The implementation and application of the International Code for Ships Operating in Polar Waters (Polar Code)

Evaluations and considerations addressing this function-based regulation's effect on safety and emergency preparedness concerning Arctic shipping

by

Espen Engtrø

Thesis submitted in fulfilment of
the requirements for the degree of
PHILOSOPHIAE DOCTOR
(PhD)

University of Stavanger

Faculty of Science and Technology
Department of Safety, Economics and Planning

2021

University of Stavanger
NO-4036 Stavanger
NORWAY
www.uis.no

ISBN: 978-82-8439-050-5
ISSN: 1890-1387
PhD: Thesis UiS No. 618

Acknowledgements

This thesis is submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy (PhD) at the University of Stavanger (UiS), in the Faculty of Science and Technology, at the Department of Safety, Economics and Planning, in Norway. This research work was carried out at the UiS in the period from January 2018 to August 2021. This project was funded by the LOTOS project. The compulsory PhD courses followed were offered at the UiS.

After graduating with a master's degree in Risk Management and Societal Safety at the UiS in 2010, I returned to the industry where I once had started my professional career in 1994. At that time, I achieved the Certificate of Apprenticeship as a skilled sheet metal worker. Employed as an apprentice in a traditional company located at Bryne producing small and large size metal constructions for the offshore and onshore industry (i.e., the oil and gas industry and the fish processing industry), I was tasked with cutting, constructing and welding together, steel constructions, i.e., pre-modules, making up entire plants.

In 2010, I started working for the oil and gas industry, with a position as a Health, Safety and Environmental (HSE) Advisor for an operator, occupied with tasks concerning the planning and follow-up of HSE-related activities associated with drilling operations for exploration wells in the Barents Sea. After five years in this role, I was offered the job of Rig HSE Advisor, working on a semi-submersible drilling rig, also performing drilling operations for exploration wells in the Barents Sea. In the summer of 2017, I became aware of an advertisement from the UiS offering the position of a PhD Candidate, to study the enforcement of the newly implemented International Code for Ships Operating in Polar Waters (Polar Code) and this function-based regulation's influence on the safety and emergency preparedness of ship operations in the Arctic Ocean. In addition to academic requirements, the required key

competencies for holding this PhD position were knowledge and experience in the utilization of function-based regulations and requirements and challenges related to operations in cold climates. Immediately, I was excited and recognized that this engagement was an opportunity I could not let pass, considering that the regulations governing HSE in the Norwegian petroleum industry contain risk- and performance-based requirements. Moreover, for the last seven years, I had been working with HSE challenges related to operations in a cold climate. I was thrilled when I finally passed the interview and was offered the position as a PhD Candidate at the UiS, starting from January 2018, where I now had the opportunity to carry out research on a topic that interested me and with which I had been working for several years.

The last four years have been a truly interesting and educational period, in which I have acquired new knowledge concerning safety and emergency preparedness related to shipping in polar waters. This period has also been one of the most challenging times in my life, not only from an academic point of view but also in my private life, where I had to cope with the tough realities that life sometimes offers. Sadly, my father, Ottar Engtrø, had a serious stroke at the beginning of 2019 and unfortunately passed away one year later. It is sad that my father does not get to see me achieving the goal of finishing this PhD, as I know he would have been tremendously proud, especially considering his passion for the written word, as he himself, in his working days, was a teacher and an author.

Many people have supported me during this work, and I cannot express my gratitude to everyone here. But some persons must be mentioned. First and foremost, I would not have made it to the finish line if it was not for the great support provided by Professor (Emeritus) Ove Tobias Gudmestad (UiS). This man is incredibly knowledgeable, practically oriented, understanding, and firm, and he has functioned as my main supervisor throughout this entire research, even though on paper he has the role of a co-supervisor. Ove Tobias is also the co-writer of four of my published papers and has further given me advice and invested time in commenting on and assisting in the two remaining papers and on this thesis. I appreciate all the occasions where Ove Tobias invited me home to his house in Tananger, where we discussed this research and planned the way forward. During these sessions, there was no rush, as Ove Tobias appreciated taking the time and discussing things through in a systematic manner. During this work, Ove Tobias emphasized in his behaviour a dedication to guiding me through this research and, at times when I have been frustrated, he has always been positive and highlighted the strength in my work. I know that I am by no means the first or the last person that Ove Tobias has guided and supported in an educational setting, and I consider that the UiS is truly lucky to have this man working for the institution.

Secondly, I would not have managed to complete this work if it wasn't for my beloved girlfriend and cohabitant, Sharareh Sanaz Madadi. Your dedication and massive support, Sharareh, has comforted me, especially at times when the easiest way seemed to let go and abort this mission. That has never been an option for Sharareh, who constantly took care of our household, so I could focus solely on this research. Thank you, Joonam, for putting yourself aside, so I could chase the goal of completing this PhD. I would not have managed it, without you, Azizam.

Moreover, I would like to thank Professor Ove Njå (UiS), who was my main supervisor during the first half of this research. Ove is also the co-writer of three of my published papers and participated during this period in many useful discussions, bringing forth considerations and formulations concerning safety and emergency preparedness related to Arctic shipping and the use of function-based requirements. At the start-up of this research, Ove implemented me in an ongoing project concerning the use of standards in regulatory governance, which was a flying start, as it resulted in the making of my first published paper, which contributes as a book chapter, edited and published by reputable Norwegian parties.

Further, I would like to thank Associate Professor Morten Sommer (UiS), who stepped in halfway in this research as main supervisor. Morten is very knowledgeable, specialized in the field of emergency preparedness, response, and management. The many conversations and discussions during this period, covering the topic of safety and emergency preparedness in the Arctic, were fruitful and guided me concerning the way forward for the completion of this work. Morten also invested time in commenting on and assisting in the last paper and on this thesis.

Finally, I would like to thank my friends and family for their support, especially my dearly beloved mother, Gunnvor Engtrø, who I can count on regardless and who will do anything to keep me happy and healthy.

Stavanger, December 2021

Espen Engtrø

Summary

People have sailed in polar waters for decades; more than one hundred years ago, Nansen and Amundsen explored the oceans of the Arctic and Antarctic with their expedition teams, with Amundsen leading the expedition that first reached the South Pole in 1911. A remarkable technological evolution has taken place since those days, bringing along even more astonishing innovations. Wooden ships with sail are replaced by standardized steel-constructed vessels, powered by diesel-electric engines or nuclear reactors, and highly technological satellite navigation and communication systems have replaced the sextant, chronometer, compass and surveyor's wheel guiding the way at that time. The knowledge and experience concerning risks and hazards associated with shipping in polar waters is outstanding. However, the increase in the shipping activity of various vessels in the Arctic region during recent years has resulted in new risks; consequently, the knowledge, experience and the capacity to handle these are limited. Seen historically, major accidents and events have raised the focus on safety and forced the way for the development, innovation and design of new technology and systems. As a response to the Titanic disaster in 1912, the International Convention for the Safety of Life at Sea (SOLAS) was agreed in 1914 and suggested the minimum number of lifeboats and other emergency equipment required to be maintained by merchant ships. Today, the SOLAS Convention is considered the most important of all international treaties concerning the safety of merchant ships and specifies the minimum standards for the construction, equipment and operation of ships. During the last century, several revisions and amendments to this Convention, adopted by the International Maritime Organization (IMO) in 1960, have strengthened the regulations for ship design and operations. Consequently, the maritime industry is forced to innovate, (re)-design and construct vessels, emergency equipment and systems, to become compliant with the SOLAS Convention.

In 2017, the IMO amended the SOLAS Convention, by implementing the International Code for Ships Operating in Polar Waters (Polar Code), providing mandatory rules and requirements applicable to ship operations in defined geographical areas in the waters around the Arctic and Antarctica. The Polar Code supplemented existing IMO conventions and regulations, with the goal of increasing the safety of ship operations and mitigating the impact on the people and environment in the remote, vulnerable, and potentially harsh polar waters. Ship systems and equipment addressed in the Polar Code are required to maintain at least the same performance standards referred to in the SOLAS Convention. The key principle of the regulation is founded on a risk-based approach in determining scope and a holistic approach in reducing identified risks. The Polar Code consists of function-based requirements, i.e., the regulation specifies *what* is to be achieved without specifying *how* to be in compliance with its requirements. The requirement to first carry out an operational (risk) assessment of the ship and its equipment, considering the anticipated range of operating and environmental conditions, is essential in the application of the Polar Code. This operational assessment shall guide the way in the establishment of ship-specific procedures and operational limitations, based on related risk factors in operating areas and taking into consideration the anticipated range of operating and environmental conditions: amongst others, operation in low air temperature, as this affects the working environment and human performance, maintenance and emergency preparedness tasks, material properties and equipment efficiency, survival time and performance of safety equipment and systems. The Polar Code requires that a Polar Service Temperature (PST) shall be specified for a ship intended to operate in low air temperature and that the performance standard shall be at least 10°C below the lowest Mean Daily Low Temperature (MDLT) for the intended area and season of operation in polar waters. The MDLT is the mean value of the daily low temperature for each day of the year over a minimum 10-year period. Survival systems and equipment are required by the Polar Code to be fully functional and operational at the PST during the maximum expected rescue time – i.e., the time adopted for the design of equipment and systems that shall provide survival support – which is defined in the Polar Code as never being less than five days.

The overall objective of this research is to contribute to the development of new knowledge concerning the implementation and application of the Polar Code and how this function-based regulation, so far, has succeeded in achieving its goal. Two research questions were developed to support the overarching objective, concerning the Polar Code's applicability as a regulatory instrument in Arctic shipping. The research questions were associated with: (1) the Polar Code's contribution to enhancing safety for shipping in the Arctic Ocean, considering the risks and hazards associated with activities in these waters, and (2) the identification of key mechanisms to ensure that compliance with the stated goal of the regulation occurs in a satisfactory manner. Individual interviews are conducted with experts in the field, concerning *the implementation and application of the Polar Code*. Moreover, two controlled experiments are performed, to assess the *risk to humans* and *equipment of low temperature* and *exposure*.

The implementation of new regulations can trigger the development of new products, systems and processes, even though, in the early stages, it can be unclear how the development will manifest itself. At the time of the implementation of the Polar Code in 2017 (1st January), there was a lack of guidelines or informative standards providing support to the Polar Code, and a variety of solutions on emergency equipment and systems could comply with the regulation's function-based requirements. Although the regulation provides additional guidance (in Part II-B) to the mandatory provisions (in Part II-A), this is in many cases general and generic. The operational assessment is required to address both individual (personal survival equipment) and shared (group survival equipment) needs, which shall be provided in the event of an abandonment of ship situation. The Polar Code states that this equipment shall provide effective protection against direct wind chill, sufficient thermal insulation to maintain the core temperature of persons, and sufficient protection to prevent frostbite of all extremities. In the guidance (Part II-B) of the regulation, samples of suggested equipment for personal survival equipment and group survival kits are provided. However, many products will comply with the suggested equipment, regardless of their suitability under real conditions. The protection against wind chill to humans, to prevent frostbite (and to increases the survival time) depends on factors such as time and type of exposure, individual physiological conditions and activity level, rather than just the types of gloves or shoes chosen and their protective status.

The sinking of a cruise liner is considered the ultimate challenge for the rescue capability in the Arctic region, and the passengers on cruise ships represent a vulnerable group for several reasons. The average passenger is typically older and less fit and would suffer from discomfort and hypothermia faster than younger persons, in a situation requiring evacuation to lifeboats, life rafts or directly onto ice. For shipowners and operators operating in polar waters and required to comply with the Polar Code, there can be economic incentives for neglecting or not actively taking part in the innovating process of improving and developing new systems and equipment sufficient to withstand low temperatures and the harsh polar conditions. High costs are expected in the work of developing and improving emergency equipment and systems, especially if technical and operational winterization upgrades of older vessels are necessary. Search and Rescue (SAR) exercises conducted in the waters surrounding Svalbard have revealed that the marine industry in general is reactive in the work of implementing the Polar Code's requirements. Consequently, many vessels are equipped with insufficient survival equipment, including insufficient food and water rations. Great variations are observed in Life-Saving Appliances (LSA) and arrangements, concerning both quality and functionality, approved by flag states and classification societies. There are, unfortunately, examples of tailored operational assessments which support marginal emergency equipment and systems, as the associated cost, weight, volume and capacity puts additional strain and restrictions on shipowners and operators. With limited communication between the suppliers of the development of survival equipment, there are large variations among the functionality of such equipment in polar waters. There is lack of harmonization and standardization amongst the subject groups supposed to comply with the Polar Code, and a common understanding of the most suitable and "state-of-the-art" LSA and arrangements required for an emergency response situation in polar waters seems not to be in reach yet.

SAR exercises conducted in the waters around Svalbard have also proved that joint efforts and collaborations amongst authorities, shipowners, operators, supply agents, experts within the shipping industry and academia are necessary to promote the development and innovation of rescue equipment and systems designed for "polar water survival", driven by scientific facts. This can force the way for new standards, guidelines and clearer requirements, supplementing the Polar Code, in respect of design, material selection, functionality and performance capacity. The main responsibility for ensuring the enforcement of internationally accepted maritime rules and regulations and the exercise of controls over ships, to ensure compliance with these, is the responsibility of the respective Flag States which the ships sail under. However, Port States are vital supplementary sources of authority that can compensate for deficiencies in these controls, particularly Port States in or near the Arctic, with a wide measure of discretion in exercising its jurisdiction over their ports. Moreover, independent classification societies, licensed by Flag States to survey and classify ships and issue certificates on their behalf, set standards for the design, maintenance, and repair of ships, covering hull strength and design, materials, main and auxiliary machinery, electrical installations, control systems and safety equipment. Class guidelines and notations issuing operational requirements for polar operations, developed by reputable classification societies, support the Polar Code development and application, practising its function-based requirements.

Raised awareness amongst social groups around implications and consequences, with regard to the risks associated with cruise traffic in polar waters and the lack of suitable and functional survival equipment and systems for polar water operations, can be a trigger and a driving force for the further innovation of ship design and the development of sufficient emergency equipment intended for storage and use in a cold climate. A valid point is who would be the voice and agent advocating for the passengers and their perspectives and interests. Other voices could argue that, instead of the constant urge to please the market-driven forces with more research, innovation and improvements, an approach with humility could be taken, where discussions concerning the need for mass tourism in remote, vulnerable and harsh polar areas could be useful. With raised concern and focus on polar voyages and passenger safety amongst social groups, stakeholders should take an active role and act as proactive technological innovators for the development of cold climate emergency equipment and systems. Holding a dominant role and leading position within maritime businesses in respect of the safe execution of polar voyages can in turn give advantages in the marketing process; returning and satisfied customers are beneficial for shipowners and operators. The further development and application of the Polar Code, and the ensuing innovation of ships, emergency equipment and systems designed for polar voyages, is expected to follow an incremental manner, i.e., existing SOLAS certified vessels, LSA and arrangements will undergo incremental changes to meet performance standards sufficient to comply with the regulation.

It must be realized that experience and training are success factors in an emergency situation. The Polar Code sets requirements for training, and an assessment of the effectiveness of training courses has been undertaken during this work. Even if the content of a course in principle is acceptable, the actual learning is no better than what is assimilated by the course participant through active participation.

Table of Contents

Table of Figures

List of Tables

List of abbreviations

ABR	Arctic Bridge Route
AIBN	Accident Investigation Board Norway
AIRSS	Arctic Ice Regime System
ALARP	As Low As Reasonably Practicable
CEO	Chief Executive Officer
DSB	Direktoratet for samfunnssikkerhet og beredskap
EEZ	Exclusive Economic Zone
FSC	Flag State Control
GA	General Alarm
GBS	Goal-Based Standards
HRO	High Reliability Organization
HSE	Health, Safety and Environment(al)
IACS	International Association of Classification Societies
III	(The IMO Sub-Committee on) Implementation of IMO Instruments
IMO	International Maritime Organization
IRGC	International Risk Governance Council
ISO	International Standard Organization
JRCC	Joint Rescue Coordination Centre

LNG	Liquefied Natural Gas
LSA	Life-Saving Appliances
MARPOL	International Convention for the Prevention of Pollution from Ships
MDLT	Mean Daily Low Temperature
MET	Maritime Educational Training
MoU	Memorandum of Understanding
MRO	Mass Rescue Operation
MSC	(The IMO) Maritime Safety Committee
NCA	Norwegian Coastal Administration
NCSR	(The IMO Sub-Committee on) Navigation, Communications and Search and Rescue
NEP	North-East Passage
NGO	Non-Governmental Organization
NMA	Norwegian Maritime Authority
NSR	Northern Sea Route
NWP	North-West Passage
PAME	Protection of the Arctic Marine Environment
PC	Polar Class
PhD	Doctor of Philosophy
POB	Personnel on Board

Polar Code	International Code for Ships Operating in Polar Waters
POLARIS	Polar Operational Limit Assessment Risk Indexing System
PSC	Polar Ship Certificate
PSC	Port State Control
PST	Polar Service Temperature
Ptil	Petroleumstilsynet
PWOM	Polar Water Operational Manual
SAR	Search and Rescue
SOLAS	International Convention for the Safety of Life at Sea
STAMP	System Theoretic Accident Model and Processes
STCW	International Convention on Standards of Training, Certification and Watchkeeping
Transport Canada	Canadian Flag State Authority
TSR	Transpolar Sea Route
UiS	University of Stavanger
UiT	The Arctic University of Norway - Tromsø
UNCLOS	United Nations Convention on the Law of the Sea
ZDS	Zone/Date System

Part I

1 Introduction

The Arctic Region is experiencing extensive growth in commercial shipping activities; simultaneously, the sea ice extent is steadily decreasing, opening the waters between the Atlantic and the Pacific Oceans during short periods of the year and enabling extended seasons and voyages in areas previously considered inaccessible for most ships during large periods of the year (Silber and Adams, 2019). This increase seen in activities related to science, tourism, shipping, fisheries and commercial aviation in polar regions means a higher probability of accidents, incidents or the requirement for emergency response, depending on the limited resources covering extremely large areas (Solberg et al., 2020). Search and Rescue (SAR) operations in the Arctic Region can be extremely demanding, and considerable risks are presented should a ship suffer ice or heavy weather damage, grounding or machinery failure, due to the extreme remoteness of the region and the limited readily deployable SAR facilities (Hill et al., 2015). The potential for delays in emergency response and the lack of suitable emergency response equipment (Solberg et al., 2016; Solberg et al., 2017; Solberg and Gudmestad, 2018; Gudmestad and Solberg, 2019), in addition to the relatively low traffic density in the Arctic Region, indicate that self-rescue is the core principle in the event of a maritime casualty and abandonment of ship (Larsen et al., 2016). The cruise industry is profit-driven, and, to remain commercially competitive, costs related to safety equipment are often kept to a minimum (Solberg, 2017). An emergency involving thousands of passengers to be rescued from a cruise ship is deemed highly critical, as the size and the capacity of SAR services in the Arctic Region are not prepared for such a scenario (Urke, 2018; Nilsen, 2018; Solberg et al., 2020). Additionally, *International Convention for the Safety of Life at Sea* (SOLAS) approved Life-Saving Appliances (LSA) and arrangements can be found on ships in voyages all around the world, whether the climatic conditions are tropical or polar. SOLAS certified emergency equipment has been scientifically tested and found to be insufficient aid for survival in emergency situations occurring in the cold and remote polar waters of the Arctic (Solberg and Gudmestad, 2018; Gudmestad and Solberg, 2019; Solberg et al., 2020).

1.1 The International Code for Ships Operating in Polar Waters (Polar Code)

On January 1, 2017, the *International Code for Ships Operating in Polar Waters* (Polar Code) was adopted by the International Maritime Organization (IMO) and came into force, applicable to the Arctic and Antarctic Oceans. The goals for implementing the Polar Code are *to provide for safe ship operation and the protection of the polar environment by addressing risks present in polar waters and not adequately mitigated by other instruments of the IMO* (International Maritime Organization [IMO], 2017, p. 5), *in order to increase the safety of ships' operation and mitigate the impact on the people and environment in the remote, vulnerable and potentially harsh polar waters* (ibid., 2017, p. 5). This function-based regulation constitutes a continuation of existing regulations, made mandatory under the SOLAS Convention (International Maritime Organization [IMO], 2001), the *International Convention on Standards of Training, Certification and Watchkeeping* (STCW) (Lovdata, 2018), and the *International Convention for the Prevention of Pollution from Ships* (MARPOL) (International Maritime Organization [IMO], 2005), applicable to all waters. The regulation consists of two parts: Part I contains provisions on safety measures, made mandatory under the SOLAS Convention; Part II contains provisions on measures to prevent pollution, made mandatory under the MARPOL Convention. Furthermore, Parts I and II are divided into two parts, with part one (I-A) being mandatory and part two (I-B) consisting of guidelines and recommendations to the mandatory provisions. In this work, the provisions on safety measures (Part I) of the Polar Code are examined.

The Polar Code's geographical area of application in the Arctic is shown in Figure 1 below. In the Antarctic, the regulations are applicable at the 60th parallel south.

Figure 1. The maximum geographical extent of the Polar Code's area of application in the Arctic (International Maritime Organization [IMO], 2017).

The Polar Code states that ships' systems and equipment addressed in the regulation shall satisfy at least the same performance standards as those referred to in the SOLAS Convention (ibid., 2017). The mandatory SOLAS Convention for merchant ships, therefore, constitutes a standardized minimum of expectations for the provision of safety measures for maritime design, equipment, systems and operations. Although the requirements in the Polar Code are distinctly functional, descriptive guidelines for the analytical processes are provided. The regulations use precise definitions, in addition to definitions referred to in the aforementioned conventions. The definitions *habitable environment, maximum expected time of rescue* and *Mean Daily Low Temperature (MDLT)* are significant for design and solutions and are determinative in the dimensioning processes of ship, systems and equipment. The most concrete and descriptive requirement concerns time of rescue, where *Maximum expected time of rescue means the time adopted for the design of equipment and system that provide survival support. It shall never be less than 5 days* (International Maritime Organization [IMO], 2017, p. 10).

1.2 Objective and research questions

The overall objective of this thesis is to contribute to the development of new knowledge concerning the Polar Code's *implementation* and how the function-based regulation, so far, has succeeded in achieving its goal: to provide for safe ships' operation and the protection of the people and the vulnerable environment, by addressing risks present in the potentially harsh polar waters (International Maritime Organization [IMO], 2017). Specifically, the following research questions support the overarching objective, concerning the Polar Code's applicability as a regulatory instrument in Arctic shipping:

- How does the function-based Polar Code contribute to enhancing safety for shipping in the Arctic, given that maritime activities in these waters are associated with great risks and uncertainties?

- What key mechanisms are determinants to ensure Polar Code application and utilization, as intended by the regulators, so that compliance with the stated goal of the regulation takes place in a satisfactory manner?

The term 'safety' is crucial in defining the objective and the research questions for this work. A general definition of safety is the condition of being protected from or unlikely to cause danger, risk or injury (Oxford University Press, 2010). Safety is a state of being safe or an activity working toward creating a safe state, i.e., safety itself is not a device but the freedom from conditions of unacceptable mishap risk (Ericson and Ericson, 2011). In this regard, the unacceptable risk shall be reduced to a level that is *as low as reasonably practicable* (ALARP), where "the burden of proof" is placed on identifying why safety measures cannot be implemented, meaning that identified safety measures must be implemented, unless an unreasonable mismatch between the cost and the benefit can be documented (Petroleumstilsynet [Ptil], 2006). The IMO's stated role regards safety of international shipping is to create working conditions so that ship operators cannot address their financial issues by simply cutting corners and compromising performance on safety, security and environmental issues. This is operated by the implementation of agreed international regulations and standards, for which the IMO is the forum in which this process takes place (International Maritime Organization [IMO], n.d. 5). Safety of shipping is, moreover, closely related to sufficient emergency preparedness and the availability of such resources. Emergency preparedness in this regard encompasses the planning and response to disasters and accidents, i.e., massive and small events, e.g., the grounding of the Titanic vs the accident of a person drowning, identified by the following the three main events (Puryear and Gnugnoli, 2020):

1. *Emergency planning:* i.e., planning and prevention of disasters and accidents – to limit the loss of life and reduce the financial impact of the event itself and the emergency response; risk assessments – to identify areas of high priority and vulnerability, which direct mitigation efforts; establishment of mitigating actions and measures, performed before the disaster or accident occurs, including proactive steps to limit vulnerability,

addressing previously identified risks to support the emergency response; preparedness measures taken to prepare for such events, outlined in, e.g., guidelines and standards; development of emergency response teams, providing clearly defined roles and responsibilities, addressing key issues in emergency response; development of emergency plans, providing details of the overall strategy to cope with disasters and accidents once they occur.

2. *Emergency response:* i.e., implementing and executing the emergency response plans, which, in the event of an abandonment of ship, generally concern the two response tactics of *evacuation*, e.g., evacuating from a ship in distress to dedicated lifeboats and rafts and evacuating from the rescue crafts to safe locations on shore; and the *establishment of shelters*, providing a safe location and resources to support survival.
3. *Emergency recovery:* i.e., normalization and the return to operational functions, as soon as the immediate threat to human life is under control.

As regards emergency preparedness concerning Arctic shipping and an accident requiring abandoning ship and escape to the water in survival craft, i.e., lifeboats and life rafts, or abandoning to ice or to land, self-rescue is the key principle. The Polar Code requires that resources shall be provided to support survival following abandoning ship, whether to the water, to ice or to land, for the *maximum expected time of rescue*, defined as the time adopted for the design of equipment and systems that shall provide survival support. This period shall never be less than five days (International Maritime Organization [IMO], 2017).

1.3 Thesis limitations and structure

In this research, the implementation and application of the Polar Code and the regulation's influence on the safety of Arctic shipping is considered. The System Theoretic Accident Model and Processes (STAMP) methodology (Leveson, 2011) is utilized to identify the main stakeholders in this system, in addition to the constraints established in this regulatory regime. Interviews of and meetings with recognized experts on the matter are conducted, covering representatives from the administration, i.e., the IMO, the Norwegian Maritime Authority (NMA), the Norwegian Coastal Administration (NCA), and classification society, in addition to persons with "hands-on" experience regarding the application of the regulation, i.e., representatives of shipowners and shipbuilders of polar vessels, and persons possessing extensive knowledge in the subject of ice identification and ice navigation in the Arctic Region. Moreover, two controlled experiments are performed to study the effects of the exposure of low temperatures on humans and equipment, which is one of the hazards highlighted in the Polar Code that shall be taken into consideration in the planning of voyages in polar waters, which also shall be reflected in the operational risk assessment, required by the regulation to be conducted.

The Polar Code is applicable to all SOLAS vessels operating in defined geographical areas in the Arctic and the Antarctic, but, in this work, the research is limited to Arctic shipping. Note that fishing vessels are not subject to the Polar Code and are not required to comply with its regulations. Moreover, this study examines Part I of the regulation, containing provisions on safety measures; Part II, containing provisions on measures to prevent pollution, is not examined. The Polar Code covers various aspects of ship structure, subdivision and stability, watertight and weathertight integrity, machinery installations, and fire safety and protection. This research is limited to the aspects in the regulation covering LSA and arrangements, ice identification and navigation, voyage planning, and manning and training.

This thesis consists of two parts, Part I of which contains eight chapters. Chapter 1 introduces the background of this thesis, defining the established objective and related research questions, including this thesis' limitations. Chapter 2 describes Arctic shipping, the applicability of the Polar Code, and related hazards and winterization measures associated with navigation in these waters. Chapter 3 presents the regulatory mechanisms and the governance of international shipping in the Arctic. Chapter 4 presents this thesis' theoretical framework, in addition to a model for understanding the interaction and constraints involved in regulating maritime activities in polar waters. Chapter 5 presents the methodology used in this thesis, while Chapter 6 presents the main findings and results of this research. Chapter 7 discusses the findings, in addition to assessing the Polar Code's influence on the safety and emergency preparedness of Arctic shipping. Chapter 8 summarizes this thesis' conclusion and the further research needed.

Part II contains the six research papers that are included in the thesis:

I. Engtrø, E., Njå, O., and Gudmestad, O. T. (2018). *Polarkoden – funksjonsbasert forskriftsverk for polare farvann. Hvordan kan standarder presentere gode nok løsninger? [The Polar Code – function-based regulations for polar waters. The contribution of standards to safe and sufficient solutions?].* In: Lindøe, P. H., J. Kringen, and G. S. Braut. Regulering og standardisering - Perspektiver og praksis [Regulation and standardization - Perspectives and practice] (pp. 146-162). Universitetsforlaget - Scandinavian University Press.

II. Engtrø, E., and Gudmestad, O. T. (2019). "Winterization and drilling operations in cold climate areas" [paper presentation]. *Proceedings - International Conference on Port and Ocean Engineering under Arctic Conditions (POAC)* (pp. 1-9). Delft, The Netherlands.

III. Engtrø, E., Gudmestad, O. T., and Njå, O. (2020). "Implementation of the Polar Code: Functional Requirements Regulating Ship Operations in Polar Waters". *Arctic Review on Law and Politics*, Vol. 11 (pp. 47-69). http://dx. doi.org/10.23865/arctic.v11.2240

IV. Engtrø, E., Gudmestad, O. T., and Njå, O. (2020). "The Polar Code's Implications for Safe Ship Operations in the Arctic Region." *TransNav - The International Journal on Marine Navigation and Safety of Sea Transportation*, Vol. 14:3 (pp. 655-661). DOI: 10.12716/1001.14.03.18

V. Engtrø, E., and Sæterdal, A. (2021). "Investigating the Polar Code's Function-Based Requirements for Life-Saving Appliances and Arrangements, and the Performance of Survival Equipment in Cold Climate conditions – test of SOLAS approved desalting Apparatus at Low Temperatures." *Australian Journal of Maritime & Ocean Affairs* (pp. 274-294).
DOI: 10.1080/18366503.2021.1883821

VI. Engtrø, E. (2021). "A Discussion on the Implementation of the Polar Code and the STCW Convention's Training Requirements for Ice Navigation in Polar Waters." *Journal of Transportation Security* (pp. 1-27). DOI: 10.1007/s12198-021- 00241-7. Accepted for publication.

2 Arctic shipping

Shipping across the northern polar region connects the Pacific and the Atlantic oceans by trans-Arctic routes (Figure 2). The three main routes connecting Asia with Europe are the Northwest Passage (NWP), the Northeast Passage (NEP), and the mostly unused Transpolar Sea Route (TSR), which bisects the Arctic Ocean through the North Pole (Farré et al., 2014; Ghosh and Rubly, 2015). In addition, the Arctic Bridge Route (ABR), a shipping route linking the Arctic seaports of Murmansk (Russia) and Churchill (Canada), could develop into a future trade route between Europe and Asia (Humpert and Raspotnik, 2012).

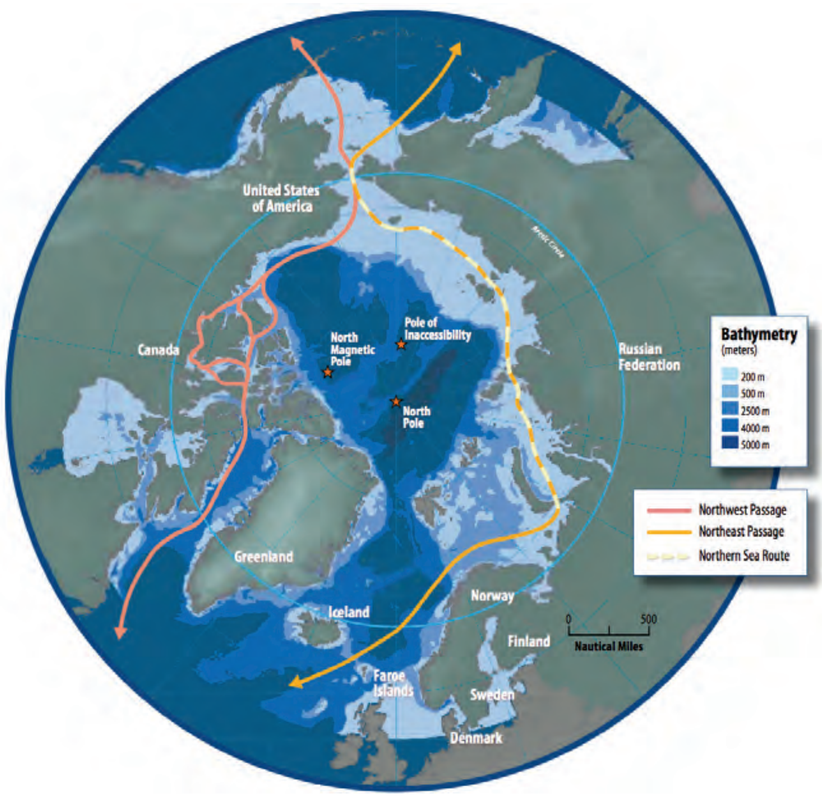


Figure 2. Main shipping routes in the Arctic Region (Arctic Council, 2009).

The NWP (Figure 3) is the name given to the various marine routes between the Atlantic and Pacific oceans, along the northern coast of North America that span the Canadian Arctic Archipelago, consisting of five recognized marine routes or passages, with variations. The NEP is defined as the set of sea routes from northwest Europe around North Cape (Norway) and along the north coast of Eurasia and Siberia through the Bering Strait to the Pacific and includes the Northern Sea Route (NSR) (Figure 3) (Arctic Council, 2009).

Figure 3. Map of Arctic Ocean shipping routes showing the NSR and NWP (Brigham, 2020).

The NSR is defined in Russian Federation law as a set of marine routes from Kara Gate (and the northern tip of Novaya Zemlya) in the west to the Bering Strait in the east (Arctic Council, 2009). The entire route lies in Arctic waters and within Russia's exclusive economic zone (EEZ).

2.1 Prevailing Arctic conditions

The Arctic Circle (Figure 3), a line of latitude around the earth, at approximately 66°33′ North, includes all the ice-covered Arctic Ocean and the surrounding land of Greenland and Spitsbergen and the northern parts of Alaska, Canada, Norway and Russia. Climate conditions in this region are characterized by long, cold winters and short, cool summers; the average winter temperatures range from −34°C to 0°C, and average summer temperatures range from −10°C to +10°C. The wind speeds over the Arctic Basin are between 4 and 6 m/s (7 and 12 knots) in all seasons. Stronger winds do occur in storms, often causing whiteout conditions (Trantzas, 2017; Cohen et al., 2017). Rapidly developing low-pressure systems (polar lows) are common weather phenomena during winter seasons. Polar lows are characterized by sudden strong winds and low temperatures, heavy snow showers, thunder and lightning, choppy sea surfaces, and increased wave heights; they can be hard to forecast and predict, due to the nature of their development (International Standard Organization [ISO], 2019; DNV GL, 2015a).

Some parts of the Arctic are covered by ice (sea ice and glacial ice) all year, and nearly all parts experience long periods with some form of surface ice (Trantzas, 2017). However, the Arctic is not homogeneous with respect to prevailing environmental conditions. Considerable differences exist between not only seasons but also geographic locations. The Beaufort and Chukchi Seas north of Alaska and Canada, for example, are covered with ice every year, whereas the southwestern part of the Barents Sea off the coast of Norway is often said to be ice-free (DNV GL, 2015a).

2.2 Ship traffic in the Arctic Region and Polar Code applicability

The ship traffic in the Arctic can be divided into four main categories (Jean-Hansen, 2003; Protection of the Arctic Marine Environment [PAME] 2020):

1. Oil tankers or Liquefied Natural Gas (LNG) tankers/condensate tankers and tankers for refrigerated gas
2. Transport ships (with cargo other than oil or gas)
3. Passenger ships (including cruise ships)
4. Fishing vessels.

Measurements of the volume of shipping within the Polar Code's geographical area of application in the Arctic, taken between 2013 and 2019, show a substantial increase in traffic, when counting both the number of individual ships (up 25 percent) and the total nautical distance sailed during the six-year period in the same area (up 75 percent). Fishing vessels represent more than 40 percent of all ships in the Arctic area, and, of the total distance sailed, fishing vessels account for 45 percent (Protection of the Arctic Marine Environment [PAME], 2020). Additionally, an increase in passenger-ship traffic in the northern areas is expected, especially due to reduced sea ice enabling ship traffic in open waters between the Atlantic and the Pacific Oceans during short periods of the year. In 2016 and 2017, the passenger ship, Crystal Serenity, sailed through the NWP from Alaska to New York, with more than 1,000 passengers, on its first voyage (Grønnestad, 2017). Until the introduction of COVID-19 to the world, the shipbuilding industry delivering polar expedition vessels for the Arctic was peaking, with 28 new builds expected to be launched in the four-year period from 2018 to 2022. This was in addition to the almost 80 polar ships already operating with passengers in these waters at that time (Nilsen, 2018). The new polar expedition vessels are, in general, delivered with higher ice classes, i.e., Polar Class (PC), than the existing ones, enabling voyages in even more remote areas outside the regular sailing season during summertime, going from May to September in the Arctic Region (Nilsen, 2018). Moreover, the extraction of natural resources in the Arctic is expanding and contributing to an increase in bulk carrier traffic in the region (Protection of the Arctic Marine Environment [PAME], 2020).

The Polar Code is, however, only applicable to vessels found in categories 1 to 3, i.e., any cargo ships of more than 500 gross tonnage and passenger ships which carry more than twelve passengers (International Maritime Organization [IMO], 2001). Fishing vessels, which are the dominant group of vessels trafficking in the Arctic, are subject to neither the SOLAS Convention nor any other international safety regulations. In 1977, IMO approved the Torremolinos International Convention (International Maritime Organization [IMO], 1977) but has yet to succeed in achieving ratification of the protocol by enough states with large numbers of fishing vessels (International Maritime Organization [IMO], n.d. 6; Petursdottir et al., 2001). In addition to fishing vessels, ships of war and troopships, cargo ships of less than 500 gross tonnage, ships not propelled by mechanical means, wooden ships of primitive build, and pleasure yachts not engaged in trade are exempt from the safety provisions of the Polar Code (Part I) (International Maritime Organization [IMO], 2001).

2.3 Navigation in the Arctic

Navigation in the Arctic involves many challenges, due to the rapidly changing landscape of sea ice, draft restrictions in many areas, lack of hydrographic data and detailed surveys, less reliable navigation and satellite communication, and reduced visibility due to fog or darkness for long periods of the year (Hill et al., 2015; Ghosh and Rubly, 2015; DNV GL, 2015a). The presence of ice represents one of the greatest hazards, with floating ice in many forms constituting an extremely hazardous condition if colliding with a ship in voyage, involving the possibility of damage to hull and structure (Ghosh and Rubly, 2015). Ice accretion caused by sub-zero temperatures and the freezing of sea spray coming into contact with the ship's surfaces is the most hazardous form of icing and also the most common, and uncontrolled sea spray icing can represent a great probability regarding loss of ship stability, integrity and equipment failure (ibid., 2015; International Standard Organization [ISO], 2019).

2.4 Winterization measures

Technical and operational winterization measures capable of withstanding the harsh and prevailing climatic conditions in the Arctic Region are required on ships intended for polar water operations. Winterization measures are primarily targeted by limiting and controlling the adverse effects of freezing, icing, low temperatures and strong winds (wind chill). The main concerns are the protection of personnel, material properties and safety critical equipment (DNV GL, 2015a). Active winterization measures require electrical or mechanical energy, e.g., heat-traced walkways and escape routes, heat-insulated piping (e.g., fire water lines), keeping circulation in lines to prevent liquid from being static (e.g., fire water mains and cooling water branch lines), or lowering the freezing point of fluids by adding chemicals (e.g., glycol). Passive winterization measures are characterized as measures in which no energy is needed, but the design, construction and packaging prevent the adverse effects of icing, freezing and wind chill, e.g., shielded walkways, escape routes and enclosed muster areas; the elimination of pockets, dead-ended pipes, and legs in piping; extra insulation and packaging; and work clothing intended for low temperatures (DNV GL, 2015a; Ghosh and Rubly, 2015; Engtrø and Gudmestad, 2019).

3 Governance and regulation of international shipping in the Arctic

Regulatory science is a relatively new field of study, developed within more established disciplines, i.e., social and jurisprudence science. Additionally, the connection to science concerning safety and risk management is strong, considering that regulations mainly aim to reduce or control identified risks (Kringen, 2018). Regulation can be understood as sustained and focused control exercised by a public agency over activities that are valued by a community. This includes the senses of: a specific set of commands, meaning a binding set of rules to be applied by a body devoted to this purpose; a deliberate state of influence, meaning all authority (state) actions designed to influence industrial or social behaviour, e.g., command-based regimes, economic incentives, contractual powers, deployment of resources, franchises, or the supply of information; and all forms of social control and influence, meaning all mechanisms affecting behaviour (Baldwin et al., 2012). Regulation is a much wider concern than an interest in governing by rule, as regulation is central to the interaction between economic, legal, political and social life (Baldwin et al., 2010). Over the last decades, *decentralized regulation* has gained focus in the literature concerning regulation, considering not only state authority in the regulating regime but also the multiple actors participating in the system, i.e., intergovernmental and Non-Governmental Organizations (NGOs), standards organizations, classification societies, expert organizations and labour organizations. Decentralized regulation has gained this attention in research, due not only to the fact of the actual appearance of the phenomenon in our societies but also to the acknowledgement that regulation of behaviour between different actors, operating at various levels, is considered as a prerequisite for maintaining safety in risk management (Kringen, 2018). Modelling risk management in a dynamic society, where all actors continuously strive to adapt to changes and the pressure of markets, needs a cross-disciplinary approach, considering risk management to be a control problem and serving to represent the control structure involving all levels of society for each identified hazard (Rasmussen, 1997). In these regards, decentralized regulation captures all the elements and activities making up the regulatory regime, including the interaction taking place between the actors operating in the system. In this sense, decentralized regulation is closely related to the term *governance*, meaning the total assembly of actors, their interactions, and the related mechanisms for regulation (Kringen, 2018). The following definition of regulation reflects on the phenomenon:

> *The sustained and focused attempt to alter the behaviour of others according to defined standards and purposes with the intention of producing a broadly identified outcome or outcomes, which may involve mechanisms of standard-setting, information-gathering and behaviour modification.* (Black, 2002, p. 26)

3.1 Flag State Control (FSC)

The primary responsibility for exercising control over ships, to ensure compliance with internationally accepted rules and regulations, rests with the respective Flag States which the ships sail under. According to the United Nations Convention on the Law of the Sea (UNCLOS) (Art. 94), every state shall effectively exercise its jurisdiction and control over ships flying its flag and take necessary measures to ensure safety at sea, regarding, e.g., the construction, equipment and seaworthiness of ships, the manning and labour conditions, and the training of crew members, according to the applicable regulations and requirements in the operating areas (Todorov, 2020). The national maritime administrations act as Flag States on behalf of the country in question and, based on technical documentation and inspections, ships are subject to registration and granted the required certificates (Kristiansen, 2004).

3.2 Port State Control (PSC)

Enforcement of international maritime rules and regulations is the responsibility of the Flag States; however, Port States are vital supplementary sources of authority that can compensate for deficiencies in FSC, particularly Port States in or near the Arctic, with a wide measure of discretion in exercising its jurisdiction over its ports (Bai and Wang, 2019; Brigham, 2017). Port State Control (PSC) is the inspection of foreign ships in national ports to verify that the condition of those ships and their equipment complies with international standards and that they are manned and operated according to the related requirements of international regulations (Bai and Wang, 2019; Roach, 2017).

3.3 Classification societies

Classification societies are independent bodies, licensed by Flag States to survey and classify ships and issue certificates on their behalf, which set standards for the design, maintenance and repair of ships, covering hull strength and design, materials, main and auxiliary machinery, electrical installations, control systems and safety equipment (Kristiansen, 2004). Class certificates are issued, based on drawings, engineering documentation, inspections during building and tests, and classed ships will be surveyed on a regular basis and given recommendations for necessary maintenance and repair to maintain their class (ibid., 2004). The class functions as a negotiation for the insurance companies and represents in this sense a quality statement regarding the ship's standard. The largest and most acknowledged and recognized marine classification societies in the world are the members of the International Association of Classification Societies (IACS) (ibid., 2004), which participated actively during the Polar Code development, by adopting the requirements concerning PC, now forming the basis for the Polar Code's mandatory provisions concerning PC (Chircop, 2017).

3.4 The Arctic Council

The Arctic Council was formally established in 1996 and is a high-level intergovernmental forum promoting cooperation, coordination, and interaction among the Arctic States, Arctic Indigenous peoples, and other Arctic inhabitants, on issues of sustainable development and environmental protection in the Arctic. The Ottawa Declaration defines the following eight states as Members of the Arctic Council: Canada, Denmark (Greenland), Finland, Iceland, Norway, The Russian Federation, Sweden, and the United States. Moreover, thirteen non-Arctic states are approved as observers to the Council, e.g., China, Japan, and France, in addition to thirteen intergovernmental and inter-parliamentary organizations, and twelve non-governmental organizations (Arctic Council, n.d.). The Council's activities are conducted in six working groups that perform the role of the forum, i.e., to monitor, assess and provide non-legally binding policy and regulatory guidance (Molenaar, 2017). During the Polar Code development, member states of the Council were proactive in pushing for the implementation of the mandatory regulation (Brigham, 2017). The IMO was granted observer status at the Arctic Council in 2019, and the Council and its Working Group on the Protection of the Marine Environment (PAME) have engaged in and promoted the implementation of the Polar Code, and various IMO representatives have participated in and contributed to PAME meetings (International Maritime Organization [IMO], n.d. 2).

3.5 The United Nations Convention on the Law of the Sea (UNCLOS)

Regulating international ship operations is based on a global regulatory regime, built on international maritime conventions, established under UNCLOS, which relies on international cooperation between intergovernmental organizations as a mechanism for the development, establishment and implementation of new conventions and regulations.

In this regard, "the competent international organization", as referred to in UNCLOS – being the lead institution to address maritime matters – is interpreted to mean the IMO (Chircop, 2017).

3.6 The International Maritime Organization (IMO)

The IMO plays an instrumental role in generating maritime regulations, rules, standards, procedures and recommended practices governing international shipping; it facilitates the national implementation of international instruments, promoting frameworks and practices for cooperation between maritime administrations and the industry (ibid., 2017; Hebbar et al., 2020). The institutional structure of the IMO consists of the Assembly, Council, Secretariat and specialized committees and sub-committees, responsible for keeping the regulatory framework of the IMO developed and maintained on a continuous basis (Chircop, 2017). National delegations drive committee work and formally make decisions, heavily influenced by the participation and involvement of other intergovernmental and NGOs, encompassing a wide range of associations for industry, maritime labour, environmental protection, education and training, and various professions (ibid., 2017).

3.7 The International Convention for the Safety of Life at Sea (SOLAS)

The most important of all international treaties concerning the safety of merchant ships is reckoned to be SOLAS (International Maritime Organization [IMO], 2001). The first version was adopted in 1914, in response to the Titanic disaster, later updated and amended on numerous occasions. The main objective of the SOLAS Convention is to specify minimum standards for the construction, equipment and operation of ships, compatible with their safety (International Maritime Organization [IMO], n.d. 3). The SOLAS Convention consists currently of 14 chapters, of which Chapter 14 – the Polar Code (See chapters 1.1 and 3.8) – is discussed in this work.

3.8 The International Code for Ships Operating in Polar Waters (Polar Code)

The Polar Code acknowledges that the risk level may differ, depending on the geographical location and time of year, and mitigating measures required to address hazards may therefore vary within polar waters. The main principle for the Polar Code and the utilization of its function-based requirements are based on the requirement to, first, carry out the operational risk assessment of the ship and its equipment, considering the anticipated range of operating and environmental conditions. The operational assessment then guides the way in the establishment of procedures or operational limitations, based on related risk factors in operating areas, covering (International Maritime Organization [IMO], 2017, pp. 6-7 and p. 12):

- operation in ice
- topside icing
- operation in low air temperature
- operation in extended periods of darkness or daylight
- operation in high latitude
- operation in remote areas, possible lacking accurate and complete hydrographic data, and information, with reduced availability of navigational aids and seamarks, with increased potential for groundings
- limited readily deployable SAR facilities, delays in emergency response and limited communications capability, with the potential to affect incident response
- potential lack of ship crew experience in polar operations, with potential for human error
- potential lack of suitable emergency response equipment, with the potential for limiting the effectiveness of mitigation measures
- rapidly changing and severe weather conditions, with the potential for escalation of incidents
- the environment with respect to sensitivity to harmful substances and other environmental impacts and its need for longer restoration

4 Theoretical foundation

The previous chapter showed that the mechanisms governing and regulating international shipping consist of a multitude of global, regional and bilateral bodies and agencies, of which the IMO is the most prominent. Given the fact that this domain is quite extensive, there is a need in this research to identify the interaction taking place in this regulatory regime and to explore the established constraints that regulate the bodies and agencies involved in Arctic shipping, regarding the management of polar water hazards and risks.

4.1 Conventional and systemic risks

There is no agreed definition of risk, and the concept of risk differs in the literature. Risk is used to define expected values, probability distributions, uncertainties, or events (Aven and Renn, 2010). The IMO defines risk as the combination of the frequency and the severity of the consequence (International Maritime Organization [IMO], 2013). However, considering consequences or events as subject to uncertainties, the following definition of risk is suggested: *risk refers to uncertainty about and severity of the events and consequences (or outcomes) of an activity with respect to something that humans value* (Aven and Renn, 2010, p. 8). Maritime stakeholders, including international organizations, national and private interests, have spent considerable resources to mitigate the adverse impacts of risk in the industry over recent decades, mainly by incorporating new legislation. Nevertheless, it is difficult to assess the effects of these efforts, particularly because isolating the effects of each implemented risk-reducing measure is impossible, considering the complexity of cause-and-effect relations in shipping (Kristiansen, 2004).

In today's world, risks and systems are deeply inter-connected, and it can therefore be useful to distinguish between conventional and systemic risks (International Risk Governance Council [IRGC], 2017). Conventional risks are characterized by a well-known probability distribution over a limited scope of adverse effects (Kristiansen, 2004), e.g., the shipwreck of a small fishing vessel in the Arctic, resulting in a limited number of casualties and negligible environmental impacts. In contrast, the concept of systemic risk refers to the probability of breakdowns in entire systems, due to high levels of connectivity, major uncertainties and ambiguities, and non-linear cause-effect relationships (ibid., 2004), e.g., the Exxon Valdez accident in 1989, where the oil tanker ran aground near the coast of Alaska, spilling more than 33,000 tons of crude oil, becoming one of history's largest environmental disasters. The shipwreck had major impacts on the ecosystem and wildlife, resulting in reductions in various fish stocks, affecting fisheries and local communities, which are still recovering today (Gannon, 2014; Struck, 2009).

Due to their complexity, the identification and mitigation of systemic risks is demanding work, as they evolve because of the increased vulnerabilities and the interconnections between geographic areas, the interaction taking place between the multiple stakeholders, and the functional dependencies between the various sectors of society (Aven and Renn, 2010). The nature of systemic risks can seriously threaten the functionality of critical systems essential to society, which means that risk management cannot be handled through the actions of a single sector. Instead, the management of systemic risks requires the involvement of different stakeholders, including governments, industry, academia and members of civil society, as they are embedded in the larger context of societal, financial and economic change (International Risk Governance Council [IRGC], 2017).

4.2 Risk and accident models

The shipping industry is recognized as being complex, characterized by significant diversity in a globalized setting (Manuel, 2011), making governance and control of safety in shipping also complex, considering the application of international, regional and national laws and regulations to be applied to, and controlled by, several actors and agencies, on a variety of vessels, during their life cycles (Kristiansen, 2004). In the nuclear, oil, gas and chemical process industries, the use of accident models, including preventive scenarios, has become a standard part of the safety system. However, in industries comparable with shipping, i.e., aviation and rail transport, accident investigations have revealed that scenario and risk modelling, containing explicit descriptions of risks and how these are controlled, in many cases has been nonexistent (Hale and Heijer, 2006). There is, nevertheless, a growing body of academic literature presenting models, approaches and frameworks for assessing the safety and environmental risks associated with shipping (e.g., Goerlandt and Pelot, 2020; Valdez Banda and Goerlandt, 2018; Wang et al., 2020).

4.3 Normal accident theory

In his book about safety and high-risk technologies, Perrow (2011) provides a detailed analysis of society's complex and tightly coupled systems. Amongst the catastrophic events and risk-exposed industries analysed, marine accidents are under discussion. Perrow (2011) claims that the marine industry is a still more complex system, compared to aviation and airways, nuclear and petrochemical plants, and a more extended analysis is therefore required.

> *Marine transport appears to be an error-inducing system, where perverse interconnections defeat safety goals as well as operating efficiencies. Technological improvements did increase output but probably have helped increase accidents; with radar,*

> *the ship can go faster; when two ships have radar, they are even more likely to collide.* (ibid., 2011, p. 230)

Perrow (2011) defined system accidents (or normal accidents) as involving *the unanticipated interaction of multiple failures*, identified by the concepts of *complexity* and *coupling*. The complexity is characterized by multi-component systems, with high levels of interaction between the components which occur in non-linear ways. Complex and non-linear interactions will generally be those not intended in the design, which lead to unexpected event sequences and are often related to feedback loops introduced to increase the efficiency. A change in one component may trigger a new feedback loop, inhibit an existing one or turn a feedback loop into its opposite (SINTEF, 2010). This interactive complexity may help create new categories of accidents and unknown side effects. On the contrary, linear interactions lead to predictable and comprehensible event sequences, and the system is functioning as per design.

The other concept (coupling) that identifies system accidents is reasonably independent from the dimensions of complex interactions and linearity. However, the notion of an error-inducing system itself is derived from the concepts of *complexity* and *coupling* (Perrow, 2011). Tightly coupled systems have more time-dependent processes, compared to loosely coupled systems, and do not allow for delays, as there is no buffer to handle unexpected events. The systems have little slack, and the quantities must be precise, with a change in one component potentially leading to a rapid and unexpected change in related components (ibid., 2011).

> *Some technological fixes on individual ships had the unanticipated consequence of changing a loosely coupled set of ship interactions to a tightly coupled one, making recovery more difficult when failures occurred.* (ibid., p. 175)

Perrow (2011) argued that major accidents are fundamentally different from minor events (typically component failure accidents), which normally do not involve any unexpected interactions, and that some system accidents eventually are inevitable in extremely complex systems, given the characteristics of the system involved.

> *The ship itself, with its power plant, explosive mixtures, steering apparatus, and draft in shallow channels is important, but so are other ships, the insurance industry, the fragmented shipping industry, attempts are regulation, rules of the road, dangerous cargoes, national jealousies and interests, and, of course, the horrendous environmental problems of fog, ice, and storms.* (ibid., 2011, pp. 229-230)

4.4 High Reliability Organizations (HROs)

Perrow's theory about system accidents, and his pessimistic view that certain high-risk technologies should be abandoned in their current form, due to lack of adequate control, formed the discourse and contributed to the development of an alternative theoretical approach, studying High Reliability Organizations (HROs) (Rochlin et al., 1987; Weick, 1987; Roberts, 1990; Roberts and Bea, 2001). This research also drew attention to high-risk technologies and complex systems, but, as it was rather challenging to explain why accidents occurred, the HRO approach cared to explain why so few serious accidents occurred (SINTEF, 2010). The HRO theorists focused on the fact that, despite the hazards of complexity and tight couplings, which are characteristic of these systems, the continuous management of safe, reliable, and functional high-risk, high-hazard organizations, over periods of time, is achieved by the organization's flexibility and ability to sufficiently decentralize to handle the interactive complexity and, at the same time, to sufficiently centralize to handle the tight coupling (ibid., 2010; Sutcliffe, 2011). Through anticipating problems (1-3), and containing problems after they happen (4-5) (Weick and Sutcliffe, 2007), five core principles guide HROs: (1) pre-occupation with failure, i.e., no failures are ignored but, rather, viewed as opportunities to improve, where evidence is gathered for all incidents and near-misses and evaluated thoroughly; (2) reluctance to simplify interpretations, i.e., the complexity defining an HRO is embraced, and every incident is considered an opportunity to thoroughly examine root causes, to better understand and manage the system; (3) sensitivity to operations, i.e., a collective state of "chronic unease" and a sense of ever-present shared alertness to the system state and its processes, where all failures are monitored; "close calls" show that something is wrong with the system since it almost crashed and the right lessons from the non-event must be learned; (4) commitment to resilience, i.e., HROs are adaptable, learning organizations and can experience a failure that requires correction but still continue operating under degraded conditions, while at the same time acquiring resources to restore capacity within a dynamic environment; (5) deference to expertise, i.e., in high-risk conditions where the circumstances change rapidly, expertise or situational knowledge are essential for urgent assessment and response, and the focus is on what the system knows and can handle, rather than taking pride in "expertise" conferred by hierarchical authority and greater seniority.

