Breaking the ice: ISE to play key role in shaping Arctic's future

Changing sea levels open northern shipping lanes but create new logistical challenges

By Thomas C. Sharkey, Thomas Birkland, Martha Grabowski, Marie Lowe and William (Al) Wallace

The impact of climate change on the Arctic is undeniable. Estimates show that "Arctic ice cover has lost about two-thirds of its thickness, as averaged across the Arctic at the end of the summer" over the past 60 years according to a NASA article by Carol Rasmussen. Models estimate that "the total volume of ice in September, the lowest ice month, declined by 78 percent between 1979 and 2012," reported Chris Mooney in the *Washington Post*.

As of Aug. 15, 2019, current sea ice levels are tracking close to those observed in 2012, which is the year with the smallest recorded sea ice levels on record, according to the National Snow and Ice Data Center (*nsidc.org/arcticseaicenews*). These changes in the Arctic marine environment bring about longer navigable summer seasons and the potential for significant industrial and maritime activities outside of the Arctic area (see Figure 1).

For example, in 2016 and 2017, the Crystal Serenity cruise ship traveled through the Bering Strait and the Northwest Passage with nearly 1,500 passengers and crew on board. That number represented about 33% of the population of the largest community, Utqiagvik (formerly known as Barrow), where the ship passed while off Alaska's coast. If the Crystal Serenity were in distress and its passengers and crew needed to be evacuated to shore, what would be the logistical challenges of evacuating and supporting the passengers and crew onshore? The remoteness of the Arctic would constrain any response efforts; for example, Utqiagvik is more than 500 miles away from Fairbanks and more than 700 miles from Anchorage, the closest hub communities prepared to respond to a major event.

During the response to the grounding of the research ship Akademic Ioffe in Arctic waters off the coast of Canada in August 2018, it took 16 hours for its sister ship to arrive to pick up passengers and crew and then another 15 hours before it arrived in Kugaaruk, with a population of 933 (Ed Struzik, "In the melting Arctic, a harrowing account from a stranded ship," *Yale Environment 360*).

These challenges highlight what role industrial and systems engineering can play in helping shape the future of the Arctic: ISE methods can help optimize the logistics of a response effort and help plan investments for such a response.

This is not the only challenge where ISE can play a role in the future of the Arctic. With sea ice melting and the Arctic experiencing longer navigable seasons, there is also a transformative potential to use the Northwest Passage, the route along the northern shore of Canada and the United States, and the Northern Sea Route, which runs along the northern shore of Russia and Europe, for global shipping. These routes could reduce the number of travel days between Europe, Asia and the Americas.

For example, a ship sailing from South Korea to Germany could potentially save more than 11 days by taking the Northern Sea Route as opposed to the route through the Suez Canal (William Booth and Amie Ferris-Rotman, "Russia's Suez Canal? Ships start plying a less-icy Arctic, thanks to climate change," *Washington Post*). However, the current viability of this route is questionable due to its limited navigable season – at best, July through October – Russia's restrictions on through traffic and challenges in accurately forecasting sea ice in the area, which could significantly impact when ships arrive at ports.

Arctic's economic impact, by the numbers

- **8:** Member states of the Arctic Council and Arctic Coast Guard Forum, which includes the U.S., Canada, Denmark (Greenland), Finland, Iceland, Norway, Russia and Sweden
- **1 million:** Square miles of U.S. territorial waters and exclusive economic zone in the Artic
- **10 million:** Tons of goods, including gas, oil, grain and coal, transported via the Northern Sea Route in 2017
- **90 billion:** Barrels of undiscovered oil reserves in the Arctic, including 30% of the world's undiscovered natural gas
- **$1 trillion:** Estimated value of rare minerals in the Arctic, including zinc, nickel and lead

