ARCTIC NAVIGATION: STAKES, BENEFITS AND LIMITS OF THE POLARIS SYSTEM

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ABSTRACT

Ensuring safe navigation is paramount for the economic development of the Arctic. Aware of this strategic issue, the International Maritime Organization (IMO), supported by the Arctic coastal states, adopted the International Code for Ships Operating in Polar Waters (Polar Code) with a set of navigation tools including the well-known Polar Operational Limit Assessment Risk Indexing System (POLARIS). Designed for assessing operational capabilities for ships operating in ice, POLARIS is useful for various stakeholders such as the International Association of Classification Society (IACS) organizations and underwriters. Other important beneficiaries are shipowners and their crew.

Even though POLARIS deals with topical issues, so far, this system has not been subjected to extensive studies of its capabilities and limitations. The aim of this analysis in hand is to assess the stakes, benefits and limits of POLARIS for Arctic navigation with a managerial approach and through the lens of risk assessment.

Results show that POLARIS integrates various parameters to assess risk of navigation in ice, and that POLARIS can provide relevant managerial solutions to shipowners. Nevertheless, certain limitations remain; in particular, human factors such as the lack of crew experience or the issue of non-compliance are not taken into consideration. Finally, it is important to highlight the fact that POLARIS is not a mandatory requirement.

KEYWORDS

Polaris; Polar Code; Risk; Arctic; Ice certification; Polar Water Operational Manual

INTRODUCTION

Despite the fact that POLARIS is not stated in the new International Code for Ships Operating in Polar Waters (called Polar Code here after) [IMO, 2014C] but simply recommended in an IMO Guidance [IMO, 2016A], it appears as a pillar in the overall decision process of various stakeholders such as classification societies, underwriters, and shipowners.

Currently, the IMO Polar Code recommends that shipowners and classification societies use POLARIS to determine the ice class required by their customers. Concerning underwriters, who are not experts in ice navigation [Faury, 2015], they usually rely on the best classification societies clustered by the International Association of Classification Societies (IACS), and examine the shipowner's experience and risk profile. In addition, underwriters shall refer to POLARIS to determine if the vessel is susceptible to being beset in ice and damaged. According to historical data and as a result of these various privileged contacts, insurance companies are able to evaluate the "polarseaworthiness" of a ship [Cullen, 2015; Fedi et al., 2018] and fix an appropriate premium rate.

Shipowners, often at the centre of interaction between classification societies and insurers, use POLARIS to define limitations on operations in the presence of ice. They may need to satisfy the requirements of the targeted market composed of their own clients, the coastal state legal provisions, and the environmental constraints, especially considering bathymetric conditions. Furthermore, POLARIS enables shipowners working in close collaboration with classification societies to choose an optimal ice class for a given route and for underwriters to choose the optimal Arctic route in order to lower insurance fees.

While POLARIS directly influences the vessel's technical parameters, it can also be used to achieve cost reductions via forecasts of the journey or by promoting deeper integration of underwriters within the decision process. However, even if POLARIS can be considered useful for these purposes, it does not solve all the potential issues encountered by vessels in Arctic waters. Among the most important concerns not covered by POLARIS is the human factor, defined as the human performance in the working environment, which represents one of the main causes of claims [Sarrabezoles et al., 2014].

The aim of the present analysis is to provide a better understanding of POLARIS' capabilities and limitations. POLARIS is investigated as a decision tool that stands at the upstream and downstream of the shipowner's decision process for safer navigation in the Arctic. Developments are mainly based on the analysis of the existing literature dealing with POLARIS, the IMO provisions on Polar Code, and POLARIS system. Following an introduction, we discuss the main stakes, main impact on the navigation and decision process, and benefits of POLARIS. The main limitations of POLARIS are also discussed while the final section provides some conclusions and recommendations.

