Emergency Response to Arctic Cruise Ship Incidents: Risk Analysis and Multi-Stakeholder Coordination

Master Thesis

MSc in Tech. Risk and Safety Management, 2025

STUDENT REPORT

AALBORG UNIVERSITY

Aalborg University
http://www.aau.dk

Title:
Emergency Response to Arctic Cruise Ship Incidents: Risk Analysis and Multi-Stakeholder Coordination

Theme:
Master thesis

Project Period:
Spring Semester 2025

Project Group:
RISK4-2

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Copies:
1

Page Numbers: 37

Date of Completion:

June 2, 2025

Abstract:

As Arctic cruise tourism continues to grow, the risks of operating at sea in this challenging region are increasing. This paper focuses on Denmark (Greenland), Iceland, and Norway. The study uses a mixed methods approach, combining a qualitative method, quantitative method, online interviews, Bowtie model, and Social Network Analysis (SNA) to identify risks, identify relevant stakeholders, and makes recommendations. The Bowtie model reveals barriers to preventing and mitigating Arctic maritime risks, while the SNA reveals gaps in cooperation, asymmetric influence, and other issues. The results show that although multiple actors such as rescue coordination centers (RCC) and maritime authorities are highly involved in operations, there are limitations and private companies are often marginalized. The study recommends strengthening stakeholder coordination and establishing a more inclusive governance model to better respond to complex Arctic cruising emergencies.

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Preface

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Abbreviations

Abbreviation	Meaning
AAU	Aalborg University
AC	The Arctic Council
AECO	Association of Arctic Expedition Cruise Operation
AIS	Automatic Identification System
CASA	Compendium of Arctic Shipping Accidents
DCC	Danish Cruise Company
DIC	Danish Insurance Company
DMA	Danish Maritime Authority
EEZ	Exclusive Economic Zone
EMCIP	European Maritime Casualty Information Platform
EMSA	European Maritime Safety Agency
EPIRBs	Emergency Position Indicating Radio Beacons
GoG	Government of Greenland
GoS	Governor of Svalbard
G-Police	Greenland police
G-Port	Greenlandic ports
GPS	Global Positioning System
ICC	International Cruise Company
ICC-Iceland	Icelandic Cruise Company
ICE-NGOs	Icelandic NGOs
ICG	Icelandic Coast Guard
ILC	Indigenous and Local Communities
IMO	International Maritime Organization
I-Port	Icelandic ports
JAC	Joint Arctic Command
JRCC Iceland	Joint Rescue Coordination Center Iceland
JRCC NN BODØ	Joint Rescue Coordination Center, Northern Norway
MARPOL	International Convention for the Prevention of Pollution from Ships
MoJ	Ministry of Justice
MRCC Grønnedal	Maritime Rescue Coordination Center Grønnedal
MRCC Torshavn	Maritime Rescue and Coordination Center Torshavn
MRO	Maintenance, Repair, and Overhaul
NCA	Norwegian Coastal Administration
NCC	Norwegian Cruise Company
NIC	Norwegian Insurance Company
NMA	Norwegian Maritime Authority
N-Port	Norwegian ports
RCC Søndrestrøm	Rescue Coordination Center Søndrestrøm
SAR	Search and Rescue
SAREX	Search and Rescue Exercise
SDU	University of Southern Denmark
SOLAS	International Convention for the Safety of Life at Sea
UNCLOS	United Nations Convention on the Law of the Sea

Chapter 1

Introduction

In recent years, the Arctic has become an increasingly popular destination for cruise tourism due to its unique and pristine environment. Advances in marine technology and the effects of climate change, such as reduced sea ice, are making these waters more suitable for tourism. However, the Arctic environment remains extreme and unpredictable, large-scale tourism infrastructure is limited, and emergency response capabilities are challenged by harsh conditions [1]. As the number of Arctic voyages increases, so does the risk of maritime accidentsraising concerns about the state of rescue operations and the adequacy of existing safety regulations.

Due to the isolation of the Arctic, frequent extreme weather conditions and logistical constraints, maritime emergencies such as groundings, engine failures or fires on board vessels pose a serious risk. Rescue operations are often delayed by weather conditions, climate conditions and the long corresponding distances, resulting in difficulties for passengers and crew when an incident occurs [2]. While international regulations such as the International Maritime Organization (IMO) Polar Code are designed to reduce these risks, past events have shown that existing frameworks may not fully address the complex challenges of Arctic cruising operations [3].

In addition, a successful emergency response depends not only on the comprehensiveness of regulations, but also on effective coordination among multiple key stakeholders. Cruise operators, local search and rescue teams, regulators, and local Arctic communities all work together to enhance emergency response capabilities [4]. Trust, communication, and the ability to quickly mobilize resources are essential to reduce risks and avoid unnecessary losses.

This paper aims to analyze the emergency response to Arctic cruise ship accidents through a literature review and risk assessment models. Failure cases from the past decades will be divided into different categories to reflect the main risk categories and make the analytical objectives of this paper clearer. In addition, stakeholder analysis will further explore the roles and responsibilities of the main players, focusing on trust, communication, and coordination in emergency situations. Based on the research results, this study will propose recommendations to improve the emergency response to Arctic cruise ships, including enhancing communication strategies, promoting stakeholder cooperation, and clarifying the cooperative relationship between different entities.

Chapter 2

State of the Art

Before starting the in-depth analysis, an overview of the Arctic environment and the harsh natural environment is first given. Covering the definition of the Arctic region, the jurisdiction of different countries, the challenges faced by extremely cold regions. This chapter provides basic background knowledge for the in-depth analysis in subsequent chapters.

2.1 Arctic

2.1.1 Geographical and environment characteristics of the Arctic

The Arctic region is usually defined as the area north of the Arctic Circle, which is approximately 66° 33'N. This dividing line means that during the summer solstice (around June 21st), the sun is above the horizon for 24 hours, while, conversely, during the winter solstice (around December 21st), the sun does not rise at all. This phenomenon results in the unique sight of polar day and night, which profoundly affects the climate and ecosystems of the region [5].

The arctic climate is characterized by long, cold winters and short, cool summers. Winters are extremely cold with stable weather and long periods of darkness, while summers are short but with continuous daylight, the phenomenon known as the midnight sun. Despite the long daylight hours, summer temperatures generally remain cool. The region also has significant seasonal variation in sea ice cover, with large amounts of ice in the winter and some melting in the summer [5].

The Arctic's geographical location poses significant challenges to maritime navigation and emergency response. From a climatic perspective, the presence of sea ice can be hazardous to navigation even in summer, while extreme cold can impair the normal operation of ship machinery and the health of crew members. The remote geographical location further complicates emergency response efforts, as lack of infrastructure and long distances can lead to delays in assistance in emergencies. These factors require specialized ships that can operate in such harsh conditions[6].

Climate change has had a significant impact on the Arctic, where temperatures are rising about three times faster than the global average due to the continued release of greenhouse gases [7]. Rapid warming has led to a significant reduction in the extent and thickness of sea ice, especially in the summer, making it easier for all kinds of ships to navigate the Arctic. While this change provides new opportunities for maritime activities, it also brings greater risks, including more unpredictable weather patterns, the presence of drifting ice, and melting permafrost, which can damage existing infrastructure. Therefore, it is necessary to develop adaptive strategies to cope with the changing Arctic environment, ensure navigation safety and effectively respond to emergencies[8].

2.1.2 Arctic jurisdiction zones

The Arctic region covers the Arctic Circle and includes the territories of the eight Arctic States: Canada, the kingdom of Denmark (via Greenland), Finland, Iceland, Norway, Russia, Sweden, and the United States [9]. These States exercise sovereignty over their respective Arctic territories and adjacent maritime areas, the extent of which is consistent with international law, in particular the United Nations Convention on the Law of the Sea (UNCLOS) [10].

According to the UNCLOS, coastal states have sovereignty over their territorial waters, which extend up to 12 nautical miles from their baselines. In addition to this, they also have an Exclusive Economic Zone (EEZ) that extend up to 200 nautical miles, within which they have special rights to explore, develop and manage natural resources [10] [11].

Beyond the 200 nautical mile EEZ, some Arctic coastal claims to extended continental shelves under international law. These claims are still under review and may overlap in some cases [12]. While there issues are mostly handled through diplomatic processes, this situation increases jurisdictional uncertainty, which can pose a challenge in responding to emergencies in remote Arctic waters.

Although these disputes has been resolved diplomatically, the lack of final border agreement can complicate emergency response coordination. For example, in the event of cruise ship accident, jurisdictional ambiguity can delay the launch or handover of search and rescue operations, highlighting the need for international cooperation and clear regulation.

Figure 2.1: Arctic jurisdiction [Source: [13]]

2.1.3 The growth of Arctic cruise tourism

In recent years, the cruise tourism industry in the Arctic has seen a significant increase. This is due to the continuous development of the global economy. More and more people are gradually pursuing spiritual enjoyment, wanting to get close to nature and understand nature. It is also because of the continuous development of science and technology that more and more problems are being solved, which can provide people with safer sailing options. Therefore, the once daunting Arctic has become a popular destination for explorers and nature lovers. Various cruise companies offer luxury cruise services, It includes high-end accommodation facilities that prioritize comfort, dining and personalized service when exploring the Arctic region. It allows people to be isolated from the world in just a few days and visit amazing natural scenery.

The number of unique vessels entering the Polar Code area will increase by 37 percentage between 2013 and 2024, from 1,298 to 1,781. Fishing vessels will account for the largest share of these, accounting for approximately 39 percentage of all vessels operating in the region by 2024. Over the same period, total distance traveled in the region will more than double, from approximately 6.1 million nautical miles in 2013 to 12.7 million nautical miles in 2024, an increase of 108 percentage. The overall growth in Arctic shipping activity is closely tied to the loss of sea ice, which will open up more navigable routes [14].

2.1.4 Challenges of maritime operations in the Arctic

Maritime operations in the Arctic present significant challenges due to the region's extreme environment, logistical constrains, and legal complexities, among other issues. These challenges impact navigation, emergency response, and overall maritime safety.