Source: U.S. Coast Guard Strategic Outlook

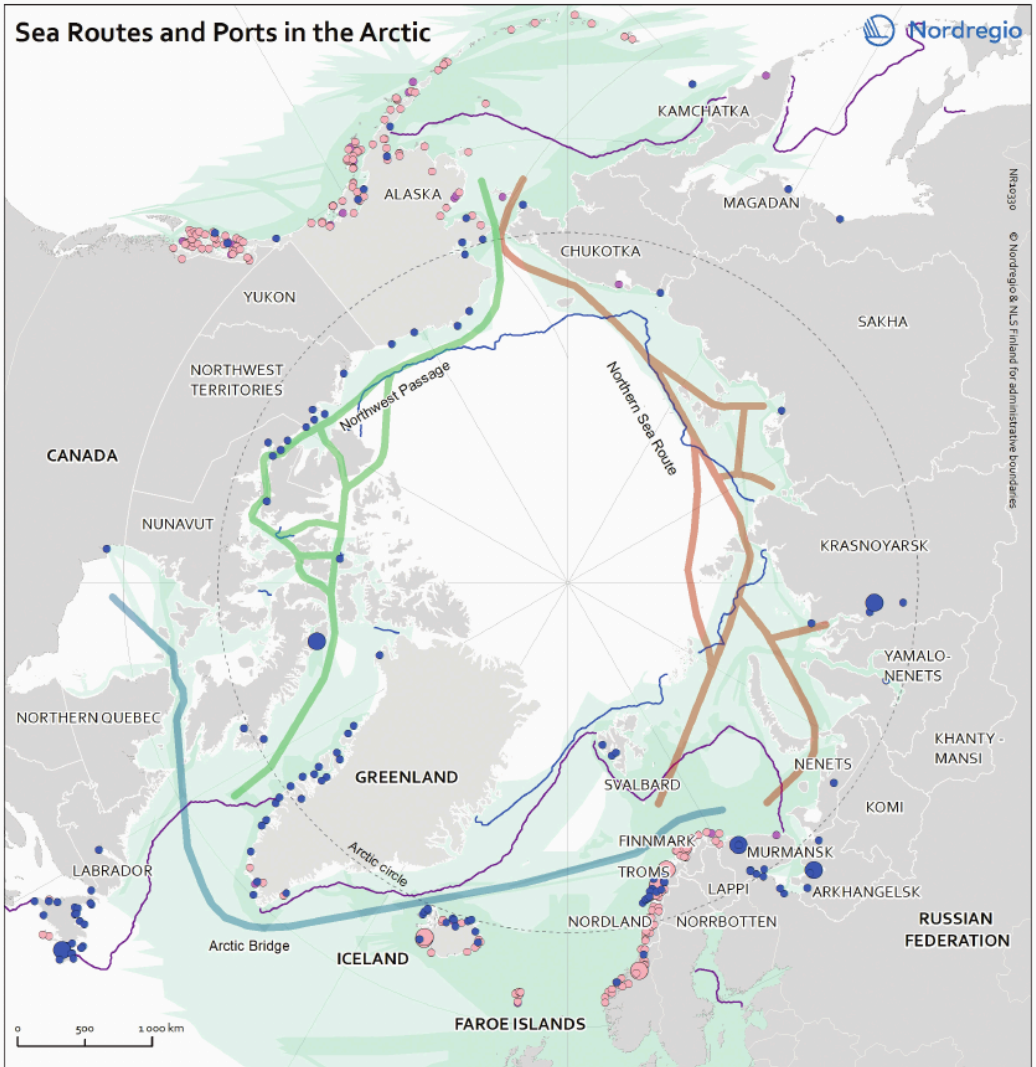
The impact on global supply chains through the use of these routes could be enormous and ISE methods can help to address a long list of related questions, including:

- How can we accurately forecast travel times through routes where sea ice can disrupt travel?
- How can we best chart the Arctic waters to improve situational awareness? As of 2016, only 1% of U.S. Arctic waters have been charted to modern standards (Hannah Hoag, "NOAA is updating its Arctic charts to prevent a nautical disaster," *Arctic Deeply*).
- How will and how should global supply chains adapt with a significantly decreased maritime transit lead time?
- What is the optimal balance between sending goods via the traditional and more consistent routes versus the new and riskier routes?
- What are the impacts and risks of accidents on these routes? For an initial simulation investigation in this area, see Jean Freitas and Hiba Baroud's report, "Impact of climate change and infrastructure risk management on Arctic shipping," 12th International Conference on Structural Safety & Reliability, Vienna, Austria, 2017.
- Do the benefits of using these routes outweigh the potential costs and environmental impacts? For example, there is a movement to ban the shipping of heavy fuel oil in the