THE STAKES AND BENEFITS OF POLARIS

POLARIS cannot be separated from the new Polar Code adopted in 2014 [IMO, 2014C] and applied since January 1, 2017. This new instrument entered into force through a direct integration into the International Convention for the Safety of Life at Sea [IMO, 1974] and the International Convention for the Prevention of Marine Pollution from Ships [IMO, 1978]. Applicable in the Arctic and Antarctic, the purpose of the Polar Code is to define enhanced safety and environmental standards for polar shipping [Chircop, 2013; Henriksen, 2014; Bai, 2015; Fedi and Faury, 2016]. Following a risk-based approach, the Polar Code identifies the main risks existing in polar areas with their potential consequences and sets out imperative and non-imperative measures called recommendations to mitigate such identified risks. The main hazard sources listed in the Polar Code include sea-ice, topside icing, low temperatures, extended period of darkness, high latitude, weather conditions, remoteness, lack of data (charts), lack of crew experience, lack of search and rescue (SAR) equipment, and the sensitivity of the environment. In addressing risks in polar navigation which were not adequately mitigated by previous IMO conventions [Henriksen, 2014], the Polar Code innovates in developing a holistic approach [Fedi and Faury, 2016].

POLARIS is supposed to be applied to new safety rules enacted by IMO, by which ships operating in the Arctic must satisfy specific requirements defining their capabilities and operational limitations. The following section explains the links between POLARIS and ship's operational assessment, the POLARIS key features, and why POLARIS can be considered as a decision support tool.

POLARIS and Ship's Operational Assessment

To put it simply, the Polar Code establishes the concept of operational limitations of a vessel. In the Arctic, ships face severe and volatile environmental hazards, in particular, due to the presence of sea-ice and low temperature worsened by high latitude and remoteness [MARSH, 2014]. These operational limitations are to be set considering the ice conditions, temperature, and latitude. Furthermore, the Polar Code assigns a ship to one of the three categories (Category A, B, C) based on the type of ice in which it is designed to operate irrespective of geographic areas. These categories primarily correspond to the IACS and Baltic Polar ice classes. In addition, the Polar Code states that a vessel's capabilities and operational limitations must be certified by two documental prerequisites: the Polar Ship Certificate (PSC) and the Polar Water Operational Manual (PWOM).

The PSC shows evidence that the ship has been surveyed (structure, equipment, materials, etc.) and has received its ice class according to its ability to sail through or in ice-covered areas. It also requires listing of ship's category and ice class as separate items. More precisely, the PSC establishes operational limitations including limitations related to ship structural ice capabilities. The PWOM defines specific procedures for mitigating risks by ensuring that the vessel operates within or beyond formal limitations or capabilities.

Moreover, the Polar Code requires that a practical methodology is used for assessing operational limitations in ice (Chap. 1, Polar Code, Certificate and Survey). Even though different methodologies exist, the IMO promoted the Polar Operational Limit Assessment Risk Indexing System (POLARIS) developed by the IACS [IMO, 2014A] and from major Arctic nations such as Canada, Denmark, Finland, Russia, and Sweden [IMO, 2014B]. The IMO published a *Guidance* on these methodologies with specific developments about POLARIS presented as a combination of the best practices from Canada's Arctic Ice Regime Shipping System (AIRSS) and the Russian Ice Certificate supplemented by pilot ice assistance as prescribed in the Rules of Navigation of the Northern Sea Route [IMO, 2016B].

POLARIS Key Features

In brief, POLARIS is a system that compares the existing ice typology to the class of the vessel in order to define a safer route and the optimal class of the vessel willing to sail within the polar waters. According to the 2016 IMO *Guidance*, there are five key elements of POLARIS (Figure 1). First, POLARIS is a combination of IACS Polar Class ice classes and ice class equivalence to Finnish-Swedish Ice Class Rules under the Baltic Marine Environment Protection Commission known as the Helsinki Commission (HELCOM hereafter; HELCOM recommendation 25/7, Safety of Winter Navigation in the Baltic Sea). Second, it uses ice type definitions in accordance with the World Meteorological Organization (WMO) nomenclature generally found on international ice charts. Third, POLARIS takes into consideration different

