

manuscript:

Four Paradoxes of the User-Provider Interface: A Responsible Innovation Framework for Sea Ice Services

Supplementary Material 1: Key Factors

Key Factor: Geopolitical stability

Definition

Geopolitical security describes the extent to which international relations (Pan-Arctic as well as on the global scale) are collaborative or contentious; and the level to which political tensions may impact demands for and access to Arctic resources, militarization efforts, and ultimately, marine operations. Instability of certain regions impact fuel prices and have a direct effect on maritime logistics and planning. In addition, control over sea routes (i.e. protection of shipping routes globally, a costly endeavor) impacts marine traffic in the Arctic region as well.

Future Projections

1. Cake for everyone:

- Increased collaboration
- No resource competitions
- Expanded scope and extent of collaborative institutions (e.g. Arctic Council)
- Common definitions of sustainability

mean plausibility score: 0.20

2. Status quo (occasional bullying):

- Current trends continue
- Showmanship: showing off military might
- Trying to out-muscle without using muscle
- Mainly verbal threats with occasional cyber and electronic attacks

mean plausibility score: 0.60

3. Cold War 2:

- Russia's interference re-divides alliances into a new organization of allied countries
- Arctic War over resources
- Militarization on the rise
- Information sharing is limited
- Much of the data produced is customized for military strategic needs
- Transiting Arctic routes becomes difficult (political and informational hurdles)
- Accidents are on the rise
- There is an escalation in cyber and electronic warfare
- Shipping sector negatively impacted by shrinking theater of globalization
- The types of resources that are highly sought-after shift (bulk fresh-water, oil, minerals)

mean plausibility score: 0.20

Key Factor: Accessibility of Arctic sea routes

Definition

Accessibility of Arctic sea routes refers to uncertainties surrounding both physical and regulatory access: In other words, the unpredictability of access that impacts maritime planning and logistics can be due to uncertainties in forecast and climatology models, and / or regulatory uncertainties. This key factor draws on the regulatory setting of Northern sea routes (west and east), any possible political tensions between Russia and the West, the predictability of sea ice seasonal variability, and search and rescue capacities of Arctic nations.

Future Projections

1. Easy access:

- Less sea ice
- Reliable predictive models
- Increasing global agreement, collaboration due to collaborative leadership as well as efficient coordination
- New icebreakers
- Strengthened Search and Rescue operational networks and infrastructure

mean plausibility score: 0.38

2. Difficult access:

- Persistent sea ice
- Unreliable predictive models
- More regulatory barriers
- No new resource developments

mean plausibility score: 0.48

3. No access:

- More sea ice or sea ice variability
- Ban on routes
- Restricted use of ice breakers

mean plausibility score: 0.14

Key Factor: User-centric information infrastructures and data

Definition

User-centric information infrastructures and data describes the extent to which there is a concerted effort amongst Arctic nations, forecast service providers toward harmonization of information, resources and models. This key factor centers around easily accessed and interpreted data, and a push toward user-centric practices in data provision, and publicly available service points.

Future Projections

1. Global harmonization:

- Single-point source (e.g. 'Copernicus')
- Investments in new systems and means of communication
- Uncertainties decrease in planning maritime activities
- Portal contents reflect the level of knowledge of users
- User-friendly data formats
- Increased co-design and production with users

mean plausibility score: 0.20

2. Few specialized, big actors (data and service providers):

- Portfolio of regular, public services remains similar to now
- Increase in specialized, commercial, subscription-based services

mean plausibility score: 0.56

3. No development toward harmonization:

- Lack of centralized portals
- Scattered data
- Fragmented infrastructure

mean plausibility score: 0.24

Key Factor: Global economic trends

Definition

This key factor describes economic drivers exerting pressures on Pan-Arctic economies and regulatory landscapes from outside of the Arctic region, and describes an overall trend towards increased or decreased investments in Arctic development.