FIGURE 1

The opening Arctic lanes

This map illustrates the Northwest Passage (Greenland, Canada and the U.S.) and Northern Sea Routes (Europe and Asia), including Arctic Sea harbors and the extent of sea ice. Source: Nordregio



Arctic Sea Transport Routes and Ports

Harbors - size[1] and ice restrictions

- Large & medium
- Small & very small

- Ice free harbor
- Ice restricting entrance some periods of year
- No data on ice conditions

Vessel traffic [2]

- Main areas
- Secondary areas

[1] Harbor size is based on World Port Index's classification that uses several applicable factors, including area, facilities, and wharf space

[2] Based on AIS vessel tracking data from 2017. Main areas are areas with remarkable traffic. Secondary areas refers to areas with less traffic

Ice conditions

- Average sea ice extent for September in 1981-2010
- Average sea ice extent for March in 1981-2010

Regions included:

US - Alaska; CA - Yukon, Northwest Territories, Nunavut, Newfoundland & Labrador, Northern Quebec; GL; IS; FO; NO - Nordland, Troms, Finnmark, Svalbard; SE - Norrbotten; FI - Lappi; RU - Komi, Arkhangelsk, Nenets, Khanty-Mansi, Yamalo-Nenets, Krasnoyarsk, Sakha, Kamchatka, Magadan, Chukotka.

Data sources: MarineTraffic, NOAA, Nordregio, NSIDC, World Port Index (NGA) 2017

Arctic (*www.hfofreearctic.org*).

- Should the nations of the world consider barring the use of these routes when both the origin and destination of the routes are outside the Arctic and what would be the impact of such a ban?

There is significant concern about the potential environmental consequences of such maritime activities as well as the potential impact from natural resource exploration of the Arctic. First, the region's indigenous people rely on marine mammals for their subsistence hunting and strongly oppose any adverse developments on these resources.

Second, oil spill response and pollution in Arctic waters may have different effects than in more temperate waters. Dispersants used to degrade oil hydrocarbons are not as effective in lower temperature water (Robert M.W. Ferguson, Evangelia Gontikaki, James A. Anderson and Ursula White, "The variable influence of dispersant on degradation of oil hydrocarbons in subarctic deep-sea sediments at low temperatures," *Scientific Reports*) and pollution released by ships, such as black carbon, can accelerate sea ice melt.

Third, the remoteness of the region poses challenges to the current infrastructure, such as emergency response capabilities, which will likely not be able to keep up with future demands. The resources needed to respond to a significant environmental disaster, such as an oil spill, could happen very far away from current response assets. In this area, ISEs have already laid the foundation to shape the future of the Arctic.

For example, work after the 1989 Exxon Valdez oil spill in Alaska's Prince William Sound, which is considered sub-Arctic, addressed the role of effective management in crisis prevention (John R. Harrald, Henry S. Marcus, William A. Wallace "The Exxon Valdez: An assessment of crisis prevention and management systems," *Interfaces* 1990). Further, ISE methods, including simulation, data analysis and expert judgement tools, have helped to guide investments to decrease oil spill risk in the Prince William Sound after the Exxon Valdez disaster (Jason R.W. Merrick, J. Rene van Dorp, Thomas Mazzuchi, John R. Harrald, John E. Spahn and Martha Grabowski, "The Prince William Sound risk assessment," *Interfaces* 2002).

As another example, operations research (OR) models have been created to help plan infrastructure investments to increase oil spill response capabilities in Arctic Alaska that specifically capture the novelty of response in remote regions (Richard Garrett, Thomas C. Sharkey, Martha Grabowski and William A. Wallace, "Dynamic resource allocation to support oil spill response planning for energy exploration in the Arctic," *European Journal of Operational Research*, 2017).