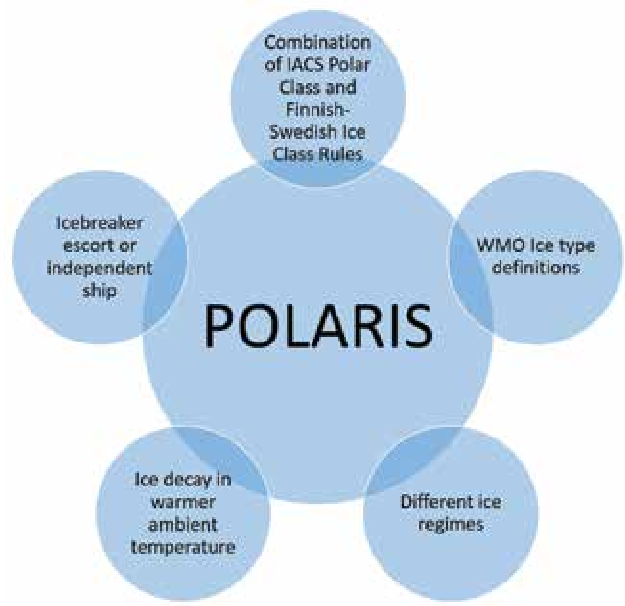

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Figure 1: POLARIS key features.

ice regimes (partial ice concentrations, ice-free waters, etc.). Fourth, it considers ice decay in warmer temperature. Finally, it acknowledges that ships operated under icebreaker escort have a different risk profile compared to ships operating independently.

Further, POLARIS uses risk index values (RIVs) which are assigned to a ship based on the ice class [IMO, 2016A]. RIVs indicate a relative risk evaluation for corresponding ice types (heavy multi-year ice, medium first year ice, ice-free, etc.) and they are completed by a risk index outcome (RIO) value to assess limitations for operating in ice. According to the IMO *Guidance*, for each ice regime met, the RIVs are used to define a RIO that constitutes the basis of the decision to fully operate or to limit operations.

As shown in Table 1, three levels of operations are determined depending on the risk level: normal operation, elevated

RIO_{SHIP}	*Ice classes PC1-PC7*	*Ice classes below PC7 and ships not assigned an ice class*
RIO ≥ 0	Normal operation	Normal operation
-10 ≤ RIO < 0	Elevated operational risk*	Operation subject to special consideration**
RIO < -10	Operation subject to special consideration **	Operation subject to special consideration **

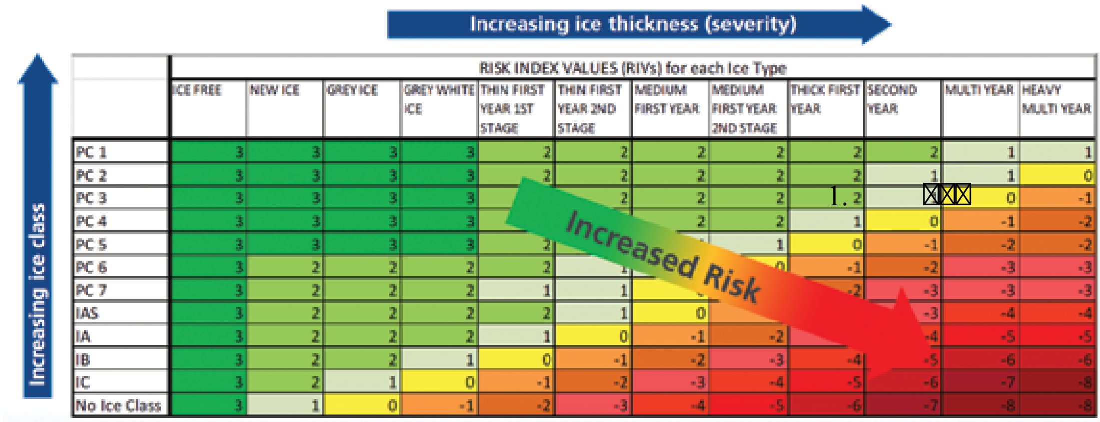
Table 1: Risk index outcome criteria. IMO

operational risk, and operation subject to special consideration. Adaptive measures may be taken in consideration of the RIO, such as limited speed, additional watchkeeping, or icebreaker support. Obviously, POLARIS participates in a classification and proceduralization of polar risks [Fedi et al., 2018]. Yet, when the RIO is below -10, the navigation is subject to special consideration. In this case, the decision to sail in such conditions is at the discretion of the master and officers even though such navigation shall usually be avoided [IMO, 2016A].

