Model Analysis of the Effect of Reduced Ice Coverage on Great Lakes Marine Transportation

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Chapter I. Introduction

The North American Laurentian Great Lakes hold nearly 20 percent of the earth's unfrozen fresh surface water. They cover an area of over 94,000 square miles. For thousands of years the Great Lakes have been a marine highway for products and people. During the past two centuries, these waterways have been major trade routes, annually shipping tens of millions of tons of cargo.

The Great Lakes Navigation System (GLNS) is approximately 1,600 miles in length, serving all five Great Lakes and connecting channels from Duluth, MN, to Ogdensburg, NY. The GLNS has nearly a quarter (22) of the nation’s top 100 harbors by tonnage. Commodities transported on the GLNS represent 10 percent of all U.S. waterborne domestic cargo.[1]

For recorded history, marine traffic on the Great Lakes has followed a seasonal pattern driven by the cold northern climate. The formation of ice that is a barrier to safe navigation puts most vessels into winter layup. The seasonality of commercial shipping drives inventory management, vessel repair, crewing and port operations.

One choke point in the Great Lakes system is the Sault St. Marie river and lock system. (See Figure I-1) This passage between Lakes Superior and Huron is the pathway for the largest quantity of cargo currently shipped on the Lakes. The Sault is located at about 46.5 degrees north latitude with relatively shallow waters. This results in it being one of the first locations on the upper Lakes to freeze over and last to thaw out. The locks installed at the Sault to allow transit around the rapids have normally closed operations corresponding to the freezing of the adjacent area.

Figure I-1 Great Lakes Shipping Lanes (University of Michigan)

Until the late 1960s, the Soo Locks typically closed for the winter season between December 15 and April 1. Per the Code of Federal Regulation, the Soo Locks are currently closed from January 15 to March 25 (about 68 days) to allow for maintenance of the two operational locks.

Two events may have the potential to change this long-standing transportation pattern. One event that is becoming more apparent in its impact on the Great Lakes is the warming of the climate. Studies indicate the average air temperature is increasing and that ice cover is starting later and ending sooner. The rise in average air temperature, coupled with reduced ice coverage, increases the average water temperature of the Great Lakes—accelerating the impacts of climate change. A reduction in both the time of ice coverage and thickness could allow vessels to extend their shipping season.

The second event is the construction of a second large lock at the Sault. This second lock would allow the largest of the locks, the Poe, to undergo maintenance while allowing the continuous flow of millions of tons of cargo when ice conditions permit. After the new Poe-sized lock is completed, lock maintenance should not be a barrier to season extension.

A Congressionally authorized, five-year demonstration project by the U.S. Army Corps of Engineers (USACE) and the U.S. Coast Guard (USCG) permitted commercial shipping on the upper Great Lakes to operate year-round from 1974-1979. Iron ore and taconite shipped out of Lake Superior were the primary commodities moved. The USACE concluded in its 1979 report to Congress about the program that "season extension is engineeringly and economically feasible year-round on the upper three Great Lakes, up to year-round on the St. Clair River-Lake St. Clair-Detroit River System and Lake Erie, and up to 10 months on Lake Ontario and the International Section of the St. Lawrence River."

There has been prior research into the impact of climate change on Great Lakes marine transportation. Rob se Loe, et al, in 2001 examined how lower lake levels would impact Canadian operations, and possible methods to address long term declines.[2] Quinn examined the impact of potential changes in lake levels and briefly outlined how reduced ice coverage may impact shipping.[3] Frank Millerd's 2005 study modeled the impact of lake level changes on Canadian vessels.[4] In 2011 Millerd provided modeling and in-depth analysis on how an extended season for the St. Lawrence Seaway would impact international shipping.[5] Posey's 2012 summary of the lake level impacts noted that some models predicted higher lake levels.[6] These studies comprehensively address the impact on Great Lakes shipping of climate induced changing lake levels. Because prior research covers the important topic of lake level impacts, this study will not research that topic.

These valuable studies were done before the approval for a second Poe-sized lock. Thus, their work does not address that change. None of the studies examined in depth the impact on upper Great Lakes shipping or the potential for new cargoes. This study will explore these topics.

Hypothesis and Research Questions

The hypothesis of this study is: A reduction in ice coverage and thickness during the year, coupled with completion of a second Poe-sized lock, could enable an extended shipping season, and this would impact the Great Lakes Marine Transportation System (GLMTS).

This study's first research question is: What would be the impacts on the GLMTS that uses the Sault St. Marie locks if the sailing season could be extended by one or two months by the year 2050?

This study's second research question is: What new cargoes might move along this trade lane with an extended season?

Study Limitations

In order to align the scope of the research with resource availability, limits have been placed on what topics the research will and will not focus upon.

This study does not predict possible ice conditions during the shipping season in 2050. Climate change is long term. Weather has monthly and annual variations. Cold snaps will result in greater ice coverage during the winters for some years. Ice breaking will still be required, but the extent and thickness of the ice may, on average, be less than that encountered during the five-year demonstration project in the 1970s.

Only shipping routes using the Soo Locks are evaluated—not all of the Great Lakes or the St. Lawrence Seaway. Only representative vessels, not all vessels, are modeled. Only representative cargoes (taconite, limestone and coal), not all cargoes, are modeled. Data is from publicly available sources and subject matter experts.

Research addressing the first research question assumes that current (five-year average) cargo levels remain constant, and no new cargoes are added.

Because prior research has addressed in-depth the impact of changing lake levels on shipping, this topic will be reviewed but not researched.

Methodology

To address the first research question, research was conducted on how a shipping season extension would impact vessel and port operations, focusing only on the existing cargo shipped inter-lake and intra-lake by vessel. Government agencies, industry experts, data and information from relevant literature were all used during the research process. Models of the economic and operational impacts were developed using three existing cargos (taconite, coal and limestone) moving between the Twin Ports of Duluth, MN and/or Superior, WI and ports on the lower Great Lakes.

Addressing the second research question required gathering information about trade routes, cargoes and vessel operations from agencies and companies that operate in the Baltic Sea.

Data was also gathered about potential new or expanded cargoes from industry experts and agencies around the Great Lakes. A table of potential new cargoes was prepared. The benefits and challenges in marine transportation of these cargos was discussed.

Chapter II. Climate Change Impacts on Great Lakes Navigation

Research on the impact of climate change on the Great Lakes region is substantial and ongoing. The research explores how the increase in temperature is impacting flora, fauna, marine organisms, hydrology, storms, lake levels and ice, among other important areas.

The ability to navigate safely is directly impacted when ice formations impede navigation and could cause damage to a vessel. Whole gales and other violent storms also impede the ability of a vessel to make a safe passage and may require a vessel seek shelter in a harbor. A vessel's cargo carrying capacity is directly impacted by the depth of the channel. Low lake levels compel a vessel to reduce the cargo aboard to ensure the vessel does not run aground.

Lake Level Impacts

As noted in Chapter 1, prior studies addressed in detail the impact of changing lake levels on Great Lakes shipping. This study does not further explore that topic but provides a recap of this critical topic.

When lake levels decline, the channel depth is lowered. If the channels can be dredged, the impact will be an increased cost for dredging and dredge disposal. Areas with rock bottom may not be cost-effectively dredged, reducing the cargo carrying capacity of vessels.

> "*For every 0.0254 meters below full draft that the lakes drop ships lose about 50-270 metric tons of capacity depending on the size of the vessel*."[7]

Should low lake levels become the norm and there is no change in fleets or facilities, then vessel loads will be reduced with the consequent increases in the number of trips and shipping costs. Millerd's 2011 study estimated that by 2050 the lower lake level impacts could raise shipping costs approximately 15-18%. Millerd summarized his and other studies to posit that a long-term low water level will result in adaptations being made.

> *"If average water levels were to permanently drop or be lower for a significant part of most navigation seasons, cost-effective remedial measures would be carried out. Lake regulation policies could be used to offset lower water levels, diversions into the Great Lakes could be increased, and diversions out of the lakes decreased. Specific lake levels could be raised by limiting outflows through sills and narrowing outlet channels. Harbours and connecting channels could be dredged, although many will have contaminated material which is costly to handle or rock bottoms requiring drilling and blasting."*[8]

This study assumed that adaptation will occur, and the vessels will be able to carry at current capacity. This decision was made in part because lake level water modeling is currently uncertain. For this report the team focused on the topics of ice formation and coverage and an extended shipping season on the Great Lakes.

Ice Coverage and Formation

While trend lines of the Great Lakes ice coverage are becoming apparent, these trends are not predictive of each season's ice coverage. Fall, winter and spring variations in the pattern of the jet stream may bring arctic air masses into the region. Conversely, the jet stream can funnel warm, moist air up from the south. These jet stream movements also impact storm formation. The National Oceanographic and Atmospheric Administration (NOAA) notes the observed changing patterns:

> "*Scientists have observed that the reduced temperature difference between the North Pole and tropics is associated with slower west-to-east jet stream movement and a greater north-south dip in its path This pattern causes storms to stall and intensify, rather than move away as they normally used to do. At midlatitudes, more extreme weather results from this new pattern, including droughts, floods, colds spells, and heat waves.*"[9]

Barnes and Screen believe that research into how and why arctic warming is impacting long-term pattern of jet streams is formative with no firm conclusions.[10] The change is being observed, but annual predictability remains uncertain.

The Great Lakes are trending toward reduced seasonal ice coverage with ice forming later in the season and melting earlier. A 38-year comparative analysis of Great Lakes Ice coverage published in 2011 provided a synopsis of the reduced ice coverage:

> "*There is a significant downward trend in lake ice cover for all of the lakes for the period 1973–2010. The largest trend occurs in Lakes Ontario, Superior, and Michigan, while the smallest trend occurs in Lakes St. Clair and Erie. This translates into a total loss in all Great Lakes ice coverage of 71% over the entire 38-yr record*."[11]

Research by Di Liberto extended the trend analysis to 2018 (see Figure II-1), indicating a continuing trend toward reduced ice coverage and significant yearly variations.[12] His report noted the cyclical nature of lake ice that spans decades and is further impacted by other weather cycles of the El Nino Southern Oscillation (ENSO), North Atlantic Oscillation (NAO), Atlantic Multi-decadal Oscillation (AMO) and the Pacific Decadal Oscillation (PDO). The greatest declines due to human as well as cyclical impacts have been in Lakes Superior, Huron, St. Clair and Erie.

Air temperature impacts ice formation and break-up. A 2019 study found a trend of upward trajectory of air temperatures in the Great Lakes Basin:

> *"Between 1901-1960 and 1985-2016, the Great Lakes basin has warmed 1.6°F in annual mean temperature, exceeding average changes of 1.2°F for the rest of the contiguous United States. By the end of the 21st century, global average temperatures are expected to rise an additional 2.7°F to 7.2°F"*[13]

How the impact of a global rise in air temperature will affect the Great Lakes basin is still being modeled.

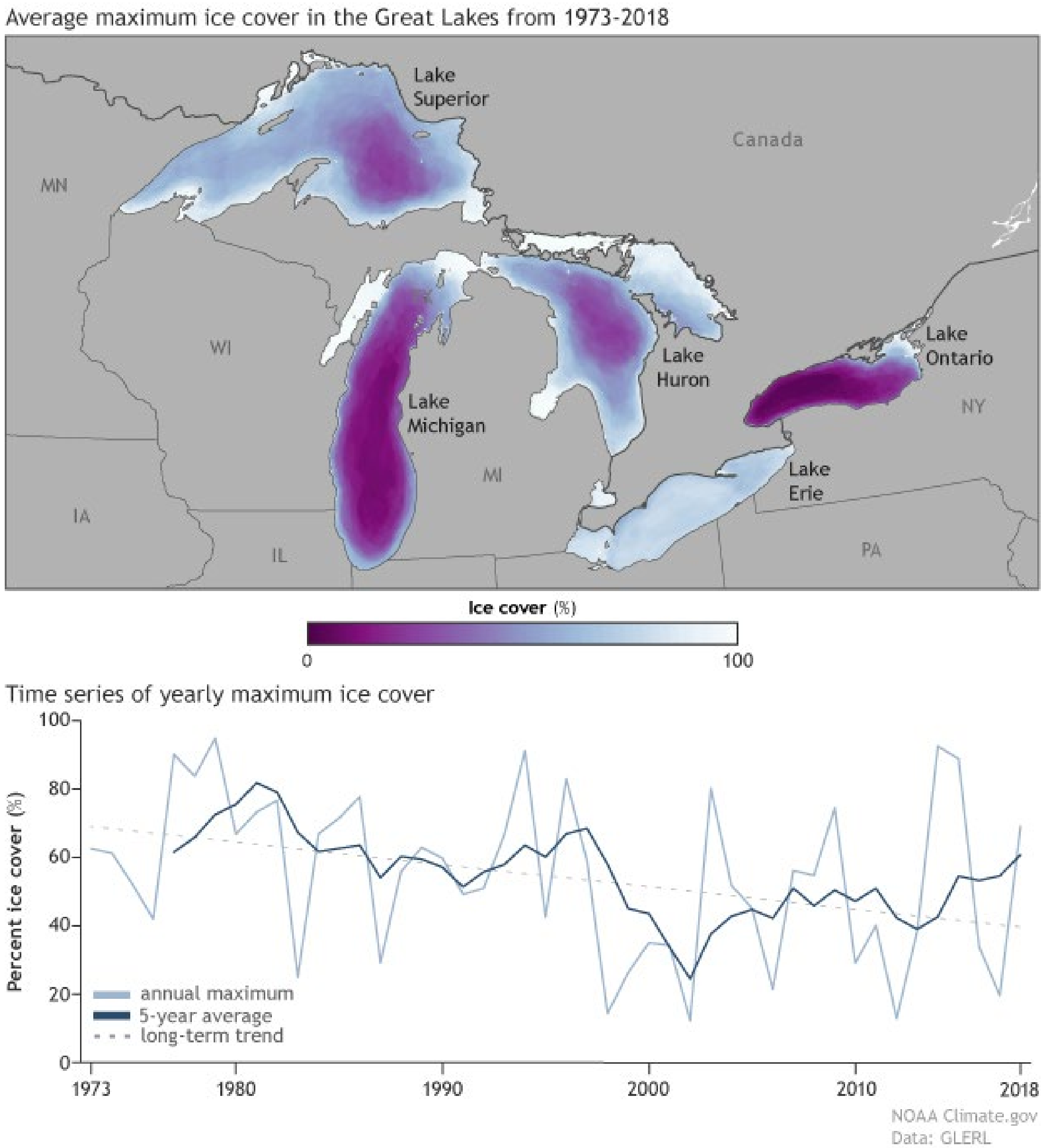
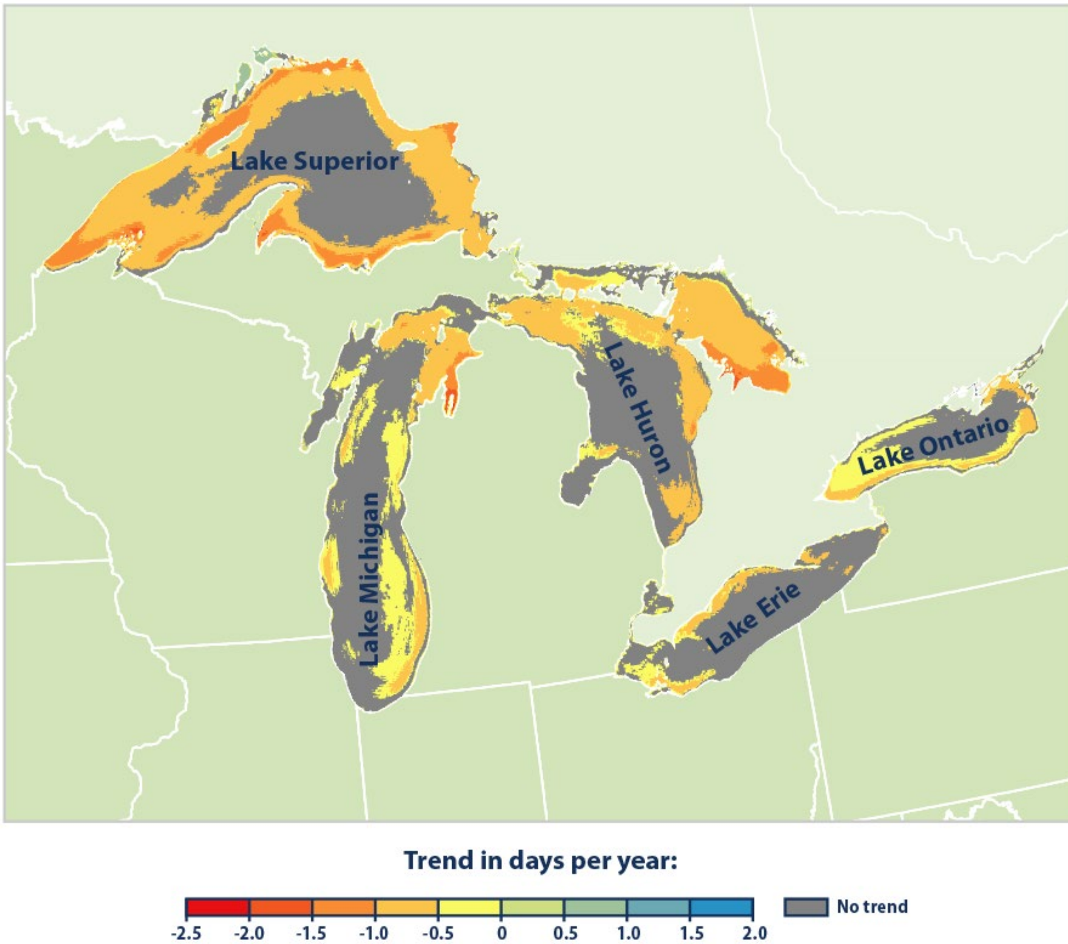


Figure II-1: Great Lakes Average Maximum Ice Coverage, 1973-2018

Water temperature also impacts ice coverage. Warmer surface water temperatures cause lake ice to form later than usual and/or go out earlier, resulting in a shorter duration of ice coverage. Bayfield Wisconsin has tracked ice duration for over a century (1850 to 2019) because of the need to have an ice road to Madeline Island. The first freeze dates have changed from late December to late January.[14]

Map II-1 shows the average annual rate of change in the duration of ice cover in the Great Lakes from 1973 to 2019.

