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The Cruise Industry and the Polar Code

Implementing the Polar Code

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Master's thesis in Technology and Safety in the High North TEK-3901 - June 2019

Acknowledgements

This thesis concludes my master's degree in Technology and Safety in the High North with specialization in nautical science at the Faculty of Science and Technology, UiT – The Arctic University of Norway.

First and foremost, I would like to thank my two supervisors; Andreas Kjøl at the Norwegian Coastal Administration who introduced the idea for the thesis and has provided valuable inputs regularly along the way, and professor Ove Tobias Gudmestad who did not hesitate to be my main supervisor when called upon and who have provided excellent guidance and feedback these last few months.

I would also like to thank everyone who has taken the time to reply to the questionnaire. The thesis would not be same without these replies.

Finally, I want to thank my little family, Lena and Henrik, for giving me the time I needed to complete this.

Bendik Skoglund Kristiansen

Tromsø, June 2019

Abstract

The mandatory Polar Code is now set into force with strengthened requirements for vessels operating in polar waters. The polar cruise shipping segment is growing as the maritime activity in polar waters is increasing. There are many challenges, and the polar environment adds an increased risk level. The preventive actions towards mitigating risks are more important due to the harsh environment, long distances and limited options for assistant rescue.

Most accidents and incidents have pre-occurring causes which are not captured until an unwanted event occurs, or not at all if the unwanted event is minor or less severe. A proper reporting regime is essential to identify these causes, and this is done through safety management with all its implications, as well as encouraging a healthy safety culture.

Relevant theory is reviewed, and terms and maritime safety challenges are explained to provide the basis for the discussion in this thesis. Further basis is provided through a survey directed towards polar cruise operators and a root cause analysis of a polar cruise vessel grounding in the Canadian Arctic utilizing reliability engineering methods.

Related to the work with the thesis, I participated in the Fourth Joint Arctic SAR TTX in Reykjavik this April. Highlights from the event are included in Appendix C and provide actualization of the research theme: *How the polar cruise shipping segment is implementing the Polar Code.*

The results of the survey and the root cause analysis are discussed related to the maritime safety challenges, and the thesis aims to provide knowledge about the implementation of the Polar Code in the polar cruise shipping segment, and to identify challenges related to this process.

Keywords: *Polar Code, Root Cause Analysis, Polar Cruise Shipping Segment, Maritime Safety Challenges, Hybrid Model, Safety Management, Arctic, Cruise, Case Study*

Abbreviations

ACGF	Arctic Coast Guard Forum
AECO	Association of Arctic Expedition Cruise Operators
AHP	Analytical Hierarchy Process
AIRSS	Arctic Ice Regime Shipping System
ARCSAR	Arctic and North-Atlantic Security and Emergency Preparedness Network
ARIF	Arctic Risk Influencing Factors
BRM	Bridge Resource Management
COLREGs	Convention on the International Regulations for Preventing Collisions at Sea
CCGS	Canadian Coast Guard Ship
ECS	Electronic Chart System
ECDIS	Electronic Chart Display and Information System
EGC	Enhanced Group Call
EPPR	Emergency Prevention, Preparedness and Response
FLS	Forward Looking Sonar
FMECA	Failure Mode, Effect and Criticality Analysis
FSA	Formal Safety Assessment
FTA	Fault Tree Analysis
GMDSS	Global Maritime Distress and Safety System
GNSS	Global Navigation Satellite System
GPS	Global Positioning System (USA)
HIFR	Helicopter In-Flight Refuelling
HSEQ	Health, Safety, Environment & Quality
IAATO	International Association of Antarctica Tour Operators
IBNS	Integrated Bridge Navigation System
ICG	Icelandic Coast Guard
IHO	International Hydrographic Organization
ILLC	International Convention on Load Lines
IMCS	Integrated Machinery Control System
IMO	International Maritime Organization
ISM	International Safety Management
JRCC	Joint Rescue Coordination Centre

LSA	Life-Saving Appliances
MCTS	Maritime Communication Traffic Service
MARPOL	International Convention for the Prevention of Pollution from Ships
MSC	Maritime Safety Committee
NAVTEX	Navigational Telex
NAVWARN	Navigational Warning
NCA	Norwegian Coastal Administration
NMA	Norwegian Maritime Authority
NORDREG	Canadian Arctic Marine Traffic System
NOTSHIP	Notice to Shipping (Former Canadian NAVWARN)
NSRA	Northern Sea Route Administration
POLARIS	Polar Operational Limit Assessment Risk Indexing System
PSC	Polar Ship Certificate
PWOM	Polar Water Operations Manual
RBD	Reliability Block Diagram
RIO	Risk Index Outcome
RPN	Risk Priority Number
SAR	Search and Rescue
SARC	Arctic Maritime Safety Cooperation
SAREX	Search and Rescue Exercise
SMS	Safety Management System
SOLAS	International Convention for the Safety of Life at Sea
SOP	Standard Operating Procedure
STCW	International Convention on Standards of Training, Certification and Watchkeeping for Seafarers
TSB	Transportation Safety Board of Canada
TTX	Table Top Exercise
VTS	Vessel Traffic Service

Definitions

The following definitions are used in this thesis

AIRSS	Canadian regulatory standard intended to minimize the risk of pollution in Arctic waters due to damage of vessels by ice; to emphasize the responsibility of the shipowner and master for safety; and to provide a flexible framework for decision-making.
Contributing Factors	Failures related to regulations, organization, procedures or design.
Basic/Advanced Polar Code Course	Requirement in the Polar Code. Masters, chief mates and officers in charge of a navigational watch on board ships operating in polar waters shall have completed training to attain the abilities that are appropriate to the capacity to be filled, and duties and responsibilities to be taken up.
FMECA	A straight forward step-by-step technique to systematically determining the ways in which a failure can occur, and the effects that each failure can have on overall functionality of a system. (Labib and Read, 2015)
GNSS	A satellite navigation system with global coverage. The United States' GPS and Russia's GLONASS are fully operational GNSSs, while the EU's GALILEO and China's BDS are expected to be fully operational by the early 2020s.
Hazards	Possible events and conditions that may result in severity, i.e. cause significant harm. (Kristiansen, 2005)
Human Error	An incorrect decision, an improperly performed action or an improper lack of action. (Rothblum et.al, 2002)
Ice Regime	A description of an area with a relatively consistent distribution of any mix of ice types, including open water. (IMO)
ISM Code	The objective of the ISM Code is to ensure safety at sea, prevention of human injury or loss of life, and avoidance of damage to the environment, in particular the marine environment, and to property. (IMO)
LSA Code	The purpose of the LSA Code is to provide international standards for life-saving appliances required by the International Convention for the Safety of Life at Sea (SOLAS). Examples of life-saving appliances are lifeboats, life-rafts, lifebuoys, lifejackets, immersion suits, thermal protective aids and so on. (IMO)

NAVWARN	Navigational information concerning navigational safety. Can be obtained through numerous methods including Inmarsat-C, SafetyNet, Navigational Area (NAVAREA) broadcasts, HF broadcasts, the relevant authority website and by contacting maritime communication traffic services.
NSRA	Russian federal state institution aimed to ensure safe navigation and protection of marine environment from the pollution in the water area of the Northern sea route.
NORDREG	Canadian Arctic marine traffic system created pursuant to the Northern Canada Vessel Traffic Services Zone Regulations. The system is designed to ensure that the most effective services are available to accommodate current and future levels of marine traffic.
Polar Code	The goal of the Polar Code is 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. (IMO)
POLARIS	A decision support system that can be used for voyage planning and on the ship's bridge. It uses the ship's actual ice class and the actual ice conditions encountered to determine a risk index outcome (RIO) – effectively, a way of assigning a level of risk to ice operations for ships with certain ice classes. (Lloyd's)
Reliability	The ability of a system or component to perform certain defined functions. (Kristiansen, 2005)
Risk	An evaluation of hazards in terms of severity and probability. (Kristiansen, 2005)
Root Causes	Pre-occurring causes which contribute to an event.
Safety	The degree of freedom from danger and harm. Safety is achieved by doing things right the first time and every time. (Kristiansen, 2005)
Safety Management	Keeping an operation safe through systematic and safety-minded organization and management of both human and physical resources. (Kristiansen, 2005)
Shoulder Season	In the polar cruise shipping segment, the periods between ice-covered and ice-free water, typically May/June and October/November

Winterization Ensuring a vessel is suitably prepared for operations in freezing temperatures. It focuses on controlling the adverse effects of icing, freezing, wind chill and material properties in cold temperatures. Effective winterization includes structural design to reduce icing and cold exposure; heating, insulation and drainage; mechanical de-icing; weather shielding; and careful selection of materials.

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1 Introduction

1.1 Background

The polar cruise shipping segment, including large cruise ships as well as small- and mid-size cruise and explorer ships, is continuing to grow. Many cruise companies offer cruises to polar destinations, and in 2019 more than 500 000 passengers are expected to call at the 12 ports that are members of Cruise Northern Norway and Svalbard (CNNS, 2019). Judging by the orderbook of Norwegian shipyards (NSF 2018, Norsk Industri 2018) there has been an increase in orders for cruise ships with length over 40 meters since 2015, shown in yellow in figure 1. Furthermore, the Cruise Ship Orderbook (CIN, 2019) show that there are over 40 planned small to medium sized expedition ships over the next 5 years, many of which have high ice-class. No doubt, the remoteness and characteristics of the polar areas make them exotic travel destinations and the accessibility to these destinations is improving due to ice melting. The tendency further shows that a larger part of the shoulder season is utilized, and some operators are also offering winter cruises.

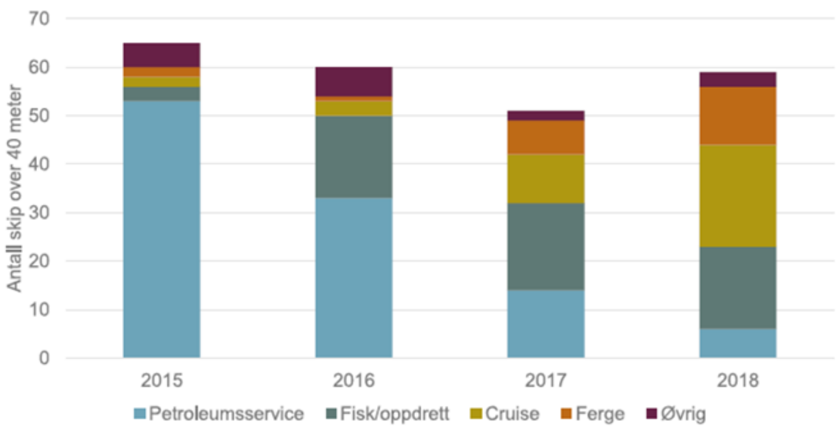

Figure 1: Orderbook for Norwegian Shipyards (Norsk Industri, 2018)

There are several challenges to consider when operating in polar waters. The previously mentioned accessibility is followed by the lack of, or poor, hydrographic data in both the newly ice-free areas and a generally large part of the waters in the polar areas. The maritime and communication infrastructure is limited. The remoteness and extreme met-ocean conditions are factors of concern for the officers on board the ship as well as stakeholders and search and rescue (SAR) entities.

International standards and regulations adopted by the International Maritime Organization (IMO) contribute to the mitigation of the risks involved with ship operations worldwide. Today's maritime safety regime is a result of several major accidents in shipping where human errors and management faults have been identified as the main causes. The International Safety Management (ISM) Code introduces an enforced self-regulatory mechanism where the shipping companies themselves are to regulate their own activities (Batalden, 2015). This is achieved through a safety management system (SMS). In 2017, more specific standards were made mandatory for ships operating in polar waters, introducing the Polar Code. The Polar Code contains strengthened requirements for the ship and its crew and acknowledges the extra sensitive environment and conditions in the Arctic and the Antarctic compared to other areas. The new standards include important improvements such as new systems and equipment on board the ship, new requirements to life-saving appliances (LSAs), new criteria for the design and construction of ships as well as risk assessments, procedures, manuals and additional officer training (IMO, 2016).

Several projects have investigated, and are still investigating, the challenges related to increased activity in the polar areas. Many of these projects are related to each other. Main examples to include are the SAR exercises SARex Spitzbergen (Solberg et.al, 2016), SARex 2 (Solberg et.al, 2017) and SARex 3 (Solberg and Gudmestad, 2018). The SARex project is closely related to the implementation of the Polar Code, as it aims to investigate some of the functional requirements that are introduced. Other projects are the SARiNOR project (SARINOR, 2018) which focuses on the general SAR challenges in the Arctic as well as preparedness related to the environment and pollution, and the ongoing SARex Svalbard project (Rederiforbundet, 2019) which involves full scale exercises in a polar environment. The SARex Svalbard project is a follow-up project from both the SARiNOR project and the SARex project and involves many of the same participants. Also ongoing is the ARCSAR (Arctic and North Atlantic Security and Emergency Preparedness Network) project, where the main goal is to establish a network of government, organizational and front-line stakeholders to meet the challenges following the increased activity in the Arctic (ARCSAR, 2019; Appendix C).

Today, the key maritime safety challenges in Norwegian waters are *crew experience, training and expertise, bridge manning and Bridge Resource Management (BRM), fatigue, personal factors, stress and commercial pressure* and *confined and complex waters* (NCA, 2015).

Combining the maritime safety challenges with the increased activity, utilizing larger parts of the shoulder season including winter cruises, and new regulations in the polar areas, it is no doubt that they will influence each other. The importance of preventive actions towards mitigating risks is clear, and this thesis aims to highlight these. The objective for serious operators should be to operate in polar waters at the same risk level as in other waters by appropriate treatment and mitigation of additional risk factors, as illustrated in figure 2.

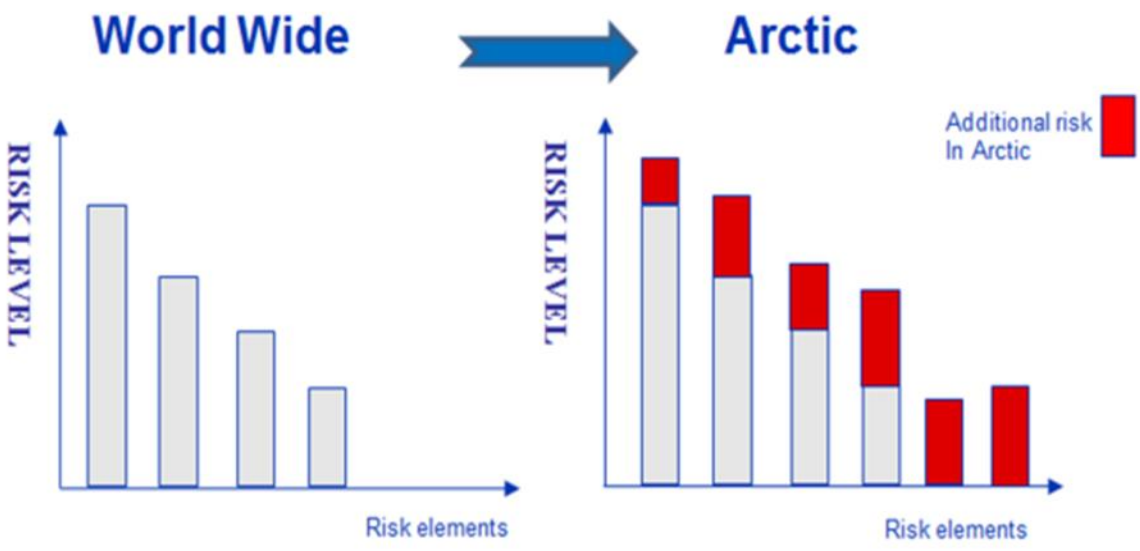

Figure 2: Arctic Risk Factors (DNVGL, 2008)

1.2 Scope and Research Theme

The mandatory Polar Code has forced shipping segments operating in polar waters to implement a new operational framework. This involves new operational assessments, new manuals and procedures, as well as new training and certification for the crew.

The main research theme for this thesis is ***how the polar cruise shipping segment is implementing the Polar Code***. From this research theme I have derived two research questions:

RQ1: What are the challenges related to the implementation of the Polar Code?

RQ2: How are previous lessons learned, non-conformities and near misses used in the implementation of the Polar Code?

The aim of the thesis is to provide knowledge about the implementation of the Polar Code in the polar cruise shipping segment, and to identify challenges related to this process. To answer the research questions, I have developed a questionnaire (Appendix A) aimed towards the polar cruise shipping segment. It attempts to identify the challenges in the Polar Code, and to gain knowledge on how the process of implementing the new regulations are conducted. Furthermore, the questionnaire aims to identify how previous lessons learned, non-conformities and near misses are utilized in developing new or updating existing manuals and procedures.

Further, a root cause analysis of a cruise vessel grounding in the Canadian Arctic is conducted, using methods from reliability engineering. A review of relevant theory and literature has been undertaken, and the findings from the survey and the root cause analysis are discussed.

1.3 Limitations

Geographically, the thesis is limited to the extent of Arctic waters according to the Polar Code (IMO, 2016), however it can also be relevant for the Antarctic waters as well as areas with similar characteristics such as the coast along Northern Norway. The incident analysed in this thesis occurred in the Canadian Arctic where the geographical remoteness and enormity are particularly evident. Furthermore, the thesis will focus on the polar cruise shipping segment.

Both the root cause analysis and the discussion of survey may be subject to the author's predispositions and understanding of the context. This bias is hard to avoid when working alone.

1.4 Structure

Chapter 1 – Introduction describes the background for the thesis and explains the research theme and the research questions. The scope of the thesis as well as the limitations is also described here.

Chapter 2 – Methodology explains the different methods used in the thesis. Both the overall case study method and the approach towards the survey is described, as well as the different logical models utilized in root cause analysis, risk analysis and risk assessment.

Chapter 3 – Maritime Safety contains the description of safety management and relevant regulations, and the maritime safety challenges are explained. Relevant terms for the root cause analysis are also described here.

Chapter 4 – Root Cause Analysis of the Clipper Adventurer Grounding is an analysis of the incident using the Hybrid Model. The findings from the accident report are utilized in reliability engineering models to enhance the ability to extract lessons learned to prevent an incident from reoccurring.

Chapter 5 – Results and Discussion presents the findings from the root cause analysis and the survey and discuss them in relation to the maritime safety challenges.