POLARIS as a Decision Support Tool

As far as is known, few studies have explored POLARIS as a decision support tool in Arctic navigation. This may be explained by its relative novelty and the recent Polar Code implementation. Nevertheless, a few scholars have started to study this risk-based system. Kujala et al. [2016] applied POLARIS in order to choose the most suitable ice class vessel in Antarctic and Arctic waters. It is likely that more studies will follow. Prior to the implementation of POLARIS, Timco et al. [2005] developed a similar prophylactic system based on the Canadian AIRSS. They explored its operational effectiveness based on the capacity of a vessel mainly depending on its ice class and the ice regime to sail within the Canadian Arctic. Yet, unlike POLARIS, this system was a “go/no go” tool and did not integrate the vessel’s speed. Stoddard et al. [2016] demonstrated the positive impact of the POLARIS system on the monitoring of vessels, route planning, and identification of ships operating in ice regimes more severe than their class allows. They also shed a light on the useful inputs of POLARIS for classification societies and underwriters for assessing risks encountered by vessels.

Through analysis of the different IMO provisions and documentation, POLARIS appears as a fairly complex and multipurpose tool that stands at the upstream and downstream of the shipowner’s decision process for safer navigation in the Arctic. First, before investing in an ice class vessel, the shipowner mandates the classification society that relies on POLARIS or an equivalent system [IMO, MSC., 2014A] to determine the appropriate ice class (see Table 2). As previously mentioned, various classification systems exist [Mulherin et al., 1996]. In order to harmonize the various systems, the Polar



	RISK INDEX VALUES (RIVs) for each Ice Type											
	ICE FREE	NEW ICE	GREY ICE	GREY WHITE ICE	THIN FIRST YEAR 1ST STAGE	THIN FIRST YEAR 2ND STAGE	MEDIUM FIRST YEAR	MEDIUM FIRST YEAR 2ND STAGE	THICK FIRST YEAR	SECOND YEAR	MULTI YEAR	HEAVY MULTI YEAR
PC 1	3	3	3	3	2	2	2	2	2	2	1	1
PC 2	3	3	3	3	2	2	2	2	2	1	1	0
PC 3	3	3	3	3	[illegible]	2	2	2	1. 2	[illegible]	0	-1
PC 4	3	3	3	3	[illegible]	[illegible]	2	2	1	0	-1	-2
PC 5	3	3	3	3	2	[illegible]	[illegible]	1	0	-1	-2	-2
PC 6	3	2	2	2	2	1	[illegible]	0	-1	-2	-3	-3
PC 7	3	2	2	2	1	1	[illegible]	[illegible]	-2	-3	-3	-3
IAS	3	2	2	2	2	1	0	[illegible]	[illegible]	-3	-4	-4
IA	3	2	2	2	1	0	-1	-2	[illegible]	-4	-5	-5
IB	3	2	2	1	0	-1	-2	-3	-4	-5	-6	-6
IC	3	2	1	0	-1	-2	-3	-4	-5	-6	-7	-8
No Ice Class	3	1	0	-1	-2	-3	-4	-5	-6	-7	-8	-8

Table 2: POLARIS risk index value.

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Code implemented three main Categories, A, B and C [IMO, 2014C]. DNV polar ship category considered that within these categories, Category A included polar class from PC1 to PC5, Category B included PC6 to PC7, and Category C corresponded to any Baltic ice class, ice class 1AS or with no ice strengthening [DNV, 2018]. Based on the shipowner's requirements, the classification company confirms that the hull structure and its capacity to resist ice load, the propulsion of the vessel, the rudders, and steering gear are in accordance with the Polar Code. This aspect is an essential and strategic part of POLARIS.

As stated earlier, the second key function of POLARIS lies in its ability to translate the physical characteristics of sea-ice into risk indexes (RIVs, RIO) related to the ice class of the vessel. The RIVs provided in tables 3 and 4 of the IMO [2016A] assess the level of risk vessels may encounter according to the ice class and the typology of ice. Yet, the RIO is a function of the RIV and integrates the concentration of ice type (Figure 2). Then POLARIS is used to determine the ship's certification (PSC) as well as for the PWOM; both shall mention POLARIS if used.

