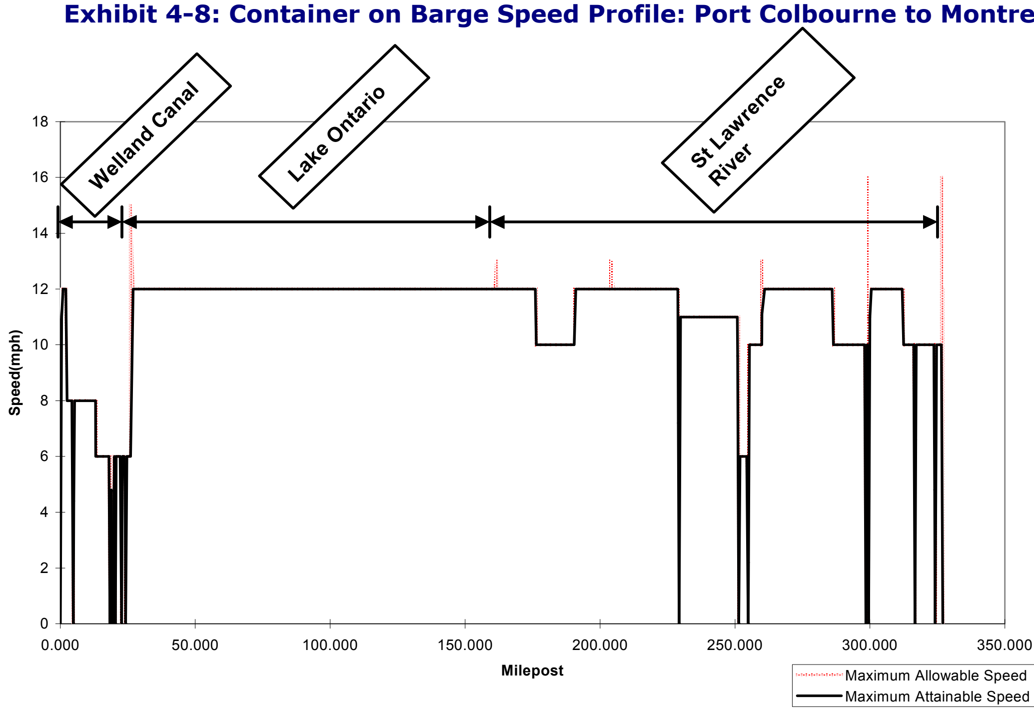
[30] Marcon International. 2006. Cost Estimate for Container on Barge Vessel. Santa Monica, California, May 18, 2006.

[31] Because of their streamlined hullforms and larger size, container ships are even more energy efficient than COB and are faster than COB as well. For a deep-draft waterway such a GLSLS, container ships are therefore generally more cost effective than COB. COB is better suited to shallow draft river navigation that excludes ships.

the vessel will be limited to a top speed of 12 knots, even on the open waters of the Great Lakes.

Exhibit 4-8 shows the speed profile for COB service from Port Colbourne – the Lake Erie entrance to the Welland Canal – to Montreal. The required transit time from Montreal to Lake Erie would be 48 hours. For a trip from Halifax to Montreal, the trip time is 84 hours for a seagoing barge. From Montreal to Port Colbourne on Lake Erie, the time would be 48 hours and from Port Colbourne to Chicago the time would be 70 hours. The total from Halifax to Chicago would be 202 hours, approximately 8½ days sailing time for a standard streamlined seagoing barge. The RAND COB vessel as described in Exhibit 4-7 is even slower than this and would take about 11 days to transit the entire length of the GLSLS.

Exhibit 4-8: Container on Barge Speed Profile: Port Colbourne to Montreal



Overall, the COB line-haul is projected to cost $0.21 per FEU-mile for Ro/Ro service, or $0.11 per FEU-mile for Lo/Lo service. While both of these costs are highly competitive with rail movement, barge service would be much slower.

On the inland rivers and canals of Europe, containers are frequently handled on barges. Barge service is especially prevalent as feeder service to the Port of Rotterdam, which is located at the mouth of the Rhine River. Container on barge service is provided on many other European waterways, as well as for intracoastal or "short sea" shipping service. However, this form of shipping has not been very popular in North America because it has been perceived as too slow as compared to rail or truck shipping.[32] Although COB service can be very economical, reducing the cost is not that helpful since the main issue is transit time, not cost. While COB service may prove useful for some low-value commodities, a higher speed at a competitive cost is the critical requirement for being able to attract traffic to the waterways from truck and rail.

[32] Crew, J.G. and Horn, K.H., "Assessment of Container-on-Barge Service on the Mississippi River System," *Journal of the Transportation Research Forum,* Vol. XXVIII, No. 1, (Washington, D.C.: Transportation Research Forum, 1987) pp.92-95.

4.3.3 GREAT LAKES-ST. LAWRENCE SEAWAY CONTAINERSHIP

The second technology we consider is a containership specifically designed to traverse the GLSLS. The size of the locks and the clearance limits throughout the system would constrain the maximum dimensions of such a vessel. Also, because freshwater is less buoyant than seawater, the capacity of such a vessel would be less than that of a similarly sized oceangoing vessel. We propose a containership with dimensions based on those of bulk freighters currently operating in the GLSLS and with a shape based on containerships of similar size. We derive a cargo deadweight and displacement for the vessel and estimate the power requirements of such a vessel.

GLSLS Container Ship

We base the prototype containership on vessels currently operating in the GLSLS. The Seaway Marine Transport Corporation operates a fleet of vessels sized specifically for the GLSLS. As a model, we choose the bulk freighter *Algoville*, as a vessel from which to size a containership. In reality, were a firm to develop a containership for the GLSLS, the design would be influenced by the constraints of the GLSLS, the expected operational scenarios including average loading, typical distances, and current and future port facilities. Typical Great Lakes freighters are squared-off and slow-moving vessels optimized for carrying bulk commodities throughout the GLSLS.[33] Despite their size, containerships are designed for relatively high speed operation and tend to be more streamlined.[34] Therefore, our prototype vessel is sized according to the GLSLS, but sacrifices cargo deadweight for speed, as typical in containerships. The basic parameters of our vessel compared with that of the *Algoville* are listed in the exhibit below.

Exhibit 4-9: Comparison of the Seaway Marine Transport Corporation Algoville bulk freighter and a prototype container vessel for use in the GLSLS.

Parameter	*Algoville*	Prototype Vessel
Length Overall (m)	222.5	222.5
Length Between Perpendiculars (m)	216.5	216.5
Length at Waterline (m)	219.5 (estimated)[a]	219.5 (estimated)[a]
Beam (m)	23.8	23.8
Draft (m)	7.9	7.9
Displacement (kg)	$33.0 * 10^6$	$26.0 * 10^6$
Cargo deadweight (kg)	$28.2 * 10^6$	$19.3 * 10^6$
Loaded TEU	N/A	1,330

[a] Estimated as the mean of the length overall and the length between perpendiculars.

[33] Gillmer, Thomas C. and Bruce Johnson. 1982. *Introduction to Naval Architecture.* Annapolis, Maryland: Naval Institute Press.
[34] Propulsion Trends in Container Vessels. No date. Copenhagen, Denmark: MAN B&W Diesel A/S.