"*Duration is measured as the number of days in which each pixel on the map was at least 10 percent covered by ice. Gray areas are labeled "no trend" because the change over time is not statistically significant (using a 90-percent confidence level)."*[15]



Map II-1: Annual rate of change in the duration of ice cover in the Great Lakes from 1973 to 2019.[16]

Climate Change and Navigation

The most difficult areas for winter navigation are the bays, rivers, channels and locks. That is where the ice forms first and is the thickest. Even in the warmest seasons, icebreakers are needed to keep these passages open. U.S. and Canadian Coast Guards combine assets in two separate operations to support winter navigation.

The Sault St. Marie (Soo) Lock System and its Role in Great Lakes Shipping

The most northern constrained passage on the GLNS is the passage from Lake Superior to Lake Huron. A vessel moving from Lake Superior to the lower lakes is "down-bound" from the "Head of the Lakes." Vessels sailing to Lake Superior from the lower lakes are "up-bound." In the current trade pattern, down-bound, U.S. flag vessels are almost always laden with coal, taconite and (to a lesser extent) grain. Up-bound vessels typically carry cargoes of aggregate, coal or limestone.

Transiting from Superior to Huron, a down-bound vessel crosses the relatively shallow Whitefish Bay, locks past the Sault St. Marie rapids and sails down the St. Mary's River to Lake Huron using the natural river channel or the artificial "Rock Cut" channel. Depending on its size, a vessel uses either the MacArthur Lock or the larger Poe Lock.

Brief History of the Sault Locks

The first federal lock to bypass the Sault St. Marie rapids was built in 1872. The U.S. Army took control of the existing Michigan Lock in 1880. The original Poe Lock was constructed in 1896 with the Davis and Sabin locks finished in 1914 and 1919, respectively. The demand for iron ore during the Second World War resulted in adding the McArthur Lock. A larger, new Poe Lock replaced the older Poe Lock in 1969. Only the Poe and McArthur locks are currently operational.

Lock Operations and Winter Closure under Federal Regulations

A 2013 study for the USACE by Peter Kakela, Ph.D. from Michigan State University, determined that that the total dollar value of iron ore shipped through the Soo Locks in 2012 amounted to $500.4 billion, or 3.2% of the U.S. Gross Domestic Product (GDP).[17] From 2007–2017, an average of 72.5 million net tons of commercial commodities passed through the Soo Locks annually. In the 2017 shipping season, 89% of the total tonnage moved through the Poe Lock. The Poe Lock is a critical link for the majority of cargo moving on the GLNS. A scheduled period of down time for lock maintenance is essential to ensure safe operations.

The principal factors that have limited year-round vessel operations on this route include lock constraints, ice in the channels, and windrows of ice in Whitefish Bay driven by the prevailing westerlies. The Soo Locks are closed to vessels for winter maintenance as directed in 33 CFR § 207.441 from January 15 to March 25. Historically, this down time has coincided with ice conditions on the St. Mary's River or Whitefish Bay impeding safe navigation. Since 1959, new technologies against ice formation in locks and canals have extended the shipping season by more than 25 days.[18] Between 1996 and 2005, the average navigation season lasted 276 days.[19]

Vessels Limited to Using the Poe Lock

As the Soo Locks were enlarged, vessels were built to match the growing capacity of the locks. The general term used to describe vessels that are built and classed solely for operation on the Great Lakes is “Laker.” The dry bulk Lakers are, with a few exceptions, self-propelled self-unloaders, (See Photo II-1). There are integrated tug barge self-unloaders, ferries, tankers, barges, and a couple of self-propelled bulk vessels that do not have self-unloading systems. According to *Greenwoods Guide to Great Lakes Shipping*, cargo vessels on the Great Lakes and St. Lawrence Seaway are classified by the USACE into ten classes by vessel size.

Photo II-1: 1000’ M/V *Edwin Gott* in brash ice transiting the Twin Ports’ Superior channel (Daniel Rust)

These classes can be divided into two fleets based on their normal areas of operation. The Intra-Laker fleet moves within the Great Lakes and is composed of Class V, VII, VIII, and X vessels. The Seaway/Laker fleet is composed of vessels that transit the Welland Canal (78-foot beam, 740-foot length) but are not engaged in international trade. These are Class I, II, III, IV, and a few VIII vessels. The 55 plus U.S.-flag Lakers used to transport dry-bulk commodities can be classified as self-propelled and composite tug-barges that the USACE designates with a Class I through X, according to vessel length. All but two of these vessels are self-unloading. Fifty-five percent of the vessels in the dry-bulk fleet are in Classes VIII to X. These vessels are too large to transit the Welland Canal and can only operate on the four upper Great Lakes. Furthermore, the Poe Lock in St. Mary’s River is the only lock in the Soo Locks system that can accommodate ships in Classes VIII through X. While vessels in Classes I through VII can navigate the Welland Canal, U.S. flag vessels infrequently transit the St. Lawrence Seaway. This profile defines not only the fleet but also the infrastructure at the ports that rely on the self-unloading capabilities of U.S.-flag Lakers.

Under normal operation parameters, the McArthur Lock can facilitate a vessel with no more than 75 feet beam and length over all (LOA) of 730 feet. The Poe can lock through a vessel with a 105-foot beam and LOA of 1,100 feet. Thus, only the Poe Lock can handle Class VIII, IX and X vessels.

Building the Second Poe-Sized Lock

In 1985, the Detroit District of the USACE completed a feasibility study for the construction of a new Poe-sized lock in the footprint of the non-operational Davis and Sabin Locks. Congress first authorized construction of the new lock in Section 1149 of the Water Resources Development Act (WRDA) of 1986 and reauthorized construction in WRDA 1990. Additional studies and funding issues delayed building until 2018 when the USACE completed a cost-benefit analysis that clearly validated the need to build a second Poe-sized lock. Release of the "New Soo Lock Economic Validation Study" enabled funding. Presidential signing of The America's Water Infrastructure Act of 2018 authorized construction of a second Poe-sized lock.

Subsequently, the USACE received $32,388,000 in its FY 2019 budget to start lock construction. The USACE estimates that it will cost $1 billion and take seven years to complete the new lock.[20] Construction on Phase II started in early April of 2021 with completion of that phase expected in 2023.[21] The USACE extended the anticipated construction completion time to 2030 with the possibility of an earlier opening date with timely approval of Continuing Contracts Clause, efficient funding and favorable weather conditions.[22] For the purposes of this study, the research team assumed an opening date of 2031. Photo II-2 is an artist's depiction of the new lock.

Photo II-2: Artist's depiction of new Soo locks (USACE)

Impact of New Poe-sized Lock on Extended Navigation and Operations

The USACE's "New Soo Lock Economic Validation Study" did not address operation of the lock system after completion of the second Poe-sized lock. In 2031 it might be possible to remove from service one of the two large locks at any time of the year to engage in maintenance. Savings in time and money might exist if repairs are undertaken in relatively warm rather than sub-zero temperatures. The need to have a "winter maintenance shutdown," as required under the Code of Federal Regulations, would be unnecessary. A warming of the region with the predicted reduction in ice coverage and the new lock might enable a new navigation paradigm by extending the shipping season. Chapter IV of this study examines how extending the navigation season for the Upper Great Lakes could impact stakeholders in the GLNS.

Cold Weather Lock Operations

On August 23, 2021, researchers interviewed Kevin E. Sprague, P.E. Mr. Sprague is the U.S. Army Corps of Engineers (USACE) Area Engineer for the Soo Area Office of the USACE. He has worked as an engineer for the USACE since 1992. He has worked at the Soo Locks since 1992 and has been Area Engineer since 2010.

Mr. Sprague noted that the equipment aboard a vessel, such as winch types and or bow thrusters, would dictate how many personnel supplied by the commercial vessel would be needed to lock through. Additional personnel may be required during cold weather operations in preparing locks and assisting vessels in locking through.

One of the problems that occurs during extreme cold weather is ice build-up on the sides of the lock chambers. A thick ice build-up narrows the chamber, preventing a vessel from fitting into the chamber. This ice is removed using a steel blade attached to a tugboat. The term for this process is "scraping the pier." He also noted that ice plates can move into the locks impeding the locking of larger vessels.

A point-source bubbler system installed at the miter gates provides air bubbles that reduce ice build-up and help move brash ice from behind the gates. The bubblers are supplied with air from three compressors located adjacent to the Poe Lock.

Photo II-3: Air compressors for the Soo Locks to service air bubblers (Richard Stewart)

In addition to the air bubbling system, the locks have a supply of steam provided by three natural gas fueled boilers. The steam is piped through coils to heat the downstream miter gates, preventing ice build-up in chambers and clearing ice build-up in other areas.

Mr. Sprague noted that even with the new Poe lock, year-round operations would be impractical with the ice conditions he has seen during his 29 years at the Sault Locks.[23]

Should the warming trend continue, there will likely be less ice, with a shorter duration. While it may be posited that these factors will ease vessel movement in the winter months, that may only be true in the open lakes. Ice forms quicker and thicker in shallow water. Harbors, lock approaches and channels will still have ice, and transiting in those areas may actually become more problematic.

LT Alexander Stewart, USCG, commanding officer of the USCG Cutter *Biscayne Bay,* has broken ice for years in the Great Lakes, including the approaches to the Soo Locks. When he was interviewed on August 22, 2021, he noted that when ice is not frozen fast to the shore, the plates will move into the channel, thus requiring more passes to keep the ice channel open.[24] He also pointed out that windrows of ice form when winds drive the ice into confined bodies of water, such as Whitefish Bay on Lake Superior, requiring the use of the most powerful icebreakers to cut a channel. Great Lakes ship masters interviewed affirmed Lt. Stewart's observations. They further commented that in confined areas the moving plates are even more problematic as there is little area to push them out of the channel.[25]

Current Great Lakes Icebreaking Operations

The U.S. Coast Guard employs their icebreaking assets in support of maritime commerce on the Great Lakes. This is a joint effort with the Canadian Coast Guard and the maritime industry. Input from these groups helps in monitoring potentially hazardous ice conditions and conduct ice breaking operations throughout the Great Lakes. Regular email and phone sessions take place to update and maximize the operations. U.S. and Canadian icebreakers will move to either side of the border as their resources are needed. Two operational activities cover the Great Lakes, providing command structure to allocate resources. The focus of these decades-long operations is the support of commercial navigation in ice conditions.

The Lake Carriers Association (LCA) has expressed concern that the current icebreaker fleet is not sufficient to carry out the ice breaking mission on the Great Lakes. The LCA has concerns with the size, readiness and number of icebreakers. The LCA has documented inadequate icebreakers due to breakdown and planned maintenance during the ice season and the inability of small icebreakers to break channels in some areas. There may be a need for further research about the best mix of icebreaking assets in the Great Lakes, but that is not the focus of this study.

Using data provided by the U.S. Coast Guard, researchers conducted an analysis of icebreaking operations to ascertain any recent changes that may be related to the impact of climate change. Operational days indicate when the USCG determines that vessels should be available for icebreaking. It is not a measure of the actual availability of sufficient icebreakers. However, for this study the information is useful for obtaining trends.

Operation Coal Shovel (OCS)

Operation Coal Shovel, under Coast Guard Sector Detroit, is the domestic ice-breaking operation with an area of responsibility spanning from southern Lake Huron to Lake St. Clair to the St. Clair / Detroit River system and into Lake Erie and Lake Ontario—including the St. Lawrence Seaway.[26] Figure II-2 shows a downward trend line for the recent 15-year period of total operational days–a measure of asset allocation. Note that Operation Coal Shovel was not activated during the 2011-2012 and 2019-2020 seasons. For the time period analyzed, the average annual operational days were 74.5.

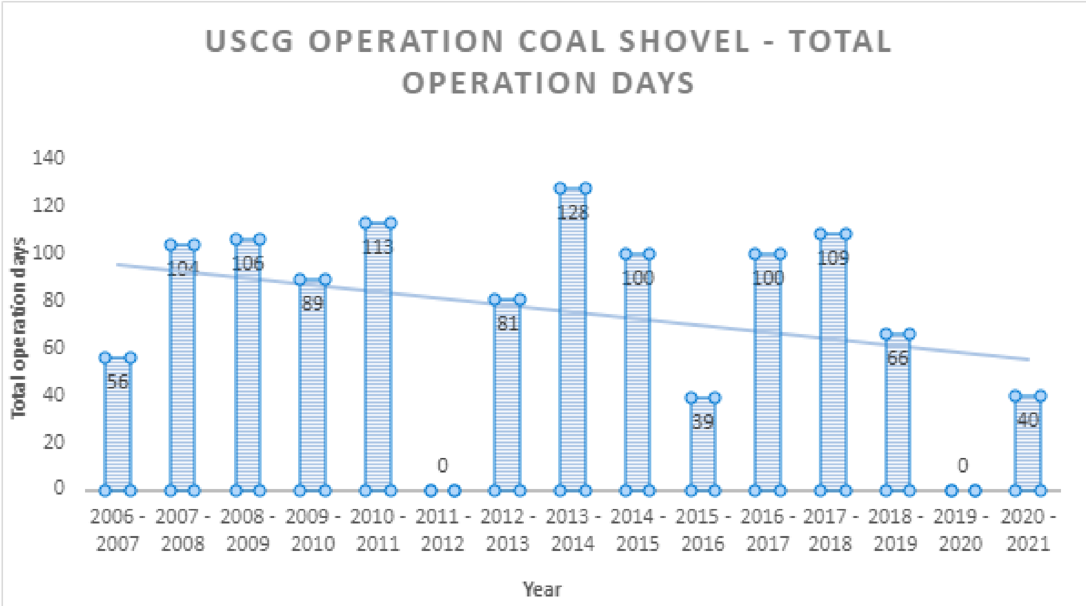


Figure II-2: USCG Operation Coal Shovel Total Operation Days (USCG data)

As depicted in Figure II-3, the opening dates of Operation Coal Shovel are trending later in the winter and the closing dates are trending earlier in the spring over the past 15 years.

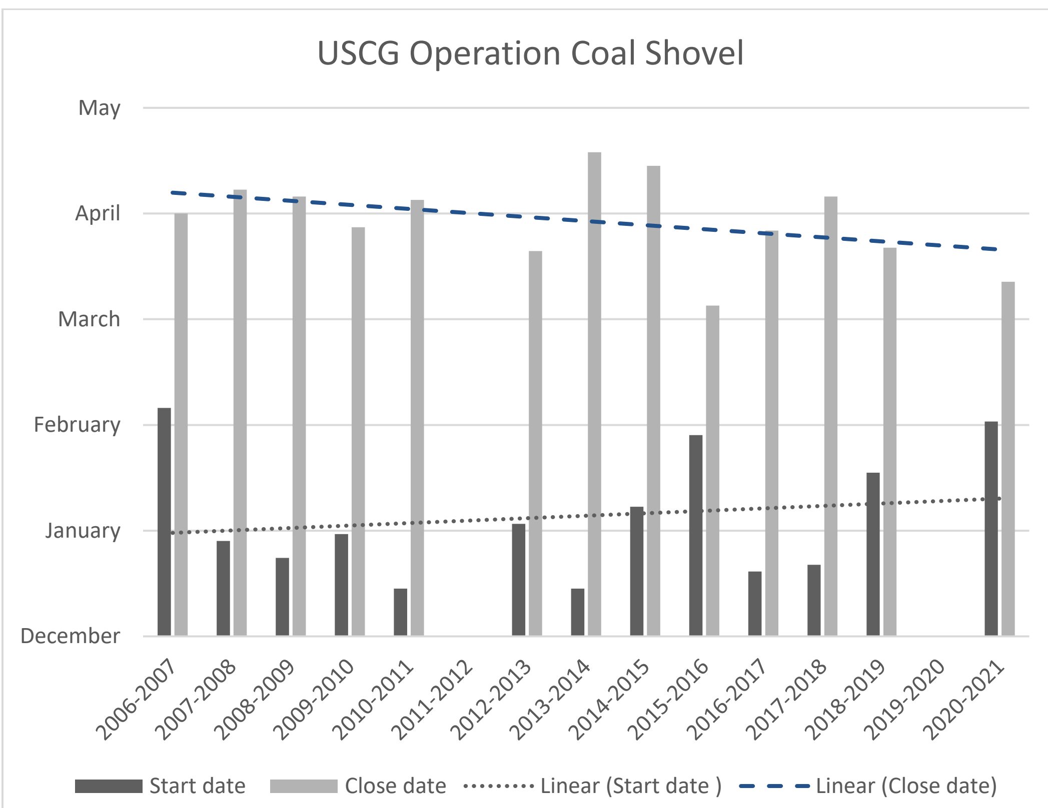


Figure II-3: USCG Operation Coal Shovel Start and Close Dates (USCG data)

Operation Taconite (OT)

Operation Taconite, under the command of Sector Sault St. Marie, is the largest domestic icebreaking operation in the U.S. Operation Taconite supports vessels moving iron ore from the mines at the Head of the Lakes to meet the demand of steel mills in Lake Erie and Lake Michigan. Because ice conditions vary from year to year in accumulation and geography, flexibility is needed to meet demands. The Sector works in cooperation with Canadian Coast Guard, the maritime industry, USACE and the Sault Locks. While the Sault Locks are closed, traffic (mostly Canadian) still moves and needs to be escorted to Sault St. Marie Canada on the St. Mary's River.