The HRO theory and its key principles are widely applied in high-risk and high-hazard industries to achieve minimal errors. A major increase in activity is being experienced in application and research associated with the HRO theory, and a growing number of other industries and sectors in society, e.g., health care systems, are taking an interest in adopting its principles (e.g., Sutcliffe, 2011; Veazie et al., 2019; Cantu et al., 2020). However, basic assumptions about HROs are being questioned, i.e., claiming a system can be reliable but unsafe or safe but unreliable, suggesting that safety and reliability are different properties (Leveson, 2011). Moreover, traditionally, causality models are based on a linear approach to modelling risk management, i.e., viewing accidents in terms of multiple events and active failures sequenced as a forward chain over time, penetrating the defences-in-depth, based on root causes and failure events (Reason, 2016; Leveson, 2011). Such event-chain models are viewed as inadequate to analyse systemic risk, which involves the entire sociotechnical system and is deeply influenced by organizational and human factors (Rasmussen, 1997). In the recognition that accidents occur due to a combination of unexpected conditions – the concurrence of two (or more) events happening at the same time and affecting each other – complex systemic models have gained attention (Hollnagel and Woods, 2006). For such models to be useful, they must be able to capture complex and tightly coupled sociotechnical systems that are controlled in an interface between humans and automated processes, driven by advanced technology and software-intensive systems (Leveson et al., 2006).

4.5 The System Theoretic Accident Model and Processes (STAMP)

During this work, the STAMP methodology is utilized to model and analyse the Polar Code's influence on safety of shipping in the Arctic Region. Maritime actors and mechanisms associated with Arctic shipping and the interaction between these environments are viewed in the hierarchical control structure, in Figure 4. The STAMP methodology is based on system theory and provides a modern theoretical foundation for system safety, based on three fundamental concepts: *constraints, hierarchical levels of control* and *process models*. In STAMP, a system dynamic approach is taken, emphasizing its core principle for maintaining system safety – the enforcement and control of safety constraints. Causations are found in the interaction between layers and components in the hierarchical system, and risk management is viewed as a control problem, where accidents occur as a result of violation of safety constraints that are inadequately controlled (Leveson, 2011; Leveson et al., 2006). In Figure 4, the legislators are viewed on top, represented in this case by the IMO, facilitating and implementing conventions and regulations; constraining governmental bodies; recognized organizations; Flag States; and classification societies. These stakeholders perform controlling activities (e.g., verifications, audits, and certifications) at lower levels in the hierarchical system, represented by maritime educational institutions and certified training institutes, shipowners, operators and respective companies, with their management, engineers and planners and, finally, the personnel assigned on ships operating in polar waters. At the bottom of the hierarchical safety control structure, the operating process is modelled.

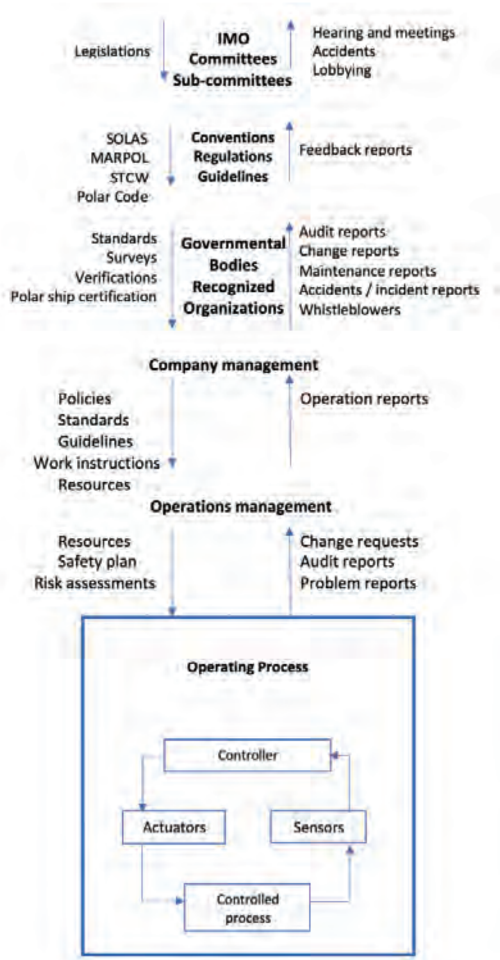


Figure 4. Modelling system safety, governance and regulation of international shipping activities (adapted from Leveson, 2011).

The core principle for maintaining system safety in the control structure is in the enforcement of established safety constraints, during the interaction taking place between the various stakeholders, sectors, and actors, indicated with reference, and measuring channels in the model between each level of the hierarchy. Risk management in STAMP is viewed as a control problem, and unplanned events occur because of inadequate control or lack of enforcement of safety constraints (ibid., 2011). Safety therefore depends on adequate control of work processes and sufficient constraints being in place, ensuring correct behaviour, functions and interaction in the hierarchical system (Rasmussen, 1997; Leveson, 2011). Risk management is enforced by the control of behaviour and functions, and in the constraints established for the design, management, manufacturing, and technical processes, driven by laws and regulations. Sociotechnical systems are not static, and both systems and their environments change over time; therefore, the specifications addressed in the established design specifications must be dynamically assessed and changed accordingly. Violation of the original hazard analyses can put uncalculated pressure on the design, leading to an event (ibid., 2011). Objectives and performance criteria for the controllers must be specified, and, from a feedback control point of view, analyses must be conducted, providing information about the current state of the system, verifying the established boundaries for safe behaviour (Rasmussen, 1997). Maintaining system safety over time depends on the controllers possessing accurate information, reflecting the context in which they operate, and designed procedures, control loops and processes, which again are controlled, being in place, driven by the dynamics of the sharing and collection of data concerning the system state (ibid., 1997; Leveson, 2011). A thorough understanding of the control requirements for all sources of hazards must be obtained, and parameters sensitive to unsafe control actions and how the system will respond to various control actions must be understood, shared and established. A systemized classification of the hazards should be presented, and, for each source of hazard, the control structure, its controllers, and their capability to control should be identified and evaluated (Rasmussen, 1997).

It is important to note that control does not only imply a strict control structure, considering that behaviour is controlled both directly by management intervention and indirectly by policies, procedures and the social and organizational context in which the behaviour occurs (Leveson et al., 2006). This requires human resources to acquire sufficient levels of competence and experience, in addition to being organized in a manner that ensures that essential information about the context of the environment is updated and shared, enabling the management system to present an accurate status of ongoing activities. Effective communication channels must be in place between the interacting levels in the hierarchy (Figure 5), in both a downward reference channel, providing the information necessary to impose safety constraints on the level below, and an upward measuring channel, to provide feedback on how effectively the constraints are being satisfied (Leveson, 2011, p. 83).

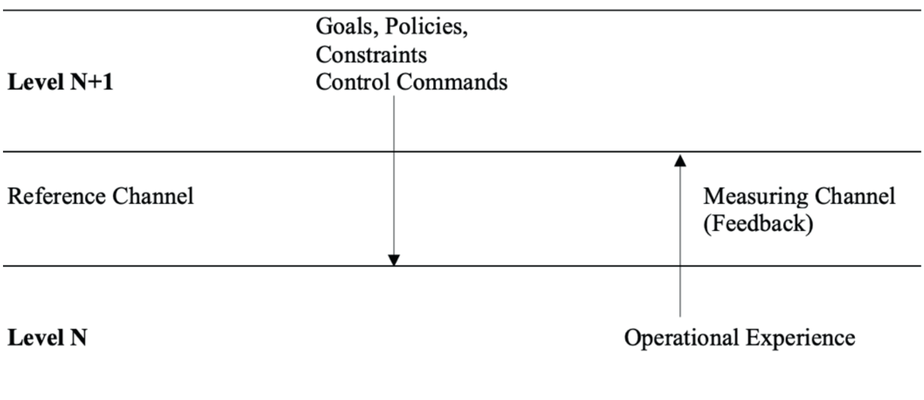


Figure 5. Communication channels between control levels (Leveson, 2011, p. 83).

System safety is maintained if established boundaries for safety constraints are not violated; however, this will eventually occur as, in the attempt to optimize their work, persons and organizations will explore these boundaries (ibid., 2011). An explicit identification of the boundaries for safe behaviour, as well as making these boundaries visible and manageable for the subjects of the regulation, seems to be a promising approach for improved risk management. Therefore, adequate models should contain descriptions of the behaviour-shaping mechanisms, in terms of work system constraints, boundaries of acceptable performance and behaviour, in addition to descriptions of the processes which dynamically manage changes (Rasmussen, 1997).

4.5.1 Risk modelling of system development and system operation

With STAMP, hierarchical control structures are modelled for both *system development* and *system operations* (Figure 6), connecting the interactions between these environments, underlining that success in operations depends on well-developed and defined plans, updated according to new information or changes that can affect the safety. The importance of information and knowledge sharing, and the transfer of experience become crucial, not only vertically, up and downstream in the hierarchical system, but also horizontally, between *system development* and *system operations*. Safe operations partly depend on planning, design and developmental aspects and partly on operational aspects, as these environments interact (Leveson, 2011).

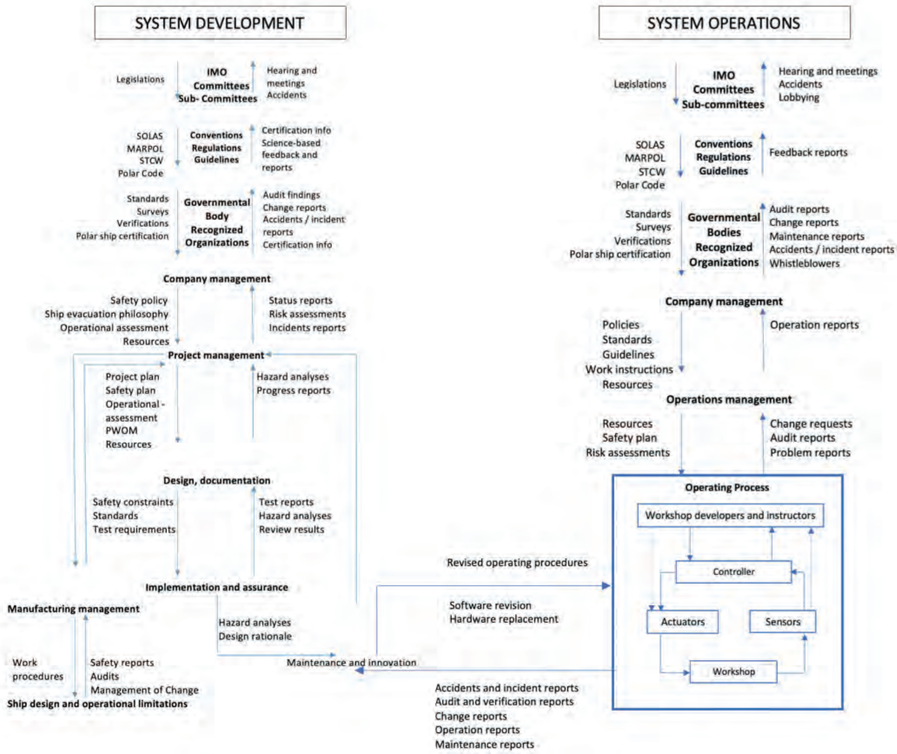


Figure 6. Model of the interaction between system development and system operations (adapted from Leveson, 2011).

In the development phase of shipbuilding, technical constraints are defined in stability calculations, hull drawings and scantling of propeller blades, according to ice class, in addition to the establishment of the evacuation philosophy and the operational assessment, defining the ship's operational limitations and capabilities. These components govern the developmental process, expressing design criteria and the operational profile, providing essential information about the context for assessing the combination of hardware, procedural and human aspects that must be applied (DNV, 2015a). The operational assessment, which must be developed for each ship and its intended polar voyages, shall provide the shipowner, ship operator, master and crew with sufficient information regarding the ship's operational characteristics, capabilities and limitations, to support their planning and decision-making processes (International Maritime Organization [IMO], 2017). The operational environment, in turn, should provide feedback to shipowners, ship builders and manufacturers about the performance and functionality of the ship and its systems and equipment in cold climate conditions, to capture findings for improvement and further development. Sufficient risk management is achieved when information, knowledge and experience are shared between the operational and the developmental environment, communicating assumptions used as the basis of risks analyses and in the development, design, planning and construction of new ships or in the upgrading and classification of existing ones (Leveson, 2011).

4.5.1.1 Example of the exploration and identification of systemic risks associated with Arctic shipping and emergency preparedness

An example of the exploration and identification of systemic risks associated with Arctic shipping and emergency preparedness is seen in the SARex I, II & III exercises (Solberg et al., 2016; Solberg et al., 2017; Solberg and Gudmestad, 2018; Gudmestad and Solberg, 2019), performed in 2016, 2017 and 2018, in ice-infested water or to onshore in the northern areas around Svalbard. These exercises were joint collaborations between the Coast Guard, leading experts from the industry, governmental organizations and academia, in which the Polar Code was used as a basis for testing LSA and rescue equipment in a cold climate. Moreover, personal capabilities for survival in real-event situations were studied, and training in emergency scenarios was conducted. The objectives were to identify and explore the gaps between the functionality provided by the existing SOLAS approved safety equipment and the functionality required by the Polar Code.

The findings from these exercises raised concerns regarding the suitability and efficiency of equipment provided in an emergency requiring the abandonment of the ship (Solberg et al., 2016; Solberg et al., 2017; Solberg and Gudmestad, 2018; Gudmestad and Solberg, 2019). Less than two years after the Polar Code was implemented (June 2019), the Maritime Safety Committee (MSC) of the IMO approved *The interim guidelines on life-saving appliances and arrangements for ships operating in polar waters* (International Maritime Organization [IMO], 2019c). The results and findings that came from the SAR exercises had considerable influence on the establishment and implementation of the new guidelines, which are discussed in Paper III *"Implementation of the Polar Code: Functional Requirements Regulating Ship Operations in Polar Waters"* and Paper IV *"The Polar Code's Implications for Safe Ship Operations in the Arctic Region"*. The SAR exercises exemplify how systemic risks are explored and identified by stakeholders at the operative end of the system and mitigated by the legislators, responding quickly at the other end, implementing necessary guidelines specifying the requirements for LSA as set out in the Polar Code.

5 Methodology

In this chapter, the research strategy and design for this work are described, in addition to the methodological approach. Finally, the research quality is addressed and discussed.

5.1 Research strategy

The research strategy was directed by the overall objective for this work, i.e., to acquire new knowledge about the Polar Code's effect on safety and emergency preparedness for Arctic shipping, considering the great hazards and uncertainties associated with these activities, and to identify the key mechanisms determined to ensure compliance with the regulation's function-based requirements.

Social research can, in general, be conducted through four different research strategies or by using a combination of them (Blaikie, 2019). These strategies are the *deductive* approach, suitable for asking "why" questions, to explain patterns in the observed matters, using existing theories or inventing new ones, aiming to find explanations between the two concepts, the relevance of which can be tested. The *inductive* research strategy is suitable for answering "what" questions, aiming to establish limited generalizations about the distribution of, and patterns of association amongst, observed or measured characteristics of the topic to be studied. Inductive reasoning moves from specific observations to broader generalizations, contrary to the deductive approach, which aims to verify hypotheses and to test theories, moving the other way round, from generalizations to the more specific (Hollis, 2002). The *retroductive* research strategy aims to discover underlying mechanisms that, in contexts, explain observed regularities. The logic of retroduction refers to the process of building hypothetical methods of structures and mechanisms that are assumed to produce empirical phenomena; it involves working back from data to a possible explanation (Blaikie, 2019, p. 87). The *abductive* research strategy can be used to answer both "why" and "what" questions; however, it answers "why" questions by producing understanding rather than an explanation and by providing reasons rather than causes. This research strategy incorporates what the inductive and deductive research approaches ignore – constructing theories that are derived from the observed individuals' language, meanings and accounts in the context of everyday activities. The social world is the world perceived and experienced by the observed individuals, from the "inside" (ibid., 2019).

An inductive approach was initially taken as the research strategy for this work, considering that scientific knowledge is based on the observations, and theories or hypotheses are proposed and tested against the facts of the real world towards the end of the research process, bringing forward (new) conclusions, data and theories of knowledge concerning the application of the Polar Code in Arctic shipping. The inductive way of exploring infers that knowledge acquired so far in known cases also holds for other cases where the same conditions prevail, and that similar events or experiences occur in similar relations or similar conditions. Inductive reasoning enables generalizations and the establishment of assumptions about the world, even not directly observed or experienced, bearing in mind that this approach cannot introduce into science anything of a kind beyond all possible experience (Hollis, 2002). Further, the epistemological assumptions that direct this work, regarding the aspects of the validity, scope and methods of acquiring this knowledge, are based on empiricism; knowledge is produced and verified by the human senses, and a neutral, trained observer, who has undistorted contact with reality, can arrive at reliable knowledge, when this knowledge is certain, when it accurately represents the external world (Blaikie, 2019).

As this work proceeded and the application of the Polar Code evolved, a deductive approach was taken in the performance of experimental research (see chapter 5.2.3 Controlled experiments). Scientific experiments are organized, and there are detailed series of steps to validate or reject a hypothesis, based on an existing theory, where a hypothesis is an explanation about a phenomenon in the natural world. This scientific method moves from theory to the establishment of a hypothesis, to the performance of an experiment, which produces data to be analysed, enabling hypothesis verification or rejection. Scientific experiments are performed under controlled conditions, where one or a few variables are changed at a time, while all others are kept constant. The independent variable is the factor that is changed during the experiment (cause), while the dependent variable is the outcome that is measured (effect) (Formplus, 2007; Kahn Academy, n.d.). Ontological assumptions direct this work, as these incorporate “the study of being” and are concerned with what kind of world is being investigated, with the nature of existence and with the structure of reality as such (Crotty, 2003). The ontological assumptions make claims about what kinds of social phenomena do or can exist, the conditions of their existence, and the ways in which they are related (Blaikie, 2019, p. 92); they are based on cautious realist ontology, where the reality has an existence independent of human minds. However, because of imperfections in human senses, and the fact that the act of observing is an interpretive process, observations can be inaccurate; hence, a cautious and critical attitude must be adopted (ibid., p. 93).

These two strategies, i.e., the inductive and deductive approaches, formed the research process and complemented each other, where data acquired in interviews with experts (see chapter 5.2.1 Experts’ interviews) triggered the initiation of the two controlled experiments (see chapter 5.2.3 Controlled experiments), which later were followed up by additional expert interviews. This research process is illustrated in Figure 7, starting with the study of the developmental aspects concerning the Polar Code implementation, addressed in Paper I, Paper II and Paper III, before an examination of operational aspects concerning the application of the regulation is addressed, in the remaining papers, i.e., Paper, IV, Paper V, and Paper VI.

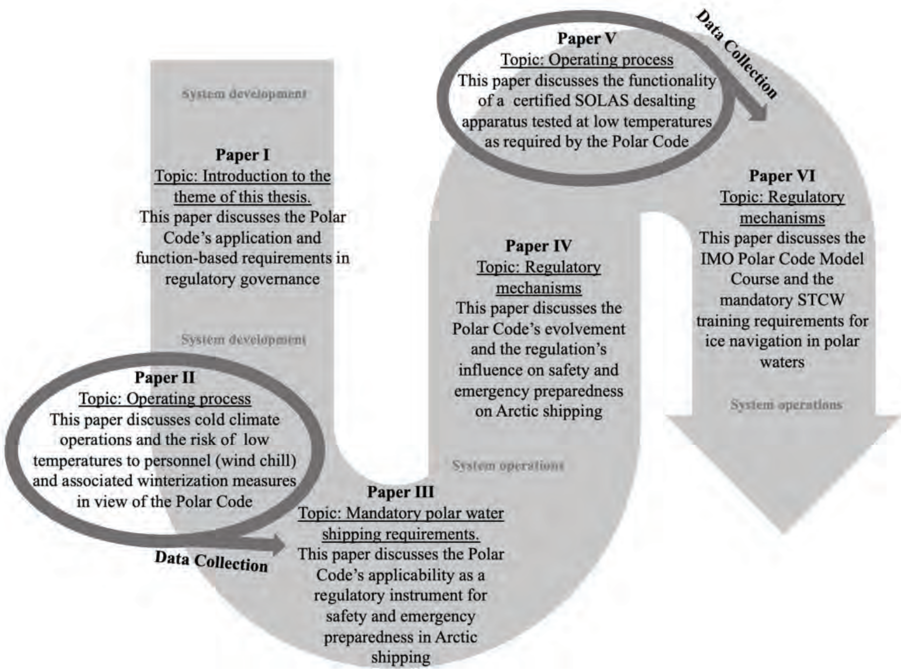


Figure 7. Illustration of this research process and the papers that follow this work.

5.2 Research design

Research methods are generally divided into quantitative or qualitative methods. Quantitative methods are associated with data collection in terms of numbers or other units, whereas qualitative methods are expressed by the written word, in text (ibid., 2019). At the beginning of this work, the Polar Code had only been in force for a year and literature covering the topic was scarce. This yielded a qualitative approach, aiming to characterize and describe the properties associated with the phenomenon to be studied (Repstad, 2007; Blaikie, 2019). Therefore, experts possessing comprehensive knowledge and experience as regards the development, implementation and application of the regulation were of special interest to get in contact and dialogue with.

The written word, i.e., observations and interviews that are analysed and processed to text, is essential in qualitative research. As the implementation of the Polar Code was a historical event that had lasted for more than two decades, interviews rather than observations were the chosen qualitative method for data collection. Interviews can be divided into respondent and key informant interviews. Respondent interviews are based on questions to get the individuals to express their own opinions or experiences regarding a certain activity or event. Key informant interviews allow persons with expertise, professionalism and firsthand knowledge within a phenomenon to provide information about the actual state or conditions of the topic studied. Often, there will be a blend of the two types of interviewing; however, in this work, key informant interviews are the main trait of data collection. The key informant can be characterized as a replacement for the observer, as it can be too time-consuming, or too late (historical events), to conduct observations oneself, where information about the past can be crucial to get access to (Repstad, 2007). Both these points are valid for the topic studied in this work. Knowledge regarding the Polar Code's implementation and experiences regarding its application can best be accessed by interviewing persons who have been working with the establishment and development of the regulation or who have hands-on experience working with regulatory compliance associated with Arctic shipping, including the requirements set forth in the Polar Code.

In the performance of the two controlled experiments, a quantitative approach was taken, with the means of systematic utilization of numbers being key to quantifying and analysing the studied topic. The controlled experiment is a useful method for measuring causality, to discover cause and effect between dependent and independent variables in the research environment (Formplus, 2007; Kahn Academy, n.d.). Of the ten hazards considered in the Polar Code, which may lead to elevated levels of risk due to increased probability of occurrence, or more severe consequences, the hazard of being exposed to low temperature was investigated. Low temperature is defined as a hazard in the Polar Code, as it affects the working environment and human performance, maintenance and emergency preparedness tasks, material properties and equipment efficiency, survival time and performance of safety equipment and systems (International Maritime Organization [IMO], 2017). The aim became to verify established theories considering low temperature and the exposure of humans and equipment to it, and to perform experiments to test these hypothesized effects.

5.2.1 Experts' interviews

Individual interviews represent the most common data collection strategy in qualitative research (Sandelowski, 2002) and were selected as the method, enabling in-depth examination, to capture the experts' knowledge and understanding of the studied topic (Jacobsen, 2015; Labuschagne, 2003). The inclusion criteria for selecting interviewees were expertise and knowledge concerning the Polar Code implementation and application, gained through work experience with the regulation, either in its making prior to 2017, after it was implemented, or both.

In total, nine people, considered experts within their field of work and occupation and in respect of the Polar Code implementation and application, are interviewed during this work, with a total of 13 interviews conducted (see Table 1).

Table 1. Interviewees and their Polar Code work experience.

Interviewees	Organisation	Quantity	Polar Code work experience before 2017	Polar Code work experience after 2017	Paper no.
Principal Adv.	NMA	3	Yes	Yes	I, III, IV
Surveyor	NMA	3	Yes	Yes	I, III, IV
Surveyor	NMA	1	Yes	Yes	IV
Director	Class. Society	1	Yes	Yes	IV
Engineer	NCA	1	Yes	Yes	IV
Prof. ice navigation	Academia in Norway	1	Yes	Yes	IV
Tech. Officer	IMO	1	No	Yes	VI
CEO	Mar. sim. & tr. centre	1	Yes	Yes	VI
Director	Mar. sim. & tr. centre	1	Yes	Yes	VI
Total interviews		13	8	9	

The first interviews started with two persons employed at the NMA as principal advisor and surveyor, both situated in the main office in Haugesund. These two people have both participated in the making of the Polar Code, as Norwegian delegates in the IMO, and remain involved in work associated with the regulation on a regular basis, either in the IMO or with follow-up duties for the NMA involving various interest groups. During these interviews, the two people were asked questions concerning the development and implementation of the regulation and could elaborate freely around the discussed topic, sharing their knowledge and way of understanding causations concerning the Polar Code's effectiveness so far as a regulatory instrument in Arctic shipping. Prepared lists of questions were used, to ensure specific topics were addressed, which were noted down consecutively (see Appendix 1 and Appendix 2). These first four interviews, each lasting approximately 60 minutes, were conducted over the telephone. Data acquired in these interviews formed the way ahead in the establishment of the research design and the research questions and provided information concerning topics discussed in Paper I "*Polarkoden – funksjonsbasert forskriftsverk for polare farvann. Hvordan kan standarder presentere gode nok løsninger? [The Polar Code – function-based regulations for polar waters. The contribution of standards to safe and sufficient solutions?]*" and Paper III "*Implementation of the Polar Code: Functional Requirements Regulating Ship Operations in Polar Waters*".

The second round of interviews took place at the beginning of 2020, interviewing six persons regarded as experts on the implementation and application of the Polar Code. Two of the interviews were conducted with the two previous interviewees representing the NMA, interviewed the year before. The other four interviewees were: one professor in ice navigation, representing academia in Norway; one director of a Norwegian-based classification society; one engineer working for the NCA; and one surveyor working for the NMA. Four of these interviews took place in person, either in Haugesund, at the main office of the NMA, or in Stavanger, at the UiS. The two remaining interviews were conducted over the telephone, all six interviews lasting approximately 60 minutes each, with the use of a pre-made interview guide (see Appendix 3). Data acquired in these interviews are reflected on in Paper IV *"The Polar Code's Implications for Safe Ship Operations in the Arctic Region"*.

The last round of interviews took place during the summer of 2020, interviewing: one technical officer representing the IMO; one Chief Executive Officer (CEO); and one director; the latter two both working with maritime simulation and Polar Code ice navigation training in Canada. These three interviewees were mainly responsible for and contributors to the planning, development and carrying out of the first of four regional capacity-building "train-the-trainer" Polar Code Model Courses workshops, arranged on behalf of and through the cooperation of the IMO and Transport Canada (Canadian Flag State authority). All three interviews were conducted over the telephone, each lasting approximately 60 minutes, with the use of a pre-made interview guide (see Appendix 4). Data acquired in these interviews are reflected on in Paper VI *"A discussion on the implementation of the Polar Code and the STCW Convention's training requirements for ice navigation in polar waters"*.

In the interviews, a semi-structured method was applied, using pre-made interview guides. However, semi-structured interviews still allow the flexibility to explore spontaneous issues raised by the interviewees (Ryan et al., 2009). All the interview sessions were recorded and then transcribed verbatim. The collected data were then analysed utilizing thematic analysis as a method, which is a widely used qualitative analytical method for identifying, analysing and reporting patterns and themes in data (Braun and Clarke, 2006). Themes were identified using a theoretical approach, providing a detailed analysis of certain aspects of the collected data. The thematic analyses were conducted with the following steps: (1) familiarizing by transcribing the data, (2) generating initial codes by exploring features of interesting data across the entire data set, (3) collating the data relevant to each code in a systematic manner, (4) collating codes into potential themes and reviewing these themes by checking the logical relationship to the coded extracts and the entire data set, (5) defining and naming the themes, (6) final analysis of selected extracts. However, analysing data is not a process conducted in a linear manner, moving from first phase to second and third. Instead, the process is dynamic, moving back and forth as needed, throughout the phases (ibid., 2006).

5.2.1.1 Meeting with experts

At the beginning of this research, two meetings were held with three people with hands-on experience regarding the Polar Code application, acquired in their occupations as technical manager and naval architecture manager, both employed at the same Norwegian shipbuilder company, and one operational director, employed at a Norwegian shipowner company. These meetings took place at the respective companies' office locations in Norway. During this research, the Norwegian shipbuilder company has built and delivered a Polar Ship Certificate (PSC) research expedition vessel, on order from the Norwegian shipowner company. The purposes of these meetings were to gather information and to understand how two respectable companies, possessing extensive maritime experience in the Arctic, interpreted various requirements set forth in the Polar Code, and how compliance was met in the various phases of planning, design, building and commissioning of the PSC vessel[1], including its emergency equipment and systems. Also discussed in the meetings, and in the following and additional email correspondence, were the number, type and design of lifeboats, life rafts and survival equipment to be available in the event of an emergency requiring the abandonment of the vessel. Amongst survival equipment planned is SOLAS approved desalting apparatus, for the provision of fresh water, according to the Polar Code guidelines for LSA (International Maritime Organization [IMO], 2019). One such desalting apparatus was lent from the respective companies and tested in the controlled experiment, in a cold climate laboratory, to verify the equipment's functionality and capacity to produce fresh water at low temperatures (see Chapter 5.2.2 Controlled experiments and Paper V *"Investigating the Polar Code's function-based requirements for life-saving appliances and arrangements, and the performance of survival equipment in cold climate conditions – test of SOLAS approved desalting apparatus at low temperatures").*

Documents provided by the two companies, established in the deliverance of the PSC research expedition vessel, are shown in Table 2.

Table 2. The PSC research expedition vessel's core documents.

Provided Data	Sources
Polar Water Operation Manual (PWOM) - Research expedition vessel, PC-6.	Shipowner
Operational risk assessment - Research expedition vessel, PC-6.	Shipowner
Operational risk assessment - Research expedition vessel, PC-6.	Shipbuilder
Ship evacuation philosophy - Research expedition vessel, PC-6.	Shipbuilder

5.2.2 Controlled experiments

During this research, two controlled experiments were conducted; see Table 3 and Paper II *"Winterization and drilling operations in cold*

[1] The PSC vessel is planned to be delivered and ready for polar water operations in 2021.

climate areas" and Paper V *"Investigating the Polar Code's function-based requirements for life-saving appliances and arrangements, and the performance of survival equipment in cold climate conditions – test of SOLAS approved desalting apparatus at low temperatures"*.

Table 3. Controlled experiments.

Experiment	Location	Quantity
Wind chill temperature study in the Barents Sea.	Working area on semi-submersible drilling rig.	Four tests performed in 2018, between May to October.
Test of SOLAS approved desalting apparatus at low temperatures.	Cold climate laboratory, The Arctic University of Norway, Narvik.	Five tests performed at temperatures ranging from +2°C to +23°C.

5.2.2.1 Wind chill temperature study on a drilling rig operating in the Barents Sea

The first controlled experiment was carried out as a field experiment on a semi-submersible drilling rig which, at that time, was operating southwest of the Barents Sea. The purpose of this experiment was to verify the efficiency of a technical winterization measure that was installed in a semi-open working area, i.e., drill floor, and check how the chosen technical solution complied with the function-based requirements to maintain safe workplace conditions, considering the probability of exposure to wind chill for personnel, leading to heat loss and hypothermia. In total, four independent tests were performed between the period from May to October in 2018. In these tests, the wind chill temperature (dependent variable) was measured, first when the forward and the aft doors were in fully opened positions and then when the same doors were in totally closed positions. The measurements of the wind chill temperature were conducted in pre-defined areas that had been identified in the initial planning of the experiment as exposing to wind chill of personnel who had long working experience in that specific working area of the rig. The wind chill temperature was measured using a handheld wind chill temperature meter, and the criteria for performing a single test were wind speed >3 mph (light breeze) and temperatures <10°C, which are the starting conditions for wind chill (Government of

Canada, 2017). The independent variable (cause) in this experiment was either: not to utilize the technical winterization measures and keep the working area open and exposed to the prevailing weather conditions or: to utilize the technical solution, by closing the hydraulically operated door located in the aft end of the working area and closing the electromechanically operated industrial sectional door located in the forward end of that same working area.

5.2.2.2 Test of SOLAS approved desalting apparatus at low temperatures

The purpose of this experiment was to identify possible gaps between requirements provided in Polar Code guidelines for LSA and survival equipment (International Maritime Organization [IMO], 2019c) and to test the actual functionality and performance capacity of SOLAS approved desalting apparatus at low temperatures. This experiment was performed in a temperature controlled and enclosed environment, in the facilities at The Arctic University of Norway in Narvik. In total, five tests were performed, each lasting 60 minutes, at the following water temperature readings (independent variables): +2°C, +4°C, +7°C, +10°C, +23°C. In each test, the equipment's capacity to produce freshwater from seawater was verified, by measuring the amount of freshwater produced (L and Kg), in addition to measuring the salinity levels (ppt) in the produced freshwater (dependent variables). To secure accurate temperature measurements, different sources of high-quality equipment were used: three sources of air temperature and two sources of water temperature. The log system was set to measure at one-minute intervals, providing 61 measurements for each test, with four variables: air temperature 1, air temperature 2, water temperature and relative humidity. In addition, measurements of water and air temperature were manually provided every five minutes with dedicated equipment. Operating criteria established in the experiment for the hand-operated desalting apparatus directed the pumping frequency and were monitored by observing the pressure indicating rod; it determined that pumping should be as fast as possible but without water spraying out from the indicator. If water sprayed out, the pump frequency was lowered. As soon as an optimum pump frequency was established, a metronome was used to ensure that a steady pump frequency was maintained during the 60-minute test. The same person operated the handheld desalting apparatus in all five tests performed, to maintain identical work settings.

5.2.3 Supplementary data - the SARex I, II & III exercises

The Norwegian Coast Guard, together with the UiS and the University of Tromsø (UiT), has taken great interest in the conditions regarding SAR and evacuation operations in Arctic waters. In the SARex I, II & III exercises, performed in 2016, 2017 and 2018 (Solberg et al., 2016; Solberg et al., 2017; Solberg and Gudmestad, 2018; Gudmestad and Solberg, 2019), respectively, the Coast Guard played a key role in the work of testing emergency response equipment, with respect to requirements for survival as set out in the Polar Code. In these exercises, the Polar Code was used as a baseline for studying emergency response equipment and personal capabilities for survival in real-event situations. Each exercise lasted for a week and was conducted from the Coast Guard ship, KV Svalbard, in northern areas around Svalbard. In joint collaborations, requirements in the regulations were used as criteria for survival and were examined and tested against SOLAS certified LSA, approved for Arctic waters. The findings and results presented in the three reports that were developed after the exercises had been conducted proved that ships on polar voyages are likely to be equipped with insufficient SOLAS certified survival equipment and resources (Solberg et al., 2016; Solberg et al., 2017; Solberg and Gudmestad, 2018; Gudmestad and Solberg, 2019). These reports, in addition to multiple discussions and meetings during this work with one of the main contributors to the establishment and performance of the SAR exercises, who also functioned as supervisor during this research, have also had great value with regard to the provision of valid data to a highly relevant and related topic.

5.3 Reflections on the use of empirical research methods

Aspects of data and research quality are most commonly associated with the scientific process, including all aspects of the study design. This quality is generally viewed in the light of the appropriateness and strength of the research design and the methods that are utilized, which generate findings and results. In quantitative research, the quality of research is traditionally assessed by its *validity*, *reliability* and *objectivity* (Flick, 2007; Denzin and Lincoln, 2011; Lincoln and Guba, 1985). Validity refers to the accuracy of the measurements and is divided into the two concepts of *internal and external validity*. *Internal validity* relates to how appropriately the study is conducted, i.e., whether the results demonstrate a causal relationship between the independent and dependent variables. Other types of validity are also suggested in the literature, and both *content validity* and *construct validity* are generally accepted to have particular importance, addressing the reasons for the outcome of the study. *External validity* refers to how well the results from the study can be applied to other similar settings, i.e., whether and how generalizable the findings and the results are, where *ecological validity* can be used to assess the strength of the experimental design (Heale and Twycross, 2015; Sürücü and Maslakçı, 2020).

The *internal validity* for the two controlled experiments performed in this research is concerned with whether there is sufficient evidence to support the notion that the data gathered in these experiments were not affected by other variables. The *content validity* is concerned with whether the experiment is representative of all aspects of the studied topic, and the production of valid results relies on the content of the measurement method covering all relevant parts of the subject it aims to measure. The *construct validity* is concerned with whether the test measures the construct adequately and inferences can be drawn about test scores related to the concept being studied (Heale and Twycross, 2015; Sürücü, and Maslakçı, 2020). In the experiment conducted in the Barents Sea on the drilling rig, the independent variables, i.e., the variables that could affect the measured outcomes, i.e., the dependent variables, were controlled by maintaining and keeping control over the two doors leading into the working area (drill floor), i.e., the forward and aft doors. These two doors were first fully opened, before measurements of the wind chill temperature (°C) and the wind speed (knots) were taken, and then fully closed, before new measurements were performed. A handheld instrument, intended for the task of measuring wind speed and wind chill temperature, was used to make the recordings, which were taken in predefined locations on the drill floor, enabling the comparison of the exposure to wind chill of personnel working in this semi-open space, located on the main deck of the drilling rig. The defined locations where the spot measurements were performed had previously been identified by the drilling personnel who were familiar with the working conditions in this area. During the rig's previous yard stay and re-classification, this working area had been re-designed and upgraded to comply with the requirements concerning winterization measures, prior to start-up of a year-long drilling campaign in the Barents Sea. This working area was pervious fully exposed to wind chill, with no means of enclosure. In the aft end of this working area, i.e., in the opening leading out to the aft riser deck, a door (>12-metre height) had been installed as part of the winterization upgrade. This multi-layer, hydraulically operated and driven metal door reached up into the drilling derrick, and the remaining derrick had been enclosed with steel plates. In the forward end of this working area, i.e., the opening leading out to the forward pipe deck, an industrial sectional door (>4-metre height) was installed, which could be mechanically lowered and opened, driven by electrical motors. Other independent variables that could influence the test results were eliminated before performing the experiment, i.e., switching off and ensuring that the external heating system in the area was kept off during the entire test samplings, in addition to performing proper venting of the working area prior to performing the measurements.

In the wind chill experiment conducted in the Barents Sea, two identical but separate instruments were used to measure the wind chill temperature (°C) and the wind speed (knots). The two instruments were calibrated between each test sampling, and the same instruments were used during the entire experiment, i.e., one instrument was used to measure the recorded wind chill temperature and the wind speed, and one instrument was used to do control measurements. Additional and supporting weather data were provided from the drilling rig's own weather monitoring system. Four independent experiments were conducted during a five-month period, with the following weather criteria set to perform one single test sampling, i.e., wind speed >3 knots (light breeze) and temperatures <10°C, which are the starting conditions for wind chill (Government of Canada, 2017). The highest wind speeds and the lowest wind chill temperatures that were recorded during one test sampling make up the recorded data set from the entire experiment. The lowest wind speed was recorded in the last experiment performed (October 2018), with a strong breeze (24.7 knots) and an air temperature of 5°C, whereas, in the first experiment (May 2018), moderate to near gale force winds (31.8 knots) and an air temperature of 4°C were recorded. In the second experiment (also May 2018), strong gales (43.3 knots) and an air temperature of 6°C were recorded, whereas, in the third experiment (August 2018), a full gale (47.4 knots) and an air temperature of 8°C were recorded. Due to the mooring position of the drilling rig, the most unfavourable wind conditions for the personnel working in this area where the experiment took place were either from the east or from the west. The wind directions during the four experiments were from the southeast (May), the southwest (May and June) and the northwest (August), concluding that the wind conditions were equally unfavourable in all four of the experiments, considering the exposure of personnel to wind chill.

In the second controlled experiment, the functionality and performance capacity of SOLAS approved desalting apparatus was tested at low temperatures, in a highly technological, temperature-controlled and enclosed environment, in the facilities at The Arctic University of Norway, in Narvik. In this experiment, the independent variable consisted of keeping the temperature in the enclosed environment at a steady level during the performance of each test. A total of five tests, each lasting 60 minutes, were performed at temperatures of +2°C, +4°C, +7°C, +10°C and +23°C, with the same person producing freshwater, by pumping saltwater using the desalting apparatus. In total, five different sources of high-quality instruments were used to measure and control the temperature inside the test facility. Temperature was measured in the stored saltwater and the produced freshwater, in addition to three independent measurements of the air temperature. Moreover, the dependent variables in this experiment, i.e., the amount of produced freshwater (L and Kg) and the salinity levels (ppt) in the produced freshwater, were measured, using calibrated instruments and equipment intended for these tasks.

The external validity for the two controlled experiments could be argued to be of a lower significance compared with the internal validity; i.e., the findings and results from these experiments have less value for other similar settings; i.e., this unique drilling rig, with its unique design, operating at a specific location in polar waters at certain times of the year will create unique settings that could be difficult to replicate and apply to other settings. Moreover, only one SOLAS approved desalting apparatus was tested in this experiment, and additional tests of different SOLAS approved desalting apparatus would be beneficial to strengthen the external validity of this experiment. However, addressing the latter issue first, regarding the variety of SOLAS approved desalting apparatus, unfortunately, very few different models exist and are available on the market. Additionally, the desalting apparatus tested in this experiment is part of the survival equipment to be maintained on the PSC vessel that is followed and studied in this research (see chapter 5.2.1.1 Meeting with experts), indicating that the functionality and performance capacity of this desalting apparatus at low temperatures is generalizable and highly valuable for similar settings. Moreover, survival equipment used at low temperature shows less performance capacity compared to when used in a tropical climate (Solberg et al., 2016; Solberg et al., 2017), which was confirmed in this experiment to test the SOLAS approved desalting apparatus. Considering the effect of humans' exposure to low temperature, the results from the wind chill experiment performed on the drilling rig in the Barents Sea are also generalizable to similar settings (e.g., Solberg and Gudmestad, 2018; Gudmestad and Solberg, 2019); i.e., enclosing open areas and reducing the exposure to wind turbulence will limit the negative effect of wind chill on humans (i.e., heat loss and lowering of the body temperature). This increases the time until rescue and of survival, in the event of an emergency, or increases efficiency, safety and production in a working environment (Engtrø and Gudmestad, 2019; Solberg et al., 2020).

Reliability refers to the consistency of the performance of the conducted experiment, i.e., applying the same methods to sample data under the same conditions should result in the same results and the experiment is therefore considered repeatable. The reliability of the two experiments was safeguarded, as the test samplings were taken over a period, at the same facilities, under similar physical conditions, using the same high-quality test sampling instruments, equipment and techniques, in the performance of the experiments. Objectivity refers to the fact that the findings and results from the study are not affected by personal biases and that these are not contaminated but represent the real picture of the matter under study. The objectivity of the two experiments was safeguarded by the controls and verifications performed by the co-workers who participated and assisted in the development and the conducting of the experiments. These persons further followed the research process and participated as co-writers in the papers that were developed to present the experiments and its findings. Moreover, the experiment to test the SOLAS approved desalting apparatus was published in an international and recognized maritime journal addressing issues related to polar water operations. The wind chill temperature experiment performed in the Barents Sea on a drilling rig was presented and discussed at an international conference addressing the unique issues related to coastal and offshore engineering in ice-covered waters.

In qualitative research design, the same quality criteria apply as in quantitative research; however, the three criteria used in quantitative research, as previously discussed, i.e., validity, reliability, and objectivity, are not suitable for judging the quality of qualitative research. Instead, *trustworthiness*, posing the question of whether the findings and results can be trusted, is considered suitable for this research approach. Several definitions and criteria of *trustworthiness* exist, but in this work the criteria of *credibility* (instead of internal validity), *transferability* (instead of external validity), *dependability* (instead of reliability) and *confirmability* (instead of objectivity) are used (Korstjensa and Moser, 2018; Lincoln and Guba, 1985). *Credibility* refers to whether confidence can be placed in the truth of the research findings, whether these findings represent both plausible information that is credible and a correct interpretation of the interviewees' original views. *Transferability* refers to whether the findings and results of the research are transferable and applicable to other contexts or settings with other respondents. *Dependability* refers to whether the findings from the research show stability and consistency over time, across researchers and methods, and whether the process of analysing data is in accordance with the accepted standards for the chosen research design. *Confirmability* refers to the degree to which the findings of the research study could be confirmed by other researchers. Confirmability is concerned with establishing that data and interpretations of the findings are not figments of the inquirer's imagination but clearly derived from the data.

Several strategies are suggested for addressing *credibility* in the research design, of which the following are used in this work: *prolonged engagement*, i.e., lasting presence during the research period, to ensure that sufficient time is invested to become familiar with the setting and the context that is studied, including the verification of obtained data, to avoid misinformation; *persistent observation*, i.e., identification of those characteristics and elements that are most relevant to the issue under study, which are focused on in detail; *triangulation*, i.e., using different data sources (e.g., using multiple data sources in time, space and people) and different methods of data collection; *peer debriefing*, i.e., external checks on the research process; and *negative case analysis*, i.e., refining the working hypotheses according to the information that becomes available (ibid., 1985). During this work, *prolonged engagement* and *persistent observation* are safeguarded by the following strategies: this research initially started off with interviews and meetings with experts possessing thorough knowledge and hands-on experience regarding the Polar Code implementation and application. During the first year, these interviews and meetings were followed up with email correspondence, for the provision of additional information and to verify topics previously discussed. Additionally, in this period, ship-specific documents concerning PSC vessels, i.e., operational assessments and the evacuation philosophy, in addition to associated information concerning the development of new Polar Code guidelines in the making by the IMO, were also acquired. In the preparation for the ensuing interviews, telephone conversations were held with each interviewee in the days before the actual interviews took place, to address the topics to be discussed. The interview guides were also provided to the interviewees in advance, to ensure that they could familiarize themselves with the purpose of this research and to prepare them for the actual interview. During the interviews, the interviewees were given sufficient time to elaborate on each question, and the semi-structured manner of conducting the interviews further facilitated this approach. *Triangulation* is safeguarded in the use of different sources of data, i.e., various experts representing various interest groups in the maritime system under study were interviewed, combined with the performance of the two controlled experiments. *Peer debriefing* is safeguarded by the fact that information and data acquired during this research were frequently discussed throughout this period with supervisors, co-writers of papers and fellow PhD students. Additionally, these data have been refined and prepared for publication in four papers (Papers I, III, IV, and VI), published in international and recognized journals. *Negative case analysis* is safeguarded in the reflection of the various work hypotheses that were established, as new information and data were obtained and the research proceeded, and which has governed the process and the way forward in the work of establishing new knowledge concerning the Polar Code implementation and application.

To ensure *transferability*, the research must provide detailed and rich descriptions of not just the behaviour and experiences but also the context where these occur, so that others are able to verify whether the findings and results are transferable, i.e., that the behaviour and experiences are also meaningful to them (Lincoln and Guba, 1985; Korstjensa and Moser, 2018). In this work, transferability is safeguarded by utilizing different methods and various sources, enabling the provision of a detailed description of the studied topic. This transferability is reflected in the different papers, which present various sides and topics concerning the Polar Code implementation and application, describing the benefits and challenges that have appeared during the period in which the regulation has been in force and applicable.

In this work, *dependability*, i.e., the concept that the research findings show stability and consistency over time, across researchers and methods, is safeguarded using recommended techniques found in the literature, i.e., overlap in methods (triangulation), stepwise replication (repetition of the data collection and analysis) and from external examination of the research process and findings (inquiry audit) (Lincoln and Guba, 1985; Korstjensa and Moser, 2018). The use of different data collection methods (triangulation) enabled comparison of whether the data collected through one method corresponded to data collected by another method. For example, in interviews with experts participating in the process of developing the Polar Code and the supporting LSA guideline, data about the topic were acquired, i.e., the provision of information concerning the intentions behind this guideline, which later could be seen in comparison with the guideline's new requirements. Moreover, the LSA guideline was used as a basic document in the planning and conducting of the experiment to test the functionality and performance capacity of the SOLAS desalting apparatus at low temperatures. In this experiment, the guideline's requirements for survival support (more specifically, the capacity for the provision of freshwater) were validated and tested against the actual delivery of freshwater at low temperature. Stepwise replication, i.e., repeated data collection and analysis, was handled by addressing similar topics concerning the Polar Code implementation and application, with different maritime actors over a period, meaning that, in this work, data were repeated, replicated and configured, using the STAMP methodology. The inquiry audit, i.e., the external examination of the research process and findings, was, as previously mentioned, safeguarded in the cooperation with other co-writers, supervisors and fellow PhD colleagues and further addressed in the papers published in international and recognized journals and presented at an international and recognized conference.

Confirmability refers to whether the discovered patterns reflect the reality of the topic studied and are not contaminated by researcher bias, using a confirmability audit, i.e., methodological reflections combined with external examination, to address these issues (Lincoln and Guba, 1985). This research, its objective and the methodological approaches have constantly been reflected on, documented stepwise and have evolved during the discussions, presentations and conversations that have followed this work, forming an audit trail.

6 Results

The overall goal of this research is to understand how the function-based Polar Code, as a regulatory instrument, contributes to increasing the safety of ships' operation in the Arctic, given the great challenges and hazards associated with maritime activities in these waters. This broad research problem is pursued and addressed in six research papers, and the following subchapters present the specific research problems and the main findings of each paper.

6.1 Summary of Paper I. "Polarkoden – funksjonsbasert forskriftsverk for polare farvann. Hvordan kan standarder presentere gode nok løsninger? [The Polar Code – function-based regulations for polar waters. The contribution of standards to safe and sufficient solutions?]"

Engtrø, E., Njå, O., and Gudmestad, O. T. (2018). *Polarkoden – funksjonsbasert forskriftsverk for polare farvann. Hvordan kan standarder presentere gode nok løsninger? [The Polar Code – function-based regulations for polar waters. The contribution of standards to safe and sufficient solutions?]*. In: Lindøe, P. H., Kringen, J., and Braut, G. S. Regulering og standardisering - Perspektiver og praksis [Regulation and standardization - Perspectives and practice] (pp. 146-162). Universitetsforlaget - Scandinavian University Press.

This paper studies the Polar Code's function-based approach of risk regulating international shipping in the Arctic, raising challenges in the work of implementing and enforcing its requirements, identified from the points of view of legislators and those subject to the regulation. The regulation's structure and principles of use are examined, and a historical review that elucidates the processes of developing and establishing ship regulations applicable for polar waters is given. The data collection in this paper is derived from three Arctic search and rescue (SAR) exercises performed between 2016-2018, examining the Polar Code's requirements for survival in polar waters, testing the functionality of SOLAS certified LSA at low temperatures (Solberg et al., 2016; Solberg et al., 2017; Solberg and Gudmestad, 2018; Gudmestad and Solberg, 2019). Moreover, data are acquired from interviews and formal meetings with representatives from the NMA, management personnel representing two reputable shipbuilding and shipowner enterprises operating in the Arctic, in addition to conversations with one of the main contributors to the above-mentioned SAR exercises.

This paper identifies and discusses major challenges anticipated in the application of the function-based Polar Code in the governance of Arctic shipping, i.e.: the expectation of high professional integrity and competence levels, from both those subject to the regulations and the authorities; the risk-based approach used to identify risk-reducing measurements deemed necessary to perform safe voyages in polar water, and the possibility of lack of sufficient levels of competence, knowledge and experience required to conduct adequate and reliable risk assessments; gaps and deficiencies explored between the Polar Code requirements for survival and the performance capacity of SOLAS certified LSA in polar waters; and lack of additional guidelines, supplementing the Polar Code with more detailed provisions and guidance for survival at low temperatures after a ship abandonment situation.

6.2 Summary of Paper II. "Winterization and drilling operations in cold climate areas"

Engtrø, E., and Gudmestad, O. T. (2019). "Winterization and drilling operations in cold climate areas" [paper presentation]. *Proceedings -*

International Conference on Port and Ocean Engineering under Arctic Conditions (POAC) (pp. 1-9). Delft, The Netherlands.

This paper examines how specific technical winterization measures installed on a drilling rig operating in the Arctic Region comply with the risk- and performance-based Health, Safety and Environmental (HSE) petroleum requirements established to safeguard personnel – in this case from exposure to wind chill and the possibility of hypothermia and heat loss.

A wind chill temperature study was conducted to evaluate the effect of enclosing an outdoor working area, which was done during a winterization upgrade of the drilling rig prior to commencing Arctic operations. The winterization measures installed were a hydraulic door in the aft opening on the drill floor and an industrial sectional door with a heavy rubber curtain in the forward opening, to prevent both personnel from being exposed to wind chill, snow and rain and snow from accumulating in the working area. Four independent wind chill temperature tests were performed over a period from May to October in 2018. The results showed that, after the installation of the enclosure, the personnel working in this area became less exposed to wind chill and the likelihood of hypothermia. An average difference in wind chill temperature, between when the aft and forward doors were in open and in closed positions, was measured at > +6 ºC. Feedback gained in informal conversations with personnel engaged in tasks on the drill floor during these measurements confirmed the findings. The passive winterization measure of enclosing the drill floor was shown to comply with applicable requirements, providing an effective safeguard for personnel against heat loss and the likelihood of hypothermia.

6.3 Summary of Paper III. "Implementation of the Polar Code: Functional requirements regulating ship operations in polar waters"

Engtrø, E., Gudmestad, O.T., and Njå, O. (2020a). "Implementation of the Polar Code: Functional Requirements Regulating Ship Operations in Polar Waters". *Arctic Review on Law and Politics*, Vol. 11 (pp. 47–69). http://dx. doi.org/10.23865/arctic.v11.2240.

The aim of this paper was to follow up on developments after the Polar Code's implementation in 2017 and the publication of Paper I in 2018 to examine the regulation's contribution to establishing new standards and guidelines and to enhancing safety for ship operations in the Arctic. In particular, the *Interim guidelines for life-saving appliances and arrangements for ships operating in polar waters* (International Maritime Organization [IMO], 2019c) and the new *Regulations on the construction, equipment, and operation of passenger ships in the territorial waters surrounding Svalbard* (Norwegian Maritime Authorities [NMA], 2019) are addressed. This paper concludes that safe Arctic shipping depends on those subject to the regulations conducting thorough operational risk assessments that cover all potential hazards, to sufficiently mitigate these. Further, the presence of authorities is found to be crucial, validating the adequacy and the dimensioning of the implemented measures.

6.4 Summary of Paper IV. "The Polar Code's implications for safe ship operations in the Arctic region"

Engtrø, E., Gudmestad, O.T., and Njå, O. (2020b). "The Polar Code's Implications for Safe Ship Operations in the Arctic Region". *TransNav - The International Journal on Marine Navigation and Safety of Sea Transportation*, Vol. 14:3 (pp. 655-661). DOI: 10.12716/1001.14.03.18.