We estimated the power requirements of the vessel using two online tools and fitting the curves to a prototype vessel of similar cargo carrying capacity. The Holtrop and Mennen method is a well-respected method for calculating the resistance of a vessel as it moves through the water.[35,36] The engine manufacturer MAN B&W used the method to evaluate the power requirements for various prototype container vessels in a recent technical paper.[37] MAN B&W added margins of 10 percent for the engine and 15 percent for sea conditions to the estimated power requirements. We used an online tool available from Schiffbau-Versuchsanstalt Potsdam GmbH to evaluate the power requirements of our vessel.[38] To this estimate, we added a 10 percent margin for the engine and machinery, a 15 percent margin for sea conditions and an additional 10 percent margin for operation in shallow water.[39] We employed another tool from an information clearinghouse on marine diesel engines to double check our calculations[40]; this tool used as inputs only the type of vessel – i.e. displacement or non-displacement – displacement weight and length overall to compute an estimated power requirement. Its estimate was approximately 35 percent greater than the estimate using the Schiffbau-Versuchsanstalt tool. To derive an estimated power requirement for the prototype GLSLS containership, we compute a weighted average based on the output of both online tools and the estimate for a 1,500 TEU containership by MAN B&W. The fuel efficiency is 0.054 kg/TEU-km at cruise speed.

Exhibit 4-10: Power and fuel consumption at common operating speeds in the GLSLS.

Speed (km/h)	Power (kW)	Fuel consumption (kg/hr)	Fuel efficiency (kg/TEU-km)
11.1	370	74	0.0050
19.4	1,940	390	0.0150
29.6	6,760	1,360	0.0350
37.0	13,300	2,680	0.0540

The GLSLS containership carries 14 crewmembers. A typical post-Panamax containership capable of carrying 6,000 or more TEU has a crew of 21.[41] The prototype vessel has less than one-quarter the cargo capacity, but because of the frequent port calls and canal crossings, additional crew are required for mooring operations and cargo maintenance. Therefore, in addition to the three certified deck officers and two engineers, we assume the employment of 9 additional crewmembers to assist in vessel operation and docking maneuvers.

Container ship technology has dramatically changed in recent years, focusing on development of faster, more streamlined hulls along with more powerful engines. Modern containerships have a cruising speed of 22-23 knots as compared to the 10-15 knots typical of older vessels. Although energy consumption has increased, the faster vessels are still very energy-efficient as compared to truck, rail, and even COB service. The higher energy consumption for operating faster is offset by savings in crew and capital costs, so the speed improvement can be attained without significantly increasing overall operating costs.

The approximate acquisition cost of a GLSLS containership would be $18 million. The Exhibit 4-11 below summarizes the performance parameters for the prototype containership for the GLSLS.

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35 Holtrop, J. and G. G. J. Mennen. 1978. A statistical power prediction method. *International Shipbuilding Progress* 25.

36 Holtrop, J. and G. G. J. Mennen. 1982. An approximate power prediction method. *International Shipbuilding Progress 29*.

37 Propulsion Trends in Container Vessels. No date. Copenhagen, Denmark: MAN B&W Diesel A/S.

38 *ePING - Engineering Assistance in Hydrodynamics* 2006. Schiffbau-Versuchsanstalt Potsdam GmbH 2006 [cited January 29 2006]. Available from http://www-sva-postsdam.de/eping/free/holtrop/holtrop.php

39 Gillmer, Thomas C. and Bruce Johnson. 1982. *Introduction to Naval Architecture*. Annapolis, Maryland: Naval Institute Press.

40 *Vessel Power Calculator* 2006. boatdiesel.com 2006 [cited January 29 2006]. Available from http://boatdiesel.com/BDR/Members/Calculators/PowerRequired.cfm.

41 Pollak, Richard. 2004. *The Colombo Bay*. New York, New York: Simon and Schuster.

Exhibit 4-11: GLSLS Container Ship Performance Parameters

Performance Parameter	Prototype Vessel
Cruise Speed (km/h)	37.0
Fuel consumption at cruise speed (kg/hr)	2,680
Fuel economy at cruise speed (kg/TEU-km)	.054
Loaded TEU/FEU capacity	1,330 / 665
Crew	14

The higher speed of modern container ships directly addresses the core concern of most shippers – that water transportation is too slow. The near doubling of the speed of modern vessels can bring GLSLS water transit times within a competitive range of ground transportation. In the GLSLS, ship speeds will still be limited in the constrained locks and channels; but there is plenty of open-water sailing on both the Great Lakes and lower St. Lawrence River where a faster vessel speed could reduce transit times.

Furthermore, it should be noted that while there is still a considerable supply of older vessels (many of which are commercially obsolete in the ocean trades) which fit the GLSLS locks and might be considered as candidates for providing GLSLS water feeder service, they lack the operating efficiency of modern vessels. As a result, despite their low capital cost, they generally operate at a much lower speed than modern ships, which typically makes them uncompetitive in time sensitive container markets.

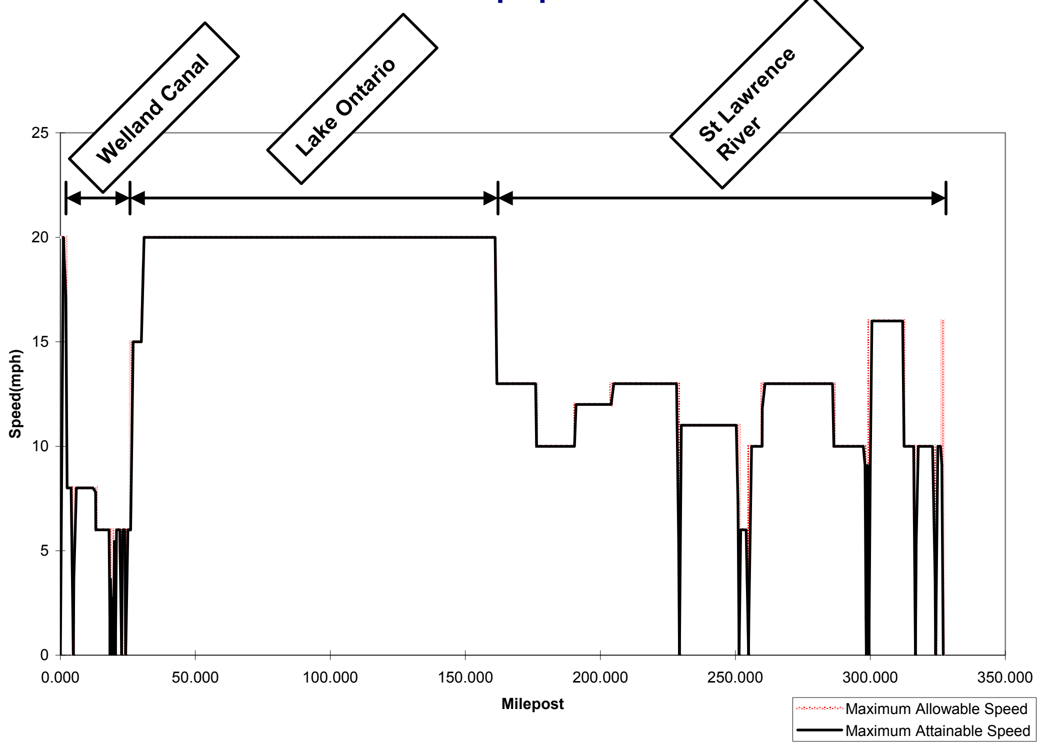
Since the GLSLS shipping lanes are fiercely competitive with ground transportation modes, it would be a mistake to try to introduce obsolete vessels into the GLSLS trade. It is considered that the operating advantages of a modern vessel outweigh the higher initial capital cost in this market. All the Container Ship demand forecasts prepared for this study assume the introduction of modern containerships that are capable of a top speed of 22-23 knots. If an older vessel is to be used instead, the results will be more consistent with the forecast developed for the slower COB service.

At the same speed, COB is slightly less efficient on a cost basis than the GLSLS container ship, mainly due to the improved fuel efficiency of the larger and more streamlined container ship hull. However, the main advantage of the container ship is that it can go more than twice as fast as COB at approximately the same cost per FEU-mile. It makes sense that deep draft vessels would provide better economics on GLSLS, since COB technology is optimized for river service, not for a deep-draft waterway system like the GLSLS.

