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WORLD MARITIME UNIVERSITY

Malmö, Sweden

STUDY ON THE IMPLEMENTATION OF FORMAL SAFETY ASSSEMENT FOR DEVELOPMENT OF THE MANDATORY POLAR CODE

By

XIE JIEYING

The People's Republic of China

A dissertation submitted to the World Maritime University in partial Fulfillment of the requirements for the award of the degree of

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In

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2013

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DECLARATION

I certify that all the material in this dissertation that is not my own work has been identified, and that no material is included for which a degree has previously been conferred on me.

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(Signature): [illegible]

(Date): 2013. 11. 13

Supervised by: Professor Dr. Neil Bellefontaine
World Maritime University

Assessor: Larry Hildebrand
Institution/Organisation: World Maritime University

Co-assessor: H.Haken
Institution/Organisation:

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ABSTRACT

Title of Dissertation: **Study on the implementation of Formal Safety Assessment for the development of the mandatory Polar Code**

Degree: **MSc**

The dissertation carries out a comprehensive analysis of the implementation of Formal Safety Assessment (FSA) for the development of the mandatory code for ships navigating in polar water ("the Polar Code"). The risk-based Polar Code is developed with functional requirements and supporting prescriptive regulations in order to ensure the safe navigation and environmental protection in polar waters, which is comparatively more environmentally vulnerable.

The key process during the development of the Polar Code is presented adopting the independent environmental protection part. A historical review of the Polar Code will be summarized from the adoption of the Guidelines for ships operating in Arctic ice-covered water in 2002 to the Guidelines for ships operating in polar waters in 2009, which is a basis for the further study.

The current achievement of FSA will be reviewed and the new direction of research of FSA will be discussed according to the research and opinions of experts. The framework and limitations of FSA will also be illustrated to point out challenges to carry out the FSA.

The recommendation of FSA for the Polar Code will be discussed through the preparatory stage and further FSA stages. The limitations, advantages and disadvantages will be carefully analyzed and discussed. Feasible and practical solutions and options will be provided based on the analysis.

As a part of the conclusion, recommendations for future work relating to the

environmental part of the Polar Code will be provided to IMO, international organizations and member states.

KEYWORDS: Polar Code, FSA, environmental protection, Arctic waters, environmental risk evaluation criteria, environmental risk acceptance criteria

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List of Acronyms

ALARP	**As Low As Reasonably Practical**
IAATO	**International Association of Antarctica Tour Operators**
CLIA	**Cruise Line International Organization**
AMSA	**Arctic Marine Shipping assessment**
FSA	**Formal Safety Assessment**
RCM	**Risk Control Measures**
RCO	**Risk Control Options**
HAZID	**Hazard Identification**
MSC	**Maritime Safety Committee**
MEPC	**Marine Environment Protection Committee**
IMO	**International Maritime Organization**
COMSAR	**Radiocommunications and Search and Rescue**
ATCM	**Antarctic Treaty Consultative Meeting**
SI	**Severity Index**
FI	**Frequency Index**
RI	**Risk Index**
CAT	**Cost to Avert one Tonne of Spilled Oil**
NCAF	**Net Cos of Averting a Fatality**
GCAF	**Gross Cost of Averting a Fatality**
CEA	**Cost Effectiveness Analysis**

1. Introduction

1.1. Background

Trends and forecasts indicate that polar shipping will grow in volume and diversify in the coming years and these challenges need to be met without compromising either safety of life at sea or the sustainability of the polar environment.

The Sub-Committee on Ship Design and Equipment has been tasked with coordinating the drafting work, and reporting to the Maritime Safety Committee (MSC) and Marine Environment Protection Committee (MEPC).

The move to develop a mandatory Polar Code follows the adoption of the recommendatory Guidelines for ships operating in polar waters (Resolution A.1024 (26)) by IMO's MSC and MEPC committees separately. The main purpose of the Guidelines is to address those additional provisions deemed necessary for consideration beyond existing requirements of the SOLAS and MARPOL Conventions. The specific climatic conditions of polar waters, the safety as well as environmental protection are all considered by the working group.

Considering the mandatory Polar Code, it aims at providing a risk-based code with proactively functional requirements and supporting prescriptive regulations for safety and environmental protection concerns. The drafting work is conducted by DE with support from member states and other interested stakeholders such as NGOs and classification societies.

The mandatory Polar Code is intended to function alongside existing IMO conventions, such as SOLAS and MARPOL. One of its functions is to augment "baseline" environmental protection of polar waters to reflect their increased environmental sensitivity. If certain specific locations within polar waters need further protection this will be provided by existing mechanisms separate from the Polar Code.

Meanwhile, the formal safety assessment has been described as "a rational and systematic process for assessing the risks associated with shipping activity and for evaluating the costs and benefits of IMO's options for reducing these risks"(MSC 91/16). It can be used as a tool to help evaluate new regulations or to compare proposed changes with existing standards.

The Guidelines for Formal Safety Assessment (FSA) for use in the IMO rule-making process were approved in 2002 and amended in 2006. The formal safety assessment involves much more scientific aspects than previous conventions. The benefits of adopting formal safety assessment as a regulatory tool include the following (Marine Safety Agency, 1993):

- A consistent regulatory regime that addresses all aspects of safety in an integrated way;
- Cost effectiveness, whereby safety investment is targeted to where it will achieve the greatest benefit;
- A proactive approach enabling hazards that have not yet given rise to accidents to be properly considered;
- Confidence that regulatory requirements are in proportion to the severity of the risks;
- A rational basis for addressing new risks posed by ever-changing marine technology.

Until now, the FSA is still the state of art for rule-making process and the topic has moved from safety issues to environmental issues. Discussion on appropriate environmental risk criteria is still underway and a working group was established in 2013 in order to finish the job as soon as possible.

Increasing vessel traffic in polar waters indicates an expected increase in accidents and incidents, which are major contributors to marine pollution. The mandatory Polar Code is the only document under development for these specific areas. The environmental protection part needs to be developed and finished according to the schedule; therefore, it is urgent and essential to consider the application of FSA into the rule-making process of the Code.

1.2. Objectives and methodology of research

The primary objective of this dissertation is to identify the challenges of the FSA studies for the Polar Code focusing on the environmental protection issues, according to an analysis of the preparatory work and the 5 steps of FSA separately. Possible and practical solutions and methods will be recommended by the author accordingly. Moreover, recommendations and suggestions for future works will be concluded according to the results of the study. The subsequent purpose of this dissertation is to give a general review of the development of FSA and the polar code. The tendency of recent research and new topics under discussion will be also introduced and discussed.

The dissertation will commence from a historical review of IMO's Polar Code and illustrate all related International regulations and IMO instruments in order to clarify the current regulatory regime for the polar waters. The environmental protection part will be highlighted by the author for further discussion. Based on an analysis of the framework of FSA, potential problems, limitations and disadvantages of current FSA will be identified and assessed, taking into consideration the recent research and opinions of experts. The new topic of establishing environmental risk evaluation criteria will be also be discussed briefly. Then the necessity of implementing the FSA for the Polar Code concerning environmental protection could be confirmed according to the aforementioned issues and the challenges for the preparatory work and each FSA step will be analyzed according to an investigation into working reports including AMSA 2009 report, IAATO report and HAZID workshop report. Then the potential choices of solutions to carry out an appropriate FSA can be approached. By comparing and analyzing the advantages and disadvantages of those potential choices, feasible recommendations will be concluded accordingly.

1.3. Organization of dissertation

To start with, chapter 1 will provide an introduction and background to the research, the objectives and methodology as well as the organization of the dissertation.

In the second chapter, the development of the IMO Polar Code will be introduced by a historical review. The present and forthcoming conventions and regulations published not only by IMO but also by related organizations will be discussed. The study achievements by experts will be reviewed as a basis for further study.

In the third part, the background and development as well as the current achievements and new topics of FSA will be introduced and analyzed. The major framework and limitations of FSA will be carefully analyzed. The environmental issues as a global trend will be concluded for further discussion.

In chapter 4, the preparatory work of FSA for the polar will be analyzed according to the status of historical data. The possibility and priority for the future FSA will be analyzed and discussed with differences between two polar waters as well as the necessity and feasibility of safety risks and environmental risks.

Chapter 5 will focus on the detailed FSA steps. The HAZID will be analyzed referring to the HAZID workshop report. During the process of analyzing, qualitative methods and the quantitative methods will be illustrated with key factors. After pointing out the challenges of FSA, possible and more feasible methods and options will be provided accordingly.

In the last chapter, all findings and outcomes of the study will be concluded. Moreover, recommendations for future work will be provided for IMO and interested stakeholders of the Polar Code to develop the environmental sector.

2. The IMO Polar Code

2.1. Historical review of the development of regulations for polar waters by IMO

From 1996, in order to harmonize those rules and regulations pertaining to Polar Regions, The Sub-Committee on Ship Design and Equipment (DE) has been tasked with coordinating the work of developing a strong Polar Code for the ice-covered waters. The results of the working group have been reported to the Maritime Safety Committee (MSC) and Maritime Environment Protection Committee (MEPC) for further discussion.

However, the progress of the Polar Code in IMO is quite slow and complex considering the nature of polar waters. According to the data of IMO document DE 41/10,1997 (Development of a Polar Code —The International Code of Safety for Ships in Polar Waters), the Polar Code was originally drafted by an outside working group of technical experts in neutral words assigned by IMO from different administrators and classification societies. The main purpose of this draft is to harmonize the different legal regimes within those areas for future shipping requirements.

From then on, this draft of the Polar Code, covering Arctic and Antarctic waters, was thoroughly discussed by IMO. After an extensive exchange of views and options from different countries and related organizations, considering the different nature of the two polar waters as well as the problem of application scope, DE transferred its Polar Code framework into a recommendatory guideline for ships navigating in Arctic ice-covered waters after MSC 71 in 1999.

Later on, the Guidelines for ships operating in Arctic ice-covered waters were approved by MSC and MEPC separately in 2002 by an MSC/MEPC joint circular (MSC/Circ.1056 – MEPC/Circ.399) as an addition to the mandatory and recommendatory provisions existing in IMO instruments.

However, The Maritime Safety Committee, at its seventy-ninth session in 2004, received a submission from South Africa on behalf of the Antarctic Treaty Consultative Parties (MSC 79/8/2 (Secretariat)). Considering the increasing level of shipping, especially in the tourist areas, ATCM invited IMO to amend the guidelines for ships operating in Arctic ice-covered waters so as to also be applicable to ships navigating in ice-covered waters within the Antarctic Treaty Area. They believed that the IMO's membership had far more States than those states under the Antarctic Treaty.

Therefore, a modification of the guidelines for compatibility with the Antarctic was proposed and open for comments from other countries and related organizations. Technical requirements relating to double bottom construction as well as the replacement of "Arctic and Antarctic" in the title of the Guidelines was proposed by ATCM. Moreover, the DE Sub-Committee noted that more attention should be paid to passenger ships that only visited the Polar Regions (DE 50/27, 2007).

As a result, IMO also adopted the Guidelines on Voyage Planning for passenger ships operating in remote areas in 2007 (A 25/Res.999) especially for passenger ships operating in remote areas in order to prevent incidents of groundings and collisions.

From further discussion on the development of the Guidelines by the Working Group, they recognized that "ice-coverage is not the only challenge when sailing in Polar waters" (DE 52/WP.2, 2009) and decided to change the "ice-covered waters" of the title into "polar waters". However, the word "Guidelines" was kept for the recommendatory nature of the provisions of this document. Finally, Guidelines for ships operating in Polar Waters was adopted by IMO Assembly on 2 December 2009 Resolution A.1024 (26).

After consulting opinions and proposals from different countries and organizations, the Guidelines for ships operating in polar waters was adopted by IMO Assembly on 2 December 2009 ((Resolution A.1024 (26)).

However, even before the adoption of the Guidelines, the further move to develop a mandatory code for polar areas was proposed by some NGO members such as FOEI, Greenpeace and WWF during the DE 53rd session in 2009. From their report submitted to DE Sub-Committee (MSC 86/23/19, 2009), the urgency of developing a mandatory code for polar waters was described according to records of accidents that happened in the Southern Ocean from 2008 to 2009 and the ship-born tourist activities in Antarctica as well as the increasing number of ships operating in the Arctic and the accidents that have happened over the last decade. A rapid ratification and full implementation including compensation and liability instruments was encouraged by these organizations.

Meanwhile, a proposed framework of the Code was submitted by Canada during DE 53rd session. The document DE/10 of 1997 was repeated again as it was written in neutral language and still sufficient in scope to work as a mandatory provision.

When it came to discussion of a mandatory code for Polar Regions, for the first time, a risk-based approach in determining the scope was proposed by Germany (DE 54/13/1) wherein the provisions of the code would be supported by the overall goals and functional requirements for ships operating in polar waters in order to mitigate identified risks to acceptable levels and minimize the consequences of identified risks.

From 2011 to 2013, discussions between various countries and organizations have focused on issues such as boundaries of the polar region and environmental aspects. During this period of time, more attention was paid by the maritime field to polar risk assessment and establishing a risk basis for the Polar Code in order to develop a powerful mandatory Polar Code.

2.2. Present and forthcoming conventions, regulations and proposals published by IMO and other Organizations for polar waters

Over the last 20 years, IMO as well as other related organizations and countries have developed a lot of regulations, guidelines and recommendations regarding the polar waters.

In this section, the major existing legal framework before and after the development of a mandatory Polar Code will be illustrated and discussed in detail.

2.2.1. UNCLOS and Antarctic Environmental Protocol

UNCLOS is a legal framework governing the rights and responsibilities of nations in their use of ocean space. The convention was concluded in 1982 and came into force in 1994. As of August 2013, 166 countries including the European Union have ratified the Convention.

According to section 8, Article 234 (Ice-covered areas):

> *Coastal States have the right to adopt and enforce non-discriminatory laws and regulations for the prevention, reduction and control of marine pollution from vessels in ice-covered areas within the limits of the exclusive economic zone, where particularly severe climatic conditions and the presence of ice covering such areas for most of the year create obstructions or exceptional hazards to navigation, and pollution of the marine environment could cause major harm to or irreversible disturbance of the ecological balance. Such laws and regulations shall have due regard to navigation and the protection and preservation of the marine environment based on the best available scientific evidence.*

This is the only Article of UNCLOS that has a direct influence in the polar waters and allows coastal states of polar waters to pass and enforce rules on pollution within their exclusive economic zones in order to solve the problem of foreign shipping traffic. However, the definition of "ice-covered area" mentioned in this article was not clearly clarified in UNCLOS. Therefore, a lot of discussions and arguments have been raised and it has not yet been agreed upon and fully applied in Polar Regions.