- Harsh environment conditions: The Arctic's extreme cold, strong winds and persistent sea ice pose a danger to ships. Even in summer, frozen waters pose a risk, while low temperatures can damage ship machinery and endanger crews and passengers safety [15].
- Logistical constrains: The region is remote and has limited infrastructure, including scarce ports, emergency facilities, and fuel stations. Lack of support complicates resupply, maintenance, and rescue operations, making emergency response slower and more risky [16].
- Navigation risks: Navigating the Arctic is dangerous due to unpredictable weather, drifting icebergs, and inaccurate maps. Limited communication systems and navigation equipment make emergency planning and coordination difficult [15].
- Legal and sovereignty issues: Competing territorial claims and diverging national regulations complicate navigation in the Arctic. Overlapping sovereignty claims lead to uncertainty over governance, maritime right and enforcement of safety regulations [17].
- Human resource constraints: Operating in Arctic conditions requires specialized training in ice navigation, cold weather, and emergency response. However, the limited number of qualified personnel increases the risk of accidents and operational errors.

2.2 Human behavior in Extremely cold environment

Human behavior is important in emergency management, and many of the effects are unconscious, so exposure to extreme cold weather can significantly affect human performance and behavior, posing significant challenges during an Arctic cruise emergency. The following subsections explore the cognitive, physical, and psychological effects of cold exposure, emphasizing their impact on emergency response operations.

2.2.1 Cognitive and physical impairment in extreme cold

Cold weather can severely impair human cognitive and physical function. Cognitively, people exposed to subzero temperatures experience decreased attention, shower information processing, poor short-term memory, and reduced decision-marking abilities. These behavioral effects are particularly dangerous in high-stress situations, such as emergency evacuations, which require more rapid coordinated responses [18].

Physiologically, coldness causes a drop in the core and peripheral body temperature, which can lead to loss dexterity and slow reaction. In extreme cases, such as prolonged exposure to cold or falling into water, coldness can even incapacitate a person. As hand function deteriorates, even simple tasks such as fastening a life jacket or holding onto a railing become more difficult. Coldness impairs higher-level cognitive functions and psychomotor coordination, both of which are critical in complex, time-critical emergency operations [18].

2.2.2 Exposure and survival limitations

The arctic environment poses a serious threat to human survival following an incident, particularly if people are exposed to freezing air or immersed in cold water. Hypothermia can occur within minutes, and survival time in near-zero water temperature is typically 15 to 45 minutes, depending on personal characteristics, clothing, and flotation support. In 0°C water, a person without thermal protection can lose consciousness within 30 minutes and may die within an hour [19][20]. Frostbite and cold shock can also lead to rapid incapacitation. These risks are more pronounced for elderly or mobility-impaired passengers, such as those commonly seen on cruise ships. Inadequate clothing or delayed rescue can quickly escalate to fatal consequences, highlighting the need for prompt and well-coordinated emergency procedures [19][20].

2.2.3 Psychological stress and group behavior

Extreme cold weather not only affects physical functioning, it can also exacerbate psychological stress in emergency situations. The combination of extreme cold, discomfort, and environmental isolation can increase anxiety, reduce rational decision making, and increase panic, especially for untrained passengers [19][20].

In Arctic cruise ship accidents, these effects are exacerbated by the unfamiliarity of the environment and the high proportion of elderly or vulnerable people on board. In such situations, psychological stress can weaken team cohesion, delay evacuation procedures, and affect the crew's ability to maintain order and communicate effectively. Studies of cold weather operations have shown that environmental stressors such as wind chill, darkness, and low temperatures can significantly reduce the period of teamwork, increase confusion and even crowd unrest, and reduce compliance with and understanding of safety instructions, all of which pose significant challenges to the success of emergency management in polar regions [19][20].

Chapter 3

Literature review

3.1 Type of Incidents

The table below, published by Allianz Commercial Insurance, provides an overview of shipping incidents reported in Arctic waters from 2014 to 2023. It includes a total of 500 recorded incidents, broken down by type, with five main categories such as machinery damage or breakdown, collision, contact, fire, etc. The data reflects incidents involving a wide range of vessel types operating in the Arctic region [21].

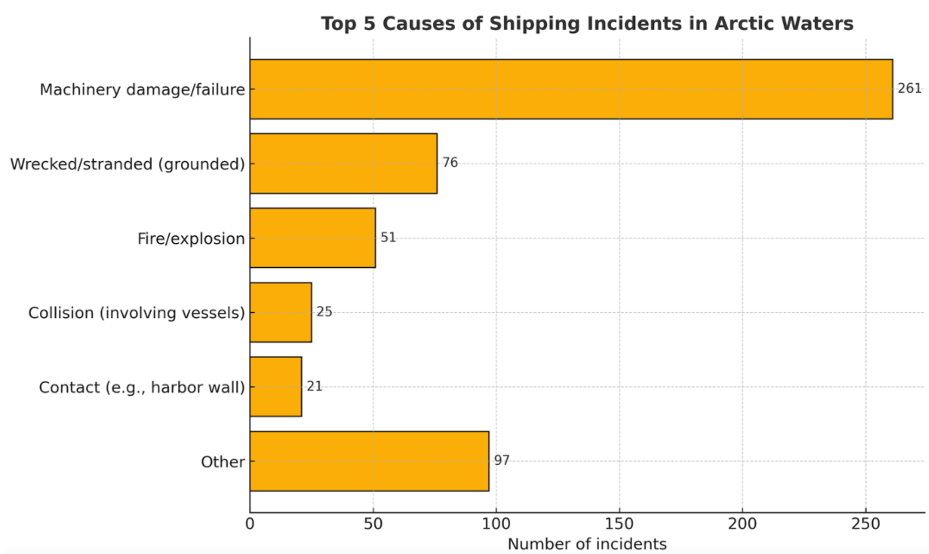

Figure 3.1: Top 5 Causes shipping Incidents in Arctic Waters (source: [21]), [Own creation]

To provide a more specific and detailed view of Arctic shipping incidents, this chapter also incorporates two tables from the Compendium of Arctic Shipping Casualties (CASA) project, which covers data submitted by Arctic countries between 2005 and 2017 [22]. The figure 3.2 presents the types of incident in their raw, unstructured form as reported by the national authorities. Due to inconsistent terminology and reporting formats, the dataset contains many overlapping or ambiguous categories.

To improve clarity and facilitate cross-comparison, the figure 3.3reorganizes the CASA accident types using the European Maritime Safety Agency (EMSA) classification system, known as the European Maritime Casualty Information Platform (EMCIP) classification [22]. This standardized structure allows accident types to be classified more consistently, providing a clear direction for future trend analysis.

In the following figure 3.2 and figure 3.3, due to the large number of types in the original data table, only the types of accidents with more than 100 accidents are selected here [22].

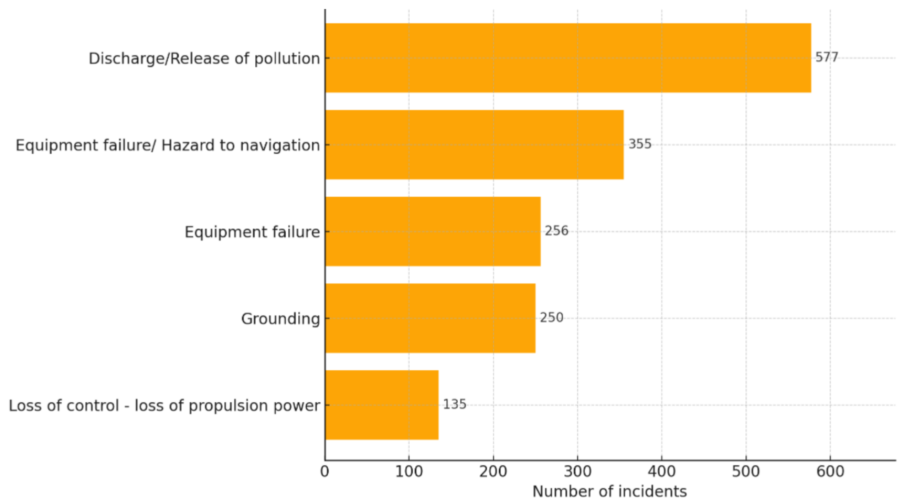

Figure 3.2: Types of Accidents (CASA raw data, source: [22]), [Own creation]

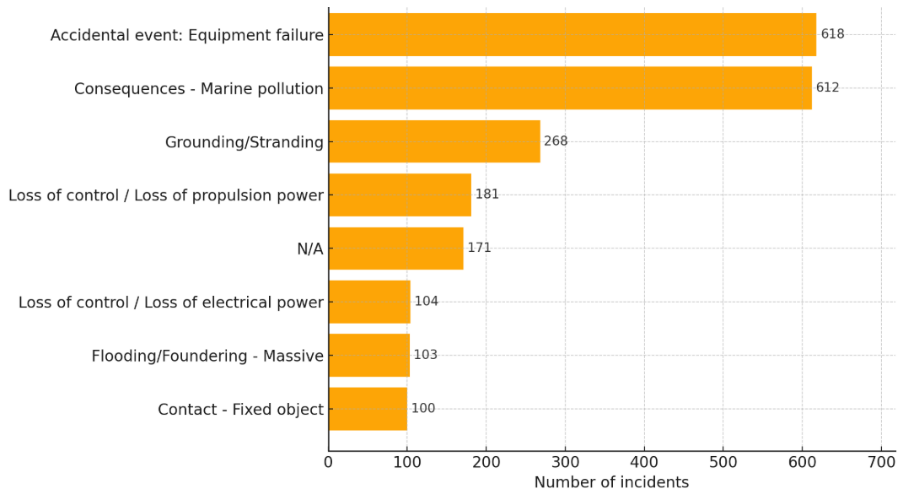

Figure 3.3: Types of Accidents (EMCIP Event Types, source: [22]), [Own creation]

Comparing the accident data in the above three tables, it is found that the types of marine accidents most likely to occur at sea or in Arctic waters are basically consistent. Mechanical or equipment failure is the most reported cause of accidents. Between 2014-2023, Allianz reported 261 such cases, while the CASA and EMCIP datasets recorded 256 and 618 accidents of similar categories, respectively. In addition, groundings also stand out in the CASA and EMCIP records, indicating that navigation challenges and environmental sensitivity in the region are associated with increased risks. Other frequently occurring causes include loss of control, flooding, and contact with fixed objects. These findings highlight the operational vulnerability of ships sailing in Arctic waters and provide a basis for prioritizing specific risk factors in emergency response plans.