Future Projections

1. Arctic rush:

- Rising global commodity prices provide incentives for natural development resources and destination shipping, fishing, and marine tourism
- Influx of people increases need for shipping supplies to remote Arctic communities
- More mineral exploration & cruise tourism leading to increased infrastructure needs, overwhelming local users / communities
- More tourism results in more development, increasing the complexity of port logistics
- Increased traffic leads to moving traffic into shoulder season, thereby increasing high risk operations

mean plausibility score: 0.62

2. High-cost closing off:

- Regulatory pressures leading to increased rules
- High taxes, high field costs
- Lack of markets, potential for disruptive technology
- Trade war

mean plausibility score: 0.38

Key Factor: Demand for Arctic resources

Definition

Demand for Arctic resources is a key factor about economic drivers of change based on global demand for Arctic living, renewable and fossil fuel resources. This key factor is closely linked with trade routes as well as status quo attitudes within the Arctic region itself toward resource development, and the politics of outside interests. The key factor describes the potential to intensify development in one sector over another, thereby increasing not only investments but available funding for metocean information and research as well.

Future Projections

1. Seafood first:

- More processing and transport of seafood products (increased fishing traffic)
- Global food demand grows
- Global demand for eco-friendly protein grows
- Seafood is an increasingly valuable export commodity from Arctic region

mean plausibility score: 0.29

2. Tourism first:

- People with disposable income eager to spend on exotic experiences
- Accessibility of Arctic destinations increases as does the portfolio of metocean services needed
- Adventure tourism grows
- Straining resources and cultural values of communities

mean plausibility score: 0.49

3. Fossil futures:

- Conflict in the Middle East increases
- Alternatives to fossil fuel are not viable
- Rising oil prices
- Oil crisis creates higher demand for Arctic fossil fuel

mean plausibility score: 0.22

Key Factor: Regulations and policies affecting Arctic operations

Definition

This key factor is determined by the level to which environmental vs. economic considerations drive regulations directly impacting Arctic operations, and the extent to which international cooperation stabilizes the political landscape to reduce uncertainty in business decisions. The tension between safety and environmental protection versus exploitation of the Arctic impacts risk tolerance and relevant legal frameworks and collaborations; while changing rules and shifting stakeholder interests raise questions regarding the extent to which rules are enforced where they should be.

Future Projections

1. Arctic 5 harmony:

- Harmonized, strict, enforced regulations and policies
- Increased investments and close links with investors strengthen essential networks for shipping sector
- Investments and steady regulatory landscapes create certainty for planning and operations
- Traffic levels in Arctic routes may or may not increase due to the certainties provided by investments and policies as traffic depends on other globally determined processes as well

mean plausibility score: 0.14

2. Economic and commercial uses dominate:

- Regulations determined by industry (industry writes code)
- Environmental requirements take a backseat to economic efficiency
- Ice class and search and rescue requirements may ease
- Traffic may increase if cost of operations decreases sufficiently

mean plausibility score: 0.36

3. Environmentally driven regulation and policy:

- Environmental basis for regulation and policy development
- Communities and human rights organizations help give access to Indigenous voices
- Ice class requirements may stiffen
- Ban on heavy fuels and incentives for alternate fuels

mean plausibility score: 0.20

4. Fragmented, soft regulatory regime (status quo):

- Lack of uniformity in rules and enforcement, rapid changes
- Difficulties arise for maritime traffic from fragmented policies
- Traffic may increase if cost of operations decreases sufficiently and there is a sense of stability in the regulatory landscape

mean plausibility score: 0.30

Key Factor: Major incidents and critical events

Definition

This key factor is determined by the cumulative learning and regulatory changes that occur in response to major incidents that help us face unpredictability. The type of incidents and critical events that are likely are driven by their locality: in Greenlandic waters it may be cargo ship stuck in ice, in Norway it may be cruise ship related or oil blowout while Iceland may see accidents leading to regulatory actions. Some sectors are more vulnerable to a political and economic fallout from incidents; for example cruise tourism doesn't need multiple incidents to experience a devastating impact on the business.