Chapter 6 – Summary and Concluding Remarks summarizes the work and addresses the main conclusions related to the research questions. Finally, topics for further work are suggested.

2 Methodology

2.1 Case Study

The scope of a case study is described as *"an empirical enquiry that*

- *investigates a contemporary phenomenon (the "case") in depth and within its real-world context, especially when*
- *the boundaries between phenomenon and context may not be clearly evident" (Yin, 2014).*

It is not only a method of approach or data collection, but a comprehensive method for covering all aspects of a study such as design, data collection techniques and approaches to data analysis.

A case study can combine qualitative and quantitative methods or consist of one or the other. A qualitative method is used on small groups or few subjects, is more in-depth and provides more detailed descriptions of events and experiences. A case study can be descriptive (describes the "case" in its real-world context), explanatory (explains how or why some condition came to be) or exploratory (identifies the case and provides basis for further studies). In addition, a case study is appropriate when the research questions start with "how" or "why" (Yin, 2014).

This thesis is designed as an exploratory case study, to identify *how the polar cruise segment is implementing the Polar Code*. The method for data collection is a qualitative open-ended questionnaire, seeking out qualitative information from experienced respondents. Furthermore, a root cause analysis is conducted on a relevant incident for explanation building and to provide a basis for further discussion. Logic models are utilized for the validity of the research design, and relevant theory is undergone for discussion and analysis of the research questions.

Some of the challenges when following a case study approach can be to remain rigorous and follow a procedure, generalizing from a single case, the resulting in massive unreadable data and that it can be unclear how the method is favourable to other methods (Yin, 2014). Using the case study approach for this thesis is a choice based upon the suitability for the approach when searching for "how" and "why".

2.2 Survey

The questionnaire used for the survey is developed from the research questions, where the aim is:

- *To explore how a company in the polar cruise shipping segment approaches the implementation of the Polar Code.*
- *To identify to which degree previously reported non-conformities and accidents are considered when developing the Polar Water Operation Manual (PWOM).*

The desired respondents for the survey are primarily from the polar cruise shipping segment. The company Health, Safety, Environment and Quality (HSEQ) manager/director or equivalent position as well as a representative from one of the ships in the company, preferably a master, are the ideal respondents. By acquiring data from these two perspectives within the company, the intention is to identify any potential differences in perceiving the challenges. The interview guide (Appendix A) provides the basis for the questionnaire and later analysis of the data and an informative text is included to explain the scope and purpose of the survey, as well as confidentiality and contact information. The questionnaire itself is made in *Google Docs*.

For this survey, the main challenge proved to be the number of respondents from the desired shipping segment – polar cruise. Distribution of the survey towards the polar cruise shipping segment was conducted through the Association of Arctic Expedition Cruise Operators (AECO), as they sent an invitation to their members with an informative text and the link to the questionnaire. Unfortunately, no AECO members responded to the survey. More direct efforts towards the polar cruise shipping segment were made with assistance from my supervisors and their network, with little luck. Because of this, none of the respondents are from the polar cruise shipping segment.

The survey still received good responses. Respondents from academia as well as masters and other experienced officers with extensive knowledge of ice operations have submitted their opinions. It has proven valuable to gain the perspective of other shipping segments in this matter, as many interesting opinions and experiences came to light. Chapter 5 gives a presentation of the findings from the survey.

2.3 Risk Analysis and Risk Assessment

Kristiansen (2005) explains risk analysis as the process of calculating risk for the identified hazards, while risk assessment is the process of using the results obtained in the risk analysis to improve the safety of a system through risk reduction. There are many methods for identifying the hazards and unwanted events that may influence an object or a process, including the related causes, probabilities and consequences. Examples of such methodology are Preliminary Hazard Analysis (PHA), Hazard and Operability studies (HAZOP), Hazard Identification (HAZID), Failure Mode, Effect and Criticality Analysis (FMECA), to mention some common ones. They all share many similarities, but the key is to have a structured approach towards the case at hand and to get some sort of overview in the end. Identifying hazards can be difficult work, it can tend to be subjective and is often restricted to the authors knowledge and understanding of the case (especially when conducted alone). Therefore, interdisciplinary groups of experts are usually working together to identify hazards.

Put in simple terms, risk is the product of probability multiplied by consequence. To illustrate this, it is common to use a risk matrix, as seen in table 1. The size of the matrix is optional, but a bigger matrix can prove to be more accurate. The *red area* indicates unacceptable conditions and risk reducing measures are required. The *yellow area* indicates tolerable conditions, but risk reducing measures should be considered. Within *the green area* the conditions are acceptable, and we do not need to consider any risk reducing measures.

Table 1: Example of a 5x5 risk matrix

Consequence → Probability ↓	Minimal	Low	Medium	High	Very high
Very high					
High					
Medium					
Low					
Minimal					

2.4 The Hybrid Model for Root Cause Analysis

Labib and Read (2015) propose a thorough and integrative approach to perform a systematic analysis of a disaster, which can lead to learning from failures. The tools in this hybrid model, as shown in figure 3, are frequently used in reliability engineering, and utilizes Fault Tree Analysis (FTA), Reliability Block Diagram (RBD), the Risk Priority Number (RPN) concept and Failure Mode, Effect and Criticality Analysis (FMECA) together with the Analytic Hierarchy Process (AHP).

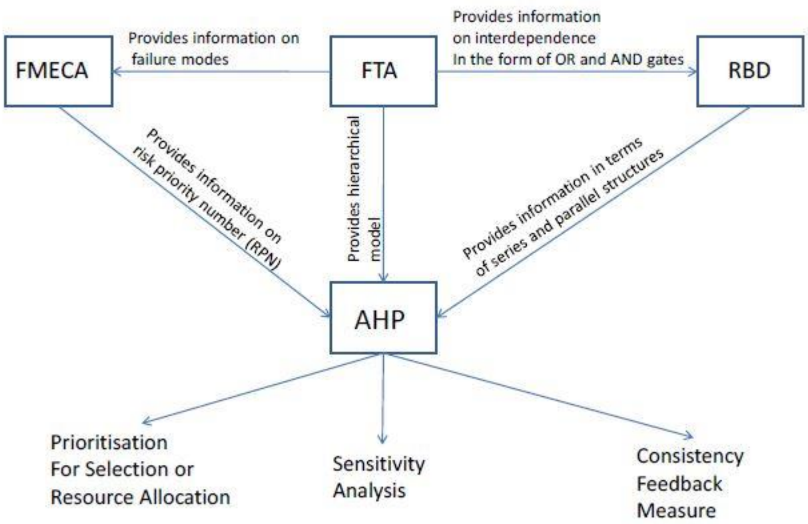

Figure 3: The Hybrid Model Structure (Labib and Read, 2015)

An incident involving the grounding of a large cruise vessel in the Arctic possesses the potential of all three attributes of a disaster; rarity, extreme impact and retrospective predictability (Taleb, cited in Labib and Read, 2015). According to Labib and Read (2015) the analysis of disasters, or in the case of this thesis, an incident involving the grounding of a cruise vessel in the Arctic, can produce four main benefits. *Firstly*, identifying the root causes of what went wrong and why. *Secondly*, act as an early warning signal prior to the event to take pre-emptive measures. *Thirdly*, to institute long term plans to prevent similar events from re-occurring. *Fourthly*, to provide decision makers with a set of priorities for resource allocation for both recovery and prevention.

By integrating tools from reliability and systems engineering, we can structure the events leading to the disaster and identify the root causes. The different tools in the model are presented below, attempting to explain the basic concepts. The Hybrid Model is used for the root cause analysis in chapter 4. Figures used in the thesis that are not gathered elsewhere and contain a reference, are made by the author utilizing the software *Edraw Max Pro v. 9.4.*

2.4.1 Failure Mode, Effect and Criticality Analysis

The Failure Mode, Effect and Criticality Analysis (FMECA) approach is a valid tool for performing a risk assessment on a system, and it is very straight forward. It provides a good overview of the system and the different risks associated with the different modules/components/actions. The stages of the approach can be described as follows (Kristiansen, 2005):

- *A general description of the components*
- *Description of possible failures and failure modes*
- *Description of failure effects for each failure mode*
- *Grading the failure effects in terms of severity, occurrence and difficulty of detection (or other parameters if deemed more relevant)*
- *Specifying method for detection of failure modes*
- *Description of how unwanted failure effects can be reduced and eliminated*

Risk Priority Numbers (RPN) can be used in an FMECA, as they can give us an idea of the risks that should be prioritized. Table 2 illustrates an RPN scaling from 1 to 5. The approach can be qualitative or, if enough data is available, the approach can be quantitative, and a different scale can be utilized.

Table 2: Example of RPN of severity(S), occurrence(O) and Detection(D)

Rank	Severity (S)	Occurrence (O)	Detection (D)
1	No effect on the system performance	Failure is unlikely	Certain detection of weakness
2	Slight deterioration of the system	Relatively few failures	Good chance of detection
3	Noticeably deterioration of the system	Occasional failures	May detect weakness
4	Failure subsystem	Repeated failures	Not likely detection of weakness
5	Affects human safety	Failure is inevitable	Cannot detect weakness

2.4.2 Fault Tree Analysis

The Fault Tree Analysis (FTA) is a method used for analysing how unwanted events occur, as well as its causes (Kristiansen, 2005). It is a top-down approach for failure analysis, starting with an unwanted event (top event) and tracing the lower level events (intermediate events) to identify sub-systems and all the different causes (basic events) leading up to the top event, as illustrated in figure 4.

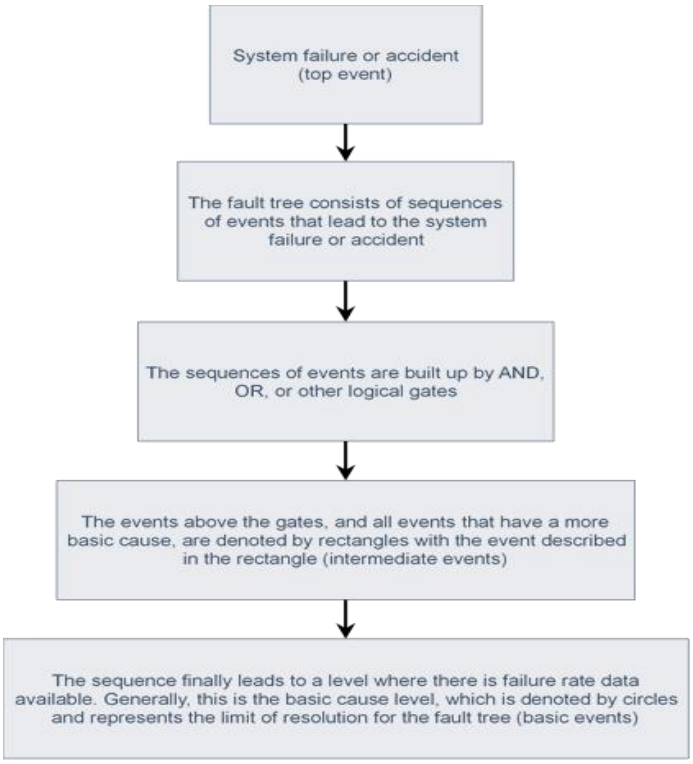

Figure 4: Principles of a fault tree (Kristiansen, 2005)

The approach can be quantitative or qualitative. The *quantitative* approach uses the failure probability of the basic events and the fault tree gates to calculate the probability of the top event, followed by an assessment by using an importance measure for each basic event. The *qualitative* approach starts by describing the system and its subsystems and components down to enough level of detail, then continues by constructing the fault tree for the top event by using this description. The AND/OR gates describe the fault logic between the events. I.e. an OR-gate implies that the output event is dependent on one of the two basic events to occur. The AND-gate implies that the output event is dependent on both basic events to occur. An example of a simple Fault Tree Model is given in figure 5 below.

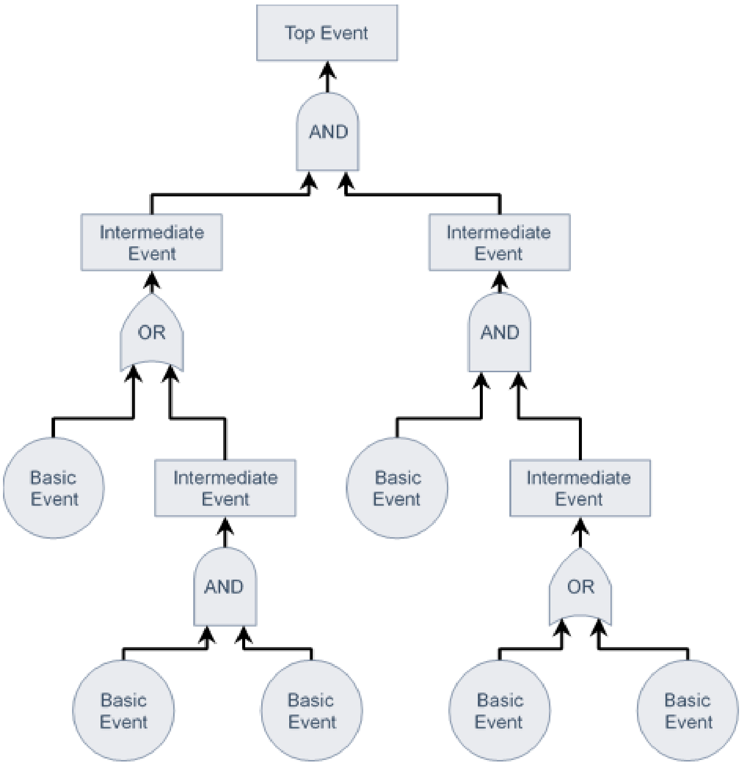

Figure 5: Example of a Fault Tree Model

2.4.3 Reliability Block Diagram

The Reliability Block Diagram (RBD) gives additional value to the analysis by providing decision makers with better understanding of the overall reliability of the model by highlighting vulnerable series structures and safer parallel structures (Labib and Read, 2015). Giving the different components a reliability value, we can calculate the system reliability. To increase system reliability, the number of components in series should be kept to a minimum. Used together with an FTA, the AND-gates are considered parallel structures and the OR-gates are considered series structures. Figure 6 show an example of an RBD of a system.

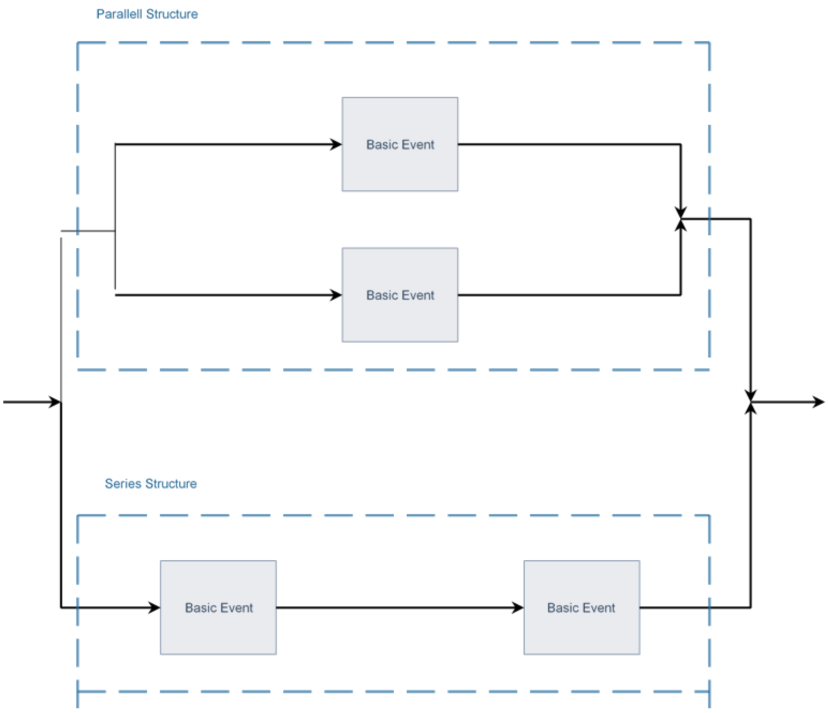

Figure 6: Example of a Reliability Block Diagram (RBD)

2.4.4 Analytical Hierarchy Process

The Analytical Hierarchy Process (AHP) is a Multi-Criteria Decision Making (MCDM) method. Complex decision-making needs organized creative thinking to structure the problem, and this structure can be provided by a hierarchy or a network (Saaty, 2013). It also needs numbers and mathematics to formalize judgements and make trade-offs. The objective of the AHP is to act as a mental model and for prioritisation to help decision makers understand the environment in question (Labib and Read, 2015). The decision makers are to provide judgements about the relative importance of each criteria, and then specify a preference on each criterion for each decision alternative.

An example of a three-level hierarchical model based on an AHP is illustrated in figure 7. The *goal* is what we want to achieve. There are three different *alternatives* to choose from and two *criteria* for choosing among the *alternatives*. Default priorities are shown as numbers in the boxes, i.e. they are equally prioritized. The sum of each level is always 1.

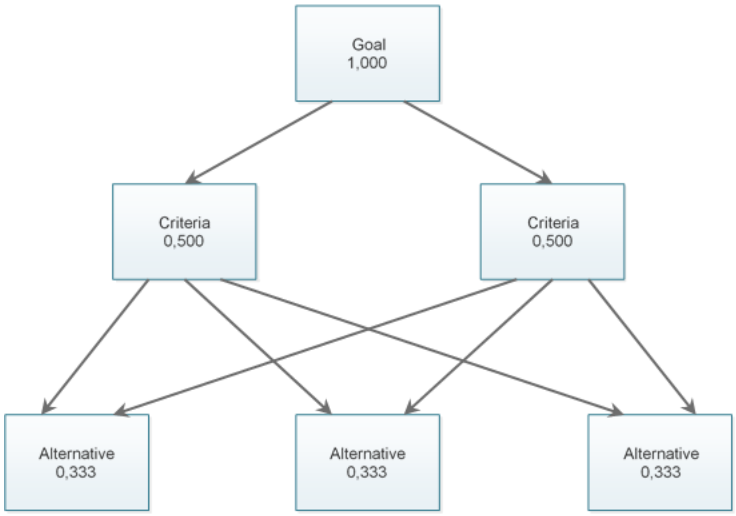

Figure 7: Example of a three level Analytical Hierarchy Process (AHP) model

The prioritization in the hierarchy is, as for the previous methods, either a qualitative process based on experience and the author's understanding of the *criteria*, or a quantitative process when appropriate data is available. A pairwise comparison is made with respect to the level above, i.e. the *criteria* are compared with respect to the *goal* while the *alternatives* are compared with respect to the *criteria*. The scale utilized when comparing is an absolute scale of numerical numbers ranging from 1 to 9, where each value explains how the component contributes to the objective compared to the other. The definitions are*: equal with* (value 1), *moderate with* (value 3), *strong with* (value 5), *very strong with* (value 7) and *extreme with* (value 9) and the integers between for compromise, and their reciprocals (Saaty, 2013).