Third, POLARIS also appears to be highly useful for underwriters since they assess risks [Fedi et al., 2018] and can make recommendations both for the shipping lane to be followed and whether icebreaker assistance is required. Finally, POLARIS represents a valuable decision tool for the master and crew officers when they face challenging situations. They are supposed to take into consideration the level of risk and to choose appropriate operational measures. This part is oriented toward operational parameters and appears as a decision support tool to avoid significant risk represented by ice.

As illustrated in Figure 3, POLARIS impacts the internal and external level of the decision process related to an Arctic voyage. At the external level, classification societies, underwriters, and coastal states impose their own expectations through POLARIS requirements. At the internal level, once a shipowner has defined his market and segment, POLARIS directly influences his ship's operational assessment, PSC and PWOM. This justifies the assertion that POLARIS stands both at the upstream and downstream of the decision process.

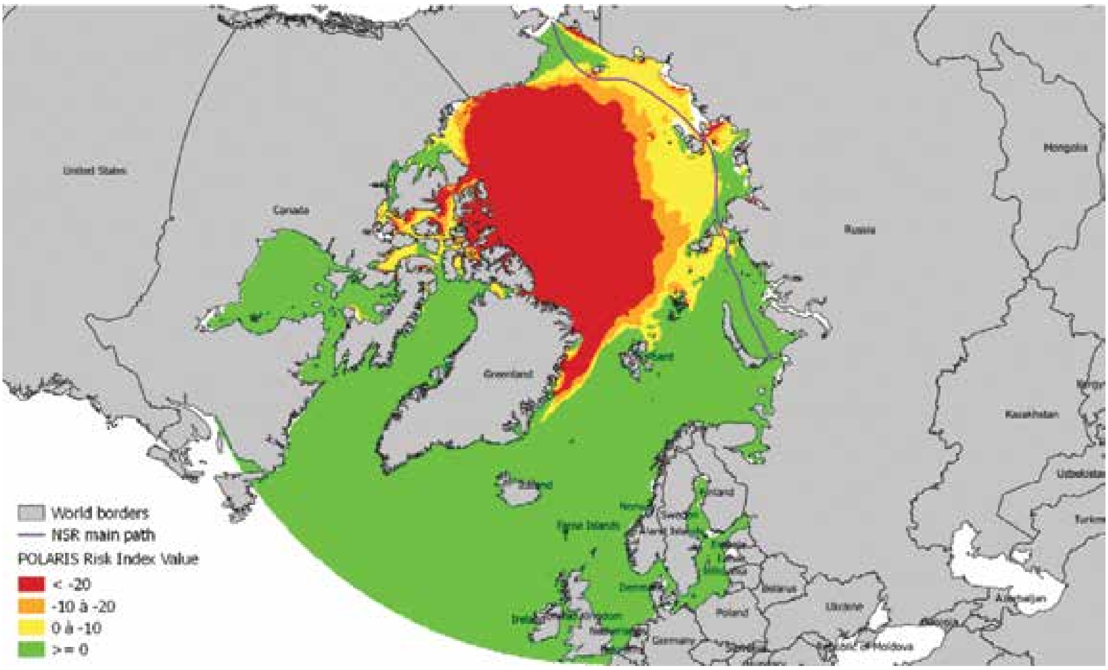

Figure 2: Risk Index Value for an ice class 1A vessel based on POLARIS. AUTHORS BASED ON COPERNICUS DATA (2018).

