Proposal for a Comprehensive Risk Framework for the Canadian Marine Shipping Industry: A Systematic Approach to Managing Transport Risks in Canadian Waters Based on an ISO 31000 Foundation

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Submitted in partial fulfillment of the requirement for the degree
of
Master of Marine Management

at

Dalhousie University
Halifax, Nova Scotia

December 2021

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List of Acronyms

CASRAS	Canadian Arctic Shipping Risk Assessment System
CCG	Canadian Coast Guard
DFO	Department of Fisheries & Oceans Canada
ECCC	Environment and Climate Change Canada
FSA	Formal Safety Assessment
IMO	International Maritime Organization
ISO	International Organization of Standardization
NRC	National Research Council Canada
PSV	Platform Supply Vessel
POLARIS	Polar Operational Limit Assessment Risk Indexing System
RIM	Risk Identification Method
RFW	Risk Framework
RTO	Risk Treatment Option
SH	Stakeholder
SLGL	St. Lawrence/Great Lakes
TC	Transport Canada

Acknowledgements

Throughout the past eight months of research and writing, I have received an abundance of support and assistance.

I would first like to first thank my supervisor, Dr. Ron Pelot, whose expertise, insightfulness, and support has been heavily appreciated in every step of the research project. Dr. Pelot's guidance helped me immensely during my internship, throughout the research project process, and has heavily expanded my interest in the field of maritime risk and risk management, in which I hope to continue work in this sector in the future.

I would like to thank the support of my colleagues at Clear Seas Centre for Responsible Marine Shipping during my summer internship, for their input and preliminary guidance in the beginning stages of the research project.

I would also like to thank my second reader, Meghan Mathieson (MBA), who was an amazing mentor at Clear Seas, and for putting in the time and effort to review this project.

Finally, I would like to thank the Dalhousie Marine Affairs faculty for their support, and my fellow classmates throughout the duration of our MMM degree.

Abstract

Marine shipping is an indispensable sector for the Canadian economy, with projections that both the number of vessels and size of vessels will increase in coming years. Although there are effective regulations in place, traversing Canadian waterways is a relatively high-risk form of transport, with an abundance of uncertainties arising from inevitable tangible and intangible hazards. As such, environmental and safety risks are evident. To mitigate risk from ships and risks to ships, effective risk management processes should be implemented. There is an array of risk assessment toolboxes, guidelines, and procedures for specific regions and shipping projects in Canada. However, a transparent, cohesive, and comprehensive risk framework (RFW) for the broad Canadian marine shipping sector that can be used as a guiding structure is still lacking. This paper proposes a RFW that can be utilized by risk practitioners, policymakers, researchers, etc., and people who are not necessarily experts in the field of risk. Drawing on an integrative literature review of secondary source data as the methodology, and using ISO 31000 as a guiding foundation, a RFW is proposed. The objective is for Canadian marine shipping transits to occur with as minimal risk as possible and become a leading nation in maritime sustainability and safety. This paper provides further research opportunities for best practices and quantifiability throughout Canadian risk management processes.

Keywords: risk framework, marine shipping, Canadian waters, maritime safety, shipping hazards, risk management, transparency, comprehensiveness

1. Introduction

Marine shipping is an integral component of society and the global economy, which has connected people, commodities, and resources for centuries. The shipping sector is the artery of the global supply chain, with estimates that over 90% of global trade by volume is transported by ship, making it fundamental for intercontinental trade and supply chain sustainability (Osobajo et al., 2021). Canada has the longest coastline in the world, which subsequently creates opportunities for robust maritime activities. As a result, 550 ports operate across the nation, many of which support ongoing shipping operations (Statistics Canada, 2019). Between 2002-2016, Canada's marine shipping exports and imports grew an average of 2.7% per year and totaled a value of $1.9 trillion (Statistics Canada, 2016). With continued demand for goods, global population growth, Canada's Arctic potentially becoming a more viable waterway for both domestic and international shipping, etc., it is projected that marine shipping will increase substantially by 2050 (Sardain et al., 2019). The significance of marine shipping is often overlooked, but it is an indispensable sector. Canada is thus a heavily influential maritime nation, creating strong economic, cultural, and societal ties with the shipping industry.

It is difficult to argue the economic benefits that marine shipping produces. However, transportation across any waterway undoubtedly presents an abundance of risk. Risk is a somewhat ambiguous term, but ISO 2009 (2) defines it as "the effect of uncertainty on objectives". In the case of marine shipping, the "objective" is for efficient and safe transport from one spatial point to another. Hazards such as an influx of marine traffic, unprecedented storms due to climate change, inflexible deadlines and demands that mariners are pressured to meet, technological/design malfunctions, etc., all elevate the level of risk. Risks from ships such as spills, waste discharge, ship strikes etc., and risks to ships such as ice, severe weather, and grounding(s) are crucial to assess. The consequences of shipping risk can have profound impacts on receptors (entities that may be harmed) including human beings, coastal and marine habitats, biodiversity, infrastructure, private property, etc. (Dinis et al., 2020). Due to this, implementing effective risk management is critical for a safe maritime sector in Canada to ensure the most efficient movement of goods and people, with the least possible level of likelihood and consequence (or impact) of evident risks. Low likelihood and low consequence are the ideal amount of risk in the Canadian shipping sector. However, hazards make this difficult to achieve in practice.