Future Projections

1. Ship Crash (medium-to-large event):

- More Arctic ship traffic increases chances for major incidents
- Incidents are on the rise
- Major incident occurs slowing down shipping
- A lack of search and rescue response capacity combined with regulations designed to facilitate merchant necessities and not the luxury cruise industry leaves major marks on the cruise sector

mean plausibility score: 0.52

2. Status Quo:

- Good record of marine operations
- Industry reputation is good, slightly blemished at times of minor incidents
- Traffic expands in linear relation with local trade

mean plausibility score: 0.48

Key Factor: Predictability of sea ice variability

Definition

This key factor describes the challenges faced by meteorological institutions in their capacity to keep up with rapid developments around new data needs due to fast-changing environmental conditions. Large seasonal variability such as East Greenland's high variability makes prediction difficult. There is a concern over a mismatch between rapid changes (and resulting need for accurate, salient information) and predictive skill, testing the limits of researchers and funders.

Future Projections

1. Breakthrough:

- Breakthrough in sea ice prediction beyond weeks, observational models
mean plausibility score: 0.16

2. Gradual improvement of predictive models:

- Sea ice prediction improves gradually over time
mean plausibility score: 0.64

3. Unforeseen changes:

- Unforeseen changes in climatic trends make current methods degrade
- Missing observations to initialize models
- Software development cannot keep up with hardware development

mean plausibility score: 0.20

Key Factor: Fluctuating energy prices

Definition

This key factor encompasses the complex role energy prices have in driving the profitability of Arctic maritime operations. On the one hand, all marine industries are greatly impacted by high fuel prices and resultant increases in operational costs. On the other hand, the sectors involved in fossil fuel extraction are incentivized by increased profitability as oil price per barrel goes up. While high bunker fuel price incentivizes the use of trans-Arctic routes, the extent to which Arctic routes are used in practice depends on certain tradeoffs in transit time: the need for slower speed in ice infested areas can tip the scale in favor of alternate, traditional shipping routes. While this key factor is linked with the key factor 'Global economic trends,' it specifically highlights the importance played by trends in energy prices in creating economic incentives for increased or decreased activities in the Arctic region.

Future Projections

1. Northern push:

- Increased bunker fuel prices
- Increased replacement of inefficient ships, and building of fuel-efficient ships
- High fuel costs results in preference toward shorter Arctic route
- Some sectors hard-hit by large fuel price fluctuations (e.g. cruise industry when price is high, extractive industries when prices are low)
- Industry-friendly regulations are likely in areas that profit from the fossil industry
- Profitable Arctic operations in extractive industries, increased revenue for fossil industry (potential for benefit sharing with communities)
- Supply chain decision making possible due to predictability of operations and contingency planning
- Increase in Arctic exports
- Insurance availability widens, cost decreases

mean plausibility score: 0.59

2. Northern blockade:

- Decrease in bunker fuel prices
- Decreased incentive for shipping industry to use trans-Arctic routes instead of traditional routes (Suez and Panama Canals)
- Decreased incentive in fossil fuel industries for Arctic operations
- Arctic shipping companies such as Royal Arctic Line (Greenland) who supply remote communities benefit from lower fuel prices
- Remote communities benefit from lower energy prices
- Likely increasing resource (energy) pressures globally, but decreasing production of resources in Arctic region
- Decrease in Arctic exports

mean plausibility score: 0.41

Key Factor: China's strategic plan

Definition

This key factor describes the interactions between China's inclusion in Arctic regional body politic, and the impacts on Pan-Arctic and domestic, national regulations. This key factor is about the extent of acceptance of China as an influential player in Arctic political economy, as well as the extent to which big ideas for development spread in response to China's strategic plans. The questions that drove the development of this key factor include: Will Arctic nations accept Chinese investments and influence, by passing favorable national legislation? Or will there be a pushback and a speeding up of domestic and Pan-Arctic cooperative development projects to preempt China's plans?

Future Projections

1. Mad Max:

- Heavy critical infrastructure investments
- Shipping shares shift toward state-owned companies
- Mining and fishing rights shift toward Chinese ownership
- China follows their own strategic plans for Arctic development
- Increased demands on local resources and communities
- Increase in shared liabilities and responsibilities of information provision
- Potential for growth in joint information hubs and cooperative solutions (price of information may decrease)

mean plausibility score: 0.34

2. Chinese finger cuffs:

- China's strategic plans provoke preemptive developments and increase in investments by Arctic nations (control remains within the Arctic)
- China's and Korea's strategic plans are controlled via pro-active action by Arctic states
- China's strategic investment plans are scrutinized and rejected to thwart outside geopolitical leverage

mean plausibility score: 0.66

Key Factor: Sustainable and resilient local communities

Definition

This key factor draws on the importance of Arctic community resilience in the wake of rapid biophysical, demographic and infrastructural changes, and the importance of self-determination as a vital resource in community sustainability. Sustainable local communities are vital constituents in safe, sustainable Arctic maritime sectors as active partners in the tourism industry, as consumers of shipping services and as influential stakeholders in extractive industries.