Operation Taconite consists of three phases:

1) "End of the navigation season" – Once ice begins to hinder navigation until the majority of commercial vessels lay-up
2) "Closed Season" - Winter lay up until 10 March
3) "Spring Breakout" - 10 March until ice no longer poses a hindrance to navigation.[27]

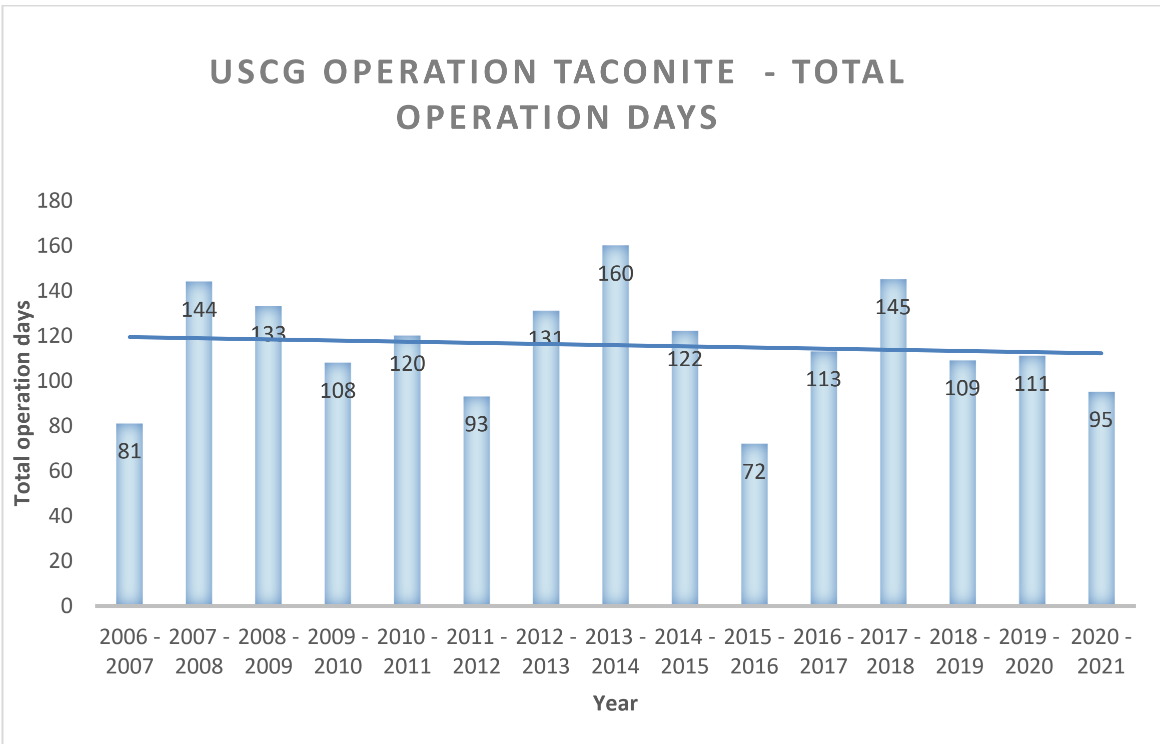


Figure II-4: USCG Operation Taconite Total Operation Days (USCG data)

Unlike Operation Coal Shovel, Operation Taconite has deployed icebreaker assets every winter season during the time period studied. Total operational days has a slight downward trend, as depicted in Figure II-4. The average annual operational days for OT were 115.8 days during the time period analyzed. While OCS did not activate during the 2011-2012 and 2019-2020 seasons, OT was ongoing with the 2019-2020 close to the average operational days. The 2015-2016 season had the lowest number of activation days for both operations.

The graph of the Operation Taconite start and close dates (Figure II-5) has a less pronounced trend line than for OCS start and close dates. The trend line indicates that OT is ending sooner in the spring and starting later in the winter.

There are other factors in Great Lakes icebreaking beyond ice that impact the duration and start and stop dates of the operations. The number of icebreakers, each vessel's tonnage, horsepower, age, operational availability and funding are all of consequence in icebreaking.[28]

This study is not tasked with determining the effectiveness of past or current icebreaking. Recent studies offer differing viewpoints on the sufficiency of icebreaking assets. The 2016 USCG Report to Congress contended that there are sufficient assets.[29] In 2021 the Lake Carriers Association cited a $2 billion loss due to inadequate icebreaking resources.[30] The recently passed Great Lakes Winter Commerce Act is intended to address resource and policy issues. None of these referenced documents discuss the potential impact of climate change.

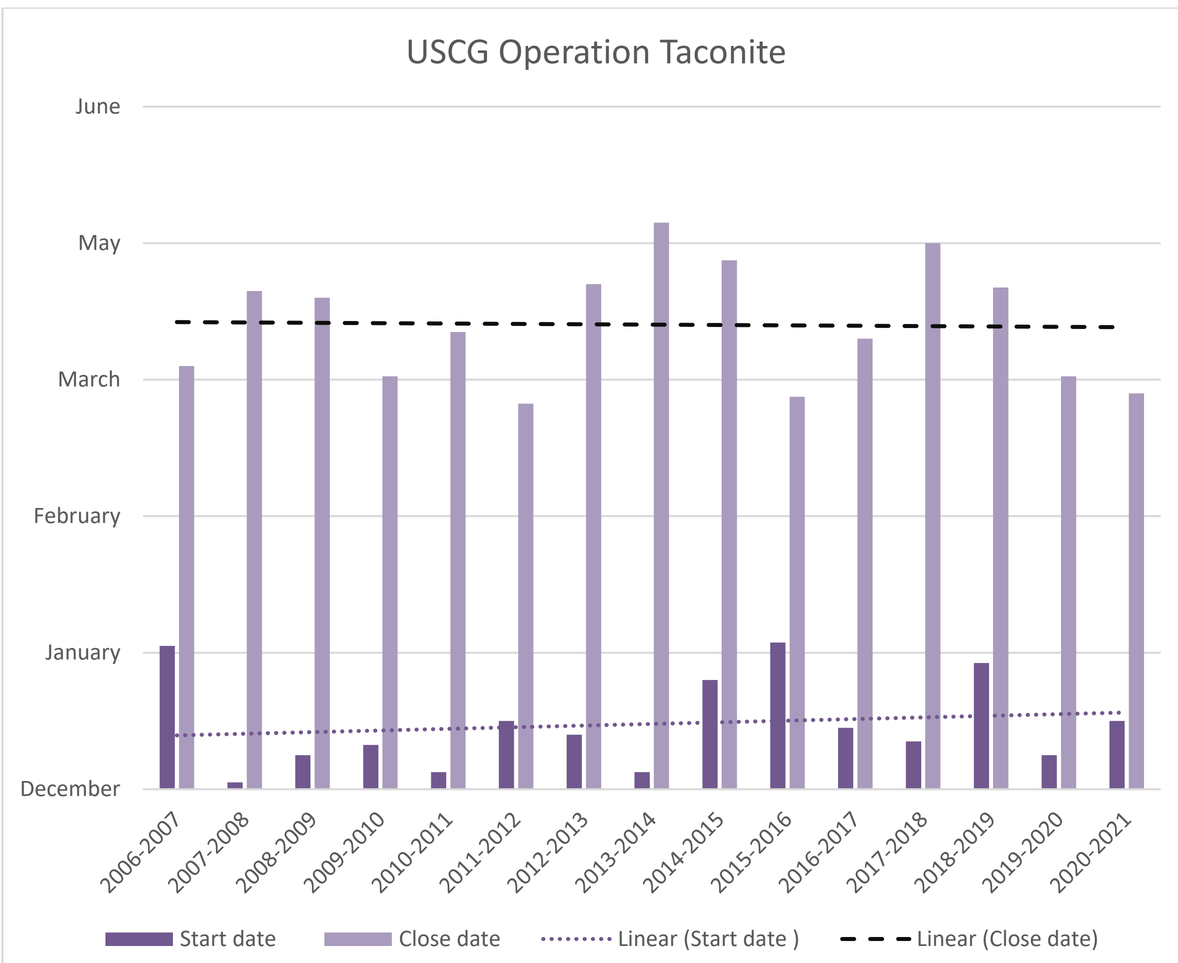


Figure II-5 – USCG Operation Taconite Start and Close Dates (USCG data)

Chapter III. Extending the Shipping Season on the Great Lakes: Decades of Controversy

The opening of the Great Lakes-St. Lawrence Seaway in 1959 and the development of taconite pellets in the late 1950s spurred shipping interests to consider the potential of year-round operations on the upper Great Lakes. Difficulties in handling natural iron ore in winter made year-round shipping on the upper Great Lakes unattractive since it tended to freeze solid in rail cars, at ore docks and in vessels during the depths of winter temperatures. The advent of taconite changed the situation since it could be more easily handled in severely cold temperatures.[31]

Railcar ferries had been operating year-round for decades on Lake Michigan.[32] However, the traditional commercial navigation season on the upper Great Lakes lasted for 8 ½ months as the Soo Locks closed for the winter season between December 15 and April 1 until the late 1960s. Interest in extending the shipping season on the Great Lakes during winter is not a recent development. In fact, an eight-year federal program resulted in year-round shipping for several years in the 1970s.[33] Congress called for a study to examine the feasibility of extending the navigation season on the Great Lakes and the St. Lawrence Seaway in 1965 and, five years later, set in motion a pilot program to investigate the issue.[34] Government and private industry worked together to extend the 8-month shipping season to 10 months in the winter of 1970-71.[35] In 1972, the *Stewart J. Cort*—the first 1,000-footer on the Great Lakes—passed through Poe Lock for first time with load of taconite. The *Stewart J. Cort* was conceived to operate year-round on the upper Great Lakes serving as its own icebreaker.[36]

The combined eight-year Great Lakes and St. Lawrence Seaway navigation season extension project cost more than $13 million dollars by the time it concluded in the late 1970s.[37] The demonstration project proved that year-round navigation was technically feasible.[38] Highlights from the project included the first U.S. ore carrier to transit the Soo Locks during the month of February in 1972, the shortest winter closure of the Soo Locks to date (8 February to April 1), testing of an air bubbler system in the Duluth-Superior harbor designed to prevent ice buildup, and the first 12-month shipping season on the Great Lakes in 1974-75 with US Coast Guard icebreaking operations focused on maintaining open channels rather than responding to requests for assistance.[39] U.S. Steel kept eight ore carrier vessels operating during the winter of 1974-75. These vessels included the *Cason J. Callaway* and the *Philip R. Clarke*—using the 800-foot MacArthur Lock at the Soo since the Poe Lock was closed for five weeks undergoing maintenance.[40]

Additional accomplishments of the season extension project included the second 12-month shipping season on the upper Great Lakes (the St. Lawrence Seaway closed December 20, 1975), an 11-month shipping season on the upper Great Lakes due to a particularly severe winter (but the Soo Locks remained operational throughout the winter at the request of Canadian authorities for delivery of emergency shipments of fuel oil), the third 12-month shipping season on the upper Great Lakes in 1977-78, and yet a fourth year-round shipping season on the upper Great Lakes in 1978-79 with 536 transits of the Soo Locks. The USACE noted in its report on the season extension project, "Over 41 million tons (approximately 4,000 vessel transits) of various cargoes were shipped through the St. Marys River during the extended season; more than half of this total was iron ore."[41]

As the project came to an end, the U.S Army Corps of Engineers concluded in a 1979 report to Congress about the program that "season extension is engineeringly and economically feasible year-round on the upper three Great Lakes, up to year-round on the St. Clair River-Lake St. Clair-Detroit River System and Lake Erie, and up to 10 months on Lake Ontario and the International Section the St. Lawrence River." The Corps recognized "that formal agreement with the Government of Canada is required for any extension on the system beyond the upper three Great Lakes."[42] The report also acknowledged that year-round navigation on the St. Lawrence Seaway "would definitely require twinning of the Welland and the St. Lawrence River Locks to permit lock maintenance."

The extended season demonstration project featured many activities and innovations that made extended season (even year-round) navigation possible. As outlined by the US Army Corps of Engineers, those activities and innovations included:

Assisting vessels through ice
- Cooperative icebreaking activities between US and Canada
- Preventative icebreaking (opening and maintaining tracks for large vessels to traverse unescorted)
- Convoy travel
- Non-conventional icebreaking
- Air cushioned vehicles
- Air bubbler system on vessel hulls to ease transit
- Air bubbler systems to suppress ice in channels (successful at Howard's Bay in Superior)
- Thermal ice suppression

Navigation aids, devices and systems
- Prototype ice buoy tests
- Deployment and testing of radar transponder beacons (RACONs)
- Mini Loran-C radionavigation system tests
- Precise laser and radar aid to navigation system (PLANS and PRANS) tests
- Development of precise all-weather aid to navigation system (PAWNS)
- Follow-the-wire guidance system (using magnetic field generated by undersea cables)
- Laser range light

Ice and weather information
- Aerial reconnaissance and remote sensing of ice conditions
- Air and water temperature measurements
- Bathytherograph measurements
- Ice forecasting
- Ice surveillance
- Ice thickness measurements
- Time-lapse photography
- Aerial photography

Safety/survival
- Survival equipment development and tests

- Detection tests
- Safety/survival equipment wintertime training
- Communication tests

Interestingly, the Federal navigation season-extension program in the 1970s did not include activities related to keeping harbors open in the winter season. As the USACE succinctly stated, “There is no intent in the Demonstration Program to prepare a system—or even complete a harbor opening plan—to keep a harbor open during winter.”[43]

Even though the USACE proclaimed the season extension project of the 1970s successful, the Corps identified many winter navigation problems that became apparent during the demonstration program.[44] These issues included those related to the effects of winter navigation on vessels and personnel such as potential vessel damage, refuge area access difficulties, adverse search and rescue conditions, and hazards to lock and dock personnel. Hazards to personnel encompassed frostbite, hypothermia, as well as ice buildup on vessels falling onto work and walk areas.

Hoping to discover the potential sociological impacts of a year-round navigation season on the Great Lakes, the US Maritime Administration (MARAD) distributed nearly 1,700 questionnaires to representative sample of Great Lakes industry groups (including vessel, terminal, lock, and pilot personnel) in the fall of 1976.[45] The survey had a 46 percent response rate and revealed several insights. For instance, while vessel personnel respondents expressed a generally positive attitude toward their jobs, they had a negative view of an extended season on the Great Lakes because of safety concerns, the need for more time off, and the fact that sailing during an extended season disturbed their families. MARAD concluded that “serious psycho-socio problems related to extension are anticipated with this group” if extended season sailing became a permanent feature of Great Lakes navigation. However, virtually all surveyed lock and terminal personnel expressed a positive opinion about extending the navigation season with unionized workers more negative about extending the navigation season than were non-unionized workers. Of the few pilots who responded to the survey, most expressed concern about a longer shipping season. They indicated that they would need to be better informed about work schedules, the possible use of volunteers and the alteration of vacation schedules to allow pilots to take vacations during summer months.

In the mid-1970s, the Great Lakes Regional Office of MARAD conducted an in-house survey project to discover the effects of winter weather on cargo handling productivity on the Great Lakes. MARAD surveyed terminal operators, shipping lines and labor organizations in the Great Lakes area. Survey respondents indicated a consensus that the effects of winter weather did not have a severe impact on cargo handling operations, with the exception of bulk coal loading and unloading. An extended navigation season would benefit labor and ports due to year-round employment for personnel. Ports and shipping lines agreed that any equipment maintenance losses due to winter operations would be offset by increased revenues, and they would need little special equipment—except for additional snow removal equipment. A majority of ports that responded to the survey considered their locations as already operating on a year-round basis due to transshipment requirements. Overall, survey respondents expressed views reflecting positively on the capability of Great Lakes ports and terminals to operate during an extended or even year-round navigation season.[46]

Potentially the most significant operational issue standing in the way of routine, year-round navigation on the upper Great Lakes was maintaining the Soo Locks without seasonal closures However, the USACE concluded in 1979 that "phasing of the lock maintenance program on the Soo Locks at Sault Ste. Marie, Michigan, to permit year-round navigation on the upper four Great Lakes is considered feasible to make year-round operation possible."[47] The single Poe Lock was the only lock at the Soo capable of accommodating the newly introduced 1,000' vessels designed to move taconite and coal on the upper lakes. The Corps noted, "If year-round traffic in 1,000-foot vessels is to be achieved, it is obvious that at least one 1,000-foot lock has to be open all year, which could entail building a second 1,000-foot lock or enlarging an existing smaller lock."[48]

Moreover, the Pennsylvania Transportation Institute concluded in a 1979 report that "… a second large lock at Sault Ste. Marie, which may be justified now and will probably be constructed, will have a significant impact on season-extension benefits."[49]

Even without the twinning of the Poe Lock, the USACE's *Final Survey Study for Great Lakes and St. Lawrence Seaway Navigation Season Extension* in 1979 recommended year-round navigation become permanent between Lake Superior to Lake Michigan and Lake Huron by the late 1980s.[50]

While U.S. Steel pioneered winter vessel operations for moving taconite on the Great Lakes in the 1970s, by decade's end the company backed away from year-round shipping. In 1979, William B. Buhrmann of U.S. Steel was quoted in the media as saying, "We have never said 12 months come hell or high water." Instead, he noted that a 10 ½-month shipping season "seems like something we could rely on year in and year out—a reasonable expectation." He went on to say that operating in January and February when ice had not fully formed was preferable to March when winds tended to "shift and tighten" ice coverage. Burhmann also contended that the "amount of ice out there (on the Great Lakes) was no different 25 or 30 years ago than it is today. During the ordinary year only about 20 percent of the Great Lakes system is ice covered. Not to take advantage of the God-given waterway because of 20 percent is not readily navigable is kind of not smart from a national standpoint."[51]

The USACE spent more than $6 million between 1979 and 1986 studying the environmental impact of winter shipping on aquatic ecosystems.[52] While the USACE biologists believed they had sufficiently studied the matter and concluded that ships operating as late as February 15 created no significant environmental impacts, the Michigan Department of Natural Resources and the Fish and Wildlife Service contended that additional research was needed—especially in the lower reaches of the St. Mary's River and in Lake Munuscong.[53] The environmental impacts of winter navigation included shoreline erosion, shore structure damage, increased pollution of waterways, and flooding. In addition, measures for ice control, such as air bubbler systems and the use of waste heat discharges in navigation channels, could adversely affect the aquatic ecology. Movement of vessels and icebreakers stirred up the riverbed, resulting in fish spawning beds covered with silt.[54] And concern also existed over the potential of petroleum from oil spilled under ice flowing in connecting rivers.[55]

Championed by Arlan Stangeland (R-MN), a 1984 water projects bill in the U.S. House of Representatives included a $609 million proposal to enable year-round navigation on the Great Lakes so that grain from the upper Midwest could move to market with greater flexibility. Proponents envisioned the Great Lakes as America's "fourth seacoast" to be promoted as an alternative to the Atlantic and Pacific oceans and the Gulf of Mexico.[56] With 221 members opposed, the U.S. House of Representatives voted down the bill authorizing year-round shipping on Lakes Superior, Huron, Michigan, and Erie plus a 10-month navigation season on the St. Lawrence Seaway and Lake Ontario. Lawmakers faced pressure to terminate extending the Great Lakes shipping season from environmentalists as well as those in the fishing and tourism industries who claimed that winter shipping damaged shoreline property, harmed fish populations and diminished lake water quality. Additionally, congressional opponents of the measure pointed out in media reports that "there is no current pressing economic need for this proposal, nor does such seem likely in the foreseeable future for major commodities moved on the lakes."[57]

In 1990 Lake Carriers Association officially endorsed January 15 as the permanent annual closing date for the Soo Locks. Knowing exactly when the locks would close each year, according to the LCA, would enable vessel operators to better plan schedules, thereby they could make more efficient use of vessels.