Risk management initiatives are increasingly being introduced in the marine shipping industry, but there is still a gap in this sector. In fact, KPMG (2013) estimates that only approximately 37% of shipping companies risk management programs meet adequate standards. Risk management is becoming a common practice across sectors. Thus, many industries in Canada follow broad standardized risk frameworks (RFW) which are widely recognized as a leading procedure for risk management, such as the Canadian Framework for the Management of Risk (Government of Canada, 2010). However, the available RFWs are broad and not targeted for the Canadian shipping industry and lack transparency, cohesion, and comprehensiveness for end-users. As such, Canada's shipping industry is left without a standardized RFW to be used by mariners, shipping companies, government agencies, etc. There are an array of maritime risk guidelines and toolboxes that are developed for specific regions, authorities, and projects, but no standardized RFW for Canada. RFW is a broad term, but in this paper, it is defined as the overarching organizational structure and guideline of how to best conduct shipping risk management in Canada, with an emphasis on the sequential and non-sequential steps to assess risk. It is a guidance structure of best practices for conducting risk assessment in the field of marine shipping in Canada, where risks are ever-present.

An increasingly broad range of literature has been produced that examines risk and analyzes potential RFWs in general, and for specific sectors/operations. For example, the ISO 17776:2016 is a widely adopted risk management process specific to the oil & gas sector (ISO, 2016). However, there are few that examine a potential RFW that is specific for the broader marine shipping industry in Canada. In this paper, a transparent, cohesive, and comprehensive shipping RFW will be proposed to ensure a safe and sustainable influx of marine transport in Canada. Risk is a broad term, and there is a wide variety of common risks for marine shipping, such as market factors, environment & safety, credit, political, financing, regulatory, oil price, etc. (KMPG, 2013). However, this paper specifically examines the *environment & safety* risk component.

The methodology involves an integrated literature review, and justification for the processes will be examined in the following section. The International Organization for

Standardization (ISO) 31000 risk management guideline will be used as a starting point and foundation for the proposed RFW, as it is an internationally accepted guiding structure in risk management (analyzed more in section 3) (ISO, 2018). This study aims to inform risk managers, policymakers, mariners, government agencies, etc., of a proposed RFW that the Canadian shipping industry could adopt for effective safety and protection to the marine environment, in a transparent and accessible rubric for end-users. The paper considers various stakeholders, geographic areas, and risk initiatives in its development.

The layout of this paper is organized as follows: Section 2 provides the methodological approach of the research, indicating the management problem and how relevant data were gathered to solve the research problem, data collection tools, processing methods of the data, etc. Section 3 analyzes foundational research on risk, shipping risk quantification, ISO 31000 as a foundation, and risk inventorying. Section 4 provides the readers with a literature review on shipping RFWs and the gaps that this research seeks to fill in the recent literature. Section 5 and its subsections present the primary findings and approach that breaks down the proposed RFW and its subsequent stages. Section 6 provides a discussion on the RFW, including limitations, recommendations, further research opportunities, etc. Finally, Section 7 concludes the paper and provides further research venues.

2. Methods

This section examines the research problem of the paper, a brief explanation of the research area and context, the research methods that were used to gather data for the RFW, and a justification for the methodology.

2.1. Management/Research Problem

Marine shipping is projected to increase in Canada, due to global demands, population growth, market shifts, climate change opening more navigable waterways for longer periods of the year, etc. (Dawson et al., 2017; Statistics Canada, 2021). The abundance of hazards to the environment and safety within the Canadian shipping industry is simultaneously increasing due to natural hazards, increasing marine traffic, etc., ultimately raising the level of risk affiliated in the sector. As such, the need for a transparent, cohesive, and comprehensive RFW specific to the Canadian marine shipping sector is evident to effectively manage the risk(s). This includes risk identification methods, effective stakeholder (SH) consultations, risk analysis, risk treatment and mitigations, monitoring and evaluation of the risks/methods, etc. There is an array of toolboxes for specific shipping operations in Canada, but a lack of a common and accessible RFW for the broad Canadian shipping industry to follow. The end users of the RFW could be mariners, shipping firms, government agencies, NGOs, research groups, etc.

2.2 Study Area & Vessel Types

Due to the Canadian context of this paper, the geographic area is the waters of Canada's exclusive economic zone and internal waters. Throughout the paper, the marine areas that will be relevant for the RFW are split in four oceanic zones: the Atlantic (yellow), the Arctic (orange), the Pacific (pink), and the St. Lawrence Seaway/Great Lakes (SLGL) (grey) (see Figure 1).