This paper investigates the Polar Code's implications as a regulation for safe ship operations in the Arctic Region, focusing on: expectations regarding regulatory compliance and the establishment of practical solutions; developmental trends in the interpretation of the Polar Code's requirements; and its contribution in defining best standards for ship operations in polar waters. Six individual interviews were performed with experts within the studied topic, meeting the inclusion criteria that were established in choosing candidates to interview, meaning that all the interviewees had expertise and knowledge concerning the Polar Code implementation and application, gained through work experience with the regulation, both in the making of the regulation and after it was implemented in 2017[2].

The following regulatory topics that are associated with Polar Code implementation were addressed during the interviews: *Guidance on methodologies for assessing operational capabilities and limitations in ice; Polar Operational Limit Assessment Risk Indexing System (POLARIS)* (International Maritime Organization [IMO], 2016); *Amendments to STCW Regulations on qualifications and certificates for seafarers* (Lovdata, 2018); *Guidance for navigation and communication equipment intended for use on ships operating in polar waters* (International Maritime Organization [IMO], 2019b); *Interim guidelines on life-saving appliances and arrangements for ships operating in polar waters* (International Maritime Organization [IMO], 2019c); *Regulations on the construction, equipment and operation of passenger ships in the territorial waters surrounding Svalbard* (Norwegian Maritime Authorities [NMA], 2019).

This article concludes that the implementation of the Polar Code is a regulatory milestone regarding the governance of international shipping in polar waters; however, several concerns are raised in these regards:

[2] The four interviewees representing the NMA and the NCA took part as exercise participants during the SAR exercises.

i.e., the diversity of actors with intentions of operating in polar waters and the varying levels of competence and experience this represents; non-SOLAS vessels that are not regulated by the Polar Code but still represent the most dominant maritime industry in the Arctic, i.e., fishing vessels; cold climate hazards presented outside the geographical area of application of the Polar Code; the gaps explored in the three Arctic SAR exercises performed between 2016 and 2018, examining the Polar Code`s requirements for survival in polar waters by testing the functionality of SOLAS certified LSA at low temperatures (Solberg et al., 2016; Solberg et al., 2017; Solberg and Gudmestad, 2018; Gudmestad and Solberg, 2019); and the new Polar Code guidelines for LSA (International Maritime Organization [IMO], 2019c), highly influenced by the results and findings from these exercises.

6.5 Summary of Paper V. "Investigating the Polar Code's function-based requirements for life-saving appliances and arrangements, and the performance of survival equipment in cold climate conditions – test of SOLAS approved desalting apparatus at low temperatures"

Engtrø, E., and Sæterdal, A. (2021). "Investigating the Polar Code's function-based requirements for life-saving appliances and arrangements, and the performance of survival equipment in cold climate conditions – test of SOLAS approved desalting apparatus at low temperatures". *Australian Journal of Maritime & Ocean Affairs* (pp. 274-294). DOI: 10.1080/18366503.2021.1883821.

This paper follows up on the newly implemented Polar Code guidelines for LSA (International Maritime Organization [IMO], 2019c), with an objective of verifying the guidance provided for survival equipment that should be available for all persons after abandonment of the vessel and for the maximum expected time of rescue; more specifically, the guidelines propose the use of de-salting apparatus in the provision of the, at least, two litres of fresh water recommended per person per day.

However, low temperatures can be critical for the composition of material used in emergency and survival equipment; steel and polymers become more brittle, and rubber sealing loses its flexible function and properties (DNV GL, 2015a). Reliance on LSA and arrangements being functional in an emergency is vital, and material weaknesses in survival equipment, not discovered until the accident is unfolding, can have fatal consequences. Previous studies performed on SOLAS approved LSA and arrangements, and their actual performance capacity under cold climate conditions, showed a discrepancy between expected and actual performance in the tested equipment (Solberg et al., 2016; Solberg et al., 2017; Solberg and Gudmestad, 2018; Gudmestad and Solberg, 2019). This experiment therefore had an objective of testing the functionality of SOLAS approved desalting apparatus, to study the equipment's capacity to produce freshwater from seawater within 60 min, at the following water temperature readings: +2°C, +4°C, +7°C, +10°C and +23°C. The desalting apparatus' salt rejection capacity was also explored by measuring salinity in the produced freshwater. The results showed that the desalinator's capacity to produce freshwater was significantly reduced at lower temperatures, but minor variations in the salinity levels were observed at the same temperature readings.

6.6 Summary of Paper VI. "A discussion on the implementation of the Polar Code and the STCW Convention's training requirements for ice navigation in polar waters"

Engtrø, E. (2021). "A discussion on the implementation of the Polar Code and the STCW Convention's training requirements for ice navigation in polar waters". *Journal of Transportation Security* (pp. 1-27). DOI: 10.1007/s12198-021- 00241-7. Accepted for publication.

This paper follows up on the 2018 amendments to the STCW Convention (Lovdata, 2018), providing new training requirements applicable to dedicated personnel in charge of a navigational watch on ships with a PSC operating in polar waters. In association with these new training requirements amending the STCW Convention, the IMO and Transport Canada (Canadian Flag State authority) signed a Memorandum of Understanding (MoU) in 2017, for Canada to develop and deliver four regional capacity-building "train-the-trainer" workshops. The objective of these events was to assist Maritime Education and Training (MET) institutes in enhancing the skills and competence of instructors to develop competence-based STCW training programmes to be provided for dedicated personnel on ships operating in polar waters. This paper examines the first workshop conducted in Canada in 2019, to understand the mechanisms in the interaction taking place between the IMO and the Canadian workshop developers and instructors, using the STAMP methodology (Leveson, 2011). Individual expert interviews are performed with the main three contributors directly involved in developing and conducting the workshop, to evaluate the event's contribution to improving and specifying the STCW Convention's training requirements, as referenced in the Polar Code, for seafarers operating in polar waters.

This paper concludes that, overall, the workshop was conducted in a manner that met the objectives established for the events. However, some concerns are raised, namely, some of the attendees' lack of relevant qualifications and, especially, the delegation to the workshop's participants of the responsibility to exchange and transfer experiences and learning outcomes from the event back to national MET institutes and Flag State authorities. The first issue, participants not being qualified to attend the workshop, will limit the goal of reaching out to as many qualified MET ice navigation instructors as possible during these events. Regarding the second issue, delegating the responsibility to the workshop's participants for the transfer of experiences and learning outcomes back to relevant stakeholders is considered a weak and unreliable way of sharing information within the maritime system. This means of interacting cannot be controlled or assessed in a satisfactory manner, to ensure compliance with the goals established for the workshops. Achieving safety performance in a dynamic system and maintaining a satisfactory safety level over periods of time must be enforced by reliable audits and other reporting tools, ensuring feedback to the system developers about necessary barriers and safety constraints (Hale et al., 2006).

7 Discussion and Assessment

In the assessment of the Polar Code's contribution to enhancing safety for Arctic shipping, it is important to acknowledge that this regulation is not a stand-alone regulation but must be regarded in the context of the related IMO instruments and other instruments of international law, in addition to applicable national regulations, depending on the areas of operation (Chircop, 2017). Therefore, it can be difficult to credit (or not) the Polar Code with enhancing safety for Arctic shipping, considering that this is just one of many regulations and requirements shipowners and operators must comply with before their ships can encounter polar waters. However, the implementation of the Polar Code is acknowledged amongst experts in the field as an important milestone regarding safety for ship operations in the Arctic Region (ref. Paper IV - Engtrø et al., 2020b), as it constitutes the first international mandatory regulations addressing risks present in polar waters and not adequately mitigated by other instruments of the IMO, regarding the design and construction of ships and equipment, operational conditions, voyage planning, manning and training, and the protection of the environment (International Maritime Organization [IMO], 2017).

For experienced and reliable operators and shipowners already engaged in polar water operations in the Arctic Region, the Polar Code implementation initially did not have a great impact, as this fleet generally consisted of winterized vessels, designed for low temperatures and built according to recognized ice classes (ref. Paper IV - Engtrø et al., 2020b). In general, for existing ships engaged in polar operations in the Arctic, only minor technical modifications were necessary to achieve compliance with the new regulation. Additionally, routines for developing operational procedures for operating in ice were also well established, and often only cross-references to the individual sections of the Polar Code were sufficient to comply with the regulation. However, shipbuilders or shipowners lacking experience and knowledge as regards ice identification and navigation in polar waters would face difficulties in acknowledging the minimum standard and expectation addressed in the Polar Code for operational elements, vessel design and construction (ref. Paper IV - ibid., 2020b). Handing the responsibility to an inexperienced actor, to identify and define the operational capabilities and limitations for a ship in ice, is a paradox, considering that the regulation addresses a minimum of specified hazards and risks to be treated in the operational risk assessment, but unexperienced personnel will have great difficulties identifying and assessing all the relevant ones. Self-regulation is based on trust (Engen et al., 2013), and those subject to the regulations need to conduct thorough operational risk assessments that identify hazards, followed by the implementation of mitigating measures, to ensure the safe performance of ship operations. Experience from the Norwegian petroleum industry indicates that not all companies and parties pay sufficient attention to this responsibility (The Office of the Auditor General in Norway [Riksrevisjonen], 2018-2019).

7.1 Regulatory mechanisms and challenges associated with the governance of Arctic shipping

The role of the authorities can be demanding, and a high level of expertise, competence and knowledge must be acquired for the assessment of company-related risks, which is essential in evaluations of adequacy and in the dimensioning of implemented measures (ref. Paper III - Engtrø et al., 2020a; and Paper IV - Engtrø et al., 2020b). One concern that should be raised is practical enforcement of the Polar Code (verifications and audits) and the management of control mechanisms within the geographical area of application, to ensure compliance with the regulations. The Port States and the classification societies are essential in this regime, and the use of sanctions – fines and withdrawal of the PSC – is a possible response to non-compliance, as well as, in extreme situations, the arrest of ships (Norwegian Maritime Authorities

[NMA], 2014). However, the primary responsibility for exercising control over ships rests with the Flag State authorities. According to UNCLOS (Art. 94), each state shall effectively exercise its jurisdiction and control over ships flying its flag and take necessary measures to ensure safety at sea, regarding, e.g., the construction, equipment and seaworthiness of ships, the manning and labour conditions, and the training of crew members, according to the applicable regulations and requirements in the operating areas (Todorov, 2020). Port States may initiate controls and check whether the seafarers' certificates are valid; whether the manning and qualifications of the crew members comply with the safe manning requirements; and whether the crew is trained according to the Polar Code and the STCW Convention's requirements for ice navigation in polar waters (Bai and Wang, 2019). However, controls initiated by Port States will be limited and can only determine whether ships have valid documents and whether the standards of the ships and the crew members conform with the information provided in the PSC (Todorov, 2020). Additionally, the Polar Code does not provide reliable tools to monitor compliance, and the issuing of the PSC is no guarantee that either the ship or the crew's composition and qualifications are compliant at any given point in time (Fedi et al., 2018). The control to ensure seaworthiness of ships and their crew members is further complicated by the fact that, if only a few Port States carry out strict inspections, the number of ships calling at their port will inevitably decrease, as they favour more lax neighbour states (Bai and Wang, 2019). Experience has shown that different Flag States cannot be relied on to carry out those responsibilities, due to varying competence and motivation to undertake their role (Roach, 2017; Kristiansen, 2004) and, in some cases, the lack of necessary human and physical resources and the political will to exercise effective control over ships flying their flag (Bai and Wang, 2019). Varying interpretations of the Polar Code and enforcement of the regulation amongst Flag States can be mitigated, e.g., in the enforcement of the new regulations on the construction, equipment and operation of passenger ships in the territorial waters surrounding

Svalbard (Norwegian Maritime Authority [NMA], 2019), i.e., the SOLAS Convention including the Polar Code, which has established the new safety standard in Svalbard. Due to Svalbard's judicial position (Svalbar Treaty, 1920), the necessity for equal rules for all Flag States can bring about predictability and clear legislation for ships carrying passengers in the territorial waters surrounding Svalbard. These new regulations ensure that the future development of the legislation in Svalbard can take place in line with new legislation being negotiated internationally in IMO, which is an advantage point for the NMA, also regulating ships flying foreign flags (Norwegian Maritime Authority [NMA], 2019).

7.2 Ship classification and the issuance of the Polar Ship Certificate (PSC)

In ship classification and certification, the classification societies have developed and established class notations to determine applicable rule requirements for the assignment and retention of class (DNV GL, 2015b). Class notations are either mandatory or optional; where these are optional, class notations from the classification society's other rule books may, upon special consideration, be assigned to a vessel complying with those rules. Class notations are divided into *main class notation* (covering hull, machinery, systems and equipment), *ship type notations* (applicable to the various types of vessels, e.g., dry cargo ships, container ships, passenger ships, oil tankers and fishing vessels) and *additional class notations*, related to: structural strength and integrity; propulsion, power generation and auxiliary systems; navigation and manoeuvring; cargo operation; equipment and design features; cold climate; environmental protection and pollution control; and survey arrangement (ibid., 2015b). The class notation related to e.g., cold climate and compliance with the Polar Code and, finally, the issuance of the PSC must therefore be considered as supplementary but also additional regulatory instruments to the other notations and requirements that shipowners and operators engaged in Arctic shipping must comply with. For passenger ships intended for voyages within the geographical area of application of the Polar Code, most of the above-mentioned notations are applicable.

Before passenger ships are allowed to encounter polar waters regulated by the Polar Code, an operational risk assessment of the ship and its equipment shall be carried out, considering the anticipated range of operating conditions and hazards the ship may encounter in polar waters, to establish procedures or operational limitations before encountering these areas. This operational risk assessment forms the basis for the establishment of procedures and operational limitations for the ship and, accordingly, the issuance of the PSC. The PSC shall specify *vessel type, ice class, polar service temperature, maximum expected time of rescue, vessel restrictions and operational limitations for ice conditions, temperature and high latitudes* (International Maritime Organization [IMO], 2017). The issuance of the PSC relies on the operational risk assessment and on the methodologies for assessing operational capabilities and limitations in ice, preferably the POLARIS (International Maritime Organization [IMO], 2016) (see Subchapter, 7.2.1). Moreover, the Polar Code requires that this ship-specific information shall be included in the Polar Water Operational Manual (PWOM), to be carried on board the ship on voyage. The purpose of the PWOM is to provide the owner, operator, master and crew with sufficient information regarding the ship's operational capabilities and limitations, to support their decision-making process. Therefore, the PWOM shall include or refer to procedures to be followed in normal operations and procedures to avoid encountering conditions exceeding the ship's capabilities. The PWOM shall also contain specific procedures to be followed in the event of an incident, if conditions are encountered which exceed the ship's specific capabilities and limitations, in addition to procedures for icebreaker assistance (International Maritime Organization [IMO], 2017).

7.2.1 The Polar Operational Limit Assessment Risk Indexing System (POLARIS)

Due to the Polar Code's risk-based principle, adequate measures will be highly dependent on geographical and seasonal variations. The Polar Code requires operational limitations, including those related to ships' structural ice capabilities, to be established and documented in the PSC and the PWOM, utilizing an acceptable methodology, preferably the POLARIS (International Maritime Organization [IMO], 2016). The basis of POLARIS is an evaluation of the risks posed to the ship by the expected ice conditions in relation to the ship's assigned ice class. In POLARIS, a ship is assigned a Risk Index, and the Risk Index Values within the Risk Index correspond to a relative risk evaluation for corresponding ice types, meaning that detailed and accurate information about ice types and ice conditions is essential input to the system. In applying a risk-based ship design, the main challenge is related to the definition of the ice environment and the ship-ice interaction in this varying environment (Kujala et al., 2019a). Comparing ice environments is a complex matter, as ice can have various forms and can be first, second or multiyear ice, which will have a large impact on the strength properties of the ice, as well as on the possible thickness. In addition, ice fields are dynamic, and changes in the ice cover characteristics can happen rapidly, e.g., due to the wind and currents (Kujala et al., 2019b).

There is still limited experience in utilizing POLARIS in the establishment of operational limitations in Norway, which can be partly explained by the lack of data in existing Norwegian ice charts, which do not have a standard colour code system separating ice types from each other, as used by other Arctic states, e.g., Canada, Denmark (Greenland), and Russia (ref. Paper IV - Engtrø et al., 2020b). In 2018, the IMO adopted new and amended ships' routeing measures in the Bering Sea and Bering Strait, aimed at reducing the likelihood of incidents – the first measures adopted for the Arctic Region where the Polar Code applies. These measures include six two-way routes and six precautionary areas, to be voluntary for all ships of 400 gross tonnage and above. In addition, three areas to be avoided in the Bering Sea are established, to improve the safety of navigation and protect the fragile and unique environment in these areas (International Maritime Organization [IMO], n.d. 2). Canada, with long traditions of ice navigation, uses two systems: The Zone/Date System (ZDS) and the Arctic Ice Regime System (AIRSS), the latter enforced in 1996 and considered an equally acceptable alternative methodology to the later developed POLARIS. The ZDS, however, is a fixed system based on historical data on ice conditions, dividing the Canadian Arctic waters into control zones and stipulating the opening and closing dates for each zone for different vessel types. The system contends that ice conditions are consistent from year to year and does not reflect long-term trends and inter-annual variability in ice conditions, leading to the development and introduction of the more flexible AIRSS (Kubat et al., 2005).

7.3 Goal-Based Standards (GBS) approach in maritime regulation

The tendency to adopt a goal-based standards (GBS) approach in regulatory governance is increasing (Maher et al., 2013; Hoppe, 2005), with responsibility for developing definitive descriptive standards and guidelines being delegated from government officials to the actors and target groups that the regulations are intended to regulate. Previously, the classic approach to standard setting for maritime regulation has been through the adoption of prescriptive rules and regulations, but the emerging focus at the IMO for developing new conventions and regulations is on a goal-based regulatory framework (Hebbar et al., 2020; International Maritime Organization [IMO], n.d. 1). In the development of the Polar Code, the GBS approach was used; this involves high-level standards and procedures that are to be met through regulations, rules and standards. The GBS are comprised of at least one goal, functional requirement(s) associated with that goal and verification of conformity that rules and regulations meet the functional requirements, including goals (International Maritime Organization [IMO], 2019a). The risk assessment is integral to the development of GBS, where the goals to be achieved are defined at the very outset, and the process of identifying hazards is the first step and the basis for the risk analysis and the formulation of risk mitigating measures (Hebbar et al., 2020).

From a rational point of view, a GBS approach enables those subject to the regulations to choose flexible solutions best suited to their own business areas and activities (Maher et al., 2013). However, there is considerable heterogeneity among the actors subject to the Polar Code, and challenges can be predicted in the enforcement of the function-based regulation (ref. Paper III - Engtrø et al., 2020a; Paper IV - Engtrø et al., 2020a; and Paper VI - Engtrø, 2021). A centralized and international process for standardization, equal to the IACS and the PC requirements for ship structure, could provide predictability. Experience can be drawn from the Norwegian petroleum industry, with its extensive experience in utilizing functional requirements in the standardization of complex operations, supported by descriptive guidelines and detailed standards. The conditions and structures of the regulatory regime for shipping in polar waters differ, however, from those of the petroleum industry; the Norwegian oil and gas industry consists largely of homogenous groups, and the power balance between employees, employers and the authorities has promoted safety-dominated practice (Engen et al., 2013).

Utilizing a GBS approach, and functional requirements, puts pressure on the authorities and the organizations recognized by IMO to issue the PSC. High levels of competency are required in the assessment of implemented measures. One must bear in mind that achieving compliance with a certain requirement does not automatically ensure compliance with the overall goals in the associated regulation. Each company is responsible for conducting adequate operational risk assessments covering their own activities. A company can, however, deliberately mislead or inadvertently underestimate certain risks in their analyses, by predicting consequences as acceptable and/or probabilities as low as reasonably practicable. Experience from comparable industries has shown that thorough re-verifications of conducted risk assessments rarely occur (Njå and Solberg, 2010; Njå and Vasstveit, 2016; Njå et al., 2013). Re-verification, not only of operational risk assessments but also of existing analytical tools, should be conducted to verify whether potential hazards for maritime activities in polar waters are covered in the planning and execution of voyages. Analytical models quantifying risk levels should also be questioned, due to the significant uncertainties that exist in analysts' risk perceptions of descriptive scenarios (Braut et al., 2012).

The involvement of the authorities, by addressing responsibilities within the industry in a competent manner, is of the essence, to reduce and eliminate favourable conditions for disreputable parties (The Office of the Auditor General in Norway [Riksrevisjonen], 2018-2019). Previous experience from maritime disasters indicates a business sector in which the reputation of some members poses a challenge (Butt et al., 2013). Parallels can be drawn with the heavy vehicle transport industry, where research indicates that functional requirements are often stretched (Kuran and Njå, 2016; Njå et al., 2012). In voyage planning, shipowners, or operators responsible for conducting adequate operational assessments, can deliberately mislead or non-deliberately underestimate the probabilities of encountering first-year ice or older and thicker ice or large ice ridges. Certain actors may take advantage of and exploit the functional requirements set out in the Polar Code, which raises questions about the role of the authorities (Lindøe et al., 2014). The use of descriptive and detail-oriented requirements should also be evaluated, especially when uncertainties about phenomena increase, e.g., geography, environmental conditions or SAR operations in remote polar areas, with limited resources. However, the use of descriptive requirements and a non-flexible framework can turn out to be counter-effective, if compliance is achieved in a mechanical manner, with just checks and controls of predefined measures (Maher et al., 2013).

7.4 The STCW Convention and the Polar Code's function-based requirements for ice navigation training

Only in the last few years has the human dimension of ship operations gained somewhat more international attention; however, the general outlook in international law-making remains technical in nature (Kirchner, 2018). Although this is also valid for the overwhelming part of the Polar Code, some chapters of the regulation cover the human dimension, e.g., *Voyage planning* (Chapter 11) and *Manning and training* (Chapter 12) (International Maritime Organization [IMO], 2017). The 1978 STCW Convention was the first IMO regulation to consider the human element's contribution to safety at sea, establishing basic requirements for training, certification and watchkeeping, for seafarers on an international level (International Maritime Organization [IMO], n.d. 4; Hagerupsen, 2019). In 1995, the STCW Convention underwent a major revision and was amended in response to a recognized need to bring it up to date and to respond to critics who pointed out vague or unclear requirements that resulted in different interpretations of the regulation. The STCW-95 Convention provided more detailed requirements for minimum standards of competencies for seafarers, essentially requiring students to demonstrate their competence regarding prescribed standards (International Maritime Organization [IMO], n.d. 4; Ghosh, 2017). The focus shifted from being a knowledge-based Convention, comprising a syllabus for qualifying examinations, to providing requirements for skills and abilities necessary to perform workplace tasks (ibid., 2017). The STCW Convention has contributed to building the capacity and education of seafarers, creating uniform standards at the global level to supplement national legislation, and introducing relevant rules to enhance professionalism on board vessels, especially in situations where seafarers carry out their jobs on board foreign flag vessels (Munari, 2020). Many of the MET institutes use simulators and practical exercises for training and assessment in selected courses, developed to satisfy the STCW Convention, which promotes the use of simulators in MET. However, it is important to consider that a seafarer's competence is usually demonstrated only in oral or written exams (Castells et al., 2016). The use of decontextualized traditional assessment methods (e.g., multiple-choice questions, pen and paper testing, oral examinations) for most of the units of competence listed in the STCW Convention cannot be ignored (Ghosh, 2017).

The Polar Code has been criticized for being vague in some of its provisions, opening the way for compliance with its functional requirements and overall goals to be interpreted in a variety of ways by administrations and classification societies. Additionally, at the time of the implementation, the regulation did not provide detailed requirements for the manning and training of crews on ships operating in polar waters (Roach, 2017; Todorov, 2020). The STCW Convention's training requirements, implemented in 2018 for dedicated personnel in charge of a navigational watch on ships operating in polar waters, suggest various methods for demonstrating competence, defined as: approved in-service experience, approved ship experience and training, approved simulator training where appropriate and approved specialist training (Lovdata, 2018). However, a lack of harmonization between IMO member states as regards the utilization of teaching methods in the training of seafarers is apparent (Castells et al., 2016; Evans et al., 2017). The practical approach towards training and educating maritime students in ice recognition and identification is a challenging task, especially if the students do not have any experience with cold climate conditions and ice (ref. Paper VI - Engtrø, 2021). Considering that ice and human error are the two main factors of occurrence related to ship accidents (collisions, stuck in ice/drift, or sinking and death) in the Arctic, this emphasizes the importance of training and experience in polar water operations (Fedi et al., 2020). The establishment by the IMO in cooperation with Transport Canada of the regional capacity-building “train-the-trainer” workshops, taking a practical approach to this topic, is therefore considered a valuable tool, specifying the function-based requirements to enhance the competence, skills and knowledge of the instructors who provide this Polar Code training (ref. Paper VI - Engtrø, 2021).

The institutional and individual knowledge concerning risks and hazards related to shipping in the Arctic Ocean remains limited, and, although technology can aid in gathering basic hydrographical information, weather and wave data etc., the human dimension should not be underestimated. The increasing trend in Arctic shipping poses challenges and the probability of having seafarers used to voyages in, e.g., the Mediterranean or Indian Ocean, suddenly finding themselves operating in polar waters, with no previous experience or knowledge about the implications and hazards associated with shipping in these parts of the world (Kirchner, 2018). Additionally, the likelihood of grounding increases, when new ships, which are better equipped, and larger vessels with deeper drafts explore new areas with limited hydrographic data, where the human element is essential, highly influenced by personnel skills, competency, knowledge and experience (ref. Paper IV - Engtrø et al., 2020b; and Paper VI - Engtrø, 2021). This situation requires adequate preparation of ships and equipment, as well as of the human element, which is where training can be one important aspect of preparing seafarers for polar voyages. However, the existing STCW regimes are questioned in this context, as they mostly define skills required by the seafarers, and there is no guarantee that these skills will prepare seafarers for ship operations in Arctic or Antarctic waters (Kirchner, 2018). Another issue is that the development and implementation of practical training requirements for seafarers operating in polar waters should be considered applicable to – not only exclusively masters, chief mates and officers in charge of a navigational watch but also the additional crew members with non-navigational duties assigned to PSC ships, e.g., persons assigned to the engine department or the remaining marine crew, as cold climatic conditions also affect equipment and human performance (ref. Paper II – Engtrø and Gudmestad, 2019; Paper IV - Engtrø et al., 2020b; and Paper V - Engtrø and Sæterdal, 2021; Chaure and Gudmestad, 2020).

Shipping in polar areas requires special knowledge, skills and experience, which are possessed by a relatively small number of professionals; the lack of clarity in defining the specific skills required of a master and crew operating in polar waters could pose a significant risk to navigation safety (Todorov, 2020). Building awareness amongst MET institutes and instructors regarding the applicability of implemented policies and regulations is the first step towards effective implementation, and it is of importance that all academic staff of MET institutions are encouraged to have good knowledge of the related matter, for effective training and compliance with the applicable regulations (Evans et al., 2017). The aim of the regional capacity-building "train-the-trainer" workshop – to enhance the skills and competence of MET instructors providing the Polar Code Model Courses for ice navigation training – could be jeopardized by relying on non-systematic methods of exchanging experiences and learning outcomes from these events (ref. Paper VI - Engtrø, 2021). In this regard, the STAMP methodology (Leveson, 2011) is a useful tool for identifying the maritime system and the stakeholders operating within it. The model helps to explore both established and lack of constraints affecting the interaction between the various stakeholders participating in the implementation of the Polar Code and the STCW Convention's training requirements for polar water operations. Safe shipping in the Arctic Ocean relies on stakeholders in the maritime system being aware of and complying with established constraints in a satisfactory manner: in this context, awareness of and compliance with applicable regulations and requirements for polar water operations. However, the controls and constraints for ensuring that PSC ships are manned with qualified, experienced and skilled personnel for polar voyages are questioned, especially since the responsibility for interpreting the functionally based Polar Code is delegated to the decision makers. Criticism raised regarding lack of practical training requirements in the STCW Convention therefore seems legitimate, considering that the Polar Code Model Courses for ice navigation can be conducted by means of classroom lectures alone (ref. Paper VI - Engtrø, 2021).

7.5 Non-SOLAS vessels and the application of the Polar Code

On 28th December 2018, the trawler Northguider, with a total crew of 14 persons, was fishing for shrimps in isolated fjords in the northern parts of the Svalbard archipelago (Rommetveit and Nøkling, 2019). The climate conditions that day were extreme, with snowstorms and temperatures at -22°C, making the wind chill temperature -37°C (the effective temperature for the human body). In the polar night, the crew physically had to remove ice from the structure of the vessel due to sea spray icing and the heavy snow showers, but, in Hinlopenstretet, a long fjord separating Spitzbergen from Nordaustlandet, control over the vessel was lost. The strong winds and the ocean current brought the vessel to shore, where it grounded. Distress signals were sent via the emergency channels on the vessel's radio, but, due to the Northguider's high latitude and consequently poor satellite coverage, the initial mayday signals were not responded to. Luckily, the crew managed to get in contact via satellite phone with their shipowner, who again contacted the Joint Rescue Coordination Centre (JRCC) North Norway, in Bodø. The closest vessel to aid the Northguider had 24 hours sailing time to the shipwreck, and the two SAR helicopters located at Svalbard airport (Longyearbyen) had one-hour flight time to the location. Around one hour and 38 minutes after the initial mayday signals were sent from the Northguider, the first of two scrambled SAR helicopters arrived at the area where the distressed vessel was located. The two SAR helicopters and their crew managed to rescue all 14 crew members on the Northguider and returned them safely ashore in Longyearbyen two hours later. During this accident, the two life rafts belonging to the vessel were lost and, eventually, the 14 crew members gathered themselves on deck, dressed in their survival suits. If the vessel sank, the only option left was to jump into the ocean and, in a hopeless attempt, swim, in metre-high waves, to the nearest ice floe approximately 50 metres from the vessel or even further to shore at Nordaustlandet, one of the busiest areas for polar bears in Svalbard (ibid., 2019).

Concerns have been raised regarding non-SOLAS vessels operating in polar waters (ref. Paper IV – Engtrø et al., 2020b; Schopmans, 2019) – as the Polar Code's safety provisions (Part I) are not applicable to these vessels – and especially with respect to fishing vessels, since they constitute the largest overall shipping presence in Arctic waters (Protection of the Arctic Marine Environment [PAME], 2020). Data covering accidents and incidents submitted to the IMO since 2010 continue to demonstrate that ships not certified under the SOLAS Convention, especially fishing vessels and yachts, are operating with increasing frequency in polar waters (International Maritime Organization [IMO], 2020). These vessels are vulnerable to the same risks as ships certified under the SOLAS Convention, including accidents or other incidents, potentially causing loss of life and injury, as well as loss of or damage to the vessels. The MSC and related sub-committees within the IMO are currently looking at the application of the Polar Code to vessels not regulated by the SOLAS Convention. At the end of 2019, the IMO assembly meeting adopted a resolution on interim safety measures for vessels not certified under the SOLAS Convention operating in polar waters, which urges IMO member states to implement, voluntarily, the safety provisions (Part I) of the Polar Code for non-SOLAS vessels (ibid., 2020). Additionally, the IMO Sub-Committee on Navigation, Communications and Search and Rescue (NCSR) is currently considering the possible application of the Polar

Code's chapters on *Safety of navigation* (Chapter 9) and *Voyage planning* (Chapter 11) to non-SOLAS vessels, and a correspondence group has been established to report back to the next NCSR session on how to best enhance the safety of these vessels when operating in polar waters (International Maritime Organization [IMO], n.d. 2).

In the aftermath of the Northguider accident, this rescue mission was described as being at the outer limits of possible and safe performance, due to the extreme weather conditions that day (Rommetveit and Nøkling, 2019). When the last four of the 14 crew members on the Northguider had been hoisted up and rescued, the second SAR helicopter only had fuel left for two more minutes, before it had to return to shore (Rypeng, 2018). If the weather conditions had been too extreme that day, exceeding the operational window of the SAR helicopters, the crew members on the Northguider could only have depended on themselves and self-rescue in this situation, with no likelihood of survival. In a news interview five days after the accident, the director representing the shipowner company admitted that the limits for safe operation were pushed to the maximum, by fishing in this area under the prevailing conditions and circumstances (Finne and Eilertsen, 2019). However, when questioned on the conducting of risk assessments prior to encountering such remote areas in the Arctic under the prevailing conditions, the director responded that the risk assessment was based on the vessel design, concluding that polar fishing vessels are designed to manoeuvre in thick ice and, therefore, they can withstand such Arctic conditions. On being questioned as to whether the shipowner could be blamed for the accident, the director denied this, arguing that the vessel was designed for Arctic operations and that fishing in these areas was a necessity for economic reasons. The director's attitude towards ship accidents in the Arctic was that *these things happen* and that the solution to the problem is to increase the emergency response resources in the area (ibid., 2019). The crew members on the Northguider were young and inexperienced, with an average age well below 30 years at the time of the accident, e.g., the second mate at 24 years old had completed the navigator education three years earlier, at age 21, and the chief engineer, at the age of 27, had been assigned to the Northguider twelve days before the accident occurred. In the debrief after the accident, some crew members on the Northguider were critical of the fact that there are limited SAR resources in the Arctic Region and that the closest vessel to aid the shipwrecked was 24 hours' sailing time away (Rommetveit and Nøkling, 2019). However, their own responsibility for assessing the risks of fishing in remote areas, with limited satellite communication and in extreme weather conditions, was not mentioned. This can be interpreted as an expectation of the establishment of more SAR resources and better satellite coverage, so that fishing in these high-risk areas can continue, regardless of all the associated hazards. Moreover, the danger faced by the SAR personnel who rescued the crew members on the Northguider that day must also be taken into consideration (Kruke and Bø, 2019).

This rescue operation was followed by months of removing fuel and other hazardous materials from the vessel, to prevent environmental harm, but damage to the vessel and weather conditions thwarted several efforts to remove the vessel, which finally was removed successfully, almost two years after the accident took place (The Maritime Executive, 2020). The shipowner was responsible for all costs associated with the removal of the vessel and was later fined NOK 300,000[3], due to safety and navigation violations (Skeie and Andreassen, 2020). In a statement from the Governor of Svalbard, the shipowner was criticized for fishing in a challenging area as regards climate and weather, including ice, low temperatures, dark and rapid changes in wind and weather conditions. Even more, the Governor of Svalbard pointed out in the statement that this area lacks a base map, lies a long distance from rescue and has unstable radio coverage. The fine was imposed for not having an adequate safety management system to identify and control the risk to

[3] The fine was reduced from the original order of NOK 500,000 because the case had been left after it was fully investigated.

the vessel, i.e., sailing and fishing with the Northguider, as well as the special conditions that apply to fishing in these areas. Additionally, the captain of the vessel was fined NOK 35,000 [4], due to negligent navigation, which resulted in grounding with subsequent danger to crew, material values and the environment. In the Governor of Svalbard's statement, the captain was criticized, as master, for not have taken sufficient account of weather data, the risk of fishing in demanding conditions in polar waters, near land, with reduced visibility due to darkness, snow and wind, and that fishing was conducted in an area with poor radio coverage and with a tidal current. Furthermore, there was a possibility of oil spills in a nature reserve, as the Northguider had, among other things, 65,000 litres of bunker oil on board (ibid., 2020).

The remaining question is whether this accident could have been avoided if compliance with the Polar Code was also applicable to fishing vessels when operating within the regulation's defined geographical areas. The operational risk assessment and the POLARIS, required to be conducted in the regulation, to establish ship-specific procedures and operational limitations for voyage planning and, finally, the issuance of the PSC, should have identified that the chosen area of operation for the Northguider, at that time of year, during the prevailing weather conditions, represented too great a risk, and another area should have been evaluated. Alternatively, the fishing should have been temporarily aborted and refuge sought in the nearest harbour until the weather had calmed down and the weather forecast improved. Moreover, the PWOM, to be carried on board ships on voyage, with the purpose of providing the owner, operator, master and crew with sufficient information regarding the ship's operational capabilities and limitations, to support the decision-making process (International Maritime Organization [IMO],

[4] The fine was reduced from the original order of NOK 50,000 because the case had been left after it was fully investigated.

2017), should have avoided those decisions that were taken, leading the Northguider to encounter conditions exceeding the vessel's capabilities.

Concerns should also be directed towards vessels operating in *ice-free polar waters* or in waters *outside* the application area of the Polar Code. The hazards of, and the concerns related to, icing, low temperature, extended periods of darkness or daylight, rapidly changing and severe weather conditions, sub-standard vessels, and lack of suitable emergency response equipment and of personnel possessing enough practical training and experience in cold climate operations are relevant to areas and waters not regulated by the Polar Code (ref. Paper IV - Engtrø et al., 2020b).

7.6 Emergency preparedness during ship accidents and the Polar Code's requirements concerning the maximum expected time of rescue

On 23rd March 2019, the cruise ship Viking Sky, with a total of 1373 Personnel on Board (POB), was on a voyage from Tromsø to Stavanger (Accident Investigation Board Norway [AIBN], 2019; Moe and Heiervang, 2019). In gale- to storm-force conditions and significant wave height of 9-10 metres, the ship experienced a blackout and loss of propulsion at Hustadvika – one of the most dangerous areas for shipping along the Norwegian coastline – and drifted towards shore. From the first engine shutdown, to full loss of engine power and propulsion on all four engines, to a mayday being broadcast, took 15 minutes. At that time, the master instructed the crew to drop the two anchors; however, the anchors did not hold, and the ship continued to drift astern towards the shore at a speed of 6–7 knots. Thirteen minutes later, the General Alarm (GA) was sounded on the ship, and the crew and passengers began to muster. On receipt of the mayday, the JRCC South Norway in Stavanger launched a major rescue operation and started scrambling resources. Approximately

24 minutes after experiencing blackout and total loss of propulsion, one of the engines was re-started, and, eventually over the next hour, the other engines were re-started, enabling the propulsion motors' output to maintain between slow ahead and half ahead. During that evening, the following night and morning, 479 passengers were evacuated from the Viking Sky by the means of six helicopters, in total. Twenty-seven people were treated at local hospitals in the region for injuries acquired on the ship during the incident. In the morning, the weather conditions had improved sufficiently to enable tugboats to be connected, and towlines were secured fore and aft, additionally to the ship maintaining its own propulsion. At that time, the master decided that the ship was out of danger and that it was safe to stop the evacuation of the passengers. On the day of this incident, the weather conditions were so rough that two rescue vessels that were mobilized to participate in the rescue operation had to return to port due to concerns for their own safety. At its closest to shore, the Viking Sky was only a ship's length from grounding and from a disaster occurring (Accident Investigation Board Norway [AIBN], 2019; Moe and Heiervang, 2019).

This rescue operation took place under severe conditions and, in the aftermath, is considered successful regarding both the evacuation, during which no incidents or injuries occurred, and the reception of passengers onshore (Direktoratet for samfunnssikkerhet og beredskap [DSB], 2020). In the evaluation of this accident, a major factor contributing to its success is recognized as being the integration of SAR services in Norway, where the coordination, management and cooperation between these actors and resources maintain the same standards, regardless of the event (at sea, land, or air). This approach facilitates the quick establishment of and response by a comprehensive rescue cooperation. One factor that has been highlighted as truly important in contributing to a safe and efficient rescue operation during the Viking Sky incident was the successful coordination of the airborne resources, which was managed by rescue leaders representing the JRCC South Norway and air traffic controllers representing Avinor. It is reasonable to consider, in this work, how such an incident would have unfolded and would have been managed if it had occurred in the Arctic Region, with limited resources and SAR services. Various experts on the matter have pointed out that this incident most likely would have turned into a major disaster with a catastrophic outcome if it had occurred in polar waters, and the event is viewed as a forewarning, considering the increase in cruise traffic in the Arctic Ocean (Ibrion et al., 2020). One of the learning points after the Viking Sky incident is that JRCC and Avinor should develop a concept for the coordination of airborne resources, *to ensure the same sufficient coverage all over Norway* (Direktoratet for samfunnssikkerhet og beredskap [DSB], 2020). Other learning points from this incident that are also applicable considering cruise traffic in the Arctic Region are accessible depots of fuel for the helicopters, to ensure efficient operations. Further, the availability of tugboats to assist ships in distress is highlighted, so that the Norwegian Coast Guard shall, at any time, have access to enough tugboats, both south and north of the 65th parallel. However, this emergency preparedness resource is not dimensioned for cruise traffic but based on the prevention of spill to the environment. To date, an assessment of the capacity of tugboats from an emergency response perspective has not been performed. However, the Norwegian government has decided to establish a committee to assess the emergency response resources regarding the increasing cruise ship traffic in Norwegian waters. Moreover, Norway has not established a national plan for Mass Rescue Operations (MRO) that could form the basis for the cooperation between the JRCC and other actors participating during an emergency of such a proportion and during exercises. It is only on rare occasions that the assembly of these resources is activated, and, therefore, exercises focusing on MROs and the cooperation and coordination between the different SAR resources should be addressed (ibid., 2020), which is highly relevant for cruise ships trafficking in the Arctic Ocean.

The three SAR exercises proved that SOLAS-certified rescue equipment was not compliant with the Polar Code requirements for survival in polar waters (Solberg et al., 2016; Solberg et al., 2017; Solberg and Gudmestad, 2018; Gudmestad and Solberg, 2019), necessitating a joint effort from the authorities and interest groups to develop provisions for the regulations, to ensure that LSA meet an expected standard when utilized under cold climate conditions (ref. Paper IV - Engtrø et al., 2020b). In this regard, the relatively swift establishment and implementation of the new interim guidelines on LSA (International Maritime Organization [IMO], 2019c) is part of the new IMO instruments developed to support compliance of the Polar Code being met in a satisfactory manner. A controversial topic during the development of the Polar Code and in the making of the LSA guidelines was the requirement regarding maximum expected time of rescue (ref. Paper IV - ibid., 2020b), set to never be less than five days (International Maritime Organization [IMO], 2017). In this regard, the chronological process within IMO, of first developing interim guidelines before they are made mandatory, is a sustainable way to handle controversial matters, considering that acceptance and consensus are more easily achieved by establishing voluntary guidelines rather than mandatory ones (ref. Paper IV - ibid., 2020b). The requirement concerning maximum expected time of rescue remains debatable and considered by some as more of a theoretical statement, questioning the capability of LSA to keep (elderly) people alive for a minimum of five days, after a vessel abandonment in polar waters (Nilsen, 2018). Operators may adopt this requirement without any further assessment of whether the expected time of rescue may also *exceed* five days, which could be the case for ships with a large number of POB, operating in the most remote parts of the Svalbard archipelago (Norwegian Maritime Authority [NMA], 2019).

The provision of suitable and sufficient LSA and arrangements on ships intended for polar voyages can be a demanding task for shipowners and operators (Solberg et al., 2016; Solberg et al., 2017; Solberg and Gudmestad, 2018; Gudmestad and Solberg, 2019), considering the total assembly of equipment that constitutes the entire emergency response system found on a ship. In this process, the selection of sufficient LSA and arrangements, and the enforcement of safety measures to ensure compliance with the requirements defined in the Polar Code, could be challenged for both economic and practical reasons (Solberg et al., 2017). LSA and arrangements intended for polar water operations imply an additional budgetary cost, compared to emergency equipment found on ships in tropical climates, due to the winterization measures required in the design, preservation and packaging process. At the same time, to withstand the harsh polar environment, additional and winterized LSA and arrangements require space for storage and impose added weight on rescue craft. A reduction in the number of passengers could therefore emerge because of the additional equipment (Solberg et al., 2016).

A dilemma in the discussion concerning time of rescue is the lack of a shared understanding or a definition concerning when one can be considered rescued, adding another uncertainty to the topic (Solberg et al., 2020). Self-rescue is the core principle in the event of a maritime incident and abandonment of ship in the Arctic Ocean, and the NMA stresses that the expected time of rescue may also exceed five days in Svalbard (Norwegian Maritime Authority [NMA], 2019). Therefore, it is expected that the companies must be able to document the operational risk assessments underlying the chosen time of rescue. After the SAR exercises, it was suggested that a level of heat loss regarded as acceptable for the human body to maintain for the expected time of rescue should be defined, based on predefined heat loss figures. The definition of a heat loss figure applicable to polar waters would allow for survival equipment and combinations of survival equipment to be assessed in a transparent way (Solberg and Gudmestad, 2018). The new guidelines for LSA recommend that manufacturers provide information on additional tests, including temperature ranges for which the equipment is intended, and that this information is included in ships' operating and maintenance manuals (International Maritime Organization [IMO], 2019c).

A concern regarding even well-defined emergency systems and plans is that they are only predictions of specified scenarios, which implies that they could be built on erroneous models of key variables. There will always be unforeseen factors, when put in combination, introducing new hazards that require the development of new scenarios, capturing risks such as sabotage, terrorism or attack from wildlife, when operating in polar areas. Cold climate conditions impose limitations on equipment, systems and personnel, which can turn out to be catastrophic if not recognized in advance (ref. Paper II - Engtrø and Gudmestad, 2019; and Paper V - Engtrø and Sæterdal, 2021; Solberg et al., 2016; Solberg et al., 2017; Solberg and Gudmestad, 2018; Gudmestad and Solberg, 2019).

During recent decades, the international maritime industry has developed sophisticated safety management systems, including policies, procedures, methods and tools, to cope with the emergence of new systemic risks. A major problem is, however, a lack of means and processes to validate the efficiency of an implemented management system and that it represents the actual safety management in an organization (Valdez Banda and Goerlandt, 2018). This is further complicated by the fact that technological changes happen much faster at the operative level than the pace of changes in management structures, and different time lags, as well as lags in response to changes, exist at different levels in the regulated regime, particularly concerning legislation and regulation (Rasmussen, 1997). Conventions, regulations and guidelines can take years to change or develop, in contrast to rapid changes in practice and new technological innovations. Adopting and amending international maritime treaties, conventions and regulations is demanding work, and the IMO has been criticized for either not managing to bring new ones into force in a timely manner (Chircop, 2017), e.g., the Polar Code's development and implementation took more than 25 years, or, when in force, not being able to achieve compliance by various stakeholders. In the effort to address this problem, the IMO established the sub-committee on the Implementation of IMO Instruments (III) (ibid., 2017), which could be a compatible division within the IMO for addressing concerns regarding the harmonization of the Polar Code and the STCW Convention’s training requirements for seafarers operating in polar waters.

8 Summary and Conclusion

The present version of the Polar Code was possibly the optimum result that could have been negotiated in IMO. However, knowledge and experience are essential in the work of defining and redefining necessary and sufficient safety constraints and requirements for polar water operations, especially since the responsibility for interpreting the functional-based regulation is delegated to the decision makers. Currently, no common understanding with regard to interpreting the Polar Code requirements exists, and there are many variations among Flag States and classification societies concerning achieving compliance with this regulation (Ibrion et al., 2020). Different stakeholders can conceptualize problems based on distinct types of knowledge and, consequently, favour different possible risk mitigation measures (Goerlandt and Pelot, 2020). The various work settings, contexts and environments are influenced and driven by economic interests, resources and motives, and regulatory failure can occur for several reasons (Leveson, 2011). A short-term focus on profit and financial criteria dominates in an environment characterized by competition and aggression, as seen in profitable businesses, in favour of focusing on long-term criteria regarding the HSE impact (Rasmussen, 1997). The Polar Code requirement to conduct operational risk assessments is, in this regard, considered a valuable tool to reduce risks in polar shipping. Still, the requirements of the regulation may be difficult to enforce in the case of non-serious actors, and the Arctic Coastal States should strictly fine attempted non-compliancy.

This research concludes that, amongst experts in the field, the implementation of the Polar Code is acknowledged as an important milestone concerning the safety and emergency preparedness for ship operations in the Polar Regions and in particular in the Arctic Region, bringing forth international mandatory requirements for polar voyages, covering vessel design, construction and equipment, operational limitations, voyage planning, manning and training, and the protection of the environment. A controversial topic during the development of the Polar Code is the requirement concerning the maximum expected time of rescue, which remains debatable and should be further addressed in research, considering the descriptive part of the requirement, i.e., the time of rescue should never be less than five days. The interpretation of this requirement is further complicated, since there is no shared understanding or clear definition concerning when one can be considered rescued, which also should be followed up further in research. The application of the Polar Code to non-SOLAS vessels, operating within the geographical areas of the regulation, which currently is being addressed within the IMO, is a developing topic that also needs further attention. This applies in particular to the ocean-going fishing fleet. Moreover, vessels operating *outside* the defined areas of application, but within areas where cold climate conditions occur at certain times of the year, should also gain more focus in future research.

The amendments to the STCW Convention, providing new training requirements applicable to dedicated personnel in charge of a navigational watch on ships with a PSC operating in polar waters, is further considered an enhancement concerning minimum competence levels required for participating in polar water operations. The establishment by the IMO, in cooperation with Transport Canada, of the regional capacity-building "train-the-trainer" workshops, covering this topic with a practical approach, is recognized as a valuable tool, specifying the function-based Polar Code, to enhance the competence, skills and knowledge of the instructors who provide this training. However, in the assessment of the Canadian workshop, by using the STAMP methodology, it became apparent that the goal of the workshops could be jeopardized by relying on non-systematic methods for exchanging experiences and learning outcomes from these events. The information flow between the legislators and the actors engaged in Arctic shipping, and the enforcement of constraints to ensure regulatory compliance, are topics that should be addressed in later work. This research concludes that, in relation with the STCW Convention's training requirements for polar water operation, the practical training requirements should in the future also be considered applicable to the additional crew members with non-navigational duties, assigned to PSC. Cold climatic conditions have an impact on the entire vessel, including the performance capacity of both the equipment and the personnel, in their performance of their daily work activities and tasks, which needs further attention.

For inexperienced operators or shipowners with the intention of operating in the Arctic Region, the Polar Code contributes to defining a minimum expected standard concerning requirements for polar water operations. However, there is considerable heterogeneity among the actors subject to the Polar Code, and challenges can be predicted in the enforcement of the function-based regulation, especially since the responsibility for assessing and defining operational requirements is delegated to the subjects of the regulation, which in this work is characterized by experts, a paradox, considering that an inexperienced actor, lacking experience and knowledge regards ice identification and navigation in polar waters, would face difficulties in acknowledging the minimum standard and expectation addressed in the Polar Code, for operational elements, vessel design and construction. During this work, the authority's role, to regulate and control Arctic shipping, is identified as being demanding, and a high level of expertise, competence and knowledge must be possessed to ensure that sufficient verifications, audits and controls are conducted. Training and education, of not only the people assigned to PSC ships operating in polar waters, but also those representing the authorities occupied with Arctic shipping, is a topic that could be interesting to follow up in future research.

During the expert interviews, it became apparent that there is a lack of data in existing Norwegian ice charts, which potentially could influence the usability of the POLARIS software in voyage planning, considering that the adequacy of the operational risk assessment and the use of POLARIS, as a methodology for assessing a ship's operational capabilities and limitations in ice, rely on detailed and accurate information about ice types and ice conditions. Moreover, during this work, the introduction of new-build ships has been highlighted as a concern, considering that they are better-equipped, however, not necessarily sufficient for more daring operations, and that larger vessels with deeper drafts, exploring new areas with limited hydrographic data, are imposing new risks that need further attention. Especially, the human element and its influence on safety for Polar shipping, i.e., practical training requirements and the development of skills, competency, knowledge and (polar water operations) experience, should gain more focus in future research. The responsibility for succeeding in achieving safe shipping in the Arctic is shared amongst the driving actors in the maritime industry, i.e., the shipbuilders, the shipowners and operators in the Arctic Region, the regulators and their recognized organizations, in addition to academia, which, in its engagement to perform research on these topics, contributes to the momentum and focus on safety and emergency preparedness concerning shipping in the Arctic being a "daily-discussed" topic. The SARex I, II & III exercises are good examples of such research, joining central maritime actors engaged in polar water operations. During these exercises, SOLAS-certified rescue equipment was proved not to be compliant with the Polar Code requirements for survival in polar waters; this speeded up the process within the IMO of establishing LSA guidelines, supporting the regulation. The requirements in this guideline, for the provision of fresh water in the event of an abandonment of vessel, for the maximum expected time of rescue, has been examined in this work. The result from this study corresponds with findings from the SARex I, II & III exercises, showing a reduction in performance capacity for survival equipment, when tested at low temperatures.

Finally, the Polar Code may not contain sufficient instruments to ensure that catastrophes related to cruise ship accidents do not occur in Polar Regions; therefore, further attempts to improve the regulation should be undertaken, and it is expected that work on safety and emergency preparedness in polar shipping is continuing within the IMO, where further research on this topic should also be supported.

References

Accident Investigation Board Norway [AIBN]. (2019). *Interim report 12 November 2019 on the investigation into the loss of propulsion and near grounding of Viking Sky, 23 March 2019.* Lillestrøm (pp. 1-10).

Arctic Council. (2009). *Arctic Marine Shipping Assessment 2009 Report.* Second printing (April).

Arctic Council. (n.d.). *Arctic Council - The leading intergovernmental forum promoting cooperation in the Arctic – Who we are.* https://arctic-council.org/en/

Aven, T., and Renn, O. (2010). *Risk Management and Governance - Concepts, Guidelines and Applications*. Risk, Governance and Society, Volume 16.

Bai, J., and Wang, C. (2019). "Enhancing port state control in polar waters". *Ocean Development & International Law*, 50:4 (pp. 299-319). https://doi.org/10.1080/00908320.2019.1644776

Baldwin, R., Cave, M., and Lodge, M. (2010). *The Oxford Handbook of Regulation.* Oxford: Oxford University Press.

Baldwin, R., Cave, M., and Lodge, M. (2012). *Understanding Regulation: Theory, Strategy, and Practice.* Oxford: Oxford University Press.

Black, J. (2002). "Critical reflections on regulation". *Australian Journal of Legal Philosophy*, 27 (pp. 1-37).

Blaikie, N. (2019). *Designing Social Research: The Logic of Anticipation* (3rd edition). Polity Press.

Braun, V., and Clarke, V. (2006). "Using thematic analysis in psychology". *Qualitative Research in Psychology*, 3:2 (pp. 77-101). doi:10.1191/1478088706qp063oa

Braut, G. S., Rake, E. L., Aanestad, R., and Njå, O. (2012). "Risk images as basis for decisions related to provisions of public services". *Risk Management: An International Journal,* 14 (pp. 60-76). DOI: 10.2307/41407083

Brigham, L. W. (2017). *The Changing Maritime Arctic and New Maritime Operations.* In: Beckmann, R. C., Henriksen, T., Kraabel, K. D., Molenaar, E. J., and Roach, J. A. Governance of Arctic Shipping, Balancing Rights and Interests of Arctic States and User States (pp. 3-23). Leiden; Boston: Brill Nijhoff. DOI 10.1163/9789004339385_005

Brigham, L. W. (2020). *Arctic Ocean routes map showing the NSR and NWP*. University of Alaska Fairbanks and Cartography by Mapmakers.com

Butt, N., Johnson, D., Pike, K., Pryce-Roberts, N., and Vigar, N. (2013). *15 Years of Shipping Accidents: A review for WWF*. Southampton Solent University.

Cantu, J., Tolk, J., Fritts, S., and Gharehyakheh, A. (2020). "High Reliability Organization (HRO) systematic literature review: Discovery of culture as a foundational hallmark". *Journal of Contingencies and Crisis Management,* 28 (pp. 399-410).