3.2 SAR

3.2.1 Background information

Search and Rescue (SAR) is a coordinated effort to locate and assist people in distress at sea, often at risk of their lives. In the Arctic, SAR operations are particularly challenging due to the reasons mentioned in chapter 1 . Ensuring an effective SAR system is essential for maritime safety given the increasing number of commercial and cruise vessels in Arctic waters. SAR in the Arctic is managed by a combination of national authorities, international agreements, and private sector participation. Each Arctic nation-Canada, the United States, Norway, Russia, Denmark (Greenland), Finland, Sweden, and Iceland – has its own SAR units, including coast guards, military forces, and emergency response agencies [21]. However, due to the vastness of the Arctic region and its sparse population, no single country can effectively handle search and rescue operations along the coast. Therefore, international coordination is essential. The Arctic Council's Search and Rescue Agreement (2011) is the first legally binding treaty signed among Arctic states, which defines each country's area of responsibility for search and rescue. The agreement promotes cross-border cooperation, ensuring that countries can aid beyond their territorial water when necessary [23].

3.2.2 Basic SAR capabilities in the Arctic Area

Arctic countries, especially those with cruising activities in their waters (e.g. Denmark/Greenland, Norway, Iceland), have designated Rescue Coordination Centres (RCCs), such as RCC Søndrestrøm in western Greenland [24] and JRCC in Northern Norway [25].The centers coordinate search and rescue efforts involving fixed-wing aircraft, helicopters, ice-resistant vessels and satellite communications systems [26]. Some Arctic states, such as Norway and Iceland, benefit from annual international joint exercises such as Search and Rescue Exercise (SAREX), which tests interoperability between states and enhances real-time coordination [27].

Emerging technologies, including remote monitoring systems, for example, AIS, GPS and satellite weather data, are increasingly being used to support early detection and enhance situational awareness [26]. These tools are essential for preventive monitoring and rapid response once distress signals are sent [28]. In addition, there is an increased focus on emergency preparedness on board ships, including Emergency Position Indicating Radio Beacons (EPIRBs), thermal survival equipment, and crew training for emergencies on Arctic cruises.

3.2.3 Boundaries of SAR capacity

Despite these advances, key limitations remain. Many areas of the High Arctic lack adequate infrastructure, such as airstrips, medical centers and permanent search and rescue bases [28]. Response times are often extended due to long distances and limited infrastructure, especially in inclement weather such as winter or sea ice. Even if aircraft or ships are deployed, real-time data availability is often insufficient to quickly help search and rescue agencies locate a target due to limited satellite coverage above 75°N [23].

In addition, the challenge of conducting a large-scale Maintenance, Repair, and Overhaul (MRO) for a cruise ship with hundreds or thousands of passengers on board is far beyond the capabilities of most Arctic search and rescue teams. And the shortage of trained personnel and specialized rescue equipment was also exposed during the exercise [27].

These limitations have raised concerns about the gap between actual SAR capabilities and public expectations, especially in light of growing Arctic cruise traffic. As a result, workshops and multilateral discussions have highlighted the need for a more coordinated SAR framework, improved contingency planning, and greater investment in a shared SAR system covering the entire Arctic [23] [27].

3.3 Relevant legislation

3.3.1 IMO Polar Code 2017

The International Code for Ships Operating in Polar Waters was developed by the International Maritime Organization (IMO) to address the specific challenges posed by maritime activities in Arctic waters. The code was formally adopted in 2014 and entered into force on January 1, 2017 within the regulatory framework of the International Convention for the Safety of Life at Sea (SOLAS) and the International Convention for the Prevention of Pollution from Ships (MARPOL) [29]. All ships subject to SOLAS and

MARPOL regulations, including passenger cruise ships sailing in polar regions, must comply with the Polar Code [29].

The structure of the rule is mainly divided into two parts: Part I A outlines the mandatory safety measures; Part II A focuses on the mandatory environmental protection requirements [30]. Although both parts play an important role in regulating polar navigation, the focus of this study is mainly on the safety and emergency response mechanisms related to cruise ship operations in the Arctic region. Therefore, this section will focus on Part I A of the rule, which details the requirements for ship design, machinery, fire protection, life-saving equipment, navigation, communications, and operational readiness [30]. Since this project does not specifically discuss pollution control or environmental emissions, Part II A will not be mentioned in this part.

The structural design and construction requirements of the specification are based on the ship's ability to navigate under different degrees of ice cover, and the ships are divided into three categories: A, B, and C. Category A ships are designed to navigate in moderate to severe ice conditions, Category B ships are suitable for lighter ice conditions, and Category C ships are limited to navigation in open waters or very light ice conditions [30]. Ships must have sufficient ice resistance, hull ice resistance, and equipment robustness to ensure structural integrity and seaworthiness in freezing temperatures [30].

In terms of subdivision and stability, the Polar Code requires that ships should maintain stability and buoyancy even after suffering ice damage. This includes compliance with watertight integrity and subdivision rules and taking into account the effects of ice accumulation and compartment freezing [30]. The aim is to ensure that the ship can remain stable after a flooding incident and maintain the necessary buoyancy under adverse conditions.

Mechanical equipment also needs to be adapted to polar operations. Engines, propulsion systems and auxiliary machinery must be winterized to ensure the reliability and stability of their equipment operation in extremely low temperatures [30]. This includes the use of heating systems, cold-resistant lubricants, etc [30]. to prevent serious mechanical failures in isolated conditions where external assistance cannot be immediately obtained.

Fire safety and protection measures are particularly important in polar regions, as the risk of delayed emergency response is high. The Polar Code requires the use of fire detection and extinguishing systems that remain effective in low temperatures, as well as escape routes that remain clear even when ice and snow accumulate on deck [30].

The rules also impose strict requirements on life-saving appliances and devices. These systems must be designed to support long-term survival in freezing temperatures and consider the possibility of extended search and rescue times. Ships must be equipped with insulated lifeboats and thermal clothing to ensure that passengers and crews can stay warm and have access to basic food in extreme conditions [30].

In terms of navigation, ships sailing in polar waters must be equipped with enhanced navigation tools, including ice radar, ice charts, and systems integrating satellite and remote sensing data [30]. These measures are designed to increase the crew's sensitivity to the surrounding environment and ensure safe navigation in areas where ice conditions change dynamically and hydrographic data is limited.

The Polar Code requires reliable communications systems capable of operating in high-latitude environments where traditional satellite coverage may be limited. Vessels must be equipped with HF/MF radio equipment and systems compliant with the Global Maritime Distress and Safety System (GMDSS) standard for polar environments [30], as well as back-up communications methods to ensure continuous contact with shore for emergency response purpose.

To operate in polar waters, ships must obtain a Polar Ship Certificate to demonstrate compliance with the safety requirements of the Polar Code. In addition, every ship must carry a Polar Water Operations Manual (PWOM), which formally details operational safety and must include procedures such as voyage planning, ice navigation strategies, emergency drift plans, and environmental response measures [30]. The manual is tailored to the specific ship and its intended polar operations, and plays a key role in helping crew members cope with unpredictable and dangerous situations.

3.3.2 The Arctic Council's Search and Rescue Agreement (2011)

The Agreement on Cooperation in Aeronautical and Maritime Search and Rescue (SAR Agreement) is an important milestone in the development of Arctic governance. Signed on May 12, 2011 in Nuuk, Greenland, by the eight Arctic States – Canada, Denmark (including Greenland and the Faroe Islands), Finland, Iceland, Norway, Russia, Sweden and the United States – it is the first legally binding agreement negotiated under the auspices of the Arctic Council [23].

The main goal of the Arctic Search and Rescue Agreement (2011) is to strengthen coordination and cooperation among Arctic countries in conducting aviation and maritime search and rescue operations [23]. This goal reflects the practical approach of Arctic countries to maintaining safety in a region with extreme environmental conditions, lack of infrastructure, frequent climate change, and increased human activities due to melting sea ice, and also reflects the importance that Arctic countries attach to the region.

The core provision of the agreement is the delineation of specific search and rescue areas, with each country primarily responsible for coordinating search and rescue operations within its designated area [23]. Importantly, these delineations have clear operational objectives and do not affect sovereignty or jurisdiction issues at all [23]. By clarifying the areas of responsibility, the agreement helps to improve the efficiency of emergency response and the clarity of jurisdictional areas.

However, there are also criticisms that the agreement is limited in scope and that its implementation or underlying resources are unevenly distributed, leading to differences in actual search and rescue capabilities between Arctic countries. In addition, geopolitical tensions between major Arctic actors, especially in the context of recent global events, have raised questions about the effectiveness of such global cooperation mechanisms in times of crisis [31].

Despite these limitations, the Search and Rescue Agreement (2011) remains an example of how Arctic states can work together to address common challenges through a legally binding framework. It highlights the potential of the Arctic Council to promote consensus-driven multilateral governance based on regional solidarity and mutual benefit. The Agreement is also an important source of information for chapter 6 to identify key stakeholders.

Chapter 4

Problem formulation

4.1 Problem background

While existing IMO regulations such as the Polar Code, SOLAS and the Arctic Search and Rescue Agreement (2011) provide a comprehensive regulatory framework, the unique challenges of Arctic shipping still expose the limitations of current emergency response capabilities. The reviewed literature highlights consistent accident trends across multiple datasets (CASA, EMSA, Allianz), such as machinery failures, groundings and loss of propulsion, underscoring that operational risks in the Arctic are both real and recurring. These risks are exacerbated by harsh environmental conditions, remote geographical locations and limited infrastructure, all of which hinder timely and effective SAR operations.

Furthermore, while the international framework establishes universal obligations and standards, its implementation is not ideal. For example, the Polar Code only applies to SOLAS-classified ships, while smaller but increasingly active commercial ships are excluded, making it more difficult to find search and rescue targets in emergencies. At the same time, search and rescue responsibilities are dispersed among Arctic countries. Although the Arctic Search and Rescue Agreement (2011) formally clarified these responsibilities, there are still problems such as unclear responsibilities and the inability to share resources in a timely manner.