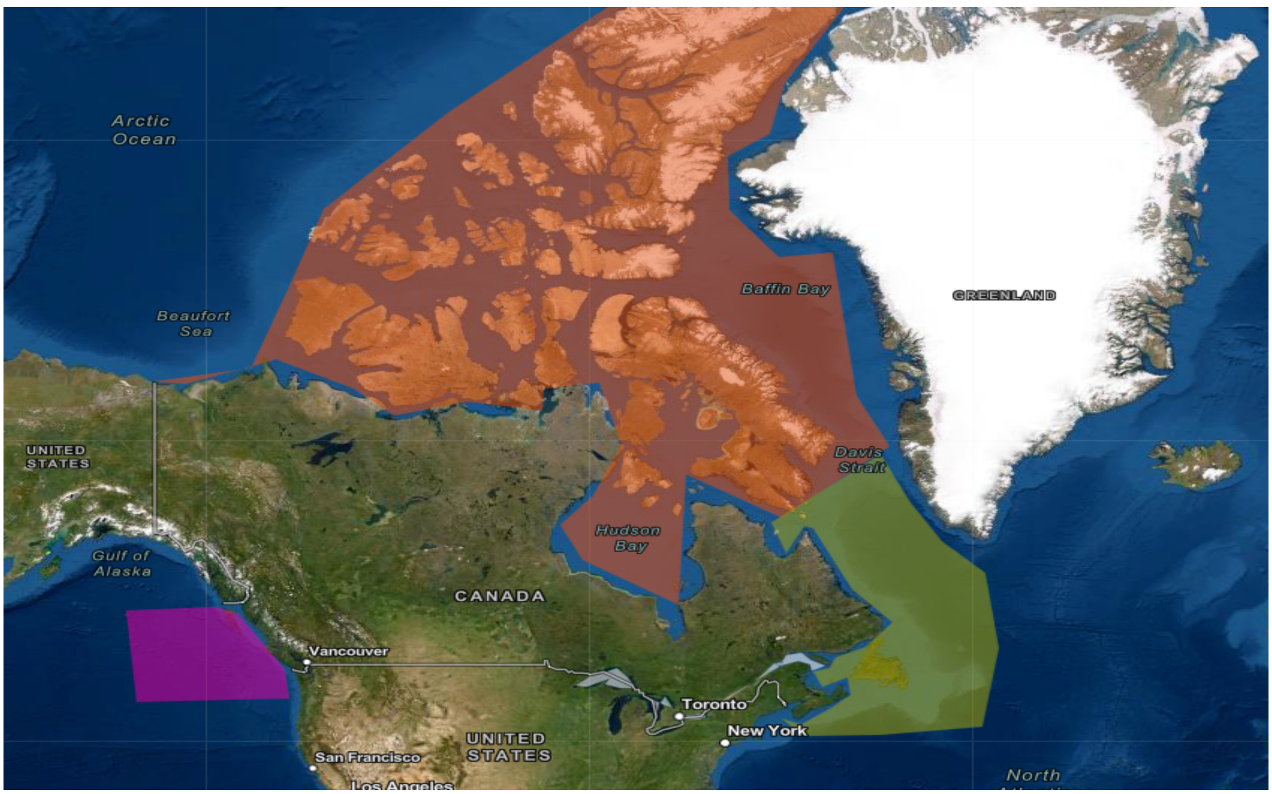

Figure 1. Four Marine regions of Canada's waters that will be applicable for the RFW.

This paper accounts for all commercial vessel types, including but not limited to container ships, bulk carriers, tankers, research vessels, ferries, passenger vessels, tugs, etc. Small-scale fishing vessels however may not be relevant due to the differing complexities between industry vessels and small-scale fishing boats. A broad range of SHs are referred to in the results section. For visualization purposes, rainbow diagram(s) are utilized to effectively display the relevant SHs in accordance with who is impacted by shipping risk and who is creating the shipping risk.

2.3 Research Methodology

The necessary data that had to be gathered to answer the research problem was a multidisciplinary outlook on the shipping industry in Canada, generic risk assessment procedures, and existing frameworks that could be implemented in a RFW for a Canadian shipping context. For effective results, the aim was to describe characteristics of shipping risk methods in Canada and gain in-depth understanding of the topic to best apply a relevant RFW. Hence, the results utilize an integrative literature review as the methodology of the study (e.g., Fowler & Sorgard 2000; Zhang & Meng, 2019). The analysis is qualitative as the results describe and demonstrate best practices for an RFW in Canada. The data that were collected include secondary source information from both grey literature and peer reviewed articles relevant to the subject. The secondary source data collected resulted in the ability to integrate recommendations on best practices on shipping risk management in Canada as a unified RFW. The research is primarily descriptive and prescriptive as opposed to experimental. Table 1 below summarizes the type of research conducted.

Table 1. Research type and methodology of this paper (in green).

Primary source data	Secondary source data
Qualitative	Quantitative
Descriptive/Prescriptive	Experimental

2.4 Data Collection & Analysis

Relevant secondary sources were utilized to gather data on the subject. There was a variety of sampling methods to gather applicable data. For identifying peer reviewed literature of shipping in Canada and risk management, Google Scholar and library sources were used to assemble the largest possible pool of publications. There was a variety of key words used, but "risk *and* shipping *and* Canada" were the broad literature searches, resulting in thousands of relevant results. From here, more narrowed literature searches were used to find applicable data. Furthermore, shipping organizations such as the International Maritime Organization (IMO) and Canadian government agencies contain public grey literature publications that were also utilized to gather data.

The goal for analyzing the data was finding trends and patterns that were used in risk management sources and when analyzing shipping data in Canada. I was then able to extract the criteria that were most relevant for the research problem. Through thematic analysis, patterns in the secondary source data and the collection of recurring concepts were utilized for finding the most effective results.

2.5 Methodology Evaluation & Justification

An iterative literature review of secondary source data to compile a qualitative, descriptive, and prescriptive research paper was the most effective method for the RFW results. Through review of existing grey and peer reviewed literature, trends and themes of risk management processes and frameworks were recognized, and this information was used to best make a framework for the Canadian shipping context. Furthermore, risk studies are becoming more common in industry, government agencies, and research agencies. Consequently, there were no limitations of secondary source data for applying to the results section.

Primary data collection methods such as interviews and surveys could have been effective, however there are limitations to this. Interviews with specific individuals fail to provide data from the macro perspective and would only focus on individual micro perspectives of what could be included in the RFW. Due to the broad nature of a shipping RFW for Canada, a broad literature search of trends and themes are thus more applicable. Surveys could have been effective but acquiring knowledge from a broad range of SHs that is necessary for the results would be beyond the scope of this research. Thus, utilizing secondary source data that has already been gathered was preferred. A key goal of this research is for it to be an iterative process to be improved upon in further research. Shipping risk in Canada is open-ended, resulting in frameworks consistently having to managed and modified. If primary data collection was conducted from individual specimens, their opinions on the results are likely to have changed as the needs in shipping risk management change. Finally, the resources are currently lacking to gain insights from individuals for something as large as a national RFW, a limitation which was aggravated due to the COVID-19 pandemic.