Castells, M., Ordás, S., Barahona, C., Moncunill, J., Muyskens, C., Hofman, W., Cross, S., Kondratiev, A., Boran‐Keshishyan, A., Popov, A., and Skorokhodov, S. (2016). "Model course to revalidate deck officers' competences using simulators". *WMU Journal of Maritime Affairs*, 15 (pp. 163-185). DOI 10.1007/s13437-015-0092-2

Chaure, M. R., and Gudmestad, O. T. (2020). "Effectiveness of the Polar Code training of cruise liner crew for evacuation in the Arctic and Antarctic". *Transnav*, 14:4 (pp. 923-928).
DOI: 10.12716/1001.14.04.17

Chircop, A. (2017). *The IMO, its Role under UNCLOS and its Polar Shipping Regulation*. In: Beckmann, R. C., Henriksen, T., Kraabel, K. D., Molenaar, E. J., and Roach, J. A. Governance of Arctic Shipping, Balancing Rights and Interests of Arctic States and User States (pp. 107-143). Leiden; Boston: Brill Nijhoff. DOI 10.1163/9789004339385_005

Cohen, L., Hudson, S. R., Walden, V. P., Graham, R. M., and Granskog, M. A. (2017). "Meteorological conditions in a thinner Arctic sea ice regime from winter to summer during the Norwegian Young Sea Ice Expedition (N-ICE2015)". *Journal of Geophysical Research: Atmospheres,* 122 (pp. 7235-7259). doi:10.1002/2016JD026034.

Crotty, M. (2003). *The Foundations of Social Research: Meaning and Perspectives in the Research Process* (3rd edition), London: Sage Publications.

Denzin, N. K., and Lincoln, Y. S. (2011). *Introduction: The Discipline and Practice of Qualitative Research*. In Denzin, N. Z., and Lincoln, Y. S. (Eds.), The SAGE Handbook of Qualitative Research (4th edition). Los Angeles: SAGE Publications.

Direktoratet for samfunnssikkerhet og beredskap [DSB]. (2020). *Evaluering av Viking Sky hendelsen [Evaluation of the Viking Sky incident]*. DSB, Tønsberg.

DNV GL. (2015a). *Winterization for cold climate operations*. (DNVGL-OS-A201).

DNV GL. (2015b). *Rules for classification - Ships.* (DNVGL-RU-SHIP-Pt1Ch2).

Engen, O. A. Et al. (2013). *Tilsynsstrategi og HMS-regelverk i norsk petroleumsvirksomhet [Revision strategy and HSE regulations in the Norwegian petroleum industry]*. Arbeidsdepartementet - Ministry of Labour, Oslo.

Engtrø, E. (2021). "A discussion on the implementation of the Polar Code and the STCW Convention's training requirements for ice navigation in polar waters". *Journal of Transportation Security,* (pp. 1-27). DOI: 10.1007/s12198-021- 00241-7. Accepted for publication.

Engtrø, E., and Gudmestad, O. T. (2019). "Winterization and drilling operations in cold climate areas" [paper presentation]. *Proceedings - International Conference on Port and Ocean Engineering under Arctic Conditions (POAC)* (pp. 1-9). Delft, The Netherlands.

Engtrø, E., Gudmestad, O. T., and Njå, O. (2020a). "Implementation of the Polar Code: Functional Requirements Regulating Ship Operations in Polar Waters". *Arctic Review on Law and Politics*, 11 (pp. 47-69). http://dx. doi.org/10.23865/arctic.v11.2240.

Engtrø, E., Gudmestad, O. T., and Njå, O. (2020b). "The Polar Code's implications for safe ship operations in the Arctic region". *TransNav - The International Journal on Marine Navigation and Safety of Sea Transportation,* 14:3 (pp. 655-661). DOI: 10.12716/1001.14.03.18

Engtrø, E., Njå, O., and Gudmestad, O. T. (2018). *Polarkoden - funksjonsbasert forskriftsverk for polare farvann. Hvordan kan standarder presentere gode nok løsninger? [The Polar Code – function-based regulations for polar waters. The contribution of standards to safe and sufficient solutions?]*. In: Lindøe, P. H., Kringen, J., and Braut, G. S. Regulering og standardisering - Perspektiver og praksis [Regulation and standardization - Perspectives and practice] (pp. 146-162). Universitetsforlaget - Scandinavian University Press.

Engtrø, E., and Sæterdal, A. (2021). "Investigating the Polar Code's function-based requirements for life-saving appliances and arrangements, and the performance of survival equipment in cold climate conditions - test of SOLAS approved desalting apparatus at low temperatures". *Australian Journal of Maritime & Ocean Affairs,* (pp. 274-294). DOI: 10.1080/18366503.2021.1883821.

Ericson, C. A. II., and Ericson, C. A. (2011). *Concise Encyclopedia of System Safety: Definition of Terms and Concepts*. John Wiley & Sons, Incorporated.

Evans, U. F., Mkpandiok, A., and Okonna, K. O. (2017). "An evaluation of the level of awareness of the STCW-78 as amended in Manila 2010, using maritime education and training institutions as collective compliance mechanism". *Australian Journal of Maritime & Ocean Affairs*, 9:3 (pp. 168-181).
https://doi.org/10.1080/18366503.2017.1306915

Farré, A. B., Stephenson, S. R., Chen, L., Czub, M., Dai, Y., Demchev, D., Efimov, Y., Graczyk, P., Grythe, H., Keil, K., Kivekäs, N., Kumar, N., Liu, N., Matelenok, I., Myksvoll, M., O'Leary, D., Olsen, J., Pavithran, A. P. S., Petersen, E., Raspotnik, A., Ryzhov, I., Solski, J., Suo, L., Troein, C., Valeeva, V., Rijckevorsel, J., and Wighting, J. (2014). "Commercial Arctic shipping through the Northeast Passage: Routes, resources, governance, technology, and infrastructure". *Polar Geography*, 37:4 (pp. 298-324). doi:10.1080/1088937X.2014. 965769

Fedi, L., Faury, O., and Etienne, L. (2020). "Mapping and analysis of maritime accidents in the Russian Arctic through the lens of the Polar Code and POLARIS system". *Marine Policy*, 118 (pp. 1-9). https://doi.org/10.1016/j.marpol.2020.103984

Fedi, L., Faury, O., and Gritsenko, D. (2018). "The impact of the Polar Code on risk mitigation in Arctic waters: a 'toolbox' for underwriters?" *Maritime Policy & Management*, 45:4 (pp. 478-494). https://doi.org/10.1080/03088839.2018.1443227

Finne, A. F., and Eilertsen, H. (2019). *Eksperter om Svalbard-havariet: På grensen til uforsvarlig [Experts on the Svalbard-shipwreck: on the limit to recklessness].* High North News. https://www.highnorthnews.com/nb/eksperter-om-svalbard-havariet-pa-grensen-til-uforsvarlig

Flick, U. (2007). *Managing Quality in Qualitative Research*. London: SAGE.

Formplus. (2007). *What is Empirical Research Study? [Examples & Method]*. https://www.formpl.us/blog/data-collection-method

Gannon, M. (2014). *Exxon Valdez 25th Anniversary: 5 Facts About the Historic Spill.* NBC News. https://www.nbcnews.com/science/science-news/exxon-valdez-25th-anniversary-5-facts-about-historic-spill-wbna54764668

Ghosh, S. (2017). "Can authentic assessment find its place in seafarer education and training?" *Australian Journal of Maritime & Ocean Affairs*, 9:4 (pp. 213-226). DOI:10.1080/18366503.2017.1320828

Ghosh, S., and Rubly, C. (2015). "The emergence of Arctic shipping: Issues, threats, costs, and risk-mitigating strategies of the Polar Code". *Australian Journal of Maritime & Ocean Affairs*, 7;3 (pp. 171-182). doi:10.1080/18366503.2015.1093695

Goerlandt, F., and Pelot, R. (2020). *An Exploratory Application of the International Risk Governance Council's Risk Governance Framework to Shipping Risks in the Canadian Arctic.* In: Chircop, A., Goerlandt, F., Aporta, C., and Ronald, P. Governance of Arctic Shipping, Rethinking Risk, Human Impacts and Regulation (pp. 15-41). Springer Polar Sciences. https://doi.org/10.1007/978-3-030-44975-9

Government of Canada. (2017). *Wind chill index.* https://www.canada.ca/en/environment-climate-change/services/weather-health/wind-chill-cold-weather/wind-chill-index.html#X-201501151120382

Grønnestad, K. S. (2017). *Cruisetrafikk gjennom Arktis [Cruise traffic through the Arctic]*. BarentsWatch. https://www.barentswatch.no/artikler/cruisetrafikk-gjennom-arktis/

Gudmestad, O. T., and Solberg, K. E. (2019). "Findings from two Arctic search and rescue exercises north of Spitzbergen". *Polar Geography*, (pp. 1-16). DOI:10.1080/1088937X.2019.1597394

Hagerupsen, R. (2019). *K33: Kontroll av skipets drift og omsorg for personer om bord [Controlling the management of the ship and the personnel care].* MARKOM FS 2020. https://www.marfag.no/k33

Hale, A., Guldenmund, F., and Goossens, L. (2006). *Auditing Resilience in Risk Control and Safety Management Systems*. In: Hollnagel, E., Woods, D. D., and Leveson, N. Resilience Engineering: Concepts and Precepts (pp. 270-294). Aldershot: Ashgate, CRC Press.

Hale, A., and Heier, T. (2006). *Is Resilience Really Necessary? The Case of Railways.* In: Hollnagel, E., Woods, D. D., and Leveson, N. Resilience Engineering: Concepts and Precepts (pp. 125-147). Aldershot: Ashgate, CRC Press.

Heale, R., and Twycross, A. (2015). “Validity and reliability in quantitative studies”. *Evidence-Based Nursing*, 18:3 (pp. 66-67). 10.1136/eb-2015-102129

Hebbar, A. A., Schröder-Hinrichs, J. U., Mejia, M. Q., Deggim, H., and Pristrom, S. (2020). *The IMO Regulatory Framework for Arctic Shipping: Risk Perspectives and Goal-Based Pathways.* In: Chircop, A., Goerlandt, F., Aporta, C., and Ronald, P. Governance of Arctic Shipping, Rethinking Risk, Human Impacts and Regulation (pp. 229-247). Springer Polar Sciences. https://doi.org/10.1007/978-3-030-44975-9

Hill, E., LaNore, M., and Véronneau, S. (2015). “Northern Sea Route: An overview of transportation risks, safety, and security”. *Journal of Transportation Security*, 8 (pp. 69-78). doi:10.1007/s12198-015- 0158-6

Hollis, M. (2002). *The Philosophy of Social Science: An Introduction*. Cambridge: Cambridge University Press.

Hollnagel, E., and Woods, D. D. (2006). *Prologue: Resilience Engineering Concepts*. In: Hollnagel, E., Woods, D. D., and Leveson, N. Resilience Engineering: Concepts and Precepts (pp. 326-336). Aldershot: Ashgate, CRC Press.

Hoppe, H. (2005). “Goal-based Standards - A new approach to the international regulation of ship construction”. *WMU Journal of Maritime Affairs*, 4:2 (pp. 169-180).

Humpert, M., and Raspotnik, A. (2012). *The Future of Arctic Shipping Along the Transpolar Sea Route.* Arctic Yearbook 2012.

Ibrion, M., Paltrinieri, N., and Nejad, R. A. (2020). “Learning from failures in cruise ship industry: The blackout of Viking Sky in Hustadvika, Norway”. *Engineering Failure Analysis*, 125:105355 (pp. 1-20).

International Maritime Organization [IMO]. (1977). *International Regulations for the Safety of Fishing Vessels.* (MSC 92/26/Add.2 Annex 25).

International Maritime Organization [IMO]. (2001). *International Convention for the Safety of Life at Sea (SOLAS)*. (1974, and 1978 and 1988 Protocol relating thereto: 2000 and 2004 amendments).

International Maritime Organization [IMO]. (2005). *International Convention for the Prevention of Pollution from Ships (MARPOL).* (1973, and 1978 and 1983 Protocol relating thereto: 1997 amendments).

International Maritime Organization [IMO]. (2013). *Guidelines for Formal Safety Assessment (FSA) for use in the IMO rule-making process*. (MSC/Circ.1023-MEPC/Circ.392).

International Maritime Organization [IMO]. (2016). *Guidance on methodologies for assessing operational capabilities and limitations in ice; Polar Operational Limit Assessment Risk Indexing System (POLARIS)*. (MSC.1/Circ. 1519).

International Maritime Organization [IMO]. (2017). *International Code for Ships Operating in Polar Waters (Polar Code).* (MEPC 68/21).

International Maritime Organization [IMO]. (2019a). *Generic guidelines for developing IMO goal-based standards*. (MSC.1/Circ.1394).

International Maritime Organization [IMO]. (2019b). *Guidance for navigation and communication equipment intended for use on ships operating in polar waters*. (MSC.1/Circ.1612).

International Maritime Organization [IMO]. (2019c). *The interim guidelines for life-saving appliances and arrangements for ships operating in polar waters*. (MSC.1/Circ.1614 2019).

International Maritime Organization [IMO]. (2020). *Interim safety measures for ships not certified under the SOLAS Convention operating in polar waters*. (A 31/Res.1137).

International Maritime Organization [IMO]. (n.d. 1). *IMO Goal-based standards.* https://www.imo.org/en/OurWork/Safety/Pages/GoalBasedStandards.aspx

International Maritime Organization [IMO]. (n.d. 2*). International Code for Ships Operating in Polar Waters (Polar Code)*. https://www.imo.org/en/OurWork/Safety/Pages/polar-code.aspx

International Maritime Organization [IMO]. (n.d. 3). *International Convention for the Safety of Life at Sea (SOLAS).* https://www.imo.org/en/About/Conventions/Pages/International-Convention-for-the-Safety-of-Life-at-Sea-(SOLAS),-1974.aspx

International Maritime Organization [IMO]. (n.d. 4). *International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW).* https://www.imo.org/en/OurWork/HumanElement/Pages/STCW-Conv-LINK.aspx

International Maritime Organization [IMO]. (n.d. 5). *Introduction to IMO*. https://www.imo.org/en/About/Pages/Default.aspx

International Maritime Organization [IMO]. (n.d. 6). *The Torremolinos International Convention for the Safety of Fishing Vessels*. http://www.imo.org/en/About/Conventions/ListOfConventions/Pages/The-Torremo-linos-International-Convention-for-the-Safety-of-Fishing-Vessels.aspx

International Risk Governance Council [IRGC]. (2017). *Introduction to the IRGC Risk Governance Framework*. Revised version. Lausanne: EPFL International Risk Governance Center. https://irgc.org/risk-governance/irgc-risk-governance-framework/

International Standard Organization [ISO]. (2019). *Petroleum and natural gas industries — Arctic offshore structures*. (ISO 19906:2019. 2nd ed).

Jacobsen, D. I. (2015). *Hvordan gjennomføre undersøkelser? Innføring i samfunnsvitenskapelig metode [How to conduct surveys? An introduction to the methods of Social Science] (*3. utg. ed.). Oslo: Cappelen Damm akademisk.

Jean-Hansen, V. (2003). *Skipstrafikken i området Lofoten - Barentshavet [The sea traffic in the Barents Sea]*. Kystverket - The Norwegian Coastal Administration, Oslo.

Kahn Academy. (n.d.). Controlled experiments. https://www.khanacademy.org/science/high-school-biology/hs-biology-foundations/hs-biology-and-the-scientific-method/a/experiments-and-observations

Kirchner, S. (2018). "The human dimension of the Polar Code". *Australian Journal of Maritime & Ocean Affairs*, 10:1 (pp. 1-8). https://doi.org/10.1080/18366503.2017.1333191

Korstjensa, I., and Moser, A. (2018). "Series: Practical guidance to qualitative research. Part 4: Trustworthiness and publishing". *European Journal of General Practice*, 24:1 (pp. 120-124). https://doi.org/10.1080/13814788.2017.1375092

Kringen, J. (2018). *Regulering, standardisering, normering: terminologi, typologier og egenskaper. [Regulation, standardization, norms: terminology, typologies, and properties].* In: Lindøe, P. H., Kringen, J., and Braut, G. S. Regulering og standardisering - Perspektiver og praksis [Regulation and standardization - Perspectives and practice] (pp. 27-49). Universitetsforlaget - Scandinavian University Press.

Kristiansen, S. (2004). *Maritime Transportation: Safety Management and Risk Analysis.* Taylor & Francis Group.

Kruke, B. I., and Bø, S. (2019). *Den beste beredskapen er å forhindre at slike havarier skjer [The best emergency preparedness is the prevention of these accidents].* Nordnorsk Debatt.

Kubat, I., Collins, A., Gorman, B., and Timco, G. (2005). "A Methodology to Evaluate Canada's Arctic Shipping Regulations" [paper presentation]. *Proceedings - International Conference on Port and Ocean Engineering under Arctic Conditions (POAC),* Delft, The Netherlands.

Kujala, P., Goerlandt, F., Way, B., Smith, D., Yang, M., Khan, F., and Veitch, B. (2019a). "Review of risk-based design for ice-class ships". *Marine Structures*, 63 (pp. 181-195). doi:10.1016/j.marstruc.2018.09.008

Kujala, P., Kämäräinen, J., and Suominen, M. (2019b). "Validation of the New Risk Based Design Approaches (POLARIS) for Arctic and Antarctic Operations" [paper presentation]. *Proceedings - International Conference on Port and Ocean Engineering under Arctic Conditions (POAC*), Delft, The Netherlands.

Kuran, C., and Njå, O. (2016). "Rule Bending in the Road Based Commercial Goods Transport Sector - A Systems Theory Approach". *The 3rd International Conference on Transport and Traffic Engineering*, ICTTE, Belgrade, Serbia.

Labuschagne, A. (2003). "Qualitative research – airy fairy or fundamental?". *The Qualitative Report*, 8:1 (pp. 100-103). https://nsuworks.nova.edu/cgi/viewcontent.cgi?article=1901&context=tqr

Larsen, L. H., Kvamstad-Lervold, B., Sagerup, K., Gribkovskaia, V., Bambulyak, A., Rautio, R., and Berg, T. E. (2016). "Technological and environmental challenges of Arctic shipping - a case study of a fictional voyage in the Arctic". *Polar Research*, 35 (1): 27977 (pp. 1-11). doi:10.3402/polar.v35.27977

Leveson, N. (2011). *Engineering a Safer World: Systems Thinking Applied to Safety*. Cambridge, Mass: The MIT Press.

Leveson, N., Dulac, N., Zipkin, D., Cuther-Gershenfeld, J., Carrol, J., and Barret, B. (2006). *Engineering Resilience into Safety-Critical Systems*. In: Hollnagel, E., Woods, D. D., and Leveson, N. Resilience Engineering: Concepts and Precepts (pp. 95-123). Aldershot: Ashgate, CRC Press.

Lincoln, Y. S., and Guba, E. G. (1985). *Naturalistic Inquiry*. California: Sage Publications.

Lindøe, P. H., Baram, M. S., and Renn, O. (2014). *Risk Governance of Offshore Oil and Gas Operations*. New York: Cambridge University Press.

Lovdata. (2018). *Forskrift om kvalifikasjoner og sertifikater for sjøfolk [Regulations on qualifications and certificates for seafarers]*. https://lovdata.no/dokument/SF/forskrift/2011-12-22-1523/*#KAPITTEL_24.

Maher, S. T., Long, G. D., Cromartie, R. S., Sutton, I. S., and Steinhilber, M. R. (2013). “Paradigm shift in the regulatory application of safety management systems to offshore facilities”. *Process Safety Progress*, 35:4. DOI 10.1002/ prs.11558

Manuel, M. E. (2011). *Maritime Risk and Organizational Learning*. Taylor & Francis Group.

Moe, I., and Heiervang, C. (2019). *Havarikommisjonen: Viking Sky var kun en skipslengde fra å grunnstøte [Accident Investigation Board Norway: Viking Sky was only one ship-length from grounding]*. Aftenposten. https://www.aftenposten.no/norge/i/g7x9da/havarikommisjonen-viking-sky-var-kun-en-skipslengde-fra-aa-grunnstoete

Molenaar, E. J. (2017). *The Arctic, the Arctic Council, and the Law of the Sea*. In: Beckmann, R. C., Henriksen, T., Kraabel, K. D., Molenaar, E. J., and Roach, J. A. Governance of Arctic Shipping, Balancing Rights and Interests of Arctic States and User States (pp. 24-67). Leiden; Boston: Brill Nijhoff. DOI 10.1163/9789004339385_005

Munari, F. (2020). *Search and Rescue at Sea: Do New Challenges Require New Rules?* In: Chircop, A., Goerlandt, F., Aporta, C., and Ronald, P. Governance of Arctic Shipping, Rethinking Risk, Human Impacts and Regulation (pp. 63-81). Springer Polar Sciences. https://doi.org/10.1007/978-3-030-44975-9_4

Nilsen, T. (2018). *Arctic cruise ship boom*. The Barents Observer. https://thebarentsobserver.com/en/travel/2018/05/arctic-cruise-ship-boom

Njå, O., Braut, G. S., and Vika, O. E. (2012). “Bending the rules in the commercial goods road transport sector”. *Procedia - Social and Behavioral Sciences*, 48 (pp. 2336-2350).

Njå, O., and Solberg, Ø. (2010). "Safety considerations in political decisions: A case study of changes to the Norwegian aviation system". *Review of Policy Research*, 27:5 (pp. 595-619).

Njå, O., and Vastveit, K. R. (2016). *Norske kommuners planlegging, gjennomføring og bruk av risiko- og sårbarhetsanalyse i forbindelse med samfunnssikkerhetsarbeidet [Societal risk governance in municipalities is based on a weak regulatory regime and unclear professional competence]*. Stavanger: University of Stavanger.

Njå, O., Vastveit, K. R., Abrahamsen, E. B., and Eriksson, K. (2013). *Evaluering av risikovurderinger i Statens vegvesen. Beslutningsstøtte og læringsverktøy [Evaluation of risk assessments in the Norwegian Public Roads Authority: Decision support and learning tool].* Stavanger: International Research Institute of Stavanger.

Norwegian Maritime Authority [NMA]. (2014). *Regulations of 24 November 2014 No. 1458 on port state control.* https://www.sdir.no/contentassets/f93d8cdd2c174379bf77e8d2850ab3d6/24-november-2014-no.-1458-port-state-control.pdf?t=1624964158472

Norwegian Maritime Authority [NMA]. (2019). *Regulations on the construction, equipment, and operation of passenger ships in the territorial waters surrounding Svalbard.* (NMA, RSR 03-2019).

Oxford University Press. (2010). *Oxford Dictionary of English* (3rd edition). DOI: 10.1093/acref/9780199571123.001.0001

Perrow, C. (2011). *Normal Accidents: Living with High Risk Technologies - Updated Edition*. Princeton University Press.

Petroleumstilsynet [Ptil]. (2006). *ALARP-prosesser – Utredning for Petroleumstilsynet [ALARP-processes – Report to the Petroleum Safety Authorities].* (Sluttrapport Fase 1, endelig rapport rev2).

Petursdottir, G., Hannibalsson, O., and Turner, M. M. J. (2001). *Safety at sea as an integral part of fisheries management*. The Food and Agriculture Organization of the United Nations (FAO) (Fisheries Circular No. 966, FIIT/C966 ISSN 0429-9329).

Protection of the Arctic Marine Environment [PAME]. (2020). *The Increase in Arctic Shipping 2013–2019*. (Arctic shipping status report (ASSR) #1 31 March 2020).

Puryear, B., and Gnugnoli, D. M. (2020). "Emergency preparedness". *StatPearls*. https://www.ncbi.nlm.nih.gov/books/NBK537042/

Rasmussen, J. (1997). "Risk management in a dynamic society: a modelling problem". *Safety Science*, 27:2 (pp. 183-213). doi:10.1016/S0925-7535(97)00052-0

Reason, J. T. (2016). *Managing the Risks of Organizational Accidents*. Aldershot: Ashgate.

Repstad, P. (2007). *Mellom nærhet og distanse : kvalitative metoder i samfunnsfag [In between proximity and distance: qualitative research in social science]*. Universitetsforlaget - Scandinavian University Press.

Roach, A. J. (2017). *The Polar Code and its Adequacy*. In: Beckmann, R. C., Henriksen, T., Kraabel, K. D., Molenaar, E. J., and Roach, J. A. Governance of Arctic Shipping, Balancing Rights and Interests of Arctic States and User States (pp. 144-169). Leiden; Boston: Brill Nijhoff. DOI 10.1163/9789004339385_006

Roberts, K. H. (1990). "Some characteristics of one type of high reliability organizations". *Organization Science*, 1:2 (pp. 160-176).

Roberts, K. and Bea, R. (2001). "Must accidents happen? Lessons from High-Reliability Organizations". *The Academy of Management Executive*, 15:3 (pp. 70-79).

Rochlin, G. I., La Porte, T. R., and Roberts, K. H. (1987). "The self-designing High-Reliability Organization: Aircraft carrier flight operations at sea." *Naval War College*, 40:4 (pp. 76-90).

Rommetveit, A., and Nøkling, A. (2019). *Alene mot Barentshavet [Alone against the Barents Sea].* NRK. https://www.nrk.no/vestland/xl/alene-mot-barentshavet-1.14381609

Ryan, F., Coughlan, M., and Cronin, P. (2009). "Interviewing in qualitative research: The one-to-one interview". *International Journal of Therapy and Rehabilitation*, 16:6 (pp. 309-314). doi:10.12968/ijtr.2009.16.6.42433

Rypeng, L. (2018). *Se video fra den dramatiske redningsaksjonen her [See video of the dramatic rescue mission].* NRK. https://www.nrk.no/tromsogfinnmark/se-video-fra-den-dramatiske-redningsaksjonen-her-1.14358398

Sandelowski, M. (2002). "Reembodying qualitative inquiry". *Qualitative Health Research*, 12 (pp. 104-115).

Schopmans, H. (2019). *Revisiting the Polar Code: Where Do We Stand?* The Arctic Institute, Center for Circumpolar Security Studies, Washington.

Silber, G. K., and Adams, J. D. (2019). "Vessel operations in the Arctic, 2015–2017". *Frontiers in Marine Science*, 6: 573 (pp. 1-18). doi:10.3389/fmars.2019.00573

SINTEF. (2010). *Organisational Accidents and Resilient Organisations: Six Perspectives.* Revision 2, SINTEF A17034.

Skeie, T., and Andreassen, R. N. (2020). *Bøteleggges etter at «Northguider» havarerte på Svalbard [Fined after the "Northguider" accident on Svalbard].* NRK. https://www.nrk.no/tromsogfinnmark/botelegges-etter-at-_northguider_-havarerte-pa-svalbard-1.15063737

Solberg, K. E. (2017). "Implications caused by SARex on the implementation of the IMO Polar Code on survival at sea". *IOP Conference Series: Materials Science and Engineering*, 276:1 (pp. 1-7).

Solberg, K. E., and Gudmestad, O. T. (2018). *SARex3: evacuation to shore, survival, and rescue*. (Report no. 75, University of Stavanger).

Solberg, K. E., Gudmestad, O. T., and Kvamme, B. O. (2016). *SARex Spitzbergen: April 2016: exercise report: search and rescue exercise conducted off North Spitzbergen*. (Report no. 58, University of Stavanger).

Solberg, K. E., Gudmestad, O. T., and Skjærseth, E. (2017). SARex2: *Surviving a maritime incident in cold climate conditions*. (Report no. 69, University of Stavanger).

Solberg, K. E., Jensen, J. E., Barane, E., Hagen, S., Kjøl, A., Johansen, G., and Gudmestad, O. T. (2020). "Time to rescue for different paths to survival following a marine incident". *Journal of Marine Science and Engineering*, 8 (12): 997 (pp. 1-16). https://doi.org/10.3390/jmse8120997.

Struck, D. (2009). *Twenty Years Later, Impacts of the Exxon Valdez Linger.* Yale Environment 360. https://e360.yale.edu/features/twenty_years_later_impacts__of_the_exxon_valdez_linger.

Sürücü, L., and Maslakçı, A. (2020). "Validity and reliability in quantitative research". *BMIJ*, 8:3 (pp. 2694-2726). doi: http://dx.doi.org/10.15295/bmij.v8i3.1540

Sutcliffe, K. M. (2011). "High reliability organizations (HROs)". *Best Practice & Research Clinical Anaesthesiology*, 25 (pp. 133-144).

Svalbar Treaty. (1920). Treaty between Norway, The United States of America, Denmark, France, Italy, Japan, the Netherlands, Great Britain and Ireland and the British Overseas Dominions and Sweden concerning Spitsbergen, signed in Paris 9th February 1920.

The Maritime Executive. (2020). *SMIT Completes Northernmost Wreck Removal Project Ever.* The Maritime Executive. https://www.maritime-executive.com/article/smit-completes-northernmost-wreck-removal-project-ever

The Office of the Auditor General in Norway [Riksrevisjonen]. (2018-2019). *The Office of the Auditor General's investigation of the PSA's follow-up of health, safety and environment in the petroleum industry.* The Office of the Auditor General in Norway, Document 3:6, ISBN 978-82-8229-454-6.

Todorov, A. (2020). "Coping with deficiencies in the Polar Code: A Russian Perspective". *The Polar Journal*, 10:2 (pp. 322-333). https://doi.org/10.1080/2154896X.2020.1799615

Trantzas, K. (2017). *A risk analysis and the insurance policies for the cruise ships in the Arctic* [Unpublished master's thesis]. University of Stavanger.

Urke, E. H. (2018). *Store cruiseskip ankommer Svalbard. Redningskapasiteten er sterkt begrenset [Large cruise ship arrives at Svalbard. The rescue capacity is highly limited].* https://www.tu.no/artikler/store-cruiseskip-ankommer-svalbard-redningskapasiteten-er-sterkt-begrenset-br/453913.

Valdez Banda, O. A., and Goerlandt, F. (2018). "A STAMP-based approach for designing maritime safety management systems". *Safety Science*, 109 (pp. 109-129).

Veazie, S., Peterson, K., and Bourne, D. (2019). *Evidence Brief: Implementation of High Reliability Organization Principles*. Department of Veterans Affairs, Veterans Health Administration, Health Services Research & Development Service, Washington, DC.

Wang, S., Jingbo, Y., and Khan, R. U. (2020). "The multi-state maritime transportation system risk assessment and safety analysis". *MDPI Sustainability*, 12:5728. doi:10.3390/su12145728

Weick, K. E. (1987). "Organizational culture as a source of high reliability". *California Management Review*, 29:2 (pp. 112-127).

Weick, K. E., and Sutcliffe, K. M. (2007). *Managing the Unexpected - Resilient Performance in an Age of Uncertainty*. Jossey-Bass.

Appendices

Appendix 1 – Interview Guide no. 1 (Paper I and Paper III)

Interviewees: Principal advisor (NMA) and Surveyor (NMA), (see Chapter 5.2.1 Experts' Interviews).

Intervjuguide Sjøfartsdirektoratet (SFD), 2018.

1. Hva er bakgrunn for valg av et funksjonsbasert regelverk ved utforming av Polarkoden?
2. Hvilke aktører har vært involvert i utarbeidelse av regelverket?
3. Er kartene over Arktis og Antarktis i Polarkoden for maksimal utbredelse av forskriften (nord og sør for den 60 breddegrad – med unntak i Arktis) endelige eller er grensen nyansert og tøyelig; pga. klimatiske forhold og, - variasjoner?
4. Hvordan fortolker SFD figurteksten som viser maksimal utbredelse av Polarkoden? (Sitat Polarkoden: "figuren er kun ment å være illustrerende / It should be noted that this figure is for illustrative purposes only».)
5. Rundt Arktis er det soner i Barentshavet og Grønlandshavet som har en egen form, og ikke følger den lineære grensen på 60 breddegrader. Hvilke forhold spilte inn for at det ble definert på denne måten?
6. Var det Norges (Island / Færøyene) ønske å holde deler utenfor den lineære grense?
7. Maksimal forventet redningstid er den tiden som er lagt til grunn ved utformingen av overlevelsesutstyr og -systemer. Den skal aldri være mindre enn 5 dager. Er det 24t x 5 d? Er det juridisk eller en innforstått forståelse? Dag vs. døgn?
8. Hva er begrunnelsen for fem dager?

9. Foreligger det vitenskapelige holdepunkt for at den gitte lenge på max. antall dager for overlevelse, under gitte forhold og med gitte overlevningsmidler?
10. Gjelder Polarkoden også for boreinnretninger (flyteinnretninger) ved evt. petroleumsaktivitet / boreoperasjoner innenfor definerte grenser satt i koden?
11. Standardiseringsprosjekter etter Polarkoden ble innført? Vurderer IMO å lage en veiledning til koden?
12. Hva baserer evt. nye retningslinjer seg på? Data, analyser eller subjektive vurderinger?
13. Hva er evt. bakgrunn for oppdateringer / nye retningslinjer? Faglige eller subjektive vurderinger?
14. Hva har SARex-øvelsene hatt å si for videre utvikling og arbeid med Polarkoden?
15. Er det en systematikk i tilbakeføring av læringer, fra det operasjonelle miljøet til IMO?
16. Retningslinje for målbasert regler GBS – utbedres. Er dette risikobasert?
17. Manglende teststandarder og ytelsesstandarder for redningsutstyr, kommunikasjonsutstyr. Hva jobbes det med?
18. Nye tekniske krav for løsninger på redningsutstyr / sikkerhetsutstyr som ivaretar kravet om 5 dagers redningstid?
19. Kan man vente seg en kvantifisering av risikobildet fra myndighetenes side (scenarioutvikling, modellering, vurdering av data)?
20. Hvilke videre prosesser er ventet fra IMO for sikkerhetsstyring på disse områdene?
21. Er det bare IMO selv som har igangsatt utvikling av veiledere til Polarkoden? Interesseorganisasjoner; Norge Rederiforbund, CLIA og representert fra NGOs deltakende i arbeid med videreutvikling av regelverk og standardisering?
22. Hvordan skal oppfølging og kontroll av Polarkodens krav skal håndteres i praksis, og har tilsynsmyndighet ovenfor aktører som

opererer innenfor Polarkodens geografiske virkeområder? Klasseselskap på vegne av flaggstater, Arktisk Råd og nasjoner med interesser i polare områder vil ha en rolle i dette arbeidet, men det fremstår likevel uklart hvordan denne rollefordelingen skal være. Hva er havnestatskontroll rolle her?

Appendix 2 – Interview Guide no. 2 (Paper I and Paper III)

Interviewees: Principal advisor (NMA) and Surveyor (NMA), (see Chapter 5.2.1 Experts' Interviews).

Intervjuguide Sjøfartsdirektoratet (SFD), 2018.

Fra forrige telefonintervju: Sjøfartsdirektoratet (IMO) er i gang med utarbeidelse av test, - og ytelsesstandarder til koden for blant annet overlevelsesutstyr og -systemer (beredskap, - og redningsutstyr).

1. Hvilke nye tekniske krav er det ventet kan komme for løsninger på redningsutstyr / sikkerhetsutstyr som ivaretar kravet om 5 dagers redningstid?
2. Hvilke nye prosessrelaterte styringsløsninger kan man vente seg? Analyseverktøy?
3. Hvilke videre prosesser er ventet fra IMO for sikkerhetsstyring på disse områdene?
4. Hvilke prosessrelaterte styringsløsninger (analyseverktøy) skal foreløpig benyttes for å imøtekomme krav i Polarkoden?
5. Kan man vente seg en kvantifisering av risikobildet fra myndighetenes side (scenarioutvikling, modellering, vurdering av data)?
6. I Polarkoden henvises det til metodologi for vurdering av operasjonelle egenskaper og begrensninger i is, som tar hensyn til retningslinjer som *skal* utarbeides av IMO (1.3.7). Det står ikke noe om når retningslinjene skal utarbeides eller hvilke operasjonelle egenskaper de skal omhandle. Er dette en del av arbeidet Sjøfartsdirektoratet (IMO) er i gang med? (Utarbeidelse av test, - og ytelsesstandarder for blant annet beredskap, - og redningsutstyr).
7. Få bekreftet / avkreftet at det diskuteres innad i IMO om å utarbeide et retningslinjedokument (Guidance note) som gir eksempler på hvordan kravene i Polarkoden kan oppfylles.

8. Hvordan er standardiseringsarbeid innad i IMO organisert? (demokratisk prosess).
9. Hvordan er ulike interesseorganisasjoner, som Norge Rederiforbund, CLIA og representert fra NGOs deltakende i arbeid med videreutvikling av regelverk og standardisering?
10. SOLAS gjelder ikke for fangs, - og fiskefartøy og Polarkoden er derfor heller ikke regulerende for denne næringen. Vil det si at store trålere (2000 – 3000 tonn) ikke er underlagt Polarkoden selv om de opererer innenfor regelverkets geografiske område?
11. Statoil Korpfjell prospekt er innenfor Polarkodens virkeområde. Vil et PSV / SBV ikke være underlagt koden (per definisjon) om det har arbeidsområde Hammerfest – Korpfjell, og det ikke er i internasjonal fart?
12. Hvordan forventer IMO at dette etterleves? Hvordan tolkes denne definisjonen / hvordan etterleves SOLAS forskriftene ut fra denne definisjonen?

Appendix 3 – Interview Guide no. 3 (Paper IV)

Interviewees: Principal advisor (NMA), Surveyor no.1 (NMA), Surveyor no. 2 (NMA), Professor in ice navigation (representing the academia in Norway), Director in Norwegian based classification society, and Engineer (NCA) (see Chapter 5.2.1 Experts' Interviews).

1. Bakgrunn.
- Hvor lenge i nåværende posisjon?
- Hvor lang arbeidserfaring innen skipsfart?
- Erfaring innenfor skipsfart i polare områder?
- Kjennskap og arbeidserfaring til Polarkoden?

2. Hvor er vi nå, og veien videre? (tre år etter ikrafttredelse av regelverket)?
- hvilke sikkerhetsmessige «milepæler» ser man som følge av Polarkoden?
- hva er årsak og bakgrunn til «milepælene»?
- hvilke hovedutfordringer ser du i det følgende for skipsfart i nordområdene? passasjertrafikk i Barents-området?

3. Kjennskap til (ny):
- IMO retningslinje (juni 2019) for redningsredskaper og-arrangementer (Interim guidelines on life-saving appliances and arrangements for ships operating in polar waters); en veileder til kap. 8.3 i Polarkoden, for sikker rømning, evakuering og overlevelse?
- Om ja: hvordan brukes retningslinjen i planlegging / gjennomføring av polare operasjoner?
- Dokumentasjon?

4. Kjennskap til: Endring av forskrift om kvalifikasjoner og sertifikater for sjøfolk (juli 2018)?
- Hvert besetningsmedlem skal gjøres kjent med prosedyrene og utstyret inkludert i eller referert til i operasjonsmanualen, som er relevante for deres tildelte plikter (Polarkoden 12.3.4). Nytt som følge av Polarkoden er tilleggskrav i STCW-koden (se under).

- Ferdighetssertifikat Polarkoden – grunnleggende. Kravet innebærer at på passasjerskip og tankskip med polarskipsertifikat som opererer i åpne polare farvann, skal skipsfører, overstyrmann og ansvarshavende vaktoffiser på bro ha grunnleggende opplæring for skip som opererer i polare farvann. Fullført og bestått opplæring skal dokumenteres med et ferdighetssertifikat.
- Ferdighetssertifikat Polarkoden – videregående. Kravet innebærer at på alle skip med polarskipsertifikat som opererer i andre polare farvann, skal skipsfører og overstyrmann ha ferdighetssertifikat Polarkoden – videregående. Må ha fullført grunnleggende opplæring og ha to måneders godkjent fartstid på skip som opererer i polare farvann.
- Krav om sikkerhetsopplæring av sjøfolk på passasjerskip?
  - Hvordan foregår denne familiariseringen på deres fartøy?
  - Skipsforlis og overlevelse i kaldt klima;
  - jevnlig trening og øvelser med mannskap?
  - familiarisering av utstyr og systemer; bruk og kombinasjon?
  - beredskapsledelse og styring av tilgjengelige ressurser (ombord på hver enkelt redningsfarkost)?
  - Risikofaktorer for overlevelse i kaldt klima (tid, menneskelig atferd i krevende overlevelsessituasjoner)
  - medisinsk førstehjelp?

5. Kjennskap og bruk av PSK and GSK?
6. Seleksjonsmetoder?
7. Analyser?
8. Testmetoder?
9. Standarder / beste praksis?
10. Kjennskap til: Guidance for navigation and communication equipment intended for use on ships operating in polar waters (June 2019)?
11. Kjennskap til : Ny forskrift om bygging, utrustning og drift av passasjerskip i territorialfarvannet ved Svalbard (Januar 2020)?
12. Kjennskap til: The Arctic Shipping Best Practice Information Forum (PAME)?

13. Kjennskap til: Guidance on methodologies for assessing operational capabilities and limitations in ice; Polar Operational Limit Assessment Risk Indexing System (POLARIS)?
14. Kjennskap til andre spesifikke retningslinjer eller standarder fra administrasjonen?
15. Andre betydningsfulle endringer som følge av Polarkoden?

Appendix 4 – Interview Guide no. 4 (Paper VI)

Interviewees: Technical officer (IMO), CEO working with maritime simulation and Polar Code training (representing Transport Canada in this workshop), and Director working with maritime simulation and Polar Code training (representing Transport Canada in this workshop) (see Chapter 5.2.1 Experts' Interviews).

Background
Applicable from July 1st, 2018; amendments to the Regulations (of 22 December 2011 No. 1523) on qualifications and certificates for seafarers, as per the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW).
The amendments primarily involve training requirements for masters, chief mates and officers in charge of a navigational watch on ships with Polar Ship Certificate, operating in open and other polar waters. The training requirement for Certificate of Proficiency (Polar Code – Basic and Advanced) is pursuant to the requirements laid down by the Polar Code (Chapter 12.3.1).

Candidates applying to the Norwegian Maritime Authority (NMA) for a Certificate of Proficiency Polar Code (Basic and Advanced) must document successfully completed training from an institution offering training in accordance with STCW (section A-V/4). Approved training means training approved by the NMA in accordance with requirements laid down by the International Maritime Organization (IMO).

Training for trainers and the capacity-building workshops
IMO and Transport Canada (signed a Memorandum of Understanding) to deliver four regional capacity-building workshops to provide training for trainers, to deliver training programmes for seafarers operating in Polar waters and on the implementation of the Polar Code. *The regional train-the-trainer workshops aim to assist Governments and their maritime training institutes in enhancing the skills and competence of maritime instructors to develop competence-based training*

programmes, update existing programmes and improve the delivery of specific IMO model workshops - Basic and Advanced training for ships operating in Polar waters. The two first workshops were conducted in 2019 in Canada and Chile respectively, and the two remaining are to be confirmed, and hosted by the Republic of Korea and the Russian Federation, originally scheduled for 2020, but currently postponed due to the global Covid-19 situation.

Interview guide for instructors

The course plan Basic training Polar Code (The Arctic University of Norway - UiT) is used as supporting material in the making of this interview guide.

1. Name?
2. Current position? Title?
3. Maritime background? Educational and occupational.
4. Polar water (or cold climate) operation experience?
5. IMO engagement? Role and position? STCW?
6. Capacity building workshops; role, position, and engagement?
7. Short description of workshop location and facilities?
8. Selection of workshop instructors?

- How were the instructors selected?
- Qualifications (theoretical / practical) for participating as an instructor at the workshop?
- Verification of qualifications?

9. Selection of workshop participants?

- How were the workshop participants selected?
- Verification of qualification?

10. Organizing, structuring and completion of workshop?

- IMO Model Workshop 7.11 used as basis?
- IMO Model Workshop 6.09 used as basis? (Training workshop for instructors).

11. How was the workshop plan developed?
12. How were Methods of teaching selected?

- Lectures?
- Problem solving in group sessions?
- Table-top exercises?
- Simulator exercises?
- Other?
- For simulator exercises (and other if relevant):
    - Were routines and practises established for briefs prior to simulator exercises, reviewing learning objectives and exercise content?

    - Were routines and practises established for debriefs after completion, reviewing the participant`s performance? Repetition, practical approaches and reflection?
- Reason for selecting chosen methods of teaching?
- Time frame on each of the selected methods?
- In what order are the chosen methods utilized and why is that?
- What is your experience on how these methods works out for training purposes and finally for implementation in real life?

13. Evaluation and feedback of the workshop provided by the participants?
- How were the participants encouraged to provide feedback about the workshop, as it unfolded?
- Were questionnaires provided to the participants at workshop completion, for written evaluation and feedback?

14. Describe the process of reviewing the evaluation and feedback received from the workshop participants?
- Reviewed by the instructors?
- Initiation of corrective measures if deemed necessary?
- Methods for evaluation?
- Competence evaluation of participants (pass / not pass) to receive workshop diploma at completion?

15. Describe how workshop information were shared amongst participants, regards expectations and objectives, prior to and after workshop completion?
16. Review and evaluation of the entire workshop when completed?
- Methods for evaluation?

17. Describe how findings and learnings from the capacity-building workshops are communicated back to the IMO system and further announced to Port States and certified MET institutes?
- How do you evaluate the effect of conducting workshops' this kind?
- Completion of workshop objectives? How do you assess the workshop with regards the fulfilment of the objective?

Part II

Paper I: Polarkoden – funksjonsbasert forskriftsverk for polare farvann. Hvordan kan standarder presentere gode nok løsninger? [The Polar Code – function-based regulations for polar waters. The contribution of standards to safe and sufficient solutions?].

Engtrø, E., Njå, O., and Gudmestad, O. T. (2018). In: Lindøe, P. H., J. Kringen, and G. S. Braut. Regulering og standardisering - Perspektiver og praksis [Regulation and standardization - Perspectives and practice] (pp. 146-162). Universitetsforlaget - Scandinavian University Press.

Paper II: Winterization and drilling operations in cold climate areas.

Engtrø, E., and Gudmestad, O. T. (2019). P*roceedings - International Conference on Port and Ocean Engineering under Arctic Conditions (POAC)* (pp. 1-9). Delft, The Netherlands.

Proceedings of the 25th International Conference on
Port and Ocean Engineering under Arctic Conditions
June 9-13, 2019, Delft, The Netherlands

Winterization and drilling operations in cold climate areas

Espen Engtrø[1], Ove Tobias Gudmestad[1]
[1] Faculty of Science and Technology, University of Stavanger, Stavanger, Norway.

ABSTRACT

Petroleum operations in remote locations offshore off northern Norway call for technical and operational solutions, sustainable and capable of withstanding extreme and harsh weather conditions. This paper discusses hazards, risks and winterization measures when working in cold climate and presents a wind chill study performed on a semi-submersible drilling rig, when operating southwest in the Barents Sea. The objective of that study was to evaluate the winterization measure of partly enclosing the drill floor, with regards to the risk of hypothermia and operational restrictions.

Five independent measurements of wind chill temperatures were performed, during a period from May to February. Information were also gathered in conversations with personnel working on the floor. It was found from the temperature measurements that the working area became less exposed for wind turbulence and the effect of wind chill after the enclosure. Feedback from personnel working in the area confirmed the findings.

The passive winterization measure of partly enclosing the drill floor showed to be an effective safeguard for personnel against heat loss and the risk of hypothermia. In addition, operational restrictions with respect to working hours at lower temperatures could be reduced

KEY WORDS: Cold climate operations; Hypothermia; Wind chill; Winterization; Working environment.

INTRODUCTION

Low air temperatures, low seawater temperatures, wind, snow, ice, fog and polar lows prevail in the far north during the winter season. Operating in a harsh environment, such as the Barents Sea, calls for technical and operational solutions which are capable of withstanding and being sustainable in extreme weather conditions.

The drilling rig in this case study is a semi-submersible drilling rig, operating in the southwest of the Barents Sea. The rig has a harsh-environment design and was recently upgraded at a yard stay to meet winterization requirements. Implemented winterization measures involved adapting and upgrading facilities, equipment and workplaces to ensure safe and regular operations in severe winter conditions. The adaptions and implemented measures are done to ensure that all activities and tasks are performed in an ergonomically sound way, concerning low temperatures, strong winds, poor visibility and restrictions imposed by Personal Protection Equipment (PPE).

WINTERIZATION

Winterization of a drilling rig comprises all measures taken to ensure safe and efficient operations in cold climates, to control and prevent freezing, icing, wind chill and other adverse effects of harsh weather conditions, for both personnel and equipment. These winterization measures are divided into active or passive measures.

Active winterization measures

Active winterization measures are electrical, mechanical or chemical and characterized as measures in which energy is addressed to avoid the adverse effects of icing, freezing or wind chill (DNVGL-OS-A201, 2015). Active winterization measures implemented on the semi-submersible drilling rig are as follows:

- Heat-traced walkways and escape routes. Either heat tracing is molded in or heat-traced rubber mats are used
- Heat tracing inside handrails, attached to coamings and specific ventilation heads to prevent icing
- Heat-insulation outside pipes, e.g. mud lines and fire water lines, using heat-tracing cable systems covered with insulation
- Heat tracing inside pipes in areas with difficult maintenance access and where forces such as waves can damage any installation outside the pipes e.g. drains under helideck and under hull
- Circulation in lines to prevent liquid from being static, e.g. fire water mains, cooling water branch lines and glycol in lines of the Blow Out Preventer (BOP)
- Chemicals added to lower the freezing point of fluids (e.g. glycol)
- Chemical and mechanical seal on instrumentation
- Mechanical de-icing by use of wooden hammers and bats
- Physical removal of snow and ice from deck using shovels, salt and flushing with heated seawater
- Improved lighting in outside areas due to 24-hour darkness in winter season
- Drainage of systems not heat insulated, to avoid freezing, or:
- Heating of the content to a minimum of 3°C above the freezing point of the content

To provide anti-freezing protection, the electrical heat tracing system on the rig is dimensioned for air temperatures down to -20°C and wind speed of up to 30 m/s.

Passive winterization measures

Passive winterization measures are characterized as measures in which no energy is addressed, but temporary or permanent constructions are set up to avoid the adverse effects of icing, freezing or wind chill (DNVGL-OS-A201, 2015). Passive winterization measures implemented on the semi-submersible drilling rig are as follows:

- Partly shielded walkways
- Enclosed working areas e.g. drill floor, derrick and lifeboat station and outdoor muster

area
- Internal heating elements and heating/ventilation systems installed, e.g. in the moon pool
- Work clothing provided to personnel working outdoors, intended for use in low temperatures
- Elimination of pockets, dead-ended pipes and legs in piping

Enclosing areas can be an effective winterization measure but also an expensive one when designing/upgrading a rig for polar operations. Additional hazards are introduced when enclosing areas, e.g. drill floor / derrick, concerning gas accumulation. Risk of explosion, must be risk assessed and taken into consideration.

A less costly passive winterization measure is floor grounding with rubber mats (around rotary and nearby areas), where drilling personnel have their working area (RED and YELLOW zone). Solid rubber mats reduce heat loss via radiation and provide an ergonomic solution to prevent work-related musculoskeletal disorders. The rubber mats' surfaces also have an anti-slip design and purpose.

COLD CLIMATE WEATHER FEATURES – HAZARDS AND RISKS

Icing, snow, polar lows and low temperatures combined with strong winds are common weather features in the Barents Sea during winter seasons. Icing can occur due to several weather phenomena but are in this paper divided into sea spray icing and atmospheric icing

Sea spray icing

Sea spray icing is caused by the freezing of sea spray on rig surfaces. Freezing sea spray is the most hazardous form of icing and also the most common (ISO 19906, 2010). Freezing sea spray usually occurs when the air temperature is less than –2ºC and the water is +7ºC or colder (Dehghani-Sanij et al., 2017). The area and rate of accumulation will vary with the conditions. The danger increases with stronger winds or colder temperatures (ISO 19906, 2010). Water salinity is an additional factor, as the risk of accumulated icing due to freezing sea spray increases when the seawater salinity is lower (Dehghani-Sanij et al., 2017). Uncontrolled sea spray icing can represent a great risk regarding loss of stability, integrity and equipment failure. However, splashing is in general less intense on a semi-submersible drilling rig compared to splashing on a vessel. Due to the high air gap, and that the splash zone seldom reaches more than 5-10 m above the sea level on a semi-submersible drilling rig (Dehghani-Sanij et al., 2017), a drilling rig is less exposed to the risk of sea spray icing on deck surfaces. Most of the icing from sea spray will occur on the under-hull structures.

Atmospheric icing

Atmospheric icing can occur do to several weather conditions, such as freezing rain and fog. It is not considered a risk for the rig as regards to the accumulated weight and loss of stability, but can represent a great risk for the integrity; atmospheric icing can cover the rig's surface with clear ice (ISO 19906, 2010), covering equipment such as valves and drains, making it difficult to operate, or the occurrence of breakdown of communications systems such as radar, antennas and safety systems. In addition, the condition can pose a risk to personnel in the form of slips, trips and falls.

Cold soaking

Cold soaking is a factor to be taken into consider when operating in polar environments. When a rig has been in cold temperatures for a long period, the structure of the rig will remain cold, even if the air temperature is warmer. This can cause more severe icing than predicted (OCIMF, 2014).

Snow

Snow can affect all heights on the rig and represent a problem on horizontal surfaces such as decks; it can cause hazards with slippery surfaces and the risk of slips, trips or falls. Snow can also adhere to vertical surfaces such as bulkheads or the derrick, especially if the surfaces are wet or if the snow is wet (ISO 19906, 2010). This can introduce the risk of dropped objects in the form of ice; wet snow accumulates on beams and structures and, when the temperature drops, the snow freezes to ice. When the temperature rises, the ice blocks melt and drop down. Snow can also accumulate on equipment such as valves, drains and communication systems, introducing the same risks as those of icing. Large amounts of snow could cause concern regarding intact stability.

Polar lows

Polar lows are low-pressure systems that develop rapidly and are therefore harder to forecast and predict (ISO 19906, 2010). Polar lows are common weather phenomena in the Barents Sea in the winter season, with weather characteristics of strong winds, heavy snow showers, thunder and lightning, choppy sea surfaces and increased wave heights. The risk of icing and poor visibility increases when polar lows occur.

PERSONNEL SAFETY – HAZARDS AND RISKS

Working in cold climate always represents a risk of hypothermia. Hypothermia is caused by cooling of the whole body or of body parts; cooling of the surface (skin and subcutaneous tissue), extremities (hands, feet, nose, ears) or the respiratory system. Heat loss vs. heat production will determine a person's thermic balance. Factors contributing to thermic balance or unbalance and hypothermia are climate, clothing and work activity performed (Nordic Innovation, 2011). The combination of wind and low temperatures, expressed as wind chill, lowers the temperature actually felt by the exposed person and contributes to increased heat loss (NORSOK N-003, 2016). Wind chill temperatures are calculated (or measured), giving the wind chill temperature index.

Heat loss can occur in several ways (Brunvoll et al., 2010):

- Convection: 50-80% of heat loss occurs via convection, with body heat being lost to the surrounding air.
- Conduction: heat loss occurs via contact with cold objects, e.g. holding tools, climbing on ladders or standing on cold surfaces.
- Radiation: heat loss to surrounding objects without physically being in contact with these. With sufficient protection of clothing, heat loss via radiation can be <20% of total loss of body heat.
- Respiration: approx. 10-15% of heat loss occurs via respiration. The use of a facemask, balaclava or buff can reduce this loss significantly.
- Evaporation: heat loss via evaporation can be a challenge when working in cold climates. The inner layer of clothes can become wet (sweat) when working / being

active and the insulation effect deteriorates as the wet clothing will cool down the skin. The alignment of clothes and work tempo to control/prevent sweating is an important principle when working in cold climates.

Work at heights and work over open sea are work activities with increased risk of heat loss:

- Increased heat loss via convection, due to exposure to weather conditions (winds + low temperatures + snow/rain).
- Increased heat loss via respiration and evaporation, as work activities are demanding and strenuous to perform.
- Increased heat loss via conduction as holding/leaning/sitting against metal structures will occur during work activities.
- Increased heat loss as the wind velocity increases with height above the surface.

