14 Polar Ship Design and Operations

Past, Present, and Future

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Introduction

From an early emphasis on geographic exploration and exploitation of the resources in the polar offshore area (by hunting for walrus ivory teeth, seals, and whales), the focus is currently shifting toward the sustainable use of the Arctic's resources. Developments in the Antarctic are mainly limited to fisheries, cruise traffic, and scientific expeditions. The focus in the Arctic is currently on using the Arctic offshore for fisheries, transport of oil and gas products, cargo traffic, and leisure (cruise traffic) in a safe and environmentally sustainable way. During this process, maritime operations have become relatively safe due to the introduction of international codes for the design and strengthening of polar vessels (ice class), the rules of the International Maritime Organization (IMO), and in particular the requirements for training of polar crew members. The continuous work to align the classification societies' rules for ships in polar regions is a step toward improved safety for sailing in these regions. Safety for crew members and passengers has also improved through the use of modern communications systems (particularly satellite navigation) and the availability of ships and helicopters to support search and rescue (SAR) operations.

The international society has implemented the IMO Polar Code (IMO, 2017) for the design and operation of ships in the polar regions (Arctic and Antarctic waters). The Polar Code is a functional code stipulating functional requirements beyond the requirements of the IMO Safety of Life at Sea (SOLAS) Convention (IMO, 2001) and the IMO Marine Pollution (MARPOL) Convention (IMO, 1983). The countries of the Arctic have, furthermore, arranged for close cooperation regarding operations, SAR in Arctic waters, and splitting the Arctic into zones where each of the countries has specific responsibilities.

Polar shipping has developed from a situation of high risk to ships and crew members, where once ships might easily be crushed in the ice and where the survival of crew was a matter of good luck. The first rules for navigating in ice were the Finnish ice class rules issued in 1890 (Kärmäräinen and Riska, 2018), and later (in 1948), international collaboration was enhanced with the establishment of IMO, issuing regulations and standards providing for safer vessels and increased probability of rescue should an operation fail. It is, however, conceded that polar

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shipping needs further development to reduce the probability of ship damage and to further mitigate the consequences of adverse events.

The objective of this chapter is therefore to document in the next Section how shipping operations in the Arctic developed from small wooden boats designed according to experience and best practice, to strong double hull ice-resistant vessels through international cooperation, with emphasis on ice class notations, as introduced by the classification societies, and how international cooperation through IMO has further improved the safety of polar shipping, in particular by introducing the International Polar Code (IMO, 2017). In Section 14.3, the safety of the seafarers is briefly discussed with reference to another chapter in this volume (Borch and Andreassen, 2021). The necessity to point out that shipping always requires SAR capabilities must never be forgotten and polar shipping is particularly vulnerable due to the lack of infrastructure in many regions. Section 14.4 highlights the needs to limit emissions from ships in polar waters, and Section 14.5 recounts the challenges encountered through international work toward improved safety standards for ships, crew, and passengers with a view to the needs of the future, where autonomous ships may be seen in the polar regions. Section 14.6 summarizes the content of the paper by pointing out the needs for further international cooperation in the design of polar vessels, for improved operational assistance, for better training of crew members, and for improved means to ensure rescue of all involved in case of vessels in distress. It must be conceded, however, that there will still be emergency situations regardless of safer vessels, increased number of international regulations, and improvements in operational support.

Maritime operations in the Arctic – developments from past to the present

The history of Arctic shipping

Arctic shipping has long traditions; the sailing of Ottar from Hålogaland (possibly from Kvaløya in the Troms area) of Norway to Bjarmeland in the White Sea area was followed by his report to the King of England around the year 870. The next significant development to note here is the expeditions of the Vikings to Greenland and Vinland (modern Newfoundland) and possibly further south, around the year 1000. Their low ships with sails (the “Viking ships”, Figure 14.1) represented the state of the art of ship design at that time as they were designed for speed and stability (wide ships), although they had no specific design feature to resist ice. The Vikings reached America, and the “Vinland Map”, possibly the first map showing America, is currently housed in Yale University’s Beinecke Rare Book and Manuscript Library. The paper on which the map is drawn dates to approximately 1434, which is nearly 60 years before Christopher Columbus arrived in the West Indies.