There are limitations and obstacles to the methodical approach in this paper, however. Secondary source data gathering fails to gather hands-on data of what specific people in agencies and SH groups would find appropriate in a RFW. Furthermore, secondary source data may not be as authentic and reliable as primary source data. However, the strengths of the research methods that were previously discussed outweighs these limitations.

3. Foundational Research & Background Information

This section aims to demonstrate critical foundational research and background information about risk that could be necessary to understand some components of the proposed RFW. It will do so by examining risk in society and shipping alike, risk matrices/quantifiability, shipping risk(s) in Canadian waters, tools and methods for conducting risk assessment, and an introduction to the shipping risk inventory project and its relevance to this paper.

3.1. Risk in Society & Shipping

The daily actions of people and organizations in society strive to meet objectives through their day-to-day lives. These objectives can be anything from driving down the road to get groceries, to more daunting objectives such as a corporation meeting their desired annual financial results. Risk itself is generally derived from uncertainty around meeting specific objectives, and the consequences that may result (Holton, 2014). Thus, the ISO Guide 73 (2009) on risk management explains risk as the effect of uncertainly on objectives. Uncertainty about meeting objectives is inevitable and in very few cases can risk be fully eliminated. However, managing uncertainties and hazards so that the level of risk is tolerable, or knowing not to partake in an unforgiving high-risk situation is a component that is in our control. This practice is referred to as risk management. Treasury Board of Canada (2016, 6) defines risk management as "a systematic approach to setting the best course of action under uncertainty by identifying, assessing, understanding, making decisions on, and communicating risk issues".

There is no exact timeline of risk, as risk and uncertainties have been pervasive in society since the beginning of humankind. However, managing these risks (or partaking in risk management) is a relatively new practice, and is ever-expanding into more industries, under different forms of risk. The emergence of risk management as a practice and field of study began in the 1950s and has been evolving ever since (Dionne, 2013). What was once a practice primarily for financial risk management has now emerged into industries such as enterprises, project management, natural disaster preparedness, information technology, and in the case of this paper, transport. Furthermore, risk management is increasingly being used and studied across sectors such as private business, government, academia, etc. For example, between 2000-2009 there were 1.8 million peer reviewed articles with the word "risk" in the title, and between 2010-2020 there were over 3.3 million. These statistics show an 83.3% increase in risk studies in 2010-2020 compared to 2000-2009, proving its growing nature.

Over the past few decades, risk studies specifically aimed at the international marine shipping industry have also undergone an expansion. Between 2000-2008 there were 12,739 peer reviewed journals with "shipping risk" in the titles, and between 2010-2020 there were 42,224. This stems from varying factors such as the increase of ships transiting waters, increase in ship size, and the increase of hazards due to both human and natural threats. In fact, Allianz (2021) reported over 26,000 shipping risk-related incidents in the last decade, with the majority of these being from cargo ships. Furthermore, the average size of container ships surged from 1,530 twenty-foot equivalent unit (teu) in 1968 to 24,000 teu in 2021 (Allianz, 2021). There is an array of risks abundant in the shipping industry which creates the need for effective risk management. These risks can be split into two separate groupings: risks *to* ships and risks *from* ships, which is relevant to this paper's findings (see Figure 2). There are many spectrums of marine shipping risk, but the scope of this paper aims at *environmental and safety risk.*