The weakness of the AHP is the dependency on the judgement of the person performing the analysis. This is mitigated by using expert groups agreeing upon the scores (Stephen and Labib, 2017).

The priorities are derived by using the traditional AHP eigenvalue method (Stephen and Labib, 2017), and the calculations of the eigenvalue in this thesis are made using an online AHP Priority Calculator (AHPPC, 2017). For a thorough review of the AHP approach, please consult Saaty (2013).

In the context of the root cause analysis, the FTA model is used as the hierarchical model and the *alternatives* are *other common factors* to consider when trying to solve the basic events (Stephen and Labib, 2017). A full example of the method is given in chapter 4.

3 Maritime Safety

3.1 Safety Management

The objective of safety management is to ensure the safe and efficient execution of an operation and should therefore be considered an essential and integral element of the overall management system of an organization (Kristiansen, 2005). The maritime safety management regime, i.e. the rules and regulations governing safety and environmental protection in shipping, have evolved over time. Kristiansen (2005) explains *three stages* of evolution.

Stage one is the early, basic stage which focused on the consequences of accidents resulting from safety related failures. In the aftermath of accidents, major efforts were made to find someone to blame for all the material, environmental or human casualties. There was a *culture of punishment* that identified and allocated blame, and frequently this was the people at the sharp end of the system, e.g. a ship officer.

Stage two is the regulation of safety by prescription, i.e. the rules and regulations the maritime industry must obey. The *International Convention on Load Lines* (ILLC), the *Convention on the International Regulations for Preventing Collisions at Sea* (COLREGs), the *International Convention for the Safety of Life at SEA* (SOLAS), the *International Convention on Standards of Training, Certification and Watchkeeping for Seafarers* (STCW) and the *International Convention for the Prevention of Pollution from Ships* (MARPOL) form the basis for the prescriptive regulatory framework in shipping today. The prescribing party in the case of the maritime industry is the International Maritime Organization (IMO), a United Nations agency. The regime affects a vessel in all its life cycle, from design and construction via operation and modification to decommissioning. This result in a *culture of compliance*.

Stage three is the *culture of self-regulation*, which concentrates on internal management and organization for safety, and encourages the establishment of targets for safety performance. Self-regulation emphasizes the need for every organization and individual to be responsible for the actions taken to improve safety. This requires the development of company-specific and vessel-specific safety management systems (SMS). Safety is in other words organized by those who are directly affected by the implications of failure.

Kristiansen (2005) also argues that these three stages must coexist to achieve safer seas, as each regime plays a significant part in influencing company and individual behaviour. The causal factors resulting in ship accidents indicates a potential for improvement related to human and organizational factors.

3.2 Regulations

The codes issued by IMO can be considered as more detailed and specific guides to achieving the aims of the conventions, such as the International Safety Management (ISM) Code and the Polar Code which are the most relevant for this thesis. The ISM Code and the Polar Code are mandatory under SOLAS, STCW and MARPOL, as they regulate safety, training, certification and environmental issues related to ship operations. The main purpose of both the ISM Code and the Polar Code is to provide an international standard for safety management, ship operations and pollution prevention in shipping.

3.2.1 The ISM Code

The objective of the ISM Code is to *"ensure safety at sea, prevention of human injury or loss of life, and avoidance of damage to the environment, in particular the marine environment, and to property"* (IMO 2018).

To achieve this objective, the ISM Code proposes the establishment of an SMS. There are 12 sections in part A of the ISM Code, which goes into detail on what the SMS should contain. Part B consists of 4 sections which regards certification and verification. The SMS provides a shipping company with a system that can greatly contribute towards identifying hazards, mitigate risks and optimize procedures. The ISM Code applies worldwide.

A shipping company must possess a Document of Compliance (DOC) as well as a Safety Management Certificate (SMC) to operate vessels in compliance with the ISM Code.

3.2.2 The Polar Code

The aim of the Polar Code is 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"* (IMO 2016).

The Polar Code applies to ships operating in *polar waters*, which is defined in the code and illustrated in figure 8 and 9 (IMO, 2016).

Figure 8: Arctic - The waters north of latitude 60°N, with deviations to include waters around the southern exposure of Greenland, but excluding those around Iceland, the Norwegian mainland, Russia's Kola Peninsula, the White Sea, the Sea of Okhotsk and Alaska's Prince William Sound. (IMO, 2016)

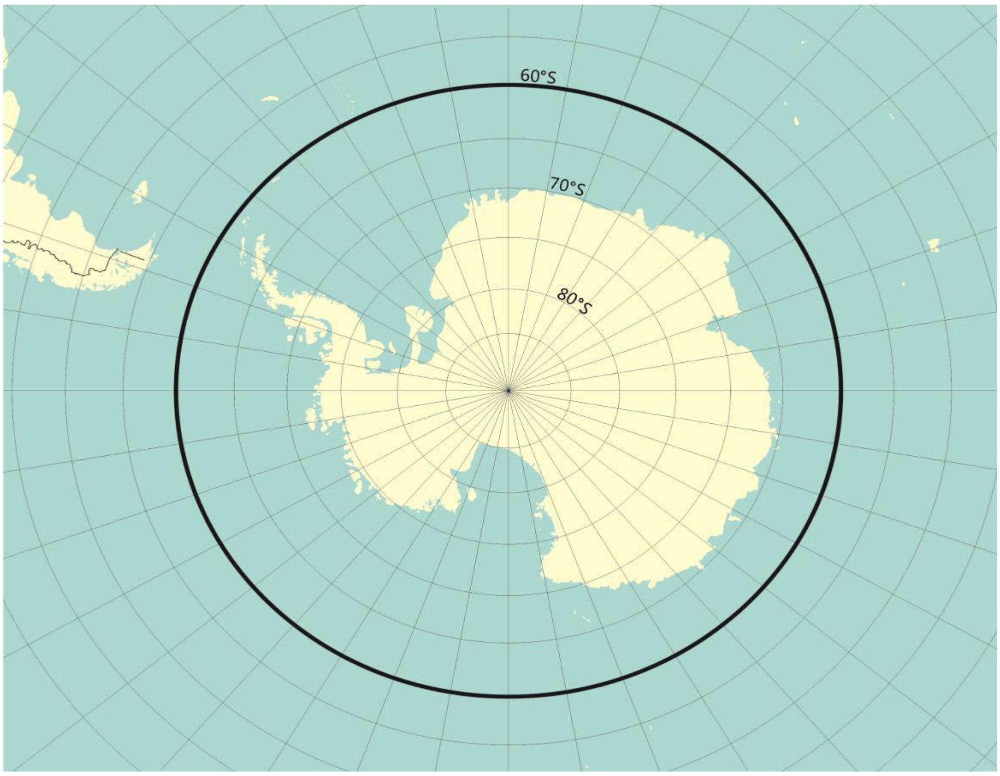

Figure 9: Antarctic - All waters south of latitude 60°S (IMO, 2016)

The Polar Code acknowledges the extra sensitive marine environment and hazardous conditions in the Arctic and Antarctic compared to other areas, hence the strengthened requirements to a ship and its crew. The Polar Code consists of part 1 A and B, as well as a part 2 A and B. Part 1A addresses safety measures through 12 chapters, while part 1B are recommendations. Part 2A addresses pollution prevention through 5 chapters, where part B also provides recommendations. Some key requirements in the Polar Code are:

- *Perform an Operational (Risk) Assessment*
- *Development of a Polar Water Operation Manual (PWOM)*
- *Carry a Polar Ship Certificate (PSC)*
- *Carry the appropriate training certificates*
- *Voyage planning to avoid areas with poor hydrographic data, remoteness ice and/or met ocean conditions that exceed the ship's design capabilities or limitations*

These requirements demand new documentation in order to operate in compliance with the Polar Code, as well as additional training of the ship officers. Other requirements are related to ship structure, stability, safety regarding navigation, fire, life-saving appliances (LSAs), as well as machinery and communication.

To establish procedures and operational limitations, an assessment of the ship and its equipment should be conducted. The Polar Code include guidance for an operational assessment (IMO, 2016):

- *Identify relevant hazards from section 3 of the Introduction and other hazards based on a review of the intended operations*
- *Develop a model to analyse risks considering (Refers to Formal Safety Assessment (FSA)):*
    - *development of accident scenarios*
    - *probability of events in each accident scenario*
    - *consequence of end states in each scenario*
- *Assess risks and determine acceptability:*
    - *estimate risk levels in accordance with the selected modelling approach*
    - *assess whether risk levels are acceptable*

- *In the event that risk levels determined in steps 1 to 3 are considered to be too high, identify current or develop new risk control options that aim to achieve one or more of the following:*
    - *reduce the frequency of failures through better design, procedures, training, etc.*
    - *mitigate the effect of failures in order to prevent accidents*
    - *limit the circumstances in which failures may occur*
    - *mitigate consequences of accidents*
    - *incorporate risk control options for design, procedures, training and limitations, as applicable.*

This will form the basis for the Polar Water Operation Manual (PWOM), where the goal is to *provide the owner, operator, master and crew with sufficient information regarding the ship's operational capabilities and limitations in order to support their decision-making process* (IMO, 2016). It is a ship specific document that describes how to operate the ship in polar waters. The PWOM must include risk-based procedures, which considers each hazard identified as relevant in the operational assessment, and it is meant to act as a supplement to the Polar Ship Certificate (PSC). An example of how the table of contents for a PWOM can look like is given in Appendix D (ABS, 2016).

The PSC is issued by a vessel's flag administration or its authorized representatives. It will verify that the vessel has conducted the necessary assessments and actions to operate in polar waters and complies with the Polar Code. The PSC will, among other information, contain specific information on the operational limitations of a vessel for *ice conditions, temperature, latitude* and *expected time to rescue* (IMO, 2016).

The new requirements for LSAs derive from the definition of *maximum expected time of rescue* in the Polar Code section 1.2.7. (IMO, 2016): *the time adopted for the design of equipment and system that provide survival support. <u>It shall never be less than 5 days.</u>* Three large live search and rescue (SAR) exercises have been conducted in the Svalbard area involving major actors from the Norwegian government, foreign and domestic academic institutions, as well as representatives from equipment manufacturers. The scope of these exercises has been to explore the gaps between existing SOLAS-equipment and the required Polar Code-equipment, where the functional survival requirement of 5 days after abandoning ship is at the centre. Important findings from these exercises involve the complicated mechanisms at play when surviving in a polar environment (equipment/functionality, mental/physical robustness, decision making, small error-margin), as well as the need for adequate training and education for the crew (Solberg, Gudmestad and Kvamme, 2016;2017; Solberg and Gudmestad, 2018).

The Polar Code is made mandatory for new ships from January 1st 2017, and ships constructed before January 1st 2017 will be required to meet the relevant requirements of the Polar Code by the first intermediate or renewal survey after January 1st 2018. The requirements on the crew members are enforced from July 2018.

3.2.3 Other Relevant Regulations, Systems and Guidelines

The Norwegian Maritime Authority (NMA) currently have additional rules for passenger ships operating in the Norwegian territorial waters around the Svalbard archipelago (NMA, 2017). This is currently only a circular however, a consultation regarding the forthcoming *Regulations on the construction, equipment and operation of passenger ships in the Norwegian territorial waters surrounding Svalbard* (NMA, 2019) was recently distributed. The deadline for inputs was set to March 3rd, 2019, and the regulation is scheduled into force on January 1st, 2020. These regulations will replace the circular.

The forthcoming regulations aim to raise the minimum safety standard requirement on passenger ships in the Norwegian territorial waters surrounding Svalbard. Important issues such as *voyage planning and monitoring, minimum distances to glacier fronts, hospital accommodation, helicopter evacuation procedures, specific requirements to tenders, life-saving appliances, construction, communication, navigation safety, safety management* and *safety measures in polar waters* are addressed (NMA, 2019). It is worth noticing that the *maximum expected time of rescue* is defined differently in the draft of these regulations than in the Polar Code: *The time adopted for the design of equipment and systems that provide survival support and could be less than 5 days* (NMA, 2019).

Canada and Russia have enforced regulatory standards in the Arctic for several years, having their own systems for ensuring safe operations in ice covered waters. The Canadian Arctic Ice Regime Shipping System (AIRSS) and the Russian Northern Sea Route Administration (NSRA) are administrating the functions of issuing permits and certificates, researching met-ocean conditions, coordination of icebreaker services etc. They also have methodologies in place for assessing the structural capabilities and limitations in different ice regimes and operational modes for ships operating in ice. In addition, IMO have issued their own methodology, the Polar Operational Limit Assessment Risk Indexing System (POLARIS), which has been developed incorporating experience and best practices from the AIRSS and the NSRA. Such a methodology is also a requirement in the PSC.

POLARIS is a decision support system that can be used for voyage planning and on the ship bridge. It uses the actual ice class of the ship and the actual ice conditions encountered to determine a Risk Index Outcome (RIO), which is a way of assigning a level of risk to ice operations for ships with certain ice classes. Based on POLARIS, the ship can get three criteria for the decision to operate (Lloyds, 2016).

- *Normal operations:* Not explicitly defined but it is implied that due caution and good seamanship are used. It is a recommendation to proceed but not to proceed blindly
- *Elevated operational risk:* More caution should be used, and a speed reduction is recommended (recommended speed limits are included). Other mitigation methods can also be employed. It is a recommendation to proceed more cautiously
- *Operations subject to special consideration:* Extreme caution is to be used. Suitable procedures should be implemented for reducing the risks including re-routing, further reduction in speed, and so on. For voyage planning, ice regimes where the RIO identifies operations subject to special consideration should be avoided. It is a recommendation not to proceed

For a thorough review of POLARIS, please consult Lloyds (2016).

The Association of Arctic Expedition Cruise Operators (AECO) and the International Association of Antarctica Tour Operators (IAATO) provide guidelines aimed towards cruise operators in the Arctic and the Antarctic, respectively. E.g. the AECO Guidelines for Expedition Cruise Operations in the Arctic (AECO, 2016) provide useful insight in how to plan, prepare and operate tours in the Arctic. These are guidelines and should not be treated as official laws and regulations.

3.3 Maritime Safety Challenges

An analysis of ship accidents from 1980 groups the following as the main causal factors for collisions and groundings (Kristiansen 2005):

- *External conditions* (i.e. the influence of external forces such as poor weather and waves, reduced visibility, etc.)
- *Functional failure* (i.e. failure or degradation of technical equipment, functions and systems)
- *Less than adequate resources* (i.e. inadequate ergonomic conditions, planning, organization and training)
- *Navigational failure* (i.e. failure in manoeuvring and operation, poor understanding of situation, etc.)
- *Neglect* (i.e. human failure, slips/lapses, and violations or deviation from routines, rules and instructions)
- *Other ships* (i.e. the influence of failures made by other ships)

The challenges in maritime safety today, compared to the 1980's, are basically the same. The focus however, seems to be more upon the human factors and organizational aspect. Findings from the maritime safety analysis conducted by the Norwegian Coastal Administration (NCA, 2015), show that the key current maritime safety challenges are: *Crew experience, training and expertise, bridge manning and Bridge Resource Management (BRM), fatigue, personal factors, stress and commercial pressure* and c*onfined and complex waters*. Batalden & Sydnes (2013) further emphasises the *lack of development of proper plans for shipboard operations* (i.e. an operation manual) as a key cause of accidents.

3.3.1 Root Causes

Root causes/underlying causes/basic events - there are many terms - can be described as pre-occurring causes which contribute to an event. However, if a root cause is perceived as for example "someone's behaviour" then it might be likely that the accident would occur by another cause at another time (Rasmussen, 1997). So, the root cause should be a "real" root cause. Labib and Read (2015) argues that a real root cause needs to be plan and policy related with respect to the current status quo. They further emphasize it should lead to initiation or modification of operating procedures, and it needs to contribute to the three features of learning from failures; feedback to design of existing procedures, use of advanced techniques to analyse failures and generation of interdisciplinary generic lessons (Labib and Read, 2015).

A root cause analysis of 65 reported marine incidents and accidents in the Arctic from 1993 to 2011 (Kum and Sahin, 2015) highlight several root causes related to *grounding* and *collision/contact*, which also relate to the current maritime safety challenges: *Conditions had greater effect than expected, manoeuvrability, competence, training which itself is inadequate, procedures inadequate, equipment not available, inadequate mode/scale/datum selected, no passage planning, no positions fixed, fatigue, task difficulty, visibility* and *speed - too fast for insufficient action taken.*

The root causes of incidents and accidents will increase or magnify when operating in polar waters, mainly due to the extreme met-ocean conditions and environmental factors.

3.3.2 Contributing Factors

Contributing factors of an incident or accident are related to broader issues than the root causes. By viewing the incident from a political, societal, theoretical or managemental perspective, we can describe it in a different way. *Regulatory, organizational, procedural* and *design* failures are examples of contributing factors. Kristiansen (2005) also emphasize the *safety culture* in an organization as an important causation of incidents, illustrated in figure 10.