Thereafter, expeditions by the Dutch, led by Wilhelm Barents (from 1594 and onwards), reached high latitudes using small wooden sailing ships, which were typical of that time with a much higher freeboard than the Viking ships.

Figure 14.1 Viking ship. A digital reconstruction shows that the *Tune* Viking Ship that must have been a fast-sailing vessel that could also be rowed. Illustration by 7Reasons for NIKU (Nikel, 2020).

The Barents Sea is named after the expeditions he led. Following Barents's expeditions, whale hunting and the extraction of oil from whales were developed into an industry on Spitzbergen with many seasonal settlements. Ivory from walruses was also in high demand at that time. Smeerenburg on Amsterdam Island (79°40´N 11°00´E), for example, was founded by Dutch hunters and traders as early as in 1620, north of present-day Ny Aalesund. Many historical documents provide accurate information about these explorations.

F. Nansen's polar expedition of 1893–1896, with the vessel *Fram* (Figure 14.2), when Nansen aimed to freeze the vessel into the ice and drift across the North Pole (Nansen, 1897), is well known to all those interested in the history and technological development of the Arctic, in particular the design of the expedition research vessel *Fram* was specially adapted to the polar regions. She had a rounded form that caused her to lift up onto the ice when subjected to ice pressure. The force caused by the horizontal ice pressure has a component normal to the hull and an uplifting component. Since then, this design has been the standard for all polar vessels. Note that when a ship moves into the ice, it is lifted up, and a vessel with *Fram* geometry exhibiting will thus break the ice due to its weight and can thereafter move forward. Evacuation was at that time onto the ice or to open lifeboats.

The fishermen making their living from fishing along the Norwegian coast used smaller vessels, and it was not until seal hunting expeditions moved into the ice that vessels were strengthened for Arctic conditions (Alme, 2009; Gudmestad and Alme, 2015). The vessels generally hunted for the seals together, so a "buddy effect" was present in case any of the vessels got into distress. The ice pressure exerted on the vessels during the closing of open leads, however, caused many vessels to be squeezed, so that they eventually sank. Even ships made of steel were damaged by drifting ice floes, to the extent that they had to be abandoned. In these situations, the crew gathered on the ice and were, in most cases, rescued by other vessels in the area. On the way to the hunting grounds, however, all vessels were exposed to the same meteorological conditions, and the loss of lives in some situations was exceptionally high. Weather conditions in 1917, when seven vessels (and 79 persons) were lost in Vestisen (northwest of Iceland), were characterized by a heavy storm from the northeast, together with cold temperatures and a polar low pressure; similar conditions were encountered in 1952 when five vessels were lost. The ships were probably hit by severe icing conditions and thus lost stability. Following these events, nothing was heard from those on board and nothing was found. It can be commented that during heavy sea spray icing, the only way to regain stability is to remove the ice, in particular ice accumulated high above the deck.

The crew of the sealer *Kapp Flora* met a better fate. In April 1924, 13 vessels were lost in the mouth of the White Sea due to forces from moving ice. The *Kapp Flora* (Figure 14.3) was on her way out of the White Sea with a full catch when she

Figure 14.2 *Fram*. A model of the ship used by F. Nansen in the Arctic 1893–1897, by O. Sverdrup in the Arctic 1898–1902 and by R. Amundsen 1910–1912 in Antarctica. With permission from the Bergen Maritime Museum.

was cracked open between ice floes. At the evacuation, another sealer, the *Godøy*, was only 500 meters away. The crew of the *Kapp Flora* failed to locate the *Godøy* in the snow and walked and dragged the lifeboats across the ice and came ashore at the rescue station at Cape Orlov on the Murmansk Coast (Vestlandsnytt, 1962). Later, they returned home aboard another vessel.