The Protocol on Environmental Protection to the Antarctic Treaty is one of the most important additions to the Antarctic Treaty System and provides for comprehensive protection of the Antarctic environment and dependent and associated ecosystems. This protocol including 27 articles and 6 Annexes was concluded in 1991 and entered into force on January 14, 1998. Until now, 33 parties have joined and ratified this protocol. Although this protocol is not able to regulate all kinds of activities of vessels operating in both Polar waters, it provides a good foundation for the environmental protection part of the Polar Code.

However, these regional groupings of states commonly have jurisdiction over vessel-borne pollution within their capacities as flag or port states, for instance, Annex IV, named "Prevention of Marine Pollution of the Environmental Protocol to the Antarctic Treaty.

2.2.2. IMO instruments

As Article 234 of UNCLOS mentioned above only provides a general jurisdictional framework regarding vessel-borne pollution for ice-covered areas, those IMO instruments have played an important role in the further operational stage.

Considering difficulties in complying with those various requirements among regional States with navigation and discharge standards, IMO instruments have long been involved in harmonizing these requirements for the overall interests in international shipping. Those major conventions including SOLAS, MAROL 73/78 and STCW will be illustrated briefly in this section.

The International Convention for Safety of Life at Sea (SOLAS) is regarded as the most important international treaty considering the safety of ships and provides minimum standards for the construction, equipment and operation of ships.

The provisions relating to the ice-covered areas can be found in Chapter V, navigation requirements. Referring to Regulation 5, Meteorological services and warnings, it says that weather information suitable for shipping shall be collected and analyzed including the ice data. Regulation 6, Ice Patrol Services, requires ships transiting the region of icebergs guarded by the Ice Patrol during the ice season to make use of the services provided by the Ice Patrol. Moreover, Regulation 31, Danger message, and Regulation 32, Information Required in Danger message, regulate masters to communicate information on dangers to navigation including dangerous ice and its specification.

In 2008, IMO adopted the International Code on Intact Stability, 2008 (2008 IS Code) and it entered into force on 1 July 2010. The provisions of part A of the IS Code are mandatory under the 1974 SOLAS Convention and the 1988 Load Lines Protocol while Part B is recommendatory (Resolution MSC.267(85)). According to Part B, Chapter 6, Icing consideration, those ships operating in ice-accretion areas are likely to experience adverse effects on the ship's stability, so icing allowance should be included during the analysis of the loading condition.

MARPOL 73/78 is the main convention regulating the prevention of pollution of the marine environment from vessel-source pollution with discharge and emission standards developed by IMO. Besides the six Annexes with general requirements for the ships navigating at sea, MARPOL73/78 also provides stricter standards for a higher level of protection for the "special areas" and more stringent discharge standards for the "SOx Emission Control Areas."

However, the Antarctic area has been designated as a special area under Annex I, Prevention of pollution by oil, Annex II, control of discharge of residues of noxious liquid substances, and Annex V, Disposal of garbage, while no part of the Arctic marine area has been designated yet. Moreover, in the Antarctic area new chapter 9 of MARPOL Annex I, establishing a ban on the use and carriage of heavy grade oils, entered into force on 1 August 2011.

Regarding oil response in ice and snow condition, a new guidance on oil spill response in ice and snow conditions is still under development by MEPC.

As human factors have been a hot topic over the last decade, a training guidance for personnel on ships operating in polar waters has also been discussed and developed during this period.

The newly adopted guidance stresses the importance for officers in charge of a navigational/engineering watch on board ships operating in polar waters to have sufficient and appropriate experience with polar waters. There are measures to ensure the competency of masters and officers of ships operating in polar waters and also recommend that Governments adopt measures to ensure that masters and officers of ships operating in polar waters have appropriate training and experience.

2.2.3. Guidelines and recommendations

Considering the specific nature of polar waters, IMO has developed several useful guidelines for ships navigating in those areas as follows:

Guidance for passenger ships operating in areas remote from SAR facilities (MSC.1/Circ.1184) enhanced planning arrangements for ships operating in remote areas, including close cooperation and liaison with relevant RCCs in 2006.

Guidelines on voyage planning for passenger ships operating in remote areas (A.999(25)) adopted on 29 November 2007. This Guidelines provide additions to voyage and passage plan, such as details on ice and ice formations, ice navigators, operational limitations due to ice, safe distance to icebergs, and carriage of special or enhanced equipment.

Guidelines for ships operating in polar waters (A.1024 (26)), adopted by the 26th IMO Assembly in 2009. Currently, this is the most comprehensive Guidelines regarding polar waters and provide a holistic approach for navigational safety in polar waters and also work as a basis for the development of the mandatory Polar Code. The details of the contents and structures of the Guidelines will be discussed in Chapter 3.

2.3. Study and research achievement of mandatory Polar Code made by working group (DE) of IMO

As the author mentioned in the first Chapter, the decision to develop a mandatory Polar code was first proposed in the 1990s, but the idea was not accepted by a lot of countries and then the recommendatory guideline was adopted by IMO. However, just before the guideline was adopted, the proposal for developing a mandatory Polar Code came back to the table for discussion and was approved by IMO. The DE

Sub-committee was again designated as the coordinator and a working group was organized accordingly for this.

According to DE 53/18, 2009, the outcome of the 32nd Antarctic Treaty Consultative Meeting (ATCM XXXII) adopted a resolution on a mandatory shipping code for vessels operating in Antarctic waters (Resolution 8 (2009)). As requested by the meeting, the Chair of ATCM XXXII corresponded with IMO in this regard and the text of the resolution was attached for the information of the Sub-Committee.

At the same time, during the period of MSC 86, countries like Argentina, Chile, Norway, and the United States as well as other related organizations submitted proposals for new mandatory work on the basis of the guidelines.

From DE53, the working group started to work with this topic. The DE sub-committee provided a justification for a new work program item "Development of a Code for ships operating in Polar waters". During the DE sessions, a correspondence group was established to work intersessionally. (DE 53/26).

During this meeting, most of the members agreed on the development of a risk based Code with functional requirements supported by prescriptive provisions with both mandatory and recommendatory parts (DE 53/26).

Later on, the discussion of the Polar Code in DE 54 moved to the environmental aspects and DE agreed to utilize a risk-based approach. Therefore, a correspondence group to review a hazard matrix was developed to identify the hazards. Meanwhile, a workshop on the environmental aspects of the Polar Code was held in Cambridge from 27-30 November 2011. The report of this workshop was focused on the Hazard identification of ships navigating in polar waters.

In 2011, DE55 continued working on the development of a mandatory Code for ships operating in polar waters, which covered the full range of shipping related matters in waters surrounding the two poles. More technical parts of the draft code w developed and discussed, taking into account the outcome of other bodies meeting in the interim including MEPC and NAV.

In 2012, DE56 continued to work with the draft and agreed with the group's recommendation to forward relevant sections to the sub-committees on

Radiocommunications, Search and Rescue (COMSAR); Fire Protection (FP); Safety of Navigation (NAV); Stability, Load Lines and Fishing Vessel Safety (SLF); and Training and Watchkeeping (STW) for their review and input.

In relation to environmental aspects of the Code, the Sub-Committee noted that the working group had been divided as to whether the environmental protection provisions should be elaborated as a part of the Code, or as amendments to the relevant annexes of MARPOL and other appropriate IMO instruments, and decided to keep any decision on environmental requirements to be included in the Code in abeyance pending further consideration by the Marine Environment Protection Committee (MEPC). The Sub-committee also agreed to urge the MEPC and the MSC to prioritize the discussion on how to make the Polar Code mandatory at their forthcoming meetings.

At DE57 of 2013, The Sub-Committee made significant progress in further developing the draft mandatory International Code of safety for ships operating in polar waters (Polar Code), in particular with the finalization of a draft chapter on environmental protection for consideration by MEPC 65, and requested the MSC to authorize the holding of an intersessional meeting of the Polar Code Working Group in late 2013, to further progress the work.

According to the draft of the Code, the aim is to finalize the draft Code in 2014 for adoption by the MSC and Marine Environment Protection Committee (MEPC). The Polar Code is intended to cover the full range of shipping-related matters relevant to navigation in waters surrounding the two poles – ship design, construction and equipment; operational and training concerns; search and rescue; and, equally important, the protection of the unique environment and eco-systems of the polar regions.

Agreement in principle was reached on definitions for the different categories of ship to be covered by the Code, as follows:

Category A means a ship capable of operating at least in medium first-year ice which may include old ice inclusions in accordance with an ice class at least equivalent to those acceptable to the Organization.

Category B means a ship capable of operating in sea ice conditions other than those included in Category A with an ice class at least equivalent to those acceptable to the Organization.

Category C means any ship which is not a Category A or Category B ship.

It was agreed that that all ships operating in polar waters should have a Polar Ship Certificate and a Polar Water Operation Manual.

As instructed by the main committees, it was agreed that the Polar Code would be adopted by separate MSC and MEPC resolutions, with amendments to mandatory instruments to be developed to make the Code mandatory. This would also impact on the structuring of the Code.

The Polar Code correspondence group was re-established to further develop the draft Code and also draft amendments to mandatory IMO instruments (SOLAS and MARPOL), to make the Code mandatory.

In addition to DE, from 2010, there has been some revision of international conventions, considering the situation of polar waters, for instance, MARPOL convention Chapter 9, Annex I added a new Regulation 43 for using of heavy grade oil, which entered into force on 1st August 2011.

2.4. Challenges in the development of a mandatory Polar Code

Developing a mandatory Polar Code has been widely discussed over last decade in the IMO and there have been great achievements, which were mentioned in last section.

The challenges that the mandatory Polar Code meets with are mostly decided by the structure of the Polar Code adopted by DE as well as by the specific nature of polar waters.

Proactive environmental protection for both poles is intended to "avoid an Exxon Valdez or Concordia-type disaster in polar waters before real regulatory action is achieved in these vulnerable regions," said John Katenstaein of Friends of the Earth.

Considering the nature of polar waters, topics such as geographical limitations, scope of ships involved, ship categories and differences between the two polar waters have been discussed and agreement has almost been arrived at, as can be found in the recent report of the working group and the current draft of the Polar code.

During DE 54 sessions, the utilization of a risk-based/goal-based approach, as proposed by Germany (DE 54/13/1), had been adopted and the recent Polar Code with goals and functional requirements supported by prescriptive provisions has been provided by the working group for further discussion in DE 56.

This risk-based approach gives not only a sufficient flexibility for alternative designs and arrangements but also major challenges for further development of the Polar Code, especially in the environmental protection aspects.

As there will be a special chapter for environmental protection in the Polar Code, the biggest challenges will include but not be limited to:

- How to identify and rank all the possible risks?
- How to set the level of need for additional environmental risks?
- How to mitigate the environmental risks?

Therefore, in this dissertation, the author would like to recommend the Formal Safety Assessment, which is a rational and systematic process for assessing the risks relating to maritime safety and the protection of the marine environment and for evaluating the costs and benefits of IMO's options for reducing these risks (MSC/Circ.1023, 5th April 2002), to work as a tool to provide support and further suggestions for the future IMO decision-making process for the Polar Code.

2.5. Summary

Global climate change is now providing new opportunities for international transportation in polar waters.

According to the speech given by Sekimizu, the secretary-general of IMO, at the opening of the 53rd session of the DE sub-committee:

> *The recent developments are opening the way for the North Pole region to be used by international navigation, and rendering its vast resources easier to*

> *access, makes it all the more important for us to take action to ensure not only the safety of ships passing through but also that any exploration and production activities taking place therein are conducted in a manner that will have no negative impact on the environment. (DE 53/INF.7)*

Therefore, although the working group on the Polar Code, with support from various international organizations, has made great achievements in developing a mandatory Polar Code, more academic studies and discussions relating to environmental risks for ship navigating in polar waters shall be continuously carried out by IMO.

The formal safety assessment is complicated with a few limitations; however, compared to other novel methods, it is still a reliable method recommended by IMO for the rule-making process.

3. The Formal Safety Assessment recommended by IMO

3.1. Background and development of IMO Guidelines for FSA

The concept of Formal Safety Assessment (FSA) was developed in the 1990's after a series of ship accidents happened, especially involving bulk carriers. Therefore, in 1993, the UK Maritime Safety Agency (MSA) submitted a document about a new approach to marine safety involving risk assessment and benefit assessment techniques for IMO's rule making process for shipping. This was the basis for the future development of FSA in IMO.

During MSC 62nd session in 1993, the proposal of the UK was accepted and a corresponding group in-between was established accordingly. After two years, a seminar on FSA was held at IMO headquarters and the FSA concept was strongly supported by member governments to be used in future IMO rule-making process. Meanwhile, MSC decided to establish a working group for the development of Guidelines for the application of FSA.

During further discussion within the working group, the MEPC committee was also invited to be involved in the development of the Guidelines in order to address environmental protection issues. Later on, the "interim Guidelines for the Application of Formal Safety Assessment to the IMO Rule-Making Process" (MSC/cir.829, MEPC/cir.335) was approved separately by MSC and MEPC in 1997.

After the MSC 68 session, more input from active participants as the result of trial applications were provided by several member states of IMO and at the MSC 69 session, the committee agreed to "expand the FSA interim guidelines in order to clarify the incorporation of the HE and to consider the mechanism by which they could be used within the IMO rule-making process."

Finally, the Maritime Safety Committee, at its seventy-fourth session (30 May to 8 June 2001), and the Marine Environment Protection Committee, at its forty-seventh session (4 to 8 March 2002), approved:

1 Guidelines for Formal Safety Assessment (FSA) for use in the IMO rule-making process (MSC/Circ.1023-MEPC/Circ.392); and

2 Guidance on the use of Human Element Analysing Process (HEAP) and Formal Safety Assessment (FSA) in the IMO rule-making process (MSC/Circ.1022-MEPC/Circ.391).

This was the sign of the official adoption of the FSA by IMO and further implementation work is still under discussion in IMO. Therefore, during the seventy-fifth session of the Maritime Safety Committee, there were various studies on bulk carrier safety submitted by different countries with different recommendations.

However, after a joint MSC/MEPC working group on the human element was established in MSC 78, the MEPC committee decided to establish a correspondence group on FSA matters under the coordination of Japan.

Later, The MSC committee decided to establish a correspondence group to review the Guidelines and prepare draft amendments and also established a working group to consider the need for a group of experts on FSA.

According to MSC-MEPC.2/Circ.5, the committee approved AMENDMENTS TO THE GUIDELINES FOR FORMAL SAFETY ASSESSMENT (FSA) FOR USE IN THE IMO RULE-MAKING PROCESS (MSC/Circ.1023 - MEPC/Circ.392) in 2006.