The risk of falling into the sea is present when working over open sea, with the adverse effects of hypothermia and possible drowning. The work activity requires the use of a safety harness (as with work at heights), to prevent personnel from dropping if they should fall. The likelihood of a safety harness failing is small, if used correctly, certified and properly controlled.

Clothing

Proper clothing is the most important means of control to avoid heat loss when working in cold climates. When working on the drilling rig, it is mandatory to wear regular PPE in all areas, except when inside the accommodation. This includes coverall, safety boots, helmet, safety glasses and gloves. In the winter season, extra clothing needs to be used in addition to the mandatory PPE. The most practical (for movement) and efficient way (control of the body's thermic balance) is to use multiple layers of clothing (Norsk olje og gass, 2013). The inner layer´s purpose is to transport moisture away and keep the skin dry (Færevik et al., 2013). Inner layers comprised of wool products are recommended, as wool materials can absorb considerable amounts of moisture without reducing the purpose of insulation. Synthetic and non-absorbing materials, e.g. polyester are also recommended as an inner layer. A cotton inner layer is not recommended, as the material absorbs and accumulates sweat and will increase heat loss, as the accumulated sweat will cool down the skin. As a mid-layer, wool products are a preferred choice, in addition to fleece products, both of which have good thermic insulating properties. As outer layers, coveralls and insulated raincoats protecting from wind, rain and snow are used (Norsk olje og gass, 2013). For the above-mentioned mandatory PPE, insulated safety boots with anti-slip soles are recommended. Using boots one size bigger than normal is often preferred, as insulated soles or extra socks then can be worn. Insulated gloves are recommended, but may not be preferred, as they limit motor skills. A balaclava, buff or insulated inner layer in the helmet is used to prevent heat loss from the head.

A common practice of rig personnel is to use disposable chemical/liquid-resistant coveralls made of polypropylene, as a final outer layer of clothing. These coveralls are wind- and water-resistant, but the coveralls do not "breathe" and prevent the evaporation of sweat, which can cause personnel to become wet and cold. The purpose of their use (protection against weather) can therefore be counter-effective. In addition, the coveralls are white, which can be a safety concern with regard to visibility, e.g. for the crane operator when performing lifts.

Work restrictions

Reduced working hours and increased intervals of rest indoors, when the temperature drops and the wind speed increases is another means of control to prevent frostbite and hypothermia. In Table 1, restrictions in working hours are given, according to set wind chill temperatures.

	Wind Chill Temperature	Consequence - Action
	Below -30°C	No outdoor work to be performed unless deemed critical from a safety or operational perspective. Must be risk assessed and compensating measures to be implemented. The work to be limited to an absolute minimum, and nobody is allowed to work alone.
	Below -21°C	Available outdoor working time is below 60% of working hour; maximum length of outdoor work periods is 40 minutes, with 20-minute breaks in heated areas. The outdoor work to be limited to total max. 5 hours per day. Not allowed to work alone, and work must be under medical surveillance.
	Below -12°C	Available outdoor working time is below 75% of working hour; maximum length of outdoor work periods should be 70 minutes with 20-minute breaks in heated areas. Limited to total max. 8 hours per day.
	Below -6°C	Available outdoor working time is below 90% of working hour; maximum length of outdoor work periods should be 90 minutes with 15-minute breaks in heated areas.
	Above -6°C	Normal work hours, but precautions and breaks in heated areas.

Table 1. Wind chill temperatures, consequences and actions. Modified from the rig`s winter operation manual.

WIND CHILL TEMPERATURE STUDY

A wind chill temperature study was performed on the drill floor. The objective of the study was to evaluate the effect of enclosing the working area, which was done in the winterization upgrade of the rig. A hydraulic door was installed in the aft opening on the drill floor. In the forward opening on the drill floor, a gate was already mounted but, during the yard stay, was modified with a heavy rubber curtain to prevent exposure to wind and snow for personnel and to hinder snow from accumulating on deck.

Method

Five measurements of wind chill temperatures were carried out, over the period from May to February. The lowest temperatures measured were logged, when the aft door and forward gate were in closed and open positions. Information was also gathered in conversations with personnel working on the drill floor, about their perception of the effect of having the area enclosed. The personnel involved in these conversations had working experience on the drill floor prior to the winterization upgrade.

Data collection

Wind chill temperatures were measured with a WeatherHawk WindMate WM-350, weather meter. Data of wind direction, wind speed, air temperatures and rig heading were collected from the drilling rig`s weather monitoring system, Fugro.

Results

The results from the wind chill temperature measurements, in combination with feedback from drill crew personnel, are utilized to evaluate the effectiveness of the passive winterization measure of enclosing the drill floor. Wind directions during the measurements no. 1 and 5 affected the aft drill floor and wind directions during the measurements no. 2, 3 and 4 affected the forward drill floor, due to the rig heading, as seen in Figure 1.

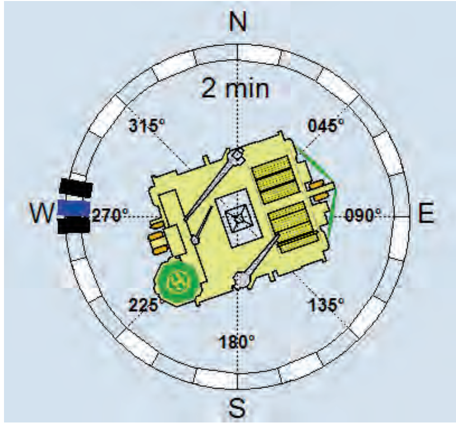


Figure 1. Rig heading showing wind from the west, affecting the forward drill floor.

Measurements of the wind chill temperatures are seen in Table 2.

Measurement no.	Wind direction	Wind speed (Knots)	Air temperature	Wind chill (doors closed)	Wind chill (doors open)
1	southeast	31.8	4.1 ºC	5.4 ºC	2.0 ºC
2	southwest	43.3	6.4 ºC	8.4 ºC	0.8 ºC
3	southwest	47.4	8.2 ºC	8.7 ºC	2.6 ºC
4	northwest	24.7	5.1 ºC	6.0 ºC	0.2 ºC
5	east	33.8	-3.8 ºC	-3.0 ºC	-10.8 ºC

Table 2. Wind chill temperatures measurements, from May to February.

An average difference in wind chill temperature, when the aft door and forward gate were in open and in closed positions, was measured to > +6 ºC. One precaution implemented on the rig to safeguard the drilling personnel from frostbite and hypothermia are reduced working hours and increased intervals of rest indoors, when the temperature drops and the wind speed increases. After enclosing the drill floor, longer working hours at lower temperatures are possible, as seen in the Table 3.

	Wind Chill Temperature	Consequence - Action		Effect of enclosing drill floor; > +6°C
	Below -36°C			Wind chill temperature < -36°C will be ≤ -30°C when aft door and forward gate are closed; no outdoor work to be performed unless deemed critical from a safety or operational perspective. Must be risk assessed and compensating measures to be implemented. The work to be limited to an absolute minimum, and nobody is allowed to work alone.
	Below -30°C	No outdoor work to be performed unless deemed critical from a safety or operational perspective. Must be risk assessed and compensating measures to be implemented. The work to be limited to an absolute minimum, and nobody is allowed to work alone.		Wind chill temperature < -30°C will be ≤ -24°C when aft door and forward gate are closed; working time <60% of working hour (40 minutes with 20-minute breaks) and total exposure of max. 5 hours per day.
	Below -21°C	Working time < 60% of working hour (40 minutes with 20-minute breaks) and total exposure of max. 5 hours per day.		Wind chill temperature < -21°C will be ≤ -15°C when aft door and forward gate are closed; working time < 75% of working hour (70 minutes with 20-minute breaks) and total exposure of max. 8 hours per day.
	Below -12°C	Working time < 75% of working hour (70 minutes with 20-minute breaks) and total exposure of max. 8 hours per day.		Wind chill temperature < -12°C will be ≤ -6°C when aft door and forward gate are closed; working time < 90% of working hours (90 minutes work periods with 15-minute breaks).
	Below -6°C	Working time < 90% of working hours (90 minutes work periods with 15-minute breaks).		Wind chill temperature < -6°C will be ≤ 0°C when aft door and forward gate are closed; 100% normal working hours.
	Above -6°C	100% normal working hours.		Wind chill temperature > -6°C will be ≥ 0°C when aft door and forward gate are closed. 100% normal working hours.

Table 3. Wind chill temperatures, consequences and actions and the effect of enclosing drill.

The feedback from personnel working on the drill floor was positive overall. No negative feedback or comments were given. When asked to range the perceived effect of having the working area enclosed, the average score was +3 on a scale from one (no effect) to five (very good effect). The aft door and forward gate are operated by panels, easily operable when wearing thick impact gloves. The panels are located near the door/gate, and the drilling personnel can swiftly open/close doors as the drilling activity and operation proceeds. It should be noted that enclosing the drill floor in this manner have not been evaluated in this study, with regards the design philosophy, area classification and on the possibility of accumulating gas in the area (DNVGL-OS-A101, 2015). However, it was noted that there still was a considerable air flow through the area after the enclosing.

CONCLUSIONS

After installing the aft door, the drill floor is less exposed to wind turbulence when the aft door and forward gate are in the closed position. Seen in comparison with the results from the wind chill temperature measurements, the passive winterization measure of enclosing the drill floor is evaluated to be effective for safeguarding the personnel against heat loss and hypothermia. Longer working hours at lower temperatures are also possible after partly enclosing the drill floor, and the passive winterization measure is considered to be reasonable from a cost-benefit perspective.

REFERENCES

Brunvoll, S., Furu, B., & Påsche, A., 2010, *Kalde utfordringer – helse og arbeidsmiljø på innretning i nordområdene*. Retrieved from http://www.ptil.no/getfile.php/1312011/PDFKalde%20utfordringer%20-%20helse%20og%20arbeidsmiljø%20på%20innretning%20i%20Nordområdene_Thelma%20juni%202010.pdf

Dehghani-Sanij, A.R., Dehghani, S.R., Naterer, G.F., Muzychka, Y.S., 2017, *Marine icing phenomena on vessels and offshore structures: Prediction and analysis,* Ocean Engineering, Volume 143, 1 October 2017, Pages 1 – 23.

DNVGL-OS-A101, 2015, *Offshore standard; Safety principles and arrangements,* DNV-GL AS, Høvik, Norway.

DNVGL-OS-A201, 2015, *Offshore standard; Winterization for cold climate operations*, DNV-GL AS, Høvik, Norway.

Færevik, H., Sandsund, M., Wiggen, Ø., & Renberg, J., 2013*, Arctic weather protection, health effects, monitoring systems and risk assessment.* Retrieved from SINTEF Rapport: *https://www.norskoljeoggass.no/globalassets/dokumenter/drift/hms-utfordringer-i-nordomradene/underlagsmateriale/helse-og-arbeidsmiljo/arctic-weather-protection-health-effects-monitoring-and-risk-assessment-sintef-2013-report-no-f24656-oppdragsgiver-statoil.pdf*

ISO 19906, 2010, *Petroleum and natural gas industries - Arctic offshore structures,* International Organization for Standardization, Geneva, Switzerland.

Nordic Innovation, 2011, *Guide for arbeid i kulde*, retrieved from http://nordicinnovation.org/Global/_Publications/Reports/2002/Handbok%20for%20arbeid%20under%20kalde%20forhold.pdf

NORSOK N-003, 2016, *Actions and action effects,* NORSOK Standard, Oslo, Norway.

Norsk olje og gass, 2013, *Arbeid i kaldt klima - faktagrunnlag*. Retrieved from https://www.norskoljeoggass.no/globalassets/dokumenter/drift/hms-utfordringer-i-nordomradene/underlagsmateriale/helse-og-arbeidsmiljo/norsk-olje-og-gass-arbeid-i-kaldt-klima---faktagrunnlag.pdf

OCIMF, 2014, *Offshore Vessel Operations in Ice and/or Severe Sub-Zero Temperatures In Arctic and Sub-Arctic Regions,* Oil Companies International Marine Forum.

Paper III: Implementation of the Polar Code: Functional Requirements Regulating Ship Operations in Polar Waters.

Engtrø, E., Gudmestad, O. T., and Njå, O. (2020). *Arctic Review on Law and Politics*, Vol. 11 (pp. 47-69). http://dx. doi.org/10.23865/arctic.v11.2240

Arctic Review on Law and Politics
Vol. 11, 2020, pp. 47–69

Peer-reviewed article

Implementation of the Polar Code: Functional Requirements Regulating Ship Operations in Polar Waters

Espen Engtrø[1], Ove Tobias Gudmestad[2] and Ove Njå[1]

[1]*Faculty of Science and Technology, Department of Safety, Economics and Planning, University of Stavanger, Norway;* [2]*Faculty of Science and Technology, Department of Mechanical and Structural Engineering and Materials Science, University of Stavanger, Norway*

Abstract

In 2017, the *The International Code for Ships Operating in Polar Waters (Polar Code)* – a set of function-based regulations applicable to Arctic and Antarctic waters, with the goal of increasing awareness and improving safety for ship operations in polar waters – entered into force. This article examines the Polar Code's contribution to the establishment of new standards and guidelines, with the problem under discussion being *the extent to which the function-based regulations contribute to enhancing safety for ship operations in the Arctic, given that maritime activities in these waters are associated with great risks and uncertainties.* The article gives a historical review, elucidating the background leading to the development of the Polar Code, followed by a review of the structure and key principles of the regulations. Further, ship traffic in the Arctic region and those subject to the Polar Code are examined, followed by a summary of findings and experiences from three survival exercises (SARex I, II and III), performed in northern areas around Svalbard between 2016 and 2018. The article concludes that safe ship operations depend on those subject to the regulations conducting thorough operational risk assessments that cover all potential hazards, in order to mitigate sufficiently. Further, the presence of authorities is found to be crucial, with validation of the adequacy and the dimensioning of the implemented measures being of the essence.

Keywords: *Arctic shipping; risk management; emergency response; regulatory governance*

Responsible Editor: Øyvind Ravna, Faculty of Law, UiT The Arctic University of Norway, Tromsø, Norway

Received: March 2020; Accepted: June 2020; Published: August 2020

*Correspondence to: Espen Engtrø, email: espen.engtro@uis.no

Citation: Espen Engtrø, Ove Tobias Gudmestad & Ove Njå. "Implementation of the Polar Code: Functional Requirements Regulating Ship Operations in Polar Waters" Arctic Review on Law and Politics, Vol. 11, 2020, pp. 47–69. http://dx.doi.org/10.23865/arctic.v11.2240

1 Introduction

The *International Code for Ships Operating in Polar Waters (Polar Code)* came into force on 1 January 2017, to increase awareness and improve safety for ship operations in polar waters, covering both the Arctic and the Antarctic.[1] The function-based regulations constitute a continuation of existing regulations, made mandatory under the International Convention for the Safety of Life at Sea (SOLAS) and the International Convention for the Prevention of Pollution from Ships (MARPOL), applicable to all waters. The goals for implementing the Polar Code are "to provide for safe ship operation and the protection of the polar environment by addressing risks present in polar waters and not adequately mitigated by other instruments of the Organization".[2] The problem discussed in this article is *the extent to which the function-based regulations contribute to enhancing the safety of ship operations in the Arctic, given that maritime activities in these waters are associated with great risks and uncertainties.* The Polar Code's risk-based approach to determining the scope of ship operations and its holistic approach to reducing identified risks[3] implies industry self-regulation as its main principle. We argue that self-regulation demands strong professional integrity and high levels of competence, both from those subject to the regulations and the authorities, and from the recognized classification societies issuing the Polar Ship Certificate. The topic addressed is risk regulation at the international and governing levels, with complex issues handled by a variety of industries and involved parties; our main concern is the capability to handle major emergency situations in cold climate areas.[4]

The article examines the processes which led to the Polar Code before evaluating implementation and enforcement of the regulations. It starts with a historical review that elucidates the work leading to the Polar Code. A review of the structure and key principles of the regulations follows. Then ship traffic in the Arctic region and those subject to the regulations are examined. This is followed by a summary of experiences and lessons learned from three Arctic search and rescue (SAR) exercises.[5] Then we discuss new guidelines under development for ship operations in the Arctic Region in the wake of the Polar Code. Finally, a systematic collection of data on related matters has been carried out, enabling us to evaluate how practices are evolving.

The issues raised in this article were first addressed by the authors in a paper published in Norwegian;[6] however, the text has been expanded considerably and updated with information about the implementation of regulations since 2018.

2 The Polar Code's historical development

In 1989, the oil tanker, Exxon Valdez, ran aground near the coast of Alaska, becoming one of history's largest environmental disasters.[7] The accident subsequently raised public awareness, and an international process was initiated, in which several countries strove to establish and agree upon international regulations and guidelines for ship traffic in polar waters.[8] Maritime activity in these waters was regulated by international laws and the laws of coastal states with territorial sovereignty, which could be contradictory.[9] Despite the additional challenges represented for ships operating in polar areas, many operators did not consider the added risks associated with cold climate operation.[10]

In 1991, IMO received a proposal from its member state Germany to include rules in SOLAS regarding ice strength for ships intended for polar voyages, in accordance with the rules of a recognized classification society.[11] The Maritime Safety Committee in IMO relayed the proposal to the subcommittee for Ship Design and Equipment, which handed the work to an informal external working group, to develop proposed guidance regarding technical concerns for ships operating in polar waters.[12] This group, led by Canada, worked according to certain key strategies:[13] the guidelines should be based on existing IMO regulations and standards for safety, environmental protection and training; an equal focus should be placed on safety for human life and environmental considerations; the United Nations Convention on the Law of the Sea (UNCLOS) for polar waters should be used as legal framework; and competence and knowledge from Russia, Canada and the Baltic states on ice navigation and regulatory regimes should be taken into consideration.

In 1998, the subcommittee for Ship Design and Equipment received a draft of the *International Code of Safety for Ships in Polar Waters*, but changes to the draft were made after submissions from several states and interest groups. Among other issues, the Antarctic was removed as a geographical area, and any contradictions to international laws were removed.[14] A new revision, *Guidelines for Ships Operating in Arctic Polar Waters*, was drafted and, after minor modifications, approved in 2002, named the *Guidelines for Ships Operating in Arctic Ice-covered Waters*. These recommended guidelines were amendments to the SOLAS convention but not made mandatory.[15] During the next two years, ship traffic increased around the South Pole, and the Antarctic Treaty Consultative Meeting requested that IMO amend the *Guidelines for Ships Operating in Arctic Ice-covered Waters* to be applicable to the ice-covered waters around the Antarctic.[16]

In 2007, the cruise ship, MV Explorer, hit the underwater part of an iceberg and eventually sank off the South Shetland Islands in the Antarctic with 100 passengers and a crew of 54, all rescued.[17] The accident placed further focus on establishing joint guidelines, applicable to the Arctic and the Antarctic,[18] and, in 2009, IMO approved the *Guidelines for Ships Operating in Polar Waters*. The United States, Norway and Denmark argued that requirements should be mandatory, and a process was initiated to finalize the guidelines by 2012, but disagreements amongst nations and interest groups contributed to a postponement of the implementation date.[19] It was particularly difficult to reach a consensus on certain requirements regarding environmental protection.[20] In 2012, IMO postponed the work, as agreements addressing environmental requirements were not reached.[21] IMO and certain member states of the Arctic Council were criticized for being reactive in the development and implementation of the new guidelines, and the shipping and shipbuilding industries were accused of showing a lack of support for adhering to the provisions in the guidelines, possibly due to infrastructure and technological constraints.[22] However, in 2014, draft guidelines were finalized, and produced as amendments to the SOLAS convention. The following year the guidelines were created as amendments to the MARPOL convention.[23] Finally, in 2017, the Polar Code came into force.

3 Structure and key principles of the Polar Code

The Polar Code consists of two parts: Part I contains provisions on safety measures, made mandatory under the SOLAS convention; Part II contains provisions on measures to prevent pollution, made mandatory under the MARPOL convention. Furthermore, Parts I and II are divided into two parts, with part one (I-A) being mandatory and part two (I-B) consisting of guidelines and recommendations to the mandatory provisions. In the following, provisions on safety measures (Part I) are examined; these apply to passenger ships carrying more than twelve passengers or cargo ships with a gross tonnage of 500 or more, engaged in international voyages.[24] The requirements in the Polar Code are mainly function-based, meaning they are related to risk factors in operating areas, such as ice conditions and temperatures.[25] Shipowners must therefore carry out operational risk assessments of areas of operation, which, together with operational capabilities and limitations, shall be documented in the ship's Polar Water Operation Manual (PWOM), to be carried on board the vessel.[26] The PWOM shall include or refer to procedures to be followed in normal operations and in order to avoid encountering conditions exceeding the ship's capabilities. The PWOM shall also contain specific procedures to be followed in the event of an incident, if conditions are encountered which exceed the ship's specific capabilities and limitations, in addition to procedures for icebreaker assistance.[27]

Under the safety measures (Part I) of the Polar Code, ten references are made to standards and guidelines for ice types, ship structure, machinery installations, voyage-planning and operational assessments. The guidelines for operational assessments are based on a mechanistic risk analysis process; estimated risk values are compared with risk acceptance criteria, to optimize solutions. As no guidelines have been issued for cold climate, the analytical techniques must be adapted to the environmental conditions. The prescriptive standards for construction referred to in the regulations were developed over time, based on empirical models aligned with regular norms for construction (load, structural response and safety margins). These standards and guidelines have not been modified since the application of the Polar Code, although "*Requirements regarding Polar Class*", sections I1 and I2, were revised in 2016.

3.1 Goal-based standards

A goal-based standards approach was used in the development of the Polar Code,[28] regarding the design and construction of ships and equipment, operational conditions and training, and protection of the environment.[29] Goal-based standards comprise at least one goal, functional requirement(s) associated with that goal, and regulation(s) which meet the functional requirement(s), including the goal.[30] The goal-based standards approach is seen in the following chapters of the Polar Code: PWOM (Ch. 2), ship structure (Ch. 3), subdivision and stability (Ch. 4), watertight and weather-tight integrity (Ch. 5), machinery installations (Ch. 6), fire safety/protection (Ch. 7), life-saving appliances and arrangements (Ch. 8), safety of navigation (Ch. 9), communication (Ch. 10), voyage planning (Ch. 11), manning and training (Ch. 12).

As an example, the goal-based standards approach for life-saving appliances and arrangements is "to provide for safe escape, evacuation and survival",[31] where the functional requirement for evacuation is that "All life-saving appliances and associated equipment shall provide safe evacuation and be functional under the possible adverse environmental conditions during the maximum expected time of rescue".[32] One regulation for evacuation states that "Ships shall have means to ensure safe evacuation of persons, including safe deployment of survival equipment, when operating in ice-covered waters, or directly onto the ice, as applicable".[33] The functional goals in the Polar Code facilitate interpretations and discretionary assessments, and those subject to the regulations must gain insight into significant environmental loads and structural responses, requiring an extensive systemic understanding.

Although the requirements in the Polar Code are distinctly functional, descriptive guidelines for the analytical processes are provided. The regulations use precise definitions, in addition to definitions referred to in SOLAS and MARPOL, which are not rendered in the Polar Code. Those subject to the regulations must therefore be familiar with the existing IMO regulations. The Polar Code specifies several explicit sources of hazards, such as icing, low temperatures and remoteness,[34] guiding the analytical approach. The definitions *habitable environment, maximum expected time of rescue* and *Mean Daily Low Temperature (MDLT)* are significant for design and solutions and are determinative in the dimensioning processes. The most concrete and descriptive requirement concerns time of rescue, where "Maximum expected time of rescue means the time adopted for the design of equipment and system that provide survival support. It shall never be less than 5 days".[35]

3.2 Polar Ship Certificate

New ships constructed after the introduction of the Polar Code (1 January 2017), entitled to operate in the application area of the regulations, are required to obtain a valid Polar Ship Certificate. Ships constructed before that date, operating in the same areas, are required to obtain the Polar Ship Certificate by the first intermediate or renewal survey, whichever occurs first, after 1 January 2018.[36] The Norwegian

Maritime Authority (NMA) issues the Polar Ship Certificate for ships flagged by the Norwegian Ordinary Ship Register. The issue of certificates for ships in the Norwegian International Ship Register is delegated to recognized classification societies on behalf of the flag state the ship is registered under.[37]

The Polar Code's geographical area of application in the Arctic is shown in Figure 1 below. In the Antarctic, the regulations are applicable at the 60th parallel south. Different industries and parties with activities in these waters are subject to the Polar Code's requirements.

Figure 1. Maximum geographical extent of the Polar Code's area of application in the Arctic.[38]

4 Ship traffic in the Arctic Region

The receding sea ice in the Arctic is enabling an increase in shipping across the northern polar region, connecting Asia and Europe by trans-Arctic routes along (Figure 2): the Northeast Passage (NEP) and the Northern Sea Route (NSR), encompassing the route along the Norwegian and Russian Arctic coasts; the North West Passage (NWP), which follows Canada's northern coastline; and the Transpolar Sea Route (TSR), which bisects the Arctic Ocean through the North Pole.[39] In addition, the Arctic Bridge Route (ABR), a shipping route linking the Arctic seaports of Murmansk (Russia) and Churchill (Canada), could develop into a future trade route between Europe and Asia.[40]

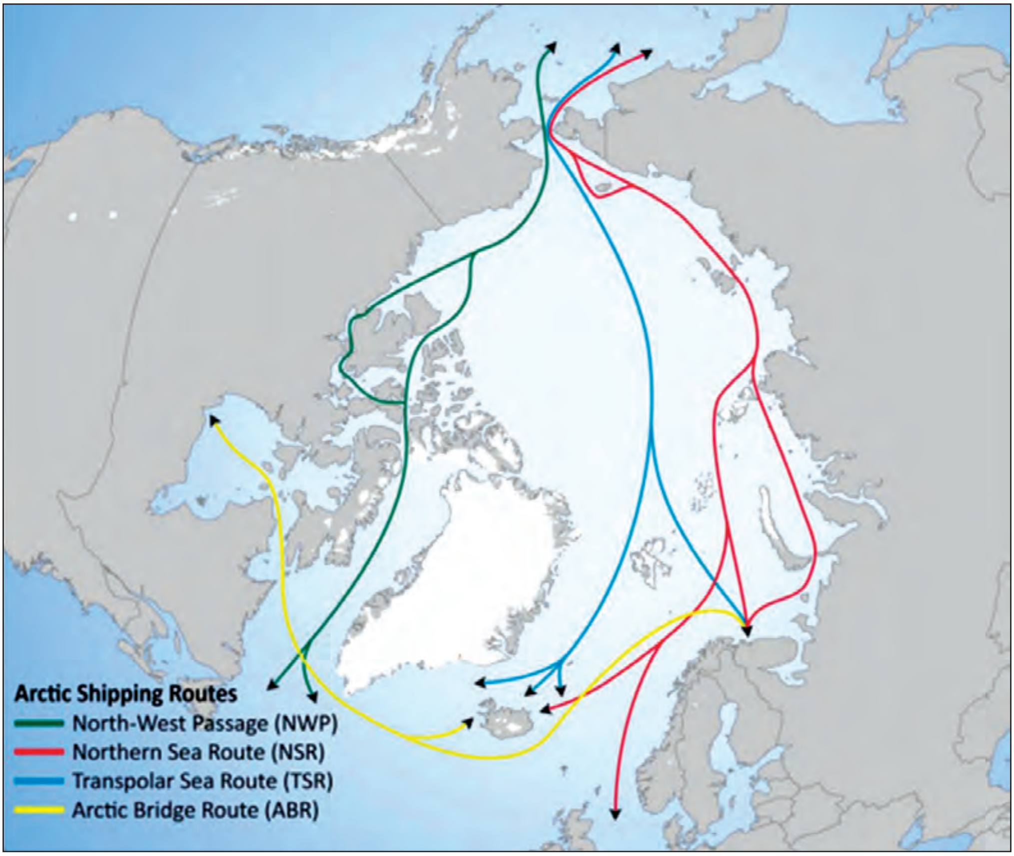


Figure 2. Shipping routes in the Arctic Region.[41]

Ship traffic can be divided into four main categories:[42]

1. Oil tankers or Liquefied Natural Gas (LNG) tankers/condensate tankers and tankers for refrigerated gas
2. Transport ships (with cargo other than oil or gas)
3. Passenger ships (including cruise ships)
4. Fishing vessels.

Measurements of the volume of shipping within the Polar Code's geographical area of application in the Arctic, taken between 2013 and 2019, show a substantial increase in traffic, when counting both the number of individual ships (up 25 percent) and the total nautical distance sailed during the six-year period in the same area (up

75 percent).[43] Fishing vessels dominate both groups, representing more than 40 percent of all ships in the Arctic area, and, of the total distance sailed, fishing vessels account for 45 percent.[44] However, fishing vessels are neither subject to the SOLAS Convention nor any other international safety regulations. In 1977, IMO approved the Torremolinos International Convention[45] but has yet to succeed in achieving ratification of the protocol by enough states with large numbers of fishing vessels.[46] In addition to fishing vessels, cargo ships of less than 500 gross tonnage, ships not propelled by mechanical means, wooden ships of primitive build, and pleasure yachts not engaged in trade are exempt from the safety provisions of the Polar Code (Part I).[47]

An increase in passenger-ship traffic in the northern areas is expected, especially due to reduced sea ice enabling ship traffic in open waters between the Atlantic and the Pacific Oceans during short periods of the year.[48] In 2016 and 2017, the passenger ship, Crystal Serenity, sailed through the NWP from Alaska to New York, with more than 1,000 passengers, on its first voyage.[49] The cruise industry is profit-driven and, to remain commercially competitive, costs related to safety equipment are often kept to a minimum.[50] The shipbuilding industry delivering polar expedition vessels for the Arctic is peaking, with 28 new builds expected to be launched in the four-year period from 2018 to 2022. This is in addition to the almost 80 polar ships already operating with passengers in these waters.[51] Moreover, the extraction of natural resources in the Arctic is expanding and contributing to an increase in bulk carrier traffic in the region.[52]

5 SARex I, II & III – Studies of the Polar Code and emergency response in polar waters

The Norwegian Coast Guard, together with the University of Stavanger (UiS) and the University of Tromsø (UiT), have taken great interest in the conditions for SAR and evacuation operations in Arctic waters. In the SARex I, II & III exercises, performed in 2016, 2017 and 2018, respectively, the Coast Guard played a key role in the work of testing emergency response equipment with respect to requirements for survival, as set out in the Polar Code. In these exercises, the Polar Code was used as a baseline for studying emergency response equipment and personal capabilities for survival in real-event situations.[53] Each exercise lasted for a week and was conducted from the Coast Guard ship, KV Svalbard, in northern areas around Svalbard. In joint collaborations, requirements in the regulations were used as criteria for survival and were examined and tested against SOLAS-certified life-saving appliances, approved for Arctic waters.[54] Regarding performance standards, the Polar Code states that "Unless expressly provided otherwise, ship systems and equipment addressed in this code shall satisfy at least the same performance standards referred to in SOLAS".[55] The SOLAS Convention's mandatory requirements for merchant ships therefore constitute a standardized minimum of expectations for the provision of safety measures for maritime design, equipment, systems and operations.

5.1 SARex I

The objectives of the first SAR exercise were to identify and explore gaps between the functionality of existing SOLAS-certified life-saving appliances and functional requirements in the Polar Code.[56] The exercise was a joint collaboration between the Coast Guard, leading experts from the industry, governmental organizations and academia. The exercise scenario, which took place in the marginal ice zone off the coast of Svalbard in late April 2016, was based on the Maxim Gorkiy accident in 1989, where an expedition cruise ship hit drifting ice and partly sank in the marginal ice zone off the west coast of Svalbard.[57] Focusing especially on the interpretation of the Polar Code's requirements for life-saving appliances and arrangements, the following definition was established: "The equipment required by the Polar Code is to provide functionality that enables the casualty to safeguard individual safety, which means to maintain cognitive abilities, body control and fine motor skills for the maximum expected time of rescue".[58]

The objectives of the exercise and the associated research program were to:[59]

- Assess the adequacy of the life-saving appliances as required by the Polar Code.
- Identify the gaps between SOLAS-approved rescue craft (lifeboat and life raft) and requirements defined in the Polar Code.
- Identify the gaps between SOLAS-approved personal protective equipment (PPE) and the requirements defined in the Polar Code.
- Assess the personal (PSK) and group survival kits (GSK) as defined by the Polar Code.
- Train the Coast Guard personnel in emergency procedures in ice-infested waters, with particular reference to evacuation and rescue from cruise ships.

One lifeboat and one life raft were filled with participants. Various types of standardized SOLAS-certified PPE were worn, ranging from life jackets to insulated survival suits. The weather conditions during the exercise were representative of the cruise-ship season around Svalbard, with an ambient air temperature of about –9°C, a water temperature of about –1°C, little wind and no clouds. The results from the exercise concluded that it would be unlikely that the majority of participants evacuated (to lifeboat or life raft) would have survived for a minimum of five days, as the Polar Code requires.[60] Critical conditions occurred, as insulation from the cold sea water provided by the bottom of the life raft was negligible, and the temperature in the lifeboat dropped dramatically when engines were shut down to save fuel. As O_2 concentrations dropped inside the lifeboat and life raft, frequent venting had to be maintained, lowering the air temperature inside both craft. The SARex I experiment demonstrated that, when tested in Arctic waters, standard SOLAS-certified life-saving appliances do not comply with functional requirements in the regulations.[61]

5.2 SARex II

The second SAR exercise was performed in Krossfjorden, North Svalbard, in May 2017. The objective of SARex II was to test whether small investments in modifications and upgrades to life-saving appliances would be sufficient, when tested in the same environmental climate and conditions.[62] The participants wore SOLAS-certified PPE of various standards. The ambient air temperature varied between +2°C and −9°C, while the water temperature was about +2°C. The following modifications to the lifeboat and life raft had been performed:[63]

- Upgraded heating system in lifeboat, maintaining the temperature inside the craft at a reasonable level.
- Insulated seating in lifeboat, protecting from hypothermia.
- Toilet installed in lifeboat (compact carry-on design).
- Double-bottom life raft, improving insulation and ensuring an air gap to be maintained between seawater and floor.
- Double-layer roof in life raft, providing insulation from cold outside air temperatures.

The results from SARex II were encouraging and significant, compared to the results from the previous exercise in 2016. Nevertheless, life-saving appliances did not meet the Polar Code's goal and requirement to provide the capability for people to survive for five days.[64] The main critical issue in the lifeboat was the buildup of CO_2 from the participants, even though the number of Personnel On Board (POB) during the exercise was lower than SOLAS requirements.[65] Air quality was continuously monitored in both rescue craft. After approximately one day, all participants had been evacuated from the lifeboat, many exhausted due to lack of comfortable seating, minimal room for movement and insufficient emergency food rations and water. After 33 hours, the remaining participants in the life raft were evacuated, experiencing hypothermia and fatigue.[66] Following the exercises, the recommendations from the emergency management team were to conduct a thorough evaluation, compare the results with the Polar Code's requirements and identify gaps to be closed, partly or fully.[67]

5.3 SARex III

In May 2018, the third SAR exercise was performed in Fjortende Julibukta, north of Ny-Ålesund, Svalbard. SARex III had three main objectives:[68]

1. Study functionality and identify gaps between typical PSK and GSK, regarding survival on ice/land, and the requirement of a minimum of five days' survival.
2. Study the challenges when rescuing many people from land/ice.
3. Assess the functionality of utilizing Maritime Broadband Radios (MBR) to develop an improved common operational picture among the different emergency response providers.

The weather conditions during the exercise were favorable, with very little wind, some snow and rain showers during the first two days and temperatures varying from a maximum of 3°C to a minimum of –3°C at night.[69] The first objective of the exercise proved to be an impossible task, due to great variations in the activity levels of the individual participants during the exercise, to compensate for heat loss. However, compared with findings from SARex I and SARex II, it became evident that there was a significant improvement in the survival rate when evacuating onto the shore, compared with a prolonged stay in the survival craft. One important finding was, furthermore, that the rations contained insufficient water for healthy survival.[70] To assess the second objective, about 50 "casualties" were evacuated from a remote beach onto the ship, Polarsyssel, revealing the additional challenges of managing many casualties with regard to time, which is a critical element in a survival situation in a cold climate.[71] Regarding the third objective, the MBR system proved reliable, but significant technical expertise was needed to initiate it.[72]

6 The Polar Code footprints

At the time of writing (June 2020), the Polar Code has been in force for more than three years, and the effects of its implementation are starting to appear. The regulation of ship operations in polar areas is determined by geographical and seasonal variation, which guide the choice of safety measures, equipment and systems provided.[73] Those subject to the Polar Code form a group, consisting of different parties,[74] amongst whom the owner of an oil or gas tanker does not necessarily share the same risk perceptions as the owner of a cruise ship with the capacity to transport several hundred passengers on a single voyage. Due to the Polar Code's functionally based approach, compliance with the regulations can be achieved using various methods and measures. The SAR exercises, with the objective of exploring gaps between SOLAS-certified life-saving appliances and arrangements, and the Polar Code's requirements for such equipment, proved that ships on polar voyages are likely to be equipped with insufficient survival equipment and resources.[75]

6.1 Interim guidelines for life-saving appliances and arrangements for ships operating in polar waters

The findings from the three SAR exercises raise concerns regarding the suitability and efficiency of equipment provided in an emergency that requires a ship to be abandoned.[76] Less than two years after the Polar Code was implemented, the Maritime Safety Committee in IMO approved (June 2019) *The interim guidelines on life-saving appliances and arrangements for ships operating in polar waters*.[77] The results of the SAR exercises and the discussions that arose after these events contributed to the development of the new guidelines,[78] providing guidance and outlining possible means of mitigating hazards, in order to comply with the requirements as set out in the Polar Code for life-saving appliances and arrangements.[79] The guidelines provide descriptive guidance for food (min. 1195 kcal per person per day) and water (min. 2 liters per person per day), and (the prevention of long-term) exposure to CO_2 concentrations (>5,000 ppm), for the maximum expected time of rescue. Guidelines for maintaining a positive metacentric height (GM), with additional ice loads (30 kg/m^2 on exposed horizontal surfaces and 7.5 kg/m^2 for the projected lateral area of each side of the lifeboat), are given for lifeboats and rescue boats, in addition to guidance and descriptions of the survival craft's capacity, equipment and winterization measures deemed necessary for cold climate voyages and survival. The guidelines also provide specifications on survival suits, protective clothing and other survival equipment, including guidance regarding the packing, storage and marking of such equipment.[80]

6.2 Regulations on the construction, equipment and operation of passenger ships in the territorial waters surrounding Svalbard

In (June) 2019, the NMA laid down new *Regulations on the construction, equipment and operation of passenger ships in the territorial waters surrounding Svalbard*,[81] which came into force on 1 January 2020. With a few exceptions and additions, the regulations are the Polar Code, made applicable for passenger ships operating in the territorial waters surrounding Svalbard.[82] Until this point, ships with national certificates had been subject not to the safety provisions (Part I) of the Polar Code, but to MARPOL and national requirements for the certificates required to operate passenger ships in Svalbard.[83] The Polar Code's safety provision applies, per definition, only to passenger ships (carrying more than twelve passengers) or cargo ships (with a gross tonnage of 500 or more) engaged in international voyages,[84] where an "international voyage means a voyage from a country to which the present Convention applies to a port outside such country, or conversely".[85] Under the new regulations, passenger ships operating in the territorial waters surrounding Svalbard and passenger ships engaged in international voyages calling at Svalbard fall under the scope of the regulations. The NMA points out that "Due to Svalbard's judicial position,[86] it is important to have equal rules for all flag States, predictability and clear legislation for ships carrying passengers in the territorial waters surrounding Svalbard".[87]

The NMA states[88] that implementing the new regulations means that future development of the legislation in Svalbard will take place in line with new legislation being negotiated internationally in IMO, which is an advantage point for the NMA, which also regulates ships flying foreign flags. In a circular,[89] the NMA acknowledges the processes within IMO leading to the development and implementation of new conventions, regulations and guidelines or changes and updates of existing ones. These processes are described as open and balanced, safeguarded by the opportunity for different interests to put forward their views before the member states lay down new provisions or change existing ones.[90]

In the comments on the individual sections,[91] reference is made to the abovementioned SAR exercises and recommendations from these events, which, supported by Canadian research (Transport Canada), guide the choice of life rafts, requiring these to be of a type with an inflatable double bottom. In the same circular, the NMA points out the systematics applicable for the regulation of life-saving appliances; "Performance requirements shall be supported by test or evaluation requirements in resolution *Revised recommendation on testing of life-saving appliances*".[92] But, due to the lack of test requirements describing the insulation properties of the raft floor, there are no parameters with which to measure equivalence. The NMA therefore decided "to lay down a requirement for an inflatable floor while waiting for the IMO to introduce a test standard that will ensure equivalence by establishing measurable requirements for insulation properties/heat loss".[93]

6.3 The Arctic Shipping Best Practice Information Forum

In response to the Polar Code's implementation, the Arctic Council's working group, Protection of the Arctic Marine Environment (PAME), launched a public web portal in 2018: *The Arctic Shipping Best Practice Information Forum*.[94] The forum's collaborative approach aims to support education, as regards implementation of the regulations, and to raise awareness of the Polar Code's provisions amongst parties involved in or potentially affected by Arctic maritime operations.[95] The goal is to facilitate the exchange of information and best practices on specific topics, e.g. hydrography, search and rescue logistics, industry guidelines and ship equipment, systems and structure.[96] Stakeholder involvement in the forum has increased since start-up and includes individual governments, regional governmental bodies (Arctic Council/Antarctic Treaty Secretariat), international regulators (IMO), the research community, the maritime industry, the indigenous community, educational institutions and other Arctic Council Working Groups.[97] The web portal, provides submissions by some of the above-mentioned stakeholders, following the chapters of the Polar Code, with hyperlinks to the SAR exercises, Arctic member states' guidance on Arctic operations, and classification societies' guidance and information regarding implementation and operations in accordance with the regulations.

7 Discussion – Standardization as part of regulatory governance

The tendency to adopt a goal-based standards approach in regulatory governance is increasing,[98] with responsibility for developing definitive descriptive standards and guidelines being delegated from government officials to the actors and target groups that the regulations are intended to regulate. From a rational approach, functional requirements enable those subject to the regulations to choose flexible solutions best suited to their own business areas and activities.[99] However, there is considerable heterogeneity among the actors subject to the Polar Code, and we predict challenges in enforcement of the regulations. A centralized and international process for standardization, equal to the International Association of Classification Societies (IACS) and the Polar Class requirements for ship structure, could provide predictability. Experience can be drawn from the Norwegian petroleum industry, with its extensive experience in utilizing functional requirements in the standardization of complex operations, supported by descriptive guidelines and detailed standards.[100] The conditions and structures of the regulatory regime for ship operations in polar waters differ, however, from those of the petroleum industry; the Norwegian oil and gas industry consists largely of homogenous groups, and the power balance between employees, employers and the authorities has promoted safety-dominated practice.[101]

7.1 Descriptive requirements and the protection of vulnerable parties' interests

Established structures under IMO administration regulate the international shipping industry, in the form of recognized conventions, regulations and guidelines.[102] The Polar Code contains a number of operational requirements and practical safety measures that apply to all types of ships, regardless of construction, design and trade area. The regulations were developed "to supplement existing IMO instruments in order to increase the safety of ships' operation and mitigate the impact on the people and environment in the remote, vulnerable and potentially harsh polar waters".[103]

During an emergency, the functionality of life-saving appliances and arrangements is vital. The Polar Code sets out requirements to ensure safe escape, evacuation and survival in the event of abandoning ship.[104] The regulations also require individual and shared resources to be provided for effective protection against direct wind chill, to ensure sufficient thermal insulation to maintain core temperature, and protection to prevent frostbite of all extremities.[105] However, the Polar Code guidelines for protective equipment[106] are vague and generic, and a variety of equipment available on the market is compliant, regardless of its usability under real conditions.[107] The SAR exercises revealed that performance criteria for certified rescue equipment did not comply with the Polar Code's requirements for survival, which state that "Resources shall be provided to support survival following abandoning ship, whether to the water, to ice or to land, for the maximum expected time of rescue".[108]

In the event of an abandon-ship situation, a dry-shod evacuation to lifeboats, life rafts or onto ice or onshore is essential for survival in cold climates, and the risk of hypothermia, leading to frostbite and eventually death, if not mitigated, increases dramatically when wet.[109] Maintaining thermic balance is essential for survival. It is determined by the body's heat loss versus heat production, and affected by cold, wet and windy climate, poor clothing, lack of shelter, low activity level, and insufficient food and water rations.[110] The new guidelines for life-saving appliances and arrangements for ships operating in polar waters point out that "Survival after abandonment will rely on several factors, such as the types and combination of equipment, crew training and good leadership of each survival craft. The expected time of rescue is a defining factor for life-saving appliances and arrangements. Conditions that are not otherwise considered critical may become critical over time".[111]

The lack of specifications and guidelines clarifying Polar Code requirements for safe escape, evacuation and survival may contribute to the great variation seen in polar protective equipment.[112] The new guidelines for life-saving appliances and arrangements put forward descriptive requirements and specifications for emergency equipment and systems that shipowners and operators must take into consideration in the planning of polar voyages. However, the use of descriptive requirements and a non-flexible framework can turn out to be counter-effective, if compliance is achieved in a mechanical manner, with just checks and controls of predefined measures.[113]

7.2 Functional requirements and the use of operational risk assessments

Utilizing a goal-based standards approach and functional requirements puts pressure on the authorities and the organizations recognized by IMO to issue the Polar Ship Certificate. We argue that high levels of competency are required in the assessment of implemented measures. One must bear in mind that achieving compliance with a certain requirement does not automatically ensure compliance with the overall goals in the associated regulation. Each company is responsible for conducting adequate operational risk assessments covering their own activities.[114] A company can, however, deliberately mislead or inadvertently underestimate certain risks in their analyses, by predicting consequences as acceptable and/or probabilities as low as reasonably practicable. Certain actors may take advantage of and exploit the functional requirements set out in the Polar Code, which raises questions about the role of the authorities.[115] Experience from comparable industries has shown that thorough re-verifications of conducted risk assessments rarely occur.[116]

Re-verification, not only of operational risk assessments but also of existing analytical tools, must be conducted to verify whether potential risks for maritime activities in polar waters are covered in the planning and execution of voyages. Analytical models quantifying risk levels should be questioned, due to the significant uncertainties that exist in analysts' risk perceptions of descriptive scenarios.[117] Mechanisms for control and constraints, and a theoretical systemic approach[118] when analyzing maritime traffic in polar waters, should gain increased focus. The use of descriptive and detail-oriented requirements should also be evaluated, especially when uncertainties about phenomena increase, e.g. geography, environmental conditions or SAR operations in remote areas with limited resources. The involvement of the authorities, by addressing responsibilities within the industry in a competent manner, is of the essence, to reduce and eliminate favorable conditions for disreputable parties.[119] Previous experience from maritime disasters indicates a business sector in which the reputation of some members poses a challenge.[120] Parallels can be drawn with the heavy vehicle transport industry, where research indicates that functional requirements are often stretched.[121]

7.3 Defining norms within the IMO system

Standardization processes within IMO involving government officials, relevant parties and interest organizations can be clarifying and provide predictability in the enforcement of the Polar Code.[122] Scientific facts can, however, be overlooked in favor of political points of view, as visions and goals are agreed upon amongst different cultures, institutions and states with competing agendas and financial situations.[123] Developing new regulations can be time-consuming work, and is only achieved through extensive cooperation,[124] as exemplified by the time (>25 years) it took to develop and agree on the Polar Code. The new guidelines for life-saving appliances and arrangements introduce design specifications and clarifications, many seen in correlation with findings from the above-mentioned SAR exercises.[125] These guidelines "are intended to assist ship designers, ship-owners and ship operators, as well as the administrators, in the uniform implementation of the Polar Code".[126]

After the SAR exercises, it was suggested that a level of heat loss regarded as acceptable for the human body to maintain for the expected time to rescue and based on a predefined heat loss figure, should be defined, allowing equipment and combinations of equipment to be assessed in a transparent way.[127] The new guidelines for life-saving appliances and arrangements recommend that manufacturers provide information on additional tests, including temperature ranges for which the equipment is intended, and that this information is included in ships' operating and maintenance manuals.[128]

Concerns have been raised regarding non-SOLAS vessels operating in the Arctic region,[129] as the Polar Code's safety provisions (Part I) are not applicable to these vessels, and especially with respect to fishing vessels, since they constitute the largest overall shipping presence in Arctic waters.[130] The Maritime Safety Committee and related sub-committees within IMO are currently looking at the application of the Polar Code to vessels not regulated by the SOLAS Convention. At the end of 2019 the IMO assembly meeting adopted a resolution on interim safety measures for vessels not certified under the SOLAS Convention operating in polar waters, which urges IMO member states to implement, voluntarily, the safety provisions (Part I) of the Polar Code for non-SOLAS vessels.[131]

The web portal, *The Arctic Shipping Best Practice Information Forum*,[132] has the potential to become a meeting ground for those subject to the Polar Code, facilitating the exchange of information, experience and best shipping practices, and exemplifying how to formalize enhanced knowledge on regulating ship operations in the Arctic Region.

8 Conclusion and summary

The implementation of mandatory regulations for ship traffic in the oceans around the North Pole and the South Pole is a step in the right direction, to sustain and protect personnel, the environment and ecosystems in vulnerable and remote parts of the world. Nevertheless, several issues concerning the Polar Code are highlighted in this article.

People have sailed in polar waters for hundreds of years,[133] and there is outstanding knowledge and experience regarding risk management and the handling of hazards in these waters.[134] But, as new risks and hazards emerge, knowledge, experience and the capacity to handle these become limited, with mass tourism in polar waters being the main activity of concern.[135]

Self-regulation is based on trust,[136] and those subject to the regulations need to conduct thorough operational risk assessments that identify hazards, followed by the implementation of mitigating measures, to ensure the safe performance of ship operations. Experience from the Norwegian petroleum industry indicates that not all companies and parties pay sufficient attention to this responsibility.[137] The role of the authorities can be demanding, and a high level of expertise, competence and knowledge must be acquired for assessment of company-related risks, which is essential in evaluations of adequacy and in the dimensioning of implemented measures. One concern that should be raised is practical enforcement of the Polar Code (verifications and audits) and the management of control mechanisms within the geographical area of application, to ensure compliance with the regulations. We assume that controls performed by the Port State and the classification societies are essential in this regime. The use of sanctions – fines and withdrawal of the Polar Ship Certificate – is a possible response to non-compliance, as well as, in extreme situations, the arrest of ships.[138] A further study to identify the main parties involved in the regulation of polar ship operations in northern areas and the key elements in this control regime, would be enlightening.

The three SAR exercises proved that SOLAS-certified rescue equipment was not compliant with the Polar Code requirements for survival, necessitating a joint effort from the authorities and interest groups to develop provisions for the regulations, to ensure that life-saving appliances and arrangements meet an expected standard. The relatively swift establishment and implementation of the new guidelines on life-saving appliances and arrangements is a positive signal for future revision. Re-assessment of the Polar Code's requirements for survival and the maximum expected time of rescue should also be addressed, for which exemptions are made when implementing the Polar Code for passenger ships operating in the territorial waters surrounding Svalbard.[139] The emergency preparedness regime in Svalbard indicates that, in many cases, assistance will be available in less than the maximum expected time of rescue, and, in our opinion, it is unreasonable to require ships that only operate in the most central areas in Svalbard, such as Isfjord,[140] to hold equipment for five-day rescue.

Even if the minimum-number-of-days requirement is not applicable, the functional requirement, as set out by the Polar Code, i.e. that every ship must be equipped to ensure survival for the expected time of rescue, remains. In circulars and comments on the individual sections of the new regulations,[141] the NMA stresses that the expected time of rescue may also exceed five days in Svalbard, particularly for ships with a large number of persons on board operating in the most remote parts of the archipelago. It is therefore expected that the companies "must be able to document the assessments underlying the chosen time of rescue".[142]

At the time of writing, it has not been possible to obtain risk analyses or assessments justifying the requirements for maximum expected time of rescue and survival in the case of an abandonment-of-ship situation, as set out in the Polar Code.

NOTES

1. International Code for Ships Operating in Polar Waters (Polar Code), International Maritime Organization (IMO), MEPC 68/21, London 2017.
2. Ibid., Introduction, 1.
3. Ibid., Preamble, 7.
4. Knut Espen Solberg and Ove Tobias Gudmestad, *SARex3: evacuation to shore, survival and rescue* (Vol. no. 75, Stavanger: University of Stavanger, 2018); Natalya A. Marchenko et al., "Arctic Shipping and Risks: Emergency Categories and Response Capacities", *TransNav* Vol. 12, No. 1 (2018) 107–114, DOI:10.12716/1001.12.01.12; Natalia Andreassen et al., "Emergency Management in Maritime Mass Rescue Operations: The Case of the High Arctic", *Springer International Publishing AG* (2018) 359–381, https://doi.org/10.1007/978-3-319-78425-0.
5. Knut Espen Solberg, Ove Tobias Gudmestad and Bjørn Odin Kvamme, *SARex Spitzbergen: April 2016: exercise report: search and rescue exercise conducted off North Spitzbergen* (Vol. no. 58, Stavanger: University of Stavanger, 2016); Knut Espen Solberg, Ove Tobias Gudmestad and Eivinn Skjærseth, *SARex2: Surviving a maritime incident in cold climate conditions* (Vol. no. 69, Stavanger: Universitetet i Stavanger, 2017); Solberg and Gudmestad, *SARex3: evacuation to shore, survival and rescue*.
6. Espen Engtrø, Ove Njå and Ove Tobias Gudmestad, "Polarkoden – funksjonsbasert forskriftsverk for polare farvann: hvordan kan standarder presentere gode nok løsninger?" [The Polar Code – function-based regulations for polar waters: The contribution of standards to safe and sufficient solutions?], In: *Regulering og standardisering: perspektiver og praksis* [Regulation and standardization: Perspectives and practice] (Universitetsforlaget – Scandinavian University Press, 2018), ISBN 9788215028934, s. 146–162.
7. Megan Gannon, *Exxon Valdez 25th Anniversary: 5 Facts About the Historic Spill*, (LiveScience, March 24, 2014), accessed April 14, 2020. https://www.livescience.com/44314-exxon-valdez-spill-anniversary-facts.html
8. Øystein Jensen, "The International Code for Ships Operating in Polar Waters: Finalization, Adoption and Law of the Sea Implications", *Arctic Review on Law and Politics 7* (2016): 60–82. https://doi.org/10.17585/arctic.v7.236
9. Jiayu Bai "The Polar Code: The Emerging Rules of Arctic Shipping Governance", *The International Journal of Marine and Coastal Law 30* (2015): 674–699. https://doi.org/10.1163/15718085-12341376
10. Knut Espen Solberg, "Implications caused by SARex on the implementation of the IMO polar code on survival at sea", *IOP Conference Series: Materials Science and Engineering*, Vol. 276(1) (2017).
11. Jensen, "The International Code for Ships Operating in Polar Waters: Finalization, Adoption and Law of the Sea Implications."
12. Ibid.
13. Lawson W. Brigham, "The Developing International Maritime Organization Polar Code", *Akureyri, Iceland: Northern Research Forum, Arctic Yearbook* (2014).