Drifting ice is a particular concern when sailing in polar waters. Outside the ice edge, the ice floes drift on the waves and can cause great harm to equipment on board vessels. Glacier ice floes or multiyear ice floes may furthermore have very damaging effects, as the "ice foot" is hidden below the waterline and may not be seen by the person on watch on the bridge. The seal hunters were particularly concerned about the risk of colliding with such ice. Further to the historical records by Alme (2009), Marchenko (2009) has prepared an exhaustive review of the experience of Russian Arctic navigation, listing the loss of vessels navigating the route from the Kara Gate to the Bering Strait during the last hundred years. She also discusses the reasons for the accidental losses of vessels and documents concerns for present shipping due to uncertainties in ice loading during ice navigation.

Figure 14.3 The *Kapp Flora* in the ice off Cape Orlov on the White Sea. Note the heavy ice and the open lifeboat. (With permission from the owner of the picture, T. Nærland, Nærbø, Norway, the daughter of P. O. Paulsen, one of the survivors.) For pictures, see also Ishavsmuseet, Brandal's Home Page.

The accidents called for design standards for vessels navigating polar waters. Ice class notations for ships were developed by several classification societies (see Figure 14.4 based on The Baltic Sea Ice Class Service). The first Finnish ice class rules were developed in 1890 for vessels sailing in the Baltic Sea. Note that the ice is harder in this area than elsewhere in the polar regions due to the lower salt content of the Baltic Sea. The Finnish ice class rules issued in 1932 introduced ice classes 1A, 1B, and 1C for ships strengthened for navigation in Baltic ice, Ice Class 2 for ships classified for unrestricted service but not strengthened for navigation in ice, and Ice Class 3 for other vessels. All class societies later developed their own ice class rules, which are compatible with and accepted by the IMO. Note that the IMO Guidelines for Ships Operating in Arctic Ice-Covered Waters (IMO, 2002) include no direct technical requirements; however, the classification societies have issued additional requirements depending on the actual thickness of the ice. Note also that ship classification is an international competitive business; however, all classification societies work according to the agreed IMO regulations. The ice class requirement has considerably reduced the risk in navigating the Arctic Seas. For modern ice class rules, see, for example, DNV (2013) and Mejlænder-Larsen (2015).

Classification Society	Ice Class				
Finnish-Swedish Ice Class Rules	**IA Super**	**IA**	**IB**	**IC**	**Category II**
Russian Maritime Register of Shipping (Rules 1995)	UL	L1	L2	L3	L4
Russian Maritime Register of Shipping (Rules 1999)	LU5	LU4	LU3	LU2	LU1
Russian Maritime Register of Shipping (Rules 2008)	Arc 5	Arc 4	Ice 3	Ice 2	Ice 1
American Bureau of Shipping	Ice Class I AA	Ice Class I A	Ice Class I B	Ice Class I C	D0
Bureau Veritas	ICE CLASS IA SUPER	ICE CLASS IA	ICE CLASS IB	ICE CLASS IC	ID
CASPPR, 1972	A	B	C	D	E
China Classification Society	Ice Class B1*	Ice Class B1	Ice Class B2	Ice Class B3	Ice Class B
Det Norske Veritas	ICE-1A*	ICE-1A	ICE-1B	ICE-1C	ICE-C
Germanischer Lloyd	E4	E3	E2	E1	E
IACS Polar Rules	PC6	PC7	-	-	-
Korean Register of Shipping	IA Super	IA	IB	IC	ID
Lloyd's Register of Shipping	Ice Class 1AS FS (+) Ice Class 1AS FS	Ice Class 1A FS (+) Ice Class 1A FS	Ice Class 1B FS (+) Ice Class 1B FS	Ice Class 1C FS (+) Ice Class 1C FS	Ice Class 1D Ice Class 1E
Nippon Kaiji Kyokai	NS* (Class IA Super Ice Strengthening) NS (Class IA Super Ice Strengthening)	NS* (Class IA Ice Strengthening) NS (Class IA Ice Strengthening)	NS* (Class IB Ice Strengthening) NS (Class IB Ice Strengthening)	NS* (Class IC Ice Strengthening) NS (Class IC Ice Strengthening)	NS* (Class ID Ice Strengthening) NS (Class ID Ice Strengthening)
Polski Rejestr Statków	L1A	L1	L2	L3	L4
Registro Italiano Navale	ICE CLASS IA SUPER	ICE CLASS IA	ICE CLASS IB	ICE CLASS IC	ID

Figure 14.4 Correspondence between the Baltic ice class (Finnish-Swedish Ice Class Rules) and the ice classes of other classification societies.