During MSC's 84th Session in 2008, the Committee agreed, in general, to establish an FSA Expert Group. From then on, the topic of Environmental Risk Evaluation Criteria became a hot topic and a corresponding group coordinated by Greece was established for this topic. Meanwhile a review of FSA studies submitted by SAFEDOR was conducted by FSA experts of IMO. As a result, in 2011, MEPC 62 considered and approved the report of its Working Group on Environmental Risk Evaluation Criteria within the context of FSA (MEPC62/WP.13). The revised guidelines for FSA was reviewed and approved at the MSC 91(2012) and MEPC 65

(2013) separately and the environmental risk evaluation criteria were included in the Annex of the Guideline. (MSC-MEPC.2/CIRC.12, 2012)

3.2. The recent achievement and application of FSA in the shipping industry

The first application of the FSA Guidelines happened after the adoption of the "Interim Guidelines" (IMO 1997) and at that time the FSA was named "Trial Applications". The first reports were submitted by the UK with the title "FSA on High Speed Craft (HSC) in 1997. However, these reports were extremely criticized because of the Regulatory Impact Diagram (RID) adopted as a risk model. Although these reports were not accepted for the rule-making process, they contributed to the future amendment of the FSA Guidelines.

Another important case of FSA for Helicopter landing Area (HLA) on Cruise ships was carried out following the Estonia Accident (Estonia 1997). This FSA/HLA was carried out by DNV (Skjong et al., 1997) and later submitted to IMO for review. This is the first case including a benefits and costs assessment in which IMO took the recommendations from the FSA reports into consideration for the rule-making process.

The unforgettable case in FSA history in IMO shall be the Bulk Carrier Double Hull case. The FSA on bulk carrier safety was proposed by the UK in 1998. After that, different countries such as Norway, UK and Japan as well as some organizations like IACS and INTERCARGO separately submitted their FSA reports and recommendations to IMO. Moreover, there was an international study coordinated by the UK from 1999 and related progress reports and recommendations were submitted accordingly.

During MSC71 (IMO, 1999) to MSC 76 (December 2002), the discussion between countries was focus on the risk control options and the quantification period of costs and benefits assessment. Many recommendations including double side skin for bulk carriers were submitted to IMO through FSA reports. After reviewing all of the FSAs, IMO agreed to implement double side skin for bulk carriers larger than 150 meters at MSC 76.

However, after accepting a review document of FSA with the title "Comparative Study of Single and Double Side Skin Bulk Carriers" (Greece, 2004) by Greece, the issue of mandating double side skin bulk carriers was taken back to the table of IMO for discussion and debate. After a voting process, this issue was abandoned by IMO in MSC 78 session. Considering the immediate change of decision, there was a lot of criticism on this action and many people considered it a failure of FSA application in IMO's rule-making process under a kind of political pressure.

Another recent successful case of FSA study in IMO is the mandatory carriage requirement for Electronic Chart Display and Information Systems (ECDIS). This study was submitted by DNV under support of Denmark and Norway (MSC 81/INF.9) in 2006 and a Bayesian Network model was adopted as a modeling technique. According to the final report of the FSA on ECDIS (MSC81/24/5), it says the ECDIS, as cost-effective equipment, should be mandatory for most ships, excluding only smaller vessels.

As a result, an amendment to SOLAS Chapter 5 about ECDIS entered into force for passenger ships of 500 gross tonnage and upwards constructed on or after 1 July 2012 and tankers of 3,000 gross tonnage and upwards constructed on or after 1 July 2012. Other sizes of ships and types will be required to carry ECDIS in the years to come.

A large project of Design, Operation and Regulation for Safety (SAFEDOR) sponsored by the European Commission is also a recent great achievement of FSA. The project started in 2005 and closed in 2009 with several FSA reports on different kinds of ships and a book titled "Risk Based Ship Design". The list of the FSA reports with related hazard identification reports submitted by SAFEFOR are listed as follows:

- FSA LNG Carriers (MSC 83/INF.3, 2007)
- FSA container vessels (MSC 83/INF.8, 2007)
- FSA crude oil tankers (MEPC 58/INF.2, 2008)
- FSA Cruse ships (MSC 85/INF.2, 2008)

- FSA RoPax ships (MSC 85/INF.3, 2008)
- FSA dangerous goods (MSC87/INF.2, 2009)

The main purpose of this project was to improve maritime safety through the integration of safety into design and also to enhance the competiveness of maritime industry by a proposal for a modern regulatory framework and new ship designs. (page 3, SAFEDOR 2006).

In the final report of this project, the mandatory review for new and major revisions of instruments of IMO with acceptable criteria (page 47, SAFEDOR 2009) as well as accident reporting and underreporting issues were also recommended by the working group. It means that the FSA is still state of art for IMO's rule-making process and more works for the Guidelines need to be done by the Organization.

After the SAFEDOR project, other than the revision of FSA guidelines, recent FSA-related activity within the IMO has moved on two parallel fronts. (Kontovas, 2009). The first one was the review of the FSA studies submitted by SAFEDOR as well as other countries and organizations by FSA experts and the second one was working with environmental risk evaluation criteria, which focuses on oil pollution (Kontovas, 2009).

Therefore, from 2009 until now, Japan is leading the group of experts to work on the environmental risk evaluation criteria and, meanwhile, IACS and Germany continue to work on FSA studies on topics such as safety of general cargo ship (MSC 88/INF.8, 2010) and stowage of water-reactive materials (DSC 16/INF.2, 2011). In 2012, during the MEPC 62, the committee established a working group on environmental risk evaluation criteria to finalize the step 4 cost-benefit assessment of FSA with an appropriate volume-dependent CATS global threshold scale (MEPC 62/24).

3.3. Framework and Limitations of FSA

According to the Guidelines of FSA (MSC/MEPC.2/Circ.12), the framework of an FSA study could be divided into five steps as follows:

Step 1: Identification of hazards;

Step 2: Risk analysis;

Step 3: Risk control options;

Step 4: Cost-benefit assessment; and

Step 5: Recommendations for decision-making.

Figure 1 shows the relationship between the 5 steps as well as the preparatory work that shall be done beforehand.

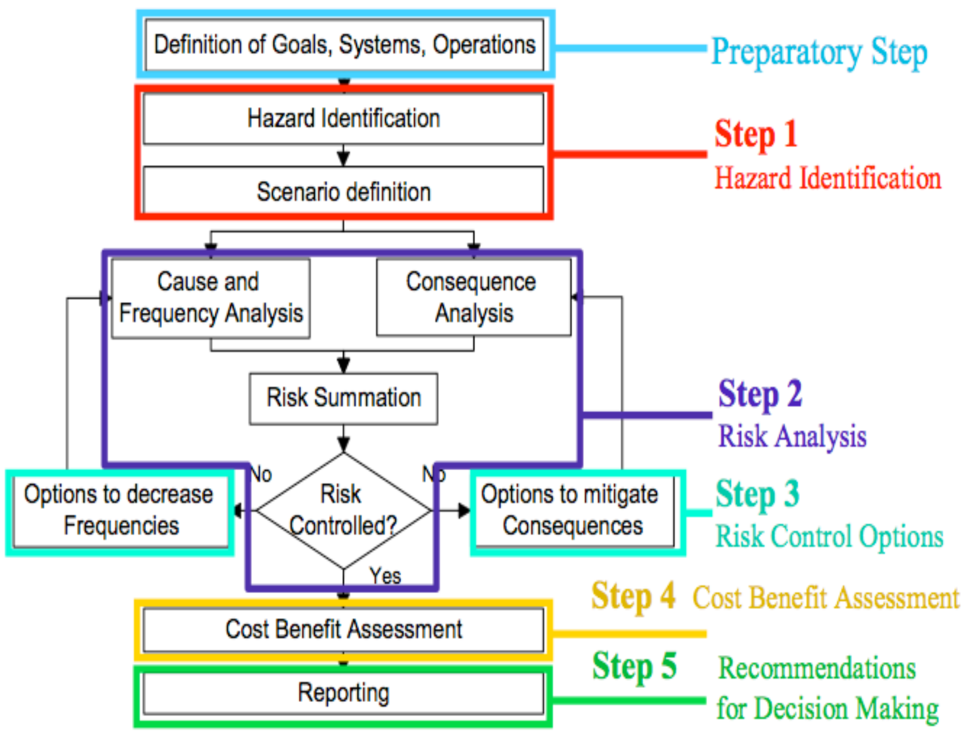


Figure 1. Flow chart of FSA (IACS, MSC75-5)

The Figure 1 of IMO shows the linkage between 5 steps throughout the FSA study. The weak linkage between step 1 and step 2 as well as step 1 and step 3 is always mentioned in the report of review of the FSA study and will be discussed later.

During the preparatory period of FSA, the definition of the problem shall be clearly illustrated referring to those types of ships and regulations that need to be reviewed. The boundary of the study is usually to be narrowed for further assessment and application. If the scope of the FSA study is too large, it may take more time to complete the final report and also is difficult for others to review as well as further implement.

For the first step, all potential hazardous scenarios shall be identified and ranked accordingly. It has been noticed that most FSA studies have used historical data from different databases of marine casualties. However, FSA study is a proactive method for rule making. A list of hazards identified only from historical data could not be used for discussions about adding new measures to reduce risk because sufficient data for these accidents needs to be collected beforehand.

Another big limitation of using historical data is the reliability and transparency of the database. A great number of warnings and "near misses" were not included in the database and those important potential hazards could not be identified at the first stage. In the report of SAFEDOR (SAFEDOR, 2009), the underreporting issues were mentioned and Global Integrated Shipping Information System (GISIS) was strongly recommended at that time.

When it comes to ranking the identified hazards, a risk matrix (Table 3) based on the severity index and frequency index (see Table 1, Table 2) can be adopted according to the annex of FSA Guidelines (MSC-MEPC.2/Circ.12)

Severity Index				
SI	SEVERITY	EFFECTS ON HUMAN SAFETY	EFFECTS ON SHIP	S (Equivalent fatalities)
1	Minor	Single or minor injuries	Local equipment damage	0.01
2	Significant	Multiple or severe injuries	Non-severe ship damage	0.1
3	Severe	Single fatality or multiple severe injuries	Severe damage	1
4	Catastrophic	Multiple fatalities	Total loss	10

Table1: Severity Index

Frequency Index			
FI	FREQUENCY	DEFINITION	F (per ship year)
7	Frequent	Likely to occur once per month on one ship	10
5	Reasonably probable	Likely to occur once per year in a fleet of 10 ships, i.e. likely to occur a few times during the ship's life	0.1
3	Remote	Likely to occur once per year in a fleet of 1,000 ships, i.e. likely to occur in the total life of several similar ships	10^{-3}
1	Extremely remote	Likely to occur once in the lifetime (20 years) of a world fleet of 5,000 ships.	10^{-5}

Table 2: Frequency Index

Risk Index (RI)					
		SEVERITY (SI)			
		1	2	3	4
FI	FREQUENCY	Minor	Significant	Severe	Catastrophic
7	Frequent	**8**	**9**	**10**	**11**
6		**7**	**8**	**9**	**10**
5	Reasonably probable	**6**	**7**	**8**	**9**
4		**5**	**6**	**7**	**8**
3	Remote	**4**	**5**	**6**	**7**
2		**3**	**4**	**5**	**6**
1	Extremely remote	**2**	**3**	**4**	**5**

Table 3: Risk matrix based on above Severity and Frequency index

Although this risk matrix will not be used for decision-making, this is an important tool that IMO provides for experts during the hazard identification step. However, the limitation of this two-dimensional table has been discussed because it overemphasizes frequent, low-consequence events over extremely rare accidents that are really catastrophic (Kontovas, 2005). Moreover, during the hazard identification step, a suitable expert group shall be carefully selected and the concordance matrix included in FSA Guidelines shall be carried out after the ranking of hazards.

According to FSA Guidelines, step 3, Risk control options, shall find out areas needing control and risk control measure (RCM) accordingly. Meanwhile, the effectiveness of RCM in risk reduction shall be evaluated by re-evaluating step 2. At last, RCMs shall be grouped into risk control options for decision-makers. However, this step, which strongly relies on the experts' subjective opinions, will be a problem for the future decision-making period. What's more, the interrelationship between different RCMs always raises questions during the review process and needs to be clarified in the report.

The cost benefit analysis (CBA) is obviously an important step and also a difficult and complicated one. Referring to the RCOs identified in step3, the benefits and costs shall be carefully compared. Currently, the Cost of Averting a Fatality (CAF) with the "$3m Criteria" is commonly adopted in FSA studies. As an outcome of step 4, the identification of cost effectiveness shall be expressed by suitable indices such as Gross Cost of Averting a Fatality (GCAF) and Net Cost of Averting a Fatality (NCAF).

However, in this quantitative model, only the expected number of fatalities is considered with a safety perspective. It means this model and criteria are not suitable for environmental assessment. According to the report of the SAFEDOR project (Skjong et al., 2005), they adopt a new CAT (Cost to Avert one tonne of spilled oil) criterion with a threshold value of $60,000 per tonne of spilled oil, which takes oil pollution into consideration in the qualitative model. However, after that numerous countries and organizations sent critical comments on the new CAT criterion adopted in FSA studies submitted by SAFEDOR, and this environmental criteria has not been widely accepted.

When it comes to the last step of FSA on recommendation for decision-making, all other four steps need to be considered and the final recommendations shall reduce the risk to the "desired level" as well as being cost effective. According to the FSA Guidelines, both the individual and society types of risk for crews, passengers and third parties shall be included in the report. In order to reduce these risks to a "desired level", an acceptable level of risk shall be decided and the As Low As Reasonably Practicable (ALARP) principle (HSE 2001) in figure 5 is often adopted during this process.