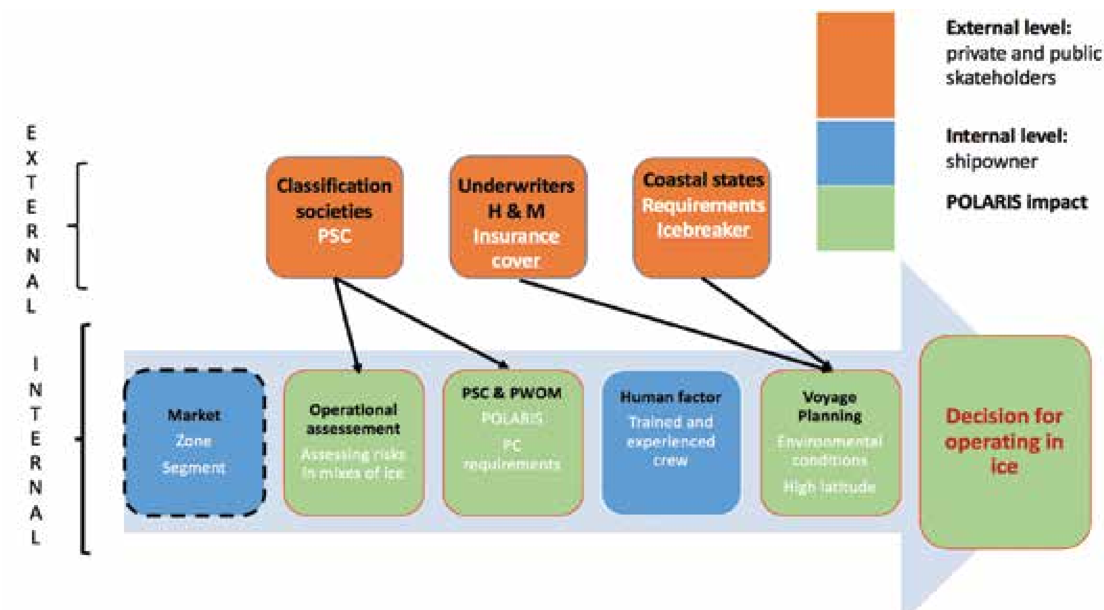

Figure 3: POLARIS as a decision support tool. AUTHORS

Notwithstanding its significance, POLARIS is not a perfect tool as explained in the second part of this paper.

LIMITATIONS OF POLARIS

There are several limitations of POLARIS. While these limitations weaken this framework, they do not significantly undermine its intrinsic value as a decision support tool that requires a comprehensive approach. Three main limits are highlighted: its legal status, its scope of application, and the human factor.

POLARIS is not Mandatory

The first POLARIS limitation lies in its legal nature. While as a matter of principle, the Polar Code remains a mandatory instrument justified by its "filiation links" to the SOLAS and MARPOL conventions [IMO, 1974; 1978], POLARIS is not compulsory. As stated in the *Additional Guidance to Chapter I*: *"Limitations for operating in ice should be determined using an appropriate methodology, such methodologies exist, have been in use for a number of years and have been validated with service experience. Existing methodologies and other systems may be acceptable to the Administration"* (Recommendations Part I-B of the Polar Code [IMO, 2014C]). POLARIS is not expressly mentioned in the Polar Code itself.

It is somewhat regrettable that POLARIS is non-binding insofar as it is defined as a modern methodology and qualified as the best present practice for the risk-based design [Kujala et al., 2016]. In addition, the Polar Code adoption was intended to harmonize disparate national legislations [Fedi and Faury, 2016; Fedi et al., 2018]. There remain some doubts concerning the full compliance with such non-mandatory provisions especially regarding the ship's limitations. It is hoped that masters and officers shall not breach the operational limitations set for their ship as indicated in the *Guidance* on POLARIS. Furthermore, previous methodologies such as AIRSS from Canada, Ice Passport from Russia, and others can be chosen by operators. On one hand, this can be considered as a paradox of the Polar Code as demonstrated in the existing literature dealing with its legal aspects [Fedi et al., 2018]. On the other hand, this enables translation of the flexibility granted by the Polar Code provisions to ensure appropriate seaworthiness solutions [Henriksen, 2014]. However, from a practical point of view, administrations have room to manoeuvre among the available methodologies for assessing operational capabilities and limitations in ice.

POLARIS is not Self-sufficient

The second main limitation is attributed to the partial scope of POLARIS. It is implicitly confirmed by the "Guidance on methodologies for assessing operational capabilities and limitations in ice" [IMO, 2016A]. The IMO *Guidance* establishes the principle that any assessment methodology for a ship's capabilities should not be considered as a go/no go tool but as a decision support tool, as previously discussed. This means that even though shipowners and Arctic operators can rely on POLARIS as a practical and modern methodology, as a preventive risk framework, it cannot be self-sufficient as POLARIS only covers one parameter of ship's operational limitations (ice conditions). POLARIS mainly provides different tables dealing with RIVs and RIO and corresponding ice class. Then operators require complementary tools in the operational assessment of the ship as well as additional data for undertaking an Arctic journey and supporting their decision making progress.