Source: HELCOM Recommendation 25/7. © HELCOM.

The present status of ship operations in the Arctic

In the Russian part of the Arctic, the authorities are becoming concerned about the strength of vessels using the Northern Sea Route (NSR), and the Russians are strengthening the requirements regarding vessels' ice-breaking capabilities, or icebreaker assistance is requested by the NSR administration (NSR's Home Page, no date). This relates in particular to the large Liquefied Natural Gas (LNG) tankers sailing from LNG plants in Ob Bay. These are of "Double Acting Tanker" design (Figure 14.5), whereby the ship goes stern first into the ice. The stern and the Azipod propellers break the ice (Aker Arctic's Home Page). The bow is a normal bulb bow designed for speed in ice-free waters. It should be noted that the NSR from the Kara Gate to the Bering Strait is open to large ice-breaking vessels for several months of the year. The Russian NSR administration imposes strict regulations for the use of the route.

While sailing in the Matisen Strait (one of the two major channels separating the groups of the Nordenskiöld Archipelago north of Russia) on September 4, 2013, an ice floe hit the "sea-river" type tanker, Nordvik. The tanker sustained a hole in one of the ballast tanks on her port side. The vessel, with an ice class of Ice 1, was loaded with 4,944 tons of Arctic diesel fuel and was following the route from Ob Bay to Khatanga (Bellona, 2013). The captain of the vessel was in

Figure 14.5 Double Acting Tanker. The Christophe de Margerie-class ice-breaking LNG carriers are built by DSME (Daewo Shipbuilding Marine Engineering) for the Yamal LNG project. Image courtesy of Dmitrii Lobusov.

violation of the permit's requirements when the ship entered the water area with medium ice conditions.

In Antarctica, the M/V *NordNorge* was involved in rescuing the crew and passengers of the M/V *Explorer* in 2007 (Gard News, 2008). The *Explorer* had a hole in her starboard side, and the *NordNorge* was 40 nautical miles away and so was able to come to the rescue. It should be noted that the *Explorer* only had open lifeboats, even though the voyage was an Antarctic cruise. According to Bignell (2011), "an 'inexperienced and overconfident' captain drove his ship too fast towards a 'wall of ice'" causing the ship to eventually sink. This event was a wake-up call, reflecting the danger of polar cruises; luckily, a "buddy-ship" was close by for rescue. The event also serves to show the need for the Polar Code for polar shipping.

Recent years have witnessed an increase in use of the Arctic navigation routes. The cruise ship *Crystal Serenity* sailed through the Northwest Passage in 2016 with more than 1,000 people on board. The Maersk container vessel *Venta Maersk* sailed from South Korea to Europe in August/September 2018 (*High North News*, 2019). In July 2018, the LNG carrier *Christophe de Margerie* set a record of 18.5 days for a non-escorted ship to transit from Sabetta in Ob Bay to China (gCaptain, 2018). However, in 2018, an Arctic cruise ship ran aground in the Canadian Northwest Passage (Humpert, 2018). The local community close to the location of the grounding site had to empty all reserves to accommodate those who were evacuated. The event made it clear that Arctic shipping is very vulnerable in case of accidents.

The IMO Polar Code (IMO, 2017), developed to ensure safer sailing in polar waters, came into force on January 1, 2017. The Polar Code sets common standards for vessels and services to navigate the polar regions. It was developed from the SOLAS Convention (IMO, 2001) regarding safety for navigating in the polar regions and the MARPOL Convention (IMO, 1983) for the prevention of pollution from ships navigating the polar regions.

It should be noted however that the Polar Code does not apply to fishing vessels. This gives rise to discussion on the safety of fishing vessels in polar waters. These vessels are susceptible to sea spray icing, as they often have a low freeboard and a large amount of deck equipment (Johansen et al., 2020). On December 28, 2020, the Russian fishing vessel *Onega* sank near Novaya Zemlya due to icing. Seventeen of the crew lost their lives (Nilsen, 2020). The vessel was fishing beyond the range of any official rescue capability. Note that ships sailing in ice conditions with ice coverage less than 1:10 are also exempted from ice class rules.