A critical choice is whether a modern ship design should be deployed in Ro/Ro or Lo/Lo configuration. Lo/Lo uses cranes to stack containers in the hold and on the deck and can carry more containers than a Ro/Ro design. The benefit of the Ro/Ro design is reduced port costs as well as shortened vessel dwell times at the docks. Both Ro/Ro and Lo/Lo container ship versions are under evaluation as sensitivities to the Lo/Lo design that was originally proposed by RAND. As well, two possible vessel sizes have been evaluated.

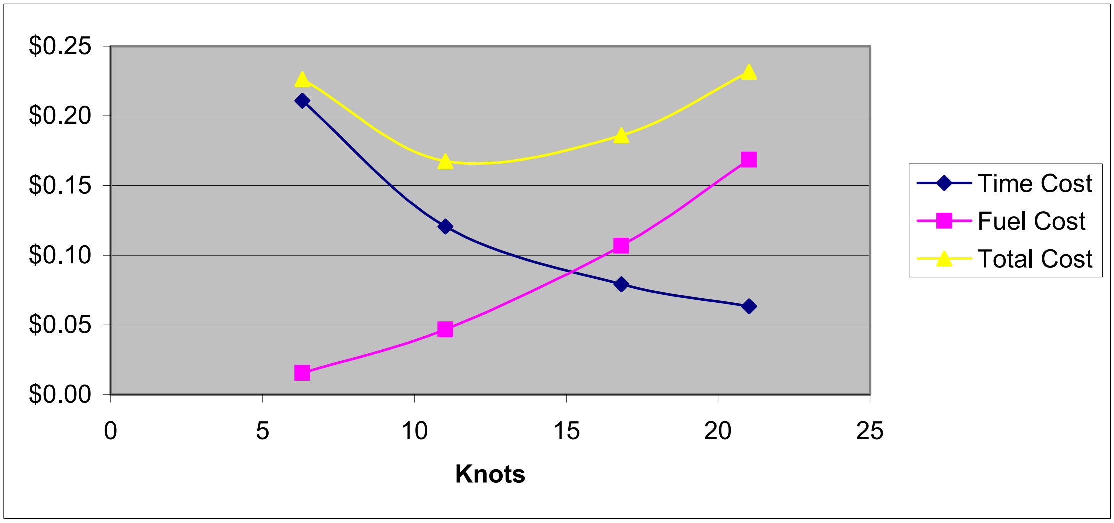
Exhibit 4-12 shows the speed profile for GLSLS Container Ship from Lake Erie to Montreal. The transit time would be 43 hours, substantially faster than the COB service, because of the ability to sail faster on the open waters of the Great Lakes. Obviously, once the open waters of the Upper Lakes are attained beyond the Welland Canal, a modern container ship could go up to twice as fast as a COB service. For a trip from Halifax to Montreal, the trip time is 50 hours for a modern container ship. From Montreal to Port Colbourne on Lake Erie, the time would be 43 hours and from Port Colbourne to Chicago the time would be 42 hours. The total from Halifax to Chicago would be 135 hours, approximately 5½ days sailing time, a dramatic saving over the best-case 8 ½ days for a COB system.

Exhibit 4-12: GLSLS Container Ship Speed Profile: Port Colbourne to Montreal



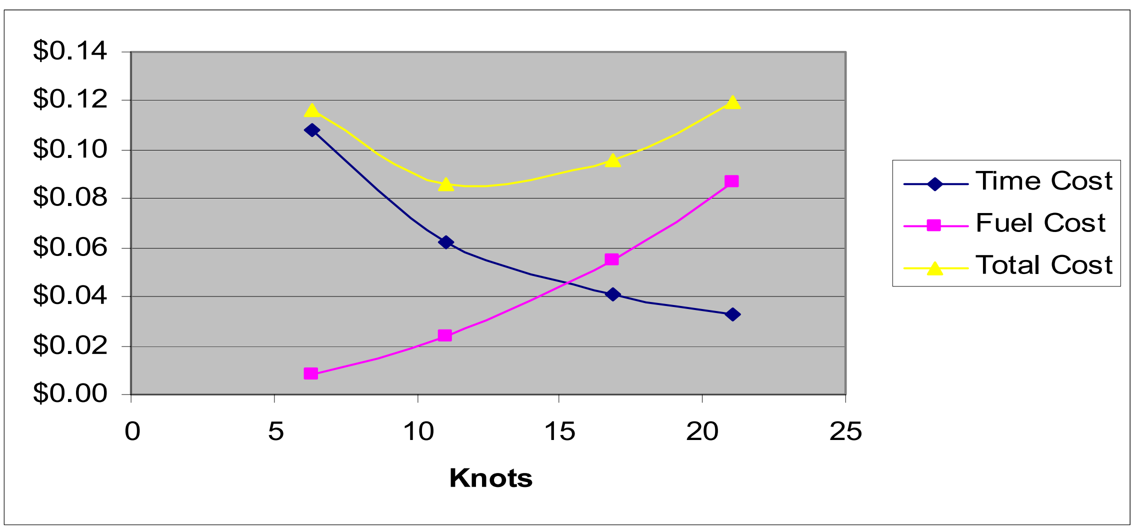
Exhibits 4-13 and 4-14 show the speed vs. operating cost tradeoff for a modern GLSLS-max container ship. Exhibit 4-23 has the ship in Ro/Ro configuration, whereas Exhibit 4-24 is for Lo/Lo. As shown in Exhibit 4-23, a 342-FEU Ro/Ro vessel's total operating cost is projected at $0.17 per FEU-mile at 11-knots, or $0.23 per FEU-mile at 20-knots. By comparison, rail intermodal line-haul cost is about $0.36 per FEU-mile and trucking costs $1.75 per FEU-mile. Therefore, it can be seen that the GLSLS-max Ro/Ro ship can be very cost-competitive with rail intermodal shipping, provided the port handling charges are not so large as to undermine the line-haul cost advantage of this vessel.

Exhibit 4-13: 342-FEU Ro/Ro GLSLS Container Ship: Cost per FEU-mile



In Exhibit 4-14, the 665-FEU Lo/Lo vessel has a substantially higher capacity, which translates into an even lower unit cost per FEU. This vessel is clearly cost competitive with rail intermodal shipping. The disadvantage is the requirement for crane loading, which would subject the vessel to higher port costs. As a rule, to maximize line-haul efficiency, Lo/Lo service would be more advantageous in the longer distance shipping lanes, whereas Ro/Ro service would offer less expensive terminal operations for shorter haul lanes.

Exhibit 4-14: 665-FEU Lo/Lo GLSLS Container Ship: Cost per FEU-mile



Exhibits 4-15 and 4-16 gives the basic performance specifications for a smaller container ship based on a design commonly used in European coastal waters. Data in Exhibit 4-16 was obtained from the vessel manufacturer[42].