In the face of likely litigation, a meeting of representatives from the Michigan Department of Natural Resources, the USACE, the USCG and the US Fish and Wildlife Service resulted in a memorandum of agreement (MOA) in July 1993. The landmark agreement bound all four entities to March 25 as the recommended permanent date for the opening of the Soo Locks as well as a joint, multi-year environmental monitoring program. Additionally, all vessels would reduce speeds by at least 2 mph "in the St. Marys River between Lakes Munuscong and Nicolet during periods of USCG ice breaking." Moreover, the Michigan DNR agreed to not legally challenge the January 15 Soo Locks closing date.[58]

Codified by 33 CFR §207.440 in 1996, the agreement appeared to settle the issue for decades to come. However, the trend toward ice forming later and receding earlier on the upper Great Lakes, combined with the construction of a second Poe-sized lock at the Soo, could prompt a reconsideration of an extended navigation season.

Chapter IV. Model of Great Lakes Shipping: Extended Season Impacts

Introduction

Lakers currently operate on the route from Duluth-Superior (Twin Ports) to ports on the lower lakes only when the Sault Locks are open. Current closure dates are January 15-March 25. The locks are closed for 68 days (69 days in a leap-year). Vessels clearing the locks continue to operate for 2-4 days as they proceed to their destinations. The maximum current days of vessel operation can be approximately 300 days. For calculation purposes, the model will assume an average of 295 "operational days" in a shipping season. Crews may remain on the vessel for days past the close of the shipping season and return days prior to the start of the first voyage. The model will assume 305 "crew days." A lack of demand resulting in a vessel being idle can reduce operational time significantly below the theoretical maximum.

A reduction in ice coverage coupled with a second Poe-sized lock could enable an extended season, allowing vessels and fleets to carry cargo in the "extended shipping season."
Factors determining the cargo-carrying capacity of a vessel would include the distance that the vessel would need to travel, the speed of transit, and port time. Storms may also incur downtime as vessels wait for wind and seas to diminish. Port delays due to dock or cargo availability and problems with cargo handling equipment can also increase voyage time. For the purposes of this study, these impacts were factored in with input from industry experts. Table IV-1 lists the distances to and from the Twin Ports to the most frequently used lower lakes ports with corresponding products.[59] This listing does not include all the ports; for example, Conneaut, Ohio is not included the table, but is a representative listing of common port combinations.

Distance Between Ports		Product
	(Miles)	
Twin Ports to Cleveland, OH	833	Taconite
Twin Ports to Gary, IN	820	Taconite
Twin Ports to Detroit, MI	726	Coal
Rogers City, MI to Twin Ports	478	Aggregate

Table IV-1: Distance between ports and products

Weather, traffic density (especially at the Sault Locks), vessel operator, power-to-tonnage ratio, and in winter months, ice conditions, impact the average speed of a Laker. Speeds on the routes in table IV-2 were modeled using average vessel speed and expert opinion from ship's masters.[60] As expected, the average vessel speed is lower in the winter months. Severe winters may incur even greater delays. One of the assumptions of this study is that there may be frigid winter periods due to variations in weather, but overall, the climate is not as cold.

Average Ships Speed July-Aug	
Ports	**Miles per hour (MPH)**
Twin Ports to Cleveland, OH	18.1
Twin Ports to Gary, IN	16.4
Twin Ports to Detroit, MI	20.2
Rogers City, MI to Twin Ports	14.9

Average Ships Speed Jan-March (MPH)	
Ports	**MPH**
Twin Ports to Cleveland, OH	16.0
Twin Ports to Gary, IN	14.6
Twin Ports to Detroit, MI	16.9
Rogers City, MI to Twin Ports	12.6

Table IV-2 - Average seasonal vessel speeds between Great Lakes Ports

Average speed provides one metric important in calculating voyage time. Another heuristic used is the average time that industry experts apply when voyage planning. That standard is derived from hundreds of voyages. The slower winter month speeds and times account for ice and weather. In open waters, vessels operate at slower speeds to avoid potential damage from collision with free-floating ice and to reduce ice accumulation when wave action is increasing spray. When the vessel is in sheltered waters where ice may be thicker, speed may be reduced. The average speeds assume the vessel is able to maneuver in open leads when there is ice coverage. These average speeds do not take into account a vessel beset in ice and assumes that icebreaking vessels are available. Table IV-3 is the average running time in hours based on input from industry experts.[61]

July-August	
	(Hours)
Twin Ports to Cleveland, OH	46
Twin Ports to Gary, IN	50
Twin Ports to Detroit, MI	36
Rogers City, MI to Twin Ports	32

January-March	
	(Hours)
Twin Ports to Cleveland, OH	52
Twin Ports to Gary, IN	56
Twin Ports to Detroit, MI	43
Rogers City, MI to Twin Ports	38

Table IV-3: Average season time between ports

Winter Shipping through the Sault Locks on the Upper Great Lakes

The Lake Carriers' Association tracks Laker vessels by product, by year and, to a degree, by month. January's shipments are lower due to reduced loadlines, the closure of the locks, and weather delays from ice and storms. Table IV-4 compares the tonnage delivered in July, March and January over an 11-year period. January and March average monthly temperatures at Sault St. Marie are noted. During an eleven-year period the average tonnage shipped in January was 2,366,337, March average was 1,311,337 and the July average was 5,779,820. January and March are short operational times due to lock closure, with July a full month. As would be expected, there is significantly more lift during a full summer month.

	Year	January average F temperature	January long tons	March average F temperature	March long tons	July long tons
1	Jan-21	21.8	2,615,447	28.5	1,283,023	5,678,842
2	Jan-20	22.8	1,822,822	27.6	1,263,191	3,510,488
3	Jan-19	7.9	2,240,377	19.8	974,772	6,562,344
4	Jan-18	13.0	1,503,879	23.0	1,595,761	6,464,312
5	Jan-17	22.1	2,227,273	22.6	2,121,859	6,031,928
6	Jan-16	18.0	1,953,733	30.0	1,460,933	4,954,697
7	Jan-15	8.4	2,470,408	18.0	533,012	5,743,637
8	Jan-14	7.0	1,789,942	10.4	862,073	6,681,796
9	Jan-13	17.6	2,930,825	22.3	1,802,941	5,668,393
10	Jan-12	19.4	3,587,016	35.5	1,874,333	5,982,324
11	Jan-11	10.9	2,887,992	23.1	1,752,814	6,299,269
	Total		**26,029,714**		**15,524,712**	**63,578,030**
	Average	*15.354*	*2,366,337*	*23.709*	*1,411,337*	*5,779,820*

Table IV-4: Taconite cargo tonnage in relation to average temperatures at Sault St. Marie

The numbers indicate that there is no direct cause and effect from average winter temperature in January and volume of cargo. For example, the average temperatures in January 2015 and 2019 were colder than 2020 and 2016 yet more cargo was moved in these colder months. These findings are also evident in March. Cold weather and ice formation no doubt has an impact, but the findings do not indicate a direct cause and effect relationship.

Shipping is a derived demand, and the quantity carried is ultimately driven by what the shippers want moved. The climate studies indicate that ice will come in later and go out sooner. This would lead to the conclusion that a 30-day season extension could occur by supporting shipping for 15 additional days at the end of January and opening 15 days earlier in March. A 30-day extension would result in a closure of the locks on January 30 and opening March 10.

Modeling the Increased Cargo Carrying Capacity with a One-month Extension

A single vessel for each product and a fleet of vessels is used for this model. Every vessel has unique characteristics, as does each port. These factors, while not employed in this model, can be applied. Operator experience is also a consideration, especially in ice operations. Fleets train future masters in ice navigation prior to their taking command, somewhat mitigating that factor. This model also assumes that a "30-day month" of extended operations will come from either end of the current closed navigation period such as 10 days in January and 20 days in March. The vessels will operate in the foreseeable most favorable conditions.

The fleet selected for modeling is the Great Lakes Fleet based in Duluth, Minnesota. Three of the fleet's vessels are currently in long-term layup with the remaining six ships operational. Five of the operating ships are restricted to the Poe Lock and only one, the *Great Republic,* could transit the St. Lawrence Seaway, though at a draft below the vessel's midsummer maximum.

Great Lakes Fleet		
Ship Name	**Ship Size (ft)**	**Poe Lock only**
Arthur M. Anderson	767	Yes
Edwin H. Gott	1,004	Yes
John G. Munson	768	Yes
Presque Isle	1,000	Yes
Edgar B. Speer	1,004	Yes
Great Republic	634	

Long-Term Laid Up		
Ship Name	**Location**	
Cason J. Callaway	Sturgeon Bay, WI	
Phillip R. Clarke	Toledo, OH	
Roger Blough	Sturgeon Bay, WI	Yes

Table IV-5: Model Fleet

Vessels typically service a particular trade, and Table IV-6 matches commodity and vessels based on past operations. In some instances, such as the *Roger Blough*, ship design defines the trade. Table IV-6 lists the cargoes that vessels in the model fleet typically carry during a shipping season, recognizing that many factors go into which vessel is assigned to a voyage. The final decision on which vessel carries a cargo will be based on factors such as vessel availability, unloading parameters (draft boom position), quantity to lift, daily cost to operate and vessel speed.

Cargo	Ship Name
Coal	*Great Republic*
	John G. Munson
	Arthur M. Anderson
Taconite	
	Arthur M. Anderson
	Edwin H. Gott
	John G. Munson
	Presque Isle
	Edgar B. Speer
	Great Republic
Limestone	
	Presque Isle
	Great Republic
	Arthur M. Anderson
	John G. Munson

Table IV-6: Cargoes commonly carried by the vessels in the model fleet

Vessel Cargo Capacity

Loadlines, in relationship to the Plimsol mark, are affixed to the hull of a vessel to ensure that the vessel can safely carry the maximum amount of cargo. The determination of the loadlines is based on the structural strength of the vessel, vessel stability, geographic range, and season. Lakers have four loadlines that correspond to cargo capacity for each of the four seasons. Table IV-7 lists the loadlines, tons per inch immersion (TPI) and deadweight capacity in long tons for the fleet. The loadlines represent the maximum draft at which a vessel can safely operate and the deadweight tonnage it can carry. However, a vessel may be constrained in its draft due to other factors such as lake water levels, silted-in channels or shallow water alongside berths. For extended season modeling, the winter load line capacities are used.

Seasonal Draft Difference *In long term layup									
Ships		**Mid-Summer**		**Summer**		**Intermediate**		**Winter**	
Ship Name	**TPI**	**M-Capacity**	**Max Draft**	**S-Capacity**	**S-Draft**	**I-Capacity**	**I-Draft**	**W-Capacity**	**W-Draft**
Arthur M. Anderson	127	25300	27	24284	26.4	23903	26-1	23395	25-9
*Cason J. Callaway**	127	25300	27	24284	26-4	23903	26-1	23395	25-9
Edgar B. Speer	267	73700	32-1	73700	32-10	73700	32-10	73700	32-10
Edwin H. Gott	267	74100	32-1	74100	32-1	74100	32-1	74100	32-1
Great Republic	108	25600	28-4	24736	27-8	24304	27-4	23764	26-11
John G. Munson	130	25550	27-4	24510	26-8	24120	26-5	23600	26-1
*Philip R. Clarke**	127	25300	27	24284	26-4	23903	26-1	23395	25-9
Presque Isle	258	57500	28-7	57500	28-7	57500	28-7	57500	28-7
*Roger Blough**	218	43900	27-11	43900	27-11	43900	27-11	43900	27-11

Table IV-7: Vessel Capacity in Long Tons with Seasonal Adjustments[62]

Typical Cargoes Carried by Great Lakes Fleet Vessels

These vessels are all self-unloaders, so they do not require shore equipment to unload. All the vessels are dependent on shore facilities for loading. Loading varies with the product, facilities, ballast pump capacity and cargo availability. The model assumes that cargo is available, ballast pumps can keep up with loading or discharge rates, and the shore facility can accept a normal discharge rate. Once a vessel docks, a load or discharge time without complication would be approximately 12 hours. However, winter loading and unloading operations are normally more difficult and time consuming, increasing the average port time to 14 hours. The formula adds a vessel refueling time of six hours. The location of the refueling will vary, but typically refueling takes place in the port of Duluth when moving cargo between the Twin Ports and the lower lakes.

Formula for a Voyage in Days

[(Load Port Time) + Loaded Transit time + (Discharge Port time) + empty transit time + fueling time] = **total voyage time in days**

Extended Winter Season Round Trip Voyage Times in Days						
Ports	**Loading port time**	**Downbound voyage**	**Discharge port time**	**Upbound voyage**	**Fueling**	**Total Time**
Twin Ports to Cleveland, OH	14 hours	52 hours	14 hours	52 hours	6 hours	138 hours **= 5.8 days**
Twin Ports to Gary, IN	14 hours	56 hours	14 hours	56 hours	6 hours	148 hours = **6.2 days**
Twin Ports to Detroit, MI	14 hours	43 hours	14 hours	43 hours	6 hours	120 hours = **5.0 days**
Rogers City, MI to Twin Ports	14 hours	38 hours	14 hours	38 hours	6 hours	110 hours = **4.6 days**

Table IV-8: Extended Winter Season Round Trip Voyage Times in Days

Increase in Cargo Carried during an Extended Season

The next step is to determine the quantity of cargo each vessel in the fleet could transport during the season's extension. There will also be a deduction from the theoretical maximum deadweight tonnage for fuel, potable water, stores and any ballast that may be carried. This model assumes diesel fuel weighs 7 pounds per gallon and a loaded vessel departs with an average of 80,000 gallons equal to 250 long tons. Potable water and stores add another 100 long tons. A total of 350 tons has been deducted from each vessel's maximum deadweight capacity to arrive at the cargo deadweight tons (DWT) the vessel can lift. The reality is that this will vary with each vessel. The model assumes that no ballast is carried.

Other factors impacting actual cargo carrying capacity may include lake water levels, quantity of cargo ordered by the shipper, and cargo requirements. Winter voyage times between ports are used for transit times. The average calculations on distance, speed, and time in section 1 are used in developing the model.

Formula for Increased Cargo Carrying Capacity

For Twin Ports to Cleveland, OH: 30 days/ {(total round trip voyage time in days) x winter cargo capacity} = **increased lift in long tons**

The model determines approximately how many additional tons of cargo can be carried by a vessel during a thirty-day season extension.

For example, for the *Edwin Gott's* extension of 30 days / 6.2-day round trip = approximately 5 additional voyages. Each voyage the *Gott* carries 73,750 cargo DWT tons, equaling a total additional lift in the month's extension of 368,750 tons of taconite. Vessel productivity during the month could increase if the vessel goes into winter lay-up at or near a discharge port so a round trip is not required for the last voyage. For example, the *Edgar B. Speer* can carry a down-bound cargo if the vessel is laid up in a Lake Michigan port, for a total of 366,750 tons. This option is incorporated into the model. Winter drafts and capacities are used, but ice, low water or other factors might reduce draft and the corresponding actual tonnage.

This fleet model assumes that all products will be at current (2021) levels of demand. The trend-line indicates that coal will continue to decline as a cargo and may disappear by 2050. The calculation in Table IV-9 assumes the last voyage of the season is loaded. The theoretical maximum DWT can be revised downward when computing an actual load which may be reduced due to channel depth limits or other factors. Many factors go into which vessel operates on a run. These are just examples. Owners will employ the most cost-effective vessels in moving cargo.

Vessel	Voyage	Days for round trip	Additional Round trips with a 30-day extension	Total additional tonnage moved
Edwin Gott	Twin Ports to Conneaut, OH	6 days	5 round trips	368,750 tons
Presque Isle	Twin Ports to Conneaut, OH	6 days	5 round trips	285,750 tons
Total tonnage of taconite to Cleveland with 30-day extended season				**654,500 tons**
John G. Munson	Twin Ports to Gary, IN	6.2	5 trips – last to lay-up in discharge port	116,250 Tons
Edgar B. Speer	Twin Ports to Gary, IN	6.2	5 trips - last to lay-up in discharge port	366,750 Tons
Total tonnage of taconite to Gary with 30-day extended season				**483,000 Tons**
Total increase in taconite shipments with 30-day season extension				**1,137,500 tons**
Arthur M. Anderson	Twin Ports to Detroit, MI	5	6 round trips	138,270 tons
Total tonnage of Coal to Detroit area with 30-day extended season				**138,270 tons**
Great Republic	Rogers City, MI to Twin Ports	4.6	7 round trips	163,898 tons
Total tonnage of limestone to Twin Ports with 30-day extended season				**163,898 tons**
Total tonnage for the Great Lakes fleet with a 30-day extension				**1,439,668 tons**

Table IV-9: Vessel and fleet tonnage increased capacity with a 30-day extension.

Increased Cargo Carrying Capacity with Sixty Day Extension

The model assumes a doubling of tonnage with another 30-day extension to a total of 60 days. This would mean that the fleet would theoretically increase lift capacity to 2,879,336 tons for a 60-day extension.

Without an increase in demand for these three products, there is a strong probability that an increase in the operating season could result in a reduction in the number of vessels needed to move the annual product quantity.

For example, if the *Arthur M. Anderson* were employed only carrying taconite on the Twin Ports to Gary, IN, run during a standard 295-day season, it would make approximately 47 round trips. Assuming the vessel would transport an average of 23,934 tons per trip, (Summer DWT 22,284 – 350 tons fuel etc.), it would lift 1,124,898 tons during the current 295-day season.

The total theoretical lift of taconite by the fleet during the 30-day extended season is 1,137,500 tons. This increased lift capacity exceeds the annual lift for the *Arthur M. Anderson,* raising the question of the need for this vessel.

If cargo volume remains at current levels and the season extends for 30 or 60 days, the number of vessels needed to move the volume of cargo currently moved in a 295-day season declines. However, for that to occur, all the elements of the supply chain, such as port equipment, personnel, and production facilities would need to be able to accommodate the change. Except for the trial in the 1970s, the industry has conformed to roughly a 295-day shipping season.