These observations show that there is a huge gap between existing legal instruments and the reality of emergency response in the Arctic, especially for cruise ships, which have large passenger capacity, limited self-rescue capabilities, uneven passenger quality, and require complex multinational coordination. Cruise ships sailing in Arctic waters are high-risk, low-frequency situations that existing systems are not adequate to cope with.

4.2 Project objective

1. **Evaluate existing risks:** To use useful risk assessment method to identify existing risks in Arctic environment.

2. **Stakeholder identification:** To identify and map the key stakeholders involved in Arctic cruise accident emergency response under the jurisdiction water of Denmark (Greenland), Norway and Iceland .

3. **Propose valueable recommendations:** To propose set of recommendations to enhance multi-level stakeholder collaboration, communication, and operational effectiveness in Arctic cruise emergency response scenarios.

4.3 Project questions

How can emergency response to cruise ship accidents in the Arctic be improved to ensure timely, coordinated, and effective action under extreme environmental and logistical constraints?

This problem formulation captures multiple research questions that this paper formulated to reach the objectives.

- What are the key environmental, logistical, and human challenges affecting emergency response in Arctic cruise tourism?
- What are the roles and responsibilities of different stakeholders, and how does trust and communication affect coordination during emergencies in the Arctic?
- What practical recommendations can be made to enhance stakeholder collaboration and response readiness in future Arctic cruise operations?

4.4 Project scope

This study explores emergency response strategies for marine incidents involving ships in the Arctic region. Due to the limited number of ship incidents in the Arctic region, the analysis covers relevant general marine incidents, but other ship types such as fishing vessels and cargo ships are not the main focus.

In terms of geographical scope, this study is limited to a specific Arctic region, namely Denmark (Greenland), Norway, Iceland and their surrounding waters. Other international Arctic regions, such as the United States, Canada, etc., are not included in the study.

In terms of data sources and methods, this study is based on primary and secondary sources. The primary sources include the insights of some experts obtained through interviews. Secondary sources include official reports, academic literature and regulatory documents.

Although the original goal was to analyze recent events, due to data limitations, this study had to include older events, some of which occurred more than a decade ago.

4.5 Limitations

1. **Limited data availability:** Cruise ship incidents in the Arctic are rare, making it difficult to find specific case studies. Many documented incidents are related to general maritime emergencies rather than cruise ship accidents.
2. **Lack of recent data:** The lack of publicly reported incidents in the past five years means that this study may not capture the latest developments in Arctic emergency response.
3. **Limited regional focus:** While this study covers Arctic maritime emergencies, its focus is limited to Denmark (Greenland), Norway, and Iceland due to data limitations. This means that the findings may not be fully representative of the wider Arctic region.
4. **Regulatory differences:** Different countries have different emergency response frameworks, which complicates direct comparisons. This study does not attempt to harmonize or standardize these differences but acknowledges that they are a challenge.
5. **Time and resource constraints:** Due to the limited time of this study, data collection steps such as stakeholder interviews, or meeting summaries are not presented one by one, but some interview results will be mentioned in the following chapters, and suggestions will be given.

Chapter 5

Methodology

This chapter describes the research methods used to study stakeholder participation and emergency response strategies in the context of an Arctic cruise ship accident. This study used a mixed method that combines qualitative and quantitative analysis, and qualitative analysis accounts for most of this paper. The research methods are mainly divided into several parts: qualitative research, quantitative research, data sources, Bowtie model and social network analysis, and ethical considerations.

5.1 Qualitative research

The qualitative research part includes an analysis of existing literature, including public reports, maritime safety documents, Arctic Council guidelines, and the gengeral response capabilities of Denmark (Greenland), Iceland, and Norway to emergencies in the Arctic. The purpose of reviewing these sources is to collect materials that help the article better identify the main risks, clearly understand and categorize risks, and identify key stakeholders, and understand their institutional responsibilities and coordination practices in the event of an Arctic cruising emergency and their relationship with each other.

Qualitative analysis helps in starting the report writing process. In the early stages of the report writing process, this type of analysis can provide a deeper understanding of some basic information and management rules in the Arctic region. By reviewing various clauses or agreements, this paper can more easily list the roles, challenges, and communication patterns that affect stakeholder interactions. However, data on emergencies in the Arctic are very limited, and where possible, the writer consulted search and rescue protocols, national emergency plans, and operational frameworks to inform the design of the stakeholder assessment model and further quantitative analysis.

5.2 Quantitative research

This study mainly uses quantitative analysis methods in Social Network Analysis (SNA). SNA provides a practical framework to quantify and visualize the relationships and interactions among different national stakeholders involved in Arctic emergency response activities, so as to better formulate subsequent recommendations.

According to the relevance of stakeholders to the Arctic cruise emergency response, different stakeholders are scored in this paper from four dimensions: interest, position, power, and influence. The rating scale ranges from 1 (low) to 5 (high). Most of the ratings are based on interviews with relevant industry experts and reading of relevant materials.

The four attributes of the stakeholders were constructed into a matrix in Excel as a node table, and a corresponding edge table was created to represent the strength of the relationship between stakeholders (0-2). The obtained data was imported into Gephi visualization software for SNA analysis. Centrality indicators (such as degree, closeness, betweenness, and eigenvector) were calculated in Gephi software to assess the strategic importance of each stakeholder in the network. Quantitative analysis can provide a more intuitive understanding of which actors have greater influence and connectivity in potential emergency response scenarios and lay the foundation for the recommendations of subsequent articles.

5.3 Data source and collection

The data for this study were collected through two methods: literature review and expert interviews to ensure that the basis for quantitative analysis and SNA was comprehensive and reliable.

5.3.1 Documentary sources

The data for this study were mainly from a variety of publicly available secondary sources, including international maritime security reports, Arctic Council policy documents, cruise industry guidelines, and national emergency preparedness strategies of Arctic countries such as Norway, Denmark (Greenland), and Iceland.

In the SNA part, the data were constructed through a structured stakeholder matrix based on the interpretation of literature and policy documents, as well as interviews with multiple experts. The matrix identified the key actors involved in Arctic SAR cooperation and mapped their relationships based on evidence of interaction (e.g. joint missions, agreements or multilateral cooperation).

5.3.2 Expert interviews

To improve the accuracy and contextual understanding of social network relationships, this project conducted online interviews with selected experts in this industry. Several interview were conducted, and the list showed below in table 5.1.

As part of the data collection strategy, the project conducted a series of semi-structured interviews with key stakeholders involved in Arctic maritime security, governance, and patrol operations. The interviews had two main purposes. First, these interviews can verify the existence of collaborative relationships identified through documentary sources. Second, the interviews can detail the nature and quality of these interactions, including informal partnerships or evolving relationships not captured in official records.

This approach follows the tradition of qualitative network analysis, where stakeholders' perceptions are used to supplement structural data and enhance the interpret ability of social network results [32]. Semi structured interviews were chosen for their flexibility and ability to balance comparability among respondents and explore unique perspectives [33].

Date	Interview Authority/ Organization	Representative Person
14.Mar.2025	Iceland Construction Authority	Senior Researcher
21.Mar.2025	Iceland Construction Authority	Senior Researcher
11.Apr.2025	German Cruise Company	Command and Control Officer for Emergency Management
17.Apr.2025	University of Southern Denmark (SDU)	Senior Researcher
29.Apr.2025	Arctic Expedition Cruise Operators (AECO)	Conference Participant
15.May.2025	Icelandic Coast Guard	Icelandic Coast Guard Officer

Table 5.1: Overview of Interviews Conducted, [Own creation]

Each interview was conducted online and lasted 50 to 90 minutes. Participants were selected based on their institutional affiliation, the relevance of their position to Arctic cruise risk management, and their potential role in cross-organizational coordination. Interview subjects included professionals from national maritime administrations, academic institutions, private cruise employee, and attendees of the AECO Annual Conference. In addition, interviews are an important source of information for stakeholder identification, and the interview content can help explain stakeholders' strategic roles, motivations, and perceived barriers to cross-border collaboration.

5.3.3 Ethical considerations

All interviews were conducted in accordance with established ethical research guidelines. Participants were fully informed of the purpose of the study, the voluntary nature of their participation, and their right to withdraw at any time. Informed consent was obtained in written or verbal form before each interview. To protect privacy, all identifying information in the research outputs will be anonymized unless participants explicitly consent to be named. Interview data will be stored securely and used for academic purposes only [34].

5.4 Risk assessment model

5.4.1 Bowtie model

This report adopts the Bowtie method to systematically identify risks and analyze the relationship between causes and consequences. Its intuitive structure helps highlight key prevention measures and mitigation measures in risk management strategies [35]. By visualizing prevention and mitigation measures around top event, the model enhances decision-making capabilities for risk reduction and security planning [35].

The Bowtie model is centered around the top event, which represents the point at which control of the hazard is lost. Causes are labeled on the left side of the model, which are events or conditions that could lead to the top event [35]. Consequences are labeled on the right side, which represent the adverse consequences of the top event. Between causes and top events, prevention measures are set up to prevent the event from occurring. Between top event and consequences, mitigation measures are set up to minimize the consequences [35].

The methodology involved applying Bowtie analysis to the scope of this report. A variety of data sources were used, including historical accident data assessment and analysis reports, The Arctic council's continuously updated website, and information from relevant stakeholder websites.

5.4.2 Social Network Analysis

5.4.2.1 Stakeholder identification and attribute

Identifying stakeholders is a challenging process. The first task is to clearly define the research objectives and scope. Without understanding these, it is difficult to determine which stakeholders should be involved in identifying relevant issues.

This study investigates the collaborative challenges among stakeholders in cruise ship incidents in the Arctic region. Accordingly, the identified stakeholders should include not only competent authorities from various nations, but also search and rescue agencies, rescue coordination centers, cruise operators, and international organizations.

Two methodologies are employed to identify specific stakeholders. The first is qualitative method, which analyzes some major stakeholders by reading relevant literature and extracting key information. The second is interview-based research, which is to talk to experts in the field and ask them to help recommend the stakeholders they think are relevant to this case.

Stakeholders are typically classified through several established frameworks for further analysis. Here are the most prevalent classification methods:

- **Functional Classification:** categorization based on operational roles in a system [36].
- **Institutional Affiliation:** grouping by organizational or jurisdictional belonging [37].
- **Spatial-Temporal Classification:** categorization by geographical proximity and incident phase involvement [38].