The three currently debated examples of potential future economic activity in the Arctic – cruise ships, increased

Changes at the top of the world

Some key facts on the changing Arctic climate:

Arctic heats up: Earth's average surface temperature has risen 1 degree Celsius (1.8 degrees F) since the 1880s. The World Meteorological Organization recorded June as the warmest ever on record, breaking the previous record from 2016. The Arctic has warmed more than twice as fast, and the past five years have been its hottest on record. The summer of 2019 was especially hot, with temperatures in North Siberia up to 8 degrees C above normal, according to the Russian meteorological institute Roshydromet, and 4 degrees warmer in the Laptev and East Siberian seas. June 2019 saw the second smallest Arctic sea ice extent for June in the 41-year record, behind the record low set in June 2016, according to an analysis by the National Snow and Ice Data Center.

Permafrost melt: Warmer summers have melted a greater portion of the Arctic permafrost, a thick subsurface layer of soil that remains frozen throughout the year in polar regions. As it thaws, it releases from the ice carbon dioxide and methane trapped for centuries from the remains of prehistoric plants and animals, adding to carbon in the atmosphere. Scientists are discovering Arctic landscapes where permafrost once thawed only a few inches a year but now thaw up to 10 feet within days or weeks. It has turned once-frozen regions in wetlands, releasing up to 1,600 gigatons of carbon trapped in the ice.

More water, more warming: While snow and ice reflect most incoming sunlight, open water absorbs more heat. As more ice melts, more sunlight is absorbed by the water, increasing the temperature.

More shipping, more carbon: As Arctic shipping lanes open due to ice melt, ships add to the carbon output in the atmosphere. Icebreaking oil tankers able to operate year-round are responsible for 33% of carbon output though they make up only 6% of the region's maritime traffic.

Sources: *National Geographic* September 2019: *The Barents Observer*

Photos by Thomas C. Sharkey

These photos illustrate the sea ice changes seen near Utqiagvik, Alaska, within 12 hours. The photo at left was taken at 7:41 p.m. June 16, 2019; the other at 8:37 a.m. the following day.

commercial shipping and natural resource exploration – arguably will be controlled by entities outside the region and a key aspect of the future of the Arctic is that "outside" systems will make their way into the Arctic. Infrastructure development to support these maritime activities, such as increasing emergency response capabilities, likely will occur near Arctic communities that are predominantly indigenous. Subsistence hunting and fishing remain integral to the lives of the Arctic's indigenous people and increased commercial maritime activities could impact traditional livelihoods.

Industrial and systems engineering can play a critical role in ensuring these systems are responsibly integrated into the Arctic and benefit the region's indigenous populations. It is the lead engineering discipline that seeks to understand how humans interact with systems and how systems affect humans and communities. The interaction of the indigenous communities with these "outside" systems is an important feature to capture in analytical models as it will allow us to understand the true impacts and consequences of the plans for these systems.

Although ISEs are uniquely capable to address this within engineering, it will be necessary to partner with experts, both academic and indigenous in disciplines such as the social sciences, who can incorporate indigenous knowledge and perceptions of the potential impact of systems presently foreign to the Arctic. Otherwise, ISE methods will be attempting to model the interactions between the systems and indigenous people with either incomplete or inaccurate information about how these systems are viewed by indigenous people. These methods can deal with inaccurate or probabilistic information in certain situations; however, a responsible approach to applying ISE methods would be to engage with these experts rather than try to tackle this problem on our own.

In addition to the need for emergency response infrastructure, the future of the Arctic will require new and improved infrastructure systems in the region, including transportation, power and telecommunications. The engineering requirements to build these systems will need to be carefully studied by other engineering disciplines but ISEs should play an important role in capturing the true costs and benefits of these systems.

For example, improved telecommunications in the Arctic could have important applications in telemedicine for the citizens of the region. ISEs can help shape future healthcare systems that can be built using these improved telecommunications capabilities. Furthermore, improvements in telecommunications could offer expanded educational opportunities, another system in the region that ISEs can help shape.