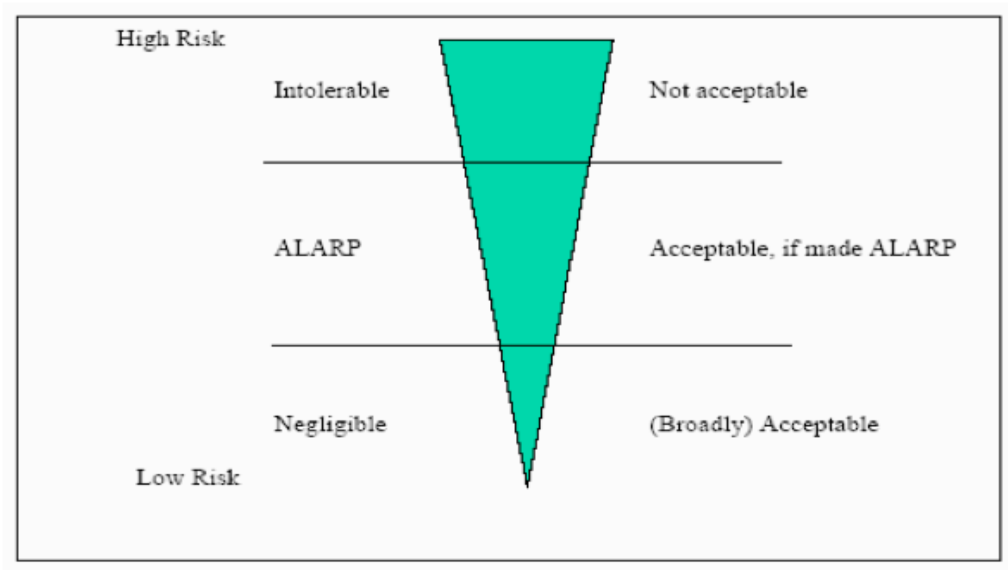


Figure 2: ALARP principle (page 48, MSC-MEPC.2/Circ.12)

The carrot diagram in Figure 2 shows that risk falling into the ALARP region shall be reduced until it is no longer reasonable to reduce the risk according to the result of step 4 Cost Effectiveness Analysis (CEA). The proposed values for NCAF and GCAF in Table 4 can be found in ANNEX of FSA Guidelines.

	NCAF [US $]	GCAF [US $]
criterion covering risk of fatality, injuries and ill health	3 million	3 million
criterion covering only risk of fatality *)	1.5 million	1.5 million
criterion covering only risk of injuries and ill health *) **)	1.5 million	1.5 million

Table 4: Cost-effective Criteria (MSC 72/16)

However, the value of indices of CEA is only provided for illustrative purpose and is not yet explicitly defined and, so far, the acceptable level of environmental risk is still under discussion.

For the individual risk, which is person and location specific, although the risk of death, injury and ill heath could all be affected by a ship accident, the risk of death is usually taken to determine the maximally exposed individual risk. The F-N curve

(Figure 3) can be adopted to express the individual risk through number of fatalities and the cumulative frequency of year. Considering the individual risk acceptance criteria usually adopted in the FSA study, maximum tolerable risk for crew members is 10E-3 annual fatal risk and the negligible risk is 10E-6 annual fatal risk. However, the individual risk for crew members and passengers may be stricter.

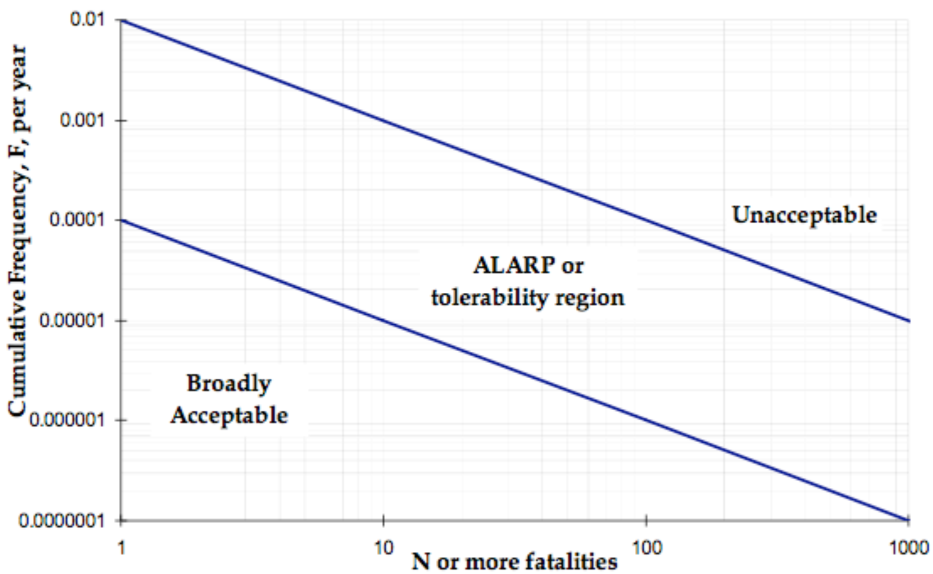


Figure 3: Example F-N curve (espoo report 2009)

According to the document submitted by Norway about risk acceptance criteria (see Table 5), the criteria adopted by different industries are similar with each other and the topic of obtaining more explicit criteria is still under discussion.

Individual Risk Criteria in Use		
Authority	**Description**	**Criterion (per yr)**
HSE (HSE, 1999)	Maximum tolerable risk to workers	10^{-3}
	Maximum tolerable risk to the public	10^{-4}
	Negligible risk	10^{-6}
Netherlands (Bottelberghs, 1995)	Maximum tolerable for existing situations	10^{-5}
	Maximum tolerable risk for new situations	10^{-6}
New South Wales, Australia (DUAP, 1997)	Sensitive developments (hospitals, schools etc.)	$5 \cdot 10^{-7}$
	Residential, hotels, motels, tourist resorts etc.	$1 \cdot 10^{-6}$
	Commercial, retail, offices etc	$1 \cdot 10^{-5}$
	Sporting complexes, active open space	$1 \cdot 10^{-5}$
	Industrial	$5 \cdot 10^{-5}$
Western Australia (EPA, 1998)	Sensitive developments (hospitals, schools etc.)	$5 \cdot 10^{-7}$
	Residential zones	$1 \cdot 10^{-6}$
	Non-industrial (commercial, sporting etc.)	$1 \cdot 10^{-5}$
	Industrial	$5 \cdot 10^{-5}$

Table 5: Individual risk criteria in use (Skjong et al. 2002)

However, the society risk is usually expressed by Potential Loss of Life (PLL) to quantify the risk in many FSA studies. Moreover, one method combining PLL with a multi-dimensional F-N diagram has been adopted currently (see Figure 4) (Knontovas, 2005). Both society risk and individual risk shall be adequately considered for a more comprehensive safety assessment according to the specific application field.

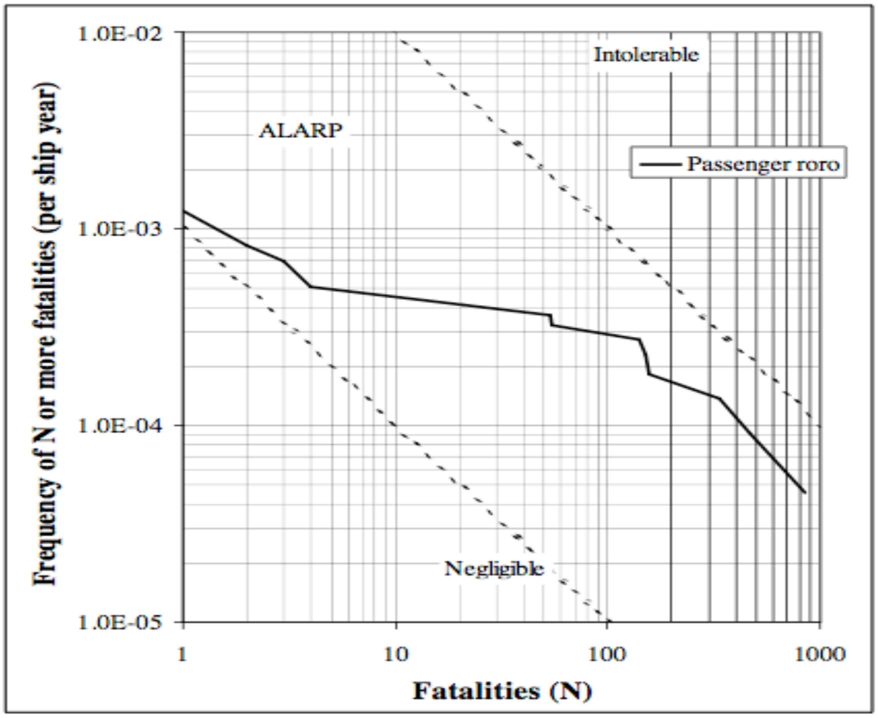


Figure 4: FN curve for passenger ro/ro ships (MSC 72/16)

3.4. Global trends and future development

The marine industry is both proactive and reactive regarding ship safety. However, the rule-making process of IMO is now moving from reactive to proactive and the formal safety assessment is still quite a useful and amateur tool for revision of existing regulations and development of new ones.

A great number of achievements have been made and more and more FSA studies need to be finished for the further improvement of IMO regulations. Currently, a new amendment of FSA Guidelines with more advanced techniques has been approved by MSC/MEPC committee. Meanwhile, the expert group of FSA is focusing on reviewing those FSA studies submitted, using more complete procedures.

As environmental protection issues became a more and more important topic in IMO, the corresponding group on environmental risk evaluation criteria was established in 2008 and is still working. After the submission of the FSA studies of the SAFEDOR project (Skjong et al., 2005), adoption of the criterion of Cost to Avert one Tonne of Spilled Oil (CAT) was widely discussed.

The outcome of the correspondence group was added into annex 7 of the newly revised FSA Guidelines in 2012. The consolidated database was developed based on IOPCF data, US data and Norwegian data and some regression formulae has been provided for further analysis. Future Guidelines for the environmental FSA have been recommended by the correspondence group to IMO for further discussion. However, so far no explicit environmental risk evaluation criterion is proposed by FSA guidelines.

Thus far FSA guidelines do not stipulate how to assess environmental risk. In the 55th session of MEPC (October 2006), however, the IMO decided to act on this subject. A major topic in Annex 3 of document MEPC 55/18 was the definition and analysis of risk evaluation criteria for accidental releases to the environment and specifically for releases of oil. The discussion on the environmental criteria was also focused on the criteria of CATS from the SAFEDOR report.

To sum up, the future work of IMO on FSA shall be the environmental related issues as well as dealing with those limitations that affect the reliability of the FSA study.

4. Preparatory work before the FSA for the development of a mandatory Polar Code

4.1. Problem definition and generic model of study

As mentioned in chapter 2, vessel traffic in both polar regions is increasing rapidly these years. Considering the vulnerable ecosystem of polar waters, stricter rules of navigation safety and environmental protection have been regulated and discussed in IMO. The mandatory Polar Code is definitely the most important one still under development.

Historically, few accidents have occurred in the Polar waters, but zero accidents today does not mean that certain accidents cannot happen. The actual risk level of vessels navigating in polar waters has been analyzed thorough a risk model in order to predict the future probabilities. The accident of the Explorer sinking in the Southern Ocean and passenger vessel Clipper Adventure grounding in the Arctic area gave us good examples, illustrating that the need for a risk model is critical. It shows that historical accident statistics can be very deceiving especially when small samples are recorded in the database.

Moreover, for ships navigating in polar waters, a major catastrophic accident could not only involve large numbers of fatalities but also would cause huge irreversible damage to the environment. Therefore, a proactive full or partial FSA study is essential because the tolerance for accidents in polar waters is quite low.

As very broad FSA studies can be harder to manage (page 6, MSC 91/16), it is necessary to narrow the boundary of analysis beforehand and define the problem clearly.

The FSA studies for ships navigating in Polar waters could be divided into several reports or parts by taking into account different relevant aspects such as ship categories, accident categories and risks associated with consequences. The functions, features, characteristics and attributes that are the same to all ships of the type in the whole FSA study will be clearly illustrated by a Generic Model. The decision on the essential elements mentioned above heavily depends on investigation into the historical database as well as opinions from experts, and it will be discussed in the next chapter.

4.2. Historical data collection and analysis related to ships navigating in polar waters

Prior to the development of the FSA studies, a number of early studies and statistics are quite useful and shall be consulted. All the further risk assessments shall be based on a sound knowledge of the traffic density and types as well as accident categories as a key input.

4.2.1. Geographical boundary of polar waters

According to the current drafting of the mandatory Polar Code, the polar waters including both Arctic and Antarctic waters are defined separately by IMO, which can be indicated in Figure 5 and Figure 6. Actually, the definition of polar waters in the Polar Code is the same one adopted in the Guidelines for ships navigating in the Polar Waters.

Figure 5: maximum extent of Arctic waters application （Guidelines for ships navigating in polar waters, 2011）

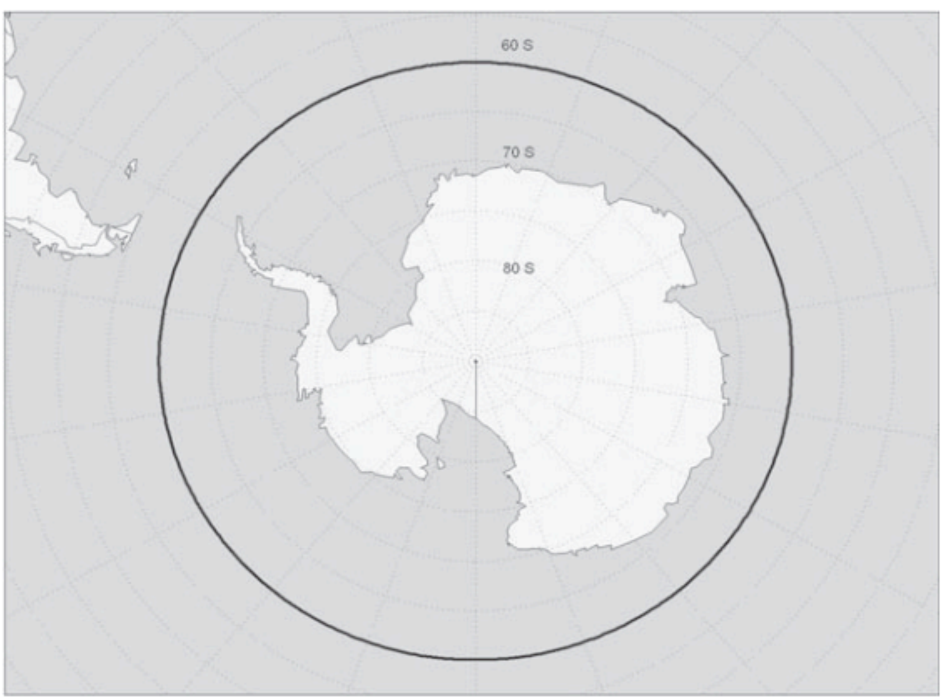


Figure 6: Maximum extent of Antarctic Waters application （Guidelines for ships navigating in polar waters, 2011）

However, it could be easily found that the traffic in the Norwegian Sea, Iceland and Faroe Islands was not included in defined Arctic water, and even some vessel activities in US and Canadian waters are not included. When looking into the database of vessel traffic, for example the AMSA report, samples are quite small if vessels and accidents are selected according to the IMO definition of polar waters, especially in Arctic waters.

A sound database with more reliable records is quite important during the preparatory stage of FSA studies in order to decide the scope and depth of the research. It can also help to correctly estimate the future tendency of vessel traffic and density and maximally determine the risks and hazards.