The attributes of stakeholders significantly influence their response behaviors in the Arctic cruise ship incident. Through literature review and interviews, this study evaluates stakeholders' attribute values in four dimensions: interest, position, power, and influence [39]. The definition of the 4 stakeholders' attribute shown below:

- **Interest :** How much they care about Arctic cruise emergency response (policy, safety, outcomes).
- **Position:** How connected they are to other actors (network-wise, coordinating role).
- **Power:** Their capacity to make or enforce decisions that impact response outcomes.
- **Influence:** Ability to shape public opinion, funding, or strategic direction.

5.4.2.2 Social Network Analysis key indicators

SNA is a methodological framework within structural analysis that examines relationships (edges) among stakeholders attribute (nodes) [39].

Firstly, it is essential to analyze and identify the attributes of stakeholders. Given the significant differences in their objective rescue capabilities and resources, this study examines their roles in Arctic cruise ship incident emergency response through four key items: interest, position, power and influence. The results of identified stakeholders and their attributes are in table 6.1 and 6.2.

Secondly, to build effective coordination mechanisms between different stakeholders, the relationship among them should be quantified. This report employ a three-tiered numerical coding system (0, 1, 2) to represent distinct categories of stakeholder relationships (edges):

- **0:** represents that there is no cooperative relationship between the two stakeholders.
- **1:** represents that there is little cooperative relationship between the two stakeholders.
- **2:** represents that there is a close cooperative relationship between the two stakeholders.

Indicators 1, 2, and 3 do not appear in the main paper of this report, as this step is used to assess the pairwise relationships between all identified stakeholders. The table is very large, so it is placed separately in Table 02 of Appendix A, called "Stakeholder Relationships". Appendix A is submitted separately for reference only.

By taking this method in carrying out interviews and analyzing the relevant literature and online resources, a relationship matrix can be made.

SNA enables computing of network metrics including degree, closeness, betweenness and eigenvector centralitiy [39]. This report uses Gephi version 0.10 software to visualize and analyze the data of stakeholders. And four main indicators calculated by this software are list below:

- **Degree Centrality:** quantifies the direct connections of stakeholders by calculating their direct partnerships, thereby identifying the key players with the broadest operational partnerships [40].
- **Closeness Centrality:** assesses the average path distance of a stakeholder to all other stakeholders in the network, highlighting organizations that are able to disseminate information quickly [40].
- **Betweenness Centrality:** analyze coordination bottlenecks, revealing stakeholders that control the flow of information between otherwise disconnected subgroups [40].
- **Eigenvector Centrality:** measures the connections between stakeholders and their partners' influence, this approach can identify embedded power structures [40].

Chapter 6

Risk assessment

The next section outlines the development of the Bowtie model for assessing the main hazards, preventive measures and mitigation measures in an Arctic cruising emergency. The subsequent stakeholder analysis helped to provide a clearer understanding of barriers to stakeholder communication and make recommendations to improve it.

6.1 Bowtie Model

Before constructing the Bowtie model, potential hazards must first be systematically identified. the Bowtie model relies on clear understanding of the initial events that could lead to a major accident. Hazard identification is fundamental to the entire model as it allows the top event to be identified and mitigation measures to be constructed. The following subsections outline the key hazards identified in this case study, which form the basis for subsequent elements of the Bowtie model.

6.1.1 Identify hazard

The Arctic region presents unique challenges to maritime operations, especially for cruise ships operating in remote and ice-covered waters.Factors such as extreme weather conditions, limited infrastructure and environmental sensitivity combine to increase the likelihood of marine accidents [22]. For the purposes of this Bowtie analysis, the main risks in this topic are defined as follows.

- **Collision with icebergs or other vessels:** There is a risk of collision with icebergs, unpredictable sea ice, or other vessels, which could cause damage to vessel's structure, leading to water ingress.
- **Grounding on an unknown seabed:** Many areas of the Arctic remain underdeveloped and under-understood, the cruise ships can easily run aground in shallow waters or on rocky seabeds, causing the hull to rupture and endangering the lives of those on board.
- **Mechanical failure or power outage:** Harsh Arctic conditions are likely to cause engine failure, fuel system failure or power outage, resulting in the ship's inability to safely navigate or maintain the ability of the onboard life support systems, requiring external support.
- **Fire or explosion on board:** Firefighting resources in the Arctic are limited and the extremely remote location does not allow quick rescue. The enclosed hull of a vessel can quickly spread a fire.

- **Severe weather conditions:** Arctic storms, flooding and extreme weather, and high waves can affect a vessel's maneuverability and environmental visibility, making navigation hazardous and increasing the likelihood of an accident.
- **Human and operational errors:** Incorrectly planned navigation routes, miscommunication, or failure to follow safety protocols can escalate a minor incident into a serious emergency.

6.1.2 Bowtie model

Cruise operations in Arctic waters are subject to significant risks due to extreme environmental conditions, technological vulnerabilities and human factors. The Bowtie analytical framework provides a structured approach to understanding these hazards. It identifies the main hazards that lead to cruise accidents in the Arctic and implements preventive measures to reduce the likelihood of such accidents. And, if an accident occurs, mitigation measures must be taken to limit its consequences.

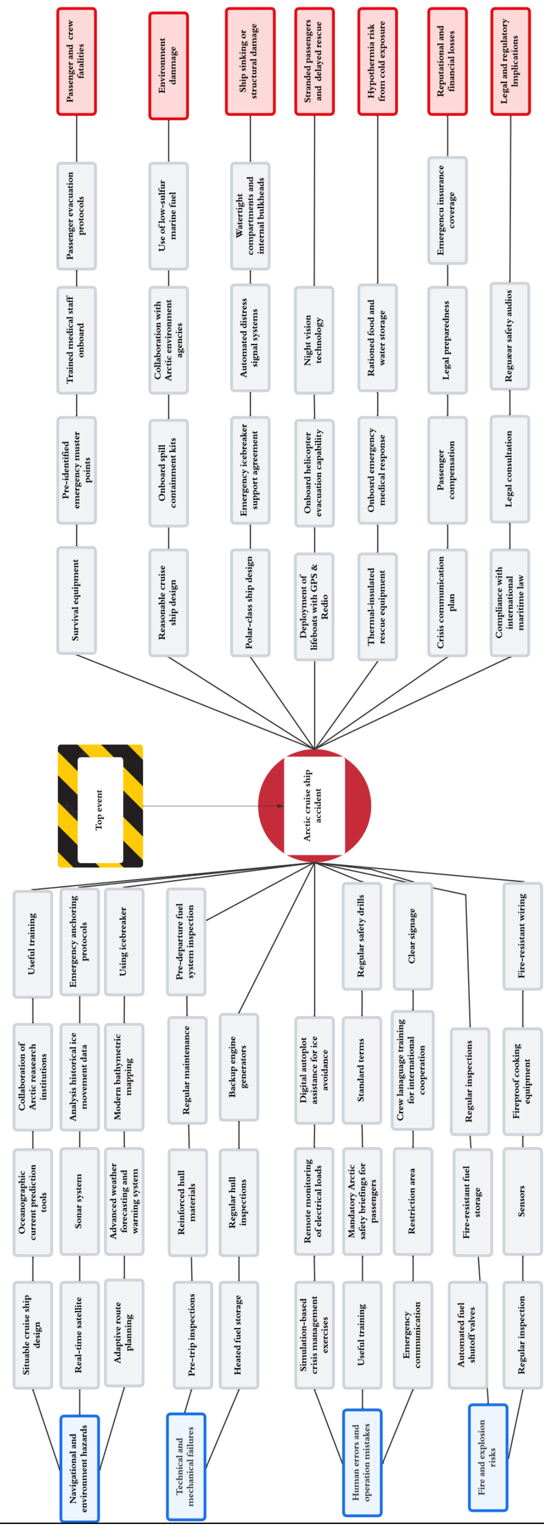

Figure 6.1: Bowtie model, [Own creation]

6.1.3 Causes and preventive measures

One of the most serious hazards facing Arctic cruise operations is navigation and environmental risks. There is a high probability of iceberg collisions, as unpredictable sea ice and floating icebergs may damage the hull and cause seawater to enter the hull, which may cause the hull to tilt or mechanical failure. To prevent such accidents, advanced ice radar systems, real-time satellite monitoring and onboard ice detection sensors are essential for navigation safety. Of course, it is also crucial to analyze historical ice movement data and conduct comprehensive training for navigators to ensure that all crew members can read basic information to prevent some basic mistakes. Another major problem is the lack of data on unknown waters and water depths, which greatly increases the risk of grounding. Therefore, modern bathymetric mapping, sonar systems, cooperation with Arctic research institutions and effective information exchange can help improve mapping accuracy, thereby achieving safer route planning.

Extreme weather conditions complicate Arctic navigation. Strong winds, snowstorms, freezing fog and huge waves can reduce visibility and severely limit the maneuverability of ships. Preventive measures can help ships avoid adverse weather conditions, such as the application of advanced weather forecasting systems, automatic adjustment of route planning and other systems. In addition, the impact of climate change on ice conditions makes Arctic routes very unpredictable. Cruise ships usually rely on icebreaker escorts, special ship designs optimized for ice navigation, and continuous satellite monitoring of ice movement to safely navigate these dangerous waters. Ocean factors such as strong currents and tides can also affect the stability of ships. Therefore, advanced and accurate current prediction tools are an important preventive measure for Arctic cruise operations.

Technical and mechanical failures are another category of hazard. Extreme cold weather can cause engine or propulsion system failures, which could potentially strand the ship in hazardous conditions. Precautions such as regular maintenance of engine systems and pre-voyage mechanical inspections ensure that propulsion systems remain operational. Similarly, power outages or electrical failures could jeopardize the normal life support systems on board, so backup generators and backup electrical systems are an important part of Arctic cruise safety. The structural integrity of the ship is critical, as a hull failure in icy waters could have catastrophic consequences. Reinforced hull materials, regular inspections, and compliance with polar-grade ship design standards can help minimize these risks.