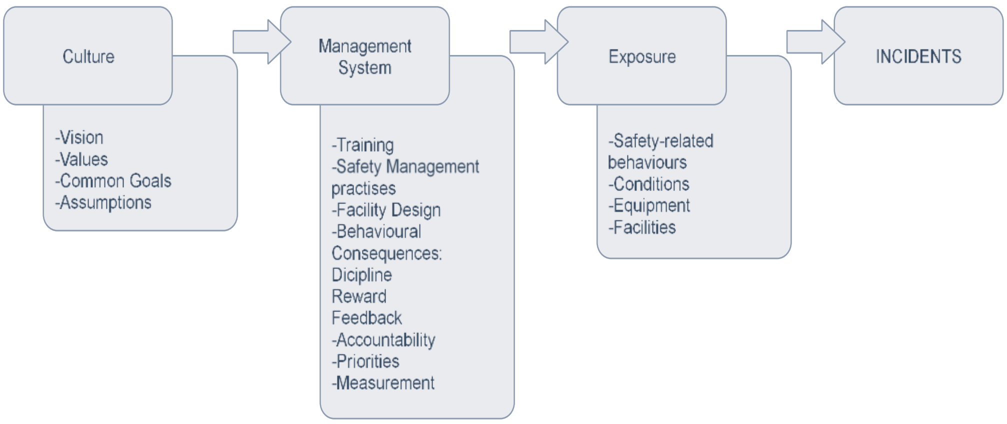

Figure 10: Causation of incidents (Kristiansen, 2005)

3.3.3 Human Factors

According to Rothblum et.al. (2002), maritime technology today is very advanced and highly reliable, yet incidents and accidents keep occurring. The maritime system is a *people* system, and human errors figure prominently in casualty situations. About 75-96% of marine casualties are caused, at least in part, by some form of human error. A human error can be described as: *an incorrect decision, an improperly performed action* or *an improper lack of* *action*. Human errors are generally caused by t*echnologies*, *environments*, and *organizations* which are incompatible in some way with optimal human performance (Rothblum et.al, 2002). Human factors can appear both as root causes and contributing factors, and they are the most important factor to consider related to incidents and accidents. The most common human factors are listed below.

Fatigue: Exhaustion, tiredness. In the maritime system, long working-hours and high work-loads are the main contributor to fatigue. Fatigue has been cited as the “number one” concern of mariners in two different studies (Rothblum et.al, 2002).

Communication: Inadequate communication internally on board the ship, ship-ship or ship-shore can be fatal. Good procedures and training can improve communication. Bridge Resource Management (BRM) - a concept originating from aviation - is a great contribution towards improving communication in the maritime system.

Complacency: *Self-satisfaction - especially when accompanied by unawareness of actual dangers or deficiencies.* When the working days are very similar, and the mariner is comfortable with the tasks at hand, it is easy to fall in to a routine state where everything is “business as usual”. The guard is dropped, and the (false) sense of security is present. Again, BRM is a great contribution to mitigate complacency.

Technical Knowledge: Lack of knowledge on how to operate ship equipment such as Integrated Bridge Navigation System (IBNS), Integrated Machinery Control System (IMCS) and Electronic Chart Display and Information System (ECDIS), as well as single components such as the navigation radar, echo sounder or gyro compass. There are many complex components and systems working together, and information can be lost due to improper use due to lack of knowledge.

Poor Design of Equipment: Equipment on a ship bridge usually originate from several different manufacturers with equally many designs and interfaces, and this will in turn vary from one ship to another. Complexity and level of integration can lead to single failures, which can give total loss of sensor information and source, which in turn can make error location and mitigation difficult. Design standardization combined with proper training and crew allocation can improve the issue.

Decisions Based on Inadequate Information: Failure to consult available information, either due to lack of technical knowledge or otherwise, can be fatal.

Poor Judgement: Actions not exercising good seamanship fall under this category. Passing too close, excessive speed and taking risks in general.

Faulty Standards, Policies or Practises: Sometimes, human error is due to poor procedures, poor management policies, risk-taking due to economic issues etc. This category is closely related to the *contributing factors.*

3.3.4 Preparedness

The main factors affecting SAR operations in polar areas are: *long distances, severe weather, ice and cold conditions, poor communications network, lack of resources presence in the region, the capacity to hoist patients, achieving situational awareness, lack of infrastructure* and *unsuitable evacuation and survival equipment* (FBG, 2017). The 8 Arctic countries have responsibilities covering an enormous area, illustrated in figure 11.

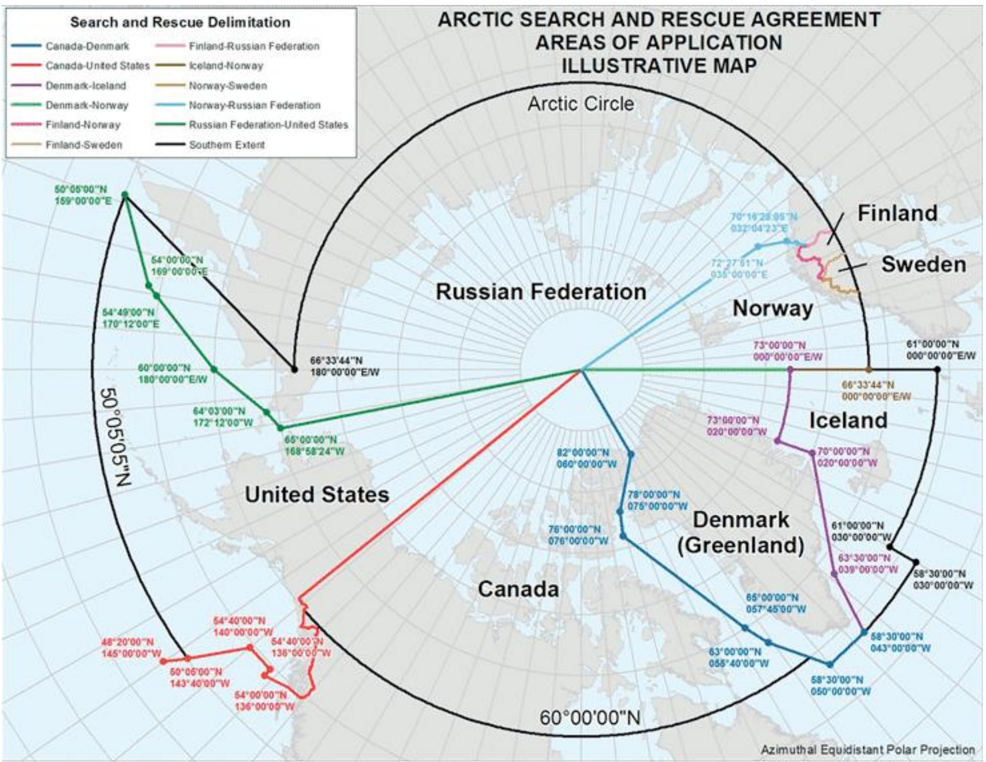

Figure 11: Arctic Search and Rescue agreement areas of application (FBG, 2017)

The 8 Arctic countries have different capabilities and different challenges, depending on the localization. The SAR agreement issued by the Arctic Council ensures cooperation between the countries. This is briefly mentioned in Appendix C.

3.3.5 Environment

The Polar Code lists sources of hazards which may lead to elevated levels of risk due to increased probability of occurrence, more severe consequences, or both (IMO, 2016). Some of these sources of hazards describe the environment well:

- *Ice, as it may affect hull structure, stability characteristics, machinery systems, navigation, the outdoor working environment, maintenance and emergency preparedness tasks and malfunction of safety equipment and systems*
- *experiencing topside icing, with potential reduction of stability and equipment functionality*
- *low temperature, 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*
- *extended periods of darkness or daylight as it may affect navigation and human performance*
- *high latitude, as it affects navigation systems, communication systems and the quality of ice imagery information*
- *remoteness and possible lack of accurate and complete hydrographic data and information, reduced availability of navigational aids and seamarks with increased potential for groundings compounded by remoteness, 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*

Table 3: Arctic Risk Influencing Factors (ARIF)

Arctic risk influencing factors									
Type	Ice	Topside icing	Low temperature	Extended periods of darkness or daylight	High latitude	Remoteness	Potential lack of ship crew experience in polar operations	Potential lack of suitable emergency response equipment	Rapidly changing and severe weather conditions
Description	May affect hull structure, stability characteristics, machinery systems, navigation, the outdoor working environment, maintenance and emergency preparedness tasks and malfunction of safety equipment and systems.	Potential reduction of stability and equipment functionality	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.	May affect navigation and human performance;	As it affects navigation systems, communication systems and the quality of ice imagery information.	Possible lack of accurate and complete hydrographic data and information, reduced availability of navigational aids and seamarks with increased potential for groundings compounded by remoteness, limited readily deployable SAR facilities, delays in emergency response and limited communications capability, with the potential to affect incident response.	Potential for human error	With the potential for limiting the effectiveness of mitigation measures.	Potential for escalation of incidents.
Types of data	EXT Ice extent (10% conc.)	AIR Air temperature	WCI Wind Chill Index	DAY Daylight/ darkness	COM Communication coverage and quality	BAT Bathymetry data coverage and quality	DAY Daylight/ darkness	LSA Ship's life saving equipment	WIN Wind speed and direction
	ICE Ice concentration	PRE Precipitation	AIR Air temperature			TOP Topography data and quality	AIR Air temperature		WAV Wave height
	TIC Ice thickness	VIS Visibility/fog	WIN Wind speed and direction			COA Coastline data (shape files)			AIR Air temperature
	ITY Ice type					SAR SAR resources and capacities			PRE Precipitation
	BER Ice berg					OIL Oil pollution prevention resources and capacity			TOP Topography data and quality
	FLO Floe size					ONS Onshore facilities/assets			
						POP Onshore population			
						POR Airport and harbour location and facilities			
						AIS AIS data			
						ATN Aids to navigation coverage and quality			
						PIL Mandatory pilotage areas			
						CAU Precaution areas and areas to be avoided			

A recent study carried out by the Norwegian Coastal Administration (NCA) on behalf of the Emergency Prevention, Preparedness and Response (EPPR) Work Group of the Arctic Council, breaks down the above-mentioned factors to quantify the additional Arctic risk, named ARIF (Arctic Risk Influencing Factors). This is illustrated in table 3.

To summarize, the environmental conditions are harsh but nonetheless fragile. Extra caution is needed when operating in these areas, and the Polar Code is an important contribution towards achieving this.

4 Root Cause Analysis of the Clipper Adventurer Grounding

An incident is examined using the Hybrid Model (Labib and Read, 2015) – the incident can be considered representative for the challenges that are present in polar waters. The incident in question is the grounding of the passenger vessel Clipper Adventurer in 2010 in Coronation Gulf, Nunavut in the Canadian Arctic. A systematic approach, utilizing the findings from the investigation report conducted by the Transportation Safety Board of Canada (TSB), is conducted to analyse the root causes of the grounding. The results will be further discussed in chapter 5.

4.1 Synopsis

On 27 August 2010, the passenger vessel Clipper Adventurer ran aground in Coronation Gulf, Nunavut while on a 14-day Arctic cruise. The vessel had a crew of 69 and 128 passengers on board at the time of the grounding, a total of 197 people on board. On 29 August, all 128 passengers were transferred to the Canadian Coast Guard Ship (CCGS) Amundsen and taken to Kugluktuk, Nunavut. The Clipper Adventurer was refloated on 14 September 2010 and escorted to Port Epworth, Nunavut. There was minor pollution and no injuries (TSB, 2012).

The Clipper Adventurer is a typical passenger vessel, as seen in figure 12. The vessel is built in 1975 with a length of 90,91 metres and a draught of 4,5-4,6 metres. The superstructure stretches the length of the vessel abaft a short foredeck. The hull is ice-strengthened, and the vessel has 2 controllable-pitch propellers and 2 semi-balanced flap rudders for improved manoeuvrability (TSB, 2012).

Figure 12: The Clipper Adventurer (TSB, 2012)

The navigational equipment comprises of 2 radars, 2 Electronic Chart System (ECS), 2 Global Positioning System (GPS), 1 echo-sounder, a Navigational Telex (NAVTEX), and a Global Maritime Distress and Safety System (GMDSS) station with Inmarsat-C Enhanced Group Call (EGC). The Clipper Adventurer is also fitted with a forward-looking sonar (FLS) mounted on the head of the bulbous bow; however, it was unserviceable at the time of the occurrence (TSB, 2012). The vessel had been extensively used in adventure cruises since 1998 and was classed 100 A1 Ice Class 1A Passenger Ship by Lloyd's Register.

The investigation report concludes with six findings as to causes and contributing factors (TSB, 2012). These findings are: *no voyage planning, high speed, FLS defect, no chart correction, inadequate SMS* and *notice to shipping (NOTSHIP) not obtained*.

4.2 FTA

By using the findings from the investigation report (TSB, 2012), input to a Fault Tree Analysis (FTA) of the incident is provided. The FTA visualizes the basic events leading to intermediate events, which in turn culminate in the grounding of the Clipper Adventurer, illustrated in figure 13. The FTA starts with categorizing the causal factors into *direct causes* and *contributing factors.* In this case the *direct causes* are specific actions or component failure that lead to the incident, while *contributing factors* are procedural, managemental or organizational causes contributing to the outcome.

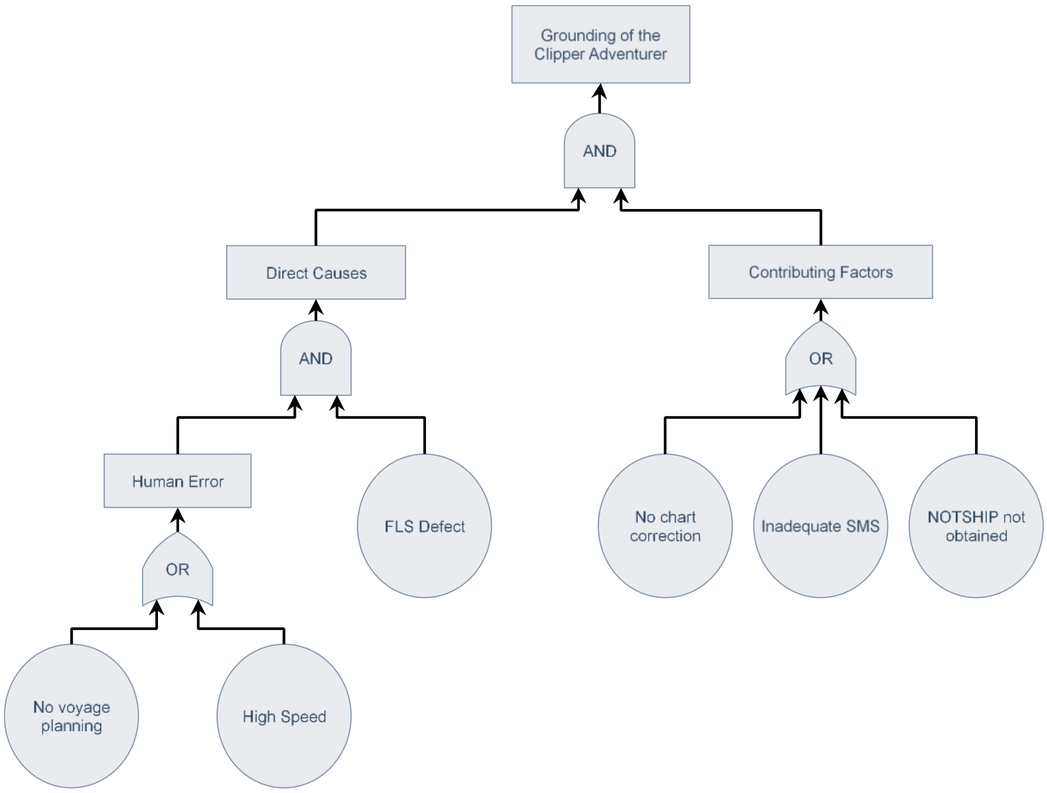

Figure 13: Fault Tree Analysis of the Clipper Adventurer grounding

The AND/OR gates describe the fault logic between the events. I.e. the gate underneath the intermediate event *human error* is an OR-gate, implying the output event *human error* is dependent on one of the two basic events to occur. In other words, either a *no voyage planning* fault OR a *high-speed* fault will result in *human error.* In turn, due to the AND-gate underneath the intermediate event *direct causes,* this event is dependent on both *human error* AND *FLS defect* to occur.

4.3 RBD

To improve the overall system reliability, a Reliability Block Diagram (RBD) is constructed. An RBD gives an overview of the system where AND-gates create parallel structures, indicating relatively safe areas. OR-gates create series structures, which are less safe – less reliable. For the grounding of the Clipper Adventurer, figure 14 show that the *direct causes* are modelled in a relatively safe parallel structure, while the *contributing factors* are modelled in a lesser safe series structure which make them more vulnerable i.e. a larger contribution.

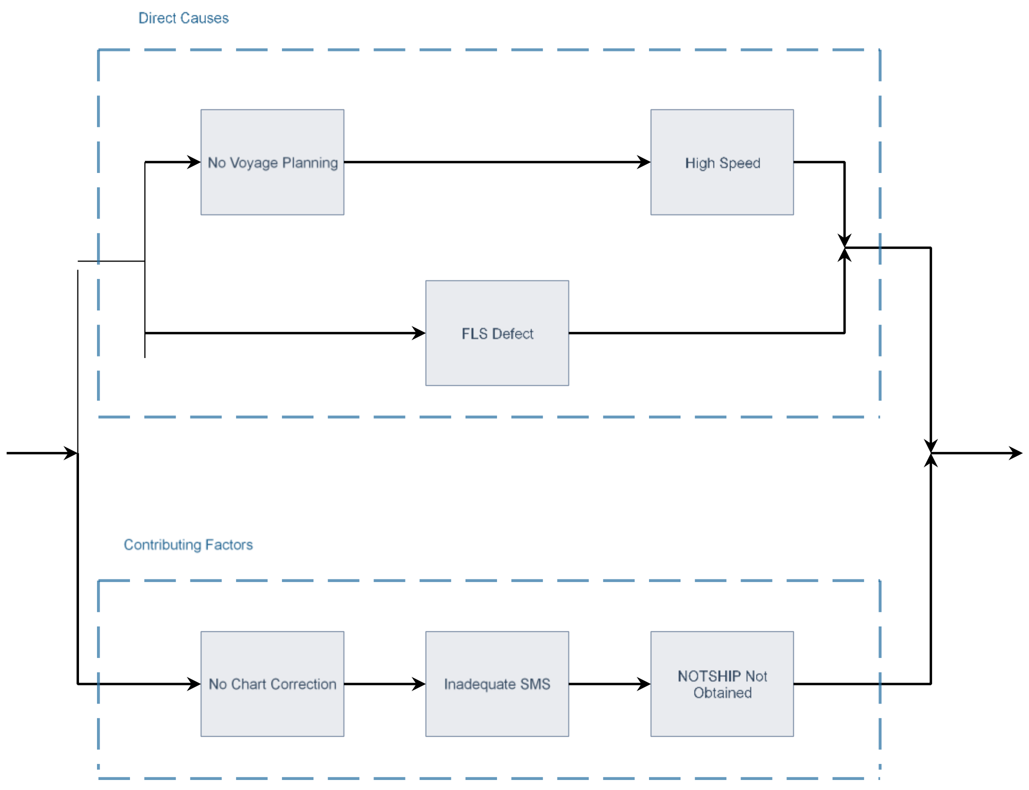

Figure 14: Reliability Block Diagram of the Clipper Adventurer grounding

4.4 FMECA and RPN

With the basic events identified, we develop a basic Failure Mode, Effect and Criticality Analysis (FMECA) to show each component – event – mode of failure, the effect, the cause of failure and how to mitigate the failure. In addition, a FMECA give us a Risk Priority Number (RPN) which we use to prioritize the events and show us which events should be focused upon.