14. Jensen, "The International Code for Ships Operating in Polar Waters: Finalization, Adoption and Law of the Sea Implications"; Vijay Sakhuja, "The Polar Code and Arctic Navigation", *Strategic Analysis*, Vol. 38, No. 6 (2014): 803–811. https://doi.org/10.1080/09700161.2014.952943
15. Ibid.
16. Jensen, "The International Code for Ships Operating in Polar Waters: Finalization, Adoption and Law of the Sea Implications".
17. Mike Schuler, *M/V Explorer – Investigation into Sinking of An Eco-Cruise Ship*, (gCaptain, 14 April 14 2009), accessed 14 April 2020. https://gcaptain.com/investigation-sinking-mv-explorer/
18. Jensen, "The International Code for Ships Operating in Polar Waters: Finalization, Adoption and Law of the Sea Implications".
19. ibid; Sakhuja, "The Polar Code and Arctic Navigation".
20. Sakhuja, "The Polar Code and Arctic Navigation".
21. Ibid.
22. Ibid.
23. Bai, "The Polar Code: The Emerging Rules of Arctic Shipping Governance", p. 679.
24. International Convention for the Safety of Life at Sea (SOLAS), IMO, 1974, and 1978 and 1988 Protocol relating thereto: 2000 and 2004 amendments.
25. Polar Code, IMO, Ch. 1.5.
26. Ibid., Ch. 2.
27. Ibid., Ch. 2.
28. "Goal-based standards, What are goal-based standards?", IMO, accessed 14 April 2020. http://www.imo.org/en/OurWork/Safety/SafetyTopics/Pages/Goal-BasedStandards.aspx
29. Polar Code, IMO.
30. "Goal-based standards, What are goal-based standards?", IMO.
31. Polar Code, IMO, Ch. 8, Para. 8.1.
32. Ibid., Ch. 8, Para. 8.2.2.
33. Ibid., Ch. 8, Para. 8.3.2.
34. Ibid., Introduction, Ch. 3.
35. Ibid., Ch. 1, Para. 1.2.7.
36. Regulations on safety measures for ships operating in polar waters and amendments to Regulations on environmental safety, Norwegian Maritime Authorities (NMA), RSR 15-2016.
37. Ibid.
38. The figure extracted from the Polar Code is for illustrative purposes only (pp. 8–9). For exact coordinates, the regulation refers to SOLAS Chapter XIV/1.3.
39. Albert Buixadé Farré et al., "Commercial Arctic shipping through the Northeast Passage: routes, resources, governance, technology, and infrastructure", *Polar Geography* 37:4, 298–324 (2014), DOI: 10.1080/1088937X.2014.965769; Samrat Ghosh and Christopher Rubly, "The emergence of Arctic shipping: issues, threats, costs, and risk-mitigating strategies of the Polar Code", *Australian Journal of Maritime & Ocean Affairs* (2015) 7:3, 171–182, DOI: 10.1080/18366503.2015.1093695.
40. Malte Humpert and Andreas Raspotnik, "The Future of Arctic Shipping Along the Transpolar Sea Route", *Arctic Yearbook* (2012).
41. Ibid.
42. Viggo Jean-Hansen, "Skipstrafikken i området Lofoten – Barentshavet" [The seatraffic in The Barents Sea], *Kystverket – The Norwegian Coastal Administration*, Oslo, 2003.
43. Protection of the Arctic Marine Environment (PAME), "The increase in Arctic Shipping 2013–2019", *Arctic shipping status report (ASSR) #1 31 March* 2020.
44. Ibid.

45. International Regulations for the Safety of Fishing Vessels, IMO, MSC 92/26/Add.2 Annex 25: London, 1977.
46. Gudrun Petursdottir, Olafur Hannibalsson and Jeremy M. M. Turner, "Safety at sea as an integral part of fisheries management", *The Food and Agriculture Organization of the United Nations (FAO), Fisheries Circular No. 966* (2001), FIIT/C966 ISSN 0429-9329; "The Torremolinos International Convention for the Safety of Fishing Vessels", IMO, accessed 14 April 2020. http://www.imo.org/en/About/Conventions/ListOfConventions/Pages/The-Torremolinos-International-Convention-for-the-Safety-of-Fishing-Vessels.aspx
47. SOLAS, IMO.
48. Kjetil S Grønnestad, *Cruisetrafikk gjennom Arktis* [Cruise traffic through the Arctic], (BarentsWatch, 17 January 2017), accessed 14 April 2020. https://www.barentswatch.no/artikler/cruisetrafikk-gjennom-arktis/
49. Ibid.
50. Solberg, "Implications caused by SARex on the implementation of the IMO polar code on survival at sea".
51. Thomas Nilsen, *Arctic cruise ship boom*, (The Barents Observer, 22 May 2018), accessed 14 April 2020. https://thebarentsobserver.com/en/travel/2018/05/arctic-cruise-ship-boom
52. PAME, "The increase in Arctic Shipping 2013–2019".
53. Solberg, Gudmestad and Kvamme, *SARex Spitzbergen: April 2016: exercise report: search and rescue exercise conducted off North Spitzbergen*; Solberg, Gudmestad and Skjærseth *SARex2: Surviving a maritime incident in cold climate conditions*; Solberg and Gudmestad, *SARex3: evacuation to shore, survival and rescue*.
54. Ibid.
55. Polar Code, IMO, Ch. 1.4.
56. Solberg, Gudmestad and Kvamme, *SARex Spitzbergen: April 2016: exercise report: search and rescue exercise conducted off North Spitzbergen*.
57. Sølve Tanke Hovden, *Redningsdåden: om Maksim Gorkiy-havariet utenfor Svalbard i 1989* [*The Rescue: about the Maksim Gorkiy-accident outside Spitsbergen in 1989*], (Sandnes: Commentum Forlag, 2012].
58. Solberg Gudmestad and Kvamme, *SARex Spitzbergen: April 2016: exercise report: search and rescue exercise conducted off North Spitzbergen*, p. vi.
59. Ibid, p. iv.
60. Ibid.
61. Ibid., pp. 32–34.
62. Solberg Gudmestad and Skjærseth, SARex2: *Surviving a maritime incident in cold climate conditions.*
63. Ibid., pp. 20–22.
64. Ibid.
65. Ibid.
66. Ibid.
67. Ibid.
68. Solberg and Gudmestad, *SARex3: evacuation to shore, survival and rescue*.
69. Ibid.
70. Ibid.
71. Ibid.
72. Ibid., p. 4.
73. Polar Code, IMO, Introduction, Ch. 3.2.
74. PAME, "The increase in Arctic Shipping 2013–2019."
75. Solberg and Gudmestad, *SARex3: evacuation to shore, survival and rescue*.

76. Solberg Gudmestad and Kvamme, *SARex Spitzbergen: April 2016: exercise report: search and rescue exercise conducted off North Spitzbergen*; Solberg Gudmestad and Skjærseth, *SARex2: Surviving a maritime incident in cold climate conditions*; Solberg and Gudmestad, *SARex3: evacuation to shore, survival and rescue*.
77. The interim guidelines for life-saving appliances and arrangements for ships operating in polar waters, IMO, MSC.1/Circ.1614 2019.
78. Regulations on the construction, equipment and operation of passenger ships in the territorial waters surrounding Svalbard, NMA, RSR 03 2019.
79. The interim guidelines for life-saving appliances and arrangements for ships operating in polar waters, IMO.
80. Ibid.
81. Regulations on the construction, equipment and operation of passenger ships in the territorial waters surrounding Svalbard, NMA.
82. Ibid., p. 2.
83. Information on certificates required to operate passenger ships at Svalbard, NMA, RSV 01 2017.
84. SOLAS, IMO.
85. Ibid., Part A: Application, definitions, etc., Regulation 2 (d).
86. Treaty between Norway, The United States of America, Denmark, France, Italy, Japan, the Netherlands, Great Britain and Ireland and the British overseas Dominions and Sweden concerning Spitsbergen, The Svalbard Treaty, signed in Paris 9 February 1920.
87. Regulations on the construction, equipment and operation of passenger ships in the territorial waters surrounding Svalbard, NMA, p. 2.
88. Ibid.
89. Ibid.
90. Ibid.
91. Ibid., Section 12, second paragraph, p. 11.
92. Revised recommendation on testing of life-saving appliances, IMO, Resolution MSC.81(70) 1988.
93. Regulations on the construction, equipment and operation of passenger ships in the territorial waters surrounding Svalbard, NMA, p. 11.
94. "The Arctic Shipping Best Practice Information Forum", PAME, accessed 20 October 2019. https://pame.is/arcticshippingforum#part-ia-safety-measures
95. Ibid.
96. "Meeting of Arctic Council's Protection of the Arctic Marine Environment Working Group at the Admiral Nevelskoy Maritime State University, Vladivostok, Russia, 1–4 October 2018", PAME, accessed 20 August 2019. https://pame.is/images/03_Projects/Forum/PDF/Presentation_PAME_II_02.10.2018_Vladivostok.Russia.Michael_Kingston_and_Hjalti_Hreinsson._Final_.pdf
97. Ibid.
98. Steven T. Maher et al., "Paradigm Shift in the Regulatory Application of Safety Management Systems to Offshore Facilities", *Process Safety Progress*, Vol. 35, No. 4 (2013), DOI 10.1002/prs.11558; Heike Hoppe, "Goal-based Standards – A New Approach to the International Regulation of Ship Construction", *WMU Journal of Maritime Affairs*, (2005), Vol. 4, No. 2, 169–180.
99. Maher et al., "Paradigm Shift in the Regulatory Application of Safety Management Systems to Offshore Facilities".
100. Ole Andreas Engen, Janne Hagen and Jacob Kringen, "Tilsynsstrategi og HMS-regelverk i norsk petroleumsvirksomhet" [Revision strategy and HSE regulations in the Norwegian petroleum industry], *Arbeidsdepartementet – Ministry of Labour*, Oslo, (2013).

101. Ibid.
102. "Introduction to IMO", IMO, accessed 14 April 2020. http://www.imo.org/en/About/Pages/Default.aspx
103. Polar Code, IMO, Preamble, Para. 1.
104. Ibid., Ch. 8.
105. Ibid., Ch. 8.3.3.3.
106. Ibid., Part I-B, Ch. 9.1 and 9.2.
107. Solberg and Gudmestad, *SARex3: evacuation to shore, survival and rescue*.
108. Polar Code, IMO, Para. 8.2.3.3.
109. Maritimt Forum Nord SA, "SARINOR WP 4 og 5 Redning og overlevelse i kaldt klima" [Rescue and survival in cold climate], *DNV GL*, Report No. 2015-0931, Rev. 0.
110. Solberg and Gudmestad, *SARex3: evacuation to shore, survival and rescue*.
111. The interim guidelines for life-saving appliances and arrangements for ships operating in polar waters, IMO, Ch. 1.3.
112. Solberg and Gudmestad, *SARex3: evacuation to shore, survival and rescue*.
113. Maher et al., "Paradigm Shift in the Regulatory Application of Safety Management Systems to Offshore Facilities".
114. Polar Code, IMO, Ch. 1.5.
115. Preben Hempel Lindøe, Michael S. Baram and Ortwin Renn, *Risk governance of offshore oil and gas operations* (New York: Cambridge University Press, 2014).
116. Ove Njå and Øyvind Solberg, "Safety Considerations in Political Decisions: A Case Study of Changes to the Norwegian Aviation System", *Review of Policy Research*, Vol. 27(5) (2010), 595–619; Ove Njå and Kirsti Russel Vastveit, "Norske kommuners planlegging, gjennomføring og bruk av risiko- og sårbarhetsanalyse i forbindelse med samfunnssikkerhetsarbeidet" [Societal risk governance in municipalities is based on a weak regulatory regime and unclear professional competence], *Stavanger: University of Stavanger* (2016); Ove Njå et al., "Evaluering av risikovurderinger i Statens vegvesen. Beslutningsstøtte og læringsverktøy" [Evaluation of risk assessments in the Norwegian Public Roads Authority: Decision support and learning tool], *Stavanger: International Research Institute of Stavanger* (2013).
117. Geir Sverre Braut et al., "Risk images as basis for two categories of decisions", *Risk management: An International Journal,* Vol. 14 (2012), 60–76.
118. Nancy Leveson, *Engineering a safer world: systems thinking applied to safety* (Cambridge, Mass.: The MIT Press, 2011).
119. The Office of the Auditor General in Norway – Riksrevisjonen, "The Office of the Auditor General's investigation of the PSA's follow-up of health, safety and environment in the petroleum industry", *The Office of the Auditor General in Norway*, Document 3:6 (2018–2019), ISBN 978-82-8229-454-6.
120. Kathrine Pike et al., "15 Years of Shipping Accidents: A review for WWF", *World Wildlife Fund*, (2013).
121. Christian Kuran and Ove Njå, "Rule Bending in the Road Based Commercial Goods Transport Sector – A Systems Theory Approach", Paper presented at: *The 3rd International Conference on Transport and Traffic Engineering,* ICTTE, Belgrade, Serbia (2016); Ove Njå, Geir Sverre Braut and Ove Erik Vika, "Bending the Rules in the Commercial Goods Road Transport Sector", *Procedia – Social and Behavioral Sciences*, Vol. 48: 2336–2350 (2012).
122. Regulations on the construction, equipment and operation of passenger ships in the territorial waters surrounding Svalbard, NMA, p. 2.
123. Solberg, "Implications caused by SARex on the implementation of the IMO polar code on survival at sea".
124. Ibid.

125. Regulations on the construction, equipment and operation of passenger ships in the territorial waters surrounding Svalbard, NMA.
126. The interim guidelines for life-saving appliances and arrangements for ships operating in polar waters, IMO, Ch. 1.1.
127. Solberg and Gudmestad, *SARex3: evacuation to shore, survival and rescue*.
128. The interim guidelines for life-saving appliances and arrangements for ships operating in polar waters, IMO.
129. Hendrik Schopmans, "Revisiting the Polar Code: Where Do We Stand?" *The Arctic Institute, Center for Circumpolar Security Studies*, Washington (11 June 2019); "Assembly, 31st session, 25 November to 4 December 2019", IMO, accessed 14 April 2020. http://www.imo.org/en/MediaCentre/MeetingSummaries/Assembly/Pages/Assembly-31st-session.aspx
130. PAME, "The increase in Arctic Shipping 2013–2019".
131. "Assembly, 31st session, 25 November to 4 December 2019", IMO.
132. "The Arctic Shipping Best Practice Information Forum", PAME.
133. William Scoresby, *An account of the Arctic regions with a history and description of the northern whale-fishery*. (Edinburgh: Printed for A. Constable & co, 1820).
134. Ove Tobias Gudmestad and Johannes Alme, "Implementation of experience from the Arctic seal hunter expeditions during the late 19th and the 20th century", *Ocean Engineering* 111 (2016), 1–7, http://dx.doi.org/10.1016/j.oceaneng.2015.10.029
135. Solberg and Gudmestad, *SARex3: evacuation to shore, survival and rescue;* Marchenko et al., "Arctic Shipping and Risks: Emergency Categories and Response Capacities"; Andreassen et al., "Emergency Management in Maritime Mass Rescue Operations: The Case of the High Arctic".
136. Engen, Hagen and Kringen, "Tilsynsstrategi og HMS-regelverk i norsk petroleumsvirksomhet" [Revision strategy and HSE regulations in the Norwegian petroleum industry].
137. The Office of the Auditor General in Norway – Riksrevisjonen, "The Office of the Auditor General's investigation of the PSA's follow-up of health, safety and environment in the petroleum industry".
138. Regulations on port State control, NMA, No. 1458, 24 November 2014.
139. Regulations on the construction, equipment and operation of passenger ships in the territorial waters surrounding Svalbard, NMA, p. 2.
140. Ibid., Section 18, p. 14.
141. Ibid.
142. Ibid., p. 14.

Paper IV: The Polar Code's Implications for Safe Ship Operations in the Arctic Region.

Engtrø, E., Gudmestad, O. T., and Njå, O. (2020). *TransNav - The International Journal on Marine Navigation and Safety of Sea Transportation*, Vol. 14:3 (pp. 655-661). DOI: 10.12716/1001.14.03.18

TRANSNAV
http://www.transnav.eu
the International Journal on Marine Navigation and Safety of Sea Transportation
Volume 14
Number 3
September 2020
DOI: 10.12716/1001.14.03.18

The Polar Code's Implications for Safe Ship Operations in the Arctic Region

E. Engtrø, O.T. Gudmestad & O. Njå
University of Stavanger, Stavanger, Norway

ABSTRACT: Simultaneously with a decreasing sea ice cover in the Arctic region an increase in ship traffic is experienced in these waters, meaning a higher probability of accidents and incidents to occur. The capability to handle emergency situations for shipowners, operators and rescuers in a cold climate environment are heavily affected by the risks present in polar waters and depends on limited emergency response resources covering extremely large areas. In 2017, the International Code for Ships Operating in Polar Waters (The Polar Code) was adopted by the International Maritime Organization (IMO), applicable for the Arctic and Antarctic regions. The goals of the functionally based regulation are to provide for safe ship operations and the protection of the polar environment, by addressing risks present in polar waters and to ensure these are mitigated sufficiently. A qualitative pilot study, with individual expert interviews, has been conducted in order to examine the Polar Code's implications for safe ship operations in the Arctic region. The study concludes that the discussions raised in the aftermath of the Polar Code has led to an increase in focus and a strengthen consciousness about hazards and risks associated with polar water ship operations and additional measures required to mitigate these. Further, the implementation of the Polar Code is considered as a milestone by establishing an international regulation, mandatory for polar water ship design and for voyage planning. However, the study points out that the main principle of the Polar Code is risk-based, meaning the performance of safe ship operations are depending on those subjects to the regulation, to conduct thorough operational risk assessments covering all actual hazards, and to ensure that those are mitigated sufficiently. In this regard, authority presence is found crucial, to validate the adequacy and the dimensioning of the implemented measures. Key words: Arctic ship operations; regulatory governance; emergency response; risk management.

1 INTRODUCTION

In 1989, the oil tanker Exxon Valdez ran aground near the coast of Alaska, and one of history's largest environmental disasters at sea was a fact. The accident subsequently raised public awareness and speeded up the process of establishing a mandatory international regulation for ship traffic in polar regions [13]. International laws and the laws of coastal states with territorial sovereignty regulated marine activity in these waters, and these laws could be contradictory [3]. From the early 1990s, the International Maritime Organization (IMO) started the work to develop a regulation which could meet the extraordinary risks associated with voyages in the Arctic and Antarctic regions, as additional requirements applicable for ship operations in polar waters were lacking. In 2016, the work was finalized, resulting in the International Code for Ships Operating in Polar Waters (The Polar Code) [9], a function-based regulation, applicable from January 1st, 2017. The Polar Code was developed in a collaboration between member states of IMO, amongst which Norway, represented by the Norwegian Maritime Authority (NMA), had a leading role.

2 THE POLAR CODE CONTENT

The Polar Code is a continuation of existing IMO regulations, made mandatory under the International Convention for the Safety of Life at Sea (SOLAS); the International Convention for the Prevention of Pollution from Ships (MARPOL); and the International Convention on Standards of Training, Certification and Watchkeeping (STCW). The regulation contains requirements regarding the design and construction of vessels and equipment, operational conditions and training, and the protection of the environment. The Polar Code consists of two parts; Part I contains provisions on safety measures, made mandatory under SOLAS Convention, defining minimum performance standards for ship systems and equipment; Part II contains provisions on measures to prevent pollution, made mandatory under the MARPOL Convention. The provisions on safety measures (Part I) are of interest in this article, applicable to passenger ships carrying more than twelve passengers or cargo ships with a gross tonnage of 500 or more engaged in international voyages [11].

The geographical area of application in the Arctic is shown in the figure 1. In the Antarctic, the regulation is applicable at 60th parallel south.

Figure 1. Maximum geographical extent of the Polar Code`s area of application in the Arctic. The figure extracted from the Polar Code is for illustrative purposes only. For exact coordinates, the regulation refers to SOLAS Chapter XIV/1.3 [11].

Ships which comply with the requirements in the regulation are issued a Polar Ship Certificate on behalf of IMO. The certificate shall specify vessel type, ice class, polar service temperature, maximum expected time of rescue, vessel restrictions and operational limitations for ice conditions, temperature and high latitudes. The Polar Code acknowledges that the risk level may differ depending on the geographical location and time of year, and mitigating measures required to address hazards may therefore vary within polar waters. Capabilities and limitations identified in the operational assessment performed for a vessel shall be documented in the Polar Water Operation Manual (PWOM), to be carried onboard when on voyage.

3 METHODS FOR INTERPRETING "THE POLAR CODE EFFECT"

The topic in this article is risk regulation of marine activities at an international and governing level, with complex problems of concern, to be handled by a variety of industries and regulated parties. Several uncertainties exist, in particular the capability to handle emergency situations, both for shipowners, operators and rescuers in a cold climate environment, heavily affected by the risks present in polar waters. As the requirements in the Polar Code are based on risk factors in the operating areas, the problem for discussion is the extent to which the regulation attributes for enhanced risk management of polar water shipping operations, considering all the uncertainties associated with voyages in these waters. Areas of interest in this regard are:

- Expectations towards regulatory compliance and the establishment of practical solutions.
- Interpretation of the Polar Code's requirements and developmental trends.
- The Polar Code's contribution in defining best standards for ship operations in polar waters.

Empirical research is conducted to provide data to assess the Polar Code's implications as regulation for ship operations, in this study limited to the Arctic region. The data for this research comes from interviews, academic papers, guidelines and reports. Academic research covering various aspects and challenges associated with Arctic ship operations and emergency preparedness in polar waters is comprehensive [1], [2], [19], [21], [38] and the implications and consequences associated with the implementation of a mandatory regulation for polar water ship operations are of interest. Research covering the topic is, for example, found in the extensive SARex I, II & III exercise reports from 2016, 2017 and 2018, respectively [34], [35], [36]. During these exercises the Polar Code was used as a base for testing life-saving appliances (LSA) and rescue equipment in a cold climate; personal capabilities for survival in real-event situations were studied, and training in emergency scenarios was conducted [34], [35], [36]. The exercises, each lasting one week, were held north of Spitzbergen in ice-infested water or to onshore, with an objective to identify and explore the gaps between the functionality provided by the existing SOLAS approved safety equipment and the functionality required by the Polar Code [34], [35], [36]. The reports from the SARex exercises, with their individual contributions from the participants in the appendices, are valid sources of data, containing detailed descriptions and evaluations of emergency response resources and requirements for polar water operations, both from a technical, operational and organizational point of view.

3.1 *Interviews*

A pilot study has been conducted in order to gain data about the Polar Code and its implications for safe ship operations in the Arctic region. Individual interview as method was selected, which is the most commonly data collection strategy in qualitative research [31]. The method of interviewing experts enables for in-depth examination to capture the informant's knowledge and understanding of the studied topic [12], [18]. The selection criteria for choosing informants for this study were thorough expertise and knowledge about the Polar Code, gained through work experience in the making of the regulation prior to 2017, after the regulation was implemented, or both. Six informants who met all the defined criteria were selected, represented by the NMA, the Norwegian Coastal Administration (NCA), the classification societies and the academia (ice navigation specialist). The interviews were conducted during January 2020 - four interviews in person and one via telephone. In addition, formal conversations were held with one of the informants during the same period, in person, via telephone and mail correspondence. An interview guide was developed containing questions concerning safe ship operations in northern areas and challenges associated with the enforcement of the Polar Code. The interviews were conducted in a semi-structured manner, allowing flexibility to explore spontaneous issues raised by the interviewees [30], all lasting approximately one hour with use of the interview guide. The following regulatory topics were addressed during the interviews, all considered as a result of the Polar Code implementation, provided as additional guidance and clarifications for regulatory compliance:

- Guidance on methodologies for assessing operational capabilities and limitations in ice; Polar Operational Limit Assessment Risk Indexing System (POLARIS) (2016) [7].
- Amendments to STCW on qualifications and certificates for seafarers (2018) [26].
- Guidance for navigation and communication equipment intended for use on ships operating in polar waters (2019) [8].
- Interim guidelines on life-saving appliances and arrangements for ships operating in polar waters (2019) [10].
- Regulations on the construction, equipment and operation of passenger ships in the territorial waters surrounding Svalbard (2020) [28].

The collected data were analyzed utilizing thematic analysis as a method, which is a widely used qualitative analytic method for identifying, analyzing and reporting patterns and themes in data [4]. Themes were identified using a deductive and theoretical approach, providing a detailed analysis of certain aspect of the collected data [4]. The thematic analysis were conducted with the following steps: (1) familiarizing by transcribing the data, (2) generating initial codes by exploring features of interesting data across the entire data set, (3) collating the data relevant to each code in a systematic manner, (4) collate codes into potential themes and review these themes by checking logical relationship to the coded extracts and the entire data set, (5) defining and naming the themes, (6) final analysis of selected extracts [4]. However, analyzing data is not a process conducted in a linear manner moving from first phase to second and third. Instead, the process is dynamical, moving back and forth as needed, throughout the phases [4]. The themes identified in the thematic analysis forms basis for the topics discussed in chapter 4.

4 DISCUSSION - REGULATORY GOVERNANCE AND FUNCTION-BASED REGULATIONS

Function-based regulations, as the Polar Code, are increasingly applied in regulatory governance, where the responsibility for developing and establishing operational standards and procedures is delegated from government officials to the subjects and target groups that the regulations are intended to regulate. From a rational approach, functional requirements enable shipbuilders, owners and operators to choose flexible solutions, suitable to own activities and operations. Self-regulation as principle demands strong professional integrity and high levels of competence, from those subject to the regulation but also from the assigned authorities, represented by the flag states, the port states and the recognized classification societies.

During the interviews it became evident that the implementation of the Polar Code initially did not have a great impact for the experienced operators and shipowners, already engaged in polar water operations in the Arctic region. Their fleet generally consisted of winterized vessels, designed for low temperatures and built according to recognized ice classes, and in most cases only minor technical modifications were necessary for reaching compliance with the new regulation. Routines for developing operational procedures for operating in ice were also well-established, and often only cross-references to the individual sections of the Polar Code were sufficient for reaching compliance with the regulation. One informant pointed out that the Polar Code has gained criticism for its functional formulations, but at least a minimum standard and expectation for operational elements and for vessel design and construction is established. Even so, the informant explained, ship builders or ship owners lacking polar experience and knowledge have difficulties to acknowledge this minimum expected standard, which manifests when operational capabilities and limitations in ice are addressed in the early stages of the design phase of a vessel. Another informant pointed out what he called the function-based paradox; the Polar Code addresses a minimum of specified hazards and risks to be treated in an operational risk assessment for the vessel and its intended voyages, however, unexperienced personnel will have great difficulties identifying and assessing all the related ones.

4.1 *From function-based regulations to descriptive guidelines*

International shipping operations are regulated by IMO Conventions and regulations, established through extensive cooperation and often time-consuming work, characterized by the time it took to develop and agree on the Polar Code (> 25 years). In these forums scientific facts can be diminished in favor of political and economic interests, as visions and goals are to be agreed on amongst differing cultures, institutions and states with competing agendas and financial situations [32]. In the making of the Polar Code, one informant recalled the discussions within IMO, addressing requirements for LSA, describing them as controversial, resulting in less descriptive requirements for this chapter compared to the other chapters of the Polar Code. However, in parallel with the ongoing work of finalizing the regulation in 2015, the same informant participated in the development of interim guidelines for LSA and arrangements, which was put on the agenda by the NMA, in order to provide additional guidance and clarification to the Polar Code. The strategy of first developing interim guidelines within IMO were debated, but according to the informant consensus were easier achieved by establishing voluntary guidelines compared to mandatory ones. During the next three years, findings from the SAR exercises [34], [35], [36] raised concerns regarding the suitability and efficiency of equipment to be provided in an emergency abandonment situation of vessels, and the exercises proved that vessels in polar voyages likely were equipped with insufficient survival equipment and resources, including food and water rations. The results from the exercises and the discussions that arose after these events contributed in the development of the interim guidelines, which were put to force in 2019 [10].

The interim guidelines for life-saving appliances and arrangements for ships operating in polar waters [10] states that survival after abandonment relies on several factors, such as the types and combination of equipment, crew training and good leadership of each survival craft. Guidance is also provided for the type and amount of survival equipment related to the maximum expected time of rescue. One informant acknowledged the guidelines for its scientifically based content, developed on experience from the SARex exercises, and considered the guidelines to be useful in verification activities of vessels and as a guiding tool for voyage planning. The informant also considered the chronological process within IMO, of first developing interim guidelines before being made mandatory, to be a sustainable way to handle controversial matters, considering that acceptance is easier achieved in the making of voluntary guidelines.

A controversial topic during the development of the Polar Code and in the making of the interim guidelines for LSA and arrangements, according to one informant, was the requirement regards maximum expected time of rescue, set to never be less than five days. The requirement is still debatable and by some considered more as a theoretical statement, questioning the capability for LSA to keep (elderly) people alive for a minimum of five days, after a vessel abandonment [39]. According to the informant, many operators adopt to the requirement without any further assessment, in particular to assess if the expected time of rescue may also exceed five days, which can be the case for ships with a large number of persons on board, operating in the most remote parts of the Svalbard archipelago. A dilemma in the discussion concerning time of rescue [33], addressed by one informant, is the lack of a shared understanding or a definition concerning when one can be considered rescued, adding another uncertainty to the topic.

4.2 *Function-based requirements - expectations and obligations*

Due to the Polar Code's risk-based principle, sufficient measures will highly be depending on geographical and seasonal variations. The Polar Code requires operational limitations, including limitations related to ship structural ice capabilities, to be established and documented in the Polar Ship Certificate and the PWOM, utilizing an acceptable methodology, namely the POLARIS. The basis of POLARIS is an evaluation of the risks posed to the ship by the expected ice conditions in relation to the ship's assigned ice class [7]. The main challenge by applying a risk-based ship design is related to the definition of the ice environment and the ship-ice interaction in this varying environment [15]. Comparing ice environments is a complex matter as ice can have various forms and can be first, second or multiyear ice, which will have large impact on the strength properties of ice as well as on the possible thickness [16]. In addition, ice fields are dynamic and changes on the ice cover characteristics can happen rapidly e.g. due to the wind and currents [16]. In voyage planning, shipowners or operators responsible for conducting adequate operational assessments, can deliberately mislead or non-deliberately underestimate the risks of encountering first-year ice or older and thicker ice or large ice ridges. Certain calculators can take advantage and exploit the risk-based principle in the regulation, which raises questions about the authority’s role in the regulatory regime [29]. One informant pointed out the importance of authority presence in Norwegian ports and waters, enforcing compliance with operational limitations, Polar Class (PC) and the maximum expected time of rescue, as specified in the Polar Ship Certificate for the vessels. The informant suggested an ad-on to be established to existing vessel reporting systems, for submission of operational assessments, to be reviewed and verified by the authorities before approval for polar voyages is given.

According to two informants, there is limited experience in Norway utilizing POLARIS in the establishment of operational limitations, which partly was explained by lack of data in existing ice charts; Norwegian ice charts do not have a standard colour code system separating ice types from each other, used by other Arctic nations as Canada, Russia and Greenland. In POLARIS, a ship is assigned a Risk Index and the Risk Index Values within the Risk Index are values corresponding to a relative risk evaluation for corresponding ice types [7], meaning detailed and accurate information about ice types and ice conditions is essential input to the system. Canada with long traditions for ice navigation uses two systems: The Zone/Date System (ZDS) and the Arctic Ice Regime System (AIRSS); the last-mentioned enforced in 1996 and considered as an equal acceptable alternative methodology to the later developed POLARIS. The ZDS, however, is a fixed system based on historical data on ice conditions, dividing the Canadian Arctic waters into control zones and stipulates the opening and closing dates for each zone for different vessel types [14]. The system encounters that ice conditions are consistent from year-to-year and does not reflect long term trends and inter-annual variability in ice conditions, leading to the development and introduction of the more flexible AIRSS [14].

The ongoing EU earth observation program, "Extreme Earth", involving the Norwegian Meteorological Institute / Norwegian Ice Service, working with large scale analysis of remote sensing data which can support information in the development of more advanced ice charts, was mentioned by the two informants. In these discussions it was pointed out the importance of obtaining high quality data about ice conditions when utilizing a risk-based ship design system.

4.3 *The establishment of international maritime norms*

In 2018, amendments to the STCW on qualifications and certificates for seafarers [26] were laid down on the background of the Polar Code implementation. The amendments primarily involve training requirements for masters, chief mates and officers in charge of a navigational watch on ships with a Polar Ship Certificate operating in open and other polar waters. During the training courses topics concerning legislations, ice classes, ice types and ice conditions, metrological and oceanographic conditions, and LSA are addressed. The training must be documented with a certificate of proficiency from an educational institution offering Polar Code training courses (basic and advanced). Two of the informants were lecturers in the above-mentioned courses and recommended the training to be applicable for additional personnel with non-navigational duties, e.g. engine department, where cold climatic conditions also will affect equipment and human performance. Both informants expressed their concern for the competence level for personnel on vessels operating in ice-free polar waters or in waters outside the application area to the Polar Code; icing, low temperature, extended periods of darkness or daylight, rapidly changing and severe weather conditions and lack of suitable emergency response equipment are hazards and concerns also applicable in waters not regulated by the Polar Code.

A general concern was addressed towards non-SOLAS vessels operating in cold climate areas, including cargo ships of less than 500 gross tonnage; pleasure yachts not engaged in trade; and fishing vessels [11]. The safety provisions (Part I) of the Polar Code is mandatory for certain ships under the SOLAS Convention and non-SOLAS vessels are therefore not regulated by the Polar Code. However, IMO's Maritime Safety Committee and related sub-committees are currently looking at the application of the Polar Code to vessels not regulated by SOLAS Convention. The IMO assembly meeting in end of 2019 adopted a resolution on interim safety measures for vessels not certified under the SOLAS Convention operating in polar waters, which urges the IMO member states to implement, voluntarily, the safety provisions (Part I) of the Polar Code on non-SOLAS vessels.

January 1st, 2020, the NMA laid down new Regulations on the construction, equipment and operation of passenger ships in the territorial waters surrounding Svalbard [28], making the Polar Code, with a few exceptions and additions, applicable as regulations in these waters [28]. Until that date, ships with national certificates have not been subjects to the safety provisions (Part I) of the Polar Code but to MARPOL and national requirements for certificates required to operate passenger ships at Svalbard [27]. The Polar Code`s safety provision applies, per definition, only to passenger ships or cargo ships engaged in international voyages [11]), where an "international voyage means a voyage from a country to which the present Convention applies to a port outside such country, or conversely" [11]. For this reason, passenger ships or cargo ships in voyages in the territorial waters surrounding Svalbard, going from and returning to a port in Norway, have not been subjects to the Polar Code`s safety provisions. According to one informant, interpreting the Polar

Code in this manner was not supported by the NMA representatives in IMO during the making of the regulation, and the NMA recommended all SOLAS vessels operating within the Polar Code application areas should comply with the regulation.

According to one informant, varying interpretation of the Polar Code and enforcement of the regulation amongst flag states can be mitigated when the new Regulations on the construction, equipment and operation of passenger ships in the territorial waters surrounding Svalbard [28], is put in to force, as future development of the legislation in Svalbard will take place in line with new legislation being negotiated internationally in IMO. Due to Svalbard's judicial position [37], the necessity for equal rules for all flag states, will cause predictability and clear legislation, which is an advantage point for the NMA also regulating ships flying foreign flags [28].

5 CONCLUSION AND SUMMARY

The shipbuilding industry delivering polar expedition vessels for the Arctic region is peaking, with 28 new builds expected launched in a four-year period going from 2018 to 2022. This is additional to the almost 80 polar vessels already in voyage in these waters [39]. The increase seen in activities related to science, tourism, shipping, fisheries and commercial aviation in polar regions, means a higher probability of accidents, incidents or requirement for emergency response, depending on limited resources covering extremely large areas [6]. New polar expedition vessels are in general delivered with higher ice-classes (PC) than existing ones, enabling voyages in even more remote areas outside the regular sailing season during summertime [39], going from May to September in the Arctic region. This concern was shared by one informant, who by use of the Automatic Identification System (AIS) for vessels, had observed the same trend; more vessels in voyages in remote and less explored areas. The informant elaborated about his concern for the increased risk for grounding, with better equipped and larger vessels with deeper drafts, exploring new areas with limited hydrographic data, and expressed his concerns related to the human element of risk, highly influenced by personnel skills, competency and knowledge.

The use of POLARIS and equal analytical models quantifying risk levels are depending on reliable input, however, a significant uncertainty is represented by the analysts' risk perception of descriptive scenarios [5]. These concerns were discussed several times during the interviews; the importance of gaining access to accurate data about weather and ice conditions, acquired on a daily basis, and that the capacity to fully understand the characteristics and severity of risks and hazards associated with ship operations in polar regions comes with experience. Operational assessments performed to identify capabilities and limitations for vessels must be re-assessed frequently before found reliable. Research from comparable industries has shown that thorough re-verifications of conducted risk assessments very rarely occur [23], [24], [25], which is a concern that needs to be addressed. The management of control mechanisms and constraints enforcing the Polar Code is of essence and key players in this control regime are port states, flag states and classification societies, followed by the Arctic Council and other nations with interests in the Arctic region. The use of sanctions – fines and withdrawal of the Polar Ship Certificate – are possible reactions, as well as, in extreme situations, the arrest of vessels. Authority involvement, by addressing responsibilities within the industry in a competent manner, is crucial to reduce and eliminate favourable conditions for disreputable parties. Previous experiences from maritime disasters indicate a business sector with some members posing a challenging reputation.

Regulating ship operations, both during design of vessels and for voyage planning, utilizing function-based requirements should be further evaluated, considering the uncertainties represented by geography, environmental conditions and challenges associated with search and rescue (SAR) operations in remote areas with limited resources. Parallels can be drawn with the heavy vehicle transport industry, where research indicates that functional requirements are being stretched [17], [22]. A systemic theoretical approach [20] in the assessment of regulatory constraints, and their functionalities for polar water ship operations could be enlightening, considering the use of function-based provisions supplemented with descriptive guidelines. However, the use of descriptive requirements can turn out to be counter-effective, if compliance is achieved in a mechanical manner, with just checks and controls of predefined measures without conducting re-assessments of the operational conditions.

During the interviews and in the conversations concerning the Polar Code's implications for safe ship operations in the Arctic region, the interviewed in unison acknowledged the implementation of the Polar Code as an important milestone achieved; an international and mandatory regulation, defining minimum expected requirements for polar water ship design and for voyage planning have been established. One informant pointed out that the "reactive" parts of the Polar Code, e.g. the chapter covering LSA and arrangements, have gained more attention than the "proactive" parts of the regulation, e.g. the chapters concerning ship structure, safety of navigation and voyage planning. In the discussions regards minimum expected standards and the way forward, the establishment of buddy-systems, with two vessels operating together in the same area, was mentioned as a mitigating measure that should gain more focus in the operational assessments and during voyage planning.

REFERENCES

[1] Andreassen, N., Borch, O. J., Kuznetsova, S., & Markov, S. (2018). Emergency Management in Maritime Mass Rescue Operations: The Case of the High Arctic. Sustainable Shipping in a Changing Arctic, WMU Studies in Maritime Affairs 7. doi:https://doi.org/10.1007/978-3-319-78425-0_20

[2] Antonsen, Y., Skjetne, J. H., Haugstveit, I. M., Walderhaug, S., Anfinsen, S., Ellingsen, M.-B., & Håheim-Saers, N. (2016). SARINOR WP 6 Delt situasjonsforståelse under søk og redning i nordområdene. doi:https://doi.org/10.13140/RG.2.2.20276.09604

[3] Bai, J. (2015). The IMO Polar Code: The emerging rules of Arctic shipping governance. The International Journal of Marine and Coastal Law, 30(4), 674-699. https://doi.org/10.1163/15718085-12341376

[4] Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. Qualitative Research in Psychology, 3(2), 77-101. doi:10.1191/1478088706qp063oa

[5] Braut, G. S., Rake, E. L., Aanestad, R., & Njå, O. (2012). Risk images as basis for two categories of decisions. Risk Management: An International Journal, 14, 60-76.

[6] Council of Managers of National Antarctic Programs (COMNAP). (2019). Antarctic Search and Rescue (SAR) Workshop IV - Improving SAR Coordination and Response in the Antarctic. Retrieved from: https:www.comnap.aq/Publications/Comnap%20Publications

[7] International Maritime Organization. (2016). Guidance on methodologies for assessing operational capabilities and limitations in ice; Polar Operational Limit Assessment Risk Indexing System (POLARIS). MSC.1/Circ. 1519. London: International Maritime Organization.

[8] International Maritime Organization. (2019). Guidance for navigation and communication equipment intended for use on ships operating in polar waters. MSC.1/Circ.1612. London: International Maritime Organization.

[9] International Maritime Organization. (2017). International Code for Ships Operating in Polar Waters (The Polar Code). MEPC 68/21/Add.1 Annex 10. London: International Maritime Organization.

[10] International Maritime Organization. (2019). The interim guidelines for life-saving appliances and arrangements for ships operating in polar waters. MSC.1/Circ.1614. London: International Maritime Organization.

[11] International Maritime Organization. (2001). SOLAS: International Convention for the Safety of Life at Sea, 1974, and 1988 Protocol relating thereto: 2000 amendments, effective January and July 2002. London: International Maritime Organization.

[12] Jacobsen, D. I. (2015). Hvordan gjennomføre undersøkelser? : Innføring i samfunnsvitenskapelig metode (3. utg. ed.). Oslo: Cappelen Damm akademisk.

[13] Jensen, Ø. (2016). The International de for Ships Operating in Polar Waters: Finalization, adoption and Law of the Sea implications. Arctic Review on Law and Politics, 7(1), 1-23. https://doi.org/10.17585/arctic.v7.236

[14] Kubat, I., Collins, A., Gorman, B., & Timco, G. (2005). A Methodology to Evaluate Canada's Arctic Shipping Regulations. Paper presented at the International Conference on Port and Ocean Engineering under Arctic Conditions (POAC).

[15] Kujala, P., Goerlandt, F., Way, B., Smith, D., Yang, M., Khan, F., & Veitch, B. (2019). Review of risk-based design for ice-class ships. Marine Structures, 63, 181-195. doi:10.1016/j.marstruc.2018.09.008

[16] Kujala, P., Kämäräinen, J., & Suominen, M. (2019). Validation of the New Risk Based Design Approaches (POLARIS) for Arctic and Antarctic Operations. Paper presented at the International Conference on Port and Ocean Engineering under Arctic Conditions (POAC).

[17] Kuran, C. H. A., & Njå, O. (2016). Rule bending in the road based commercial goods transport sector - A systems theory approach. Paper presented at the The 3rd International Conference on Transport and Traffic Engineering, ICTTE, Belgrade, Serbia.

[18] Labuschagne, A. (2003). Qualitative research--airy fairy or fundamental?(Report). The Qualitative Report, 8(1), 100.

[19] Latola, K., & Savela, H. (2017). The Interconnected Arctic — UArctic Congress 2016 (1st ed. 2017. ed.).

[20] Leveson, N. (2011). Engineering a safer world: Systems thinking applied to safety. Cambridge, Mass.: The MIT Press.

[21] Marchenko, N., Andreassen, N., Borch, O. J., Kuznetsova, S., Ingimundarson, V., & Jakobsen, U. (2018). Arctic Shipping and Risks: Emergency Categories and Response Capacities. TransNav, the International Journal on Marine Navigation and Safety of Sea Transportation, 12(1), 107-114. doi:10.12716/1001.12.01.12

[22] Njå, O., Braut, G. S., & Vika, O. E. (2012). Bending the rules in the commercial goods road transport sector. Procedia - Social and Behavioral Sciences, 48, 2336-2350.

[23] Njå, O., & Solberg, Ø. (2010). Safety considerations in political decisions: A case study of changes to the Norwegian aviation system. Review of Policy Research, 27(5), 595-619.

[24] Njå, O., & Vastveit, K. R. (2016). Norske kommuners planlegging, gjennomføring og bruk av risiko- og sårbarhetsanalyse i forbindelse med samfunnssikkerhetsarbeidet [Societal risk governance in municipalities is based on a weak regulatory regime and unclear professional competence]. Stavanger: University of Stavanger.

[25] Njå, O., Vastveit, K. R., Abrahamsen, E. B., & Eriksson, K. (2013). Evaluering av risikovurderinger i Statens vegvesen. Beslutningsstøtte og læringsverktøy. [Evaluation of risk assessments in the Norwegian Public Roads Authority: Decision support and learning tool]. Stavanger: International Research Institute of Stavanger.

[26] Norwegian Maritime Authority. (2018). Amendments to the Regulations on qualifications and certificates for seafarers. NMA, RSR 05-2018.

[27] Norwegian Maritime Authority. (2017). Information on certificates required to operate passenger ships at Svalbard. NMA, RSV 01-2017.

[28] Norwegian Maritime Authority. (2019). Regulations on the construction, equipment and operation of passenger ships in the territorial waters surrounding Svalbard. NMA, RSR 03-2019.

[29] Renn, O., Lindøe, P., & Baram, M. S. (2014). Risk governance of offshore oil and gas operations. New York: Cambridge University Press.

[30] Ryan, F., Coughlan, M., & Cronin, P. (2009). Interviewing in qualitative research: The one-to-one interview. International Journal of Therapy and Rehabilitation, 16(6), 309-314. doi:10.12968/ijtr.2009.16.6.42433

[31] Sandelowski, M. (2002). Reembodying qualitative inquiry. In (Vol. 12, pp. 104-115).

[32] Solberg, K. E. (2017). Implications caused by SARex on the implementation of the IMO polar code on survival at sea. IOP Conference Series: Materials Science and Engineering, 276(1), 012017.

[33] Solberg, K. E. (2020). Safety and emergency response associated with cold climate marine operations. Appendix 5, paper no. 10. (UiS PhD thesis no. 493). University of Stavanger, Faculty of Science and Technology, Department of Mechanical and Structural Engineering and Materials Science, Stavanger.

[34] Solberg, K. E., Gudmestad, O. T., & Kvamme, B. O. (2016). SARex Spitzbergen : April 2016 : exercise report : search and rescue exercise conducted off North Spitzbergen (Vol. no. 58). Stavanger: University of Stavanger.

[35] Solberg, K. E., Gudmestad, O. T., & Universitetet i Stavanger. (2018). SARex3: evacuation to shore, survival and rescue (Vol. no. 75). Stavanger: University of Stavanger.

[36] Solberg, K. E., Skjærseth, E., & Gudmestad, O. T. (2017). SARex2 : Surviving a maritime incident in cold climate conditions (Vol. no. 69). Stavanger: Universitetet i Stavanger.

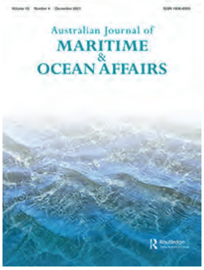
[37] Svalbar Treaty. (1920). Treaty between Norway, The United States of America, Denmark, France, Italy, Japan, the Netherlands, Great Britain and Ireland and the British overseas Dominions and Sweden concerning Spitsbergen, signed in Paris 9th February 1920.

[38] Sydnes, A. K., Sydnes, M., & Antonsen, Y. (2017). International Cooperation on Search and Rescue in the Arctic. Arctic Review on Law and Politics, 8(0), 109-136. doi:10.23865/arctic.v8.705.

[39] The Barents Observer. (2018). Arctic cruise ship boom. Retrieved from https://thebarentsobserver.com/en/travel/2018/05/arctic-cruise-ship-boom

Paper V: Investigating the Polar Code's Function-Based Requirements for Life-Saving Appliances and Arrangements, and the Performance of Survival Equipment in Cold Climate conditions – test of SOLAS approved desalting Apparatus at Low Temperatures.

Engtrø, E., and Sæterdal, A. (2021). *Australian Journal of Maritime & Ocean Affairs* (pp. 274- 294). DOI: 10.1080/18366503.2021.1883821



Australian Journal of Maritime & Ocean Affairs

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/ramo20

Investigating the Polar Code's function-based requirements for life-saving appliances and arrangements, and the performance of survival equipment in cold climate conditions – test of SOLAS approved desalting apparatus at low temperatures

Espen Engtrø & Ane Sæterdal

AUSTRALIAN JOURNAL OF MARITIME & OCEAN AFFAIRS
2021, VOL. 13, NO. 4, 274–294
https://doi.org/10.1080/18366503.2021.1883821

Routledge
Taylor & Francis Group

OPEN ACCESS Check for updates

Investigating the Polar Code's function-based requirements for life-saving appliances and arrangements, and the performance of survival equipment in cold climate conditions – test of SOLAS approved desalting apparatus at low temperatures

Espen Engtrø[a] and Ane Sæterdal[b]

[a]University of Stavanger, Stavanger, Norway; [b]The Arctic University of Norway, UiT, Narvik, Norway

ABSTRACT
As the sea ice extent steadily decreases, the Arctic region is simultaneously experiencing extensive growth in commercial shipping activities, in areas which previously were considered inaccessible for most ships during large periods of the year, increasing the probability of accidents or incidents occurring. *The International Code for Ships Operating in Polar Waters (The Polar Code)* states that resources shall be provided to support survival following abandoning a ship; desalting apparatus is proposed for the provision of the recommended amount of freshwater. However, previous studies have shown that the expected performance criteria for survival equipment are significantly reduced in cold climate conditions. In this paper, we present and discuss the results of testing SOLAS approved desalting apparatus at low temperatures in a controlled and enclosed environment, studying the equipment's performance capabilities.

KEYWORDS
The Polar Code; cold climate operations; function-based requirements; performance criteria; SOLAS approved life-saving appliances and arrangements; desalting apparatus

Introduction

The Arctic region has experienced extensive growth in commercial shipping activities, while, simultaneously, the sea ice extent is steadily decreasing, enabling extended seasons and voyages in areas previously considered inaccessible for most ships during large periods of the year (Protection of the Arctic Marine Environment [PAME] 2020; Silber and Adams 2019). The total increase in ship traffic experienced in the Arctic region, driven by fisheries, shipping and tourism (Protection of the Arctic Marine Environment [PAME] 2020), substantiates the probability of accidents or incidents occurring and puts pressure on the requirements for emergency response, dependent on limited resources covering vast areas (Hill, LaNore, and Véronneau 2015). *The International Code for Ships Operating in Polar Waters (The Polar Code)* was adopted in 2017 by the International Maritime Organization (IMO) and is applicable to the Arctic and Antarctic Oceans

CONTACT Espen Engtrø espen.engtro@uis.no Løkkeveien 10, 4008 Stavanger, Norway

(International Maritime Organization [IMO] 2017). The Polar Code supplements existing IMO instruments, in order to increase the safety of ships' operations, and mitigates the impact on the people and environment in the remote, vulnerable and potentially harsh polar waters (ibid.). Mass tourism and the presence of large cruise ships operating in remote areas in the Arctic region represent the main concern (Solberg and Gudmestad 2018; Marchenko et al. 2018; Andreassen et al. 2018). In the event of an abandonment of ship situation, requiring thousands of passengers to muster to either lifeboats or life rafts, the Polar Code states that resources, including the means to provide sustenance, shall be provided to support survival, whether on the water, ice or land, for the maximum expected time of rescue, defined to be at least five days (International Maritime Organization [IMO] 2017).

The provision of suitable and sufficient life-saving appliances (LSA) and arrangements on ships intended for polar voyages can be a demanding task for ship owners and operators (Solberg, Gudmestad, and Kvamme 2016; Solberg, Gudmestad, and Skjærseth 2017; Solberg and Gudmestad 2018), considering the total assembly of equipment that constitutes the entire emergency response system found on a ship. In the process of selecting LSA and arrangements, the enforcement of companies' safety philosophies and policies, established to comply with the Polar Code, could be challenged for both economic and practical reasons (Solberg, Gudmestad, and Skjærseth 2017). LSA and arrangements intended for polar water operations imply an additional budgetary cost (ibid.), compared to emergency equipment found on ships in tropical climates, due to the winterisation measures required in the design, preservation and packaging process. At the same time, in order to withstand the harsh polar environment, additional and winterised LSA and arrangements require space for storage and impose added weight on rescue craft. A reduction in the number of passengers could therefore emerge as a result of the additional equipment (Solberg, Gudmestad, and Kvamme 2016).

In the event of a survival situation, the provision of food and water is essential. However, humans can survive for weeks without food but only a matter of a few days without water (Piantadosi 2003), whether shipwrecked in the ice-infested and cold Arctic Ocean or stranded in the dry Sahara desert. The IMO guidelines applicable to LSA and arrangements (International Maritime Organization [IMO] 2019b) outline possible means of mitigating hazards, to comply with the Polar Code. They recommend food rations that provide a minimum of 5,000 kJ (1,195 kcal) per person per day and at least 2 litres of freshwater to be available per person per day for the maximum expected time of rescue (min. five days). The guidelines propose the use of desalting apparatus to provide the recommended amount of freshwater, and this could be a choice favoured by operators and ship owners equipping ships for voyages in the Arctic region.

The development and implementation of the above-mentioned guidelines on LSA and arrangements for polar waters (International Maritime Organization [IMO] 2019b) were driven by findings and experience from three survival exercises, performed in northern areas around Svalbard between 2016 and 2018 (Solberg, Gudmestad, and Kvamme 2016; Solberg, Gudmestad, and Skjærseth 2017; Solberg and Gudmestad 2018). These exercises led concerns being raised regarding the gaps explored between the expected performance requirements for SOLAS approved LSA and arrangements and the actual performance of related emergency equipment when tested in cold climate conditions (ibid.; Norwegian Maritime Authorities [NMA] 2019). The objectives for this experiment were, therefore, to verify the newly implemented guidelines and test the functionality of SOLAS approved desalting apparatus at low temperatures; to study the equipment's capacity to produce freshwater from seawater at various temperature readings; and to explore the salt rejection capacity at low temperature readings, by measuring salinity in the produced freshwater.

First, this paper presents the IMO regulatory framework applicable to ships operating in the Arctic region and regarding requirements for LSA and arrangements. Then, shipping in the Arctic region is discussed, considering environmental conditions, related hazards and mitigating winterisation measures associated with voyages in the harsh polar climate. The last part of the paper presents and examines the experiment of testing SOLAS approved desalting apparatus at low temperatures in a cold climate laboratory.

International maritime conventions and regulations applicable in the Arctic region

The International Convention for the Safety of Life at Sea (SOLAS) (International Maritime Organization [IMO] 2001) is reckoned to be the most important of all international treaties concerning the safety of merchant ships. The first version was adopted in 1914, in response to the Titanic disaster, later updated and amended on numerous occasions. The main objective of the SOLAS Convention is to specify minimum standards for the construction, equipment and operation of ships, compatible with their safety (International Maritime Organization [IMO] n.d.). The SOLAS Convention consists currently of 14 chapters, of which Chapter 3 (Life-Saving Appliances and Arrangements) and Chapter 14 (The Polar Code) are of interest in this paper.

Chapter 3 of the SOLAS Convention contains provisions for LSA and arrangements, including requirements for lifeboats, rescue boats and life jackets, according to the type of ship (International Maritime Organization [IMO] 2001). Chapter 3 makes further reference to *The International Life-Saving Appliance Code (LSA Code)*, providing specific technical requirements for LSA and arrangements (International Maritime Organization [IMO] 1998a). The performance requirements in the LSA Code can be supported by test or evaluation requirements as put forth in the *Revised recommendation on testing of life-saving appliances* (International Maritime Organization [IMO] 1998b), for defined survival equipment.

Chapter 14 of the SOLAS Convention (The Polar Code) (International Maritime Organization [IMO] 2017), amended in 2017, contains safety and environmental provisions for ships operating in defined geographical areas around the South and North Poles. The Polar Code's geographical area of application in the Arctic is shown in Figure 1 below.