Exhibit 4-15: Coaster Container Ship

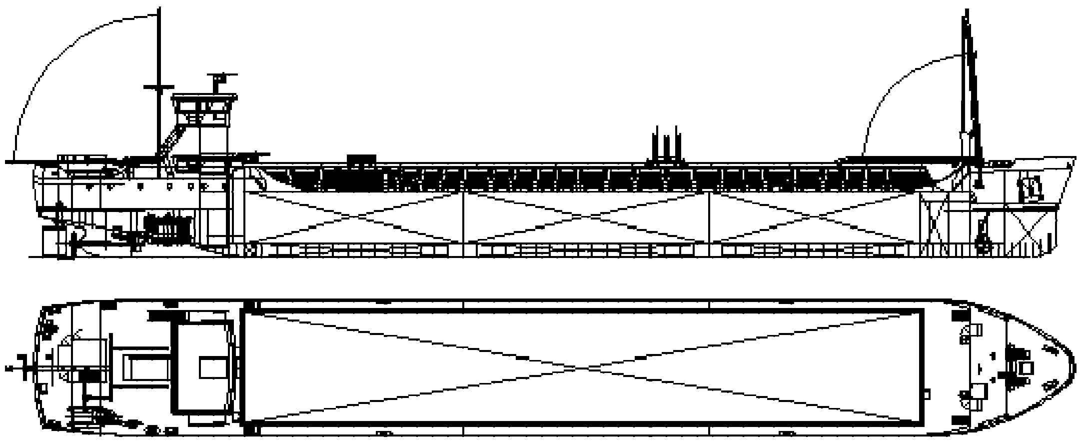


Exhibit 4-16: Coaster Container Ship Performance Parameters

Performance Parameter	Prototype Vessel
Cruise Speed (km/h)	37.0
Fuel consumption at cruise speed (kg/hr)	1,005
Fuel economy at cruise speed (kg/TEU-km)	.078
Loaded TEU/FEU capacity	350 / 175
Crew	8

Exhibit 4-17 gives the cost per FEU-mile for this smaller ship in Ro/Ro configuration. A 90-FEU Ro/Ro vessel's total operating cost is projected at $0.45 per FEU-mile at 17-knots, or $0.48 per FEU-mile at 20-knots. By comparison to rail line-haul cost of about $0.36 per FEU-mile and $1.75 for a truck, it can be seen that the smaller vessel in Ro/Ro configuration may have a hard time directly competing with rail intermodal service, although it could certainly still compete with trucking.

[42] UAB Laivu Projetai, Lithuania. http://www.laivuprojektai.com/index.php?page=coasters

Exhibit 4-17: 90-FEU Ro/Ro Coaster Container Ship: Cost per FEU-mile

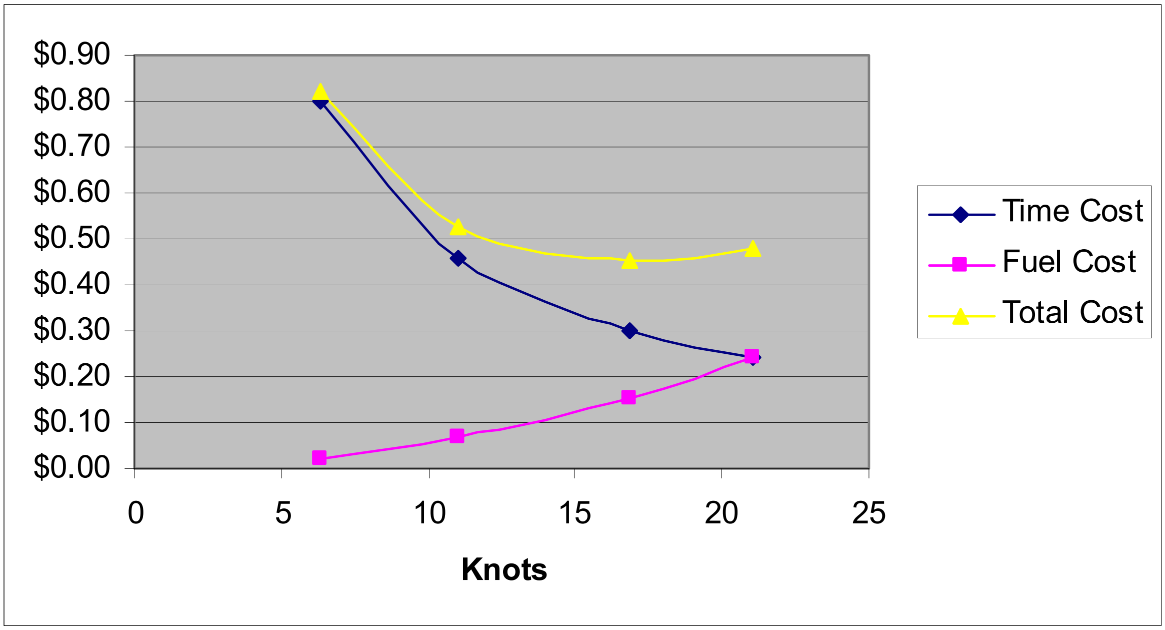
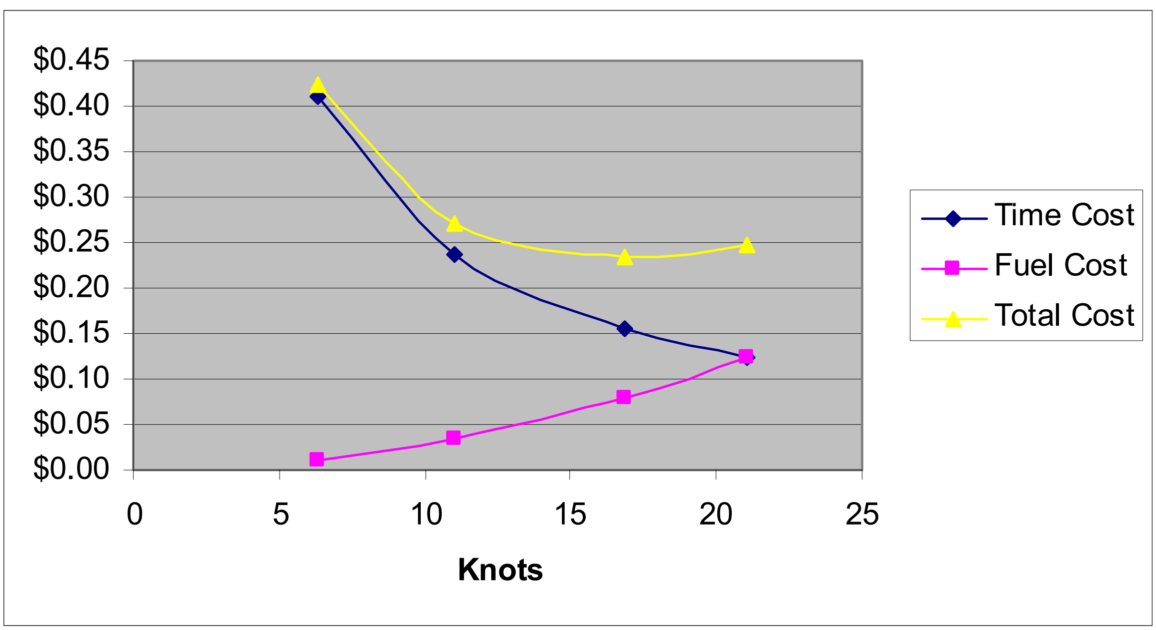


Exhibit 4-18 gives the cost for this Coaster vessel in Lo/Lo configuration. A 175-FEU Lo/Lo vessel's total operating cost is projected at $0.23 per FEU-mile at 17-knots, or $0.25 per FEU-mile at 20-knots. Rail line-haul costs about $0.36 per FEU-mile; trucking costs $1.75. It can be seen that the Coaster vessel could very effectively compete with rail in Lo/Lo configuration if port loading and unloading charges are not too high.

Exhibit 4-18: 175-FEU Lo/Lo Coaster Container Ship: Cost per FEU-mile



4.3.4 A Ro/Ro Fast Freighter

The third technology we consider is a "fast freighter." The vessel is a high-speed catamaran configured to handle Ro/Ro cargo. These vessels are primarily designed for high-speed movement and low-cargo capacity relative to other technologies examined in this analysis. Traditionally, the technology has focused on passenger movement. At times, however, vessels are configured to handle cargo. The size of the locks and the clearance limits throughout the GLSLS do not constrain the maximum dimensions of most vessels of this type.

Fast Freighter (Ferry)

Many manufacturers produce such vessels, including Austal and Incat of Australia. Austal produces a passenger ferry that operated between Rochester, New York and Toronto, Ontario for several years[43] and built a similar vessel through its U.S. subsidiary to operate between Milwaukee, Wisconsin and Muskegon, Michigan.[44] The vessel prototype examined in this analysis is a proposed vessel by Austal.[45] The beam of the prototype vessel is several meters wider than that allowed by the GLSLS; we make the assumption that a fast freighter constructed for the GLSLS would have approximately the same deadweight tonnage. The basic parameters of the vessel are listed in the exhibit below.