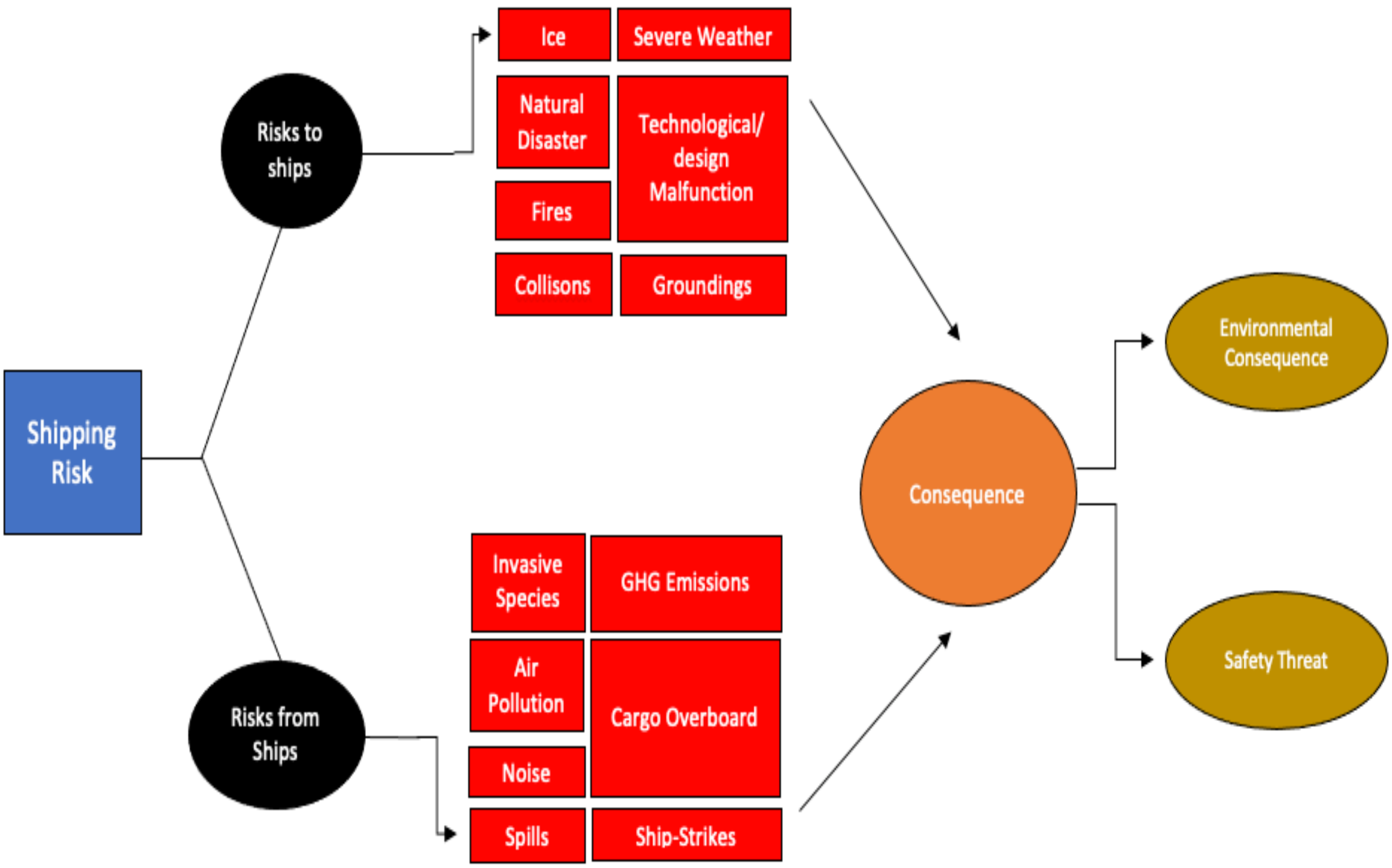

Figure 2. Threats and risks involved in the marine shipping industry and subsequent consequences with relevance to this paper.

Figure 2 demonstrates risks associated with the marine shipping industry, split between risks *to* ships and risks *from* ships. It is important to note that there are other risks involved with shipping, but these are the most prominent and relevant for this paper (Alexandridis et al., 2018). The risks to ships and risks from ships therefore produce undesired consequences, which will result in either an environmental consequence or a safety threat. The consequence of a risk is the outcome of something occurring, which in this case are the hazards (ISO, 2009). For example, a prominent risk from ship is oil and/or waste discharge spills, which will lead to a consequence (the outcome), which could be both environmental damage and safety threats to nearby communities. Figure 2 briefly demonstrates some of the risks and threats involved in the international marine shipping industry which is essential knowledge to further understand the proposed RFW.

3.2. Risk Matrices and Tolerance of Shipping

To understand risk management within the shipping sector, examining what makes a situation high risk, low risk, or somewhere in the middle is critical. There are obvious cognitive approaches to understand the difference between a high risk and low risk shipping operation. For example, an in-depth analysis does not need to be conducted to determine that traversing through an open-water hurricane in an oil tanker is higher risk than sailing through a seaway on a calm day in a pleasure craft with no hazardous substances on board. However, risk is not always such a clear distinction. Thus, a generic concept used in risk management is a risk matrix. Risk levels are a byproduct of the *likelihood* of a hazardous event occurring, and the severity of the *consequence* (Lauden, 1994). A risk matrix is a classic tool used to conduct semi-quantitative risk assessment, which measures the severity of consequence and its likelihood of occurring (Ni et al., 2010). This can be expressed in a graph which demonstrates how with increasing consequence and increasing likelihood, the level of risk rises (see Figure 3).

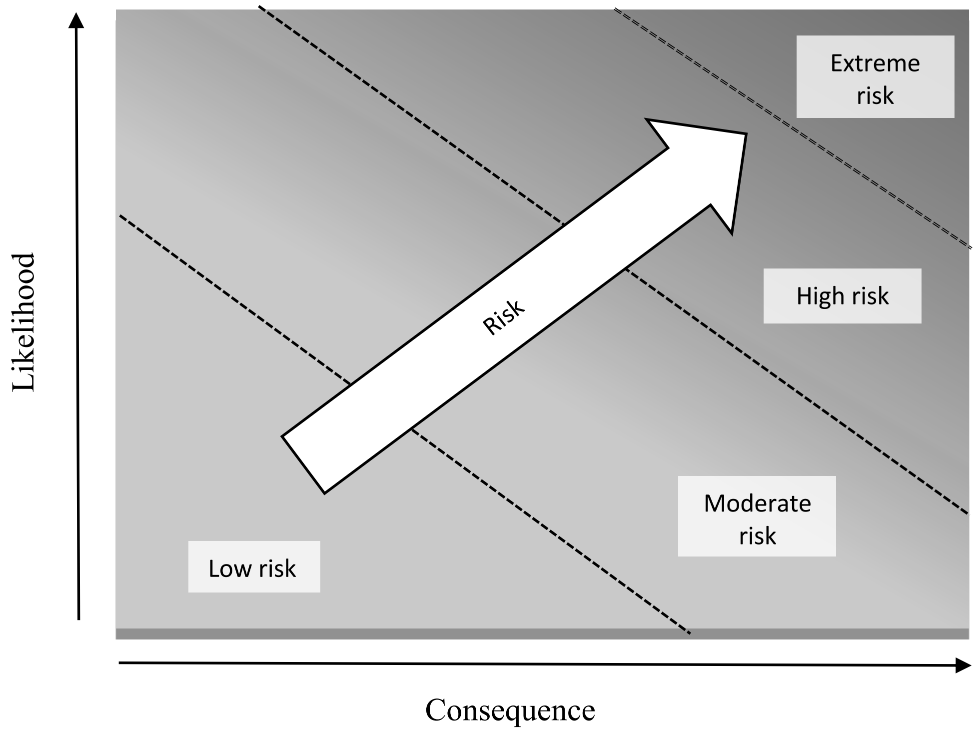

Figure 3. Basic Risk Matrix for Determining Risk level.