The Polar Code states that ships' systems and equipment addressed in the regulation shall satisfy at least the same performance standards as those referred to in the SOLAS Convention (International Maritime Organization [IMO] 2017). The mandatory SOLAS Convention for merchant ships, therefore, constitutes a standardised minimum of expectations for the provision of safety measures for maritime design, equipment, systems and operations. Nevertheless, SOLAS approved LSA and arrangements, for use in emergency situations, can be found on ships in voyages all around the world, whether the

Figure 1. The maximum geographical extent of the Polar Code's area of application in the Arctic (International Maritime Organization [IMO] 2017).

climatic conditions are tropical or polar (Solberg and Gudmestad 2018). However, for the Polar Code and the utilisation of its function-based requirements, the main principle is based on the requirement to carry out an operational risk assessment of the ship and its equipment, in order to establish procedures or operational limitations, based on related risk factors in operating areas, such as ice conditions and temperature (International Maritime Organization [IMO] 2017, Ch. 1.5).

After the Polar Code came into effect, the *Guidance for navigation and communication equipment intended for use on ships operating in polar waters* was implemented (International Maritime Organization [IMO] 2019a), in addition to the aforementioned guidelines on LSA and arrangements for polar waters (International Maritime Organization [IMO] 2019b). Further, mandatory minimum requirements for the training and qualification of masters and deck officers on ships operating in polar waters were amended to the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW), applicable from 1 July 2018 (Norwegian Maritime Authorities [NMA] 2018).

The applicability of the Polar Code, with its goal to increase the safety of ship operations and to protect the vulnerable polar environment, is under discussion (Engtrø, Njå, and Gudmestad 2018; Engtrø, Gudmestad, and Njå 2020; Schopmans 2019); functional requirements vs performance requirements for LSA and arrangements, as well as the functionality of survival equipment and its capacity to perform adequately under cold climate conditions, are being questioned (Solberg, Gudmestad, and Kvamme 2016; Solberg, Gudmestad, and Skjærseth 2017; Solberg and Gudmestad 2018).

Shipping in the Arctic region – prevailing polar conditions and hazards

The Arctic region (Figure 2) extends to all the ice-covered Arctic Ocean and the surrounding land of Greenland and Spitsbergen and the northern parts of Alaska, Canada, Norway and Russia (Trantzas 2017). Climate conditions are characterised by long, cold winters and short, cool summers; the average winter temperatures range from −34°C to 0°C, and average summer temperatures range from −10°C to +10°C. The wind speeds over the Arctic Basin are between 4 and 6 m/s (7 and 12 knots) in all seasons. Stronger winds do occur in storms, often causing whiteout conditions (ibid.; Cohen et al. 2017). Rapidly developing low-pressure systems (polar lows) are common weather phenomena during winter seasons. Polar lows are characterised by sudden strong winds and low temperatures, heavy snow showers, thunder and lightning, choppy sea surfaces and increased wave heights; they can be hard to forecast and predict due to the nature of their development (International Standard [ISO] 2010; DNV GL 2015).

Some parts of the Arctic are covered by ice (sea ice and glacial ice) all year, and nearly all parts experience long periods with some form of surface ice (Trantzas 2017). However, the Arctic is not homogeneous with respect to prevailing environmental conditions. Considerable differences exist between not only seasons but also geographic locations. The

Figure 2. Map of the Arctic region (U.S. Department of State n.d.).

Beaufort and Chukchi Seas north of Alaska and Canada, for example, are covered with ice every year, whereas the south-western part of the Barents Sea off the coast of Norway is often said to be ice-free (DNV GL 2015).

Navigating in the Arctic region involves many challenges, due to the rapidly changing landscape of sea ice, draft restrictions in many areas, lack of hydrographic data and detailed surveys, less reliable navigation and satellite communication, and reduced visibility due to fog or darkness for long periods of the year (Hill, LaNore, and Véronneau 2015; Ghosh and Rubly 2015; DNV GL 2015). The presence of ice represents one of the greatest risks, with floating ice in many forms constituting an extremely hazardous condition if colliding with a ship in voyage, involving the risk of damage to hull and structure (Ghosh and Rubly 2015). Ice accretion caused by sub-zero temperatures and freezing of sea spray coming into contact with the ship's surfaces is the most hazardous form of icing and also the most common, and uncontrolled sea spray icing can represent a great risk regarding loss of ship stability, integrity and equipment failure (ibid.; International Standard [ISO] 2010).

Shipping across the northern polar region is increasing, connecting Asia and Europe by trans-Arctic routes along (Figure 3): the Northeast Passage (NEP) and the Northern Sea Route (NSR), encompassing the route along the Norwegian and Russian Arctic coasts; the North-West Passage (NWP), which follows Canada's northern coastline; and the

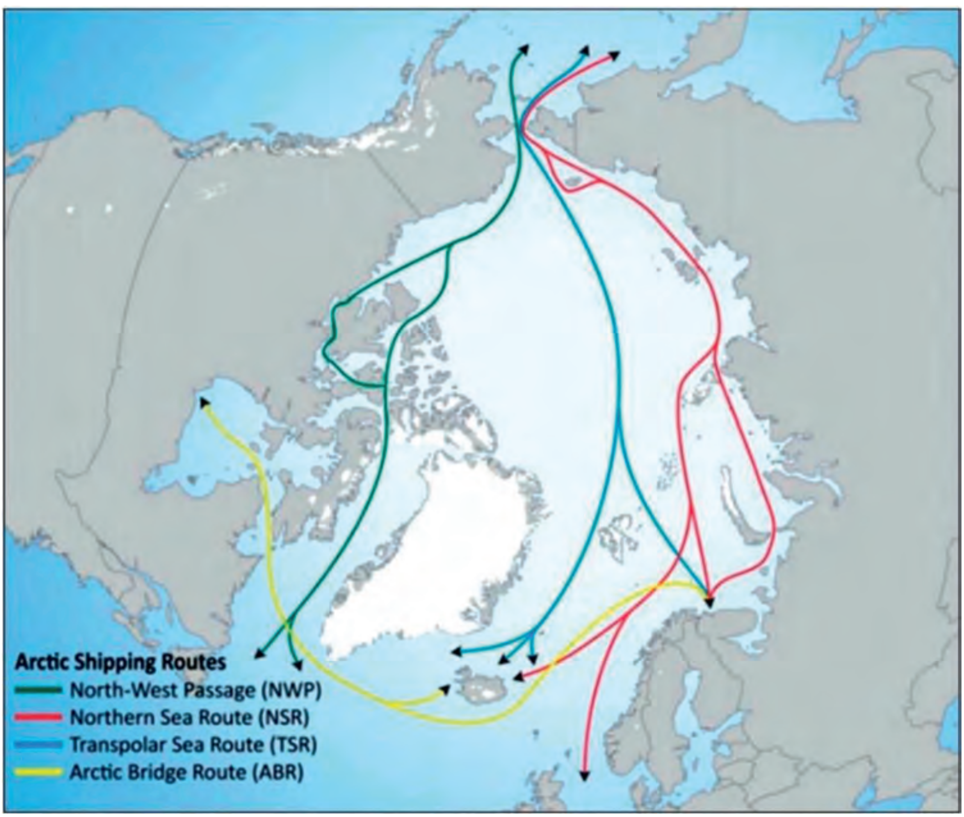


Figure 3. Shipping routes in the Arctic region (Humpert and Raspotnik 2012).

Transpolar Sea Route (TSR), which bisects the Arctic Ocean through the North Pole (Farré et al. 2014; Ghosh and Rubly 2015). In addition, the Arctic Bridge Route (ABR), a shipping route linking the Arctic seaports of Murmansk (Russia) and Churchill (Canada), could develop into a future trade route between Europe and Asia (Humpert and Raspotnik 2012).

Measurements of the volume of shipping within the Polar Code's geographical area of application in the Arctic, taken between 2013 and 2019, show a substantial increase in traffic, when counting both the number of individual ships (up 25 percent) and the total nautical distance sailed during the six-year period in the same area (up 75 percent) (Protection of the Arctic Marine Environment [PAME] 2020). The increase in ship traffic in recent years in the northern areas has been anticipated, especially due to the reduced sea ice enabling shipping in open waters between the Atlantic and the Pacific Oceans during short periods of the year (Grønnestad 2017). In 2016 and 2017, the passenger ship, Crystal Serenity, sailed through the North-West Passage (NWP) from Alaska to New York, with more than 1,000 passengers, on its first voyage (ibid.).

Search and Rescue (SAR) operations in the Arctic region can be extremely demanding, and considerable risks are presented should a ship suffer ice or heavy weather damage, grounding, or machinery failure, due to the extreme remoteness of the region and the limited readily deployable SAR facilities (Hill, LaNore, and Véronneau 2015). The potential for delays in emergency response and the lack of suitable emergency response equipment (Solberg, Gudmestad, and Kvamme 2016; Solberg, Gudmestad, and Skjærseth 2017; Solberg and Gudmestad 2018), in addition to the relatively low traffic density in the Arctic region, indicate that self-rescue is the core principle in the event of a maritime casualty and abandonment of ship (Larsen et al. 2016). An emergency situation involving thousands of passengers to be rescued from a cruise ship is deemed highly critical, as the size and the capacity of SAR services in the Arctic region are not prepared for such a scenario (Urke 2018).

Technical and operational winterisation measures capable of withstanding the harsh and prevailing climatic conditions in the Arctic region are therefore required on ships intended for polar water operations (DNV GL 2015). Winterisation measures are primarily targeted at limiting and controlling the adverse effects of freezing, icing, low temperatures and strong winds (wind chill). The main concerns are the protection of personnel and material properties (DNV GL 2015). Active winterisation measures are functional, addressing electrical or mechanical energy, e.g. heat-traced walkways and escape routes, heat-insulated piping (e.g. fire water lines), keeping circulation in lines to prevent liquid from being static (e.g. fire water mains and cooling water branch lines), or lowering the freezing point of fluids by adding chemicals (e.g. glycol). Passive winterisation measures are characterised as measures in which no energy is addressed, but the design, construction and packaging prevent the adverse effects of icing, freezing and wind chill, e.g. shielded walkways, escape routes and enclosed muster areas; the elimination of pockets, dead-ended pipes and legs in piping; extra insulation and packaging; and work clothing intended for low temperatures (DNV GL 2015; Ghosh and Rubly 2015; Engtrø and Gudmestad 2019).

Test of SOLAS approved desalting apparatus at low temperatures

Low temperatures can be critical for the composition of material used in emergency and survival equipment; steel and polymers become more brittle, and rubber sealing loses its flexible function and properties (DNV GL 2015). Reliance on LSA and arrangements being functional in an emergency situation is vital, and material weaknesses in survival equipment, not discovered until the accident is unfolding, can have fatal consequences. Previous studies performed on SOLAS approved LSA and arrangements, and their actual performance capacity under cold climate conditions, showed a discrepancy between expected and actual performance in the tested equipment (Solberg, Gudmestad, and Kvamme 2016; Solberg, Gudmestad, and Skjærseth 2017; Solberg and Gudmestad 2018).

The objectives of this experiment were therefore to verify the newly implemented guidelines on LSA and arrangements for polar waters (International Maritime Organization [IMO] 2019b) and test the functionality of SOLAS approved desalting apparatus, to study the equipment's capacity to produce freshwater from seawater within 60 min, at the following water temperature readings: +2°C, +4°C, +7°C, +10°C, +23°C. The desalting apparatus's salt rejection capacity was also explored by measuring salinity in the produced freshwater. The experiment was performed in a temperature controlled and enclosed environment, in the facilities at The Arctic University of Norway in Narvik.

General considerations, instrumentation and setup

The seawater for the experiments was sourced by boat in the Ofotfjord close to Narvik, a city in northern Norway. All required seawater was collected simultaneously, to provide the various tests with identical initial conditions with respect to water quality. To avoid a build-up of bacteria and algae, the seawater was collected in food-grade closed containers just in time to be acclimatised to the assigned test temperatures. The sealed containers also prevented evaporation and external contamination prior to the experiment.

The experiment was conducted in a temperature controlled and enclosed environment: an insulated room of about 40 m^2, cooled to the required test temperatures. The heating and cooling system is automatically regulated to sustain a given temperature. As the maximum temperature regulating capacity for the test facility is +10°C, the test performed at a room temperature of +23°C was conducted outside the insulated room, in a regulated indoor area – heating, ventilation, and air conditioning (HVAC), capable of maintaining a stable air temperature during the test, utilising the same measuring equipment used inside the insulated room.

In order to secure accurate temperature measurements, different sources of high-quality equipment were used: three sources of air temperature and two sources of water temperature. The log system was set to measure at one-minute intervals, providing 61 measurements for each test, with four variables: air temperature 1, air temperature 2, water temperature and relative humidity. In addition, measurements of water and air temperature were manually provided every five minutes with a Fluke instrument (Picture 7). The chosen sample interval provided an adequate set of information regarding the test environment and revealed, for example, variations caused by the periodic cooling system.

The instruments used during the experiment were a Hioki memory HiLogger LR8400-20 with two IEC code T – thermocouples and a Fluke 54 II B thermometer with 80PK-25 and 80PK-26 probes. During the tests, the instruments were situated close together to minimise the effect of varying temperatures within the test room. Measurements were also performed in close proximity to the test station, and care was taken to let the probes hang freely in the medium, not connecting to a surface (floor, wall, inside of the container, wires, etc.); see Picture 7. In addition, the relative humidity in the room was monitored by a Hioki Z2000 humidity sensor. A scale was used to control the amount of water, and the result was thereafter converted to litres by standard density values. A list of equipment, including range and error specifications, can be found in Table 1 below.

All equipment and infrastructure, except temperature sensitive equipment, was placed in the insulated room prior to the experiment, to acclimatise. Before being placed in the room, the containers with seawater were weighed and marked, to avoid disturbing the set temperature at the start of a test. While entering the room, care was taken to minimise the time the door was left open. Before starting a test, the temperature was verified to ensure that the room had stabilised after entry. Further considerations, preventative measures and challenges are described in Table 2 below.

After the five tests were completed, the salinity of the refrigerated samples was measured with a Hanna HI98192 USP compliant EC, TDS, NACL, resistivity temperature meter, with electrode HI763133. Between each sample, the probe was cleaned with distilled water.

Table 1. Equipment used in the experiment.

Equipment	Product specification	Comment
Salinity metre	Hanna HI98192 USP compliant EC, TDS, NACL, resistivity temperature metre, with electrode: HI763133	
Water sample container	VWR Borosilicate 3.3 500 ml 215–1594	Used for storing water samples
Volumetric glass	Schott Duran BlauBrand NS12/21 100 mL	Used for weighing liquid
Bucket 16 L	Product number Biltema: 86–2771	Used for wastewater
Bucket 40 L	Product number Biltema: 86–898	Used for wastewater
Mercury thermometer	Two glass mercury thermometers	
Fluke	Fluke 54 II B thermometer	
Air probe for Fluke	Fluke 80PK-26 SureGrip Tapered Temperature Probe	Accuracy ± 2.2°C, range −40°C to 293°C
Water probe for Fluke	Fluke 80PK-25 SureGrip Piercing Temperature Probe	Accuracy ± 1.1°C, range 0°C to 350°C
Log system	Hioki memory HiLogger LR8400-20 no: 141208749. Temperature probes: T – thermocouple (IEC code). Hioki Z2000 humidity sensor no. 150430107.	IEC Tolerance Class EN 60584-2; JIS C 1602, class 1. Accuracy ± 0.5°C, range −40°C to +80°C
Cold room	PTG Kuldeteknisk AS	Range −30°C to +10°C
Water container 20 L	Transparent PEHD, approved for drinking water. Product number Biltema: 37–361	Used for transport and storing of seawater
Scale	August Sauter GmbH D-7470 Albstadt 1-Ebingen. Type AZ/N2E nr 0103016.	Range 2.5–120 kg. e =dd= 50g.
Desalting apparatus	Katadyn Survivor-35. Article No.: 8013433 standard.	Range water temperature +2°C to +45°C. Average salinity 35 ppt TDS.
Distilled water		Used to rinse the salinity probe

Table 2. Considerations, preventative measures and challenges identified for the experiment.

Concern	Preventive measure	Challenges during testing
Evaporation	The caps were left on until the containers were used.	
Spilt water	Care was taken to try to reduce spillage.	Some minor spillage occurred, approximating to less than 1 dl per test.
Leakages from the indicator on the desalinator	Prior to the experiment, time was spent becoming acquainted with the desalinator. During the tests, the pressure indicating rod was observed, in order to minimise leakages from the indicator.	
Rest water in containers	Care was taken to empty the containers properly.	The shape of the containers prevented the complete emptying of each container. Rest water, including water adhering to the inside of the container, approximated to less than 1 dl per container emptied.
Varying temperature as the containers were emptied	The container was changed before it was empty, and, if needed, the remaining water was added to the next container. This did not greatly influence the temperature, as the amount added was relatively small.	
Stop in pumping while changing water supply	The time lost while changing water supply was added to the end of the test, prolonging the test with x pumping motions.	
Reduced water intake as the container was emptied	To prevent the water supply to the pump being too small, a new container was provided prior to emptying the first.	
Manually operating the desalinator with a given frequency	A metronome was used throughout the experiment. The same person conducted all tests.	Adjustments to determine the appropriate metronome beat took place within the first minute.
Human error, manual logging	A checklist was used while logging manually observed data of weight and temperature.	
Inefficiency of the desalinator during start-up	To reduce the error in efficiency that would occur while filling the desalinator with seawater, two-three pumps were performed prior to starting each test. The processed clean water from this start-up was routed to the wastewater. The used water in this process was considered spilt water.	
Varying density with temperature	All containers were initially measured simultaneously at approximately +12°C.	Rest water and clean water were measured after each test with varying temperature. Three containers were measured at approximately +7°C.
Temperature variation	The containers were situated in the test temperature at least 12 h prior to the test, to secure a stable water temperature.	The air temperature varied as a result of repeated cooling in the test room.
Temperature spike because of entering	All equipment and infrastructure, except temperature sensitive equipment, was placed in the room prior to the experiment, to acclimatise. While entering the room, care was taken to minimise the time the door was left open. Prior to starting a test, the temperature was tested, to ensure that the room had stabilised after entering.	

(*Continued*)

Table 2. Continued.

Concern	Preventive measure	Challenges during testing
Accuracy of weight measurements	Available measuring instrument for the weight was used. Between measurements, the scale was reset.	The scale rounds to the closest 0.5 kg.
Accuracy of salinity measurements	To ensure a similar salinity level in all tests, all seawater was sourced simultaneously. In addition, the water was sourced far from the shore, where salinity levels are lower, due to outflow of freshwater. Samples were secured in clean glass containers and kept refrigerated until testing. Prior to each salinity test, the probe was rinsed with distilled water.	
Accuracy of temperature measurements	Different sources of high-quality equipment were used. Prior to the experiment, a test was performed with four instruments for measuring water temperature. During the tests, the instruments were situated close together, to minimise the effect of varying temperatures within the test room. Measurements were also performed in close proximity to the test station. Further, care was taken to let the probes hang freely in the medium, not connected to a surface (floor, wall, inside of container, wires, etc.).	
Desalinator functionality	Instructions were followed.	
Storing of the desalinator between tests	To prevent the storage of the desalinator to influence the result, 4 out of 5 tests were performed within the time span of 5 h.	One test, at +2°C, was performed the following day, and some discrepancy could occur as a result of overnight storage of the desalinator.

Katadyn Survivor-35 desalinator

The Katadyn Survivor-35 desalinator (Picture 8), tested in the experiment, is specified by the vendor as an approved desalting apparatus, as defined in the 1983 conditions of the SOLAS Convention.

The desalinator is a hand-operated pump – intended for emergency situations, for the provision of freshwater from seawater – whose materials consist of stainless steel and plastics. The equipment utilises reverse osmosis and high pressure to remove dissolved salts from seawater, which is filtered through a semipermeable membrane (Figure 4). The semipermeable membrane acts as a molecular filter, and when the pump pressurises seawater to 55 bar and forces it against the membrane, only the water molecules can pass through; salt molecules are unable to pass and flow out of the system.

The desalting apparatus tested in the experiment was provided by a recognised Norwegian shipbuilding company which designs and builds standardised – as well as highly specialised – Polar Code-certified ships. The Katadyn Survivor-35 desalinator is part of the survival equipment, making up the total assembly of LSA and arrangements, delivered by the shipbuilding company to ships intended for polar water operations.

Operating instructions for the Katadyn Survivor-35 desalinator

The Katadyn Survivor-35 is designed to operate during conditions with seawater temperature specifications ranging from +2°C to +45°C and average salinity levels of 35 parts per thousand (ppt) Total Dissolved Solids (TDS). The desalinator is specified to provide 4.5 litres of freshwater per hour (+/- 15%), with an average salt rejection capacity of 98.4% and a minimum of 96.8%. The manual specification states that degree of desalination depends on factors such as water temperature and salinity.

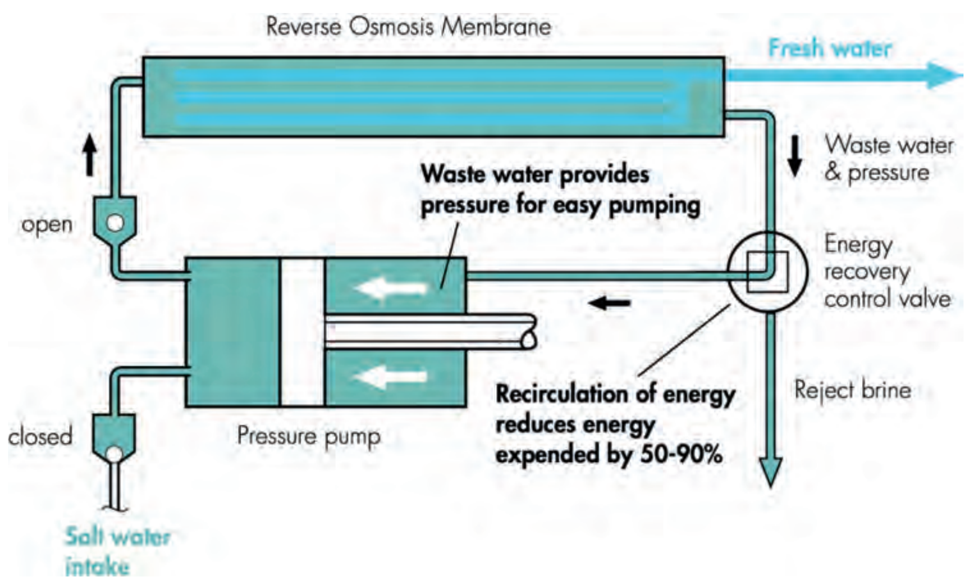


Figure 4. Reverse osmosis technology (Katadyn Fact Sheet n.d.).

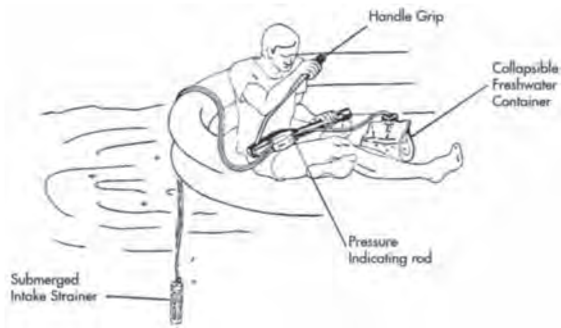


Figure 5. Illustration of a person using the Katadyn-35 desalinator, sitting in a life raft (Katadyn Manual n.d.).

The hand-operated desalinator is to be placed on the lap, with one hand on the handle grip and the other on the membrane housing, as shown in Figure 5. The intake and discharge hoses, attached in a strainer, shall be fully submerged into the seawater, and the freshwater hose is to be placed into a storage container (or directly into the mouth). Optimum pump frequency is set to be 30 strokes (up and down) per minute. If the pump frequency is too fast, a pressure indicating rod extends itself and, finally, water sprays from the indicator.[1]

Operating criteria for the desalinator

Operating criteria established in the experiment for the desalinator directed the pumping frequency and were monitored by observing the pressure indicating rod; it determined that pumping should be as fast as possible but without water spraying out from the indicator (Picture 9). If water sprayed out, the pump frequency was lowered. As soon as an optimum pump frequency was established, a metronome was used to ensure that a steady pump frequency was maintained during the 60-minute test. The same person operated the desalinator in all the tests performed.

Discussion concerning measuring accuracy and deviations

Salinity

Ocean salinity is generally defined as the salt concentration (e.g. sodium and chloride) in seawater and often described in units of ppt. Salinity can also be expressed in Practical Salinity Units (PSU): a measure of the water conductivity at a constant pressure and temperature that is about equivalent to ppt (CATDS – Ocean Salinity Expert Center n.d.).

The seawater samples from the Ofotfjord were measured to a salinity of 26.8 ppt, whereas the average salinity of seawater is 35 ppt (International Standard [ISO] 2019). The seawater samples were gathered less than 0.5 m below the surface. Collecting water from the upper sea layer combined with the fjord location is assumed to give the resulting deviation from average seawater salinity.

Presumably, lower salinity levels in the seawater could result in better test results for the desalinator's capacity to produce freshwater and reject salt molecules. Therefore,

Table 3. Test results with lower salinity levels.

Seawater temperature [°C]	21.3	23.1
Seawater salinity [ppt]	5.0	26.8
Cleaned water salinity [ppt]	0.06	0.12
Cleaned water [kg]	6.8	5.3

an additional test was performed with seawater gathered from Ornesvika, with a salinity measured at 5.0 ppt. Compared with the test results from seawater with a salinity of 26.8 ppt, with otherwise comparable conditions, the processed water with initial lower salinity levels also contained less salt; see Table 3. The low salinity test also yielded a higher amount of cleaned water. However, the discrepancy in the amount could be due to a watch being used to sustain the manual pumping rhythm in the low salinity test: a method found to be somewhat inaccurate. The results are inconclusive, and a test of the desalinator's efficiency at different salinity levels could be explored. Nevertheless, the results are within the prescribed margins of the desalinator.

The desalinator used in the experiment is designed to operate with an average seawater salinity of 35 ppt, expressed in TDS, and measurements of both salinity PSU and TDS were performed. The concepts of salinity PSU and TDS are very similar, with TDS being a measure of the total ionic concentration of dissolved minerals in water. Since most dissolved solids in seawater typically consist of inorganic ions, which are the components of salts, the concepts are sometimes considered to be synonymous (Fondriest n.d.).

Temperature measurements

During the tests, different measuring instruments were used: three measures for air temperature, and two temperatures for the liquid entering the desalting apparatus. Consequently, some discrepancy between the measurements occurred.

Prior to the experiment, a point sample with two additional instruments was performed for the crucial water temperature, as shown in Table 4 below. The Fluke 54 II B thermometer with the appropriate water temperature probe, the Hioki HiLogger LR8400-20 with T-thermocouple and two submergible mercury thermometers were tested simultaneously.

The initial investigation with one sample is far from an adequate calibration of the temperature instruments. However, it confirmed that differences in temperature would occur as a result of using different measuring instruments. Moreover, the discrepancy in the result was not alarming and did not discourage further use of the tools.

After the experiment, the results from all measurements were averaged to investigate the difference between the individual instruments, as shown in Table 5 below.

The difference in air temperature averaged from all measurements included in the experiment shows a difference of approximately 0.6°C higher temperature from the

Table 4. Test of measured seawater temperature one-point sample [°C].

Hioki memory HiLogger LR8400-20 with T – thermocouple	8.8
Mercury thermometer 1	9.5
Mercury thermometer 2	11
Fluke 54 II B thermometer with 80PK-25 probe	10

Table 5. Difference between the individual measuring instruments.

	Hioki T-thermocouple 1, air	Hioki T-thermocouple 2, air	Fluke B54, 80PK-26 air	Hioki T-thermocouple 3, water	Fluke B54, 80PK-25 water
Average of all measurements [°C]	7.1	7.1	7.7	8.8	9.2
Difference from Fluke [°C]	−0.6	−0.6		−0.4	

Fluke instrument than the thermocouples connected to the Hioki system. Similarly, the difference in water temperature was averaged to about 0.4°C higher with the Fluke equipment.

The instruments were placed in close proximity to each other to avoid the effect of location-dependent temperature variations. Some difference in temperature could be explained, as the devices utilise different types of thermocouples. Types K (Fluke) and T (Hioki) contain distinctive alloys as electrical conductors, respectively chromel vs alumel and copper vs constantan. The standardised accuracy of the thermocouples is given in Table 2. The difference in temperature is within the margin of required accuracy.

Standard deviations in the dataset from mean values give a sense of the data spread. The largest standard deviation for water temperature, 0.29°C, occurred at room temperature with the Fluke instrument. The largest standard deviation for air temperature, 0.79°C, was measured with the t-thermocouple when the cooling system was set to one degree Celsius. As shown by the two green lines in Figure 6, almost indistinguishable from each other, the air temperature varied in cycles. Additionally, Figure 6 shows the disturbance in temperature caused by entering and exiting the test facility. The thermal capacity of water is evident from the stable temperature illustrated by the lilac graph throughout the

Figure 6. Hioki logger plot output showing the disturbance in temperature caused by cooling cycles and entering and exiting the test facility.

repeated cooling cycles and opening the door. The red graph indicates the measurements of relative humidity. The relatively larger standard deviation for air temperature can, therefore, be explained by the continued cooling cycle in the test facility.

When comparing measurements performed with Hioki vs Fluke, the temperature variations followed a similar pattern or trend.

There is a correspondence between the different temperature measurements, and the greater standard deviation in air temperature is mainly due to the heating/cooling cycles of the environment. In the following chapter, the average results from the Fluke instrument are chosen to represent the values for air and water temperature.

Results and discussion

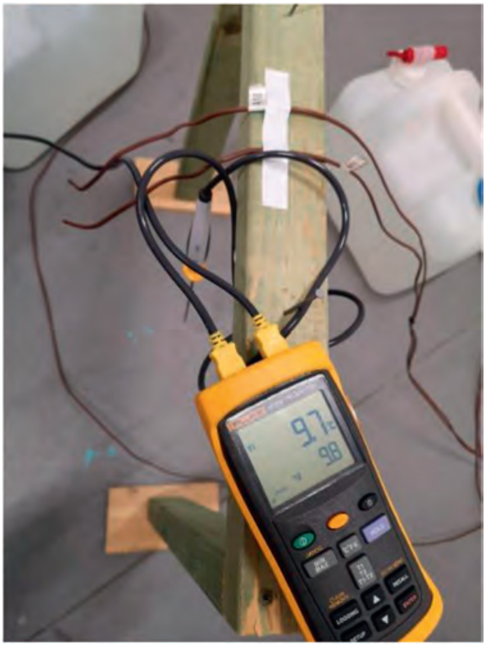
The desalinator`s capacity to produce freshwater was significantly reduced at lower temperatures, but minor variations in the salinity levels were observed at the same temperature readings; see Table 6 below.

In the test performed at +23°C, the desalinator produced 5.4 litres of freshwater within 60 min, which is above the maximum specification. At +10°C, the desalinator produced 4.5 litres of freshwater, which is the average specification. In the remaining tests performed at +7°C, +4°C and +2°C, the desalinator produced less freshwater than the minimum specification for the equipment. The pump frequency during the test at +2°C was the same (17.5 bpm (bpm)) as in the test performed at +4°C; however, the frequency could have been reduced to 15 bpm in the test at +2°C, as the indicator occasionally sprayed out some water during this test, which did not occur at +4°C. Dividing the amount of freshwater produced by the total number of pumps performed during a 60-minute test gives an approximate 0.003 litres freshwater produced per pump. Reducing the pump frequency to 15 bpm in the test performed at +2°C would have resulted in 2.7 litres of freshwater (15 bpm×60×0.003 litres), instead of the 3.2 litres produced in the tests performed at +4°C and +2°C. The test performed at +2°C was conducted the day after the other tests; during this period the desalinator was stored at room temperature. This pause could potentially have had an effect on the desalinator's capacity to reject salt molecules; the salinity level measured in the test performed at +2°C (0.36 ppt) was higher than in the other test results but still well within the specification for the desalinator; average salt rejection capacity is set to a salinity level of 0.43 ppt and a minimum of 0.86 ppt. The low salinity levels measured in the produced freshwater could be associated with an initial lower salinity level in the collected seawater (26.8 ppt) than the average salinity specification of the desalinator (35 ppt).

Reliable data on the possible health effects associated with the ingestion of TDS in drinking water are not available (World Health Organization [WHO] 1996). Nevertheless, the presence of dissolved solids in water may affect its taste (Bruvold and Ongerth

Table 6. Test results of processed seawater at the various temperatures; initial salinity level PSU 26.8.

Mean seawater temperature [°C]	2.2	3.7	6.9	9.9	23.1
Mean air temperature [°C]	0.3	2.3	6.9	9.4	19.8
Desalted water obtained over 60 min [litres]	3.2	3.2	3.6	4.5	5.4
Pump frequency [bpm]	17.5	17.5	20	25	30
Salinity PSU for processed water [ppt]	0.36	0.19	0.15	0.11	0.12



Picture 7. The Fluke 54 II B thermometer and probes measuring air temperature, taped to a wooden rail. The photo was taken during the test performed at +10°C.

1969), defined by water's organoleptic properties, evaluated by objectionable smell and tastes, odours, colours and turbidity. The palatability of drinking water, rated in relation to its TDS levels, is categorised as: excellent, less than 0.3 ppt; good, between 0.3 and 0.6 ppt; fair, between 0.6 and 0.9 ppt; poor, between 0.9 and 1.2 ppt; and unacceptable, greater than 1.2 ppt (World Health Organization [WHO] 1996). The quality of the produced freshwater in the experiment can therefore be categorised as excellent in four of the tests and good in the test performed at +2C°, considering the evaluation of taste, sight and smell.

Previous studies exploring the expected performance criteria for survival equipment in cold climate conditions show a significant reduction in the tested equipment`s functionality (Solberg, Gudmestad, and Kvamme 2016; Solberg, Gudmestad, and Skjærseth 2017; Solberg and Gudmestad 2018). The maximum expected time of rescue is defined in the Polar Code as the time adopted for the design of equipment and systems that provide survival support and shall never be less than five days (International Maritime Organization [IMO] 2017, Ch. 1.2.7). In this experiment, the desalinator was only exposed to low temperatures during each test and for a total of five hours. The use and storage of the desalinator over a five-day period in cold climate conditions could potentially affect the equipment in a way which was not explored in this experiment, due to set time limitations for the entire project.

Conclusions and recommendations

The test of the desalinator revealed that low seawater temperatures had a negative effect on the desalting apparatus`s capacity to produce freshwater, showing the importance of testing

Picture 8. Katadyn Survivor-35 desalinator (Katadyn Fact Sheet n.d.).

Picture 9. The (white) pressure indicating rod, extending from the (black) indicator housing while pumping. The freshwater outlet hose is seen above. The photo was taken during one of the tests.

essential survival equipment in cold climate conditions, to reveal weaknesses and challenges not experienced in a tropical climate. This experiment provided a controlled and monitored environment that could be difficult to achieve in the field. A similar experiment could be conducted in outdoor areas, to explore added stress elements and on-site challenges which might appear; e.g. operating the desalinator from a lifeboat vs a life raft would increase the distance to sea surface, considering the limited length of the desalinator`s seawater inlet hose (see Picture 8), which hypothetically could introduce a practical challenge.

A standardised test for desalting apparatus should be developed, similar to the temperature cycling tests described in the *Revised recommendation on testing of life-saving appliances* (International Maritime Organization [IMO] 1998b). In addition, if this type of survival equipment is planned for in the provision of freshwater, the ship's operational risk assessment should reflect the desalting apparatus`s reduced capacity to produce freshwater at low seawater temperatures, which could be compensated for by carrying additional desalting apparatus.

Note

1. In the manual specifications for the Katadyn-35 desalinator (Katadyn Manual n.d.), an orange band on the pressure indicating rod is described, revealing itself when pumping the handle. The purpose of the orange band is to determine pump frequency; pump frequency should be maintained as long as the orange band remains visible. If water sprays from the indicator, pump more slowly. If the orange band is not visible, pump faster. However, there was no orange band on the desalinator tested in the experiment.

Acknowledgement

The authors would like to thank Narvik Harbour Services and PhD candidate, Sujay Deshpand (UiT), for their help in sourcing seawater for the experiment. Further, the authors greatly appreciate the time Professor Per-Arne Sundsbø (UiT) and Professor Emeritus Ove Tobias Gudmestad (UiS) invested in commenting on and assisting the project. The project was conducted with desalting apparatus lent by Vard Design AS / REV Ocean. In this regard, the authors would like to thank Severin Åkervik Ulstein, Roy-Sindre Nystøyl, Øystein Mikelborg and Håvard Noem, representing the two companies, with a special thanks going to last mentioned, for being truly helpful, arranging the logistical parts of locating and sending the equipment.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Notes on contributors

Espen Engtrø (b. 1975) is PHD Candidate within the field of Risk management and Societal Safety at the Faculty of Science and Technology at the University of Stavanger (UiS) in Norway. Engtrø holds a master's degree in Societal Safety at the UiS (2010) and has been working as Offshore Rig HSE Advisor within the oil and gas industry for several years, occupied on a drilling rig located in the Barents Sea.

Ane Sæterdal (b. 1987) is PHD Student at the Faculty of Engineering Science and Technology at the Arctic University of Norway (UiT), studying multiphase flow and thermodynamics. Sæterdal holds a master's of science degree in engineering design from UiT (2017).

References

Andreassen, N., O. J. Borch, S. Kuznetsova, and S. Markov. 2018. "Emergency Management in Maritime Mass Rescue Operations: The Case of the High Arctic." *Springer International Publishing AG* 7: 359–381.

Bruvold, W. H., and H. J. Ongerth. 1969. "Taste Quality of Mineralized Water." *Journal of the American Water Works Association* 61: 170.

CATDS - Ocean Salinity Expert Center. n.d. Sea Surface Salinity: Definition and units. http://www.salinityremotesensing.ifremer.fr/sea-surface-salinity/definition-and-units.

Cohen, L., S. R. Hudson, V. P. Walden, R. M. Graham, and M. A. Granskog. 2017. "Meteorological Conditions in a Thinner Arctic sea ice Regime from Winter to Summer During the Norwegian Young Sea Ice Expedition (N-ICE2015)." *Journal of Geophysical Research: Atmospheres* 122: 7235–7259. doi:10.1002/2016JD026034.

DNV GL. 2015. *Winterization for cold climate operations* (DNVGL-OS-A201).

Engtrø, E., and O. T. Gudmestad. 2019. Winterization and drilling operations in cold climate areas [paper presentation]. *Proceedings - International Conference on Port and Ocean Engineering under Arctic Conditions*, Delft, The Netherlands.

Engtrø, E., O. T. Gudmestad, and O. Njå. 2020. "Implementation of the Polar Code: Functional Requirements Regulating Ship Operations in Polar Waters." *Arctic Review on Law and Politics* 11: 47–69. doi:10.23865/arctic.v11.2240.

Engtrø, E., O. Njå, and O. T. Gudmestad. 2018. "Polarkoden – Funksjonsbasert Forskriftsverk for Polare Farvann: Hvordan kan Standarder Presentere Gode nok Løsninger? [The Polar Code – Function-Based Regulations for Polar Waters: The Contribution of Standards to Safe and Sufficient Solutions?]." In *Regulering og Standardisering: Perspektiver og Praksis [Regulation and Standardization: Perspectives and Practice]*, edited by P. H. Lindøe, G. S. Braut, and J. Kringen, 146–162. Delft: Universitetsforlaget – Scandinavian University Press.

Farré, A. B., S. R. Stephenson, L. Chen, M. Czub, Y. Dai, D. Demchev, Y. Efimov, et al. 2014. "Commercial Arctic Shipping Through the Northeast Passage: Routes, Resources, Governance, Technology, and Infrastructure." *Polar Geography* 37 (4): 298–324. doi:10.1080/1088937X.2014.965769.

Fondriest. n.d. *Conductivity, Salinity & Total Dissolved Solids*. https://www.fondriest.com/environmental-measurements/parameters/water-quality/conductivity-salinity-tds/.

Ghosh, S., and C. Rubly. 2015. "The Emergence of Arctic Shipping: Issues, Threats, Costs, and Risk-Mitigating Strategies of the Polar Code." *Australian Journal of Maritime & Ocean Affairs* 7 (3): 171–182. doi:10.1080/18366503.2015.1093695.

Grønnestad, K. S. 2017. *Cruisetrafikk gjennom Arktis [Cruise traffic through the Arctic]*. BarentsWatch. https://www.barentswatch.no/artikler/cruisetrafikk-gjennom-arktis/.

Hill, E., M. LaNore, and S. Véronneau. 2015. "Northern sea Route: an Overview of Transportation Risks, Safety, and Security." *Journal of Transportation Security* 8: 69–78. doi:10.1007/s12198-015-0158-6.

Humpert, M., and A. Raspotnik. 2012. The Future of Arctic Shipping Along the Transpolar Sea Route. *Arctic Yearbook 2012*.

International Maritime Organization [IMO]. 1998a. *LSA-Code International Life-saving appliance Code* (MSC.48(66)).

International Maritime Organization [IMO]. 1998b. *Revised recommendation on testing of life-saving appliances* (MSC.81(70)).

International Maritime Organization [IMO]. 2001. *International Convention for the Safety of Life at Sea (SOLAS)* (1974, and 1978 and 1988 Protocol relating thereto: 2000 and 2004 amendments).

International Maritime Organization [IMO]. 2017. *International Code for Ships Operating in Polar Waters (Polar Code)* (MEPC 68/21).

International Maritime Organization [IMO]. 2019a. *Guidance for navigation and communication equipment intended for use on ships operating in polar waters* (MSC.1/Circ.1612).

International Maritime Organization [IMO]. 2019b. *The interim guidelines for life-saving appliances and arrangements for ships operating in polar waters* (MSC.1/Circ.1614 2019).

International Maritime Organization [IMO]. n.d. *International Convention for the Safety of Life at Sea (SOLAS), 1974*. http://www.imo.org/en/About/Conventions/ListOfConventions/Pages/International-Convention-for-the-Safety-of-Life-at-Sea-(SOLAS),-1974.aspx.

International Standard [ISO]. 2010. *Petroleum and natural gas industries — Arctic offshore structures* (ISO 19906:2010(E)).

International Standard [ISO]. 2019. *Petroleum and natural gas industries — Arctic offshore structures* (ISO 19906:2019. 2nd ed).

Katadyn Fact Sheet. n.d. *Katadyn Survivor-35*. https://www.katadyn.com/downloads/katadyn/factsheets/desalinators/factsheet_survivor35_en.pdf.

Katadyn Manual. n.d. *Katadyn Survivor-35, model #8013433*. https://www.katadyn.com/downloads/katadyn/manuals/desalinators/manual_survivor-35_en.pdf.

Larsen, L. H., B. Kvamstad-Lervold, K. Sagerup, V. Gribkovskaia, B. Bambulyak, R. Rautio, and T. E. Berg. 2016. "Technological and Environmental Challenges of Arctic Shipping—a Case Study of a Fictional Voyage in the Arctic." *Polar Research* 35 (1): 27977. doi:10.3402/polar.v35.27977.

Marchenko, N. A., N. Andreassen, O. J. Borch, S. Y. Kuznetsova, V. Ingimundarson, and U. Jakobsen. 2018. "Arctic Shipping and Risks: Emergency Categories and Response Capacities." *TransNav, the*

International Journal on Marine Navigation and Safety of Sea Transportation 12 (1): 107–114. doi:10.12716/1001.12.01.12.

Norwegian Maritime Authorities [NMA]. 2018. *Amendments to the Regulations on qualifications and certificates for seafarers* (RSR 05-2018).

Norwegian Maritime Authorities [NMA]. 2019. *Regulations on the construction, equipment and operation of passenger ships in the territorial waters surrounding Svalbard* (RSR 03-2019).

Piantadosi, C. A. 2003. *The Biology of Human Survival: Life and Death in Extreme Environments*. New York: Oxford University Press.

Protection of the Arctic Marine Environment [PAME]. 2020. *The Increase in Arctic Shipping 2013–2019* (Arctic shipping status report (ASSR) #1 31 March 2020).

Schopmans, H. 2019. *Revisiting the Polar Code: Where Do We Stand?* The Arctic Institute, Center for Circumpolar Security Studies. https://www.thearcticinstitute.org/revisiting-polar-code/.

Silber, G. K., and J. D. Adams. 2019. "Vessel Operations in the Arctic, 2015–2017." *Frontiers in Marine Science* 6: 573. doi:10.3389/fmars.2019.00573.

Solberg, K. E., and O. T. Gudmestad. 2018. *SARex3: evacuation to shore, survival and rescue* (Report no. 75, University of Stavanger).

Solberg, K. E., O. T. Gudmestad, and B. O. Kvamme. 2016. *SARex Spitzbergen: April 2016: exercise report: search and rescue exercise conducted off North Spitzbergen* (Report no. 58, University of Stavanger).

Solberg, K. E., O. T. Gudmestad, and E. Skjærseth. 2017. *SARex2: Surviving a maritime incident in cold climate conditions* (Report no. 69, University of Stavanger).

Trantzas, K. 2017. A risk analysis and the insurance policies for the cruise ships in the Arctic [Unpublished master's thesis]. University of Stavanger.

Urke, E. H. 2018. *Store cruiseskip ankommer Svalbard. Redningskapasiteten er sterkt begrenset [Large cruise ship arrives at Svalbard. The rescue capacity is highly limited]*. https://www.tu.no/artikler/store-cruiseskip-ankommer-svalbard-redningskapasiteten-er-sterkt-begrenset-br/453913.

U.S. Department of State. n.d. *Map of the Arctic Region*. https://2009-2017.state.gov/e/oes/ocns/opa/arc/uschair/258202.htm

World Health Organization [WHO]. 1996. *Guidelines for Drinking-Water Quality* (2nd ed. Vol. 2. Health criteria and other supporting information).

Paper VI: A Discussion on the Implementation of the Polar Code and the STCW Convention's Training Requirements for Ice Navigation in Polar Waters.

Engtrø, E. (2021). *Journal of Transportation Security* (pp. 1-27). DOI: 10.1007/s12198-021-00241-7. Accepted for publication.

Journal : SmallExtended 12198 | Article No : 241 | Pages : 27 | MS Code : 241 | Dispatch : 9-12-2021

Journal of Transportation Security
https://doi.org/10.1007/s12198-021-00241-7

A discussion on the implementation of the Polar Code and the STCW Convention's training requirements for ice navigation in polar waters

Espen Engtrø[1]

Received: 1 July 2021 / Accepted: 26 November 2021

Abstract

AQ1

In 2017, the International Maritime Organization (IMO) implemented the *International Code for Ships Operating in Polar Waters* (Polar Code), with mandatory requirements covering the Arctic and Antarctic Oceans. In this conjunction, the *International Convention on Standards of Training, Certification and Watchkeeping* (STCW) were amended in 2018. New training requirements were made applicable for dedicated personnel in charge of a navigational watch on ships with a Polar Ship Certificate (PSC) operating in polar waters. In association with the new training requirements amending the STCW Convention, the IMO, and Transport Canada (flag state authority) signed a Memorandum of Understanding in 2017, for Canada to develop and deliver four regional capacity-building "train-the-trainer" workshops. The objectives of these events were to assist maritime education and training (MET) institutes in enhancing the skills and competence of instructors, to develop competence-based STCW training programs, for dedicated personnel on ships operating in polar waters. This paper examines the first workshop conducted in Canada (2019), to understand the mechanisms in the interaction taking place between the IMO and the Canadian workshop developers and instructors, using the System Theoretic Accident Model and Processes (STAMP). Individual expert interviews are performed, with the main contributors directly involved in developing and conducting the workshop, to evaluate the event's contribution to improving and specifying the STCW Convention's training requirements, as referenced in the Polar Code, for seafarers operating in polar waters.

Keywords Polar Code · STCW · Training requirements · STAMP · Risk management

A1 ✉ Espen Engtrø
A2 espen.engtro@uis.no

A3 [1] Faculty of Science and Technology, University of Stavanger, Stavanger, Norway

Abbreviations

HRO	High Reliability Organization
IACS	The International Association of Classification Societies
III	(The IMO Sub-Committee on) Implementation of IMO Instruments
IMO	The International Maritime Organization
IRGC	The International Risk Governance Council
ISO	The International Standard Organization
MARPOL	The International Convention for the Prevention of Pollution from Ships
MET	Maritime Education and Training
MSC	The IMO Maritime Safety Committee
NGOs	Non-Governmental Organizations
NMA	Norwegian Maritime Authorities
PAME	Protection of the Arctic Marine Environment
Polar Code	The International Code for Ships Operating in Polar Waters
POLARIS	Polar Operational Limit Assessment Risk Indexing System
PSC	Polar Ship Certificate
PWOM	Polar Water Operation Manual
SOLAS	The International Convention for the Safety of Life at Sea
STAMP	System Theoretic Accident Model and Processes
STCW	The International Convention on Standards of Training, Certification and Watchkeeping
STPA	System-Theoretic Process Analysis
Transport Canada	Canadian Flag State Authority
UNCLOS	The United Nations Convention on the Law of the Sea

Introduction

AQ2

The Arctic region is experiencing extensive growth in commercial shipping activities, while, simultaneously, the sea ice extent is steadily decreasing, enabling extended seasons and voyages in areas previously considered inaccessible for most ships during large periods of the year (Protection of the Arctic Marine Environment [PAME] 2020; Silber and Adams 2019). Shipping in the Arctic Ocean is associated with additional risks, considering the adverse and prevailing climate conditions with the presence of ice, representing great hazards. Ice accretion, caused by sub-zero temperatures and freezing sea spray coming into contact with ships' surfaces, is the most hazardous form of icing and also the most common (Karahalil et al. 2020). Uncontrolled, sea spray icing is a great hazard in respect of the risk of loss of ship stability and integrity, as well as equipment failure (International Standard Organization [ISO] 2019). Further, floating ice in many forms constitutes an extremely hazardous condition if colliding with a ship in voyage, involving the risk of damage to hull and structure (Ghosh and Rubly 2015). Ship navigation in Arctic waters can be extremely challenging, with a changing landscape of sea ice, draft restrictions in many areas, lack of hydrographic data and detailed surveys, less reliable navigation and satellite communication, and reduced

Journal : SmallExtended 12198	Article No : 241	Pages : 27	MS Code : 241	Dispatch : 9-12-2021

visibility due to fog or darkness for long periods of the year (Hill et al. 2015; Ghosh and Rubly 2015; DNV GL 2015).

In 2017, *The International Code for Ships Operating in Polar Waters* (Polar Code) was adopted by the International Maritime Organization (IMO), applicable to the Arctic and Antarctic Oceans (International Maritime Organization [IMO] 2017). In conjunction with the Polar Code's implementation, the *International Convention on Standards of Training, Certification and Watchkeeping* (STCW) was amended the following year (2018); new *Regulations on qualifications and certificates for seafarers* were made applicable, providing training requirements for masters, chief mates and officers in charge of a navigational watch on ships with a Polar Ship Certificate (PSC), operating in open and other polar waters (Norwegian Maritime Authorities [NMA] 2018). In this regard, in 2017, the IMO and the Government of Canada (Transport Canada, flag state authority) signed a Memorandum of Understanding, for Canada to provide financial support and expertise in supporting the implementation of the Polar Code; more specifically, it was agreed that Canada would deliver four regional capacity-building "train-the-trainer" workshops. The objectives were to assist flag state authorities and maritime education and training (MET) institutes in enhancing the skills and competence of maritime instructors, to develop competence-based training programs, to update existing ones, and to improve the delivery of the STCW Basic and Advanced training for dedicated personnel on ships operating in polar waters (Offshore Energy 2017; International Maritime Organization [IMO], (n.d.c).

Governance of polar water ship operations is of interest, and various academic disciplines are involved in investigating the efficacy, implications and consequences associated with the implementation of the Polar Code. The enforcement and application of its function-based requirements and how practices evolve are complex matters to study, considering the various stakeholders involved in ship operations in the Arctic and related maritime activities. This paper uses the System Theoretic Accident Model and Processes (STAMP) (Leveson 2011) to model the complexity of contributing factors. Individual expert interviews are performed with the main contributors to the Canadian capacity-building "train-the-trainer" workshop, to evaluate the event's contribution to specifying and improving the STCW Convention's training requirements, as referenced in the Polar Code, for seafarers operating in polar waters. The System-Theoretic Process Analysis (STPA) developed from STAMP is used in this assessment of the workshop (See Results).

In the following, the methodological approach of this paper is provided, followed by a summary of the most relevant IMO instruments applicable for international ship operations in the Arctic, before the results of the analysis of the workshop are presented, which are discussed and concluded on at the end of this paper.

Method

Literature review

Accident models

During accident investigations, the causes leading up to events and their consequences are investigated. This work is conducted by collecting and analyzing available information, enabling reasoning about the causations, often identified as latent conditions and root causes, influence of human errors, technical malfunctions, poor maintenance, or lack of safety culture (Reason 2016). In a developmental trend, earlier accident models addressing safety and high-risk technologies consider linear interactions as those interactions – of one component in the system with one or more components preceding or following it immediately in the sequence of production – that are recognized as leading to predictable and comprehensible event sequences (even during accidents), and the system is functioning as per design (Perrow 1984). On the contrary, system accidents (or normal accidents) involve the unanticipated interaction of multiple failures, identified by the concepts of complex and tightly coupled systems. This complexity is characterized by multi-component systems, with a high level of interaction between the components occurring in non-linear ways. Complex and non-linear interactions will generally be those, not intended in the design, that lead to unexpected event sequences and that are often related to feedback loops introduced to increase efficiency. A change in one component may trigger a new feedback loop, inhibit an existing one or turn a feedback loop into its opposite, and this interactive complexity may help create new categories of accidents and unknown side effects (ibid., 1984).

Another approach to viewing system accidents also focusing attention on high-risk technologies and complex systems. But rather challenging to explain *why accidents occur*, this research explains *why so few serious accidents occur* (SINTEF 2010). The High Reliability Organizations (HROs) approach is that, despite the hazards of complexity and tight couplings which are characteristic of these systems, the continuous management of safe, reliable, and functional high-risk, high-hazard organizations, over periods of time, is achieved by the organization`s flexibility and ability to sufficiently decentralize, to handle the interactive complexity, and at the same time sufficiently centralize, to handle the tight coupling (ibid., 2010; Sutcliffe 2011). The HRO theory and its key principles are widely AQ3 applied to achieve minimal errors in high-risk and high-hazard industries, often operating under unpredictable conditions. An explosion of activity has been experienced in application and research associated with the HRO theory, and a growing number of other industries and sectors in society, e.g., health care systems, are showing interest in adopting its principles (e.g., Sutcliffe 2011; Veazie et al. 2019; Cantu et al. 2020).

The HRO theory is, however, also challenged, i.e., claiming a system can be AQ4 reliable but unsafe or safe but unreliable suggests that safety and reliability are different properties (Leveson 2011).The traditional way of modeling causations, based on a linear approach is questioned, i.e., accidents are viewed in terms of multiple events and active failures sequenced as a forward chain over time, penetrating the defenses-in-depth, based on root causes and failure events (Reason 2016; ibid., 2011). Such event-chain models are viewed as inadequate for analyzing system accidents and systemic risks involving the entire sociotechnical system, deeply influenced by organizational and human factors (Rasmussen 1997). Systemic risks appear, due to the interaction taking place between the multiple stakeholders defining the system and are deeply interconnected, which means they cannot be managed through the actions of a single sector (International Risk Governance Council [IRGC] 2017). Instead, the management of systemic risks requires the involvement of different stakeholders, including governments, industry, academia, and members of civil society, as they are embedded in the larger context of societal, financial, and economic change (ibid., 2017). In the recognition that accidents occur due to a combination of unexpected conditions – the concurrence of two (or more) events happening at the same time and affecting each other – complex systemic models have gained attention (Hollnagel and Woods 2006). For such models to be useful, they must be able to capture complex and tightly coupled sociotechnical systems that are controlled in an interface between humans and automated processes, driven by advanced technology and software-intensive systems (Leveson et al. 2006).