Human error and operational errors significantly increase the risk of a top event. There are many reasons for navigation errors, such as misreading charts, miscalculating routes or delayed response to danger due to panic, which can lead to serious accidents. To solve or prevent these issues, shipping companies should implement crew training specifically for the Arctic region and apply digital autopilot assistance systems. Effective communication is also important, because poor communication between crew members or with external agencies can delay emergency response. Standardized emergency communication terminology and crew language training can enhance internal and external cooperation and coordination capabilities. In addition, inadequate training for Arctic operations can lead to crew members being caught off guard in emergencies. To cope with this situation, relevant departments should enforce Arctic survival and evacuation training, regular safety drills, and simulation-based crisis management exercises. Passenger behavior can also increase onboard safety risks, especially when safety guidelines are ignored. Since most passengers cruise for pleasure, mandatory Arctic safety briefings, clear signage, restricted access to high-risk areas, and remote monitoring of passenger activities help reduce risks associated with human behavior.

Fire and explosion risks are particularly dangerous in remote Arctic conditions, where external fire-fighting support is limited. Electrical short circuits caused by wiring failures, overloaded circuits, or heating system malfunctions can cause cylinder fires. Fire-resistant wiring, thermal circuit breakers, and regular electrical inspections are key preventive measures against electrical fires. Fuel leaks and explosions also pose significant risks, making automated fuel shut-off valves, leak detection sensors, and fire-resistant fuel storage systems necessary preventive measures. In addition, kitchen and galley fires, common sources of onboard fires, are mitigated through automatic fire suppression systems, fireproof cooking equipment, and crew fire safety training.

6.1.4 Consequences and Mitigation Measures

Despite the comprehensive preventive measures listed above, the risk of an Arctic cruise accident cannot be completely eliminated. In this case, the effectiveness of the mitigation measures is very important to minimize the consequences. The most immediate hazard of an accident is loss of life, which can quickly lead to death from hypothermia or drowning. To reduce the occurrence and severity of such dangers, ships must be equipped with specialized Arctic survival equipment, such as sufficient insulated life rafts and thermal clothing according to the number of passengers on board. In addition, preset emergency muster points, well-trained crew and medical personnel, and clear passenger evacuation plans can also help reduce casualties.

Environmental damage will have other consequences, especially in the event of fuel spills or pollution in Arctic waters, which are difficult to recover naturally due to the fragility and inaccessibility of the local environment. Therefore, preventive ship design is very important, such as double hull structure, which can reduce the percentage of leakage, and leakage control components and automatic monitoring systems on board to ensure that the crew can be quickly alerted or the outside world can be alerted in the event of pollution. In addition, the use of low-sulfur marine fuel can also help minimize the impact of accidental spills on the environment.

In the more serious case of an Arctic cruise ship accident, there is a high probability that the ship will sink or suffer severe structural damage, leaving passengers and crew members stranded in the Arctic. Polar-class ship designs feature reinforced hulls, emergency icebreaking support systems, automatic distress signal systems, and extremely sealed cabins, all of which help reduce the likelihood of a complete loss of the ship. However, if the ship does sink or become inoperable, rescue operations or emergency evacuation are extremely important. Therefore, the need for pre-coordinated search and rescue plans, GPS-equipped lifeboats, onboard helicopters for rapid evacuation, and night vision devices for search can greatly mitigate such dangers.

One of the most urgent risks following an accident is hypothermia due to cold exposure, which can quickly become fatal. Emergency measures include thermal-insulated rescue equipment, onboard medical treatment facilities for hypothermia, and sufficient emergency food and water storage to sustain passengers during extended rescue operations.

In addition to some direct losses, there are also some long-term losses to consider. Arctic cruise accidents will also cause long-term reputational and financial losses to cruise operators. Negative media reports will lead to a loss of confidence among some potential passengers and will cause the public to think and discuss the perfection of laws and regulations. Therefore, in order to cope with these impacts, it is very important to develop a comprehensive crisis communication plan and maintain a good supervisory relationship with the media. In addition, if an accident occurs, operators and relevant departments actively develop passenger compensation strategies and make legal preparations to greatly reduce the long-term negative impact of the accident on the industry.

Failure to comply with Arctic cruise shipping regulations could have legal and regulatory implications. Ensuring that cruise ships produced by shipping companies for polar travel comply with international maritime laws such as the Polar Code and the SOLAS, that the various departments jointly conduct regular safety audits, and accept third-party inspections can help cruise operators reduce regulatory risks and maintain operational credibility.

Although the Bowtie model intuitively presents the potential causes and consequences of Arctic cruise accidents, as well as the corresponding prevention and mitigation measures in a structured manner, the Bowtie model can only show the corresponding measures, which require some real-life institutions and departments to implement. The implementation, effectiveness, and coordination of these measures are highly dependent on the participation of multiple stakeholders, including governments, relevant agencies, and private enterprises. Therefore, in order to make the overall risk assessment more comprehensive and easier to understand, the next section will conduct a stakeholder analysis to identify these participants, assess their roles and responsibilities, and understand the relationship between them. Taking these two approaches can make this article better show how to make these measures work in real life.

6.2 Social Network Analysis

An effective emergency response to an Arctic cruise ship incident relies on the coordinated efforts of a wide range of stakeholders. Identifying these stakeholders is the first step in understanding the complex network of actors.

This study identified stakeholders based on their relevance to the emergency response phase of an Arctic cruise ship incident, their formal responsibilities, and their potential to influence or be affected by emergency operations. The identification process included a review of official organizational structures, existing cooperation frameworks, for example, the Arctic Search and Rescue Agreement (2011), and online interviews.

The identified stakeholders include national and regional competent authorities, search and rescue coordination centers, maritime regulatory agencies, and other important stakeholders.

6.2.1 Stakeholder identification and attribute

Through literature review, mainly the Arctic Search and Rescue Agreement (2011) [23], and expert interviews, 27 stakeholders related to Arctic cruise ship incidents were identified.

- Danish Maritime Authority: Responsible for regulating maritime safety, navigation, and ship operations within Denmark's jurisdiction, including oversight of Arctic shipping standards and compliance.

- Maritime Rescue and Coordination Center Torshavn (MRCC Torshavn): Overseas maritime search and rescue (SAR) operations in the Faroe Islands region and contributes to broader Danish SAR coordination in the Arctic zone.
- Danish Insurance Company (Danish Shipowners' Accident Insurance Association-UFDS): Provides maritime insurance and post-incident financial support to Danish shipowners, offering indirect support to risk and emergency management systems.
- Government of Greenland: Functions as the autonomous regional government responsible for implementing emergency policy, healthcare, infrastructure coordination, and community safety within Greenland.
- Joint Arctic Command (JAC): Operates under the Danish Ministry of Defence to coordinate defence, sovereignty enforcement, and search and rescue effort in Arctic regions, including Greenland.
- Greenland police: Ensures public safety and law enforcement in Greenland, with roles in onshore emergency coordination, crowd management, and logistical support during incidents.
- Maritime Rescue Coordination Center Grønnedal (MRCC Grønnedal): Manages SAR operations in southern Greenlandic waters, enhancing local and international emergency collaboration.
- Rescue Coordination Center Søndrestrøm (RCC Søndrestrøm): Coordinates SAR activities in central-western Greenland, including air support and emergency communications.
- Danish Cruise Company (Albatros Expeditions): Plays a critical logistical role in the transport of goods and passengers, and it is operations are central to emergency supply chains and port mobilization.
- Greenlandic ports (Nuuk, Ilulissat, Qaqortoq, Sisimiut): Serve as key martime entry points that facilitate cruise docking, evacuation, refueling, and emergency support infrastructure in Arctic cruise operations.
- Joint Rescue Coordination Centre, Northern Norway (JRCC NN BODØ): Responsible for coordinating all maritime SAR operations north of 65°N, including the Svalbard region. It manages emergency alerts, asset deployment, and interagency coordination during Arctic cruise incident.
- Norwegian Maritime Authority: Supervises maritime safety, ship inspections, and regulatory compliance for vessels operating in Norwegian and Arctic waters, ensuring cruise ship meet safety and environmental standards.
- Norwegian Coastal Administration: Manages navigational safety, port operations, and coastal emergency in infrastructure, providing critical support to maritime traffic and emergency responses in Arctic Norway.
- Governor of Svalbard: Acts as the Norwegian government's administrative authority in Svalbard, coordinating local emergency management, law enforcement, and land-based evacuation efforts during cruise-related emergencies.
- Norwegian ports (Longyearbyen): Serves as the main port for Arctic cruise ships in Svalbard, facilitating passenger embarkation, emergency evacuation, resupply operations, and acting as a key logistical hub in crusis situations.
- Norwegian Insurance Company (Norwegian Hull Club): A major marine insurance provider in Norway that offers coverages for cruise operators, including Arctic voyages. It plays an indirect but important role in emergency response, salvage operations, and post-incident financial response.

- Norwegian Cruise Company (Hurtigruten Expeditions): A leading Arctic cruise operator with direct responsibility for onboard emergency preparedness, passenger safety protocols, and coordination with SAR authorities during operations.
- Ministry of Justice: Responsible for developing national policy related to civil protection, emergency preparedness and crisis management. It plays a vital role in developing the legal and organizational framework for search and rescue operations and ensures coordination between civilian and military agencies.
- Icelandic Coast Guard: Responsible for maritime safety, surveillance, and emergency response in Icelandic waters, including Arctic cruise incidents near the Icelandic EEZ.
- Joint Rescue Coordination center Iceland (JRCC Iceland): Coordinates maritime and aeronautical search and rescue (SAR) operations, issuing alerts and directing emergency resources in Iceland's SAR region.
- Icelandic NGOs (Icelandic Association for Search and Rescue): A volunteer-based national rescue organization that assists with onshore evacuations, search and rescue operations, and cruise-related emergencies.
- Icelandic ports (Reykjavik): Iceland's main cruise port, serving as a key logistical point for cruise ship docking, passenger transfers, and emergency evacuation infrastructure.
- Icelandic Cruise Company (Iceland ProCruise): A local Arctic cruise operator based in Iceland, responsible for onboard safety, navigation in remote coastal waters, and coordination with Icelandic emergency services.
- Association of Arctic Expedition Cruise Operation (AECO): An international industry organization representing cruise operators in the Arctic. AECO promotes responsible tourism, environmental protection, and safety standards, and plays a coordinating role in developing emergency preparedness protocols among its members.
- Indigenous and Local Communities (Saami): Communities living in Arctic regions who may be directly affected by cruise traffic and emergency events. They contribute local knowledge, infrastructure, and support capacity during incidents, and are important partners in sustainable and culturally sensitive emergency planning.
- The Arctic Council: An intergovernmental forum that promotes cooperation among Arctic states and Indigenous peoples. It plays an indirect but strategic role in shaping emergency preparedness policies and fostering environmental and safety standards relevant to cruise operations.
- International Cruise Company (Epic Polar): A boutique polar cruise company operating in remote Arctic regions. It holds responsibility for onboard safety management, passenger evacuation procedures, and coordination with local authorities and SAR services in case of emergencies.