The future of polar shipping and need for improved international norms

In the 21st century, Arctic shipping has increased considerably and the Arctic waterways have become global waterways. A large increase in marine activity in the Arctic region is expected in the coming years as the area covered by ice during the summer months has been diminishing considerably (National Snow and Ice Data Center's Home Page) in recent years:

- Increase in marine traffic due to oil and LNG transportation
- A general increase in transshipment of cargo due to reduction in ice cover
- Russian official policy regarding increased use of the NSR
- Increase in cruise traffic as Arctic cruises are advertised as "adventure tours"
- Increase in numbers of passengers on board cruise ships making rescue an increasingly challenging task
- Increased fishing activity in the region

After the recovery from the COVID-19 pandemic, an increase in Antarctic cruise traffic is also likely.

Due to this anticipated increase in sailings in the polar regions, IMO considered it necessary to strengthen the Polar Code by providing an Informative Annex on how the requirements of the Polar Code can be satisfied. (IMO, 2019). By issuing such a document, the IMO provides a recommendation that should be followed by the classification societies, reducing competition between the classification societies regarding the least expensive ways to satisfy the requirements of the code. Similar concerns are valid regarding the required training of ships' officers. In the reports from the SARex exercises conducted off northwest Spitzbergen (Solberg et al., 2016, 2017) and by Solberg and Gudmestad (2018; see also Gudmestad and Solberg, 2019), it is demonstrated that the competence of the leaders of the means of rescue play a major role in the safety of those being rescued.

Discussion is moreover needed on whether fishing vessels should be covered by the Polar Code requirements as the number of people involved in fishing, particularly in the Arctic region, is in the order of thousands, and their lives are as precious as those of personnel on commercial vessels and of the passengers and crews on board cruise ships. The responsibility for rescue operations should be further clarified.

The role of insurance companies is also important. How will the insurance companies ensure that they will not be liable to indemnify in the order of billions of dollars in the case of the loss of many passengers on a cruise ship? Only where the risk is small will the insurance industry agree to insure passengers and vessels as well as the environmental clean-up after a potential accident. This will necessitate improvements in the attitude of the cruise industry to rescue in case of accidents. The industry may decide to limit the number of passengers on board polar cruises.

Finally, the responsibility of the shipowner should be stressed. Note also that the captain of the ship, the commander, has the most important role in deciding whether the sailing entails an acceptable risk. It will take a brave captain to go against the decision of the vessel's owner; however, in case of an accident, the captain will eventually be taken to court to document that the risk of the sailing was as low as was reasonably practicable (ALARP).

The increased activities in the polar regions, in particular in the Arctic, call for further development of international cooperation. It is expected that the work in IMO related to polar shipping will continue with increased intensity, whereby rules and regulations will be even better aligned to ensure safe polar shipping. Also, the classification societies are encouraged to continue to cooperate to ensure that all ships sailing in polar regions maintain the same safety standards (International Association for Classification Societies, IACS, 2019).

Challenges for international cooperation related to search and rescue

The history of Arctic search and rescue from vessels in distress

Prior to the telecommunications era, SAR depended on the availability of vessels spotting the ship in distress or on the means for evacuation. The only option for rescue was evacuation into open lifeboats. The wait in the lifeboat was extremely challenging in cold and snowy weather, in darkness, and in stormy sea conditions. The loss of lives during World War II was huge, following torpedo attacks and subsequent evacuation into open lifeboats (see, example, e.g., Brekmoe, 2020). Survivors from shipwrecks often walked over the ice to reach inhabited areas; an example is the loss of the sealer *Kapp Flora* (see Figure 14.3 and subsequent discussion). The crew of the *Kapp Flora* dragged the lifeboats across the ice and came ashore at Cape Orlov on the Murmansk Coast.