The RPN is a product of three models; the probability of occurrence of the failure (O), the severity of the failure (S) and the difficulty of detection of the failure (D). The three models range from 1 to 5, as seen in table 4 to 6. It is important to note that this is a subjective tool and the numbering of the models is based on the author's understanding of the event in question.

Table 4: RPN Word Model for FMECA of the Direct Causes and Contributing Factors of the grounding of the Clipper Adventurer in terms of probability of Occurrence (O)

Keyword	Score
Very unlikely	1
Unlikely	2
Possible	3
Probable	4
Frequent	5

Table 5: RPN Word Model for FMECA of the Direct Causes and Contributing Factors of the grounding of the Clipper Adventurer in terms of Severity (S)

Keyword	Score
Repair cost only	1
Minor property damage	2
Significant property and minor environmental damage	3
Major property and significant environmental damage	4
Loss of life, major property and environmental damage	5

Table 6: RPN Word Model for FMECA of the Direct Causes and Contributing Factors of the grounding of the Clipper Adventurer in terms of difficulty of Detection (D)

Keyword	Score
Almost certain	1
High	2
Moderate	3
Low	4
Absolute uncertainty	5

By developing a FMECA, Labib and Read (2015) emphasizes three main achievements. *Firstly*, we utilize a straight forward step-by-step technique that is universally accepted as a method for systematically determining the ways in which failure can occur and the effects each failure can have on overall functionality. *Secondly*, we can anticipate the failures and prevent them from occurring. And *thirdly*, with a good FMECA we can identify known and potential failure modes, cause and effect of each failure mode and provide for problem follow-up and corrective action and prioritize according to the RPN.

Table 7 shows the six basic events using an FMECA. The effect of the failure is explained, followed by the cause of the failure, RPN calculation and risk mitigating measures.

The score from the word models resulting in an RPN are subjective and based on the author's understanding of the incident. It is worth noticing that the severity – S – in the FMECA is very high in all failures. This is based upon the area in question and the available search and rescue (SAR) resources in this area. The Canadian arctic is an extremely large area, and most of the SAR resources are based in the south. The distances and the climate are the two largest concerns for SAR entities when an incident occurs in polar areas. *Human error: No voyage plan*, *Human error: High speed* and *Inadequate safety management system* stands out as the three failures with the highest RPN.

Table 7: FMECA of the grounding of the Clipper Adventurer

Component and Mode of failure	Effect	Cause of failure	O	S	D	RPN	Risk mitigating measures
Human error: No voyage plan	Unsafe navigation in inadequately surveyed waters	Bridge team not following voyage planning procedures	3	5	3	45	BRM, safety culture, proper SMS
Human error: High speed	Steaming full speed ahead without knowing the water depth or navigational hazards	Bridge team choosing full speed ahead in unchartered waters.	3	5	3	45	BRM, safety culture, proper SMS
FLS defect	Bridge team not provided with safety critical information	Unserviceable condition	3	4	1	12	Maintenance schedule, spare parts, competence
No chart correction	Bridge team deprived of critical information	Authorities not issuing chart correction	2	4	3	24	Procedures, organizational
Inadequate safety management system	Bridge team deprived of systematic tools to maintain overall safety	Company SMS not providing proper safeguards to mitigate well-known risks	3	5	3	45	Continous improvement of company SMS, dynamic risk assessments
NOTSHIP not obtained	Bridge team unaware of the shoal	Inadequate voyage planning procedures	2	4	3	24	Procedures, organizational, continous improvement of company SMS

4.5 AHP

The FTA model is used as the hierarchical model in the Analytical Hierarchy Process (AHP). For this analysis, two AHP models are developed; one for the *direct* causes of the grounding and the other for the *contributing* factors. This is done to consider them as series and parallel structures, as seen from the RBD. The *alternatives* are now *other common factors* to consider when trying to solve the basic events. These factors are: the *probability of re-occurrence when the basic event remains unsolved*, the *safety impact (severity) caused by the basic event* and the *cost incurred when trying to device a solution* (Stephen and Labib, 2017). These three common factors are considered as decision variables since any decision taken will focus on mitigation against risk in the form of both probability of re-occurrence and severity as well as resource allocation in terms of cost incurred. These *other common factors* are the same as the ones used in the reference (Stephen and Labib, 2017), as they are transferable to the context in this analysis. An illustrative AHP model for this analysis is shown in figure 15.

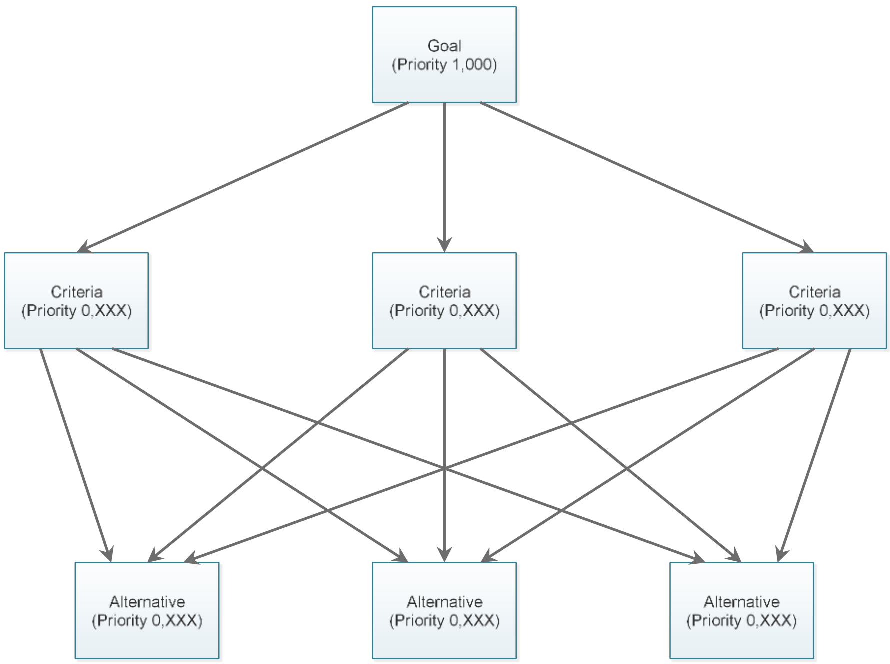

Figure 15: Illustrative AHP model of the Clipper Adventurer grounding

4.5.1 Direct Causes

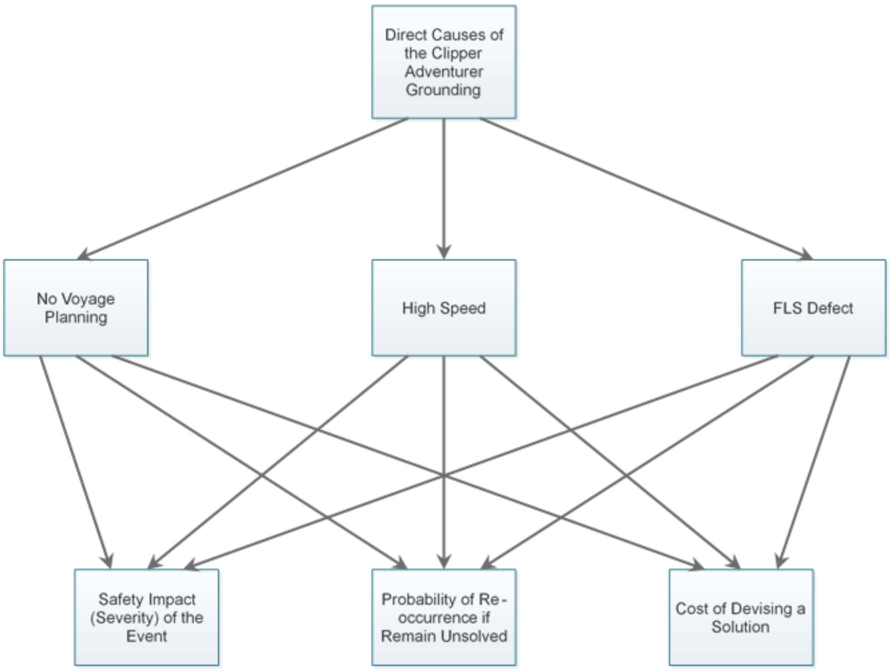

Figure 16: AHP model of the direct causes of the Clipper Adventurer grounding

The hierarchy in figure 16 represents the decision. There are three different *alternatives* to choose from and three *criteria* for choosing among the *alternatives*. First, a pairwise comparison of the *criteria* with respect to the *direct causes* is executed to derive the priorities. To demonstrate the whole process, table 8 shows the reasoning behind this pairwise comparison, where the authors subjective considerations make use of the absolute scale ranging from 1 to 9 (Saaty, 2013). The calculations made for deriving the priority from the eigenvalue method (Stephen and Labib, 2017), are conducted by using the online AHP Priority Calculator (AHPPC, 2017). Table 9 shows the results of the pairwise comparison.

Table 8: Reasoning behind pairwise comparison of the criteria with respect to the direct causes

No Voyage Planning	3	High Speed	1	No voyage plan is considered a moderately greater (3) contribution than high speed towards causing the grounding.
No Voyage Planning	5	FLS Defect	1	No voyage plan is strongly favoured (5) over the FLS defect towards causing the grounding.
High Speed	5	FLS Defect	1	High speed is strongly favoured (5) over the FLS defect towards causing the grounding. The FLS defect should have been well known and actions to compensate should have been initiated, i.e. reduce speed.

Table 9: Pairwise comparisons of the criteria with respect to the direct causes of the grounding

	No Voyage Planning	High Speed	FLS Defect	**Priority**	Rank
No Voyage Planning	1	3	5	**0,618**	1
High Speed	$^1/_3$	1	5	**0,297**	2
FLS Defect	$^1/_5$	$^1/_5$	1	**0,086**	3

Next, the *alternatives* are compared with respect to the *criteria*. As for the previous pairwise comparison it is based on the authors subjective considerations, however now only the results will be shown in tables 10 to 12. For the convenience in the given tables; Safety Impact of the Event = SI, Probability of Re-occurrence if Remain Unsolved = PR and Cost of Devising a Solution = CD.

Table 10: Pairwise comparison of alternatives with respect to No Voyage Plan

	SI	PR	CD	Priority	Rank
SI	1	3	7	0,669	1
PR	$^1/_3$	1	3	0,243	2
CD	$^1/_7$	$^1/_3$	1	0,088	3

Table 11: Pairwise comparison of alternatives with respect to High Speed

	SI	PR	CD	Priority	Rank
SI	1	2	7	0,574	1
PR	$1/2$	1	7	0,361	2
CD	$1/7$	$1/7$	1	0,065	3

Table 12: Pairwise comparison of alternatives with respect to FLS Defect

	SI	PR	CD	Priority	Rank
SI	1	$1/2$	3	0,292	2
PR	2	1	7	0,615	1
CD	$1/3$	$1/7$	1	0,093	3

Finally, the priorities of the *criteria* are multiplied with the priorities of each *alternative* and summarized. The synthesis of the priorities of the *alternatives* with respect to the *direct causes* is given in table 13.

Table 13: Synthesis of the priorities of the alternatives with respect to the direct causes

	No Voyage Planning	High Speed	FLS Defect	**Priority with respect to direct causes**	**Rank**
SI	0,413	0,170	0,025	**0,608**	**1**
PR	0,150	0,107	0,053	**0,310**	**2**
CD	0,054	0,019	0,008	**0,081**	**3**

The alternative *safety impact of the event* (SI) is considered the highest priority with respect to the *direct causes* with 60,8 percent. It is considered almost twice as important as the second-highest ranked alternative *probability of re-occurrence if remain unsolved* (PR).

4.5.2 Contributing Factors

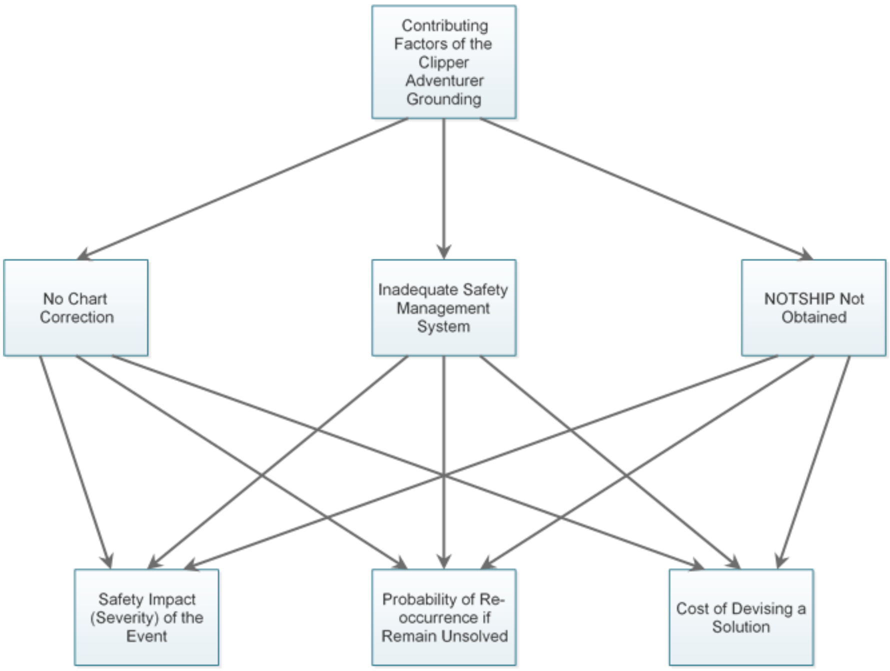

Figure 17: AHP model of the contributing factors of the Clipper Adventurer grounding

Again, the hierarchy in figure 17 represents the decision. There are three different *alternatives* to choose from and three *criteria* for choosing among the *alternatives*. First, a pairwise comparison of the *criteria* with respect to the *contributing factors* is executed to derive the priorities. To demonstrate the whole process, table 14 shows the reasoning behind this pairwise comparison, where the authors subjective considerations make use of the absolute scale ranging from 1 to 9 (Saaty, 2013). The calculations made for deriving the priority from the eigenvalue method (Stephen and Labib, 2017), are conducted by using the online AHP Priority Calculator (AHPPC, 2017). Table 15 shows the results of the pairwise comparison.

Table 14: Reasoning behind pairwise comparison of the criteria with respect to the contributing factors

No Chart Correction	1	Inadequate SMS	3	Inadequate SMS is moderately favoured (3) over no chart correction towards contributing to the grounding.
No Chart Correction	2	NOTSHIP Not Obtained	1	No chart correction is slightly favoured (2) over NOTSHIP not obtained towards contributing to the grounding.
Inadequate SMS	7	NOTSHIP Not Obtained	1	Inadequate SMS is very strongly favoured (7) over NOTSHIP not obtained towards contributing to the grounding.

Table 15: Pairwise comparisons of the criteria with respect to the contributing factors of the grounding

	No Chart Correction	Inadequate SMS	NOTSHIP Not Obtained	**Priority**	Rank
No Chart Correction	1	$^1/_3$	2	**0,216**	2
Inadequate SMS	3	1	7	**0,682**	1
NOTSHIP Not Obtained	$^1/_2$	$^1/_7$	1	**0,103**	3

Next, the *alternatives* are compared with respect to the *criteria*. As for the previous pairwise comparison it is based on the authors subjective considerations, however now only the results will be shown in tables 16 to 18. Again, for the convenience in the given tables; Safety Impact of the Event = SI, Probability of Re-occurrence if Remain Unsolved = PR and Cost of Devising a Solution = CD.

Table 16: Pairwise comparison of alternatives with respect to No Chart Correction

	SI	PR	CD	Priority	Rank
SI	1	$^1/_3$	6	0,285	2
PR	3	1	8	0,653	1
CD	$^1/_6$	$^1/_8$	1	0,062	3

Table 17: Pairwise comparison of alternatives with respect to Inadequate SMS

	SI	PR	CD	Priority	Rank
SI	1	2	7	0,566	1
PR	$1/2$	1	8	0,373	2
CD	$1/7$	$1/8$	1	0,061	3

Table 18: Pairwise comparison of alternatives with respect to NOTSHIP Not Obtained

	SI	PR	CD	Priority	Rank
SI	1	$1/3$	5	0,279	2
PR	3	1	7	0,649	1
CD	$1/5$	$1/7$	1	0,072	3

Again, the priorities of the *criteria* are multiplied with the priorities of each *alternative* and summarized. The synthesis of the priorities of the *alternatives* with respect to the *contributing factors* is given in table 19.

Table 19: Synthesis of the priorities of the alternatives with respect to the contributing factors

	No Chart Correction	Inadequate SMS	NOTSHIP Not Obtained	**Priority with respect to contributing factors**	**Rank**
SI	0,062	0,379	0,029	**0,470**	**1**
PR	0.141	0,254	0,067	**0,462**	**2**
CD	0,013	0,042	0,007	**0,062**	**3**

With respect to the contributing factors, the alternative *safety impact of the event* (SI) is considered just slightly more important than the alternative *probability of re-occurrence if remain unsolved* (PR). For all practical purposes, they are equally ranked.