Exhibit 4-19: Performance parameters for a prototype fast freight vessel for use in the GLSLS.

Parameter	Prototype Vessel
Length Overall (m)	115.0
Length at Waterline (m)	100.0
Beam (m)	28.7
Draft (m)	4.2
Cargo deadweight (kg)	$1.52 * 10^6$
Loaded TEU	95
Engines	4 x 9,000 kW

The performance parameters for the fast freighter are much different than that of the GLSLS containership. Since it operates in non-displacement mode, current GLSLS regulations allow it to operate at 63.9 km/h when traversing the Great Lakes and entering the GLSLS from the Gulf of St. Lawrence. The hourly fuel consumption increases

43 U.S. Department of Transportation. 2004. Fast Ferries on the Great Lakes: Success is Here to Stay. In *Seaway Compass*.
44 Egan, Dan. 2006. *Futuristic high-speed catamaran ferry plies uncharted waters in lake travel.* LakeNet, December 14, 2003 2003 [cited May 30 2006]. Available from http://www.worldlakes.org/shownews.asp?newsid=1583.
45 Fast Freighter Outline Spec 1. 2004. Henderson, Australia: Austal.

considerably: the fuel consumption at cruise speed, assuming a specific fuel consumption of 0.201 kg/kW-hr, is 6,510 kg of MDO, yielding a fuel efficiency of 1.07 kg/TEU-km.

The cargo capacity of the fast freighter is greatly reduced from that of the containership. Because the vessel is to be used for Ro/Ro carriage, the vessel also must carry the intermodal chassis, which has a mass of 3,240 kg.[46] The $1.52 * 10^6$ kg deadweight tonnage can theoretically accommodate 47 40-foot containers with their chassis, or 95 TEU. This number fits within the lane capabilities of a similar vessel, which has 730 lane meters on a single deck, enough to accommodate approximately 60 40-foot containers.[47],[48]

Our estimate for crew on the fast freighter differs from that of the manufacturer. The manufacturer proposes that the vessel be manned by 14 crewmembers.[49] However, since the vessel carries relatively little cargo and is smaller than other vessels, we assume that 9 crewmembers are sufficient to operate the vessel, tend cargo, and assist in docking.

Fuel consumption for the fast ferry has been estimated by Austal and is reported in the exhibit below.

Exhibit 4-20: Fuel consumption for a fast freighter at common operating speeds in the GLSLS.[50]

Speed (km/h)	Fuel consumption (kg/hr)	Fuel efficiency (kg/TEU-km)
11.1	510	0.484
19.4	810	0.440
29.6	1,200	0.427
37.0	1,500	0.427
63.9	6,510	1.07

Austal, Inc. estimates the acquisition cost of the fast ferry to be approximately $50 million.[51]

Fast Ferry vessels employ very powerful engines to operate in non-displacement mode at a high speed. The ships were initially designed as automobile and truck ferries. To reduce weight, they often employ welded aluminum hull construction. Despite the lightweight design cruising at 40-knots, unfortunately, these vessels have very high-energy consumption – almost 20 times more fuel per FEU-mile than the container ship. The result is that the Fast Freighter (Ferry) consumes substantially more fuel per TEU-mile than trucking. Exhibit 4-21 gives the basic performance specifications for the Fast Freighter (Ferry).

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[46] *GE Equipment Services, Rail Services* 2006. General Electric 2006 [cited February 12 2006]. Available from http://www.ge.com/railservices/productsservices/intermodal/containers.html.

[47] This discrepancy between tonnage and lane capacity would be a major consideration in the design of a GLSLS-specific fast ferry. The manufacturer estimates that the vessel can carry 132 TEU.

[48] *Fast Freight - Austal* 2006. Austal 2006 [cited February 12 2006]. Available from http://www.austal.com/go/product-information/commercial-products/fast-freight

[49] Fast Freighter Outline Spec 1. 2004. Henderson, Australia: Austal.

[50] Operating in non-displacement mode changes the drag characteristics of vessels, a phenomenon witnessed here as the vessel speed increases. (Regan 2006)

[51] Regan, Richard. 2006. Austal Fast Ferry Product Information. Santa Monica, California, May 10.

Exhibit 4-21: Fast Freighter (Ferry) Performance Parameters

Performance Parameter	Prototype Vessel
Cruise Speed (km/hr)	63.9
Fuel consumption at cruise speed (kg/hr)	6,510
Fuel economy at cruise speed (kg/TEU-km)	1.07
Loaded TEU / FEU capacity	95 / 42
Crew	9

As shown in Exhibit 4-22, the Fast Freighter (Ferry) needs 40 hours to go from Port Colbourne to Montreal: three hours faster than the container ship and eight hours faster than COB service. The difference is entirely due to faster speeds on the open waters of Lake Ontario, since it is assumed the vessel is constrained by normal speed limits on the St Lawrence Seaway and Welland Canal. For a trip from Halifax to Montreal, the trip time is 25 hours for the Fast Freighter (Ferry). From Montreal to Port Colbourne on Lake Erie, the time (Exhibit 4-31) would be 40 hours and from Port Colbourne to Chicago the time would be 21 hours. The total from Halifax to Chicago would be 86 hours, approximately 3½ days sailing time. This is less than half the time for a COB vessel and a 36 percent savings over a container ship. Exhibit 4-23 shows the cost of the Fast Ferry, which is higher than trucking per FEU-mile, in large part due to the high fuel consumption of the vessel.