Season Extension Impact on Vessel Crewing

Operating vessels require sufficient qualified personnel to meet the requirement of the USCG issued Certificate of Inspection (COI). The number and qualifications of the mariners will vary from vessel to vessel. Mariners are interchangeable between vessels as long as they serve within the capacity of their license or rating. The weather, rapid turnarounds, close-quarters navigation, and frequent port calls create a high-pressure work environment on Lakers. To ensure safe operations, there are limits on how many hours a mariner can work in a day or week. In addition, mariners have time away from the vessel to reduce stress and maintain a home life.

Mariners on the Lakes rarely sail continuously for the entire season. Depending on the terms of their contract, mariners will have a month or more of time off during the shipping season, as well as being off the vessel during winter lay-up. The paid leave time varies by contract and the length of "sailing" varies. Most Lakers call some crew back for fit-out and keep some crew members on preparing for lay-up.

In order to comply with the COI, relief mariners need to be available to sign on the vessel(s) when mariners take leave during the operational sailing season. These relief mariners may rotate between vessels. The maritime industry refers to this pool of qualified available mariners to keep the fleet running as the "establishment."[63] The fact that the majority of Lakers go into winter lay-up means that there are about 60 days in the winter when virtually all crewmembers can take leave without the need for relief personnel. Extending the Great Lakes shipping season by 30 or 60 days will require a larger establishment.

For modeling purposes, the study assumes with season extension mariners will be sailing for a total of eight months and have a total of four months paid leave. Mariners typically sail for four months total and take two months off. A rotation schedule ensures that key personnel will overlap. This model is common for ocean vessels operating 355 days a year. The type of service the vessels are operating in, illnesses, personal difficulties, and access to qualified personnel create variations in the rotation schedule.

The model assumes that a Laker with an average of 25 crewmembers operates 295-days per year, and a crewmember sails for 235 days and gets two months (60 days) off during the sailing season. A mariner will have an additional 60 days off while the vessel is in winter-lay up for a total of 355 days employment. A 25-person relief crew sailing for 235 days will be able to cover the 60-day leave periods taken during the summer for approximately four Lakers.

Vessel's crew	**Operating Season**	**Days Relief Crew Needed**	**Relief Crew Coverage**	**Relief crew coverage/days needed = Ships Covered**
25	295 days	60 days per vessel	235 days	235/60 = 4 Lakers
25	355 days	120 days per vessel	235 days	235/120 = 2 Lakers
Establishment for 4 Lakers – 295 - day season				**125 mariners**
Establishment for 4 Lakers – 355 – 60-day season extension				**150 mariners**

Table IV-10: Changes in Establishment with Season Extension

These findings are approximations based on industry standards. There will be variations. There are Great Lakes vessels operating on the lower lakes more than 295 days, and they may provide insight into addressing crewing with season extension. Extending the shipping season by 30 or 60 days will create a need for more mariners. The reduced need for vessels, as noted in the prior section, may mitigate some of the increased need for mariners. Automation may also reduce the total number of mariners, but automation may result in a need for higher qualified mariners with additional training and skill sets.

Season Extension Impact on Vessel Maintenance During Lay-up

Most Lakers go into lay-up when the Soo Locks are closed. Vessel maintenance is normally undertaken during lay-up. A vessel's lay-up port is determined by several factors: the degree of maintenance that will be done on the vessel, proximity to ship repair facilities, lay-up berth infrastructure, lay-up berth costs and location of the vessel to cargo at break-out time. A vessel that needs major repair or retrofitting may need to lay-up where there is a shipyard, such as Sturgeon Bay or Superior, WI. Even vessels with routine maintenance may elect shipyard ports to ensure the availability of skilled personnel but will not dock at the shipyard itself. Lay-up berths in any location need power, security and access to the vessel.

Crews will be laid off from the vessel in a staggered manner with some key personnel attending the vessel to supervise repairs. Repair crews will work on the vessel, with heat and power in work locations and areas that cannot handle temperatures below freezing. Major work dealing with underwater areas will require the vessel to drydock. Historically work gangs have at least two months to carry out repairs. While lock closure and ice are the primary reasons for winter lay-up, economic factors may also impact the date of lay-up. During the economic recession in 2008 some vessels were laid up in November 2008 for a lack of cargo.[64]

The lay-up season can have a major financial impact on the ports where the fleets lay-up. Docks are rented, repair crews are paid, parts and supplies are delivered to the vessel and support personnel, such as marine engineers and naval architects, employed. Exact amounts spent on each vessel are not publicly shared, but port officials have estimated expenditures based on tax revenue and other indicators. In 2006, it was estimated that a vessel laid up in the port of Duluth-Superior generates an average of $800,000 worth of work.[65] In 2008 the port of Milwaukee estimated that the economic impact of four ships in winter lay-up in the port would be $3 million. In 2009, 12 vessels spent the winter in the Duluth-Superior harbor with each vessel representing approximately $500,000 to $800,000 in repairs, for a total well over $7 million in economic impact.[66] Based on these reports, a conservative economic impact of one ship laid up for 68 days in either a load or discharge port would be $500,000. The average daily economic impact would be $7,352, so a 30-day extension would lower the economic impact by $220,588.

Lift and/or draw bridge operations will increase in ports during an extended season. Personnel to operate these systems will be needed and the repair season for this infrastructure will be shortened.

Some of the ports' revenue loss from reduced lay-up time may be recovered by the services rendered to vessels operating during the extension. These vessels will need fuel, stewards' stores and spares. Vessels may need ice-breaking support alongside docks during cold snaps. Federal channels will be opened by government vessels where icebreakers are available. Docks and approaches outside of USACE-maintained (federal) channels will be maintained by private companies.

Impact on Vessel Maintenance and Repairs (M&R)

Ocean vessels are accustomed to operating with only an average of 10 days per year of off-hire downtime for maintenance. Down time will be different for each vessel because of age, quality of prior maintenance procedures, and operations. When the vessel reaches the five-year shipyard period (or six-year, if year of grace is granted), the downtime may be two weeks or longer. A vessel that is off-hire is not generating revenue for the vessel operator.

An extended shipping season on the Upper Great Lakes would reduce available lay-up time for Lakers, and consequently, available repair time. Impacts could include repair gangs working overtime, riding crews on vessels to make repairs/upgrades while the vessel is sailing, and significantly larger work gangs on vessels in order to complete repairs. The selection of ports for maintenance may be determined by available supplies, expertise, and work gangs. The goals of vessel maintenance plans are to get the maintenance and repair work done in the least possible time with minimum costs. Vessels that can operate longer with minimal downtime generate more revenue for better asset utilization. That, in turn, reduces the cost of shipping—making vessels more price competitive.

Preventive and routine maintenance can be planned. However, equipment failure presents a problem when the season is extended. Great Lakes vessel operators may start to utilize to a greater degree a condition monitoring, a preventive maintenance program, or a predictive maintenance model. Maintenance prediction is a proactive approach in addressing unplanned downtime due to equipment failure. Lean maintenance techniques can also be applied with the objective of reducing waste such as waiting for tools, documentation, spare parts, qualified personnel, obsolete material, wrong spare parts, defective spare parts, unnecessary steps, and authorization redundancy. Research will need to be done on the impact to ballast-water management systems, oily-water separators, and stack-scrubber systems for extended ice/cold water operations. Research should also be conducted on the impact on a vessel's fatigue life when operating during an extended season. There might be a difference in fatigue life of ice-classed versus ice-strengthened vessels.

Impact on Marine Insurance

Historically, Lakers would have to stop navigation on the Great Lakes at the onset of the ice season or lose insurance protection. In the early 20th century, early December was the deadline for Lakers to stop operation as noted in a December 5, 1900, article in a Duluth, MN newspaper:

> "Hull insurance on vessels of the A-1 Class expired at noon today and the insurance rates on grain will expire at 6 o'clock tonight. Several boats took advantage of that fact to ship out this afternoon".[67]

A vessel that is damaged may be able to make a claim with their insurance company. Vessel owner will have a hull and machinery (H&M) policy covering damage to the vessel and a protection and indemnity (P&I) policy covering injury to crew members or claims from third parties. Insurance companies are risk averse and want companies to avoid the possibility of damage wherever possible. An insurance company may have a rider in their policy that make the policy null and void if the vessel is knowingly heading into certain known dangers.

The common H&M policy insures the vessel for worldwide trading within the so-called International Navigational Limits (INL). Navigating into or through one of the either seasonal or permanently “excluded areas” without advising the hull insurance underwriters and without paying the additional insurance premium will void the vessel’s hull insurance coverage and is considered breaching the contract. Areas permanently excluded include Polar Regions, North and South, typically above latitude 50˚ or 52˚. Also permanently excluded are the St. Lawrence Seaway and Great Lakes, Aleutian and Queen Charlotte Islands, and the Bering Sea, with conditions.

In most voyage charger parties, there is a “General Ice Clause” that, in effect, states that the vessel named in the charter party shall not be obliged to force ice but, subject to the vessel owners' approval and having due regard to its size, construction and class, may follow icebreakers when reasonably required.”

Improved vessel construction methods, stronger materials, higher horsepower-to-tonnage ratios, ice strengthening, and the assistance of icebreakers have all contributed to extending the season and reducing damage. However, if insurance company data indicates that an extended season is resulting in increased damage to vessels, injuries to crewmembers or third parties, insurers will likely require that vessel owners make changes to address the issues or lose insurance coverage. The vessel owners will then have two options: complying with the marine insurance company’s requests or becoming self-insured. All parties are interested in avoiding loss and will work towards that end. Assuming a reduction in ice coverage as predicted in the climate change studies, vessels would be operating during the extended season in conditions similar to what they currently operate in during January and March.

Impact on Cargo Owners

With the current 295-day Great Lakes shipping season, cargo owners need to carry buffer inventory to keep plants operational when vessels are unable to deliver product. The amount of inventory is considerable, both in quantity and cost. Carrying costs (holding costs) are expenses from keeping products in storage. These costs typically include storage, labor, transportation, handling, insurance, taxes, item replacement, shrinkage and depreciation. Opportunity costs may also be included. Opportunity costs are the investment opportunities a company must forego because resources are tied up in inventory. Each of the three industries in this study maintain inventory to carry them through the closed Great Lakes shipping season.

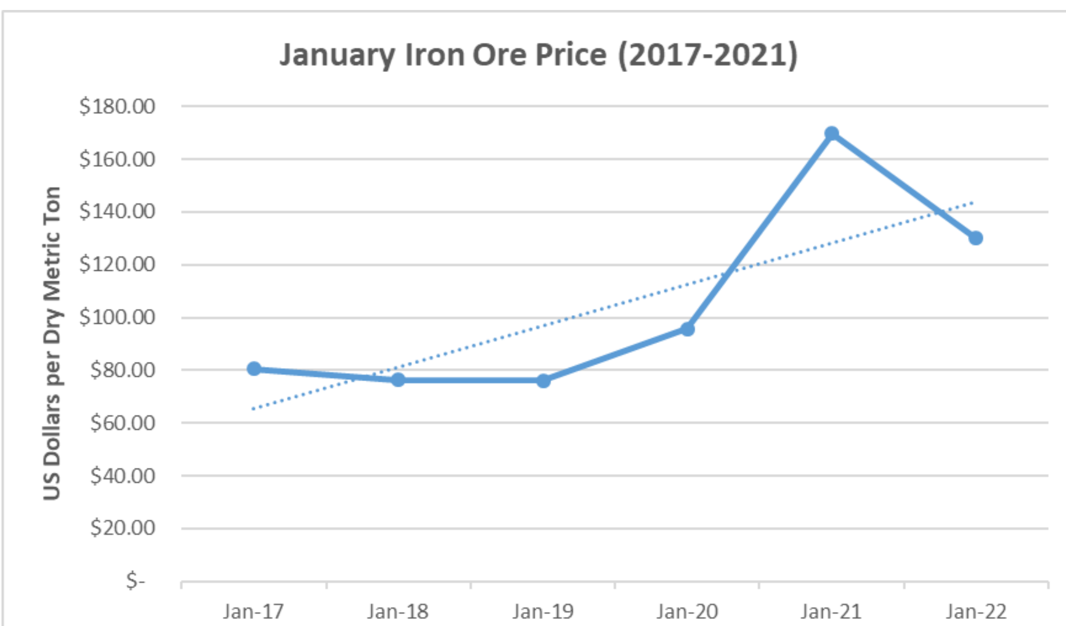
Inventory may be priced at the cost of production or the market price. The addition costs beyond the assigned price of the product can be substantial. In 2018 the Association for Supply Chain Management, (ASCM) surveyed a variety of industries to estimate inventory carrying cost benchmarks, as indicated in Table IV-11.[68]

Carrying Cost Type	Carrying Cost Percentage of Total Inventory
Capital	6–12%
Shrinkage	3–6%
Expiration and Obsolescence	6–12%
Warehousing	2–5%
Handling	2–5%
Inventory Management & Control	3–6%
Taxes	2–6%
Insurance	1–3%

Table IV-11: ASCM benchmark of additional inventory carrying costs

Shutting down a steel mill is an extensive and expensive operation. Taconite buffer stock costs could, in part, be based on the market price of the product, the lost opportunity cost of holding inventory and storage facilities.

The market price of taconite is tied to the world market price for iron ore that fluctuates with demand, transportation costs and available ore supply. In November 2021, iron ore was valued at approximately 96.24 U.S. dollars per dry metric ton unit (dmtu), as compared to 124.36 U.S. dollars per dmtu in November 2020.[69] Over the past five years there has been significant variation in price, (see Graph IV-1). The price is trending upwards with a five- year average price of $104.72 per metric ton.



Graph VI-1: January Iron Ore Price (2017-2022)[70]

The production cost may also be used as a base for calculating buffer inventory costs. A plant's total cost of production is normally a closely held number. All taconite mines in Minnesota pay a tax based on a cost of production for each ton. The Production Tax is assessed on "taxable tons" produced. For taconite and Direct Reduction Iron (DRI) production, this means the tax is based on a mining facility's average production over three years—the current year and the previous two years. The mine submits a form listing many but not all costs of production. Mine production is monitored by the Minnesota Department of Revenue, providing annual production numbers. At times companies publicly provide approximate production costs. For example, in 2015 Cliffs indicated that their approximate cost of production was $59 per long ton.[71] Inflation will likely have raised this cost of production over the past seven years to the $70 range.

2020 Production Tonnage by Product Type

Producer	Pellets			Chips and Fines			DRI/Iron Nuggets	Total Tons by Mine
	Acid	Fluxed	Partial Fluxed	Acid	Fluxed/ Partial Fluxed	Concentrate	Nuggets	
Hibbing Taconite	---	---	5,262,948	---	---	---	---	5,262,948
Keewatin Taconite	---	---	1,786,962	---	0	3,295	---	1,790,257
Northshore	---	---	3,541,633	---	115,596	0	---	3,657,229
Minntac	1,066,042	10,754,629	---	---	0	---	---	11,820,671
Minorca	---	2,616,481	---	---	0	---	---	2,616,481
United Taconite	---	1,750,224	3,254,847	---	0	0	---	5,005,071
Total Tons	**1,066,042**	**15,121,334**	**13,846,390**	**0**	**115,596**	**3,295**	**0**	**30,152,657**

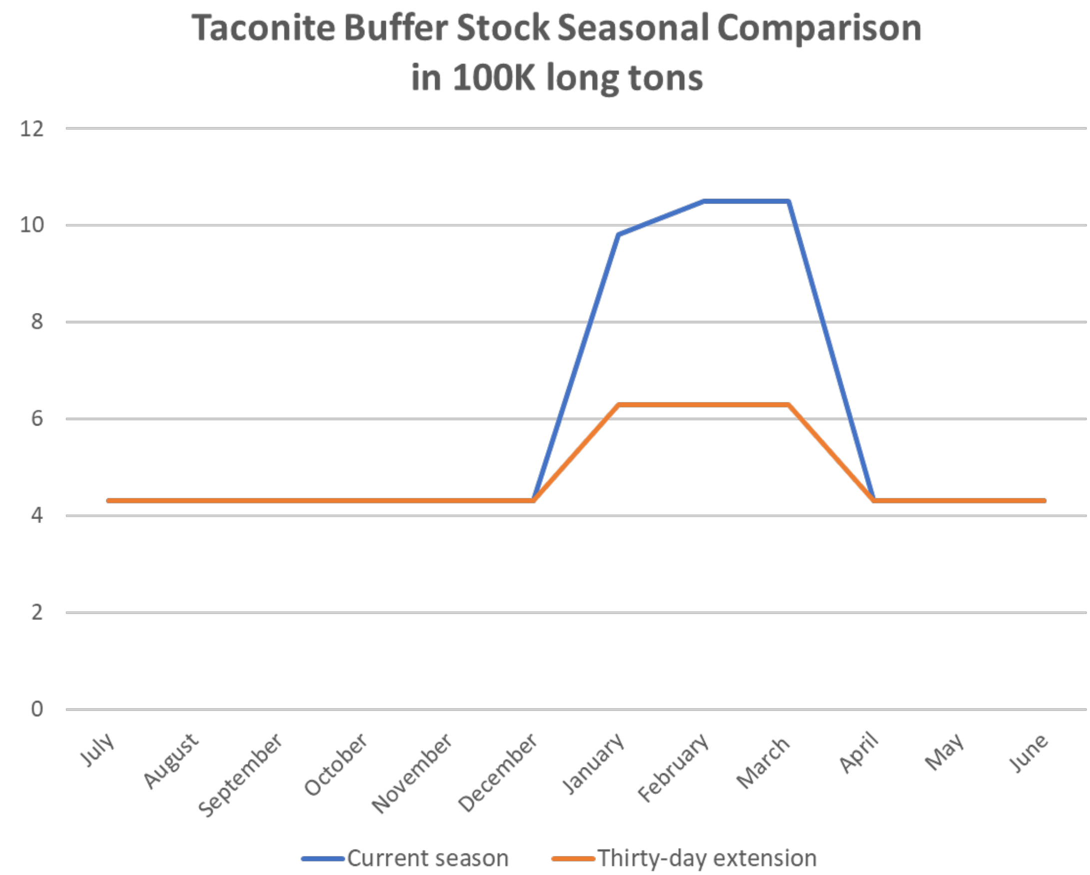
Notes:
Partially fluxed pellets contain less than 2 percent flux.