STAMP One such model, STAMP, with its dynamic approach, provides a modern theoretical foundation for system safety, in which the various stakeholders and NGOs defining a system are identified in hierarchical safety control structures, recognized by its emergent properties (Leveson 2011). The core principle for maintaining system safety is the enforcement of established safety constraints, where causations are recognized in the interaction taking place between the various stakeholders, sectors, and actors making up each level of the system hierarchy (Leveson 2011). STAMP, moreover, models the interaction taking place between system development and system operation, recognizing that safe operations depend on sufficient transfer of information, experience, and knowledge, not only between the levels in the hierarchy but also between system development and system operation; safe operations depend partly on planning, design, and developmental aspects and partly on operational aspects (Leveson 2011). Risk management in STAMP is viewed as a control problem, and unplanned events occur because of inadequate control or lack of enforcement of safety constraints (Leveson 2011). STAMP views the legislators, i.e., the IMO, at the top of the hierarchical system, facilitating and implementing conventions and regulations and constraining governmental bodies, recognized organizations, flag states and classification societies at the levels below. These stakeholders perform controlling activities (e.g., verification, audits, and certifications) at lower levels in the hierarchical system, represented by certified MET institutes, shipowners, and operators, with their management, engineers, and planners and, finally, the personnel assigned on ships operating worldwide. Proper control of established work processes, with adequate constraints ensuring correct behavior, function and interaction in the hierarchical system, is of essence to manage risks in such systems (Leveson 2011; Rasmussen 1997).

Journal : SmallExtended 12198	Article No : 241	Pages : 27	MS Code : 241	Dispatch : 9-12-2021

The Polar Code and Arctic shipping

Empirical data was gathered in document studies covering risk governance of shipping in the Arctic region and the implementation of the Polar Code and the STCW Convention's training requirements for seafarers operating in polar waters. A survey of scholarly sources was carried out, using databases found under the categories of science and technology, safety, economics, and planning, i.e., Scopus and Web of Science. In addition, cross-checking of the obtained data sources was performed in the multi-discipline database of Google Scholar, combining the search words: "Polar Code", "STCW", "Arctic shipping", "Safety", "Training", and "Risk management".

Data collection and analysis of the Canadian workshop

Interviews

Information was collected through individual interviews with the three persons responsible for developing the Canadian workshop, who also functioned as facilitators and instructors during the event. In the initial design of the study, a request was forwarded to the contact person in the IMO for disclosure of the contact information of the participants in the Canadian workshop, to perform interviews, capturing the participants' points of view and perceptions regarding the workshop's objectives and learning outcomes. However, the Legal Division within the IMO stated that names and contact details of participants attending IMO events are confidential information which cannot be disclosed to third parties, for reasons of privacy and the protection of individuals' integrity. Therefore, the study design was changed to examine the development, conducting, and outcome of the Canadian capacity-building workshop, from the developers and instructors' point of view. The interviews were performed during July 2020 via telephone, using a prepared interview guide, provided to the interviewees prior to the sessions. This interview guide contained questions concerning the establishment, development, performance, and outcomes of the workshop. The interviews, all lasting approximately one hour, were conducted in a semi-structured manner, allowing flexibility to explore spontaneous issues raised by the interviewees (Ryan et al. 2009). Individual interviews represent the most common data collection strategy in qualitative research (Sandelowski 2002) and were selected as the method, enabling in-depth examination, to capture the experts' knowledge and understanding of the studied topic (Jacobsen 2015; Labuschagne 2003).

All the interviewees have years of experience in work regulated by the STCW Convention, both prior to and after the Polar Code implementation in 2017 and following the amendments to the STCW in 2018. Interviewee no. 1 has been working within the IMO for more than a decade and is employed as a technical officer in the maritime safety division and the training and human element section. This interviewee works with the STCW Convention and the training and certification of seafarers, including the new STCW Polar Code ice navigation model courses (basic

Journal : SmallExtended 12198	Article No : 241	Pages : 27	MS Code : 241	Dispatch : 9-12-2021

and advanced). In their role as an IMO representative, this interviewee was responsible for overseeing that the workshop was planned and executed according to IMO standards and the objectives set for the event; Interviewee no. 1 also participated in developing the course material and facilitated the workshop as it unfolded. Interviewee no. 2 worked for years at sea (master mariner), mainly in the Arctic Ocean, and possesses years of experience in building and delivering maritime simulation training, including various IMO model courses. This interviewee participated as a representative for Transport Canada in the IMO, with the work of defining the new STCW training requirements that arose from the Polar Code. In connection with this work, the interviewee was engaged to develop and participate as main instructor in the first of four regional capacity-building workshops. Interviewee no. 3 also has years of experience in Arctic shipping (master mariner) and works as the director at the maritime simulation training center where the workshop took place. This interviewee participated in developing the workshop material and facilitated as the event unfolded. The five-day capacity-building "train-the-trainer" workshop was held at a highly technological maritime simulation training center in Canada. This center had previously collaborated with the IMO, due to its extensive experience, stretching back two decades, in developing and providing ice navigation training courses (basic and advanced). These courses were used as basic examples during the development of the current basic and advanced Polar Code ice navigation training courses.

Additional data

The interviewee who acted as the main instructor in the workshop provided the handbook "Workshop Materials – Worked Examples" (pp. 71–110), covering the topics: regional regulations, basic operations, passage planning and advanced operations. This workbook contains references to regulatory documents and, for each of the named topics, provides: worked examples of open book exploration questions; job task analysis worksheets; table-top exercises; polar exercise briefing documents; and scenario creation worksheets. Additionally, this interviewee provided a video link (5 min and 34 s) showing a remote-control simulation session that was recorded after workshop completion at the same maritime simulation training center. The objectives of recording this session were to document and present to the IMO how online remote simulation training can be provided to maritime students who do not have access to MET centers providing highly technological simulation, by use of virtual communication systems.

The IMO model courses (6.09) Training course for instructors (International Maritime Organization [IMO] 2010) and (7.11) Basic and Advanced Training Ice Navigation in Polar Waters (Arctic University of Norway – UiT, n.d.) were used as supporting material in the development of the interview guide. The 6.09 model course material has been designed to identify the basic entry requirements and trainee target group for each course in universally applicable terms, and to clearly specify the technical content and levels of knowledge and skill necessary to meet the technical intent of IMO conventions and related recommendations (International Maritime Organization [IMO] 2010, p. 1).

Journal : SmallExtended 12198	Article No : 241	Pages : 27	MS Code : 241	Dispatch : 9-12-2021

Analysis

In the interviews, this author addressed the following four areas of concern, assumed to be of high criticality for the performance and outcomes of the workshop: (1) competence level of workshop developers, instructors, and participants; (2) suitability of learning plan and methods of teaching; (3) routines for workshop evaluation and documentation (4) and for the exchange of information and learning outcome to MET institutes after workshop completion. Moreover, the collected data has been analyzed utilizing thematic analysis, which is a widely used qualitative analytic method for identifying, analyzing, and reporting patterns and themes in data (Braun and Clarke 2006). Themes were identified using a theoretical approach, providing a detailed analysis of certain aspects of the collected data. The thematic analysis was conducted using the following steps: (1) familiarizing, by transcribing the data; (2) generating initial codes, by exploring features of interesting data across the entire data set; (3) collating the data relevant to each code in a systematic manner; (4) collating codes into potential themes and reviewing these themes, by checking the logical relationship to the coded extracts and the entire data set; (5) defining and naming the themes; and (6) final analysis of selected extracts (Braun and Clarke 2006). Further, STAMP and the related STPA were used as methodologies to assess the workshop (See Results).

Governance and regulation of international ship operations in the Arctic

Regulating international ship operations is based on a global regulatory regime, built on international maritime conventions, established under the United Nations Convention on the Law of the Sea (UNCLOS). UNCLOS relies on international cooperation between intergovernmental organizations as a mechanism for the development, establishment and implementation of new conventions and regulations. In this regard, "the competent international organization", as referred to in UNCLOS – being the lead institution to address maritime matters – is interpreted to mean the IMO (Chircop 2017).

The international maritime organization – IMO

The IMO plays an instrumental role in generating maritime regulations, rules, standards, procedures and recommended practices governing international shipping; it facilitates the national implementation of international instruments, promoting frameworks and practices for cooperation between maritime administrations and the industry (ibid., 2017; Hebbar et al. 2020). The institutional structure of the IMO consists of the Assembly, Council, Secretariat and specialized committees and subcommittees, responsible for keeping the regulatory framework of the IMO developed and maintained on a continuous basis (Chircop 2017). National delegations

Journal : SmallExtended 12198 | Article No : 241 | Pages : 27 | MS Code : 241 | Dispatch : 9-12-2021

drive committee work and formally make decisions, heavily influenced by the participation and involvement of other intergovernmental and non-governmental organizations (NGOs),[1] encompassing a wide range of associations for industry, maritime labor, environmental protection, education and training, and various professions (ibid., 2017).

The international convention for the safety of life at sea – SOLAS

The most important of all international treaties concerning the safety of merchant ships is reckoned to be the *International Convention for the Safety of Life at Sea* (SOLAS) (International Maritime Organization [IMO] 2001). The first version was adopted in 1914, in response to the Titanic disaster, later updated and amended on numerous occasions. The main objective of the SOLAS Convention is to specify minimum standards for the construction, equipment, and operation of ships, compatible with their safety (International Maritime Organization [IMO], n.d.b).

The international code for ships operating in polar waters – polar code

The implementation of the Polar Code was the first international mandatory regulation addressing risks present in polar waters and not adequately mitigated by other instruments of the IMO, regarding the design and construction of ships and equipment, operational conditions, voyage planning, manning, and training, and the protection of the environment (International Maritime Organization [IMO] 2017). The geographical area of application for the Polar Code in the Arctic Ocean is seen below in Fig. 1.

The Polar Code constitutes a continuation of existing regulations, made mandatory under SOLAS, the STCW Convention, and the *International Convention for the Prevention of Pollution from Ships* (MARPOL), applicable to all waters and providing mandatory safety and environmental provisions for ships operating in defined geographical areas around the South and North Poles (International Maritime Organization [IMO] 2017). Ships' systems and equipment addressed in the Polar Code shall satisfy at least the same performance standards as those referred to in the SOLAS Convention (International Maritime Organization [IMO] 2017), and in this way a standardized minimum of expectations is established for merchant ships for the provision of safety measures for maritime design, equipment, systems, and operations in polar waters.

[1] During the development of the Polar Code, stakeholders representing various NGOs actively participated in the discourse and deliberations concerning the regulation's provisions and requirements, e.g., the adoption of the Requirements Concerning Polar Class carried out by the International Association of Classification Societies (IACS), now forming the basis for the Polar Code's mandatory provisions concerning polar class (Chircop 2017).

Journal : SmallExtended 12198 | Article No : 241 | Pages : 27 | MS Code : 241 | Dispatch : 9-12-2021

Fig. 1 The maximum geographical extent of the Polar Code's area of application in the Arctic (International Maritime Organization [IMO] 2017)

The polar code "Toolbox"

The Polar Code is not a stand-alone regulation but must be regarded in the context of the related IMO instruments and other instruments of international law, in addition to applicable national regulations, depending on the areas of operation (Chircop 2017). First, in order to establish procedures and operational limitations for a ship and, accordingly, the issuance of the PSC, an operational assessment of the ship and its equipment is required, taking into account the anticipated range of operating conditions and hazards the ship may encounter in polar waters (International Maritime Organization [IMO] 2017). Ten sources of hazards are listed in the Polar Code that shall be addressed in the operational assessment; of relevance in this paper is the potential lack of ship crew experience in polar operations, with the potential for human error. Additionally, the issuance of the PSC relies on an assessment of the ship's operational limitations in ice, with reference to methodologies for assessing operational capabilities and limitations in ice and the Polar Operational Limit Assessment Risk Indexing System (POLARIS) (International Maritime Organization [IMO] 2016). Moreover, the Polar Code requires that information on ship-specific capabilities and limitations in relation to the aforementioned operational assessment shall be included in the Polar Water Operational Manual (PWOM), to be carried on board the ship on voyage (International Maritime Organization [IMO] 2017). The purpose of the PWOM is to provide the owner, operator, master, and

Journal : SmallExtended 12198 | Article No : 241 | Pages : 27 | MS Code : 241 | Dispatch : 9-12-2021

crew with sufficient information regarding the ship's operational capabilities and limitations, to support their decision-making process (ibid., 2017).

The international convention on standards of training, certification and watchkeeping – STCW

Chapter 12 of the Polar Code contains provision on manning and training, with a goal to ensure that ships operating in polar waters are appropriately manned by adequately qualified, trained and experienced personnel (ibid., 2017). In order to achieve that goal, companies must ensure that masters, chief mates and officers in charge of a navigational watch on board ships with a PSC, operating in polar waters, have completed appropriate training, taking into account the related provisions in the STCW Convention (ibid., 2017). In conjunction with the work of implementing the Polar Code, in 2016, the Maritime Safety Committee (MSC) of the IMO adopted mandatory minimum requirements for the training and qualifications of masters and deck officers on ships operating in polar waters. These became mandatory under the STCW Convention from 1 July 2018, as *Amendments to the Regulations on qualifications and certificates for seafarers* (Norwegian Maritime Authorities [NMA] 2018).

The 1978 STCW Convention was the first IMO regulation to consider the human element's contribution to safety at sea, establishing basic requirements for training, certification and watchkeeping for seafarers on an international level (International Maritime Organization [IMO], n.d.a; Hagerupsen 2019). In 1995, the STCW Convention underwent a major revision and was amended in response to a recognized need to bring it up to date and to respond to critics who pointed out vague or unclear requirements, which resulted in different interpretations of the regulation (International Maritime Organization [IMO], n.d.a). The STCW-95 Convention provided more detailed requirements for minimum standards of competencies for seafarers, essentially requiring students to demonstrate their competence to prescribed standards (ibid., n. d. 1; Ghosh 2017). The focus shifted from being a knowledge-based Convention, comprising a syllabus for qualifying examinations, to providing requirements of skills and abilities necessary to perform workplace tasks (Ghosh 2017).

The STCW Convention has contributed to building the capacity and education of seafarers, creating uniform standards at the global level to supplement national legislation, and introducing relevant rules to enhance professionalism on board vessels, especially in situations where seafarers have been carrying out their jobs on board foreign flag vessels (Munari 2020). Many of the MET institutes use simulators and practical exercises for training and assessment in selected courses, developed to satisfy the STCW Convention, which promotes the use of simulators in MET. However, it is important to consider that a seafarer's competence is usually demonstrated only in oral or written exams (Castells et al. 2016). The use of decontextualized traditional assessment methods (e.g., multiple-choice questions, pen and paper testing, oral examinations) for most of the units of competence listed in the STCW Convention cannot be ignored (Ghosh 2017). In this regard, the Polar Code has been criticized for being vague in some of its provisions (Todorov 2020) and for not providing

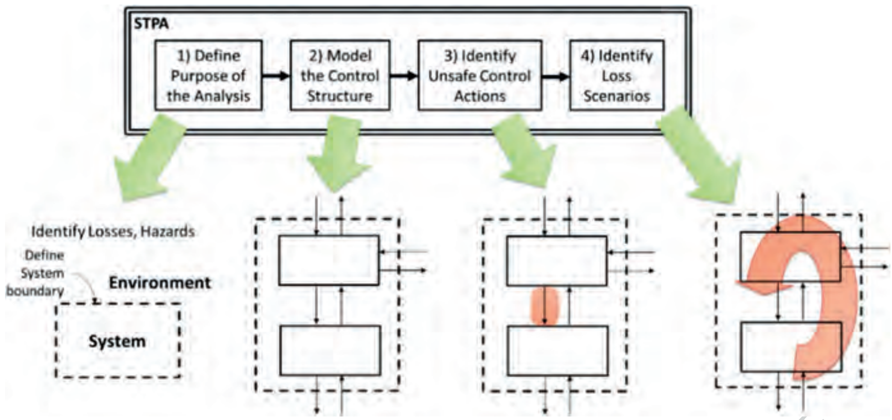


Fig. 2 Overview of the basic STPA method (Leveson and Thomas 2018)

sufficient requirements for the manning and training of crews on ships operating in polar waters (Roach 2017). The STCW Convention's training requirements, implemented in 2018, for dedicated personnel in charge of a navigational watch on ships operating in polar waters, suggest various methods for demonstrating competence, defined as: approved in-service experience, approved ship experience and training, approved simulator training where appropriate, and approved specialist training (Lovdata 2018). However, a lack of harmonization between IMO member states regards the utilization of teaching methods in the training of seafarers is apparent (Castells et al. 2016; Evans et al. 2017).

Results

The methodology of the STAMP and its related STPA are used in the process of analyzing and assessing the collected data. STPA is a proactive method used to analyze complex processes and the interactions among system components, enabling hazards to be eliminated or controlled before accidents occur. A graphical representation of the four steps in the basic STPA (Leveson and Thomas 2018), which are applied in this analysis, is shown in Fig. 2.

Phase 1 – Defining the purpose of analysis

The Polar Code is applicable to SOLAS-certified ships operating in the Arctic and Antarctic regions that are passenger ships carrying more than 12 passengers or cargo ships with a gross tonnage of 500 or more, engaged in international voyages (International Maritime Organization [IMO] 2001). The STCW Regulations regarding qualifications and certificates for seafarers and requirements for the completion of appropriate ice navigation training primarily involve training requirements for masters, chief mates, and officers in charge of a navigational watch on ships with PSC operating in open and other polar waters. This training shall be conducted at a MET institute offering an approved test, which shall be documented with an associated Certificate of Proficiency, basic or advanced (NMA 2018).

The IMO's mission is to promote safe, secure, environmentally sound, efficient, and sustainable shipping through cooperation. This shall be accomplished by adopting the highest practicable standards of maritime safety and security, efficiency of navigation, and prevention and control of pollution from ships, as well as through consideration of the related legal matters and effective implementation of the IMO's instruments, with a view to their universal and uniform application (IMO, n.d.). The development and conducting of the regional capacity-building "train-the-trainer" workshops is aligned with this mission, aiming to assist in the implementation of the Polar Code and the enhancement of the skills and competence of maritime instructors working at national training institutes (IMO, n.d.). Failing its mission would represent a loss for the IMO, resulting in mismanagement and failure to achieve the objectives established for the workshop. The following four hazards, identified by this author, could compromise the objectives of the workshop, if safety constraints are not established (see Table 1, below).

Phase 2 – Modeling the control structure

The Canadian workshop, modeled in Fig. 3 below, shows the IMO at the top interacting with the Government of Canada, represented by Transport Canada (Canadian flag state authority), previously mentioned as initiating and supporting the implementation of the Polar Code, both financially and by means of expert personnel, in the delivery of four regional capacity-building workshops. At the level below, the interaction between Transport Canada and the persons responsible for developing and conducting the workshop is modeled, where, e.g., instructions, guidelines, and IMO model courses control the development of the workshop, to ensure it meets its objectives. Moreover, the interaction between the workshop's developers and instructors and its participants is modeled, constrained by, e.g., the training material developed for the event, the competence levels of the instructors and the technological facilities available, i.e., simulators. The participants provide feedback to the instructors regarding the workshop's progress, in e.g., regularly performed debriefs and questionnaires, and in the delivery of training programs, highly influenced by the participants' level of competence and experience with polar water operations.

Phases 3 and 4 – Identification of unsafe control actions and loss scenarios

The term "unsafe" refers to the hazards identified in STPA. These can include issues related to loss of human life or injury (traditional safety), but they can also be defined much more broadly to include other losses, like a mission loss and loss of performance (Leveson and Thomas 2018), as discussed in this paper. After the

Journal : SmallExtended 12198 | Article No : 241 | Pages : 27 | MS Code : 241 | Dispatch : 9-12-2021

Table 1 Hazards and safety constraints established by this author for the workshop

No	Hazards	Safety constraints
1	Incompetent workshop developers, instructors, and participants	Only competent personnel to attend as workshop developers, instructors, and participants, i.e., check of work background, references, CV, etc
2	Inadequate learning plan methods of teaching	The learning plan and methods of teaching must be validated prior to workshop start-up
3	Inadequate evaluation and documentation of workshop learning outcome	Routines for evaluation and documentation must be in place, i.e., regular debriefs between instructors and participants to be documented
4	Insufficient transmission of information and learning outcome to MET institutes after workshop completion	System verification to ensure certified MET institutes receive and implement recommended methods of teaching established for the Polar Code ice navigation courses

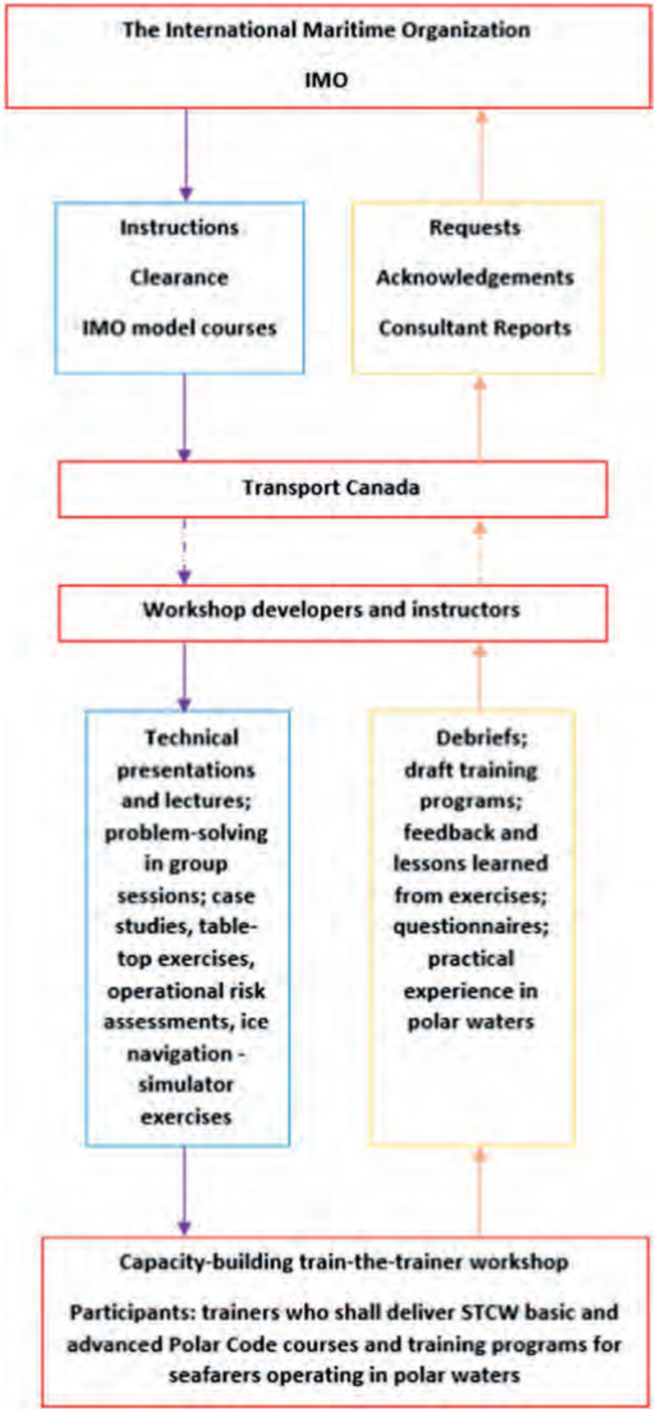


Fig. 3 System safety modeling the governance and implementation of the capacity-building "train-the-trainer" workshop (adapted from Leveson 2011)

Journal : SmallExtended 12198 | Article No : 241 | Pages : 27 | MS Code : 241 | Dispatch : 9-12-2021

Table 2 Summary of hazards, control actions, loss scenarios and controlling constraints for the workshop, identified by this author

No	Hazard	Control action	Not providing causes hazard	Providing causes hazard	Control action provided too early or too late, i.e., at the wrong time or in the wrong sequence	Loss scenario	Redefining controlling constraints
1	Incompetent workshop developers, instructors, and participants	Competence verification of workshop developers, instructors, and participants	Not performing competence verification of workshop developers, instructors, and participants	Inadequate competence verification of workshop developers, instructors, and participants	Competence verification of workshop developers, instructors, and participants not performed in a timely manner	Workshop developed and performed by incompetent personnel and attended by unqualified participants	Verification of routines for competence verification of workshop developers, instructors, and participants
2	Inadequate learning plan and methods of teaching	Quality control of learning plan and methods of teaching	Not performing quality control of learning plan and methods of teaching	Inadequate quality control of learning plan and methods of teaching	Quality control of learning plan and methods of teaching not performed in a timely manner	Learning plan and methods of teaching do not meet the defined objectives for the workshop	Verification of routines for quality control of learning plan and methods of teaching
3	Inadequate evaluation and documentation of workshop learning outcome	Routines for debriefs after training sessions, incl. close-up meetings at the end of the workshop between instructors and participants to be documented	Not performing debriefs and documentation after training sessions, incl. close-up meetings at the end of the workshop between instructors and participants	Insufficient debriefs and documentation performed after training sessions, incl. close-up meetings at the end of the workshop between instructors and participants	Routines for debriefs and documentation after training sessions, incl. close-up meetings at the end of the workshop, between instructors and participants, not performed in a timely manner	Training sessions are not adequately performed, incl. debriefs, and the learning outcome of the workshop is not documented	Verification of routines for debriefs and documentation after training sessions, incl. close-up meetings at the end of the workshop between instructors and participants

Table 2 (continued)

No	Hazard	Control action	Not providing causes hazard	Providing causes hazard	Control action provided too early or too late, i.e., at the wrong time or in the wrong sequence	Loss scenario	Redefining controlling constraints
4	Insufficient exchange of information and learning outcome with MET institutes after workshop completion	System verification to ensure certified MET institutes receive and implement recommended methods of teaching for the Polar Code ice navigation courses	Not performing system verification to ensure certified MET institutes receive and implement recommended methods of teaching for the Polar Code ice navigation courses	Insufficient verification performed to ensure certified MET institutes receive and implement recommended methods of teaching for the Polar Code ice navigation courses	System verification to ensure certified MET institutes receive and implement recommended methods of teaching for the Polar Code ice navigation courses not performed in a timely manner	Certified MET institutes do not receive and implement recommended methods of teaching for the Polar Code ice navigation courses	Audit of system verification to ensure certified MET institutes receive and implement recommended methods of teaching for the Polar Code ice navigation courses

Journal : SmallExtended 12198	Article No : 241	Pages : 27	MS Code : 241	Dispatch : 9-12-2021

unsafe control actions are defined,[2] the loss scenarios can be identified, describing the causal factors that can lead to the unsafe control actions and to hazards, followed by a redefinition of the controlling constraints (ibid., 2018), summarized in Table 2.

Evaluation of the Canadian capacity-building "train-the-trainer" workshop

Only in the last few years has the human dimension of ship operations gained somewhat more international attention; however, the general outlook in international lawmaking remains technical in nature (Kirchner 2018). Although this is also valid for the overwhelming part of the Polar Code, some chapters of the regulation cover the human dimension, e.g., voyage planning (Chapter 11) and manning and training (Chapter 12) (International Maritime Organization [IMO] 2017). The regional capacity-building "train-the-trainer" workshops aim to enhance the skills and competence of maritime instructors, who provide this training, and the qualifications of dedicated personnel in charge of a navigational watch on PCS ships operating in polar waters. These regional workshops are approaching the human dimension, in an interface and combination with technology, using simulator training and practical exercises to address hazards and risks related to voyages and navigation in ice and the associated challenges when working in extreme and harsh polar conditions (International Maritime Organization [IMO], n.d.c).

Canada's role in the implementation of the Polar Code and the regional capacity-building "train-the-trainer" workshops

As part of the Polar Code implementation, the Government of Canada provided expertise and financial support, to develop and provide four regional capacity-building "train-the-trainer" workshops, delivering training programs covering the new STCW Convention's requirements applicable for polar water operations (Offshore Energy 2017). Transport Canada was, according to one of the interviewees, requested by the IMO to provide nominees, who nominated the maritime simulation training center where the Canadian workshop took place. This approach was taken, due to the center's reputation for delivering world-class simulation technology and industry-driven expertise to solve simulation problems for maritime clientele, one interviewee explained. With years of experience in developing and delivering ice navigation courses, even many years before the implementation of the Polar Code, the center had previously cooperated with the IMO in related matters.

Canada is one of the largest and most politically powerful Arctic states, with a long history of maritime activities in polar waters, mainly consisting of destination traffic to support northern communities and mining industries (Rothwell 2017; Goerlandt and Pelot 2020). Leveraging over 40 years of experience in the oversight of Arctic shipping, Canada played an instrumental role in the development of the

2FL01 2FL02 [2] The failure type, "control action stopped too soon or applied too long" (iv) (Leveson and Thomas 2018), was found not to be relevant and is therefore omitted from the analysis.

Journal : SmallExtended 12198	Article No : 241	Pages : 27	MS Code : 241	Dispatch : 9-12-2021

Polar Code (Fraser 2020). This active engagement had great results for the final content of the regulation, which is significantly influenced by Canadian safety and environmental standards (ibid., 2020). From this perspective, the IMO's approach of engaging Transport Canada to provide financial support and expertise in the deliverance of the regional capacity-building "train-the-trainer" workshops, which were developed and conducted by experts in related matters, is considered by this author as sufficient to ensure the continuation in supporting the implementation of the Polar Code.

Attendees at the Canadian workshop and requirements for attendance

Eleven participants from seven countries (Canada, The Bahamas, Chile, Denmark, Iceland, India, Jamaica) attended the five-day capacity-building "train-the-trainer" workshop in Canada in 2019, with representatives from flag state authorities and MET institutes. According to one of the interviewees, the aim was to include most IMO member states involved in navigation in polar waters, having seafarers operating in these parts of the world, with the technical cooperation's department within the IMO choosing relevant countries. Around ten countries were requested to provide two attendees for the workshop, meaning that up to 80 participants potentially could attend if all four regional workshops were conducted.[3] The Canadian workshop developers were not involved in the selection process of participants, but prerequisites for attendance were forwarded to the IMO. In general, the IMO invites member states to attend IMO seminars, by sending out a profile request for candidates. One interviewee pointed out that not all the countries have delegates with a profile matching these requests and that the candidates nominated are therefore accepted regardless. Based on their previous experiences with the flag states, this interviewee anticipated, in the planning of the workshop, that the prerequisites in many cases would not be used in the selection process of candidates. This interviewee described the selection process as a much more random choice, e.g., a person representing the administration who oversees training and approves a course provider's submission for Polar Code and STCW Convention ice navigation training can be sent to such an event, to give them briefing and insights into related matters.

The aim and expectation of conducting the workshops – to assist flag state authorities and MET institutes in enhancing the skills and competence of maritime instructors – could be thwarted if many of the attendees are not qualified to attend the events. According to the interviewees, some of the attendees in the Canadian workshop had no experience either with polar water operations and ice navigation or in functioning as certified MET instructors in the subject. The increasing trend in Arctic shipping poses equal challenges and risks of having seafarers used to voyages in e.g., the Mediterranean or Indian Ocean, suddenly finding themselves operating in polar waters, with no previous experience or knowledge about the implications and hazards associated with shipping in these parts of the world (Kirchner 2018).

3FL01 [3] The currently imposed travel restrictions (COVID-19) have put the implementation of the two remain-
3FL02 ing workshops, planned to be conducted in the Republic of Korea and the Russian Federation, on hold.

Journal : SmallExtended 12198	Article No : 241	Pages : 27	MS Code : 241	Dispatch : 9-12-2021

The institutional and individual knowledge concerning risks and hazards related to shipping in the Arctic Ocean remains limited, and even if technology can aid in gathering basic hydrographical information, weather and wave data etc., the human dimension should not be underestimated (ibid., 2018).

Methods of teaching used in the Canadian workshop

The new situation of increasing shipping in the Arctic Region requires sufficient preparation of ships and equipment, as well as of the human element, which is where training can be one important aspect of preparing seafarers for polar voyages (Kirchner 2018). The establishment of regional capacity-building "train-the-trainer" workshops, covering the topic of ice navigation in polar waters, aims to standardize this training provided to seafarers operating in the Arctic and Antarctic Oceans (International Maritime Organization [IMO], n.d.c). The development and preparation of work documents and material for the Canadian workshop took place during a six-month period, with correspondence and communication going back and forth between the developers, Transport Canada and the IMO, as regards, e.g., objectives, content, learning plan and expected outcomes of the event. Based on previous experience related to flag states affairs, one interviewee explained that it was anticipated that the attendees would be a blend of recently experienced and highly experienced persons, in addition to those with no experience, either as MET instructors or in polar water operations. Therefore, the philosophy guiding the development of the learning plan was that, in a week-long period, a person with zero experience could not reach the level of not only being advanced but able to instruct at an advanced level. The aim became to demonstrate how to develop ice navigation courses, focusing on *what we do, how we do what we do, and how we assess the participants*, as it was expressed by one of the interviewees, and that "*death by PowerPoint presentations*" is not an effective way of delivering these courses.

The main priority was for the various methods of teaching to be useful in the delivery of ice navigation training, rather than focusing on the specific topics and risks associated with ship operations in polar waters. The workshop was structured around practicing skills and competence, with the objective of getting the participants to gain an understanding of the possible achievement, by utilizing practical exercises in the delivery of ice navigation training, even if the requirements in the STCW Convention can be interpreted in terms of a theoretical approach using lectures, as pointed out by one of the interviewees. If the workshop only turned into a lecture piece, with barely any practical elements, it would not be beneficial and in accordance with the objectives established for the event, this interviewee continued. Therefore, more than half of the workshop consisted of exercises or other activities, in which the participants were *doing things*, such as creating lesson plans, designing curriculums, discussing strategies, performing tabletop exercises and risk assessments, with the simulator exercise being the finale part of each session. This approach was selected, this interviewee explained, to get participants to see and experience the merit of not trying to carry out the Polar Code training only through lectures and PowerPoint presentations. Additionally, as pointed out by this interviewee, this approach could highlight weaknesses concerning the STCW Convention's lack of requirements for practical training in the delivery of courses concerning ice navigation. The existing STCW regimes are questioned in this context, as they mostly define skills required by the seafarers, and there is no guarantee that these skills will prepare seafarers for ship operations in Arctic or Antarctic waters (Kirchner 2018). The development and implementation of practical training requirements for seafarers operating in polar waters should be considered applicable – not only exclusively to masters, chief mates, and officers in charge of a navigational watch but also to the additional crew members assigned to PSC ships (Chaure and Gudmestad 2020).

Improving Polar Code training through the establishment of regional capacity-building "train-the-trainer" workshops

During the Canadian capacity-building "train-the-trainer" workshop, the participants were engaged to share their opinions during the training sessions, one interviewee explained, in addition to the daily "hot wash" (immediate after-action) debriefs, where the participants shared their experiences. Additionally, the IMO had sessions at the end of the workshop, in which feedback was gathered from the participants through questionnaires. Moreover, this interviewee reported, a daily debrief was conducted between the workshop instructors and the IMO representatives present at the event; these were documented and included in the instructor's consultant report. The delivery of a consultant report after such an event is a standardized IMO process, this interviewee explained, with a report being produced by the consultant(s) responsible for conducting the event, containing, e.g., descriptions of performed exercises, practices and feedback from the participants.

Participants attending the Canadian workshop desired more practical training and discussions and less lecturing; however, more lectures covering ice recognition were requested. Specifically, participants wanted explicit pointers on how to teach this matter. One interviewee explained that, generally, the ice recognition module does not need to be elaborated in the same manner as was required in the Canadian workshop, where participants had no experience in polar water operations or in functioning as MET instructors. The Canadian workshop was considered a pilot to gain experience, leading to some adjustments before the second workshop was conducted in Chile (November 2019). One of the main improvement points was to provide certain basic knowledge and information for personnel with no experience of polar water operations, as regards ice recognition and identification of the different conditions of ice during the year. These and other findings from the workshop should be taken into consideration going forward, when conducting the remaining workshops, and in future work in developing and establishing new guidelines specifying practical training requirements for seafarers operating in polar waters.

The Polar Code has been criticized for its significant vagueness in some provisions, opening the way for compliance with its functional requirements and overall goals to be interpreted in a variety of ways by administrations and classification societies (Todorov 2020). Further, the practical approach towards training and educating maritime students in ice recognition and identification is a challenging task, especially if the students do not have any experience with cold climate conditions and ice, described as an impossible task by one of the interviewees. Considering that ice and human error are the two main factors of risk occurrence related to ship accidents (collisions, stuck in ice / drift, or sinking and death) in the Arctic, this emphasizes the importance of training and experience in polar water operations (Fedi et al. 2020). The establishment of the regional capacity-building "train-the-trainer" workshops, covering the topic with a practical approach, is therefore considered, by this author, a valuable tool to enhance the competence, skills and knowledge of the instructors who provide the Polar Code training.

Enhancing the Polar Code training requirements by exchanging information and experiences gathered from the regional capacity-building "train-the-trainer" workshops

After the Canadian capacity-building "train-the-trainer" workshop was conducted, feedback and learning outcomes acquired during the event were included in the consultant's report and handed over to the IMO. One of the interviewees assumed that this report would only be filed and not used, unless the IMO decided to run a similar workshop at a later stage. According to the interviewees, the task of, and responsibility for, exchanging course material and experiences acquired in the workshop with the respective flag state authorities and MET institutes are placed on the workshop's participants. This manner of exchanging information was one of the purposes of the workshops, one interviewee explained, assuming that, if course material or other information was distributed by mail only, this would not be prioritized by the recipients. Therefore, the preference for the workshops is to have two attendees representing one member state and, hopefully, as this interviewee expressed it, these participants will bring back and implement what they have learned.

Shipping in polar areas requires special knowledge, skills and experience possessed by a relatively small number of professionals; the lack of clarity in defining the specific skills required of a master and crew operating in polar waters could pose a significant risk to navigation safety (Todorov 2020). Building awareness amongst MET institutes and instructors regards the applicability of implemented policies and regulations is the first step towards effective implementation, and it is of importance that all academic staff of MET institutions are encouraged to have good knowledge of the related matter, for effective training and compliance with the applicable regulations (Evans et al. 2017). The aim of the regional capacity-building "train-the-trainer" workshop – to enhance the skills and competence of MET instructors providing ice navigation training, according to the Polar Code and the STCW Convention (International Maritime Organization [IMO], n.d.c) – could be jeopardized by relying on non-systematic methods of exchanging experiences and learning outcomes from the events.

Journal : SmallExtended 12198	Article No : 241	Pages : 27	MS Code : 241	Dispatch : 9-12-2021

Final Discussion and Conclusion

Adopting and amending international maritime treaties, conventions and regulations is demanding work, and the IMO has been criticized for either not managing to bring new ones into force in a timely manner (Chircop 2017), e.g., the Polar Code's development and implementation took more than 25 years, or, when in force, not being able to achieve compliance by various stakeholders. In the effort to address this problem, the IMO established the sub-committee on Implementation of IMO Instruments (III) (ibid., 2017), which could be a compatible division within the IMO for addressing concerns regarding the harmonization of the Polar Code and the STCW Convention's training requirements for seafarers operating in polar waters. However, the primary responsibility for exercising control over ships rests with the flag state authorities. According to UNCLOS (Art. 94), every state shall effectively exercise its jurisdiction and control over ships flying its flag and take necessary measures to ensure safety at sea, regarding, e.g., the construction, equipment and seaworthiness of ships, the manning and labor conditions, and the training of crew members, according to the applicable regulations and requirements in the operating areas (Todorov 2020). Port states may initiate controls and check whether the seafarers' certificates are valid; whether the manning and qualifications of the crew members comply with the safe manning requirements; and whether the crew is trained according to the Polar Code and the STCW Convention's requirements for ice navigation in polar waters (Bai and Wang 2019). However, port state controls will be limited and can only determine whether ships have valid documents and whether the standards of the ships and the crew members conform with the information provided in the PSC (Todorov 2020). In addition, the Polar Code does not provide reliable tools to monitor compliance, and the issuing of the PSC is no guarantee that either the ship or the crew's composition and qualifications are in compliance at any given point in time (Fedi et al. 2018). The control to ensure seaworthiness of ships and their crew members is further complicated by the fact that, if only a few port states carry out strict inspections, the number of ships calling at their port will inevitably decrease, favoring more lax neighbor states (Bai and Wang 2019).

This author considers the Canadian involvement to be adequate, as the first regional capacity-building "train-the-trainer" workshop was developed and conducted by highly competent and experienced persons, with extensive knowledge and skills to teach in the relevant topics. However, some concerns regarding the workshop are raised, namely, some of the attendees' lack of relevant qualifications and, especially, the delegation to the workshop's participants, of the responsibility to exchange and transfer experiences and learning outcomes from the event back to national MET institutes and flag states authorities. The first issue, participants who are not qualified to attend the workshop, will limit the goal of reaching out to as many qualified MET ice navigation instructors as possible during these events. Regarding the second issue, delegating the responsibility to the workshop's participants for the transfer of experiences and learning outcomes back to relevant stakeholders is considered a weak and unreliable way of sharing information within the maritime system. This means of interacting cannot be controlled or assessed in a satisfactory manner, to ensure compliance with the goals established for the workshop. Achieving safety performance in a dynamic system and maintaining a satisfactory safety level over periods of time must be enforced by reliable audits and other reporting tools, ensuring feedback to the system developers about necessary barriers and safety constraints (Hale et al. 2006). In this case, feedback to the legislators was provided after completion of the Canadian capacity-building "train-the-trainer" workshop; however, an inadequacy is pointed out concerning poor control over the transfer and exchange of experiences and outcomes from the legislators and back to relevant stakeholders in the system. Proper information channels and control actions from the IMO to flag state authorities and national MET institutes should be established, to ensure that the majority of relevant stakeholders receive and benefit from the experiences and learning outcomes acquired during the workshops.

In this regard, the STAMP methodology is considered by this author to be a useful tool to identify the maritime system and the stakeholders operating within it. The model helps to explore both established and lack of constraints, affecting the interaction between the various stakeholders participating in the implementation of the Polar Code and the STCW Convention's training requirements for polar water operations. Safe shipping in these areas relies on stakeholders in the maritime system being aware of and complying with established constraints in a satisfactory manner, in this context awareness of and compliance with applicable regulations and requirements for polar water operations. However, the controls and constraints to ensure that PSC ships are manned with qualified, experienced and skilled personnel for polar voyages are questioned, especially since the responsibility for interpreting the functionally based Polar Code is delegated to the decision makers. The criticism raised by one interviewee, regarding lack of practical training requirements in the STCW Convention, therefore seems legitimate, pointing out that the Polar Code ice navigation courses can be conducted by means of classroom-lectures alone.

Acknowledgements This author would like to thank Associate Professor Morten Sommer (University of Stavanger – UiS) and Professor Emeritus Ove Tobias Gudmestad (UiS) for the time invested in commenting on this paper.

Journal : SmallExtended 12198 | Article No : 241 | Pages : 27 | MS Code : 241 | Dispatch : 9-12-2021

References

AQ5

Arctic University of Norway – UiT (n.d.) Emneplan for Polarkoden Grunneleggende Kurs og Polarkoden Videregående Kurs [Course Plan Basic and Advanced Training Ice Navigation in Polar Waters]. https://kvalitetshandbok-its.uit.no/docs/pub/DOK00102.pdf.

Bai J, Wang C (2019) Enhancing port state control in polar waters. Ocean Development & International Law 50(4):299–319. https://doi.org/10.1080/00908320.2019.1644776

Braun V, Clarke V (2006) Using thematic analysis in psychology. Qualitative Research in Psychology 3(2):77–101. https://doi.org/10.1191/1478088706qp063oa

Cantu J, Tolk J, Fritts S, Gharehyakheh A (2020) High Reliability Organization (HRO) systematic literature review: Discovery of culture as a foundational hallmark. J Contingencies and Crisis Management 28:399–410

Castells M, Ordás S, Barahona C, Moncunill J, Muyskens C, Hofman W, Cross S, Kondratiev A, Boran-Keshishyan A, Popov A, Skorokhodov S (2016) Model course to revalidate deck officers' competences using simulators. WMU J Marit Affairs 15:163–185. https://doi.org/10.1007/s13437-015-0092-2

Chaure MR, Gudmestad OT (2020) Effectiveness of the Polar Code training of cruise liner crew for evacuation in the Arctic and Antarctic. Transnav 14(4):923–928. https://doi.org/10.12716/1001.14.04.17

Chircop A (2017) The IMO, its role under UNCLOS and its Polar Shipping Regulation. In: Beckmann RC, Henriksen T, Kraabel KD, Molenaar EJ, Roach JA (eds) Governance of Arctic Shipping, Balancing Rights and Interests of Arctic States and User States. Brill Nijhoff, Leiden; Boston, pp 107–143. https://doi.org/10.1163/9789004339385_005

DNV GL (2015) Winterization for cold climate operations (DNVGL-OS-A201). Høvik, Norway. https://rules.dnvgl.com/docs/pdf/dnvgl/os/2015-07/dnvgl-os-a201.pdf

Evans UF, Mkpandiok A, Okonna KO (2017) An evaluation of the level of awareness of the STCW-78 as amended in Manila 2010, using maritime education and training institutions as collective compliance mechanism. Australian Journal of Maritime & Ocean Affairs 9(3):168–181. https://doi.org/10.1080/18366503.2017.1306915

Fedi L, Faury O, Etienne L (2020) Mapping and analysis of maritime accidents in the Russian Arctic through the lens of the Polar Code and POLARIS system. Marine Policy 118:1–9. https://doi.org/10.1016/j.marpol.2020.103984

Fedi L, Faury O, Gritsenko D (2018) The impact of the Polar Code on risk mitigation in Arctic waters: a "toolbox" for underwriters? Maritime Policy & Management 45(4):478–494. https://doi.org/10.1080/03088839.2018.1443227

Fraser D (2020) A Change in the Ice Regime: Polar Code Implementation in Canada. In: Chircop A, Goerlandt F, Aporta C, Ronald P Governance of Arctic Shipping, Rethinking Risk, Human Impacts and Regulation. Springer Polar Sciences, https://doi.org/10.1007/978-3-030-44975-9 pp. 285–300

Ghosh S (2017) Can authentic assessment find its place in seafarer education and training? Australian Journal of Maritime & Ocean Affairs 9(4):213–226. https://doi.org/10.1080/18366503.2017.1320828

Ghosh S, Rubly C (2015) The emergence of Arctic shipping: issues, threats, costs, and risk-mitigating strategies of the Polar Code. Australian Journal of Maritime & Ocean Affairs 7(3):171–182. https://doi.org/10.1080/18366503.2015.1093695

Goerlandt F, Pelot R (2020) An Exploratory Application of the International Risk Governance Council's Risk Governance Framework to Shipping Risks in the Canadian Arctic. In: Chircop A, Goerlandt F, Aporta C, Ronald P. Governance of Arctic Shipping, Rethinking Risk, Human Impacts and Regulation (pp. 15–41). Springer Polar Sciences. https://doi.org/10.1007/978-3-030-44975-9

Gudmestad OT, Solberg KE (2019) Findings from two Arctic search and rescue exercises north of Spitzbergen. Polar Geography 1–16. https://doi.org/10.1080/1088937X.2019.1597394

Hagerupsen R (2019) K33: Kontroll av skipets drift og omsorg for personer om bord. MARKOM FS 2020. https://www.marfag.no/k33

Hale A, Guldenmund F, Goossens L (2006) Auditing Resilience in Risk Control and Safety Management Systems. In: Hollnagel E, Woods DD, Leveson N (eds) Resilience Engineering: Concepts and Precepts. Ashgate, CRC Press, Aldershot, pp 270–294

Hebbar AA, Schröder-Hinrichs JU, Mejia MQ, Deggim H, Pristrom S (2020). The IMO Regulatory Framework for Arctic Shipping: Risk Perspectives and Goal-Based Pathways. In: Chircop A, Goerlandt F, Aporta C, Ronald P. Governance of Arctic Shipping, Rethinking Risk, Human Impacts and Regulation (pp. 229–247). Springer Polar Sciences. https://doi.org/10.1007/978-3-030-44975-9

Hill E, LaNore M, Véronneau S (2015) Northern sea route: an overview of transportation risks, safety, and security. Journal of Transportation Security 8:69–78. https://doi.org/10.1007/s12198-015-0158-6

Hollnagel E, Woods DD (2006) Prologue: Resilience Engineering Concepts. In: Hollnagel E, Woods DD, Leveson N (eds) Resilience Engineering: Concepts and Precepts. Ashgate, CRC Press, Aldershot, pp 326–336

International Maritime Organization [IMO] (2016) Guidance on methodologies for assessing operational capabilities and limitations in ice (MSC.1/Circ.1519). Geneva

International Maritime Organization [IMO] (2019) The interim guidelines for life-saving appliances and arrangements for ships operating in polar waters (MSC.1/Circ.1614 2019). Geneva, Switzerland.

International Maritime Organization [IMO] (2017) International Code for Ships Operating in Polar Waters (Polar Code) (MEPC 68/21). Switzerland, Geneva

International Maritime Organization [IMO] (2001) International Convention for the Safety of Life at Sea (SOLAS) (1974, and 1978 and 1988 Protocol relating thereto: 2000 and 2004 amendments). Switzerland, Geneva

International Maritime Organization [IMO] (n.d.a). International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW). Geneva, Switzerland. https://www.imo.org/en/OurWork/HumanElement/Pages/STCW-Conv-LINK.aspx

International Maritime Organization [IMO]. (n.d.b). *International Convention for the Safety of Life at Sea (SOLAS)*, 1974. Geneva, Switzerland. https://www.imo.org/en/About/Conventions/Pages/International-Convention-for-the-Safety-of-Life-at-Sea-(SOLAS),-1974.aspx AQ6

International Maritime Organization [IMO]. (2010). IMO model course (6.09) Training course for instructors (2nd edition)

International Maritime Organization [IMO]. (n.d.c). *Shipping in Polar Waters.* Geneva, Switzerland. https://www.imo.org/en/MediaCentre/HotTopics/Pages/polar-default.aspx

International Risk Governance Council [IRGC] (2017) Introduction to the IRGC Risk Governance Framework, Revised version. Lausanne: EPFL International Risk Governance Center. https://irgc.org/risk-governance/irgc-risk-governance-framework/

International Standard Organization [ISO] (2019) Petroleum and Natural Gas Industries — Arctic Offshore Structures (ISO 19906:2019. 2nd ed)

Jacobsen DI (2015) Hvordan gjennomføre undersøkelser? Innføring i samfunnsvitenskapelig metode (3. utg. ed.). Oslo: Cappelen Damm akademisk

Karahalil M, Ozsoy B, Oktar O (2020) Polar Code application areas in the Arctic. WMU Journal of Maritime Affairs 19, (pp. 219–234). https://doi.org/10.1007/s13437-020-00200-4

Kirchner S (2018) The human dimension of the polar code. Australian Journal of Maritime & Ocean Affairs 10(1):1–8. https://doi.org/10.1080/18366503.2017.1333191

Labuschagne A (2003) Qualitative research--airy fairy or fundamental? The Qualitative Report 8 (1):100–103. https://nsuworks.nova.edu/cgi/viewcontent.cgi?article=1901&context=tqr

Leveson N (2011) Engineering a Safer World: Systems Thinking Applied to Safety. The MIT Press, Cambridge

Leveson N, Thomas JP (2018) STPA Handbook (March). https://psas.scripts.mit.edu/home/get_file.php?name=STPA_handbook.pdf.

Leveson N, Dulac N, Zipkin D, Cuther-Gershenfeld J, Carrol J, Barret B (2006) Engineering resilience into safety-critical systems. In: Hollnagel E, Woods DD, Leveson N (eds) Resilience Engineering: Concepts and Precepts. Ashgate, CRC Press, Aldershot, pp 95–123

Lovdata (2018) Forskrift om kvalifikasjoner og sertifikater for sjøfolk, Tabell A-V/4–1: Spesifikasjon av minstekrav til kompetanse i grunnleggende opplæring for skip som opererer i polare farvann. https://lovdata.no/dokument/SF/forskrift/2011-12-22-1523/*#KAPITTEL_24

Munari F (2020) Search and Rescue at Sea: Do New Challenges Require New Rules? In: Chircop A, Goerlandt F, Aporta C, Ronald P (eds) Governance of Arctic Shipping, Rethinking Risk, Human Impacts and Regulation (pp. 63–81). Springer Polar Sciences https://doi.org/10.1007/978-3-030-44975-9_4

Norwegian Maritime Authorities [NMA] (2018) Amendments to the Regulations on Qualifications and Certificates for Seafarers (RSR 05–2018). https://www.sdir.no/en/shipping/legislation/directives/amendments-to-the-regulations-on-qualifications-and-certificates-for-seafarers2/

Norwegian Maritime Authorities [NMA]. (2019). Regulations on the Construction, Equipment and Operation of Passenger Ships in the Territorial Waters Surrounding Svalbard (RSR 03–2019). https:// AQ7 www.sdir.no/contentassets/ead426c9e3ae473d8b29bfa08a8dbbbf/rsr-03-2019-en.pdf?t=1606608000030

Offshore Energy (2017) IMO: Canada Provides Financial Support for Polar Code. https://www.offshore-energy.biz/imo-canada-provides-financial-support-for-polar-code/

Perrow C (1984) Normal Accidents: Living with High Risk Technologies. Princeton University Press

Protection of the Arctic Marine Environment [PAME] (2020) The Increase in Arctic Shipping 2013–2019 (Arctic shipping status report (ASSR) #1 31 March 2020). https://www.pame.is/projects/arctic-marine-shipping/arctic-shipping-status-reports/723-arctic-shipping-report-1-the-increase-in-arctic-shipping-2013-2019-pdf-version/file

Rasmussen J (1997) Risk management in a dynamic society: a modelling problem. Safety Science 27(2):183–213. https://doi.org/10.1016/S0925-7535(97)00052-0 AQ8

Reason JT (2016) Managing the Risks of Organizational Accidents. Ashgate, Aldershot

Roach AJ (2017) The Polar Code and its Adequacy. In: Beckmann RC, Henriksen T, Kraabel KD, Molenaar EJ, Roach JA (eds) Governance of Arctic Shipping, Balancing Rights and Interests of Arctic States and User States. Brill Nijhoff, Leiden; Boston, pp 144–169

Rothwell DR (2017) Canada and the United States. In: Beckmann RC, Henriksen T, Kraabel KD, Molenaar EJ, Roach JA (eds) Governance of Arctic Shipping, Balancing Rights and Interests of Arctic States and User States. Brill Nijhoff, Leiden; Boston, pp 217–244. https://doi.org/10.1163/9789004339385_008

Ryan F, Coughlan M, Cronin P (2009) Interviewing in qualitative research: The one-to-one interview. International Journal of Therapy and Rehabilitation 16(6):309–314. https://doi.org/10.12968/ijtr.2009.16.6.42433

Sandelowski M (2002) Reembodying qualitative inquiry. Qualitative Health Research 12:104–115

Silber GK, Adams JD (2019) Vessel operations in the Arctic, 2015–2017. Frontiers in Marine Science 6(573):1–18. https://doi.org/10.3389/fmars.2019.00573

SINTEF (2010) Organisational Accidents and Resilient Organisations: Six Perspectives, Revision 2, SINTEF A17034

Sutcliffe KM (2011) High reliability organizations (HROs). Best Practice & Research Clinical Anaesthesiology 25:133–144

Todorov A (2020) Coping with deficiencies in the Polar Code: a Russian Perspective. The Polar Journal 10(2):322–333. https://doi.org/10.1080/2154896X.2020.1799615

Veazie S, Peterson K, Bourne D (2019) Evidence Brief: Implementation of High Reliability Organization Principles. Department of Veterans Affairs, Veterans Health Administration, Health Services Research & Development Service, Washington, DC.