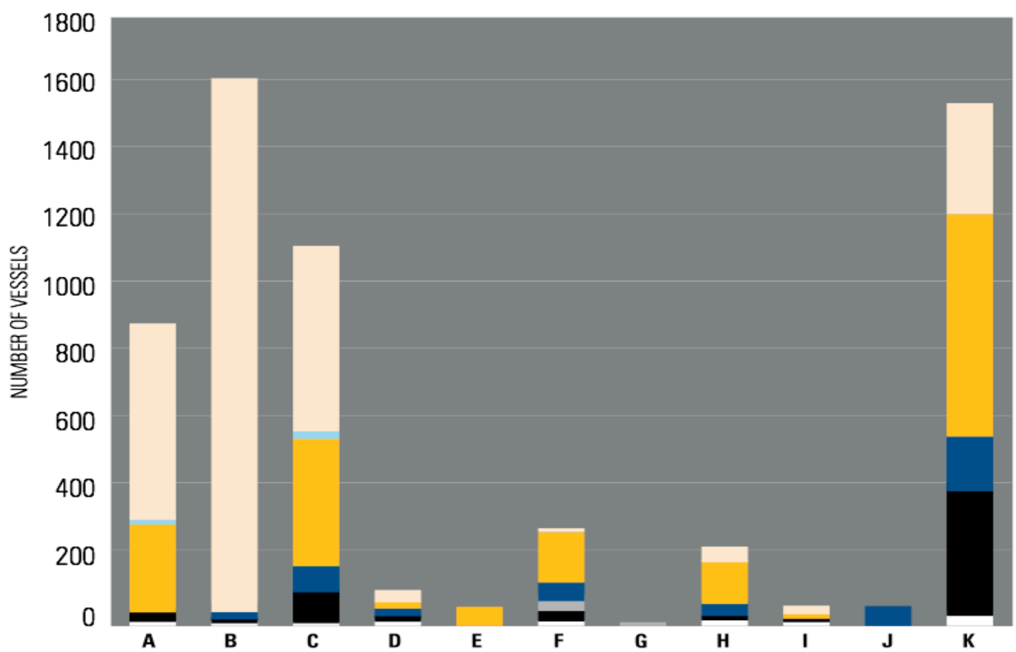
Therefore, the geographic limitation of the FSA shall be defined according to the IMO adopted polar waters. However, during the preparatory historical data collection and analysis stage, the author strongly recommends that all "Circumpolar North Region" defined by Arctic Marine Shipping Assessment (AMSA) report shall be covered. The database of AMSA includes various kinds of vessels such as icebreakers, container ships, tankers, offshore supply vessels, ferries and coast guard ships (Brigham, 2010). This kind of database can provide a holistic approach for the experts involved with the FSA to identify more potential risks to the arctic marine environment as well as navigation safety.

Moreover, considering the purpose of the FSA study, the possibilities to narrow the geographical scope into Arctic waters and Antarctic waters separately shall be further discussed considering the significant differences between the Arctic and Antarctic water areas such as geographical features, types of vessel categories, as well as sea ice, meteorological and environmental conditions.

Above all, the geographic scope of the FSA study for a mandatory polar code shall comply with the polar waters defined in it and the historical data analysis for the traffic and accidents could be broader and more flexible regarding the study purposes.

4.2.2. Analysis of traffic data in polar waters

Currently, vessel traffic data can be collected from the ArcticData portal (www.articdata.is) of the Protection of Arctic Marine Environment Working Group (PAME), which is one of the six arctic council working groups. A summary of the total number of vessels per category per country in Figure 11 within the annual report of AMSA in 2009 can be adopted as a useful resource for FSA preparatory work. The chart below (Figure 7) shows that container ships, bulk carriers, fishing vessels and general cargo ships are the dominant categories of ships navigating in arctic waters.



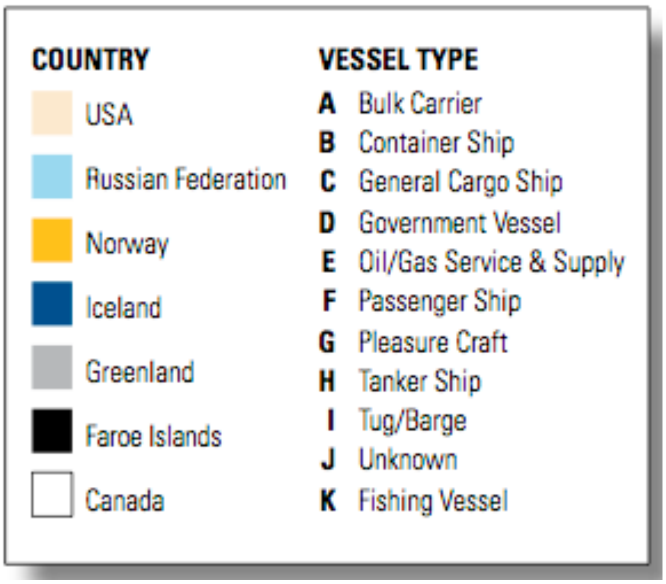


Figure 7. Total number of vessels for each country by vessel type

However, when taking these statistics into consideration, the data provided by the U.S. with a large number of containers and general cargo ships includes the vessels plying the Great Circle Routes below 60 degrees north. Therefore, according to the AMSA report, four categories of vessel activities were highlighted for marine use: community re-supply, bulk cargo, tourism and fishing vessel activities operations. One thing that should be mentioned is that fishing vessels have been excluded from the scope of ships for application according to the new draft of the mandatory Polar Code. Leaving aside the importance of the Polar Code for fishing vessels, the historical accidents and traffic records of fishing vessels are quite useful for the hazard identification stage and should be carefully collected and analyzed.

The ArcticData portal can also provide data relating to marine accidents and incidents for 2008 and 2009 with Excel form. The information includes the following information from 1995 to 2004 for further analysis:

- Source of Information
- Categories of ships
- Date and position of accident happened,
- Related Large Marine Ecosystem (LME) and EEZ,

- Lives lost and total fatalities
- Fuel spill with amount spilled
- Total loss, actual/constructive loss and ice damage
- Primary reason and description

According to the statistics in 2009, there were 294 accidents and incidents recorded by different countries. Figure 11 shows the summary of statistics within the AMSA report 2009.

Vessel Type	Number
Bulk carrier	37
Container ship	8
Fishing vessel	108
General cargo ship	72
Governmental vessels	11
Oil/Gas Service & Supply	1
Passenger ship	27
Pleasure Craft	0
Tanker ship	12
Tug/Barge	15
Unknown	2

Primary Reason	Number
Collision	22
Damage to Vessel	54
Fire/Explosion	25
Grounded	68
Machinery Damage/Failure	71
Sunk/Submerged	43
Miscellaneous	10

Table 6. Accidents and Incidents in the Arctic, 1995-2004

A study of tiered risk assessment based on ArcticData provided by the International Association of Antarctica Tour Operation (IAATO) was submitted to IMO in 2011. However, the scope of the study was narrowed to focus on passenger ships navigating in Polar waters as defined by IMO Guidelines of polar waters. Figure 12 and Figure 13 show the development of the statistics based on ArcticData by IAATO.

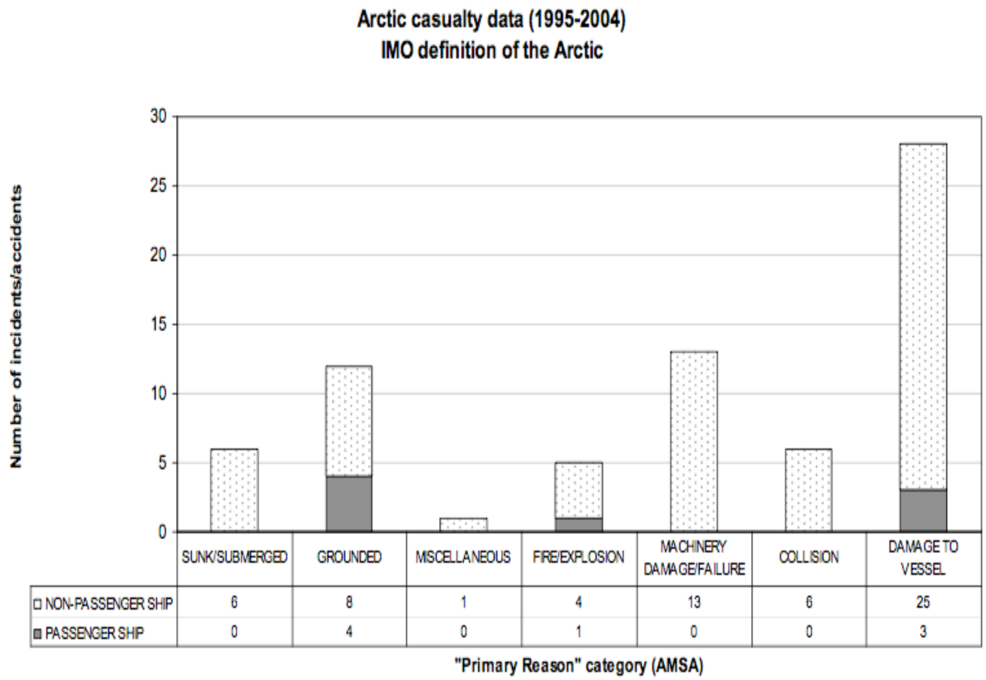


Figure 8: Overview of casualty data for the Arctic – breakdown of incident/accidents per category

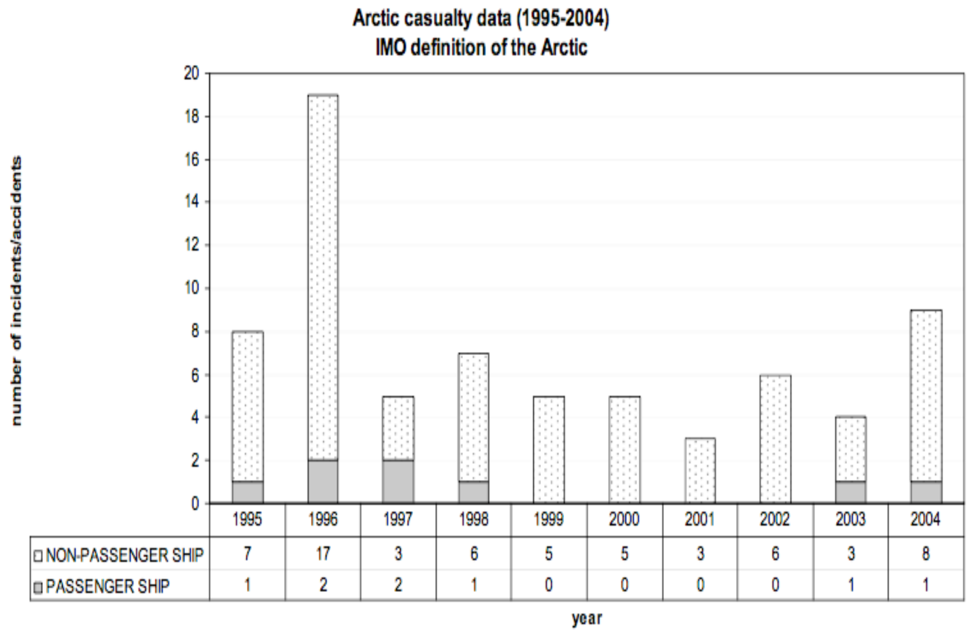


Figure 9: Overview of casualty data for the Arctic – breakdown of incidents per year (year round operations)

The number of passenger vessels illustrated in the diagrams is quite small when the IMO geographical definition of arctic water is adopted. Compared to the total number of 4,475 individual vessels including 277 passenger vessels listed in ArcticData, the number of the sample is too small to be reliable and convincing. Therefore, some consequences based on these statistics as well as the final conclusion may not be directly adopted in the further assessment. As the author mentioned in the last section, a larger navigable area with similar geographical features could be included in the preparatory stage and hazard identification stage.

4.2.3. Limitations of utilizing historical data in preparatory work of FSA studies

During the preparatory stage of FSA studies, regarding historical data analysis, the major limitations can be discussed in two aspects. One is the limitation of the database itself, and the other one is the limitation of the future application.

The limitation of the database depends on those key elements such as database structure, geographical scope, vessel categories and accident categories. Generally speaking, only accidents with consequences that could be checked are recorded. However, there could be a large amount of "near miss" accidents without any recording. Actually, these "near miss" cases or warnings are critical to the first hazard identification step. Therefore, the underreporting issue is always mentioned in the limitations of FSA study. For water areas like the Arctic and Antarctic with small vessel samples, the limitation of the database may totally change the final results of the study. The analysis of historical data should be consulted more scientifically and carefully.

As to the limitation of the future application, the proactive approach of FSA studies has to be emphasized here. Studies only derived from historical data may not help to develop proactive regulations. The brainstorming of experts during the preparatory stage is strongly recommended in order to maximally mitigate the limitation. The combination of historical data and expert opinion could provide a more solid foundation for further FSA studies.

4.3. Discussion of the priority for FSA studies for ships navigating in Polar waters

The purpose of developing a mandatory Polar Code is to provide strong safety and environmental provisions for the shipping industry and IMO member nations, who are interested in future polar navigation. FSA study is still the method recommended by IMO for the rule-making process. However, a full and comprehensive FSA study takes a comparatively longer time. Some former FSA studies took more than one year to complete. The development of the Polar Code has taken several years and it should be completed according to the schedule and to be implemented in those areas as soon as possible. Therefore, the priority fields of study become quite important at the preparatory stage. The major considerations of this will be discussed according to the differences between the two polar waters and between safety risk and environmental risk.

4.3.1. Arctic waters vs. Antarctic waters

The analysis of historical traffic and accident data is aimed at developing a comprehensive representation of current and future traffic conditions in the polar waters. Compared to the Antarctic, vessel traffic especially cruise ships in the Arctic waters is increasing more rapidly because of the disappearance of large amounts of sea ice, in summer time especially. According to a 2009 AMSA report, the number of cruise ship passengers had more than doubled. Moreover, the number of cruise ships will continuously increase, considering the growth of the economies of the circumpolar nations due to tourism. Besides cruise ships, more shipping lines and cargo owners interested in transit Arctic routes are preparing to take the newly opened shipping lane in Arctic waters. As a result, more ship accidents and incidents will happen in Arctic water in the forthcoming years.

Regarding the environmental protection aspect, although both Arctic and Antarctic waters have the same ecological features and vulnerabilities, the condition of Antarctic waters is much better than Arctic waters. As mentioned before, the waters south of 60 degrees south latitude have been designated as Antarctic special Area under MARPOL 73/78 Annex I, Annex II and Annex V with stricter requirements and also the use and carriage of heavy fuel oils is prohibited in Antarctic waters according to a new amendment to Annex I of MARPOL. However, the Arctic waters have not been included in the list of special areas.