Table IV-12: 2020 Production of Iron Ore in Long Tons[72]

Extending the shipping season should enable plants to carry lower buffer stock levels as the vessels would continue to deliver product. Reducing inventory would result in cost savings to the consignors and consignees who both carry buffer stock. Modeling at least a portion of the potential cost savings would reflect an impact to cargo owners during an extended season.

For modeling buffer stock costs, the 2020 production level for Hibbing Taconite mine of 5,262,948 long tons is used as the annual taconite production. Assuming a constant rate of production, the monthly production level would be 438,579 long tons. There may be variance in monthly production rates due to scheduled maintenance or other factors.

It is assumed that two and half months of buffer stock is located at the mills that receive Hibbing's taconite to carry the mills through the closed shipping season. Graph IV-1 provides a comparison of buffer stock in the current season and the reduction in stock with a 30-day extension of the shipping season. As the loadline seasons change, the lift of many vessels will be reduced, and that is factored into the graphical representation. During the summer and midsummer seasons, the lift is assumed to be identical. Numbers are approximate in the model and actual tonnage moved will depend on demand, vessel traffic, channel depth and other factors.



Graph IV-1: Taconite Buffer Stock Seasonal Comparison in 100k Long Tons

Graph IV-1 provides a graphic comparison of buffer stock in the current season versus a 30-day extension that allows a month's reduction of Hibbing Taconite's buffer stock.

Converting one month of Hibbing Taconite's mine production from long tons to metric tons is 445,616 metric tons. Multiplying that amount by the five-year average iron ore market price of $104.72 results in a month's buffer stock equal to $46,664,907, calculated at market price. The buffer inventory savings may be computed at market rates if the mill has purchased the product from the taconite producer and it is stockpiled at or near the mill.

Multiplying one month's production of 438,579 long tons and an estimated production cost of $70 per long ton, the cost of that one month's buffer stock is $30,700,530. Using vendor managed inventory, the mill may not pay for the product until it is used even if it stocked at the mill location, and then production cost would be more applicable. By either measure, reducing one month's buffer stock is financially significant for shippers.

These comparative cost of inventory totals do not reflect all the inventory costs. Table IV-12 provides comparative values of one months' buffer stock with the addition of warehousing, as well as handling and management costs using percentages from the ASCM study. The totals in Table IV-12 do not include insurance, taxes or opportunity costs. A complete accounting of all costs would require access to private data that varies by company. A combination of both market value and production cost evaluation may be used in some instances. The model presented clearly indicates significant inventory savings.

Average monthly taconite production at Hibbing Taconite in 2020	**445,616 metric tons**			**438,579 long tons**
Market Price @ $104.72 per ton	$46,664,907		Production Cost @ $70 per ton	$30,700,530
Warehousing @ 2%	$933,298		Warehousing @ 2%	$614,010
Handling @ 2%	$933,298		Handling @ 2%	$614,010
Inventory Management & Control @ 3%	$1,399.947		Inventory Management & Control @ 3%	$921,015
Buffer Stock Market Valuation Totals	$49,931459		Buffer Stock Production Valuation Total	$32,849,565

Table VI-12: One-month partial taconite buffer stock costs

Table VI-12 is an example of the monetary impact of a reduction taconite buffer stocks for a single mill when there is a season extension. Of note is the fact that in 2020, Hibbing Taconite only represented about 20 percent of the annual taconite production in Minnesota. Thus, a 30-day extension could result in hundreds of millions of dollars in inventory savings. A similar benefit would apply to all industries that use buffer stock to carry their operations through the closed shipping season.

The higher an inventory's value the greater the financial impact of carrying buffer stock. Inventory holding costs is likely one of the factors that has deterred some industries from using Great Lakes shipping as part of their supply chain operations. Expanding the shipping season due to the reduction of ice coverage creates new supply chain models that may appeal to shippers currently using other modes of transportation.

The Baltic Sea has many similarities to the Great Lakes in terms of ice impacting shipping. Chapter V will examine markets in the Baltic Sea that make use of marine transportation in their supply chain. This study does not examine international cargo in or out of the St. Lawrence seaway. Only intra-lake and inter-lake options, including service between Canada and the US, are explored.

Chapter V. New Cargo Opportunities

Basic Requirements by Shippers

The current Great Lakes marine transportation market is almost exclusively composed of vessels dedicated to the transportation of wet or dry bulk commodities using vessels specially designed for those trades. The market exists because these vessels are part of reliable and efficient supply chain that other modes are not competitive in. A season extension offers the opportunity to change supply chains. Shipper's currently using rail or truck to move their cargo will consider switching to marine provided there is a supply chain that meets their basis requirements. A marine supply chain is composed of suitable vessels, port infrastructure, connections to serve the first and last mile and supporting institutions such as shipyards.

The principal categories of marine cargoes are listed in Table V-1. Vessels are typically constructed to provide optimum service for category of cargo. For example, a self-unloading Laker is designed to provide excellent service for the transportation of dry bulk cargoes. However, this vessel as constructed could not practically transport wet bulk cargoes, breakbulk cargo, or containers. Currently there are no container vessels or break-bulk vessels operating on the upper Great Lakes. There is very limited Roll-on/Roll-off (RORO) service on Lakes Michigan and Huron.

Cargo	Vessel types
Individually packaged or palletized cargo	Break-bulk
Unitized	Container
Dry Bulk	Bulk vessels
Wet Bulk	Tankers
Oversize	RORO
Overweight	Heavy lift

Table V-1: Marine Cargoes by Category

Up until the 1930s “Package vessels”, that were often owned by railroads, carried a wide variety of break-bulk cargoes on scheduled liner service.[73] As roads were paved and trucks increased in size, these vessels disappeared from service and the movement of bulk products became the mainstay of Great Lakes maritime commerce. The trucks captured high value cargo from both rail and marine service through comparative advantages in speed and year-round service.

A 1999 study completed for the National Highway Administration listed five critical qualities shippers desire in freight transportation service; reliability, transit time, efficiency, cost and damage minimization.[74] The need for reliability has not diminished, but rather increased since 1999, as noted in a 2021 TRIP study.[75] While carrier selection for a single shipment may be driven by cost or speed, the establishment of a long-term supply chain seeks a carrier that is trustworthy and performs consistently well. Reliability is more important than cost or speed in selecting a carrier.

Increased traffic density, especially in urban areas like Chicago, adversely impact the delivery times of truck and rail operations. Ongoing labor operator shortages in both rail and truck industries have further acerbated reliable cargo delivery. There is increasing pressure for shippers to utilize more environmentally-friendly modes of transportation. Vessel movement remains the most environmentally friendly mode of transportation in terms of emissions and fuel consumption per ton-mile.

One of the difficulties in expanding marine cargo movement on the Great Lakes has been the two-month winter shutdown, creating for many potential customers a broken link in the potential supply chain. Extending the shipping season by a month or more can allow the development of supply chains for products that either have never moved by lake vessels or may have moved in the past.

Cargoes that by their nature need to travel at high speeds, such as perishables or dated medical supplies, will not be compatible with relatively slow vessel speeds. Cargoes that can accept a longer transport time are able to move between modes, provided vessel operations reliably conform to shippers needs.

Reliability is one of the key criteria in establishing a supply chain. An extended shipping season on the Great Lakes would theoretically create new supply chains if the movement of the cargo occurred in a reliable manner.

An old adage states that freight, like water, follows the path of least resistance. Barriers to the movement of freight can be physical or administrative. Having a suitable vessel is part of the solution to improved freight movement. There also needs to be infrastructure in the form of ports that link to the interior with serviceable highways and railroads. Any constriction in terms of slow cargo-handling equipment or low highway weight limits, is akin to placing a 1-inch diameter garden hose between two 3-inch diameter fire hoses and expecting the flow of a fire hose. Extended customs’ clearance time, slow gate turn times and restricted operating hours are examples of administrative delays.

Cargo should have minimum handling during transit. Every time cargo is handled, there are added monetary and time costs as well as danger of damage to the goods. Individually packaged or palletized cargo can stow aboard a vessel more compactly, but they require significant time and handling in port. Packaged and break-bulk (general cargo vessels) operate on the oceans because the port stays are a relatively small portion of the time spent on the long voyages. However, Great Lakes voyages are short between ports. Competition from railroads and trucks provide a faster and possibly less expensive total cost option if long port stays are the norm for ships. Break-bulk ships that handle palletized cargo in the manner of package vessels in the past will likely not be cost effective on inter-lake or intra-lake routes. Cargo that is unitized in containers or semi-trailers will provide the best options for rapid port operations, minimal handling, faster vessel transits and better asset utilization.

Consolidating small packages in larger containers (unitization) prior to reaching the vessel enables, with the right equipment, faster loading and unloading time, thereby reducing port time. Faster port turnaround time enables better vessel utilization. These facts led to the development of the all-container ship. For non-bulk cargo there is a constant evolution to transport by land and sea unitized systems rather than small package movement. In order to standardize equipment, the transportation industry is shipping break-bulk cargo in International Organization of Standards (ISO) 20-foot (TEU) and 40-foot (FEU) containers for international trade and 53-foot units for domestic U.S. trade. Most of these vessels operate on a timetable with the liner vessel leaving on schedule even if it is not full of cargo. Reliable maritime commerce for this cargo requires liner service so that shippers can schedule their supply chains. Ideally there is cargo visibility from the point of origin to point of destination. Cargo that is unitized in containers or semi-trailers will provide the best options for rapid port operations, minimal handling, multi-modal connectivity, faster vessel transits and better asset utilization.

The Great Lakes Compared to Baltic Sea

The Baltic Sea is similar to the Great Lakes in terms of weather conditions. The combined Great Lakes have 26 percent less surface area but 30 percent more water volume than the Baltic Sea. The Baltic Sea extends from latitude 65.4 degrees north to 54.3 degrees north. The Great Lakes upper and lower latitude limits are 48.5 degrees north and 41.22 degrees north. The Baltic Sea has temperature mitigating effect from the Atlantic Ocean and Gulf Stream. However, the sea's higher latitude means that, like the Great Lakes, ice is a factor in vessel operations. The Finnish Metrological Institute notes that:

> *"On average, ice covers an area of some 170 000 km², which stands for 40% of the total Baltic Sea area (422 000 km², including Kattegatt and Skagerrak). The minimum ice extent has been on winter 2020 when there was only 37 000 km² ice in maximum."*[76]

The Finnish Ice Service classifies the severity of the Baltic Sea ice seasons into three classes: mild, average and severe. Navigation is year-round, but unlike the Great Lakes, the Baltic Sea does not have a major lock system. An examination of the impact of global warming on the Baltic, how their year-round shipping operates, and cargo types can provide insights into future Great Lakes vessel operations and cargoes.

Impact of Climate Change on the Baltic Sea

Climate change impacts on the Baltic Sea have been a diminution of its ice extent with less and less severe winters. These impacts are predicted to keep decreasing under different scenarios (A2 and B2 SRES emission scenarios)[77]. The temperature is projected to increase by 4 degrees Celsius between 1990 and 2100.

This phenomenon could be explained by the rise in sea level caused by global warming. As several studies suggest that global warming is one of the main causes of ice melting in the Arctic, the ice melt causes the sea level to rise which inevitably has an impact on the ice coverage of northern water. The Baltic Sea level trend since 1970 has been increasing in the southern and middle area of the Sea with a continuous trend for the projected change in the 21st century in the same regions.

As for the northern regions, especially in the Gulf of Botnia, the trend since 1970 has been decreasing water levels. It is predicted to continue over the 21st century.[78] which could explain why under mild winters, the region is the only area undergoing large ice extent and thick ice covers. These regions are experiencing considerable land rise as a consequence of post-glacial rebound and changes in the gravity field of the Greenland ice sheet.

As the global trend in ocean level rise is increasing throughout the lower Baltic as well as throughout Europe, the North Sea ports are forced to make significant changes and developments to adapt to the new conditions. The port of Hamburg for instance, has built additional new defenses to respond to the increased water levels and the changes of waves and tidal waters level. The port has developed the Tidal Elbe Concept to give more space to contain a flood.[79]

Another example is the port of Rotterdam. The port is located in the Netherlands, a region particularly low land elevation and is easily flooded, has to make constant adaptation strategies and developments in many areas of the port to remain flood resistant.[80] Another impact from global warming is that Rotterdam recently sold its last icebreaker since it has not been used in over a decade.[81]

The USCG defines large icebreakers as vessels with more than 10,000 horsepower and able to enter the Arctic Ocean alone. The largest icebreaker on the Great Lakes is the USCGC *Mackinaw*, and at 9,914 HP is not considered a large icebreaker. The nations bordering the Baltic (not including Russia) have 25 icebreakers over 10,000 horsepower and as of 2017 only 3 of these have been to the Arctic Ocean with most operating in the Baltic Sea. Russia with 46 icebreakers has the largest single collection of large icebreakers in the world. (See Appendix A). These countries are building even more icebreakers intended for Baltic usage only.[82] A number of current Baltic icebreakers “are showing their age and the equipment on board is simply beginning to wear out. There have been no spare parts left on the shelf for many years.”[83]

Icebreaker assistance has changed in recent years. The merchant ships are getting bigger, and they are also undergoing new environmental restrictions and standards. These changes often limit their power and thus their ability to navigate ice-covered waters without icebreaking assistance. Vessels operating during the winter months in the Baltic will usually be ice classed.

The warmer seasons in the Baltic are making ice navigation more difficult. Average seasons tend to be the hardest for ice navigation. The warm and windy periods between cold periods cause ice plates to drift, followed by ice pressure and ridging in the ice fields. Windrows and brash ice barriers are formed, requiring additional ice-breakers support and ice-classed vessels.[84]

Ice-Classed Vessels

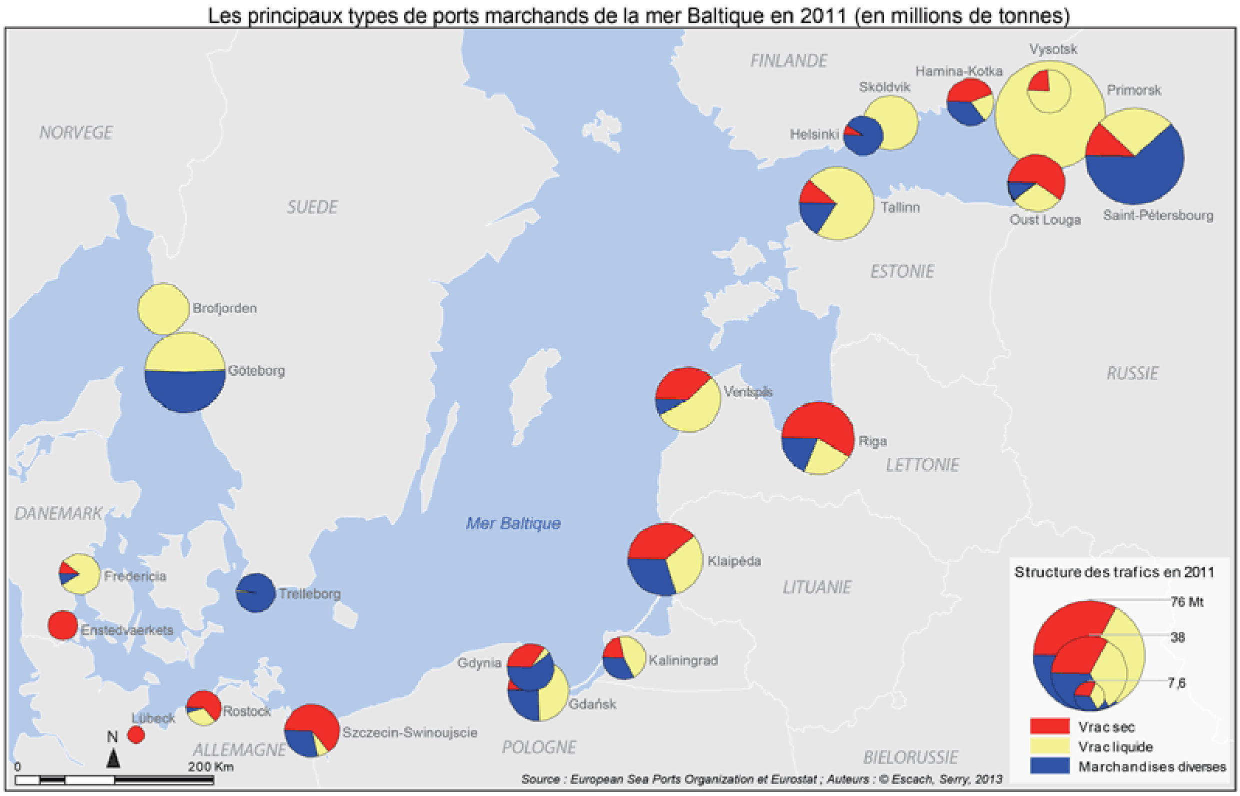
Construction of a vessel with scantlings sufficient to operate in ice is standard in the Baltic and other regions where ice navigation is common. Such vessels are “Ice Classed” by their respective classification societies. The American Bureau of Shipping (ABS) is the classification society for many of the US flag Great Lakes vessels. The ABS has established standards for Ice Classed vessels. A review of several ABS classed Lakers that operate in ice did not indicate that any of these vessels were Ice Classed by ABS. To be ice classed, the steel hull must be thicker, and have additional scantlings (aggregate of girders, stiffeners, beams, and bulkheads resulting in stronger structural integrity). In addition, openings in the hull for seawater intake (sea chests) may need to be arranged differently to ensure that sea chests do not become blocked with ice. ABS assigns Ice-Class notations A5 through A0; B0, C0, and D0. A5 class is the strongest built of the classes, with D0 being the weakest. ABS Class A5 is the only Arctic Class that may act independently in extreme Arctic waters with no limitations. Other classes are subject to limitations on time of year, and ice conditions and they might also require an escort by a vessel of higher ice class.

Industry experts did report that Lakers were frequently strengthened for ice operations. Examples of ice strengthening include thicker plating in the bow area and stronger or more closely-spaced framing at impact points, along with additional protection for the propeller and rudder. A key protection is the policy of many companies to have Masters who have been trained and experienced in ice navigation command the vessels.