The present and the future status of search and rescue in the Arctic Seas

On the present status regarding SAR in the Arctic Seas, see Borch and Andreassen (2021). It should be noted that there is a need to strengthen polar shipping SAR due to the increase in polar shipping in consequence of the diminished ice cover. There is no approved guidance on how the requirements of the code could potentially be satisfied; however, an IMO work group (IMO, 2019) has developed "*draft interim guidelines* on life-saving appliances and arrangements for ships operating in polar waters" (see Gudmestad et al., 2019). In June 2019, the Norwegian Maritime Administration incorporated these suggestions into new regulations specifically for the Svalbard waters (Norwegian Maritime Administration, 2019).

However, the capability of coastal nations to rescue large groups of people, particularly from cruise ships navigating "exotic polar locations", is inadequate. Captains deciding to sail in uncharted waters (Sollid et al., 2018), where there is a risk of running aground, far away from means of rescue and without contact to other vessels, cannot expect rescue vessels to arrive within days. The Polar Code requirement for five days' survival while the rescue means are on their way is generally realistic. However, in some cases, the time to rescue may even exceed five days (Solberg et al., 2020) should there be a huge number of survivors to attend to. It may be advisable for the coastal nations to issue a disclaimer note, clarifying the limitations in rescue capabilities and the estimated rescue time for ships sailing in polar regions. This will limit the possibility of legal actions against coastal nations because of limited rescue capacity and capability.

The need to limit pollution of the polar region by shipping

The depositing of soot and dust on ice and snow accelerates the melting of the polar regions' white cover of ice and snow. This situation accelerates global warming and measures are being taken to limit the "blackening" of the Arctic region in particular. The main concern is with the emission of black smoke and particles from shipping due to burning of heavy oil as fuel. Norway, for example, has enacted that all vessels within the economic zone of Svalbard must use low sulfur oil as fuel (HFO-free Arctic, 2020). "The eight nation Arctic Council has set targets to limit black carbon (or soot) emissions between 25 and 33 percent below 2013 levels by 2025 in a bid to slow Arctic warming" (Climate and Clean Air Coalition, 2017).

Further to pollution of the air, there is an urgent need to limit pollution of the sea. The disposal of bilge into sea is a problem, in particular in the Arctic, where degradation processes are slow. Disposal of plastics from fishing vessels is of grave concern as plastics degrade into nanoparticles which enter the food chain, eventually ending up in the human body. Fisheries must be regulated so as to end the dumping of obsolete/broken equipment. IMO (2018) has adopted an Action Plan to address marine plastic waste from ships.

Cleaning of ballast water has been an issue in the maritime industry. International regulations are in place (IMO, 2004). Foreign species brought from warmer waters may thrive in the fresh water of the Arctic, the more so with the warming trend in the Arctic Seas. There is thus a need to keep ballast water cleaning high on the international agenda.

International norms for Arctic ship design and operations and the future outlook

International norms have been developed by the IMO. The organization includes most of the UN's member countries. These countries have different interests; some countries register ships for shipowners so as to minimize tax and maintenance costs. In addition, shipowners' associations and certifying bodies are represented in IMO meetings. The broad membership makes it difficult to pass the necessary regulations for safer and cleaner shipping. The work to obtain approval for the International Polar Code (IMO, 2017) took decades. However, regulations with a broad mandate and agreed with general consensus are strong and will be adhered to. The key to success was to develop a functional code stating objectives that can be achieved in different ways (Engtrø et al., 2020). The classification societies will thereafter develop detailed rules or standards, whereby the IMO regulations can be fulfilled. This approach works well, provided the classification societies develop rules which are at the same safety level and which are adhered to in the approval of new designs and class reviews. On the other hand, it must be noted that the classification business is a commercial undertaking and classification societies might be tempted to approve vessels that should have been upgraded rather than being deemed seaworthy.

Individual countries may also impose specific restrictions on vessels sailing in their territorial waters. Norway imposed specific requirements on vessels within the 12-mile limit at Svalbard (NMA, 2019) and several countries (e.g., around the Mediterranean) have requirements on use of low sulfur fuel. There are also examples where the Arctic Council has imposed specific requirements on Arctic shipping (Arctic Council, 2011). It has been suggested that this body, representing all Arctic countries, should impose a low sulfur fuel requirement on all Arctic shipping within their areas of responsibility. The NSR may benefit from such a requirement, whereby the market and the companies shipping goods may consider the NSR a "greener" choice for their shipping services.