Figure 3 demonstrates how risky a situation is, depending on how high the likelihood of an event or consequence is. For example, if it has a very high likelihood and consequence, it will end up in the extreme risk quadrant, which should be avoided at all costs (Bouder et al., 2007). An important aspect that the risk matrix demonstrates is that just because something has an extremely high consequence or an extremely high likelihood, does not necessarily mean it is high risk. If we were to determine the amount of risk of a bulk carrier being knocked over by a small wave it would still be only a moderate risk. Although the consequences of this would be detrimental, the likelihood of this happening is so slim that it cannot be as high of a risk of something that is moderate-high level of consequence and moderate-high level of likelihood (Lauden, 1994). Generally, it is up to the decision makers to determine what is a tolerable amount of risk (ISO, 2018).

To relate this to a Canadian marine shipping context, the following figure will consider three shipping examples: a LNG carrier traversing through the remote Canadian Arctic in winter (labeled A), a ferry travelling from North Sydney, Nova Scotia to Newfoundland's west coast (labeled B), and a tug traveling across the Halifax harbor on a windless summer day (labeled C). Scenario A is generally high-risk due to increased hazards and increased consequences due to harsh environments and remote areas (Fu et al., 2021). Scenario B would be moderate risk due to a relatively high potential consequence (casualties of large amount of people), but low likelihood because of experienced mariners, large boat size, etc. Scenario C would be low risk due to the low likelihood of an event happening and the low consequence. As such, the risk matrix would look something like what is shown in Figure 4. This is a generic example for context based on guesswork, but a more quantitative example will be analyzed in subsection 3.3.

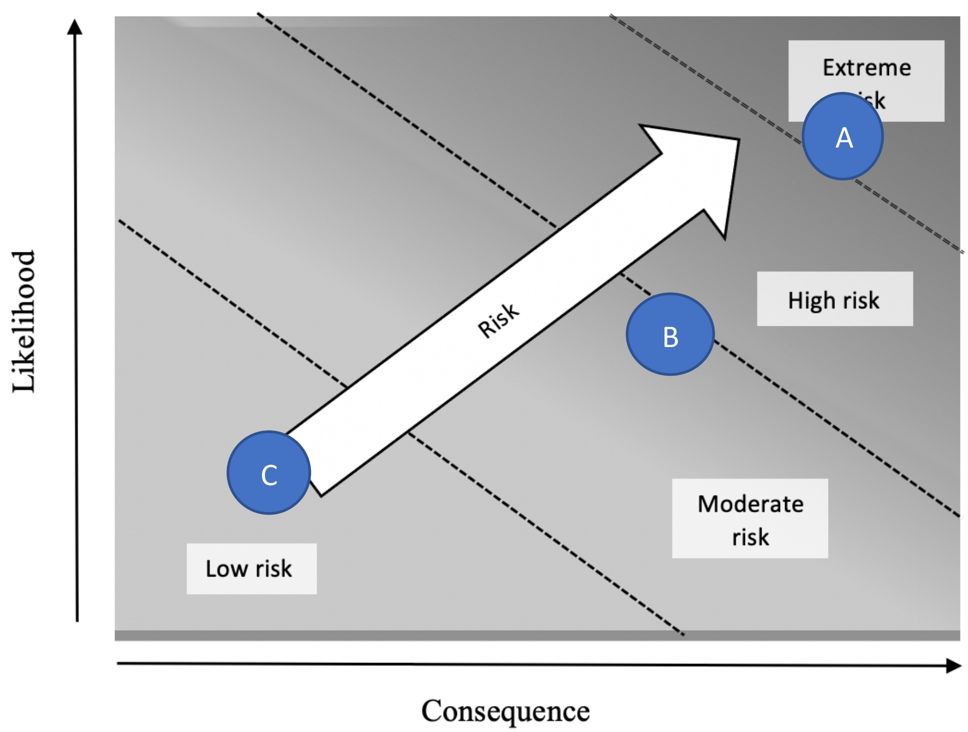

Figure 4. Risk Matrix of various shipping operations in Canada.

3.3 Shipping Risk(s) in Canadian Waters & Applied Risk Matrix

Understanding the general risk levels of shipping in the specific regions of Canada is fundamental for the RFW. Canada has the largest coastline in the world, resulting in varying levels of shipping risk depending on the marine region or subregion and the vessel type. Recall that the study areas for this paper focuses on four marine regions in Canada: the Atlantic, the Arctic, the Pacific, and St. Lawrence/Great Lakes. These four regions all undergo different levels of ship traffic and reported incidents. This can be calculated to a percentage that dictates the chance that one of these vessels was involved in an incident in each specific region, as demonstrated in Table 2. An incident will be defined as any shipping event that resulted in an environmental accident or safety accident.

Table 2. Number of vessels traveled in Canada compared to Number of Incidents between 2004-2014. Data from: (CCA, 2016).