Furthermore, the Antarctic governance is a good example of regional cooperation based on the Antarctic treaty with several agreements. The Protocol on Environmental Protection to the Antarctic Treaty is a powerful tool for protection of the Antarctic waters. As to the Arctic waters, for the time being, there is still no equivalent powerful legal regime to govern this area.

Therefore, the mandatory Polar Code, once enforced, will become the most important rule for polar navigation, especially for Arctic water. The provisions for environmental protection will, to some extent, fill the gap of sustainable development between the two polar waters.

4.3.2. The navigation safety risk vs. environmental risk

As a full FSA study, both navigation safety issues and environmental protection issues shall be considered in every step of FSA. However, the scope of most of the FSA studies until now has been narrowed to navigation safety of ship and personnel in order to facilitate the approach to the assessment.

Moreover, the environmental issues are usually not included in the study because some kinds of ships do not present extraordinary hazards to the environment through the investigation of historical data. However, considering the environmental vulnerability of both polar waters, the risk of ship-borne oil spill could be quite significant and irreversible.

Moreover, IMO is still constantly working with member states and other organizations to protect the marine environment from damage caused by ships, especially oil spills by ships. A cost-benefit assessment (CBA) based on environmental risk assessment has been carried out in the FSA FOR Crude oil tanker SAFEDOR project. The recommendation relating to CBA aroused a lot of discussion between countries and organizations, especially for the newly adopted CAT model and related environmental risk evaluation criteria (EREC). As a result, a correspondence group was established to develop an EREC and review of the environmental part of this FSA. Moreover, as mentioned before, the correspondence group even recommended developing IMO Guidelines for the environmental FSA. It shows that the environmental risk assessment is now a greater concerned to the international community and the gap between navigation safety and environmental safety is going to be filled owing to technological improvements and broader international discussion and cooperation.

Referring to the historical data provided in Table 6 from AMSA 2009, it can be seen that grounding is one of the most common accidents in Polar waters and one of the major contributors to oil spills. The environmental risk of grounding has to be assessed in order to make appropriate provisions accordingly.

Therefore, the author recommends, during the preparatory stage of FSA for the mandatory Polar Code, the environmental FSA shall be considered as important as the safety FSA. Regarding the progress of development of the Code, an environmental FSA for the working group of IMO could be more urgent and useful to the working group of IMO. The comments and discussion aroused by environmental FSA could also provide important sources for future amendments to the Code.

4.4. Summary

The preparatory step of the FSA is quite important and linkage between the preparatory step to other following steps is also strong, especially the hazard identification step. The FSA studies of the mandatory Polar Code should be carried out for the rule-making process (if time is sufficient) or as soon as possible after the adoption of the Code for further amendment. A full FSA study considering both safety and environmental protection for the whole polar waters is definitely helpful; however it is also more complicated and time-consuming.

Therefore, the author suggests that the scope of study shall be narrowed to focus on more urgent requirements from the international community and other areas of concern could be completed based on this study.

Considering all related matters mentioned in this Chapter, the author thinks the most important FSA study for the Code should be the environmental FSA for the Arctic waters. Cruise ships or bulk carriers can be the categories of ships involved at the first stage and the main accident category shall be focused on the grounding of vessels.

5. Challenges of the Application of FSA for the mandatory polar code

5.1. Potential hazard identification and analysis

5.1.1. IMO HAZID workshops for Polar Code

As a risk-based Polar Code, the structure and outcome of the Code have to be consistent with a risk assessment. It is necessary to gather all stakeholders of the Code to discuss all the possible risks for the early adoption of the Code.
According to the report of the HAZID workshop (DE 53/18/5, 2009) submitted by Denmark concerning human life of Arctic waters, a risk matrix (Figure 10) was developed during the meeting in accordance with the Guidelines of FSA. The high, medium and low risk of navigation in arctic waters was ranked through the discussion during the meeting, which recommended being a basis for the further development of the Polar Code.

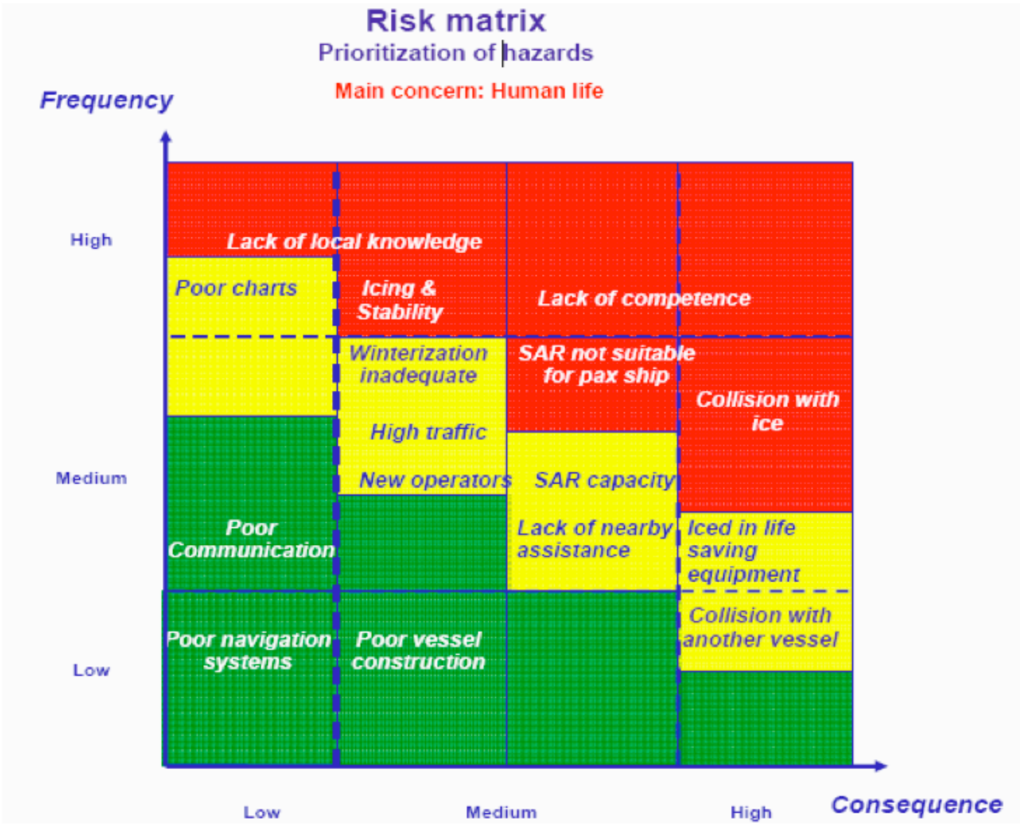


Figure 10: Risk Matrix for ships operating in Arctic waters (source DE 53/18/5)

Therefore, in order to encourage the development of environment aspects of the Polar Code, the work of the Polar Code Hazard Identification workshop has already been carried out coordinated by NDV in 2011. Comparing with the HAZID of human life, the difficulties of environmental HAZID are the lack of data and information on the impact of environmental hazards as there is relatively lower vessel traffic density than any other sea area. Therefore, the analysis of the historical accident data can provide limited contributions for the HAZID process. The integrity of the potential hazard list as well as the further risk matrix with ranking of hazards mostly depends on discussion and brainstorming between experts.

According to the report of HAZID workshop 2011, a draft hazard matrix (see Annex I) has already been developed, which can be quite useful for further discussion. However, the outcome of the workshop is not quite satisfactory because of the limited time of discussion. The full hazard list relating to the impacts of the environment as well as the corresponding control options was not completed by experts. Moreover, the work of ranking listed hazards was not covered in this workshop. Therefore, a lot of work still needs to be done for hazard identification, especially the determination of the priority of risks.

5.1.2. Ranking of risk scenarios

Although the workshop on the Polar Code in 2011 did not provide a complete HAZID for further environmental FSA studies, this workshop has already provided a good direction for the future HAZID work. According to the report, the release assessment has been considered as an important step of HAZID. The environmental impacts of ships' activities are divided into possible routine releases into the environment and possible accidental releases into the environment with a detail description list (see Annex II) of release categories. Moreover, the contributing factors and some related risk control measures are also listed in the report. Taking these factors into consideration, a more useful qualitative or quantitative risk analysis could be constructed accordingly.

A qualitative assessment can be adopted according to the release scenario. A group of experts could be organized regarding the assessment requirements and work together on the ranking process. The probability of routine release and accidental release as well as the severity of consequences can be discussed and completed during the meeting of experts. Meanwhile, the related control options could be listed for step 3 risk control options.

5.1.3. Challenges of HAZID for Polar Code

As mentioned above, the first challenges of HAZID for the Polar Code is the completeness of the hazard list. As a basis of all further assessments, all potential risks should be identified in this stage. Considering the drafting hazard list provided by IMO, some important potential hazards such as introduction of alien species and underwater noises (DE 56/INF 3) have still not been included or discussed. More systematic analysis should be carried out by work groups by adopting the methods recommended in FSA Guidelines such as HAZOP and FMEA in order to identify all environmental hazards as well as initial events.

Another big challenge for the HAZID process is the ranking of risks as there is no specific risk matrix recommended by IMO for the environmental FSA study. Until now, the discussion within the IMO has only covered oil spills as a consequence of accidents. However, the discussion of the oil spill could be a preparatory work for further improvement of the generic environmental risk assessment.

Regarding the report of the correspondence group for environmental risk evaluation criteria, the frequency index (FI) has been proposed by the working group for use in the safety FSA methodology (MEPC 60/22). However, the severity index (SI) is still under discussion as related environmental risk evaluation criteria for the quantitative assessment has not been agreed upon.

However, concerning the ranking of hazards for the development of the Polar Code, there may not be enough time to wait for the organization to provided generic reference criteria. The better way to carry out the job within a limited time might be to accept the SI decided by the experts based on the IMO SI table. The types, amounts and timings of the release of hazards (Fairman, 1999) could also be considered in order to make the SI more appropriate for the environmental assessment. Once the related criteria are approved by IMO, it could be adopted in the future amendment process for the Polar Code.

5.2. Measures for Risk assessment

The second step of FSA is the detailed assessments of the causes and initial events and consequences of those release scenarios identified in step one (MSC 91/16).

Compared to qualitative assessment by experts, a quantitative method is much more complicated and takes more time to finish. However, it is a more systematic way to identify and rank the hazards compared to the limited knowledge of experts. The quantitative method to estimate the probability of all potential data can be carried out through different ways. For example, the historical data could be used for investigation. As the database for Polar waters is comparatively small, the outcome of the assessment could be not reliable. Moreover, the quantitative method could only be carried out according to the implicit environmental risk evaluation criteria approved by IMO. As mentioned before, these generic criteria have not been discussed while the specific criteria for oil spills are under development.

Another method that could be adopted here is the simulation of scenarios. After listing the contributory factors and causes of routine and accidental scenarios, the probability of release could be concluded on the basis of the statistics collected during and after the simulation process. Those historical data in polar waters as well as in other sea areas could be used to verify the results. As to the quantitative method of determining the severity of the consequences of the risk scenarios, various methods of ecological impact assessment could be adopted and the related consequences of risk scenarios can be estimated by those methods such as Predicted No Effect Concentration (PNEC) and fuzzy logic. However, the accuracy of the consequences assessment of a ship's release based on an ecological impact assessment with related assessment criteria has to be further considered by the experts.

Compared to the quantitative method, qualitative assessment is easier and timesaving. According to FSA Guidelines, the use of techniques like Dalphi for expert judgment could be used, where data is unavailable (page 11, MSC 91/16).

5.3. Risk Control Options

The step of risk control options aims at identifying all the risk control measures (RCM) for the identified risks with new methods of operation or management and providing a combination of RCM for further cost benefit assessment. According to the report of a work shop in 2011, the following RCO has been listed:

- Ice strengthening for ships.

- Ice forecasts.
- Availability of ice breakers.
- Navigation aids that fully function in polar waters.
- Equipment and systems that function correctly, and on demand, in extreme cold.
- Additives for fuel to prevent waxing (prevent failure or failure on demand).
- Restricted bunker fuel oil type(s).
- Stricter routine discharge limits compared to IMO baseline (MARPOL).
- Enforcement of discharge limits.

The RCO is based on the risk levels of hazards provided by the first step. The limitations of step one will strongly affect the result of the RCO. One of the limitations of step one that has to be mentioned is the conclusion based on expert opinion. According to the discussion in the last two sections, the better way or more timesaving way to carry out the HAZID and risk assessment strongly relies on the decisions made by experts. What's more, the RCO step also relies on expert opinion (Knotavas, 2009). Compared with finding RCO from historical data, the reasonable estimation of risk reduction could be more proactive and helpful to find new operation and management measures. Therefore, these two important steps, even step two for re-evaluation, are all decided by experts. The experts become quite a vulnerable chain of the assessment.

Taking advantage of reliable techniques for experts as mentioned could be an option to solve the problem. However, the calculation of concordance coefficient, as proposed by FSA Guidelines, provides a technical way to judge the degree of agreement between experts. After calculation of concordance coefficient by formula, the level of agreement will be described as:

W	> 0.7	Good agreement
W	0.5 – 0.7	Medium agreement
W	< 0.5	Poor agreement

Table 7: Concordance coefficient (MSC-MEPC.2/Circ.12)

The decision made by experts with a concordance coefficient could be adopted and the result could be regarded as a reference for the next linking steps as well the final decision-making step.

5.4. Cost benefit assessments

The cost-benefit assessment is an important step and it has been completed with quantitative methods. The cost and benefit of the RCOs obtained from step 3 shall be carefully calculated by proper methods and techniques. The biggest challenges of this step must be the calculation of indices for the cost-effectiveness as the environmental risk evaluation criteria has not yet been decided.

However, the risk evaluation criteria of oil release have been discussed within IMO after the adoption of the criterion of CATS within the SAFEDOR report. In this repot, the threshold value of \$60,000/tonne aroused debate at IMO, as it is a critical issue for the future decision-making process. As a result, a decision was made by MEPC 62 to establish a working group on environmental risk evaluation criteria to finalize step 4 based on the CATS model (MEPC 62/24). This means there will be a criteria proposed by IMO soon.

Compared with the complexity of the cost benefit assessment of oil spills, the comprehensive assessment involved in environmental FSA for the Polar Code will be more complicated. The discussion of generic environmental criteria has not been put on the table yet. However, the specific model could be adopted if the scope of study was narrowed into specific accident categories, for example the accidents of grounding. As one of the primary causes of accidents in polar waters as well as one of the major contributors to oil spills, the CATS model could be adopted for the cost-benefit assessment and related criteria recommended could also be used for the determination of SI of the HAZID period and the decision making period. The full environmental FSA could be carried out after adoption of the generic criteria for amendments of the related regulations in the future.