Such tools are explicitly stated in the Polar Code. In order to correctly evaluate the ship's capabilities for a global voyage or a specific risky event, the shipowner and crew members shall take into consideration an anticipated range of operating and environmental conditions. These conditions are related to low air temperature, the presence of ice, high latitude and the potential for collision with ice or land, and the main hazards identified by the Polar Code. Due to an updated PWOM and well-known procedures, appropriate and complete voyage planning (maximum information collected on hydrography, navigation aids, extent and type of sea-ice, vicinity of icebergs, places of refuge, or remoteness from SAR capabilities), and a certified and trained crew, the vessel shall be ready to be conducted safely. Finally, the decision for operating in ice depends on cumulative parameters as acknowledged by the IMO *Guidance* [IMO, 2016A].

POLARIS does not include the Human Factor

The human factor, that is to say the human performance in the working environment, is not included in POLARIS. While this may be surprising, the Polar Code is not mainly focused on the human factor even though the ship and its crew must be certified for operations in polar waters as required under the amended International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW) entered into force in July 2018 (Resolution MSC.416(97) [IMO, 2016B]). The Polar Code does state that some hazards such as lack of crew experience and training in polar operations can lead to human error and that extended periods of darkness or daylight may affect human performance (Sources of hazards, Polar Code Introduction, [IMO, 2014C]). Nonetheless, the training requirements and certification imposed by the Polar Code are not very stringent [Fedi and Faury, 2016]. This is somewhat contradictory as concluded by several studies. One study identified the lack of crew experience as a primary cause of accidents [Tikka et al., 2008]. A second study detailed a survey based on 19 years of analysis of Arctic marine accidents (1993 to 2011) that stressed the significance of crew training and pointed out that accidents involving the human body were most frequent [Kum and Sahim, 2015]. Further, according to the Arctic Marine Shipping Assessment [AMSA, 2009], the human factor was the primary contributor to the total number of accidents (roughly 77%), due to inattention, heavy weather, age, and lack of communication. Other studies showed that the harsh environment in Arctic waters profoundly influences ships' technical systems and the functioning of the human body as well [Montewka et al., 2015; Haavik, 2017].
Finally, recent statistics on marine accidents in the Arctic have revealed an increasing number of casualties. While there were only eight incidents in 2006, the number reached 55 in

2014; 71 in 2015 [Allianz, 2016]; 55 in 2016 including one total loss [Allianz, 2017]; and 71 in 2017 [Allianz, 2018].

These studies and reports clearly indicate that Arctic shipping risks cannot be taken lightly and the human factor remains a major contributor to risk in Arctic waters. As explained earlier, POLARIS takes into consideration specific technical and objective values (RIVs and RIO) and is not designed to include human factors that are more subjective and challenging to measure quantitatively. Therefore, the final decision for operating in ice shall be mainly based on the qualified personnel on board in accordance with the Polar Code, and POLARIS cannot replace the masters' and officers' judgments. They have the appropriate skills, training, and experience to evaluate dangers related to ice and understand well the anticipated ship-ice interactions [IMO, 2016A].

CONCLUSION

In this research effort, we attempt to fill a gap in contemplating the main stakes, benefits, and limits of POLARIS. As for its stakes and benefits, we pointed out POLARIS played a key role in the assessment of the ships' operational limitations and conditioned safety prerequisites such as the PSC and PWOM. Results stressed a balanced picture of this system that could be considered as a practical decision making tool. Its limitations are mainly related to its non-binding nature, its partial scope of application, and the gap concerning the human factor.

Despite the demonstrated and potential benefits of POLARIS, it is not designed as a single solution intended to address all challenges and difficulties faced by ships during an Arctic voyage. POLARIS belongs to a systemic framework including numerous complementary tools such as PSC, PWOM, and voyage planning where experienced and trained human resources remain the most important factors in the final decision making.

Taking into consideration the recent entry into force of the Polar Code, it would be premature to definitively evaluate POLARIS. Some time will be necessary before its relevance for current and future Arctic operators can be fully verified. This mid-term evaluation shall constitute the next step of a future research agenda. In the meantime, we argue that POLARIS should be promoted and encouraged as much as possible by operators and classification societies in particular.

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