The future may see changes in shipping through the use of modern technology. The trend to minimize the number of crew members onboard ships continues, with a goal of developing autonomous ships. This may not mean that the ship is completely unmanned, but rather that the ship should be in a position to sail without supervision for certain distances. An autonomous ship is considered to be supported by a digital twin, whereby the operation of the ship is supported and monitored from an office possibly far away. The risk of cyber collapse or cyberattack, however, must be taken into account. One real concern is communication collapse due to increased solar activity and particles that would damage the satellite communication network. This threat is particularly great in the Arctic as the solar particles are attracted toward the magnetic North Pole. In this respect, it is necessary to carry out risk analysis to document that the risk of disaster is exceptionally low, as the collapse of communication would affect all relevant vessels.

When it comes to designing vessels for the Arctic, a trend toward risk-based design is being promoted (Kujala et al., 2019). This approach could save investment costs; however, it is necessary for all relevant risks to be included in the analysis, including possible future risks. The evidence of failure to consider risks is a matter of grave concern, that is, the "black swans" (Aven, 2014). Furthermore, the economic impact of wet and dry bulk shipping in Arctic waters is being discussed (Solakivi et al., 2018). It must, however, be realized that the pressure to limit costs must be compared to a potential increased risk for vessel and crew. It may be difficult to disregard the impacts of floating ice in the Arctic, even if the area covered by ice is diminishing. The future will see larger waves in the Arctic due to longer stretches of open water. The ice floes will have more impact power, including those thrown against vessels during "green sea" submergence of the bows of vessels.

The present-day international norms are in general ready to regulate activities in the future too, but the next section lists challenges where future international regulations are required.

Conclusions and recommendations regarding international cooperation related to shipping in the Arctic

This chapter has reviewed progress in shipping in the polar regions from the early explorers via the daring seal hunters and whalers and from the ice-strengthened ships to the modern design of large vessels for commercial and leisure traffic in the polar regions. The recent focus is on passenger safety and the requirement to minimize pollution of the sea and air. The important role of the IMO in this respect has been highlighted, and a scenario of shipping in polar waters moving in the direction of sustainability and further international cooperation of the traffic is suggested as the main learning point.

Of key concern is the climate impact, regarding which the NSR could be presented as a green intercontinental transportation route, with reference the concerns of the Intergovernmental Panel on Climate Change (IPPC, 2021), by prohibiting the use of heavy fuel oil and by highlighting the support of icebreakers to ensure that schedules for all traffic can be maintained while still reducing fuel consumption compared to southern routes and by ensuring the safety for ships sailing along the route. The total climate impact of using the NSR should be compared to that of alternative routes and be communicated as a key opportunity for sustainable intercontinental sea transportation.

The near future will see new challenges caused by the rapid introduction of new requirements related to clean fuel and the safety aspects associated with the potential explosion risk of utilizing these new fuel types. This will be reflected in the operations of the vessels. Furthermore, interest in autonomous ships will introduce needs for relevant international standards, taking into account the cyber threats to which ships are exposed, particularly when sailing in Arctic waters. It is also expected that larger fishing vessels will need to be covered by the Polar Code, given the yearly losses of fishing vessels and crews. The reduction of the polar ice cap will in particular necessitate such a move, as the fishing vessels will enter even more remote areas. Finally, grave concern is raised in relation to the safety of passengers and crew onboard large cruise liners and a limitation in the size of cruise liners could avoid scenarios with the greatest loss of life. Cooperation between all members of the international maritime community is called for, whereby insurance companies also become involved in ensuring safer design and operations.

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Ex-post reflections

This chapter was prepared in 2021, at a time of peaceful cooperation in Europe. An increase in international traffic along the NSR was predicted. The recent challenging relations between Russia and other nations operating in Arctic waters would probably limit the international trade along the NSR.

Regarding the design of vessels, cooperation related to ship transport and on issues related to SAR, few changes are envisaged as the Arctic countries all benefit from the present international agreements.

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Note: All links were accessed on 16 September 2021.

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