Future Projections

1. Expat haven:

- Increased influx of people from outside the Arctic region
- Increase in labor force
- Increasingly mixed cultural identity

mean plausibility score: 0.44

2. Education boost:

- Investments in increased Indigenous Knowledge inclusion and Indigenous teachers teaching in Arctic Indigenous community schools
- Incentives for youth to remain in community
- Increasing elder-youth contact
- Strengthening local identity
- Building resilience via increased fate control

mean plausibility score: 0.26

3. Tax haven:

- Fossil fuel industry making profit without being part of the local communities
- Arctic exports are on the rise but benefit sharing agreements are not representative of this boom

mean plausibility score: 0.30

Key Factor: Trajectory of development in marine technologies¹

Definition

This key factor recognizes the role played by the direction of technological developments toward disruptive vs. green development, as well as the speed of advancements made in Arctic marine navigation, automation, fuel innovation and route accessibility. The significance of marine technological developments ultimately lies in the safety and efficiency of operations, impacting greatly the economic viability of Trans-Arctic routes. The future projections and their descriptions below have been developed based on the Global Marine Technology Trends 2030 report.²

Future Projections

1. Techno-utopia for some, stormy seas for others:

- Favorable regulatory frameworks and intense competition for smart marine technologies speed up worldwide technical standardization and cooperation
- Portfolio of technologies supporting electromagnetic stealth and resilience to electromagnetic attacks increases
- Private sector is confident to invest
- Big-data analytics advance coupled models ground-truthing forecast information with in-situ data
- Robotics, advanced materials and new communication technologies increasingly saturate marine operations
- These new, expensive technologies will require changes in supply chain management and likely adopted quicker by larger corporates
- The speed of green development picks up due to policies incentivizing cleaner, more efficient vessels
- New build orders based on clean, efficient propulsion and powering increase
- Onboard energy management increases in efficiency, marine fuels focus on novel technologies
- Environmental regulations play catch-up with intensifying activities and new places of exploration, increased focus phasing out heavy fuels and search-and-rescue capacities
- Increasing complexity of technologies and speed of development requires new skills and training from people operating systems and equipment
- Growing demand for highly-qualified sea-going staff
- Unprecedented amount of data available to users aids those with access to big data analytics, while those without struggle to translate complex data sets for use
- Demand for increased portfolio of metocean services continues to rise rapidly:

¹ This key factor was recognized by participants as an important driver of change, however participants felt they lacked the necessary expertise to develop it further. Workshop Lead B. Blair used notes from the workshop on the discussion surrounding this topic and literature to develop future projections.

² Lloyd's Register, QinetiQ and University of South Hampton. (2015) *Global Marine Technology Trends 2030*. Available online: <https://www.lr.org/en/insights/global-marine-trends-2030/global-marine-technology-trends-2030/>

increasing demand for data transfer services

- Public services struggle to keep up to finance growing service demands, private subscription-based providers grows
- Increasing deployment of sensors in remote locations to support users and decision makers in decision making, and a better understanding of environmental preservation needs

mean plausibility score: 0.70

2. Slow innovation and adoption

- Rate of transition from emergent technologies to mature technologies slows down
- Accessibility and viability of Trans-Arctic routes remains about the same as today
- Private sector lacks the confidence to invest in marine technologies and infrastructure to prop up viability of Arctic ports and routes
- Demand for information continues to grow from some sectors in destination shipping while others in transit shipping continue to prefer alternate routes
- Intelligent port management technologies lag behind the complexity of increased traffic density due to expected growth in destination shipping
- Marine fuel sources focus on proven technology, with start of adoption of LNG

mean plausibility score: 0.30