Region	Number of Vessel Movements (2004-2013)	Number of Incidents	Percentage of vessels that experienced an incident(s)
Atlantic	114,543	113	0.098%
Arctic	3,607	37	1.026%
Pacific	380,472	456	0.122%
St. Lawrence/Great Lakes (SLGL)	206,235	1,055	0.512%

These numbers demonstrate that the regions with the highest number of vessel movement do not necessarily undergo the highest number of incidents. The Arctic only experienced 37 incidents, which is significantly lower than that of other regions. However, if is converted to a percentage, the result is that over 1% of vessels experienced an incident in the Arctic, which is much higher than other regions. These percentages show the likelihood that a vessel experienced an incident in its specific marine region. However, as discussed in section 3.2, risk level is dependent on both likelihood and consequence. ClearSeas (2016) examines how even though the Pacific experiences the highest levels of vessel movement, the nature of the cargo is low risk, making it relatively low risk. SLGL experiences a relatively high level of incidents, however most of the consequences are low impact due to being close to shore (CCA, 2016). The Atlantic region has the lowest percentage of ship incidents. However, the Atlantic region ships large amounts of crude oil compared to other regions, which increases the potential consequence of an event (CCA, 2016). Lastly, the Arctic is of highest risk due to the high likelihood (1.026%) and high consequences because of the remote region, severe cold, lack of search and rescue and environmental response, etc. (Chircop et al., 2020). Thus, if this were to be placed on a risk matrix it would appear as in Figure 5, where Atlantic resembles A, Arctic resembles B, Pacific resembles C, and SLGL resembles D.

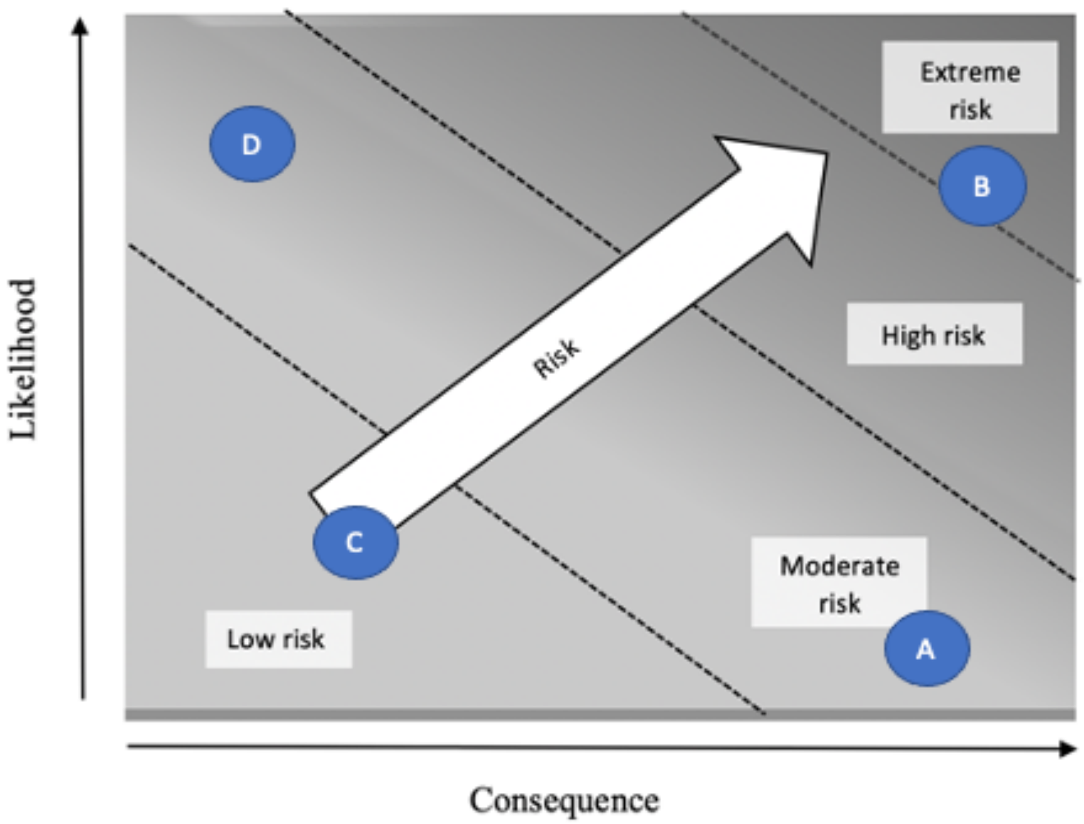

Figure 5. Risk Matrix of shipping risk levels per marine region in Canada.

The Atlantic region (A) experiences the lowest likelihood of an incident (0.098%), but due to high levels of crude oil being shipped and unforgiving weather conditions, the consequence is high. Thus, it falls under moderate risk. Although the Arctic (B) experiences low levels of ship traffic, the likelihood (1.026%) and consequence of an incident are both high resulting in high risk/extreme risk. The Pacific (C) has low incidents per capita and low consequence if an incident were to occur (relative to other regions), which places it in the low-risk category. Finally, SLGL (D) is somewhat opposite of the Atlantic. It has high likelihood of incident (0.5116%) (but not as high as the Arctic), but low consequence, resulting in moderate risk. Understanding the levels of risk in each region is important to understand aspects of the RFW.

3.4 Tools & Methods for Conducting Risk Management & Assessment

Risk management is now a common practice across various sectors and industries. Consequently, there is no "one size fits all" approach to conducting risk assessment or for a RFW because the needs, threats, demands, and requirements vary depending on what is being assessed. Nevertheless, there are common tools and models used to assess risk that can also be utilized in the Canadian shipping sector. These include, but are not limited to fault tree analysis, bowtie analysis, event trees, fishbone diagrams, and the previously discussed risk matrix. These all differ in structure but have the overarching goal of identifying the causes of the events, predicting the consequences that could happen from that event, and in some cases mitigation options (McNeil et al., 2015).