Exhibit 4-22: Fast Freighter (Ferry) Speed Profile: Port Colbourne to Montreal

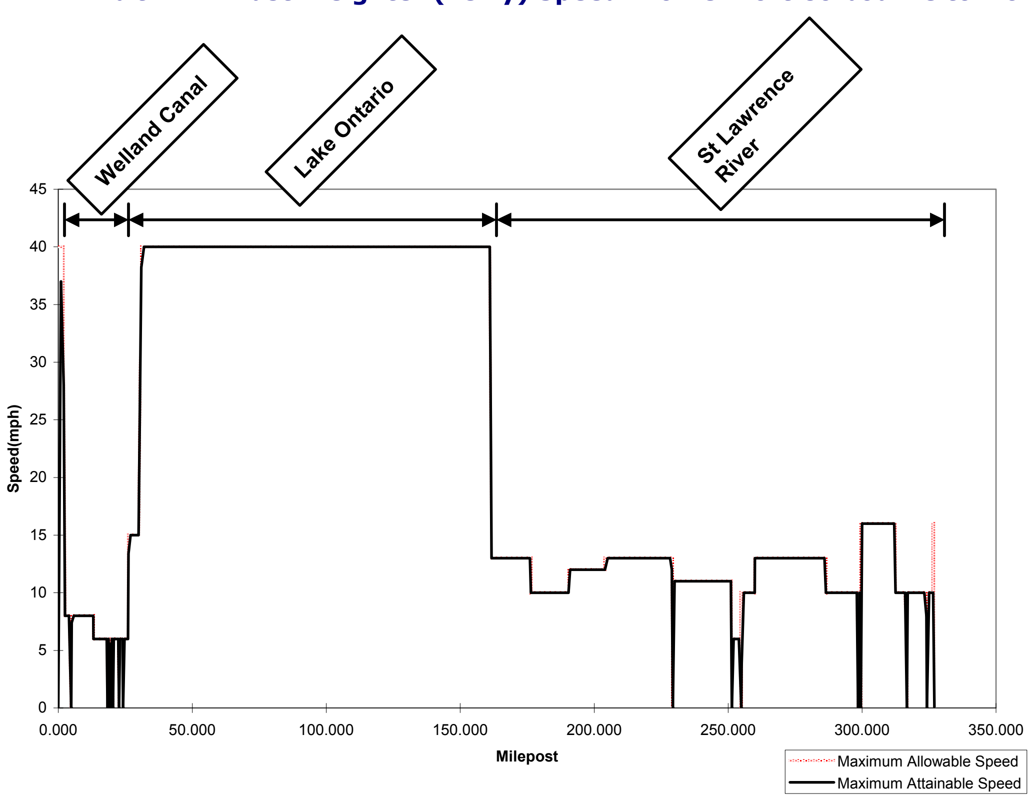
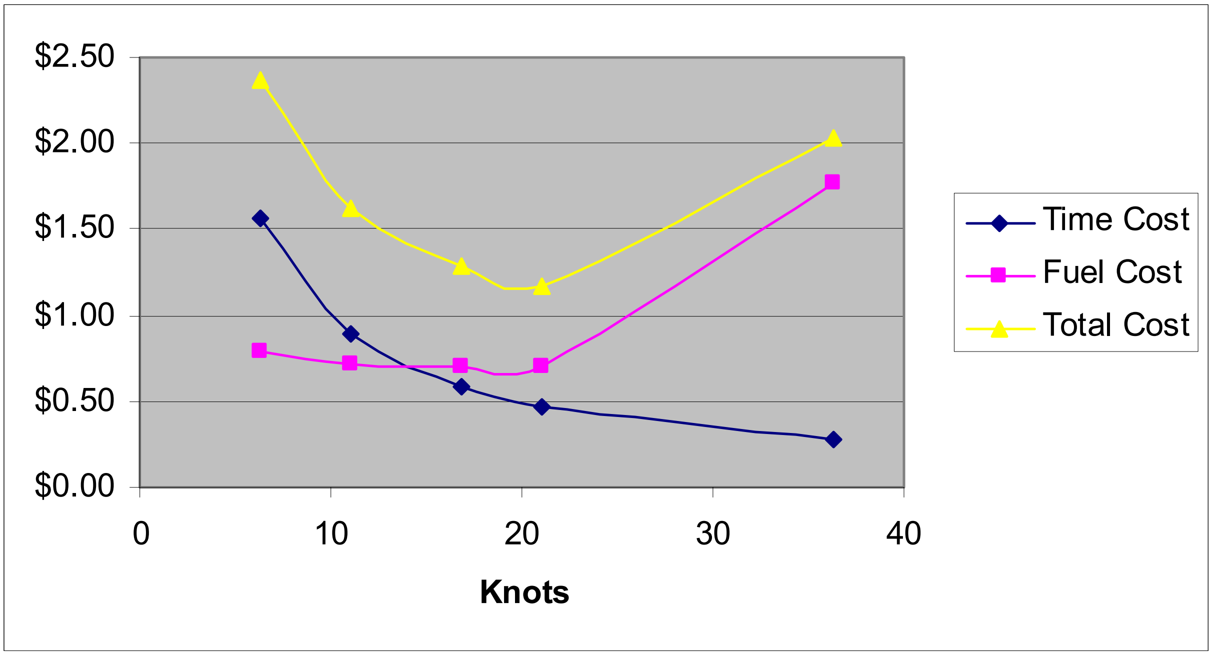


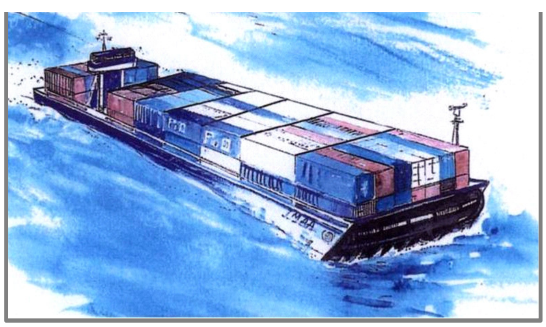
Exhibit 4-23: 46-FEU Fast Ferry: Cost per FEU-mile



4.3.5 THE PARTIAL AIR-CUSHION SUPPORT CATAMARAN

The final technology we consider is the PACSCAT. The PACSCAT is a slender-hulled catamaran partially supported by a lift fan. Vessels with partial aerostatic support have been in existence for several decades.[52] Features include reduced resistance and fuel consumption, increased speed, shallow draft, and reduced wake when compared to conventional displacement or other high-speed vessels. The size of the locks and the clearance limits throughout the GLSLS do not constrain the maximum dimensions of prototype PACSCAT vessels.

Partial Air Cushion Catamaran – PACSCAT



[52] Gillmer, Thomas C. and Bruce Johnson. 1982. *Introduction to Naval Architecture*. Annapolis, Maryland: Naval Institute Press.

The PACSCAT discussed here is similar those that have been designed for use in inland European waterways.[53] If PACSCAT were to be put into operation in the GLSLS, a particular vessel would need to be developed, optimizing the size, power and lift system to maximize deadweight tonnage and meet GLSLS speed restrictions. The vessel, whose parameters is listed in the exhibit below, is a novel design provided by Independent Maritime Assessment Associates and has a cargo deadweight of $3.05 * 10^6$ kg, which translates into 210 loaded TEU when used in a LoLo configuration.[54]

Independent Marine Assessment Associates estimates the acquisition cost of the PACSCAT described in this section to be approximately $20 million.[55]

Exhibit 4-24: Characteristics of a PACSCAT vessel appropriate for use on the GLSLS.[56]

Parameter	Prototype Vessel
Length Overall (m)	225
Beam (m)	23.8
Draft (m)	1.8
Cargo deadweight (kg)	$3.05 * 10^6$
Loaded TEU	210

Performance characteristics of the PACSCAT are a result of the use of the air cushion to reduce draft, resistance and wake. The cruise speed of the vessel is 37.0 km/h, which is the same cruising speed as the prototype containership, but less than that of the fast freighter. The fuel consumption of the vessel at cruise speed is 2,460 kg of MDO and the fuel efficiency is 0.316 kg/TEU-km. We assume slightly increased crew requirements for the PACSCAT over that of the fast freighter, due to the increased cargo capacity of the vessel. The performance characteristics of the vessel are listed in the exhibits below.

Exhibit 4-25: Power and fuel consumption for a prototype PACSCAT vessel.[57]

Speed (km/h)	Propeller power (kW)	Lift power (kW)	Total power (kW)	Fuel consumption (kg/hr)	Fuel efficiency (kg/TEU-km)
11.1	380	1,200	1,580	318	0.136
19.4	2,730	1,200	3,930	790	0.194
29.6	7,300	1,200	8,500	1,710	0.275
37.0	11,000	1,200	12,200	2,450	0.316
55.6	34,000	1,200	35,200	7,075	0.606
63.9	42,000	1,200	43,200	8,683	0.657

53 Clements, R., John C. Lewthwaite, P. Ivanov and P. Wilson. 2005. The Potential for the Use of a Novel Craft, PACSCAT, in Inland European Waterways. Paper read at International Conference on Fast Sea Transportation, June, at St. Petersburg, Russia.
54 Lewthwaite, John C. 2006. 225m PACSCAT Freighter Specifications. Independent Maritime Assessment Associates. Santa Monica, California, April 10.
55 Lewthwaite, John C. 2006. 2000t PACSCAT River Freighter Fuel Consumption. Independent Maritime Assessemnt Associates. Santa Monica, California, February 14.
56 Clements, R., John C. Lewthwaite, P. Ivanov and P. Wilson. 2005. The Potential for the Use of a Novel Craft, PACSCAT, in Inland European Waterways. Paper read at International Conference on Fast Sea Transportation, June, at St. Petersburg, Russia.
57 Lewthwaite, John C. 2006. 2000t PACSCAT River Freighter Fuel Consumption. Independent Maritime Assessemnt Associates. Santa Monica, California, February 14.