Since this study aims to examine how nations can effectively collaborate in Arctic cruise ship incidents, a mere functional classification of stakeholders would be of limited significance. Therefore, stakeholders were classified into five groups, namely (1) Denmark, (2) Norway, (3) Iceland, (4) Nordic Organization, (5) International Organization, which are shown in table 6.1. Moreover, in figures 6.2, 6.3, 6.4 and 6.5, different categories are shown in different colors, Denmark is red, Norway is orange, Iceland is dark blue, the Nordic Organization is pink, and the International Organization is light blue.

Category	Stakeholders
Denmark (10 stakeholders)	• Danish Maritime Authority • Maritime Rescue and Coordination Center Torshavn • Danish Insurance Company • Government of Greenland • Joint Arctic Command • Greenland Police • Maritime Rescue Coordination Center Grønnedal • Rescue Coordination Center Søndrestrom • Danish Cruise Company • Greenlandic Port
Norway (7 stakeholders)	• Joint Rescue Coordination Centre, Northern Norway • Norwegian Maritime Authority • Norwegian Coastal Administration • Governor of Svalbard • Norwegian Port • Norwegian Insurance Company • Norwegian Cruise Company
Iceland (6 stakeholders)	• Ministry of Justice • Icelandic Coast Guard • Joint Rescue Coordination Center Iceland • Icelandic NGOs • Icelandic Port • Icelandic Cruise Company
Nordic Organization (2 stakeholders)	• Association of Arctic Expedition Cruise Operation • Indigenous and Local Communities
International Organization (2 stakeholders)	• The Arctic Council • International Cruise Company

Table 6.1: List of Stakeholders by Category, [Own creation]

Based on the result this paper got from the interviews with relevant industry experts and reading of relevant materials, the estimated scores of each stakeholder in interest, position, power and influence are shown in table 6.2.

Stakeholder	Interest	Position	Power	Influence
Danish Maritime Authority	4	5	4	5
MRCC Torshavn	5	4	5	4
Danish Insurance Company	2	3	2	3
Government of Greenland	4	5	4	5
Joint Arctic Command	4	5	5	4
Greenland Police	4	5	4	4
MRCC Grønnedal	5	4	5	4
RCC Søndrestrøm	5	4	5	4
Danish Cruise Company	4	3	3	2
Greenlandic Port	4	4	4	4
JRCC NN BODØ	5	3	5	4
Norwegian Maritime Authority	4	5	4	5
Norwegian Coastal Administration	3	4	4	4
Governor of Svalbard	4	5	4	4
Norwegian Port	4	4	5	5
Norwegian Insurance Company	2	3	2	3
Norwegian Cruise Company	3	3	2	2
Ministry of Justice	3	3	5	4
Icelandic Coast Guard	5	4	5	4
JRCC Iceland	5	4	5	4
Icelandic NGOs	3	4	2	3
Icelandic Port	3	4	4	3
Icelandic Cruise Company	3	2	2	2
AECO	4	4	2	4
Indigenous and Local Communities	4	4	2	4
The Arctic Council	5	5	4	5
International Cruise Company	3	3	2	2

Table 6.2: Stakeholders' score in four dimensions, [Own creation]

6.2.2 Stakeholder matrix

The following stakeholder matrix is generated based on the table 6.2stakeholder attributes (node) and the pairwise relationship data included in the Appendix A table 02. The key indicators were automatically computed using Gephi, and the key result are shown in table 6.3.

Stakeholders	Degree centrality	Closeness centrality	Betweenness centrality	Eigen centrality
The Arctic Council	25	0.96	0.06	1.00
Danish Maritime Authority	22	0.87	0.03	0.95
MRCC Grønnedal	22	0.87	0.02	0.97
RCC Søndrestrøm	22	0.87	0.02	0.97
Icelandic Coast Guard	22	0.87	0.02	0.97
AECO	22	0.87	0.03	0.94
Norwegian Maritime Authority	20	0.81	0.03	0.86
JRCC Iceland	20	0.81	0.01	0.89
Icelandic Port	20	0.81	0.01	0.91
MRCC Torshavn	19	0.79	0.01	0.88
Danish Cruise Company	19	0.79	0.02	0.84
Greenlandic Port	19	0.79	0.01	0.88
Norwegian Coastal Administration	19	0.79	0.02	0.84
Norwegian Cruise Company	18	0.76	0.04	0.72
Government of Greenland	17	0.74	0.00	0.81
Joint Arctic Command	17	0.74	0.00	0.81
Indigenous and Local Communities	17	0.74	0.02	0.72
International Cruise Company	16	0.72	0.01	0.73
Icelandic NGOs	15	0.70	0.00	0.69
Greenland Police	14	0.68	0.00	0.64
JRCC NN BROØ	13	0.67	0.01	0.57
Icelandic Cruise Company	13	0.67	0.01	0.58
Norwegian Port	11	0.63	0.01	0.42
Ministry of Justice	10	0.62	0.00	0.49
Danish Insurance Company	7	0.58	0.00	0.28
Governor of Svalbard	7	0.58	0.00	0.29
Norwegian Insurance Company	6	0.57	0.00	0.22

Table 6.3: Network metrics, [Own creation]

Based on the result, the Arctic Council had the highest rank, which meant that the Arctic Council plays the most crucial role in Arctic affairs, maintains extensive collaboration with most regional stakeholders and has the capacity to facilitate consensus among nations on solutions for Arctic cruise ship incidents.

The DMA ranked second in comparative evaluations, while peer agencies such as the Norwegian Maritime Authority occupies middle position. This divergence mainly stems from Denmark's forthcoming Arctic Council chairmanship (2025-2027) [41], which requires greater engagement in Arctic affairs.

It is worth noting, however, that while government agencies such as the DMA have significant influence on policy making and cross-border coordination, their direct involvement in Arctic emergency response operations is relatively low.

The Danish and Icelandic RCC performed well, showing a high level of operational involvement in responding to Arctic cruise ship incidents. However, as can be seen in the table 6.3, the Norwegian JRCC is ranked in the middle, but this does not mean that the Norwegian response is immature, but simply reflects that the Norwegian JRCC is not closely connected with other departments in the random analysis of information in this report, although Norway's resources and capabilities are recognized as relatively strong among Nordic JRCC. However, compared to government agencies such as the DMA, these professional rescue organizations still lack sufficient influence and cannot effectively mobilize a wider range of stakeholders for cooperation.

The relatively low ranking of domestic and foreign cruise companies indicates that their cooperation with relevant stakeholders in the Arctic is limited. This leads to weak risk management capabilities for cruise accidents and the inability to quickly mobilize search and rescue resources. This may also be related to market competition. In order to protect their own interests and uniqueness, cruise companies are reluctant to share too much information and company details with the outside world.

To fully understand the stakeholder landscape involved in the Arctic cruise emergency response, the report used SNA to generate four separate network diagrams. Each network corresponds to one of four specified attributes: interest, position, power, and influence, and the maps shown in Figure 6.2, 6.3, 6.4 and 6.5. These network diagrams provide a more intuitive understanding of stakeholder roles and involvement.

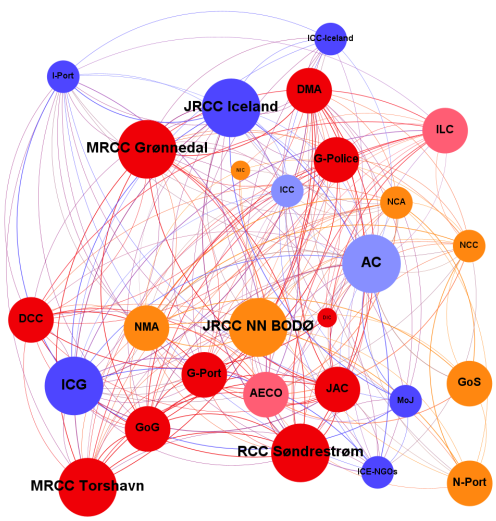

Figure 6.2: Network map based on the interest of different stakeholders, [Own creation]

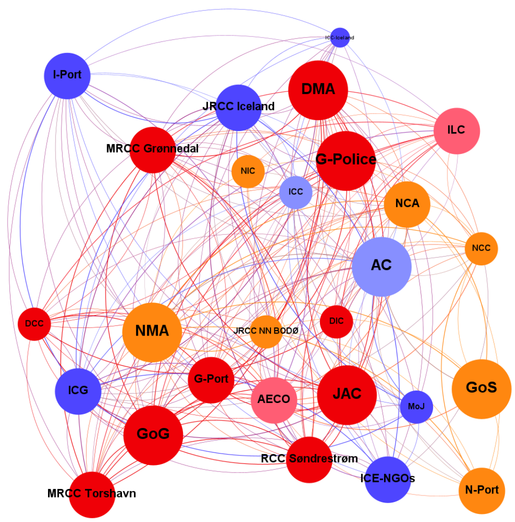

Figure 6.3: Network map based on the position of different stakeholders, [Own creation]

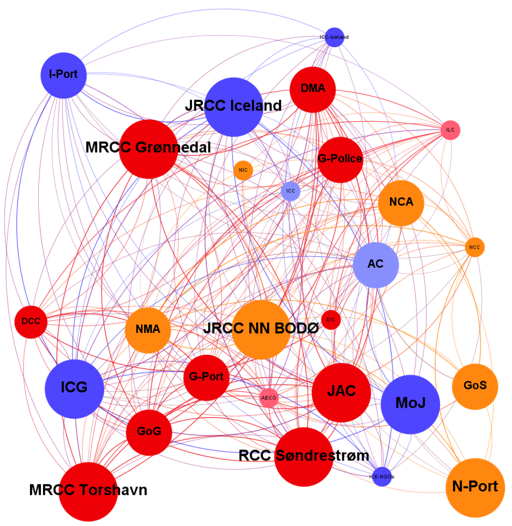

Figure 6.4: Network map based on the power of different stakeholders, [Own creation]