Therefore, a high-level view – exactly what ISEs do – should be undertaken in planning for new and improved infrastructure systems with an eye to understanding how these systems can benefit Arctic communities.

Another example is to build road systems in remote communities. This would significantly decrease the costs of construction and capital improvement projects since using these roads would alleviate the need to either ship by barge or fly in material and equipment. Given the potential for development in the Arctic, ISE methods can help calculate the break-even point when it becomes more cost-effective to build road systems rather than barge resources into the area to develop the outside systems. More importantly, these methods can factor in the benefits that would be provided to the Arctic communities through the construction of such road systems and thus capture the true impact of the investments, which includes both decreasing construction costs and benefiting the communities.

As a final example, there are both energy and water security concerns, especially as it pertains to outside activities impacting Arctic communities. There are some communities where the only reliable energy source is to barge in fuel during the summer and others where they need to begin filling their water reservoir once the ice thaws in the spring in order to prepare for the next winter.

In these cases, any unplanned demand, such as a mass rescue bringing people into the community, would need to carefully consider the impact on the long-term energy and water security for the community. ISE methods can help determine the level of investment into the security necessary for energy and water demands to be met both within the community as well

US Coast Guard urges boost in icebreaker investment

The opportunities and challenges of increased shipping options in the Arctic have the eight nations that touch the region scrambling to stake their claims.

The United States Coast Guard, in a strategy assessment released April 22, urges the nation to invest more in ice-breaking vessel capacity to keep up with the increasing presence of Russia and China on Arctic trade routes.

In its report, available at *https://link.iise.org/uscg_arctic*, the agency asserted that since its last Arctic assessment in 2013, increased investments by and competition from Russia and China have coincided with decreasing amounts of permanent sea ice and longer seasonal windows of open trade lanes.

"The interaction of these drivers has made the Arctic a strategically competitive space for the first time since the end of the Cold War," the report stated.

Cargo tonnage transported on the Northern Sea Route (NSR) since the Coast Guard's last assessment has doubled due to significant shipments of natural gas and oil products from Russia's Yamal liquefied natural gas (LNG) terminal, using special "ice-class" LNG tankers Russia built specifically for that operation.

Russia is also expanding its icebreaker fleet, which is already the world's largest, the USCG reported, and now has 14 such ships. Russia is also rebuilding or expanding other Arctic assets such as ports, air bases, commercial hubs, search and rescue operations and weapons systems. It has built six military bases since 2003, the USCG reports.

Meanwhile, China has been increasingly active in the region since 2013 even though its borders don't extend to the Arctic Ocean as do those of the eight members of the Arctic Council – Russia, Canada, Iceland, Denmark (Greenland), Sweden, Norway, Finland and the U.S. Early in 2018, it announced its "Polar Silk Road" initiative with a range of infrastructure activities to include ports, undersea cables and airports.

But the agency warned that these expansion plans "could impede U.S. access and freedom of navigation in the Arctic as similar attempts have been made to impede U.S. access to the South China Sea."

To close the gap, the Coast Guard urges investment in vessels such as a Polar Security Cutter (PSC), which would be the first U.S. heavy ice-breaker built in decades. PSCs, according to the Coast Guard, would not only help keep the U.S. ready defensively in both the Arctic and Antarctic but would provide vessel escort services to help move freight and personnel. The agency plans to award a detailed design and construction contract to build three PSCs, with $675 million in initial funding coming from the 2019 federal budget. The FY 2020 budget proposal released earlier this year includes a request of $35 million to keep the PSC program moving.

The U.S. controls 1 million square miles of territorial waters and an Exclusive Economic Zone in the Arctic.

Source: freightwaves.com

as outside the community.

In summary, ISEs can play an important role in helping shape the future of the Arctic. They have the unique ability to examine systems at a high level and understand the interactions between humans and these systems. These capabilities will be critical in understanding how different kinds of systems will be integrated into the Arctic.

At the same time, our methods will only be valuable if we have accounted for the true nature of the Arctic and its people. We should partner with experts in the Arctic, both academic and indigenous, to understand the region and its people so that our methods are being applied responsibly to the true problems that will shape the future of the Arctic. ❖

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