The PACSCAT is a prototype design for a surface-effect ship – a vessel that uses an air cushion to partially lift itself out of the water. This reduces the draft of the vessel as well as its wave-making effect. The vessel was designed for the Rhine and coastal waters of Europe, as an environmentally more friendly way of operating at higher speeds. The surface-effect concept is not new – it has been applied to military vessel design for a long time. Normally a surface-effect vessel operates in displacement mode up to a certain speed – usually the vicinity of 20 knots – above which the air cushion is activated to allow the vessel to go faster, up to 40 knots.

The PACSCAT, however, employs lift in a novel fashion at low speeds, as well as high speeds. The 'Rhine' river-freighter version of the PACSCAT technology has been designed to operate at speeds up to 20 knots. The advantage of this vessel is that it reduces the waves in the river to acceptable levels while permitting a higher vessel operating speed. For this application, the air-lift system is kept on all the time. The air-lift system also reduces required water depth, a valuable feature in shallow river environments.

The "North Sea Freighter" version of PACSCAT is designed to operate both on river channels and in the open waters of the North Sea. As such, it is designed with a higher vertical clearance in order to handle larger waves in open ocean operation. As well, the North Sea Freighter is equipped with more powerful engines to be able to attain a maximum speed of 40 knots. Exhibit 4-26 gives the basic performance parameters for both versions of the PACSCAT.

Exhibit 4-26: PACSCAT Performance Parameters

Performance Parameter	River	North Sea
Cruise Speed (km/h)	37.0	63.9
Fuel consumption at cruise speed (kg/hr)	2,450	8,683
Fuel economy at cruise speed (kg/TEU-km)	.315	.647
Loaded TEU/FEU capacity	210 / 105	210 / 105
Crew	11	11

While both versions of PACSCAT were included in the scope of the initial analysis, it quickly became apparent that the River version of PACSCAT may not be particularly well suited to the GLSLS.

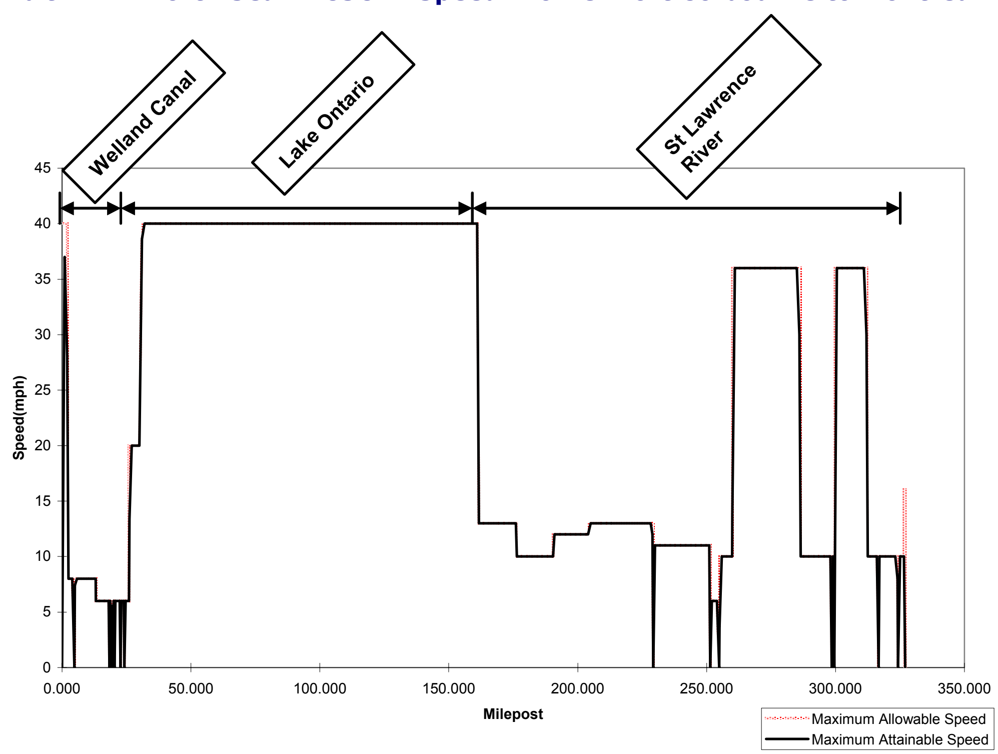
- Since it is an improved deep-draft waterway, the GLSLS does not present the same constraints of a typical river system in terms of channel depth or vertical clearance. In locks and canal sections, PACSCAT may not be permitted a higher speed limit because of safety considerations.
- Opportunities to utilize PACSCAT's higher-speed in the St. Lawrence River are limited to Lake St Louis and Lake St Francis. On the Great Lakes, a container ship can go just as fast as the river version of PACSCAT and the container ship is more seaworthy than the PACSCAT River Freighter.
- PACSCAT's capital cost is more expensive than a container ship but offers much smaller capacity.

- The River PACSCAT burns almost as much fuel as a GLSLS container ship at the same cruising speed but offers only one-sixth the capacity. Therefore, by comparison to modern containership designs, it is clear that the PACSCAT River Freighter offers little benefit to GLSLS.

However, the North Sea freighter version of PACSCAT is much more interesting for a potential GLSLS application. This vessel can go twice as fast as a container ship on the open waters of the Great Lakes and below Montreal and it offers higher capacity and better fuel economy than the Fast Ferry.

As shown in Exhibit 4-27, the North Sea PACSCAT needs only 37 hours to go from Lake Erie to Montreal: the fastest time of any vessel available. The PACSCAT can go 40-knots on the open waters of Lake Ontario, the same as the Fast Ferry. However, it is also assumed that the vessel could go up to 35-knots in non-displacement mode on Lake St Louis and Lake St Francis, because of PACSCAT's reduced wave-making as compared to conventional ship designs.

Exhibit 4-27: North Sea PACSCAT Speed Profile: Port Colbourne to Montreal

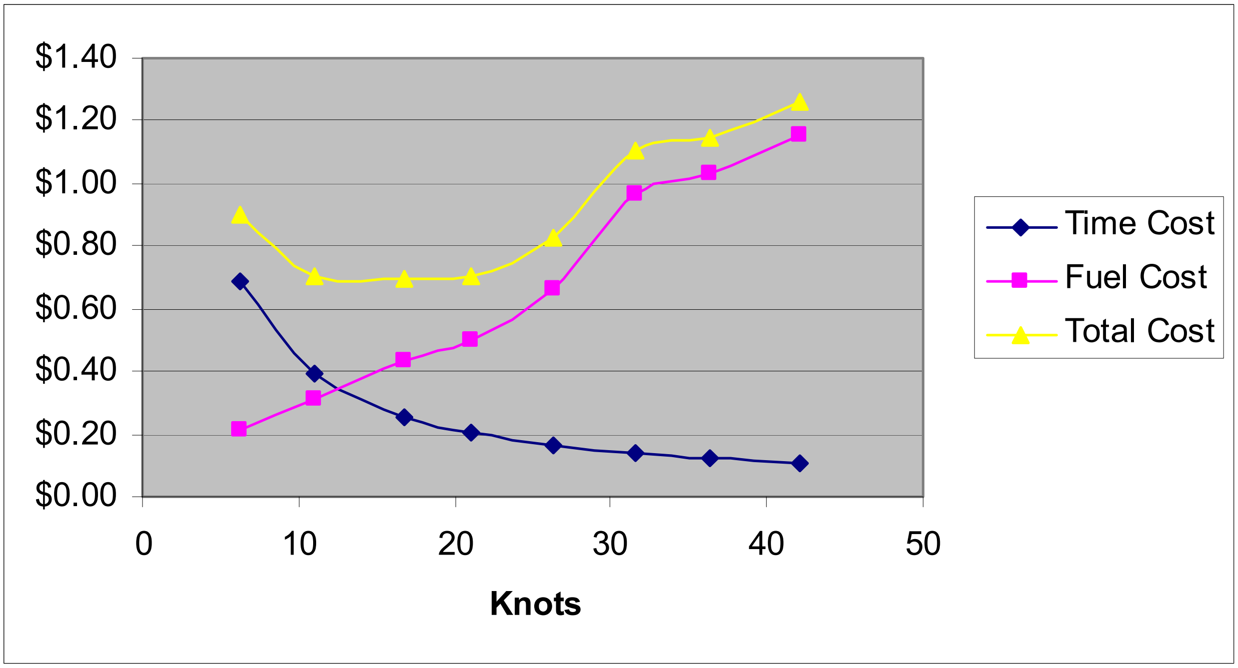


For a trip from Halifax to Montreal, the trip time is 25 hours for the North Sea PACSCAT. From Montreal to Port Colbourne on Lake Erie, the time (from Exhibit 4-32) would be 37 hours and from Port Colbourne to Chicago the time would be 21 hours. The total from Halifax to Chicago would be 83 hours, approximately 3½ days sailing time, the same time as the Fast Freighter (Ferry).