4.6 Aftermath

4.6.1 Responsibility

The owners of the Clipper Adventurer were ruled responsible of the grounding and will have to pay nearly 500000 dollars in environmental costs to the Canadian government (CBC, 2017). This sets an important precedence, as the decision reads "*Had Officer Mora … taken serious note of the publications with which he was required to be familiar, he would have known perfectly well that there were written NOTSHIPs [notices to shipping], and that if he could not get them by visiting the Canadian Coast Guard website, all he had to do was call MCTS Iqaluit*" (CBC, 2017). The decision further states that "*As it was, this nonchalant attitude put the lives of close to 200 souls at risk*" (CBC, 2017). This emphasises the importance of a good safety culture, good Bridge Resource Management (BRM) and a proper and dynamic safety management system (SMS) on board a vessel operating in the Arctic. The Polar Code is a huge step in the right direction, forcing ship owners and management companies to revise and update their plans and standard operating procedures (SOPs).

4.6.2 Organizational Changes

As of January 2019, the Canadian Coast Guard's Maritime Communication Traffic Service (MCTS) program has launched a national navigational warning (NAVWARN) issuing service to replace the existing domestic NOTSHIP services. The new NAVWARN Issuing System will provide greater harmonization in both the format and content of navigational warnings (MARINFO, 2019). This was one of the risk findings after the Clipper Adventurer grounding (TSB, 2012), and it is a great contribution towards reducing the risk of communication failure due to different terminology. A minimum of standardized terminology should be in place for actors operating in polar areas, reducing the risks even further.

4.6.3 A Similar Incident

The passenger ship Akademik Ioffe ran aground in the Gulf of Boothia near Kugarook in the Canadian Arctic on August 24th, 2018, carrying 162 passengers and crew on board. The incident shares many similarities to the Clipper Adventurer in terms of damage potential and is still under investigation by the TSB. In the case of the Ioffe incident, one difference compared to the Clipper Adventurer stands out. The Akademik Sergey Vavilov, the sister ship of the Ioffe, was the closest vessel and the first to arrive the scene to assist, apparently by chance. Acting as a "buddy", the two vessels could utilize the same small boats and the same davits to transfer people from the Ioffe to the Sergey Vavilov. As a bonus, the passengers knew their way around the Sergey Vavilov. Though coincidental, this serves as a good example of the buddy system in action. We may not always have two identical vessels pairing up, but it is a reminder that a minimum of standardization, e.g. ability to use each other's small boats, is an advantage. The incident is mentioned in Appendix C.

5 Results and Discussion

What encourages risk taking when operating a vessel? Good seamanship would be to play it safe and avoid danger, always thinking ahead. The results from the root cause analysis of the Clipper Adventurer grounding and the responses from the survey are presented below and discussed in relation to maritime safety challenges and the research questions. The discussion highlights the importance of preventive actions towards mitigating risks in polar waters, due to the severity of the potential consequences when cruise ships are involved.

5.1 Root Cause Analysis

The Fault Tree Analysis (FTA), in which the top event is the grounding of the Clipper Adventurer, derives two immediate intermediate events; *direct causes* and *contributing factors*, as well as a third placed under the *direct causes; human error*. There are six basic events in total. The FTA illustrates how the different events depend on each other and how they together contribute to the occurrence of the top event.

The six basic events in the FTA derive from the findings in the investigation report (TSB, 2012). The *direct causes* consist of three basic events. *No voyage planning* represents the bridge team and them choosing not to follow the company voyage planning procedures, while *high speed* represents the bridge team and their decision to steam full ahead even though they were in unchartered waters. Either of these two events result in *human error. FLS Defect* is a specific component failure that contributed directly to the incident. Further, the *contributing factors* in the grounding of the Clipper Adventurer are the last three basic events. *No chart correction* represents the mapping authorities not issuing a chart correction even though the shoal was known. *Inadequate SMS* represent the SMS on board lacking proper safeguards to mitigating well-known risks. *NOTSHIP not obtained* represent the difficulty in obtaining the NOTSHIP in question – in this case a combination of procedural and organizational causes.

The Reliability Block Diagram (RBD) show that the *direct causes* are modelled in a relatively safe parallel structure, while the *contributing factors* are modelled in a lesser safe series structure which make them more vulnerable. This indicates that the occurrence of only one *contributing factor* (series) will have a larger impact on the event than a *direct cause* (parallel), i.e. a contributing factor will “contribute more” to the event. Hence, the *contributing factors* should be given more equal priority between each other.

The Failure Mode, Effect and Criticality Analysis (FMECA) illustrate the events as components that fail, what causes the failures and how to mitigate the risks related to them. A FMECA is best applicable for failure modes, therefore the Risk Priority Numbers (RPN) for the *direct causes* are most representative. The *contributing factors* are more subjectively assessed than the *direct causes*, and the Analytical Hierarchy Process (AHP) can provide a better prioritizing of the *contributing factors*. The RPN values are shown in table 20 below.

Table 20: RPN values from the FMECA

Component and Mode of Failure	RPN	Rank
Inadequate SMS	45	1
Human error: No voyage plan	45	2
Human error: High speed	45	3
No chart correction	24	4
NOTSHIP not obtained	24	5
FLS defect	12	6

The ranking is based on the author's subjective understanding, as discussed below.

Human error: No voyage planning. According to the investigation report (TSB, 2012) the bridge team chose to navigate a route on an inadequately surveyed single line of soundings. Had the bridge team chosen to go through with a proper voyage planning procedure in accordance with IMO res A.893 (21) *Guidelines for Voyage Planning*, they might have become aware of the Notice to Shipping (NOTSHIP) warning of the shoal and they might have chosen a different route. The effect of these actions is obvious – the ship is sailing in unchartered waters. This involves high risk regardless of where the ship is operating. To reduce the risk of this failure, a good safety culture within the bridge team must be established. This is achieved with high competence in Bridge Resource Management (BRM) and a safety management system (SMS) that cover all risks that may occur.

Human error: High speed. The Clipper Adventurer was proceeding at full speed, even though they were in unchartered waters, the forward-looking sonar (FLS) was defective and they were not on a planned route (TSB, 2012). By heading at full speed, several aspects need to be considered. For example, the time to make decisions is reduced, the damage potential is greater, and hydrodynamic effects may also start affecting the ship. These are important aspects for the bridge team to bear in mind. Risk reducing measures to prevent this failure of happening again is like the previous failure; BRM competence, an adequate SMS and good seamanship.

FLS defect. The inoperative state of the FLS resulted in the Clipper Adventurer having no shipboard means of assessing the water depth ahead of the vessel (TSB, 2012). The fault is easily detected and should have resulted in extra vigilance from the bridge team, being deprived of one of their most important sensors. To prevent this failure from re-occurring, the maintenance scheme, the shipboard spare parts storage and the shipboard competence should be investigated. Also, one could argue that the operational area of the ship is reduced when losing this sensor. An adequate SMS and a proper maintenance schedule could have prevented this cause.

No chart correction. As explained in the investigation report (TSB, 2012), the Canadian Hydrographic Service (CHS) Central and Arctic did not issue a chart correction. This meant that the bridge team was deprived one source of information about the shoal (the other being the NOTSHIP). Published charts are subject to amendments and corrections as new information becomes available. The CHS Central and Arctic practices *not* to issue and apply chart corrections when the hydrographic data does not meet their demands, as do many other hydrographic services. However, the information of the shoal, obtained by the CCGS *Sir Wilfrid* Laurier, did meet the International Hydrographic Organization (IHO) criteria for a chart modification in a remote area. In this case the symbols for Position Approximate (PA) or Position Doubtful (PD) could have been used. But, the CHS Central and Arctic tries to avoid issuing PAs or PDs on arctic charts because of the risk that incorrect or incomplete information in poorly surveyed areas could mislead mariners as to the true location of the hazard, or onto another unreported hazard. So, the shoal was known but there was no chart correction issued. The CHS Central and Arctic could investigate the procedures within their organization to reduce the risk of this happening again.

Inadequate safety management system. The ship management company's SMS did not provide the bridge team with proper safeguards to mitigate well-known risks. This includes revision of the voyage plan in conjunction with the management company; assurance that the FLS was operable; use of the zodiacs with portable echo-sounders when necessary; assurance that the vessel transited at lower speed when operating in poorly charted areas; and acquisition of NOTSHIPs local navigation warnings (TSB, 2012). Had the proper tools for identifying the (well-known) risks been in place, the Clipper Adventurer might have avoided the grounding. Again, the importance of a proper SMS and dynamic risk assessments are key elements to safe ship operations.

NOTSHIP not obtained. The shoal had been previously identified and reported in a NAVWARN, at the time called a NOTSHIP in Canada. However, the bridge team was unaware of and did not actively access local NOTSHIPs, nor did the Canadian Arctic Marine Traffic System (NORDREG) specifically advise them of the NOTSHIPs applicable to the vessel's area of navigation (TSB, 2012). Amongst the risk findings in the investigation report (TSB, 2012), when NOTSHIPs are no longer broadcast, vessels operating in Canadian Arctic waters can only obtain the information on written NOTSHIPs by specific requests to Maritime Communication Traffic Services (MCTSs) or by accessing the Canadian Coastguard website. In areas with unreliable internet connectivity, this may limit the mariner's awareness of known hazards. Also, the term "Notice to Shipping" is not used outside Canada, whereas the terms Local Warning or Navigational Warning are more widely used and recognized by foreign crews. Herein lies the causes of this failure; the unavailability of the information combined with the unfamiliar local terminology of the NOTSHIP and the inadequate voyage planning procedures. To reduce the risk of this failure, an organizational investigation may identify some areas of interest (availability of the information and terminology), and a revision of the SMS and voyage planning procedures by the ship management company is recommended.

The Analytical Hierarchy Process (AHP) provided a numerical representation of the author's judgements, and it was interesting to see how the numbers came out. They largely represent the author's view on the matter, and obviously they are subject to the bias concerning the author's predispositions and understanding of the context. The accuracy of the outcome of the Hybrid Model process could likely be improved by having a group of subject matter experts involved, as is often the case for qualitative risk analysis.

The result of the AHP is the priority of the *alternatives* with respect to the *direct causes* and the *contributing factors* as shown in table 21.

Table 21: Summary of priorities of alternatives

	Direct Causes	**Contributing Factors**
Safety Impact of the Event	**0,608**	**0,470**
Probability of Re-occurrence if Remain Unsolved	0,310	**0,462**
Cost of Devising a Solution	0,081	0,062

With respect to the *direct causes*, the alternative *safety impact of the event* is considered the highest priority with 60,8 percent. It is considered almost twice as important as the second-highest ranked alternative *probability of re-occurrence if remain unsolved* with 31,0 percent, which in turn is almost four times as important as the *cost of devising a solution* with 8,1 percent. This indicates that the *direct causes* (no voyage planning, high speed and FLS Defect) contribute greatly to the *safety impact of the event*. I.e. the severity would be less if the bridge team had a voyage plan or the speed was reduced.

With respect to the *contributing factors*, the alternative *safety impact of the event* is considered just slightly more important than the alternative *probability of re-occurrence if remain unsolved,* with 47,0 percent and 46,2 percent respectively. They are as good as equally ranked and they are both considered almost eight times as important as the *cost of devising a solution* with 6,2 percent. This indicates that the *contributing factors* (inadequate SMS, no chart correction and NOTSHIP not obtained) are more equally contributing to both the *safety impact of the event* and the *probability of re-occurrence if remain unsolved.*

For both *direct causes* and *contributing factors*, the *cost of devising a solution* have the lowest priority. This is simply explained by the author’s opinion that the cost should not be an issue when it comes to safety. The *safety impact* and the *probability of re-occurence* will always outweigh the *cost* when it comes to the safety of human life. If the solution is to revise the company SMS or repair the FLS, this is a small price to pay compared to the alternatives.

5.2 Survey

The questionnaire, as shown in Appendix A, generated 7 responses, where 5 have answered all the questions. Although none of the respondents are from the cruise industry, several challenges have been mentioned in the survey that apply for cruise vessels operating under the Polar Code. Vessels operating in polar waters mostly face the same challenges. What separates cruise vessels from other vessels is the severity of the potential consequences of e.g. a grounding or any situation where people must abandon ship and/or be evacuated. The number of passengers vary from only a few dozen on board the smallest explorer vessels to hundreds or thousands on board the largest vessels. The SAR challenges will increase dramatically along with the number of passengers. The answers are presented in full in Appendix B, highlights are presented below.

Q1: In your experience, what are the challenges meeting the STCW requirements of the Polar Code?

- *Make basic/advanced course participants aware of the dangers and limited resources for assistance in remote areas* **(R1)**
- *Experience in ice of the participants in basic/advanced courses is limited – the benefits of a basic/advanced course for a crew with some ice experience is far better* **(R2)**
- *Accumulating sea time. Advanced course requires 2 months of seagoing service in polar waters (as defined in the Polar Code), for most passenger ships this will take years* **(R3, R4)**
- *Crew getting certificates with only summer operation experience* **(R5)**
- *A simulator can only provide so much – real experience is needed* **(R6)**

Regarding the challenges related to training and certification (STCW), several issues are mentioned. According to the *STCW Convention Regulation V/4, Section A-V/4, and Tables A-V/4-1 and A-V/4-2,* the sea time required for a certificate in advanced training for ships operating in polar waters is at least 2 months of approved seagoing service in the deck department, at management level or while performing watchkeeping duties at the operational level, within polar waters or other equivalent approved seagoing service. As R3 points out, this can take a long time for some deck officers, and when they do get their license, they may only be experienced in summer operations as R5 highlights. Combined with little or no experience before entering a Polar Code training course, the total output of competence can be quite low even for a licenced deck officer. It seems there should be a distinction between summer and winter operations, rather than a distinction between basic and advanced courses. Further, a simulator can go a long way in creating a realistic training environment. Even if real experience in polar waters is preferred, as stated by R6, simulator experience is perhaps the most realistic approach in terms of time and cost. Efforts should be made towards achieving high standard simulators for ice conditions and polar water operations.

Q2: In your experience, what are the challenges meeting the SOLAS requirements of the Polar Code?

- *There should be more detailed specifications towards the requirements* **(R1)**
- *Vessels are not ready for a real incident even though they are complying with SOLAS* (refers to the SARex exercises) **(R2)**
- *The goal-based approach for part 1 of the Polar Code does not give good standards for manufacturers* **(R2)**
- *LSAs today are inadequate for polar waters and 5-day survival requirement* **(R3, R7)**
- *Many vessels have insufficient winterization characteristics* **(R3)**
- *Different interpretation from classification societies and flag states* **(R4)**
- *Distinguish between summer operation and winter operation with regards to equipment* **(R5)**
- *Reason must be applied when selecting area of operation and operational season with regards to winterization* **(R6)**

The main challenges related to SOLAS seem to involve the LSAs and the "5-day survival requirement" derived from the definition of the *maximum expected time of rescue* in the Polar Code (IMO, 2016). 5 days is a long time to survive after abandoning a ship in polar areas, and some might say this is impossible and only a theoretical requirement. However difficult this may seem, the reason for such a requirement is based on the environmental factors in the area, and it also points out that safety of the passengers should not be taken lightly. It is important to set a high standard in the beginning, and maybe there will be more specifications and adjustments as more experience is gained. No doubt, the requirement forces the survival equipment to a new level of performance and presents challenges regarding arrangements and capacity on board a vessel. There is ongoing work in this area both nationally and internationally. The forthcoming *Regulations on the construction, equipment and operation of* *passenger ships in the Norwegian territorial waters surrounding Svalbard* (NMA, 2019), proposes a new definition of the *maximum expected time of rescue* as it states that it *could be less than 5 days*. This would in theory reduce the LSA requirements for the area in question substantially. Still, the Polar Code also requires operational (risk) assessments, procedures and measures to mitigate the risks and these must consider the expected time of rescue. Further, the IMO Sub-Committee on Ship Systems and Equipment (SSE) have drafted interim guidelines on life-saving appliances and arrangements for ships operating in polar waters (SSE, 2017), which will supplement the Polar Code. The draft specifies several important improvements to e.g. thermal protective aids, life rafts, life boats and rations, many which are based on the recommendations from SARex Spitzbergen (Solberg et.al, 2016) and SARex 2 (Solberg et.al, 2017). The goal of the draft is to assist in the global and uniform implementation of the Polar Code, and it also provides more detailed specifications for suppliers of LSAs. Perhaps if the requirements to LSAs are specific and dimensioned for 5 days or more, the maximum expected time of rescue definition is not so crucial. This is also one of the recommendations from SARex 3 (Solberg and Gudmestad, 2018), which proposes to define a few key parameters that enable flag states and classification societies to verify equipment packages in a transparent way.

As an example, the LSA-Code paragraphs 4.1.5.1.18 and 4.1.5.1.19 requires the rations and fresh water on a life raft to be a total of 10000kJ *per person* and 1,5 litres of fresh water *per person*. The drafted interim guidelines (SSE, 2017) proposes an increase to 12000kJ *per person per day* and 2 litres of fresh water *per person per day*. A massive increase, and most certainly an expensive one if you have several hundred passengers and the appropriate amount of life rafts and life boats on board. Obviously, the Polar Code requirements may lead to high costs for a cruise vessel.

Still, as of now the “5-day survival requirement” is in force, and most of the respondents have mentioned it. The LSAs on board vessels today are mostly in compliance with regulations that do not consider the hazards in polar waters, and therefore most vessels have inadequate LSAs for areas covered by the Polar Code. The SARex projects have identified many challenges related to survival in polar areas, and it seems there still is a way to go regarding LSAs complying with the Polar Code as it is today.

R5 mentions the difference between summer and winter conditions, perhaps there should be a distinction also here between LSAs and equipment requirements for summer and winter operations. R6 states that the issues related to winterization, in terms of costs and potential follow-up equipment, starts with selecting the appropriate Polar Service Temperature (PST) for the proposed area of operation and operational season. This could be equally important when it comes to selecting the appropriate LSAs and equipment.

The IMO Sub-committee on Navigation, Communications and Search and Rescue (NCSR) also recently drafted general guidance for navigation and communication equipment intended for use on ships operating in polar waters (NCSR, 2018), which recommends new standards for equipment to adjust for the polar environment.

Q3: In your experience, what are the challenges meeting the MARPOL requirements of the Polar Code?