Baltic Sea Maritime Shipping

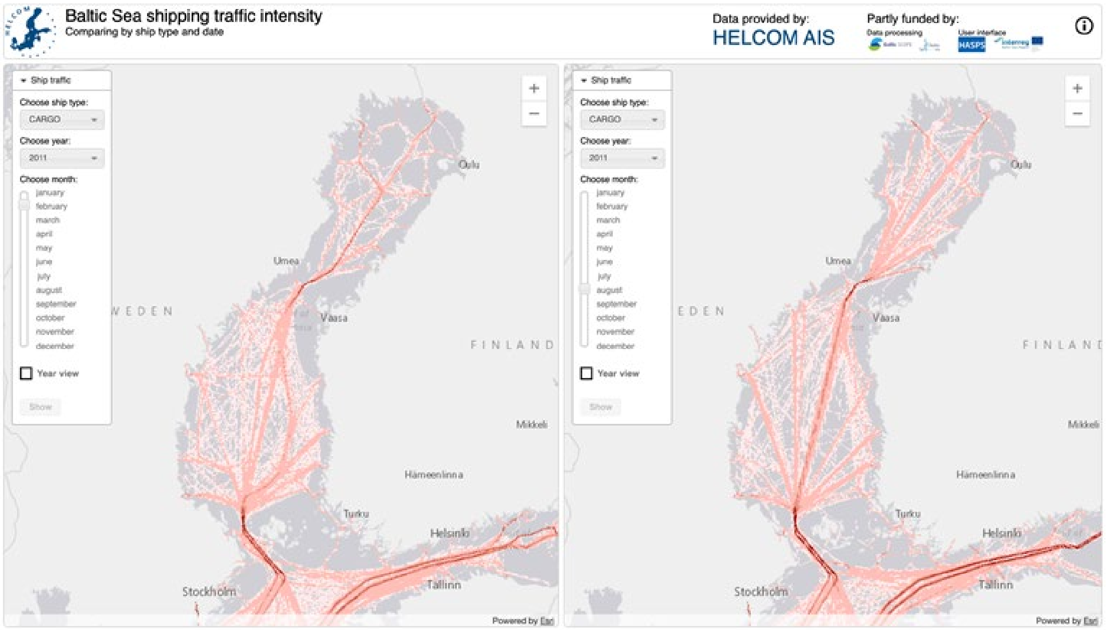
Trade routes can be divided into three different areas: traffic within the Baltic (which is traffic between Baltic countries such as Sweden, Finland, Denmark, Germany, Russia, Estonia, Lithuania and Latvia). Most of the traffic in the Baltic is being made within the Baltic. The connections are therefore local, and distributed around three main areas: the Oresund, the region of the Gulf of Finland, and the central Baltic. The second area is marine traffic between the Baltic countries and the EU. There is trade outside of the EU (this includes the rest of the world but also countries such as the UK or Norway for instance since they are not part of the EU). The last type of traffic is not well developed due to its location. The global traffic doubled from 1997 to 2011 growing from 420 million tonnes to 790 million tonnes.[85]

Map V-I provides major regional ports' share of types of traffic (blue is other merchandises, often within containers, trailers, pallets, crates, tubes, bags, packages and manufactured products; red is dry bulk and yellow is wet bulk).



Map V-1: Comparison of Baltic Marine Cargoes in 2011

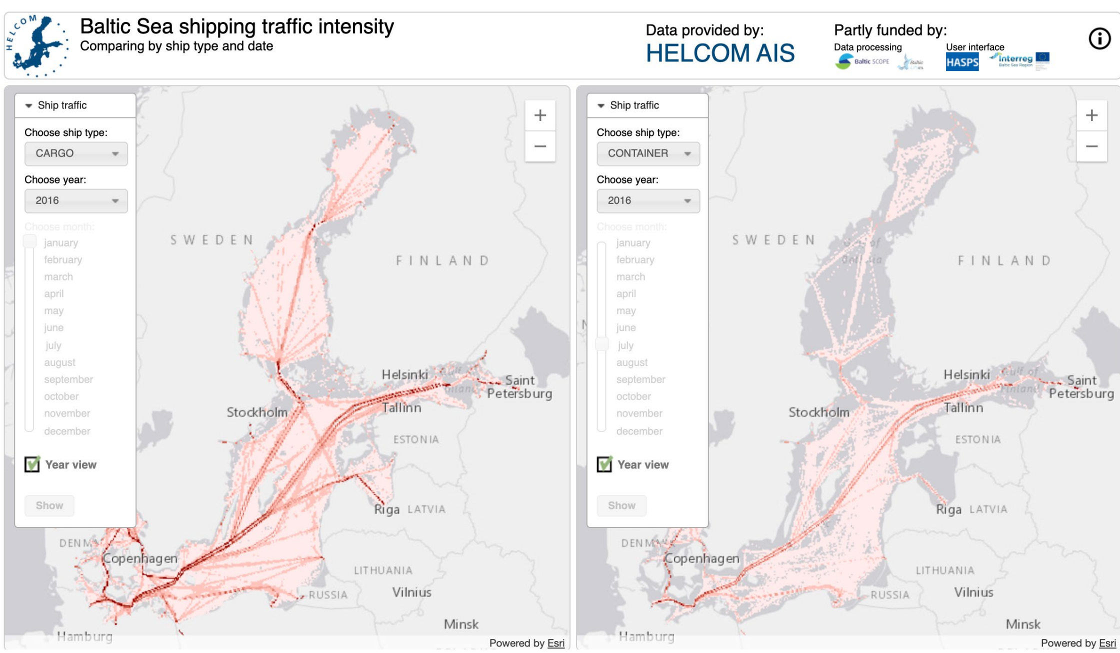
In parallel with the overall growth in maritime traffic, maritime flows have experienced a categorical redistribution in favor of hydrocarbons and container traffic which now constitute the bulk of tonnages handled alongside the specificity of Baltic RO-RO. In 2011, liquid bulk traffic represented 40 percent of the volumes handled in regional ports. Wet bulk hydrocarbons constitute a big share in countries such as Russia which is a big petrol exporter. In the Baltic dry bulk accounted for less than 30 percent.[86]



Map V-2: Botnia Bay, Baltic cargo vessel traffic comparison February 2011 vs August 2011

Botnia Bay is the region of the Baltic that is most impacted by ice coverage during the winter. While service is year-round, there is a difference between the month of February and the month of August in terms of traffic density for cargo vessels.

Cargo is the main types of ship used in the Baltic. We can clearly see the difference between cargo and container ships, for example, during 2016:[87]



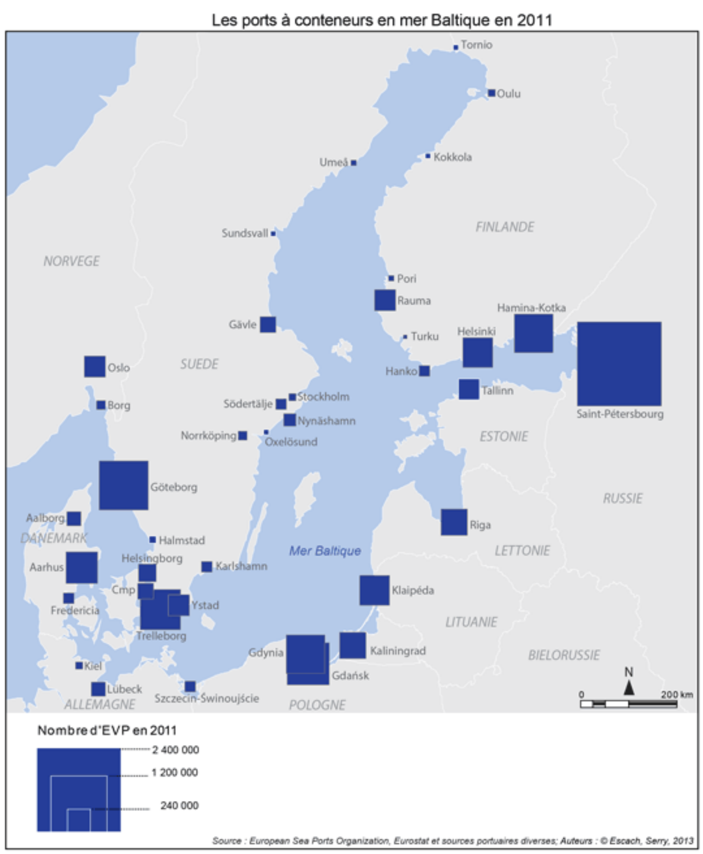
Map V-3: 2016 Container and Cargo traffic comparison

The left side of Map V-3 represents the average yearly (2016) density of IMO (International Maritime Organization) registered cargo ships operating in the Baltic[88], and the right side is the average yearly density of all IMO container ships servicing the Baltic Ports.[89] Cargo ship density is greater than container vessels, with the greatest traffic difference in Botnia Bay.

Baltic Container Service

When it comes to containerization in the Baltic, there is a big disparity between ports. When trading from outside of Europe, North Sea ports such as Rotterdam or Bremen are the main hubs for container vessels. These ports often load and discharge feeder container vessels trading in the Baltic. The feeder vessels that range up to 3,000 TEU and are usually ice classed.

There are vessels trading internationally and calling directly at Baltic ports such as St. Petersburg. The west coast of the Baltic is very well developed with ports that are integrated into the containerization network, especially the Russian ports. On the East coast, containerization is not as developed. In the northeast Baltic there are significantly more TEUs moved. Container traffic is very light in the northern region of the Bay of Botnia.[90]



Map V-4: Baltic Ports' share of Twenty Foot Equivalent Units (TEU ~ EVP) in 2011

Potential Great Lakes Container Trade

Container movement on the Great Lakes may be an option with an extended season. Containerization has the advantages of minimum cargo handling, rapid port turn-around times, added protection for the cargo and ease of transfer to another mode. Vessels could move containerized cargo and empty containers that need to be repositioned for loading. Great Lakes container vessels could transport not only international 20' and 40' containers, but also 53' domestic containers.

Container service would not be a new trade on the Great Lakes. There is at least one example of inter-lake intermodal operations that started just after Malcom McLean commenced modern container operations in 1956. For a brief period in 1959 containers were transported as deck cargo on gearless Lakers between Cleveland, OH and Duluth, MN. See Photo V-1. The service carried canned goods but only lasted part of season. The service closed because there was no back-haul cargo from Cleveland to Duluth.[91] The Duluth port cranes depicted below loading the containers are still in operation.

Photo V-1: Loading containers on *SS Norman Foy* at Duluth, MN (U.S. Maritime Administration)

The timeline found below for international container service on the Great Lakes provides insight on how the decline in break bulk operations, the consolidation of shipping lines, the growth of mega container ships, the deregulation of transportation in the US and the development of interstate highway system impacted this service.[92]

<u>1959: St Lawrence Seaway opened</u> (draft increased from 14 to 27 feet)

<u>1960s: Start of container service on the Great Lakes</u>

Containers were carried on the decks of break bulk ships operated by Fednav, Zim, Manchester lines and other companies. Manchester Line started container ship service to Montreal, Quebec in 1968.

1970s: Peak of container service on the Great Lakes

Manchester Liners began sending feeder container ships from their Montreal hub into Great Lakes ports. Great Lake container service peaked in about 1973 with a gradual decline thereafter. Examples of some of the lines providing container service include: Lykes, Fednav, Black Sea Shipping, European Canada Lines, NYK, Shinwa, Hapag Lloyd, Yugoslav Lines, Head Donaldson, Hamburg American, North German Lloyd, Sanguenay Shipping, Netumar, Canadian African Line and CP. The port of Duluth, MN, invested in and used a container quay crane. See Photo V-2

1980s-1990s: Further decline of container service on the Great Lakes

Several factors played into the decline of Great Lakes container service, such as the economic recession in early 80s, US deregulation of rail and truck operations, and the completion of most of the U.S. Interstate Highway system. Most liner service and container operations disappeared from the Great Lakes by the 1990s.

Photo V-2: Duluth Container Quay Crane (Ron Johnson)

2016: Port of Cleveland, OH re-instituted international liner container trade[93]

The route linked key European ports such as Antwerp, Rotterdam, Hamburg and various ports in the United Kingdom to the Port of Cleveland. The Spliethoff Group, the largest ship owner in the Netherlands, provided vessels. Dutch ice-classed, Seaway-sized ships sailed to Antwerp, Belgium from Cleveland in about 13 days.

Establishing New Great Lakes Container Service

There are several challenges to establishing intra-lake and/or inter-lake container service on the Great Lakes, even with season extension.

1. There are no container vessels on the Great Lakes
    a. While it is feasible to carry a very limited number of containers on the deck of a Laker, it would not be practical or cost-effective. Lakers are not designed to carry containers. Currently there are no US or Canadian flag container vessels on the Great Lakes. A vessel operating between US ports would need to meet the Merchant Marine Act of 1920 (Jones Act) requirements, and building a new Jones Act vessel would be cost prohibitive without contracts to ensure revenue. It is possible for a Canadian flag operator to buy a used foreign flag container vessel and reflag it so it could operate in Canadian waters or between US and Canadian ports. A significant increase in international container service to the Great Lakes could result in the need for inter-lake feeder vessels. The need for feeder vessels would occur if a hub-and-spoke system were developed for maritime container movement.
2. There are no container quay cranes in Great Lakes ports
    a. There are cranes in ports that can handle containers but are slow compared to quay cranes. Rapid port turn-around times require high-speed, dedicated container quay cranes. Even used container cranes require ports spend millions for the crane and related crane infrastructure.
3. The port infrastructure is, in most cases, not set up for container operations.
    a. For the past half-century, the Great Lakes ports have focused on dry bulk and, to a lesser extent, wet bulk maritime commerce. The physical layout of ports, storage facilities, as well as road and rail access have been optimized for these trades.
    b. Many of the busiest Great Lakes' marine terminals are privately owned. If a private terminal were the best option for container service, public access to the facility would require negotiation and compensation.
    c. Optimal container operations require a systems approach. This means that highways, distribution centers and railroads, as well as the marine portion of the route are designed to move the cargo on the intermodal route with minimal disruption between modes. Federal, state and local agencies are ensuring the planning, financing and construction of intermodal corridors that employ marine transportation as part of the solution. This model is done on the US and Canadian ocean coastal ports, including Montreal and Quebec but not on the Great Lakes. A study by the Pennsylvania Transportation Institute recommended a supply chain analysis to determine if international container trade would again work in the Great Lakes.[94] A 2007 study found over 200 shippers willing to consider marine container service if it were

reliable and competitive with other modes. The study examined three potential markets including inter-lake and intra-lake routes.[95]

d. The ports of Duluth, MN, and Cleveland, OH, have been cleared by US Customs for the import and export of containers.[96] The ports of Milwaukee, WI, and Monroe, MI, have been actively considering container operations.[97] These ports are examining the possible expansion of container operations and could be in the forefront of Great Lakes inter-lake and or intra-lake container operations.

There are not as many challenges in setting up RO-RO operations. Dedicated RO-RO vessels can carry containers on chassis, semis, automobiles, and passengers. Port infrastructure includes a docking with ramp interface locations and easy access to highways. RO-RO service in the Baltic is extensive.

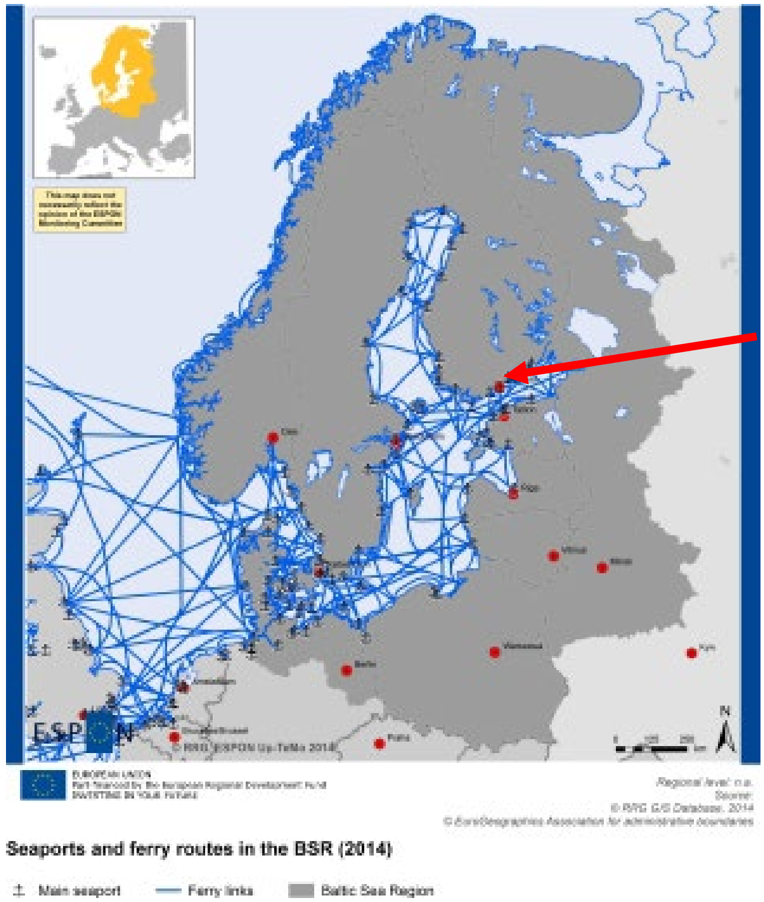
The Baltic Sea and Potential Great Lakes Roll-On-Roll-Off Service

RO-RO operations in the Baltic transport trucks, autos, and passengers—usually on the same vessel. An example of a RO-RO vessel operating between Helsinki, Finland and Tallinn, Estonia is the M/V *Star,* International Maritime Organization (IMO) number 9364722. The M/V *Star* is a RO-RO built in 2007 by STX Finland Helsinki. The ship is currently sailing under the flag of Estonia and is managed by Tallink Group. The ship's gross tonnage is 36249 tons, deadweight is 4700 tons, length is 186 m (610 ft 3 in), breadth is 27 m (90 ft 11in), with a summer draft of 6.50 m (21 ft 4 in). The vessel is ice classed 1A Super by Det Norske Veritas. The M/V *Star* operates year-round taking about two hours to make the 80 km trip. The *Star* currently makes three round trips per day. The *Star* is one of several large RO-RO vessels on this route. See timetable for Helsinki - Tallinn service by Tallink Group, one of multiple companies providing RO-RO service on this route.

The vessel has undergone accommodation reconfiguration since it was launched and currently has a capacity for 2,080 passengers with 520 beds in 131 cabins. There are 2,300 seats in three classes.[98] The vessel has restaurants, shops and internet service. Depending on the use of lane meter space[1] the vessel can on each trip accommodate 450-520 automobiles and 120 freight vehicles.[99]

Map V-6 shows ferry (RO-RO) service in the Baltic region. The Helsinki-Tallinn route is noted with a red arrow. It is possible to drive instead of taking the RO-RO. The driving distance from Helsinki-Tallinn is 607 kilometers (377 miles) The time and paperwork to clear customs at each border is an added deterrent to driving.