5.5. Recommendations for decision making

According to the flow chart of FSA methodology (Figure 11), the final step of recommendations for decision-making is directly and indirectly based on all other previous steps.

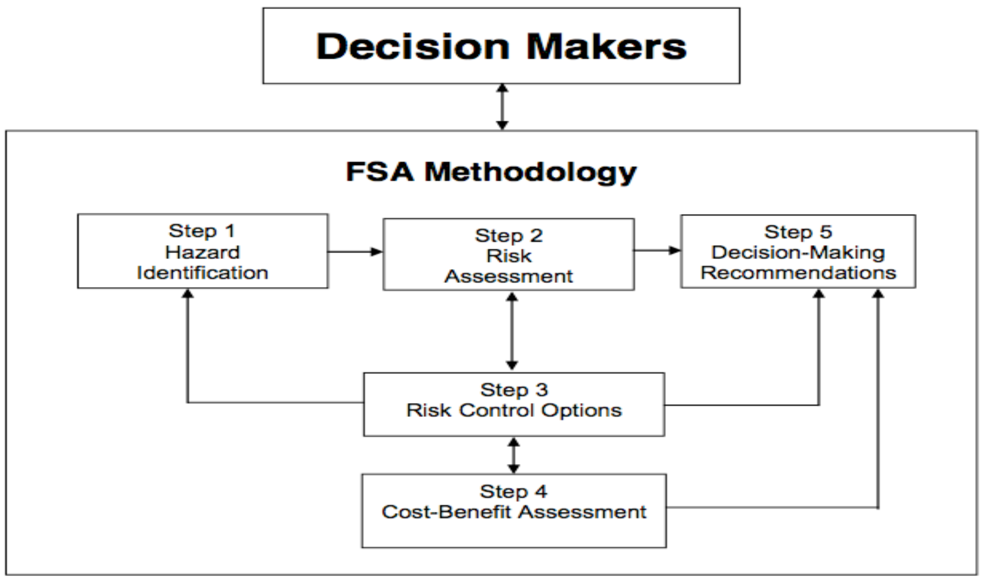


Figure 11: Flow chart of FSA methodology (MSC 91/16)

The RCOs recommended by step 4 shall reduce the risks to a level "as low as reasonably practical" and to be "cost effective". Subsequently, the suggestion for rule improvement or amendment shall be carried out accordingly. Moreover, the list of recommended RCOs with the application of RCOs shall be listed.

For environmental FSA, the difficult part of this step is how to find an ALARP region with appropriate risk acceptance criteria. However, both individual and societal risks adopted in former FSA studies are based on crew fatalities or passenger fatalities, which is not the major concern of environmental protection. The acceptance criteria for assessing damage to the environment could be established by adopting the extent of environmental damage to replace the extent of personal injury. Both quantitative method and qualitative method can be used to establish the environmental criteria. Compared to quantitative risk acceptance criteria with explicit numbers, the qualitative criteria including environmental damage in defined by seriousness classes (Nijs, 2009) could be simpler and more appropriate. The risk acceptance matrix for society risks established in France (see Figure 12) is an example of this.

Seriousness / Frequency class	Moderate	Serious	Major	Very major	Disastrous
A	ALARA	No	No	No	No
B	OK	ALARA	No	No	No
C	OK	ALARA	ALARA	No	No
D	OK	OK	ALARA	ALARA	No
E	OK	OK	ALARA	ALARA	No

Figure 12: (Nijs, 2009) Risk Acceptance Matrix for Society Risks

The red fields represent an unacceptable risk and the yellow fields show where the new plant can be approved, on condition that all ALARA safety measures are implemented. The seriousness of the hazard and the frequency could be decided by the expert group. Considering the specific nature of polar waters, the seriousness degree of environmental damage will be comparatively higher than other sea areas. The environmental acceptance criteria, which have been established by other countries regarding local waters or rivers, can also be used to verify the final results.

5.6. Summary

The major challenges of the environmental FSA for the polar code are the lack of generic environmental risk evaluation criteria, which makes the qualitative method a better choice for early stages of study. However, the progress of the working group involving the environmental risk evaluation criteria for oil spills is satisfactory owing to the support from member states and related organizations. After appropriate definition of the scope of study, the environmental FSA with qualitative assessments could be carried out based on the current available criteria and the future generic criteria could be adopted for a full and more comprehensive FSA for further amendments.

As to the experts, the decision relying on judgment of experts cannot be avoided in every step of FSA. A more technical method such as Delphi as well as the calculation of concordance coefficient can be adopted to improve and check the results of experts. Moreover, the qualification of the experts with requirements has been regulated in the FSA Guidelines (page 70, MSC-MEPC.2/Circ.12) in order to ensure the reliability of the expert decision.

6. Conclusion and recommendations for the future works

6.1. Conclusion

With climate change and other activities of human beings already placing pressure on the polar region, additional marine activities are inevitably increasing the burden of the vulnerable ecosystems of Polar Regions. However, the increase in areas without ice-coverage in Arctic waters has aroused more interest from the maritime industry to open new shipping routes. The number of vessels taking advantage of the trans-Arctic routes almost doubled this year, which shows the growth tendency of future vessel traffic. As a result, risks such as oil spill, illegal release and introduction of invasive species are increasing rapidly. Therefore, the development of a mandatory Polar Code is quite important in order to protect the last pristine land for human beings.

Considering the development of the Polar Code in IMO, from the proposal for guidelines first submitted in 1996 to the recommendatory guidelines for Arctic ice-covered areas approved by IMO in 2002, it has taken almost seven years to finish the job. It has taken another seven years for the organization to develop guidelines for ships operating in the polar waters, from 2002 to 2009. During this period, more accidents happened in these areas, arousing the concerns of countries and organization to provide more specific regulations both mandatory and recommendatory for the polar waters. Therefore, the mandatory Polar Code has become one of the most important tasks of the DE sub-committee.

However, compared to the recommendatory guidelines, the development of a mandatory Polar Code is more complicated and time-consuming. At the early stage, the member groups have approved the major structure of the Code, which provides functional requirements supported by prescriptive provisions with both mandatory and recommendatory parts by risk based approach. Nowadays, the discussion of the mandatory Polar Code in IMO is now moving from some basic principles such as main structure, scope of ship categories and definition of geographic coverage to more detailed functional requirements and regulations. Recently, proposals for a specific environmental protection chapter have been approved and listed as chapter 15 in the draft for further discussion. Therefore, how to make appropriate regulations to reduce environmental damage in polar waters is widely discussed among member states and organizations. All kinds of suggestion and recommendations from different stakeholders submitted to IMO makes the decision-making process more and more complicated and difficult. The formal safety assessment, as a risk-based tool recommended by IMO, can proactively provide useful and practical suggestions for the final decision-making process and speed-up the progress of approval and implementation of the Code.

Considering the development of FSA, a lot of studies and achievements before2006 were focused on safety issues. During that time, the first official version of FSA guidelines was approved in 2002 and the amendments for FSA guidelines were adopted in 2006. The benchmark for environment issues shall be the submission of a series of FSA studies included in the EU SAFEDOR project. The special environmental concerns about oil spills from reports of crude oil tankers aroused wide debates and discussions in IMO. A significant breakthrough on the study of environmental risk evaluation assessment has been achieved by the designated correspondence group. Therefore, the author thinks the environmental FSA with appropriate criteria could be quite useful for the development of an environmental protection chapter of the mandatory Polar Code.

In order to facilitate the progress of the FSA, the scope of area concerned has to be narrowed and carefully defined beforehand. The historical data was analyzed by the author in order to decide the priority area to be considered. Moreover, the further investigation into differences between the two polar waters and the essentialities between environmental issues and safety issues for the current drafting stage of the Code provides more useful information for the preparatory work. According to the outcome of these analyses, the author recommends carrying out an environmental

FSA for Arctic waters for bulk carriers or passenger ships concerning specific accident categories like grounding or collision.

After investigation into of each step of environmental FSA, the challenges of each step were analyzed and discussed and possible methods to solve the problems were also provided by the author. The lack of generic environmental risk evaluation criteria is a key contributor to the failure of adopting a quantitative method. Therefore, the qualitative method is a better choice at early stages of study. What's more, special attention should be paid to the qualification of experts, as it is a critical factor for the whole process. Furthermore, another option was provided by the author considering the current specific criteria for oil spills provided by the working group. The quantitative method can be achieved by narrowing the scope of ship release to oil spills only. This might be a more systematic and comprehensive method that can verify the results obtained by a qualitative approach.

6.2. Recommendations for future studies

As far as the challenges and possible solutions are concluded, the author would like to make the following recommendations for future works to IMO, interested international organizations and states:

- A correspondence group for environmental FSA should be established to improve future studies. The improvement of mandatory Polar Code is one of the major tasks need to be accomplished currently.
- IMO should encourage the DE sub-Committee to further investigate the environmental protection part of the Code in order to identify those factors of inappropriate and out of concern in order to support the environmental FSA study.
- Classification societies such as DNV and GL should continue to work on the environmental FSA study for improving the future ship design standard of environmental protection for those ships operating in polar waters.
- A workshop for polar code HAZID should be held again to complete the list of

potential hazards and risk matrix for risk assessment.

- Member states, especially circum-arctic countries and member states of the Antarctic treaty should further improve vessel traffic monitoring and accidents database for polar waters in order to provide more reliable statistics for further investigation.
- Those member states, especially circum-arctic countries should also organize the environmental FSA studies in order to improve the local environmental regulations relating to polar waters.
- Those related international organizations such as IAATO and Clean shipping Coalition (CSC), which have experts in different areas such as ecology, biology and ship design, should continue to work together with IMO to improve the environmental protection part of the Code. Those experts should also be encouraged to be involved in all stages of the environmental FSA in the future.

REFERENCES

Alisafaki, A., and Papanikolaou A. D. (2006) *SAFEDOR Annual Public Report Year1 (D-7.2.5)*. Retrieved from http://www.safedor.org/resources/SAFEDOR-D-07.02.05-2006-03-13-NTUA-Annual_Public_Report_Year_1.pdf

Papanikolaou A. D. (2009) *SAFEDOR Annual Public Report Year 4 (D-7.2.8)*. Retrieved from http://www.safedor.org/resources/SAFEDOR-D-07.02.08-2009-01-31-NTUA-Public_report_and_newsletter_Year_4-rev-1.pdf

Brigham, L. W. (2010). *Arctic Marine Shipping Assessment of the Arctic Council.* DNAK Security Brief, Retrieved from http://www.americanpolar.org/wp-content/uploads/2011/01/AMSA_Secuirty_Brief_DNAK_Jan2011.pdf.

Division for Ocean Affairs and the Law of the Sea. (1982). *SECTION 8 ICE-COVERED AREAS. United Nations Convention on the Law of the SEA* (pp. 113). Retrieved from http://www.un.org/depts/los/convention_agreements/convention_overview_convention.htm

Fairman R., Mead C. D. and Williams W. P. (1999). *Environmental Risk Assessment –Approaches, Experiences and Information Sources* (EEA Environmental issue report No. 4th ed.). Retrieved from King's College, Monitoring and Assessment Research center, London

Health and Safety Executive. (2001). *Reducing Risk, Protecting People: HSE's decision-making process.* Retrieved from http://www.hse.gov.uk/risk/theory/r2p2.pdf

Heike Deggim, (2009) *International requirements for ships operating in polar waters*, Meeting of experts on the management of ship borne tourism in the Antarctic Treaty Area, Weillington, New Zealand, 9 to 11 Dec 2009

Heike Deggim, (2010) *Ensuring safe, secure and reliable shipping in the Arctic ocean,* NATO Advanced Research Workshop on "Environmental security in the Arctic Ocean" Cambridge, Scott Polar Research Institute, 13 to 15 Oct 2010

International Maritime Organization. (2009, December 18). *Development of a mandatory code for ships operating in polar waters HAZID analysis of ships navigating in arctic waters submitted by Denmark* (DE 53/18/5). London: Author.

International Maritime Organization. (2012, February16). *Development of a mandatory code for ships operating in polar waters. Report of Working Group (Part 1) (*DE 56/WP.4*)*. London: Author

International Maritime Organization. *(2012 August 28) FORMAL SAFETY ASSESSMENT Outcome of MSC 90 Draft Revised FSA Guidelines and draft HEAP Guidelines Note by the Secretariat* (MSC 91/16). London: Author

International Maritime Organization. (2010, January 18) *Resolution A.1024(26) Adopted on 2 December 2009 (Agenda item 10) GUIDELINES FOR SHIPS OPERATING IN POLAR WATERS* (A 26/Res.1024). London: Author

International Maritime Organization. *(2002, December 23) GUIDELINES FOR SHIPS OPERATING IN ARCTIC ICE-COVERED WATERS* (MSC/Circ. 1056&MEPC/Circ.399). London: Author

International Maritime Organization. *(2004,August 18) SHIP DESIGN AND EQUIPMENT Outcome of the XXVIIth Antarctic Treaty Consultative Meeting Note by the Secretariat* (MSC/79/8/2). London: Author

International Maritime Organization. (2009,March 19) *GUIDELINES FOR SHIPS OPERATING IN ARCTIC ICE-COVERED WATERS Report of the working group* (DE 52/WP.2). London: Author

International Maritime Organization. (2009, April 7) *WORK PROGRAMME Mandatory Polar Code Submitted by Friends of the Earth International (FOEI), Greenpeace, IFAW and WWF (MSC 86/23/19)*. London: Author

International Maritime Organization. (2009, January 6) *REPORT OF THE MARITIME SAFETY COMMITTEE ON ITS EIGHTY-FIFTH SESSION, ANNEX 2 RESOLUTION MSC.267(85) (adopted on 4 December 2008) ADOPTION OF THE INTERNATIONAL CODE ON INTACT STABILITY, 2008(2008 IS CODE)*(MSC 85/26/Add.1). London: Author

International Maritime Organization. *(2008,January 3) RESOLUTION A.999(25) Adopted on 29 November 2007 (Agenda item 9) GUIDELINES ON VOYAGE PLANNING FOR PASSENGER SHIPS OPERATING IN REMOTE AREAS* (A 25/Res.999). London: Author

International Maritime Organization. (2006, May 31) *ENHANCED CONTINGENCY PLANNING GUIDANCE FOR PASSENGER SHIPS OPERATING IN AREAS REMOTE FROM SAR FACILITIES* (MSC.1/Circ.1184). London: Author

International Maritime Organization. (2011, June 20) *STOWAGE OF*

WATER-REACTIVE MATERIALS Report of the Formal Safety Assessment Submitted by Germany (DSC 16/INF.2). London: Author