- *Possible future challenges with regards to fuel substances with severe environmental impact in case of spill* **(R3)**
- *Few receiving facilities for waste and sludge, and possibly grey water* **(R4, R5)**
- *MARPOL focus on transiting or destinational shipping – compliance can be difficult for vessels spending longer periods of time in ice covered waters* **(R6)**

R4 and R5 highlight few receiving facilities for waste and sludge, and possibly grey water, as potential challenges. Receiving facilities could be expanded, but there are limitations in the infrastructure. A suggestion is to increase capacity on board, and strict routines for depositing all waste and sludge before entering polar waters.

R3 also points out that heavy fuel oil (HFO) is allowed today, but a future prohibition may lead to some challenges for vessels who rely on HFO. Still, the protection of the polar environment is one of the main goals of the Polar Code and a spill of a substance with major environmental impact is to be avoided.

Q4: In your company, how is the operational (risk) assessment of the ship conducted?

- *Follow classification society "templates"* **(R2)**
- *On board prior to each ice related operation including all crew who is involved* **(R3)**
- *Conducted by office personnel and experienced ship staff* **(R4)**
- *Initially done by chartering, technical, HSEQ and crewing departments to check if vessel and crew is fit for purpose. In-house ice and arctic expertise are involved through the whole process* **(R5)**
- *Combination of internal and external* **(R6)**

The optimal approach to the operational assessment of a ship seem to involve the different office departments as well as experienced crew members. The operational assessment is supposed to *consider the anticipated range of operating and environmental conditions, such as: operation in low air temperature, operation in ice, operation in high latitude, the potential for abandonment onto ice or land, hazards (as listed in section 3 of the Introduction, as applicable, and additional hazards, if identified* (IMO, 2016). No doubt, the inclusion of all involved departments, onshore and offshore, is reasonable. The operational assessment is ship specific, hence personnel with knowledge and experience operating the ship (deck, technical, engineering) is important. For newbuilds, the work towards a Polar Ship Certificate (PSC) should be integrated by designers and shipyard.

Perhaps a template can provide some guidance in how to get started or where to end up, but it seems that all the serious operators utilize on board and in-house expertise in this process. This is probably easy for operators with extensive experience in polar waters, but where do you start when there is no expertise in-house? A solution might be external aid from experienced personnel. There are several consultants with extensive experience in polar waters offering their services. The Polar Code also offer guidance on how to perform an operational assessment. The guidance is a good place to start, but the input from experienced personnel is very important in order to identify all hazards possible.

Q5: In your company, how is the Polar Water Operation Manual (PWOM) developed?

- *Operators already operating in polar areas for decades have most of the PWOM already covered in their SMS* **(R2, R3, R4, R5)**
- *In the process of developing the PWOM, several already existing procedures and checklists in the SMS was updated to comply with the Polar Code and the PWOM also refers to this ISM document* **(R5)**
- *For new vessels; external support from designer and shipyards. For existing vessels; in-house development using own subject matter experts* **(R6)**

An interesting finding is that well established operators already have most of the requirements to a PWOM covered in their existing SMS. For an operator already established in polar waters, naturally the existing procedures cover this, and it should not be a surprise as personnel with experience from polar areas are probably involved in the development of the Polar Code itself. Still, these operators possess valuable knowledge of operations in polar waters. The consultants aiding an inexperienced operator and the lecturers of basic/advanced courses are probably from said operators and will naturally share their knowledge in the process towards a PSC or during one of their basic/advanced courses. Perhaps a more standardized method for knowledge sharing should be established? An example of how a PWOM could look like is shown in Appendix D.

Q6: In your company, who participate in the development of the Polar Water Operation Manual (PWOM)?

- *Manual table of contents same as for operational risk assessment, shipboard personnel more involved in the manual development itself (end users)* **(R6)**
- *Mostly same as for operational risk assessment* **(All)**

Naturally, and hopefully, the same personnel are involved in the whole process.

Q7: Are the non-conformities and lessons learned from previous operations considered when performing the operational (risk) assessment or developing the Polar Water Operation Manual (PWOM)?

- *Previous experience from sub-arctic does not always compare to polar waters* **(R2)**
- *Operators already operating in polar areas for decades have all their experience available in the same SMS* **(R2, R3, R4)**
- *Debriefing after an arctic operation including all departments. Lessons learned are followed up to improve systems and procedures* **(R5)**
- *Not easy to update a document stamped by the class society or flag state* **(R5)**
- *Yes, although a very small percentage of total incidents attributed to operations in ice* **(R6)**
- *The PWOM will be auditable under the organizations safety management system* **(R6)**

I find it an interesting remark from R2 that some of the previous experience from areas other than polar waters does not always compare to polar waters. This is of course true, but still there are many factors that apply for an operation regardless of the geographical location. It would be very interesting to learn how cruise operators do this, especially operators inexperienced in polar waters. Many expedition cruise operators have been operating in polar waters for many years, and it is likely to assume that they also have many of the requirements in the Polar Code already covered. Still, the non-conformities and lessons learned from previous operations should always be brought forward to improve the safety of an operation. It is important that the SMS document these properly, so that new personnel can access this knowledge and it does not leave the organization with experienced personnel.

It is also a good routine as R5 describe it, to have a debriefing including all personnel after an operation, to identify important lessons and implement them in the SMS. A key concept here must be to do this immediately after the operation, as to ensure the capture of all elements. Further, all input from all involved personnel is important in this matter. If a process like this is conducted after every operation, over time the procedures will be optimized, and the safety level will be very satisfying.

In the offshore shipping segment, charterers influence safety management (Batalden, 2015), and any non-compliance or consistent lack in following procedures will result in the company not getting re-hired. Perhaps a regulatory regime more similar to the offshore shipping segment would be beneficial for the polar cruise shipping segment in terms of safety.

Q8: Is compliance to the Polar Code considered beneficial to the company?

- *Yes, to avoid claims. One of the passengers can be a member of Greenpeace collecting evidence (Greenpeace is also following Basic and Advanced courses)* **(R2)**
- *There is absolutely no reason NOT to follow the requirements in the Polar Code, whereas there are numberless reasons to do. Any negative attitude towards the Polar Code will most likely end up being an organizational suicide for any cruise company that travels the polar regions* **(R3)**
- *Each competitor needs to comply as well, so there is no difference* **(R4)**
- *We are very much depended that we have vessels complying with the code* **(R5)**
- *Regulatory compliance is done in the spirit of the applicable codes and regulations to show industry that we are leading the way and face the same challenges that they do* (Coast Guard) **(R6)**

Many interesting views in this matter. From a competitive point of view, everyone is required to comply to the Polar Code so there should be no difference. However, there is a large difference between the operators and the vessels in terms of company culture, economic factors, age, standards and specifications of the vessels, experience in polar waters and so on. All these factors determine the level of compliance. Also, there is a large focus on safety and environmental issues, and any irregularly actions can potentially result in claims.

I must agree with R3, there is no reason NOT to comply. Even if it seems like many of the challenges with the implementation of the Polar Code, e.g. the LSA requirements, seem to be up for discussion, the serious operators should always strive for regulatory compliance in accordance with the regulations in force.

Additional information: Is there something you wish to add?

- *Icing stability: in chapter 4 related to intact conditions. The scenario of icing in combination with damage stability is not considered. I hear that for cruise vessels this scenario can be a problem* **(R2)**
- *In my opinion there should be only one Polar Code license, not two. What is the reason for distinguishing between basic and advanced? Either you are in polar waters or you are not. Either you are prepared and skilled or you are not. There is no such thing as "basic" or "advanced" polar conditions* **(R3)**
- *Some of the vessels heading in to arctic never call in to one of the arctic states and is only visited by inspectors in "warmer" countries. Is the competence there?* **(R5)**

It may seem that icing in combination with damage stability is not considered in chapter 4 of the Polar Code. This is a good observation from R2, and further investigation would require more insight in the probabilistic damage stability calculations as well as knowledge of the icing contribution related to these calculations.

The view of R3 regarding basic and advanced polar code licence is a fair one. A junior officer, who might only need a basic course today, will need an advanced course tomorrow. It would perhaps make more sense to have more personnel with “advanced” knowledge of polar waters, to strengthen the bridge team and mitigate some of the risk.

Also, R5 indicates that a vessel could find itself in polar waters without having any experience, but still be complying and have all the right certification and theoretical knowledge. This is an interesting thought. Is the Polar Code good enough?

6 Summary and Concluding Remarks

As a reminder, the research theme is *how the polar cruise shipping segment is implementing the Polar Code*. The research questions are listed below.

RQ1: What are the challenges related to the implementation of the Polar Code?

RQ2: How are previous lessons learned, non-conformities and near misses used in the implementation of the Polar Code?

There are no respondents to the survey from the cruise industry. This has consequences for this thesis. Most importantly, the number of respondents is obviously too low for a significant response rate, so the collected data must be considered unreliable for the polar cruise shipping segment. The collected data can provide some insight into the general shipping segment, but there can still be differences compared to polar cruise.

Why no respondents from the cruise industry? The motivation level involved in answering an email-distributed survey from a random student about a subject where many issues are still unclear or under discussion, is perhaps the most key factor here? We must assume that they are busy implementing the Polar Code.

The collected data is still good for providing useful insight in the general challenges. Based on the results and discussion of the survey, the *main challenges with implementing the Polar Code* seem to involve:

- Issues related to basic and advanced certificate training for ships operating in polar waters (accumulating enough sea time, gaining experience)
- Issues involving the “5-day survival requirement” (LSAs, economy)
- Distinction between summer and winter operations
- Relatively few options for waste and sludge disposal
- Issues related to economy (LSAs, winterization)

Furthermore, the survey shows that some experienced operators extract *lessons learned* after each operation and utilize the knowledge to optimize procedures if deemed necessary.

From the root cause analysis, the *direct causes* are placed in a parallel structure in the RBD due to the AND-gate in the FTA. The *contributing factors* are, due to the OR-gate in the FTA, placed in a series structure in the RBD and hence they give a stronger contribution than the *direct causes* towards the unwanted event. Further, the FMECA gives the highest RPN rankings to the *direct causes Human error: No voyage plan* and *Human error: High speed*, as well as the *contributing factor Inadequate SMS*.

In the AHP of the *direct causes*, the *criteria no voyage plan* and *high speed* have the first (61,8%) and second (29,7%) priorities with respect to the *direct causes*. The *alternative safety impact of the event* has the highest (60,8%) overall priority with respect to the *direct causes*.

In the AHP of the *contributing factors*, the *criterion inadequate SMS* have the highest (68,2%) priority with respect to the *contributing factors*. The *alternatives safety impact of the event* and *probability of re-occurrence if remain unsolved* have almost equal (47,0% and 46,2%) priorities with respect to the *contributing factors*.

These results emphasize the importance of human factors and the SMS. The human factors contributing to an unwanted event can be mitigated trough a healthy safety culture within the organization, bridge resource management (BRM) and an adequate SMS. From this, I must conclude that the SMS is the most important factor towards preventing an unwanted event. Indirectly, this is saying that today, compliance to the Polar Code is the most important factor towards mitigating unwanted events in polar waters.

For the Clipper Adventurer, there is one issue the investigation report (TSB, 2012) does not address. *Why* did the bridge team deviate from the standard known route? Was the intention to save fuel costs, or maybe save time? Was there operational pressure from the management to deliver an experience so exotic that the bridge team decided to steam full speed ahead through unchartered waters? What does it take for the bridge team to deviate from the voyage plan? No doubt the commercial pressure, leading to cutting corners and saving costs and time, can be a major contributing factor towards an unwanted event. Stress and commercial pressure are also identified as key maritime safety challenges by the NCA (2015).

From the TTX (Appendix C), one of the main takeaways was the importance of the practical leadership exercised by expedition leaders in a stranding scenario. This is further emphasized in the reports from the SARex project, which have identified large differences in groups of people attempting to survive on shore after an evacuation from a ship (Solberg, Gudmestad and Kvamme, 2016;2017; Solberg and Gudmestad, 2018). Groups that manage to keep up morale, who establish routines for duties and food/drink, as well as being led by a suitable individual, seem to survive the longest. A parallel can be drawn between the role of the expedition leader and the survival craft commander. One of the contributions to the SARex 3 report emphasizes the importance of the company management being made aware that there should be criteria involving suitability, experience and skills related to survival in polar areas early in the process when hiring new personnel for on board positions.

On a final note, it is the risk-based approach in the Polar Code that will contribute to reducing the identified risks in polar waters. The combination of the operational (risk) assessment, the PWOM, POLARIS, the functional requirements e.g. related to the LSAs, and the determined operational limitations will ensure the safest possible operations. If one of these are removed, then the other ones will become more important. The precautionary and preventive nature of the Polar Code is especially important due to the potential severity of an unwanted event involving cruise ships in polar waters.

6.1 Suggestions for Further Work

Competence and experience in polar waters seem easily available (usually in-house) for operators well-established in the area. It would be interesting to learn how the cruise industry approach this. A survey, where the cruise industry responds, could give useful insight in this regard.

The forthcoming expedition cruise ships with high ice class can provide a false sense of safety, stretching the shoulder season and pushing the operational limitations. Combined with poor hydrographic data in the polar area, especially in newly ice-free waters, this could lead to a grounding. More research regarding the probability of this should be conducted.

The Akademik Ioffe incident (Chapter 4.6.3; Appendix C), where the “coincidental buddy-ship” Akademik Sergey Vavilov happened to be the sister ship, was very interesting. Perhaps more work related to the buddy concept and standardization of the procedures and equipment used in evacuation (davits, small-boats, vests etc) could prove useful.

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Appendix A

Interview Guide

Questionnaire – Implementation of the Polar Code

This questionnaire is part of a master thesis at UiT - The Arctic University of Norway. The purpose of the questionnaire is to gain qualitative data regarding the implementation of the Polar Code in the cruise industry. All answers will be anonymized when used in the thesis. You can choose not to answer at any time.

The questions are mainly directed towards the cruise industry but may also be answered by others who are familiar with the Polar Code to provide a larger basis for discussion.

Below each question there is a complementary text providing further description of the question.

The questionnaire takes approximately 15-20 minutes to complete.

The head supervisor for the thesis is Professor Ove Tobias Gudmestad.

Thank you for helping me in my master thesis.

Please contact me if there are any questions.

Email address: bkr007@post.uit.no
Private email: bendikskoglundkristiansen@gmail.com

Sincerely,

Bendik Skoglund Kristiansen

Master student - Technology and Safety in the High North
UiT - The Arctic University of Norway

Appendix A

Question	Additional Description
Q1: In your experience, what are the challenges meeting the STCW requirements of the Polar Code?	E.g.: Basic/advanced courses, in-house or external facilities, sea time.
Q2: In your experience, what are the challenges meeting the SOLAS requirements of the Polar Code?	E.g.: Stricter demands, life-saving appliances, economy, installation/fitting of new equipment.
Q3: In your experience, what are the challenges meeting the MARPOL requirements of the Polar Code?	E.g.: Type of fuel, alternative power generation (hybrid, electric, Liquified Natural Gas (LNG)), holding capacity of sludge, sewage and greywater, garbage handling.
Q4: In your company, how is the operational (risk) assessment of the ship conducted?	E.g.: In-house or external? Operating profile and operational limitations. Who is involved (crew, superintendent, fleet captain, HSEQ director, other high-level management)? Occupational or dynamic (part of voyage plan)? Try to describe the process.
Q5: In your company, how is the Polar Water Operation Manual (PWOM) developed?	E.g.: In-house or external? Is PWOM integrated in existing safety management system (procedures, checklists, contingency plans)? Are there cross references from PWOM and operational risk assessment? Try to describe the process.
Q6: In your company, who participate in the development of the Polar Water Operation Manual (PWOM)?	E.g.: In-house or external? Who is involved (crew, superintendent, fleet captain, HSEQ director, other high-level management)? Why these organizations/functions?
Q7: Are the non-conformities and lessons learned from previous operations considered when performing the operational (risk) assessment or developing the Polar Water Operation Manual (PWOM)?	E.g.: What kind of reporting regime is in place for reporting non-conformities and accidents? Can experience from previous operations be transferred to the PWOM?
Q8: Is compliance to the Polar Code considered beneficial to the company?	E.g.: Can it be used in advertising? Can it be used for other purposes?