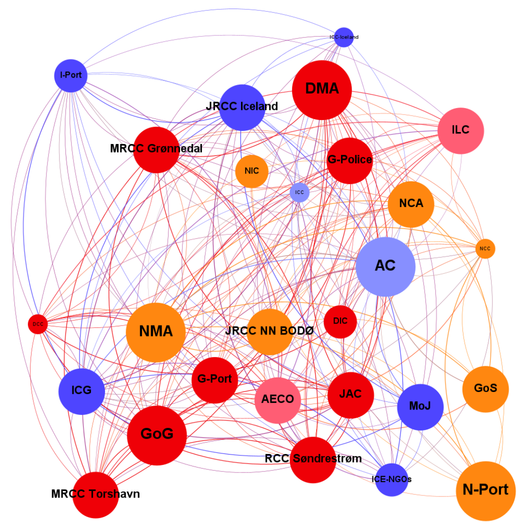

Figure 6.5: Network map based on the influence of different stakeholders, [Own creation]

Figure 6.2 shows the level of interest of various stakeholders in the emergency response to the Arctic cruise. Stakeholders such as MRCC Grønnedal, JRCC Iceland and the Icelandic Coast Guard are ranked prominently, indicating that they have a strong interest in this issue. This is because the most important responsibility of these organizations is to pay attention to the occurrence of some emergencies and how to respond actively and quickly, which is an important topic for them to study.

Figure 6.3 reflects the level of stakeholder coordination with the Arctic Emergency Response System and other stakeholders. Organizations such as the DMA, the JAC and the MoJ are listed as key positional players. Compared to the interest-based map, some stakeholders here have higher positional authority but are less important in the positional map, indicating a potential gap between formal authority and actual engagement.

Figure 6.4 highlights the ability of stakeholders to control resources, make operational decisions or perform actions. Entities such as MRCC Torshavn and JRCC NN BODØ become more prominent, reflecting their operational command and control functions. These actors can therefore be considered as direct participants in the emergency response, playing a central role in emergency planning.

Figure 6.5 focuses on the ability of stakeholders to shape policy, guide collaboration, or influence other actors. The AC, and GoG, and other national authorities, while not always dominant in power or interest, are more central to this map. This highlights that national government departments are still recognized to be strong in terms of influence, whether it is for the formulation of relevant policies, the negotiation of national diplomacy, or the establishment of funds in this field. This influence-based map does not directly reflect the level of participation in the actions of various stakeholders, but rather reflects the relationship between policy making and economic support over a long period of time.

Chapter 7

Discussion and Recommendation

Based on the risk assessment, stakeholder interviews, and SNA indicators, this section proposes several strategic recommendations to improve emergency response to cruise ship incidents in the Arctic. These recommendations focus on improving coordination among stakeholders, reducing information gaps, eliminating information barriers between agencies, and strengthening the role of agencies in the field of Arctic maritime safety.

The Bowtie model shows that human errors and operational errors, such as poor communication between crew members and the outside world, major decision-making errors, or insufficient crew training are major threats to Arctic cruise accidents, but this type of error is controllable and not as difficult to control as extreme weather, which is why this paper chooses to discuss this point first. Therefore, preventive measures such as safety drills and operation checklists usually exist, but their application is inconsistent across operators and jurisdictions, resulting in some information gaps and information delays in communication. To address this issue, it is recommended that Arctic cruise operators adopt standardized human factors training programs, strengthen the standardization of industry terminology, and emphasize cold weather operations, emergency coordination, and scenario-based drills. This uniformity will reduce differences in response speed and procedures and greatly reduce the occurrence of human errors.

Bowtie's analysis also shows that even if preventive measures fail, harsh environmental conditions and long search and rescue response times are still important obstacles that limit the safe evacuation of passengers. Although mitigation measures such as lifeboats, immersion suits and rescue coordination are in use, their effectiveness will be reduced in isolated waters prone to ice formation, and even lifeboats may fail. Therefore, it is recommended to pre-deploy mobile search and rescue forces and emergency shelters along popular Arctic cruising routes. This will shorten evacuation time and increase survival rates in the event of rescue delays.

One of the most common hazards in the Bowtie model is technical failure, ranging from propulsion system failure to fire extinguishing system failure. While mitigation measures exist such as onboard alarms and fire-resistant compartments, these are reactive and may not fully prevent escalation in remote Arctic regions. It is recommended that authorities make it mandatory for ships sailing in high latitudes to be equipped with redundant safety systems and real-time equipment monitoring technology. Early detection through automated diagnostics will allow for early intervention and reduce the likelihood of a full-blown emergency requiring the deployment of search and rescue personnel.

One conclusion that can be drawn from the SNA is that domestic and foreign cruise companies are relatively marginalized in the stakeholder network. This low ranking is partly due to limited contact with Arctic authorities and a reluctance to share operational information due to market competition. To solve this problem in a certain way, it is recommended to establish an Arctic cruise industry coordination platform. Although there is an organization called AECO, during the interviews for this paper, it can be seen that not all Arctic countries are taken seriously and only some large stakeholders are present at the meetings. So ideally, the platform should be facilitated by a neutral body such as the Arctic Council or national maritime authorities to facilitate the exchange of non-commercial information between cruise operators, such as voyage plans, emergency communication procedures and emergency response plans. And ensure that as many stakeholders as possible are included in each update of the information. Cruise operators participating in the platform can be encouraged to actively participate by providing additional rewards for joint training programs, emergency exercises or regulatory incentives.

A recurring issue during interviews, particularly with the Icelandic Coast Guard, was the lack of real-time voyage reporting by maritime agencies. While cruise ships require a general permit to sail in Arctic waters, such permits are typically valid for one to two years and do not require reporting of specific positions or sailing times for each voyage. The lack of up-to-date position information severely impairs emergency response capabilities as it is difficult to locate. To address this, an enhanced Arctic voyage reporting protocol should be introduced. Cruise ships entering Arctic waters should be required to submit real-time position updates and itinerary changes to the relevant search and rescue agencies, and where a pass is available, should also be notified on each entry into Arctic waters. This could be achieved using existing AIS technology and integrated into a shared maritime safety database accessible to Arctic coastal states.

Although the RCC and JRCC in Denmark, Iceland and Norway show high levels of operational engagement and adequate technical preparedness, their ability to influence wider policy processes remains limited. Therefore, it is recommended that the role of these RCC be formally expanded within national and regional policy frameworks. Greater participation of SAR professionals in strategic planning workshops and intergovernmental forums would help bridge the gap between on-the-ground emergency operations and high-level decision-making, as these people who are actually involved in rescue operations have more experience and real feedback.

Icelandic Coast Guard officer mentioned in interviews that cooperation between Denmark and Iceland is particularly close, mainly due to common commercial shipping interests, while Norway seems to be less integrated into these cooperations. But this does not mean that Norway is not important. On the contrary, it is recognized in the Nordic region as having strong crisis response capabilities, but its ties with the other two countries are not very close. Therefore, it is recommended that Denmark, Iceland and Norway establish a trilateral Arctic emergency response framework. This framework should include joint risk assessments, coordinated search and rescue simulations, and mutual assistance agreements on the deployment of equipment and personnel, while also strengthening trust and communication between countries and eliminating some information barriers. Such arrangements could be strengthened through annual Arctic cruise season preparation exercises, or regular meetings.

The Arctic Council will become the most central and influential stakeholder in the network analysis. Its position enables it to play an important transnational convening and coordination role. Given Denmark's upcoming chairmanship of the Arctic Council (2025-2027), this provides an excellent opportunity to further expand the Arctic Council's role in Arctic cruise safety. Specifically, the Arctic Council should promote a more structured public-private dialogue, support the establishment of a multilateral search and rescue forum, and take the lead in actively updating rules similar to the Polar Code to provide guidance for stakeholder cooperation in cruise ship emergencies.

Several stakeholders, including cruise company, non-governmental organizations, and some government agencies, either lack sufficient influence or have limited involvement in operational response activities. Targeted improvements are recommended to enhance the influence and information sharing networks of these stakeholders and improve the resilience and response speed of the overall system. These initiatives may include joint scenario simulation exercises aimed at increasing the participation and motivation of grassroots actors.

Chapter 8

Conclusion

A careful analysis of this topic shows that Arctic cruise emergencies represent extremely complex risk scenarios that are beyond the current state of the art, involving harsh environments, limited technology, and organizational challenges. Despite the existence of international regulatory frameworks such as the IMO Polar Code and the Arctic Search and Rescue Agreement (2011), there are still significant gaps in infrastructure, inter-agency coordination, and emergency response capabilities, and the regulatory framework itself has some limitations. Through the Bowtie model, this study maps a range of hazards and their corresponding causes and consequences, emphasizing the need to establish a robust prevention system and targeted mitigation strategies. SNA further reveals that the most influential stakeholders, such as the Arctic Council, national or regional administrations, and rescue coordination centers, do not always have the strongest operational and response capabilities. In addition, cruise operators, some non-governmental organizations, and indigenous communities, while directly affected, often lack sufficient voice or power under the current governance model. Bridging these gaps requires more than legal reform and continued institutional improvement. To better explore this topic, this article proposes the need to rethink cooperation mechanisms, build trust across jurisdictions, and continue to invest in cross-border search and rescue capabilities. In summary, a safer future for Arctic cruise travel depends on a more networked, inclusive, and adaptive approach to emergency management.

Acknowledgment

I gratefully acknowledge the support of the LRF-UArctic scholarship project "Risk Management: Assessment of Rescue Capabilities for Cruise Ship Accidents in the Nordic Arctic", which was essential for data collection for this article and interviews with relevant experts.

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Vancouver-based hybrid style was applied for referencing. [1]
[1]

[1] All ideas, arguments, and interpretations in this paper are entirely our own. The project group used ChatGPT purely to help with sentence flow and refining structure, LaTeX coding, ensuring our original content was clear and well-organized.