[1] A lane meter is a unit of deck area in roll-on/roll-off ships, cargo vessels where containers or other cargo, including ferried vehicles, can be rolled or driven on and off. A lane meter is defined as a strip of deck one meter long and 2 meters wide, making a lane meter equivalent to 2 square meters (21.528 sq ft). Semi-trucks take about 18 lane meters while a car takes about 6 LM depending on models of vehicles.



Map V-6: Seaports and ferry routes in the Baltic Sea Region[100]

Helsinki → Tallinn

Departure	Arrival	Weekday	Ship
07.30	09.30	Mon-Sat	Star
10.30	12.30	every day	Megastar
13.30	15.30	every day	Star
16.30	18.30	every day	Megastar
18.30	22.00	every day	Silja Europa / Victoria I
19.30	21.30	every day	Star
22.30	00.30	Mon-Fri, Sun	Megastar

Tallinn → Helsinki

Departure	Arrival	Weekday	Ship
07.30	09.30	Mon-Sat	Megastar
10.30	12.30	every day	Star
12.30	16.00	every day	Europa / Victoria I
13.30	15.30	every day	Megastar
16.30	18.30	every day	Star
19.30	21.30	every day	Megastar
22.30	00.30	Mon-Fri, Sun	Star

Table V-II: Timetable for Tallink Group RO-RO Service, Helsinki -Tallinn[101]

Past and Proposed Great Lakes RORO Applications

At one time there were multiple RO-RO vessels operating on the Great Lakes, many of them on year-round service. During the height of the car ferry era in the 1950s, seven ships sailed year-round from the port of Ludington, MI transporting rail freight and passengers across Lake Michigan to the Wisconsin ports of Manitowoc, Milwaukee and Kewaunee.[102] These vessels were ice strengthened and the terminals equipped for all-season operations. As state and federal governments spent hundreds of billions of dollars upgrading highways, about 50 percent of the nation's rail lines were taken out of service or abandoned and RO-RO service on the Great Lakes all but disappeared.

Increasing congestion on highways, railroads and urban areas is now slowing traffic. The current increasing costs of maintaining existing land infrastructure, environmental issues, energy costs and labor shortages that were not factors in the 1950s now merit reconsideration of the use of marine highways. RO-ROs have advantages such as ease of loading and off-loading, not requiring handling the cargo, and carrying autos and passengers in addition to freight.

Several studies have examined the opportunities and challenges of RO-RO (ferry operations) on the Great Lakes. In 2005, Wright proposed a variety of inter-lake, intra-lake and Canada U.S. routes.[103] A business case analysis in 2008 determined that using a Great Lakes RO-RO vessel instead of an all-road route from Madison, WI to Detroit, MI saved the shipper 18 percent in expenses.[104] The study also listed public benefits reduced air emissions, energy saving and employment growth in using the proposed ferry. An extensive modeling of inter-lake and intra-lakes RO-RO routes was undertaken in a report by ABS Consulting for the U.S. Maritime Administration.[105] The study found a real opportunity for the introduction of a reliable RO-RO service. Essential to realizing the maximum public benefits is low-cost vessel financing. None of the studies considered the possibility of an extended season.

An interesting comparison with the Baltic RO-RO operations is the current Lake Michigan ferry route of the SS *Badger.* The ferry distance from Manitowoc, WI to Ludington, MI is 97 km (60 miles). The highway route around the bottom of Lake Michigan through the densely populated Chicago metropolitan region is 662 km (411 miles). The red arrow on Map V-7 shows this route where the SS *Badge*r currently provides service during the summer season. The *Badger* and her sister ship the *Spartan* were originally built in 1953/1952 as ice strengthened RO-RO vessels carrying rail cars and passengers. SS *Badger* dimensions are length 125.1 m (607 ft), breadth 18.4 (60.6 ft), draft 7.32 (23.6 ft). The cross-lake route between Milwaukee and Muskegon has seasonal service by the Lake Express. This is high speed catamaran vessel carrying automobiles and passengers but not semis.

Map V-7: Water route (red arrow) between Manitowoc, WI and Ludington, MI

Chapter VI. Conclusions

Rail and highway transportation are all being adversely impacted by congestion, lack of labor, high energy costs and environmental concerns. The need for freight transportation will continue to grow, and truck and rail will lack adequate capacity. Environmental concerns will increasingly shape transportation decisions. Shippers are looking for transportation companies that are problem solvers not just moving cargo from one point to another.

With a season extension, the potential exists for Great Lakes marine highways to expand service to new supply chains. There are issues that need to be addressed if the Great Lake maritime commerce is to transition and grow.

Merchant Vessels

There will be a need for new merchant vessels designed for their respective services. These vessels will need to be fuel efficient and have minimal environmental impact. Jones Act regulations and the restrictions of the St. Lawrence Seaway will require vessels to be built in U.S. Great Lakes shipyards if their dimensions exceed the limits of Seaway locks. Research into vessel design, construction methods, and support services is needed. Ice classed vessels may be needed to ensure reliable service.

Icebreakers

Research into the Baltic Sea maritime commerce indicates that more, not fewer icebreakers will be needed to ensure that traffic is reliable. Research into optimal icebreaker configuration by both U.S. and Canadian agencies, with input from industry, is needed.

Integration of Transportation Systems

Current and future Great Lakes vessels are a part of the marine supply chain. Ports need to be updated to provide efficient access for new types of vessels. State and Federal transportation planning agencies need to optimize the use of all modes of transportation. Suitable highway access with ports is needed to provide the critical first and last mile of supply chains. Transportation planning needs to view supply chain holistically, so the cargo and passengers flow efficiently and sustainably. Barriers to achieving this can be structural and/or institutional. For example, overweight freight highways linking industrial facilities to ports reduce the total number of trucks on highways by allowing an increase in truck weight limits when operating in the corridors.

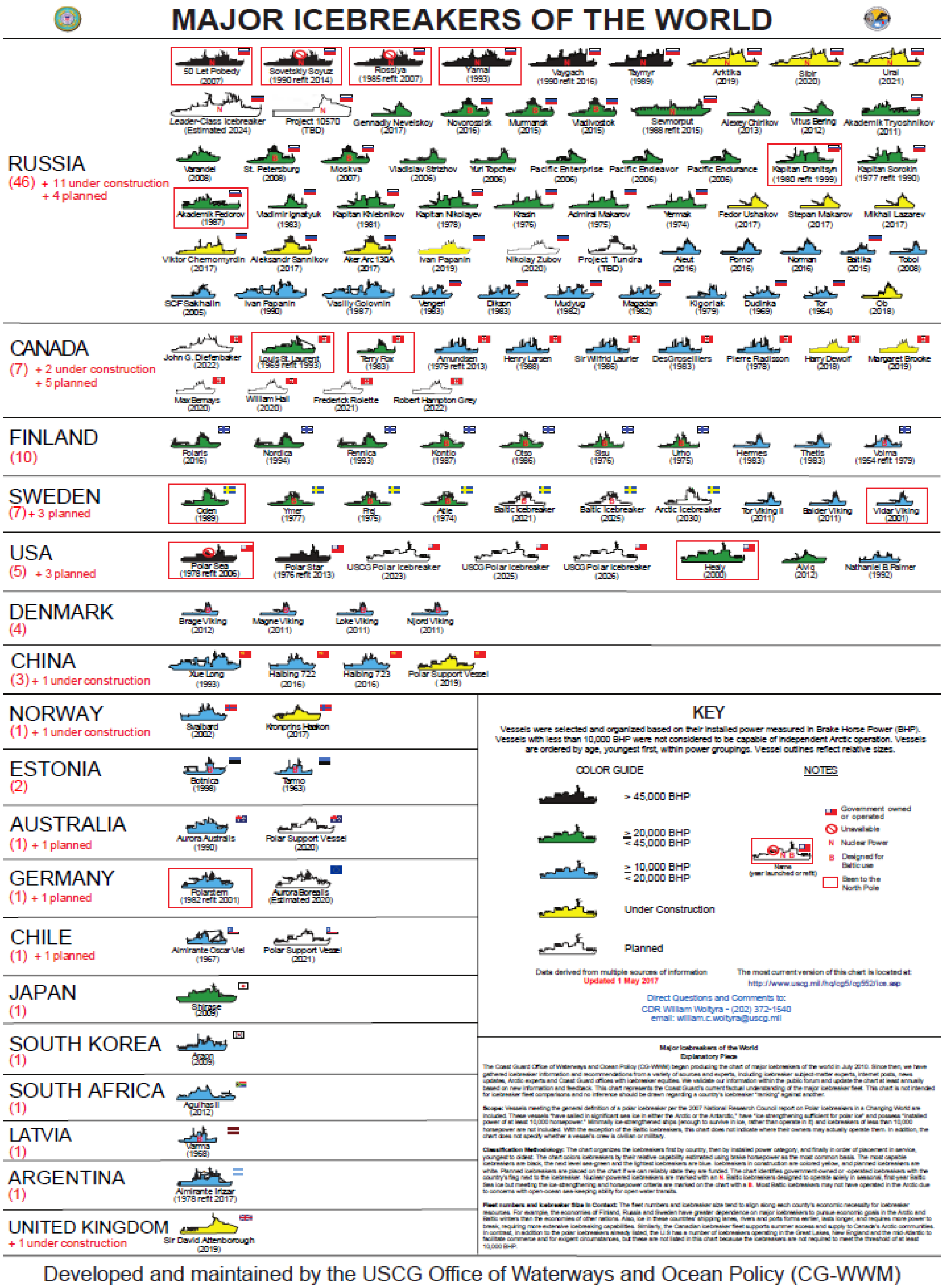
Governmental Support and Policy

The expansion of maritime commerce on the Great Lakes with season extension due to climate change is a transformational opportunity. When canal boats, railroads, truck and aircraft created new transportation options, federal, state and even local governments provided generous financial and institutional support to grow the modes. The land grants for railroads, interstate highway system and air traffic control systems are examples of government assistance. The marine industry has also had governmental assistance. The unanswered question remains: Is current maritime support by governments adequate for the future impact of climate change? In some instances, financial support can be not taking funds from a mode, such as reducing taxes, rather than giving funds to a mode.

An ad velorem Harbor Maintenance Tax (HMT) equal to 0.125 percent of the value of the cargo is charged on freight moved by vessels using Great Lakes ports. RORO/Ferry service can be excluded if freight is a minor portion of the business. A robust Great Lakes RORO service would see truck-based cargo as a significant part of their business model. The M/V *Incan Superior* transported rail cars from Superior, WI to Thunder Bay, Ontario, avoiding a long rail trip. The service lasted from 1974 through 1992 when the owners ceased operation due to reduced rail rates and a significant increase in the HMT.[106] Container vessels would also have to pay HMT tax. If all other factors are equal, shippers facing HMT taxes and accompanying paperwork will likely see this is a barrier to transitioning their cargo from highway or rail to vessels.

This study has not found a magic cargo of high volume that will seamlessly transition to marine commerce from other modes with an extended season. Shippers will weigh many factors in making modal shifts. Traditional dry and wet bulk cargoes will be a natural fit for vessels. The Baltic Sea model indicates that non-bulk vessels carry a diverse mix of cargos. They attract and retain shippers by providing reliable, efficient, and frequent service. The Baltic Sea maritime commerce benefits from international governmental cooperation supporting vessels, ports and related land infrastructure. The U.S. and Canada have a similar but smaller and less maritime-focused collaborative structure to build upon. There are challenges in building sustainable marine highways as ice coverage is reduced on the Great Lakes, but these obstacles are largely policy rather than physical and, with political will, can be addressed.

Appendix A


MAJOR ICEBREAKERS OF THE WORLD
50 Let Pobedy (2007)
Sovetskiy Soyuz (1990 refit 2014)
Rossiya (1985 refit 2007)
Yamal (1993)
Vaygach (1990 refit 2016)
Taymyr (1989)
Arktika (2019)
Sibir (2020)
Ural (2021)
Leader-Class Icebreaker (Estimated 2024)
Project 10570 (TBD)
Gennady Nevelskoy (2017)
Novorossiysk (2016)
Murmansk (2015)
Vladivostok (2015)
Sevmorput (1988 refit 2015)
Alexey Chirikov (2013)
Vitus Bering (2012)
Akademik Tryoshnikov (2011)
RUSSIA
(46) + 11 under construction
+ 4 planned
Varandei (2008)
St. Petersburg (2009)
Moskva (2007)
Vladislav Strizhov (2006)
Yuri Topchev (2006)
Pacific Enterprise (2006)
Pacific Endeavor (2006)
Pacific Endurance (2006)
Kapitan Dranitsyn (1980 refit 1999)
Kapitan Sorokin (1977 refit 1990)
Akademik Fedorov (1987)
Vladimir Ignatyuk (1983)
Kapitan Khlebnikov (1981)
Kapitan Nikolayev (1978)
Krasin (1976)
Admiral Makarov (1975)
Yermak (1974)
Fedor Ushakov (2017)
Stepan Makarov (2017)
Mikhail Lazarev (2017)
Viktor Chernomyrdin (2017)
Aleksandr Sannikov (2017)
Aker Arc 130A (2017)
Ivan Papanin (2019)
Nikolay Zubov (2020)
Project Tundra (TBD)
Aleut (2016)
Pomor (2016)
Norman (2016)
Baltika (2015)
Tobol (2008)
SCF Sakhalin (2005)
Ivan Papanin (1990)
Vasiliy Golovnin (1987)
Vengeri (1983)
Dikson (1983)
Mudyug (1982)
Magadan (1982)
Kigoriak (1979)
Dudinka (1969)
Tor (1964)
Ob (2018)
CANADA
(7) + 2 under construction
+ 5 planned
John G. Diefenbaker (2022)
Louis St. Laurent (1969 refit 1993)
Terry Fox (1983)
Amundsen (1979 refit 2013)
Henry Larsen (1988)
Sir Wilfrid Laurier (1986)
Des Groseilliers (1983)
Pierre Radisson (1978)
Harry Dewolf (2018)
Margaret Brooke (2019)
Max Bernays (2020)
William Hall (2020)
Frederick Rolette (2021)
Robert Hampton Grey (2022)
FINLAND
(10)
Polaris (2016)
Nordica (1994)
Fennica (1993)
Kontio (1987)
Otso (1986)
Sisu (1976)
Urho (1975)
Hermes (1983)
Thetis (1983)
Voima (1954 refit 1979)
SWEDEN
(7) + 3 planned
Oden (1989)
Ymer (1977)
Frej (1975)
Atle (1974)
Baltic Icebreaker (2021)
Baltic Icebreaker (2025)
Arctic Icebreaker (2030)
Tor Viking II (2011)
Balder Viking (2011)
Vidar Viking (2001)
USA
(5) + 3 planned
Polar Sea (1978 refit 2006)
Polar Star (1976 refit 2013)
USCG Polar Icebreaker (2023)
USCG Polar Icebreaker (2025)
USCG Polar Icebreaker (2026)
Healy (2000)
Aiviq (2012)
Nathaniel B. Palmer (1992)
DENMARK
(4)
Brage Viking (2012)
Magne Viking (2011)
Loke Viking (2011)
Njord Viking (2011)
CHINA
(3) + 1 under construction
Xue Long (1993)
Haibing 722 (2016)
Haibing 723 (2016)
Polar Support Vessel (2019)
NORWAY
(1) + 1 under construction
Svalbard (2002)
Kronprins Haakon (2017)
ESTONIA
(2)
Botnica (1998)
Tarmo (1963)
AUSTRALIA
(1) + 1 planned
Aurora Australis (1990)
Polar Support Vessel (2020)
GERMANY
(1) + 1 planned
Polarstern (1982 refit 2001)
Aurora Borealis (Estimated 2020)
CHILE
(1) + 1 planned
Almirante Oscar Viel (1967)
Polar Support Vessel (2021)
JAPAN
(1)
Shirase (2009)
SOUTH KOREA
(1)
Araon (2009)
SOUTH AFRICA
(1)
Agulhas II (2012)
LATVIA
(1)
Varma (1968)
ARGENTINA
(1)
Almirante Irizar (1978 refit 2017)
UNITED KINGDOM
+ 1 under construction
Sir David Attenborough (2019)
KEY
Vessels were selected and organized based on their installed power measured in Brake Horse Power (BHP). Vessels with less than 10,000 BHP were not considered to be capable of independent Arctic operation. Vessels are ordered by age, youngest first, within power groupings. Vessel outlines reflect relative sizes.
COLOR GUIDE
> 45,000 BHP
≥ 20,000 BHP
< 45,000 BHP
≥ 10,000 BHP
< 20,000 BHP
Under Construction
Planned
NOTES
Government owned or operated
Unavailable
N Nuclear Power
B Designed for Baltic use
Been to the North Pole
Name (year launched or refit)
Data derived from multiple sources of information
Updated 1 May 2017
The most current version of this chart is located at:
http://www.uscg.mil/hq/cg5/cg552/ice.asp
Direct Questions and Comments to:
CDR William Woityra - (202) 372-1540
email: william.c.woityra@uscg.mil
Major Icebreakers of the World
Explanatory Piece
Developed and maintained by the USCG Office of Waterways and Ocean Policy (CG-WWM)

Appendix B

City and MSA Population	**City & MSA Population**	**RORO distance**	**RORO Service**	**Land distance**
Helsinki 1,317,000	Tallinn 449,000	80 km/50 m	Year round; more than 10 vessels; daily trips carrying passengers, autos, and trucks	607 km/ 377 m
Milwaukee 1,575,179	Muskegon 173,883	139 km/86 m	Seasonal; one vessel-*Lake Express;* 3 daily trips carrying passengers and autos	460 km/286 m
Manitowoc 78,757 The Fox Cities (45 miles away) have 250,000	Muskegon 173,883	144 km/90 m	None	574 km/357 m
Manitowoc 78,757 The Fox Cities (45 miles away) have 250,000	Ludington 29,164	97 km/ 60 m	Seasonal; one vessel-*Badger;* 3 daily trips carrying passengers, autos, and trucks	662 km/411 m

Comparison between Baltic Sea and Great Lakes Road and RO-RO Routes

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