Appendix B

Responses - Questionnaire

Appendix B

Question	R1	R2	R3	R4	R5	R6	R7
Q1	The challenges are to convince participants of STCW (polar code) courses that they become aware of the dangers that are present in remote area's and the limited resources to assist you.	Providing a good basic and advanced course is not the problem; if you have the correct simulators and (ice) experienced teachers you can do a lot in 1 week. But the effect of the courses depends of the experience of the participants. None of the crew of cruisevessels have (because of the low or no icestrengthening of their vessels) real experience in ice with their own ships. (The so called expedition vessels with icestrengthening is something else). The impact of the same courses for crew with ice strengthened vessels (for example Redbox with PC3 vessels) is much better. Crew on cruisevessels with previous ice experience on cargo vessels is already better.	Accumulating sufficient sea time. In order to get polarcode advanced license, two months of seagoing service in polar waters or equivalent as deck officer is required. The definition of Polar waters in a Polarcode-context is those areas where the polarcode applies, respectively Arctic and Antarctic pc-region. For most deck officers on board passenger ships, it will take years to obtain 2 months real sea time in PC areas, as such vessel spend only a few days per year inside those areas.	There is a requirement in advanced level that someone needs to have two months of seagoing service in management level before someone can get the advanced training. But you can;t sail in management level without an advanced certificate. the interpertation by flagstates varies in this matter.	Lack of relevant seatime with navigating in ice. You might getting your certificate without any real ice navigation done and only summer operation as experience.	Gaining sea time in actual ice conditions the ship will be potentially operating in with experienced ice navigators is key to developing suitable experience. A simulator can only provide so much even with experienced ice navigators as instructors. This is based on nearly 40 years of experience in summer and shoulder season Arctic (all areas) and southern Canadian winter sea ice with the Canadian Coast Guard.	Potential lack of competence to give such courses. More research and industry improvements is needed and improvments of STCW requirements to come.
Q2	In the polar code many things are suggested, it should be mandatory (e.g. what should be in a survival kit and also the quality of the equipment and materials)	Emergency preparedness. Although all the vessels are complying with SOLAS they are not ready for a real incident. See the Sarex exercises on Svalbard. The goal based approach of Part 1 of the Polar Code doesn't give a good standard for the manufactures.	LSA. Most of today's passenger ship's LSA is not adequate for polar regions. I have reason to believe that less than 10 percent of ships traficking polar regions carry LSA that will provide the required 5 days survival for personell. In adition, relatively few vessels have winterization-characteristics that make them suitable for sailing in worst-case polarconditions.	The defnitions of the code are clear. The interpertatin by various classification societies and flagstates vary. And current items under discussion (such as the interpertation for guidelines on life saving appliances in polar waters) may cause huge implications.	A proper risk assessment must be the base of what equipment is needed on-board. The outcome of his risk assessment can be questioned by different crew and during port state or flag-state inspections. The equipment must be relevant to the actual operation and this must be stated in the PWOM and also referred to the vessels PST. Also the requirement of 5 days survival can be challenged. What equipment must be carried in a summer vs winter operation on the same location?	An existing ship with a recognized ice class, not so difficult to meet based on recent experience. For a new ship there are many more additional equipment costs to be incurred and it is very easy to go overboard very quickly with winterization which gets very expensive, very quickly and drives other requirements like auxiliary generator sizing. There really has to be rational thinking applied to degree of application of winterization and this starts with selection of an appropriate Polar Service Temperature for the proposed area of operation and the operational season.	5 days survival and balance equipment and training.
Q3	NA	The only problems I hear is with the ballastwater treatment due to the seawater temperature. But this is a bigger problem for the cargovessels as for the cruisvessels. If you see part1 of the polar code as the "prevention side" the focus must be there (impossible to clean the environment in a remote area under Arctic conditions)	All the MARPOL requirements are uncomplicated to meet. One of the two main topics for the polarocode is to mitigate the impacts on the environment. A possible future requirement for the polarcode, may be that no ships are allowed to carry HFO or any other fuel-substances with potentially severe environmental impacts in case of spill. This will lead to challenges for larger (cruise) ships that normally uses HFO as main fuel in other regions.	There are to less receiving facilities, so while there is a restriction in the use of an oily water seperator for example there are no receiving facilities where you can discharge.	The most challenging is lack of reception facilities and that vessels not equipped with systems large enough to hold the waste for the duration of the voyage if for example you have a longer cruise. Lack of receptions facilities for waste and sludge and if there will be a ban of gray water as well. Lack of bunker facilities especially if you are trying to run you vessel on LNG.	For the Canadian Arctic the main constraint is basically no shore infrastructure to support shipping. As well, MARPOL requirements are really geared toward transiting or destinational shipping making compliance difficult or nearly impossible in terms of waste holding for research and government vessels/icebreakers which spend longer periods of time in ice covered waters.	Not so much. There are good sollutions here. But stil large room for improvments.
Q4	NA	The Operational Assessment is mostly done by following the "templates" of the class (LLoyds). So you can see who is involved. Most of the time crew (staff) is also involved.Must be because the Polar Code is due to the goal based approach a sort of "mini ISM system" and crew must be involved to keep it realistic.	The risk assessment is conducted on board prior to each ice-related operation and includes all crew that one way or another will be involved in the operation. This means bridge officers, engine officers, deck crew and all other relevant personell. I would say it is both occupational and dynamic - there is a well funded and well documented risk assessment system that covers ice/polarcode operations in general. In adition, each single operation is subject for more thorough and detailed planning and preparation - a dynamic risk assessment to say.	We operate over 25 years in the polar regions, the assesment has been done by office personell and experienced ships staff.	The operational RA is first done by chartering department together with technical department, HSEQ and Crewing to see if the vessel and crew is fit for purpose. We have in house expertise with ice and arctic operations and this persons are involved early in the process as well during and in the followup. The vessels captain and chief engineer are also involved in an early stage to have comments and input on the operation and what might be done to prepare the vessel and crew.	We have used a combination of internal and external, ship and shore-based operational and engineering (shipboard, naval architect, mechanical and electronic) subject matter experts with a subject matter expert facilitator (external to organization) utilizing a workshop format to perform these types of assessments.	NA
Q5	NA	PWOM is (again with assistance of class) part of the ISM system. And most of the time you can see cross references. Also to AECO etc. PWOM is directly based on the O.A.	The PWOM for the specific ship is based on a company made manual for polarcode/ ice operations in general. Further, the PWOM is integrated in the ISM-system and is a fundamental product for risk asessment, voyage planning and contingency plans.	As we soley operate in Polar areas our ISM system already contains most information with regards to Polar Water operaytions, therefore our POWM is an addition to what already is covered in our ISM.	The PWOM was done in-house in the company with input from the vessels and different departments. On-board RA as well as table top RA in the office was conducted and implemented in the PWOM. In the process of developing the PWOM, several already existing procedures and checklists in the SMS was updated to comply with the Polar Code and the PWOM also refers to this ISM documents.	For new vessels external support has been utilized through the designer and shipyard for manual development. For existing vessels we will attempt in-house development using our own subject matter experts. The Operational Assessment is the basis for much of the content of the PWOM thus they go hand-in-hand.	NA
Q6	NA	Same as with the Operational Assessment. With larger input of crew.	The PWOM is developed on board and based on experiences gained from polar operations / voyages over a period of several years. Officers from both deck and engine department has contributed in developing the manual. It is considered that the personell actually performing the tasks has the best base for describing and doing reccomendations for ice / polarcode operations. In turn, this on board-developed manual eventually became the framework for the fleet manual that covers non-ship-sepcific polarcode operations.	Office personell and ships staff.	Vessel crew, superintendent, HSEQ director, chartering director and crewing director. The coordinating and writing was done by a teem of experienced ice navigating officers and projects managers that was working with this project during the process of develop and implementation and certification	Same as the OA (to develop the manual table of contents) but, more shipboard personnel involved (for manual development itself) as they will be the end users of the PWOM.	NA
Q7	NA	Should be. But especially experience in the subarctic (ice infested waters outside the Polar Code area) doesn't always meet the Polar Code. For example: Polar Code is asking for a method to assess the ice regime, most of the time POLARIS is used. Difficult for cruisevessels: what is safe speed and what is a safe distance to glacial ice (must be mentioned in PWOM according to POLARIS) But they are not willing to use the same risk assesment of glacial ice outside the polar code area (safe speed while in transit during the nigt to the next location /port).	See answer above.	No as our vessels were already operational in Polar Waters and 95% was already implemented.	Yes! After an arctic operation we have a debriefing session with the captain and chief engineers together with the chartering, technical and HSEQ department. Lessons learned are followed up to improve systems and procedures. As the PWOM is a document stamped by Class or flag state it is not that easy to update. Procedures refereed to is easier to update and a new RA can be added in the system	Yes, although a very small percentage of total incidents attributed to operations in ice. The PWOM will be auditable under the organizations safety management system.	NA
Q8	NA	Yes. To avoid claims. When I show pictures of cruisevessels wich are (far) beyond their limitations (and we calculate a Ris Index Outcome to proof it) they are always getting uncomfortable when I mention that 1 of the passengers can be a member of Greenpeace collecting evidence. (Greenpeace is also following Basic and Advanced courses). Port State Control: Negative publicity when the vessel is detained.	Yes. The introduction of the polarcode was an essential leap forward in terms of safety for both humans and environment, and any lack of will or ability to act in accordance with the code will lead to severe negative impacts for the company. Basically, there is absolutely no reason NOT to follow the requirements in the polarcode, whereas there are numberless reasons to do. Any negative attitude towards the polarcode will most likely end up being an organizational suicide for any cruiseship company that travels the polar regions.	In our market each competitor needs to comply as well. So there is no difference.	Yes. As we are operating or bidding on tenders that is inside the Polar Code area we are very much depended that we have vessels complying with the code. We use our Polar Code compliance in marketing as well.	The Canadian Coast Guard is technically exempt from the code and any associated regulations as government vessels in non-commercial service. However, regulatory compliance is done in the spirit of the applicable codes and regulations to show industry that we are leading the way and face the same challenges that they do.	NA
Additional information	NA	Icing stability: in chapter 4 related to intact conditions. The scenario of icing in combination with damage stability is not taken into account. I hear that for cruisevessels this scenario can be a problem.	In my opinion there should be only one polarcode license, not two. What is the reason for distinguishing between basic and advanced? Regardless the rank/posistion on board, every (deck) officer will sooner or later have to deal with Polar conditions, and the training offered to officers should thus be the same. Either you are in polar waters or you are not. Either you are prepared and skilled or you are not. There is no such thing as "basic" or "advanced" polar conditions.	I would be interested in the outcome. Good luck!	Very interesting topic and it will be interesting to see how different Arctic states will implement and handle the inspection and how the Polar Code is followed by the vessels operating in the area. Some of the vessels heading in to arctic never call in to one of the arctic states and is only visited by inspectors in "warmer" countries. Is the competence there?	Please feel free to contact me if any follow-up required.	NA

Appendix C

Highlights - Fourth Joint Arctic SAR TTX

Fourth Joint Arctic SAR Workshop & TTX

Scope

The Icelandic Coast Guard (ICG), the Joint Rescue Coordination Centre (JRCC) North Norway and the Association of Arctic Expedition Cruise Operators (AECO) have since 2016 arranged a table top exercise (TTX), inviting cruise operators, Search and Rescue (SAR) responders. Academia, industry and other interested stakeholders to participate. The Canadian Coast Guard (CCG) was responsible for leading the TTX this year, and the 2019 TTX called "Stranded" painted a scenario where 66 cruise passengers were prevented from returning to the ship due to sea ice after a small boat excursion. The situation is then complicated by weather, medical issues and the need to spend the night on the shore. The theme of the TTX vary each year, but the main goal is to contribute to a common understanding between the participants regarding SAR in the Arctic. The two-day event consisted of a variety of speakers among the participants on day one and two, while the TTX was conducted during the last part of day two. Starting this year, the event falls under the ARCSAR project (Arctic and North Atlantic Security and Emergency Preparedness Network) as it is a forum for dialogue and networking between stakeholders in the Arctic corresponding to the ARCSAR objectives (ARCSAR, 2019).

The speakers presented highly relevant topics. Some of the most interesting presentations were related to first hand experiences from recent incidents, including perspectives from Lufttransport related to the Northguider grounding in December 2018, One Ocean Expeditions sharing their experience from the Akademik Ioffe grounding in August 2018 and JRCC South Norway talking about the very recent Viking Sky incident in March 2019.

Lessons Learned 2016-2018

The main findings from previous SAR TTXs are related to communication, preparedness and technical improvements.

- *Communication:* media handling, clear messages, correct and updated information, "who says what and when"
- *Preparedness:* more self-reliant, acknowledge limitations, risk assessments, exercises
- *Technical improvements:* fire extinguishing system, survival and rescue equipment, means of communication
- *Proactive information sharing*

Appendix C

Highlights 2019

Different perspectives: The overall impression is that the need for this kind of forum for knowledge-sharing and networking is present. The different stakeholders seem to have some different perspectives and seem to prioritize differently on many issues. For example, the SAR entities want to know about an incident as early as possible – preferably before it even IS an incident – so they can start preparing by for example scrambling or re-positioning SAR units. As one of them put it: *"We are professional pessimists"*. Some cruise operators on the other hand, have both the capacity, equipment and personnel to handle many incidents themselves, they want to be self-reliant and may not immediately recognize the need for assistant rescue.

Networking: A good example of the positive outcome of this kind of event came from One Ocean Expeditions during the presentation of the Akademik Ioffe incident. They specifically stated that their successful response to the incident was largely due to the lessons learned during the previous SAR TTXs. This was especially related to communication between the operator and the JRCC and the benefits of a solid media strategy.

Knowledge-sharing: There were several discussions which led to new knowledge of each other's capacities. For example, some operators learned about the SAR helicopters ability to conduct Helicopter In-Flight Refuelling (HIFR) and some of the operators were surprised to learn that the SAR helicopters could assist with polar bear watch using their thermal cameras, as stated in the press release (AECO, 2019). Also, some of the SAR entities learned that many of the operators have highly skilled personnel in different categories and high-tech equipment such as drones and remotely operated underwater vehicles.

ARCSAR: The (brief) description of the ARCSAR project is that the ARCSAR network will address the Arctic and North-Atlantic (ANA) region, preparing to cope with the security and safety threats that will result from increased commercial activity in the region including traffic through the Northern passages, cruise traffic and offshore oil & gas activity. JRCC North Norway oversees the project, which is a 5-year EU funded project. The project consists of 5 extensive work packages (WPs) divided between JRCC North Norway, the University of Portsmouth (UP), Laurea University of Applied Sciences (LUA), JRCC Iceland and Cork Institute of Technology (CIT). A very interesting project, also relevant for my thesis.

AECO information: AECO shared some new guidelines, statistics and a little bit about what lies ahead. The number of cruise operators (expedition), passengers and vessels are all increasing, and over the next 5 years over 30 new vessels are expected. AECO also have several tools that can prove very helpful, for example the field staff online assessment, the vessel tracking and the Off-Vessel Risk Assessment Tool (O-VRAT).

Off-Vessel Risk Assessment Tool: Checks the safety, sustainability and human aspect of an off-vessel activity, using existing guidelines and risk scoring systems. Still in a testing phase. A very good initiative which can prove to be very helpful, especially for expedition leaders.

Academic methodology: The ARCSAR project have conducted 2 workshops (so far) facilitated by UP. The first workshop's objectives were to identify target areas for improvement, to map current gaps and needs in technology and innovation related to requirements in the Polar Code, and to identify barriers and innovation related to this. The second workshop's objectives were to examine and exercise methods to learn from failures and introduce techniques for decision analysis with emphasis on the use of advanced operational research techniques. The methodology proposed by Professor Ashraf Labib at UP (Labib, 2014) is a method used for root cause analysis to help the decision-making process. It involves case studies of previous incidents and disasters by using a systematic approach based on techniques from reliability engineering. Extremely interesting and, again, highly relevant for my thesis.

Arctic Coast Guard Forum (ACGF): Strongly related to the SAR agreement issued by the Arctic Council, the ACGF is an operational cooperation between the 8 Arctic countries. It enhances SAR cooperation by exchanging procedures, technique and experiences, information and conducting live exercises. A survey performed in cooperation with the Finnish Border Guard (FBG) as a part of the Arctic Maritime Safety Cooperation (SARC) project is the Arctic Search and Rescue Capabilities Survey (FBG, 2017). The intention is to have reference material for the ACGF and it provides a good overview of the SAR capabilities of the 8 Arctic countries.

Local SAR: The CCG presented a project involving the engagement of indigenous peoples in the Canadian Arctic for local search and rescue. Due to the enormity of the Canadian Arctic, the locals can be an extreme asset if involved in the SAR infrastructure. The settlements scattered around the Canadian Arctic are given training and equipment for conducting minor

SAR missions and act as first responders. The bonus of the project is the sense of pride and affiliation that the locals experience, and all the local knowledge that is put into good use.

"STRANDED" – TTX: The strategic objective of the TTX, taken from the handouts at the event, was for *"AECO members to conduct a TTX in order to determine the challenges, constraints and opportunities for passengers and personnel to survive a period of time stranded on land away from the cruise vessel and to evaluate and execute options for self and assisted rescue".*

The participants were divided into 4 groups representing different areas (US/Canada, Iceland, Faroe Islands and Norway), each with a mix of cruise operators, captains, RCC, expedition leaders and government representatives. A step by step walkthrough of the scenario, naturally discussing the actions taken as progressing through.

Main takeaways from the 2019 TTX (from the author's point of view) are:

- Knowledge of each other's capabilities and limitations
- Keep the RCC in the loop – even if the emergency has yet to emerge
- A solid media strategy can reduce much of the stress for the involved actors
- The low temperature in the scenario did not seem to be an issue until about half way through – keep in mind the wind chill effect and the fact that it is cold (if we add fatigue, fear, low morale, hunger, lack of comfort etc, the situation is not so simple)
- The expedition leader(s) must be able to keep up the morale and must exercise good practical leadership in a scenario like this – VERY important
- There can be a huge difference between passenger groups; for example, elderly people with various medical dependencies vs healthy middle-aged people with outdoor experience

As a final note, the Polar Code was not often mentioned, neither in the presentations or during the TTX. It can be argued that some of the activities conducted by an expedition cruise operator should be specified and assessed in the Polar Water Operational Manual (PWOM), and that there are supposed to be procedures in place for an incident such as the given scenario.

Appendix D

Polar Water Operation Manual – Example

Appendix D

1 - Operational Capabilities & Limitations	**1.1**	**Operations in ice**
	1.1.1	Operator guidance for safe operation
	1.1.2	Icebreaking capabilities
	1.1.3	Maneuvering in ice
	1.1.4	Special features
	1.2	**Operations in low air temperatures**
	1.2.1	System design
	1.2.2	Protection of personnel
	1.3	**Communication and navigation capabilities in high latitudes**
	1.4	**Voyage duration**
2 - Ship Operations	**2.1**	**Strategic planning**
	2.1.1	Avoidance of hazardous ice
	2.1.2	Avoidance of hazardous temperatures
	2.1.3	Voyage duration and endurance
	2.1.4	Manning
	2.2	**Arrangements for receiving forecasts of environmental conditions**
	2.2.1	Ice information
	2.2.2	Meteorological information
	2.3	**Verification of hydrographic, meteorological and navigational information**
	2.4	**Operation of special equipment**
	2.4.1	Navigation systems
	2.4.2	Communications systems
	2.5	**Procedures to maintain equipment and system functionality**
	2.5.1	Icing prevention and de-icing
	2.5.2	Operation of seawater systems
	2.5.3	Procedures for low temperature operations
3 - Risk Management	**3.1**	**Risk mitigation in limiting environmental condition**
	3.1.1	Measures to be considered in adverse ice conditions
	3.1.2	Measures to be considered in adverse temperature conditions
	3.2	**Emergency response**
	3.2.1	Damage control
	3.2.2	Firefighting
	3.2.3	Pollution response
	3.2.4	Escape and evacuation
	3.3	**Coordination with emergency response providers**
	3.3.1	Ship emergency response services
	3.3.2	Salvage
	3.3.3	Search and rescue
	3.3.4	Spill response
	3.4	**Procedures for prolonged entrapment by ice**
	3.4.1	System configuration
	3.4.2	System operation
4 - Joint Operations	**4.1**	**Escorted operations**
	4.2	**Convoy operations**