The operating cost comparison for PACSCAT is shown in Exhibit 4-28. This shows that PACSCAT has a cost of $0.71 per FEU-mile at 20-knots and $1.26 per FEU-mile at 42-knots. PACSCAT has higher costs than North American railroads, but still comes in at a lower cost than trucking. This is consistent with the European commission's finding, where PACSCAT is being introduced mainly in lanes where rail intermodal service is very weak. However, in North America, rail freight is much better developed than in Europe and our analysis of comparative economics for the GLSLS reflects this differential.

PACSCAT technology shows much more favorable economics for hauling freight than does the Fast Freighter (Ferry). Both technologies are capable of top speeds in the 40-knot range, but PACSCAT appears to have more capacity, better fuel consumption and lower overall operating costs than does the Fast Freighter (Ferry). Perhaps this should come as no surprise, since PACSCAT was purpose-designed as a freight transport system, whereas the Fast Freighter (Ferry) was designed primarily for automobile and passenger transport.

Exhibit 4-29: 105-FEU PACSCAT: Cost per FEU-mile



4.4 Comparison of the Performance of the Vessel Technologies

Exhibit 4-30 provides a summary of the parameters for technologies presented in the document. This exhibit compares the performance characteristics of the four vessel technologies and summarizes the inherent strengths and weaknesses of each vessel relative to the others.

Exhibit 4-30: Summary of performance characteristics of the candidate vessel technologies.

	Container on Barge	Containership	Fast Ferry	PACSCAT
Length Overall (m)	179.8	222.5	115.0	225
Beam (m)	21.9	23.8	28.7	23.8
Draft (m)	3.7	7.9	4.2	1.6 with lift / 2.5 at rest
Cargo deadweight (kg)	$9.00 * 10^6$	$19.3 * 10^6$	$1.52 * 10^6$	$3.05 * 10^6$
Loaded TEU	620	1,330	95	210
Starting and stopping time and distance	We assume that the time/distance to full speed/stop under normal operating conditions to be 5 minutes and 2 km			
Environmental compliance	We assume that all vessels are configured to comply with ballast exchange and other environmental requirements of the GLSLS.			
Port infrastructure requirements	We assume that all ports have the appropriate facilities and equipment to handle containerized cargo operations.			
Cruise speed (km/h)	14.8	37.0	63.9	37.0
Fuel consumption at cruise speed (kg/hr)	560	1,360	6,510	2,450
Fuel consumption at 19.4 km/hr (kg/hr)	N/A	390	810	790
Fuel consumption at 11.1 km/hr (kg/hr)	370	74	510	318
Fuel economy (kg/TEU*km) at cruise speed	0.061	0.054	1.07	0.315
Crew	9	14	9	11
Approximate acquisition cost ($M)	11	15	50	20

Exhibit 4-31 builds on the fuel efficiency data presented above and adds truck and rail data to compare the candidate vessel technologies to the other prevailing options. Fuel efficiency is a per-TEU measure of fuel used over a given distance. Among the four candidate vessel technologies, the containership is the most fuel efficient (0.054 kg/TEU-km) closely followed by container on barge (0.061 kg/TEU-km). PACSCAT is the third most fuel efficient vessel (0.315 kg/TEU-km) while the fast ferry is the least fuel efficient vessel (1.07 kg/TEU-km). Both the containership and container on barge vessels are more fuel efficient than truck (0.186 kg/TEU-km) and rail (0.070 kg/TEU-km).[58] Both high-speed vessel technologies, PACSCAT and Fast Ferry, have significant fuel consumption and have less fuel efficiency than that of truck or rail. The fast ferry is the least fuel-efficient option.

[58] Inland Waterway Navigation: Value to the Nation. 2000. Washington, District of Columbia: U.S. Army Corps of Engineers.

Exhibit 4-31: Summary of fuel efficiency of the candidate vessel technologies.

	Container on Barge	Containership	Fast Ferry	PACSCAT	Truck	Rail
Fuel efficiency at cruise speed (kg/TEU-km)	0.061	0.054	1.07	0.315	0.186	0.070
Fuel economy at cruise speed (ton-mi/gal)	514	582	29.4	99.5	148	390

Chicago to Halifax transit times for the different vessel technologies are summarized in Exhibit 4-32. This exhibit includes both the river and sea versions of PACSCAT:

Exhibit 4-32: St. Lawrence Seaway: Vessel Transit Times Summary

Section	Seagoing COB (12 kts)	Cont Ship (20 kts)	River PACSCAT (20 kts)	Fast Ship (40 kts)	Sea PACSCAT (40 kts)
Chicago to Pt Colbourne	70	42	42	21	21
Welland Canal	13	13	13	13	13
Lake Ontario	12	7	7	4	4
St. Lawrence to Montreal	23	23	22	23	20
Montreal to Halifax	84	50	50	25	25
Total Hours	202	135	134	86	83
Approx Days	8½	5½	5½	3½	3½

For comparing the performance of the four vessel technologies considered –

- The simplest and slowest, technology is container on barge (COB), which consists of two barges configured to handle containers, towed by a towboat. The COB has the slowest cruising speed (14.8 km/h) but is relatively fuel-efficient (560 kg/hr), for its cargo capacity (620 TEU).
- The trend in the construction of containerships has been to larger and larger vessels; the containership we consider is a moderate-size vessel built especially for use in the GLSLS. Like the COB, this technology has a high cargo capacity (1,330 TEU). This vessel also consumes a significant amount of fuel at its top speed (2,680 kg/hr). A key difference between the two technologies is that the cruising speed of the containership (37.0 km/h) is more than twice the speed of the COB.[59]
- We also examined a novel technology called a "fast freighter", which is a catamaran configured to handle Ro/Ro cargo. The cruising speed of the fast ferry is 63.9 km/h but the container carrying capacity of the fast ferry is only 95 TEU. The vessel consumes a significant amount of fuel at cruise speed (6,510 kg/hr).

[59] Because the containership is a displacement vessel, it must travel at a slower speed (29.6 km/h) in many parts of the GLSLS.

- The final technology we examined was the partial air-cushion support catamaran (PACSCAT). The PACSCAT technology consumes more fuel at a cruise speed of 37.0 km/h (2,450 kg/hr), when compared to the containership. Since the PACSCAT is a novel technology, the prototype we examined was not designed for the GLSLS. This version is capable of carrying 210 TEU but a vessel designed specifically for the deeper channel of the GLSLS might carry more cargo.

Choosing the technology best suited for the GLSLS is a complex function of a number of factors, including average trip distance, the type of cargo, and the constraints of the GLSLS. While the top speed of the PACSCAT and the fast ferry makes them attractive for quick turnaround shipping for high value commodities or accompanied trailers, their limited cargo carrying capacity with respect to other technologies and increased fuel consumption may constrain their economic viability.