International Maritime Organization. (2010, February 23) *ADDRESS OF THE SECRETARY-GENERAL AT THE OPENING OF THE FIFTY-THIRD SESSION OF THE SUB-COMMITTEE ON SHIP DESIGN AND EQUIPMENT* (DE 53/INF.7). London: Author

International Maritime Organization. (1997, November 17) *INTERIM GUIDELINES FOR THE APPLICATION OF FORMAL SAFETY ASSESSMENT (FSA) TO THE IMO RULE-MAKING PROCESS* (MSC/Circ.829&MEPC/Circ.335). London: Author

International Maritime Organization. (2011, July 13) *FORMAL SAFETY ASSESSMENT Report of the Working Group on Environmental Risk Evaluation Criteria within the context of Formal Safety Assessment* (MEPC 62/WP.13). London: Author

International Maritime Organization. (2006, February 6) *ANY OTHER BUSINESS FSA Study on ECDIS/ENCs: Details on Risk Assessments and Cost Benefit Assessments Submitted by Denmark and Norway* (MSC 81/INF.9). London: Author

International Maritime Organization. (2006, February 6) *ANY OTHER BUSINESS FSA Study on ECDIS/ENCs Submitted by Denmark and Norway* (MSC 81/24/5). London: Author

International Maritime Organization. (2006, October 16) *AMENDMENTS TO THE GUIDELINES FOR FORMAL SAFETY ASSESSMENT (FSA) FOR USE IN THE IMO RULE-MAKING PROCESS (MSC/Circ.1023 - MEPC/Circ.392)*(MSC-MEPC.2/Circ.5). London: Author

International Maritime Organization. (2010, September 3) *DEVELOPMENT OF A MANDATORY CODE FOR SHIPS OPERATING IN POLAR WATERS Comment on the tiered risk assessment study submitted by CLIA Submitted by New Zealand* (DE 54/13/1). London: Author

International Maritime Organization. (2013, July 8) *REVISED GUIDELINES FOR FORMAL SAFETY ASSESSMENT (FSA) FOR USE IN THE IMO RULE-MAKING PROCESS* (MSC-MEPC.2/Circ.12*)*. London: Author

International Maritime Organization. (2009, December 18) *DEVELOPMENT OF A MANDATORY CODE FOR SHIPS OPERATING IN POLAR WATERS HAZID analysis of ships navigating in Arctic waters Submitted by Denmark* (DE 53/18/5). London: Author

International Maritime Organization. (2010, September 20) *GENERAL CARGO SHIP SAFETY IACS FSA study – summary of results Submitted by the International Association of Classification Societies (IACS)* (MSC 88/INF.8). London: Author

International Maritime Organization. (2010, September 3) *Development of a mandatory code for ships operating in polar waters Comment on the tiered risk assessment study submitted by CLIA Submitted by New Zealand* (DE 54/13/11). London: Author

International Maritime Organization*. (2011, December 9) Development of a mandatory code for ships operating in polar waters IAATO polar risk assessment submitted by the cruise lines international association (CLIA)* (DE 56/INF.9). London: Author

International Maritime Organization. (2010, March 22) *FORMAL SAFETY ASSESSMENT Comments by SAFEDOR on the report of FSA Experts Group (FSA on cruise ships) Submitted by Denmark* (MSC 87/18/3). London: Author

Kontovas, C.A. *Formal Safety Assessment Critical Review and Future Role.* Diss. SCHOOL OF NAVAL ARCHITECTURE AND MARINE ENGINEERING NATIONAL TECHNICAL UNIVERSITY OF ATHENS, GREECE, 2005.

Knotovas C.A. & Harilaos N. Psaraftis (2006), *Assessing Environmental risk: Is a single figure realistic as a estimate for cost of averting one tonne of spilled oil?* (Working Paper NTUA-MT-06-01). Retrieved from National Technical University of Athens, Athens.

Knotovas C.A. & Harilaos N. Psaraftis (2009), *Formal Safety Assessment: A critical review*. Marine Technology, Vol. 46, No.1, January 2009, pp. 45-59

Maria M. N. (2010) *International and national regulation of intentional vessel-source pollution in arctic ice-covered areas.* (JUR – 3910) Retrieved from University of Tromsø, Norway.

Nataliya Marchenko (2012) *Ice conditions and human factors in Marine Accidents at the Arctic*. Retrieved from Arctic portal library http://library.arcticportal.org /id/eprint/1642

Nijs Jan Duijm (2009), *Acceptance criteria in Denmark and the EU (*Environmental Project No.1269 2009). Retrieved from Danish Ministry of the Environment, Environmental Protection Agency http://www2.mst.dk/udgiv/publications /2009/978-87-7052-920-4/pdf/978-87-7052-921-1.pdf

Nord Stream. (2010). *ESPOO Report: Chapter 5 Risk Assessment.* Retrieved from https://www.nord-stream.com/press-info/library/?q=espoo+risk&type=&category=&country=

Protection of the Marine Environment Working Group. (2013). *Arctic Council : Status on Implementation of the AMSA 2009 Report Recommendation*. Retrieved from http://www.pame.is/amsa-2009-report

Skjong R, Adamcik P, Eknes M L, Gran S, Spouge J (1997) Formal Safety Assessment of Helicopter Landing Area on Passenger Ships as a Safety Measure. DNV Report 97-2053. (Public as IMO/COMSAR 3/2 and IMO/DE 41 documents).

Skjong, R., E. Vanem, Ø. Endresen (2005), *"Risk Evaluation Criteria"* *(*SAFEDOR-D-4.5.2-2005-10-21- DNV, October). Retrieved from www.safedor.org

Wang, J. "Offshore Safety Case Approach and Formal Safety Assessment of Ships."*Journal of Safety Research* 33.1 (2002): 81-115. Print.

Soares, C. Guedes, and Apostolos Papanikolaou (2009) *Risk-based Ship Design: Methods, Tools and Applications*. Berlin: Springer, 2009. Print.

APPENDIX A

Polar Code – Hazards Matrix previously prepared by IMO Work Group

(sources: Polar Code HARZID Workshop Report , 2011)

Conditions/Areas of concern Table 1 of 4 Environmental Conditions			
Potential Hazards	**Possible consequences**	**Intermediate Result**	**Potential Result**
1.1 Low air temp	1.1.1 Loss of material performance	1.1.1.1Side shell rupture	Water ingress – capsize – sinking – pollution
		1.1.1.2 Side shell fitting failure	Flooding – machinery damage – capsize
		1.1.1.3 Rupture of deck piping	Pollution
			System failure e.g. fire main
	1.1.2 Machinery [equipment] malfunction	1.1.2.1 Reduced maneuverability	1.1.2.1.1. Grounding, stranding, trapped in ice
	1.1.2.a Battery fails to start unit	Emergency equip non-start	Evacuation problems
	1.1.2.b Electric contacts malfunction	Remote control failure, false alarms	Various
	1.1.2.c Loss of working clearance - seizure	Fire flaps won't close; cargo vents freeze	Fire uncontrollable; cargo over-pressure
	1.1.2.d Loss of lubricant performance (high viscosity)	Rotating equipment starting problems	Emergency fire pump won't start Emergency Generator won't start
	1.1.2.e Moisture freezes – mechanical seizure	Fire flap won't close; cargo vents freeze; winch brakes fail	Fire uncontrollable; cargo over-pressure; can't let go or retrieve anchor; mooring difficulties; assistance difficulties
	1.1.3 Freezing of fluid/cargo	1.1.1.1 Side shell rupture 1.1.3.1 Cargo damage 1.1.3.2 Can't discharge cargo 1.1.3.3 Cargo expands/contracts – structural damage	Water ingress – capsize - sinking 1.1.3.3 Pollution
	1.1.4 .1 Increased fluid viscosity – machinery – diesel engine	1.1.4.1 Fuel pumping difficulties	1.1.4.1.1 Loss of electrical and/or propulsive power
	1.1.4.2 Increased fluid viscosity – machinery - hydraulic	1.1.4.2 Hydraulic deck equipment performance	1.1.4.2.1 Anchor and mooring line handling problems
	1.1.4.3 Increased fluid viscosity - cargo	1.1.4.2 Cargo pumping difficulties	1.1.4.3.1Can't lighten ship in emergency
	1.1.5 Effect of cold cargo on hull materials	1.1.1.1.1; 1.1.1.2	Pollution
	1.1.6 Loss of functionality of operating and emergency equipment		
	1.1.7 Loss of functionality of doors and closing appliances	Can't access spaces; can't close down spaces to prevent water ingress or to fight fire	
	1.1.8 Reduced survival time /hypothermia		
	1.1.9 Reduced human performance, physical and	Various	

Conditions/Areas of concern Table 1 of 4 Environmental Conditions			
	cognitive functions		
	1.1.10 Ice on deck and superstructure	Loss of stability Loss of footing	List/capsize Personal accident, death
	1.1.12 Limitation of SAR capabilities		
	1.1.13 Increased hotel load??	Electric power shortage	
1.2 Low water temp	1.2.1 Reduced survival time		
	1.2.2 Malfunction of fluid systems		
	1.2.3 Clogging of inlets & outlets	Machinery malfunction	1.1.3.1.1
1.3 Extreme & rapidly changing weather	1.3.1 Difficult to prepare for or avoid dangerous weather conditions		
	1.3.2 Propulsion and/or manoeuvring Difficulties		

Conditions/Areas of concern Table 2 of 4 High Latitude			
Potential Hazards	**Possible consequences**	**Intermediate Result**	**Potential Result**
2.1 Reduced navigational aids	2.1.1 Grounding, standing, trapped in ice		
	2.1.2 Impact with ice or other structures		2.1.2.1 Injuries or fatalities
	2.1.3 Lack of signals/disturbance DGPS		
	2.1.4 Unstable gyro		
2.2 Varying availability of charts/hydrographical information	2.2.1 Grounding, stranding		
	2.2.2 Voyage planning		
	2.3.3 Anchoring		
2.3 Varying availability of charts/hydrographical information	2.3.1 Voyage planning		
	2.3.2 Difficult to prepare for or avoid dangerous weather conditions/ situations		
	2.3.3 Insufficient clothing and supplies (optimistic planning)		

2.4 Variable infrastructure	2.4.1 Insufficient actions to incidents and accident		2.4.1.1. Potential for incidences to escalate
	2.4.2 Insufficient spill preparedness		
	2.4.3 Limited compliance and enforcement (local infrastructure, waste reception facilitations)		
2.5 Interference with long range electronic communications	2.5.1 loss of possibility to send distress messages/contact SAR		
	2.5.2 No weather/ice forecast		
	2.5.3 Loss of communication possibilities		
2.6 Variable [local] communication capabilities	2.6.1 Communication difficulties		
2.7 Limited search and rescue capabilities	2.7.1 Insufficient response to incidents and accidents		
	2.7.2 Lack of medical support		
	2.7.3 Capability of emergency source of electrical power.		
2.8 Limited availability of oil spill preparedness	2.8.1 Insufficient response to spills		2.8.1.1 Potential for incidences to escalate
	2.8.2 Damage to ecological systems		
	2.8.3 Damage to flora and fauna		

Conditions/Areas of concern Table 3 of 4 Environmental Sensitivity			
Potential Hazards	**Possible consequences**	**Intermediate Result**	**Potential Result**
3.1 Discharges from normal operation	3.1.1 Damage on ice caused by soot		
	3.1.2 Environmental damage from grey water		
3.2 Oil and	3.2.1. Inability to operate pollution response		

Conditions/Areas of concern Table 3 of 4 Environmental Sensitivity			
chemical spill	systems due to surrounding ice		
	Note 3.2.1 is not a consequence - it's a hazard???		
3.3 Air Pollution			
Conditions/Areas of concern Table 4 of 4 Human Element			
Potential Hazards	**Possible consequences**	**Intermediate Result**	**Potential Result**
4.1 Lack of knowledge of personal protection	4.1.1 Frostbite		
	4.1.2 Hypothermia		
4.2 Unfamiliarity of polar environment			
4.3 Working environment			

APPENDIX B

Checklist for HAZID provided by IMO working group

(sources: Polar Code HARZID Workshop Report , 2011)

Possible Routine Releases into the Environment

- Combustion gases from main power plant (e.g. oxides of nitrogen, oxides of sulphur, oxides of carbon, unburnt and partially burnt hydrocarbons, soot, ash, etc.).
- Combustion gases from ancillary plant, such as incinerators (dioxins, poly chlorinated biphenyls (PCBs)), inert gas generators, etc..
- Fugitive Volatile Organic Compounds (VOCs) from cargo and fuel tanks.
- Liquid waste from accommodation blocks (dirty water, sewage, etc.).
- Food waste and other solid waste from accommodation blocks.
- Liquid waste from bilge.
- Ballast water exchange.
- Greases or lubricants, for example from main propulsion or steering systems.
- Anti-fouling paints from ship hulls.

Possible Accidental Releases into the Environment

- Cargo from damaged cargo tanks or compartments.
- Cargo containers that have fallen overboard.
- Bunker fuel oil from fuel oil tanks.

Contributing Factors

- Ice bergs as collision hazard.
- Ice bergs as ship crush hazard (structural failure).
- Ice on ship superstructure (loss of stability, foundering).
- Extreme cold leading to brittleness of metal (structural failure).
- Extreme cold or icing leading to technical failure of equipment, including emergency or backup equipment that might fail on demand due to extreme cold or icing.
- Poor communications.
- Long response times and limited response capability.
- Weak or non-existent conventional navigational aids (lights, distinguishable features for bearings, etc.)?
- Poor charts?

Other issues to be considered?

- High latitude effects on navigation systems (lack of GPS, cosmic radiation effects)?
- Variations of magnetic north/ south?
- Long days or long nights resulting in interrupted sleep patterns, loss of alertness, poor decision making?
- Weak primary radar returns from icy shorelines?
- Difficulty of distinguishing sea ice from wave clutter with primary radar?
- Effect of cold water on spilled materials?
- Extremely low visibility or low visibility for long periods of time?
- Extreme sea state (wave height)?
- Extreme wind speed?
- Extreme brightness due to low sun, 24 hours per day?
- Seismic (volcano, earthquake) effects?

Risk Control Measures and Risk Control Options

- Ice strengthening for ships.
- Ice forecasts.
- Availability of ice breakers.
- Navigation aids that fully function in polar waters.
- Equipment and systems that function correctly, and on demand, in extreme cold.
- Additives for fuel to prevent waxing (prevent failure or failure on demand).
- Restricted bunker fuel oil type(s).
- Stricter routine discharge limits compared to IMO baseline (MARPOL).
- Enforcement of discharge limits.