Although risk assessment is scenario specific, there are general guideline frameworks that are developed to align with multiple sectors. One of the most common and internationally recognized is the ISO 31000 risk management guideline. ISO 31000 provides principles, a framework, and process for assessing and managing risk, regardless of the size of the organization, activity, or sector (ISO, 2018). ISO 31000 manages risk based on the principles, framework, and process, outlined in Figure 6.

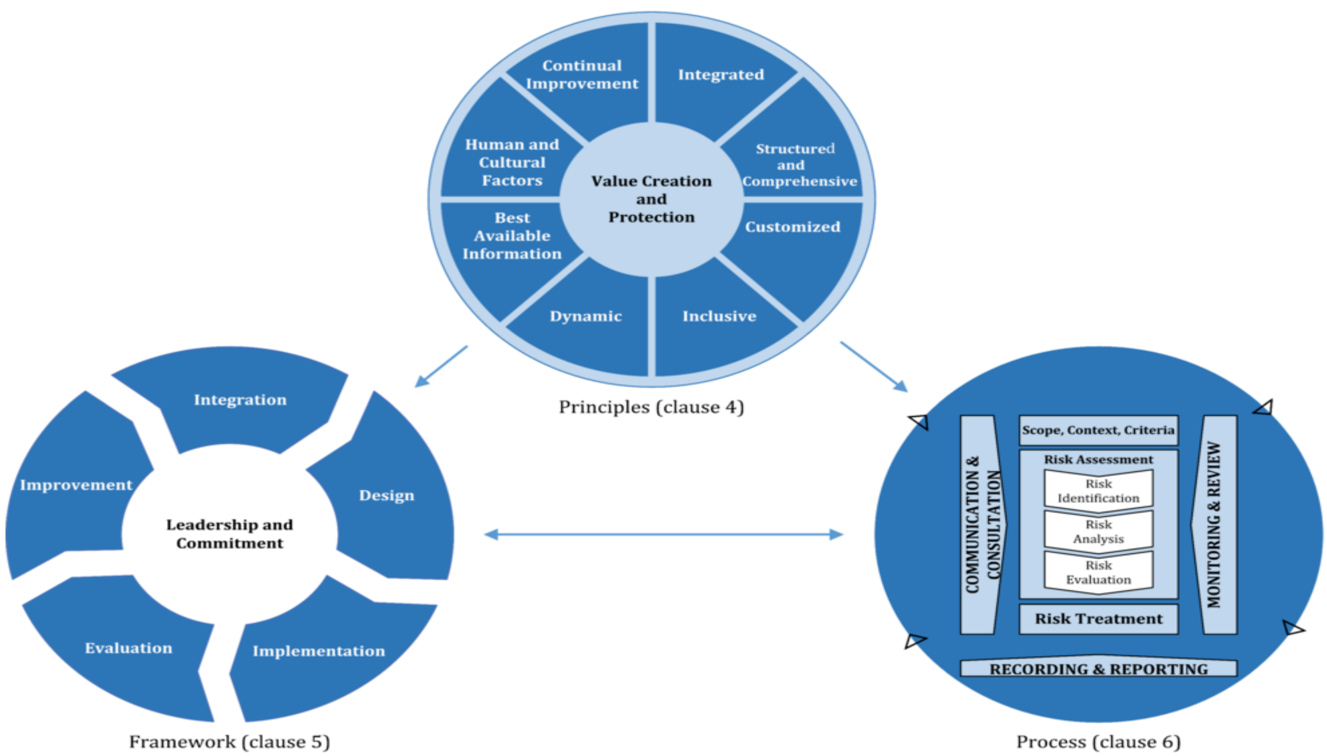

Figure 6. ISO 31000 Risk Management Guideline Overview. From (ISO, 2018)

ISO 31000 is split into three main pillars: framework, principles, and process. The *principles* pillar is used to analyze the underlying values and considerations in a risk assessment, the *framework* for assisting the organization in integrating risk management into functions, and the *process* comprises the steps to assess risk, act, and mitigate (Lalonde & Boiral, 2012). Brief background knowledge on ISO 31000 is critical because it will be used as the foundation for the proposed RFW in this paper, with emphasis on the process pillar as these are the steps to assessing risk which is relevant for the RFW. This paper's RFW will not be a replica of the process pillar, but will borrow its main theme(s), overarching steps, etc. The goal for this paper's RFW (compared to the overarching ISO 31000) is to create a more transparent, comprehensive, and cohesive process pillar that is designed specifically for the Canadian shipping industry. Furthermore, it will go more in-depth into critical steps and actions compared to the broad nature of ISO 31000.

3.5 Risk Inventory & Relevance to this Paper

A project that has been ongoing in Canada is a risk inventory project led by the Canadian Marine Shipping Risk Forum (ClearSeas, 2020). The inventory will eventually be a database that compiles the different people/groups and studies/projects related to shipping risk management in Canada. The main objective is to develop an open-ended inventory of people and studies in Canada involving shipping risk. An outcome of the inventory will show risk practitioners where there are gaps in risk studies/projects, where there are redundancies, etc. Consequently, the result of the inventory gives insights into what is best to include in the inventory. For example, areas where there are groups of risk or studies missing will be important to include.

To date, the inventory is still in its protype phase, but much of its results show that there are large research/project gaps in risk monitoring and communication & consultation processes, risks from fires, risks from remoteness, and SLGL risk initiatives. Therefore, the RFM is developed with these lacking initiatives in mind. Filling these gaps through risk practices in the RFM will thus be a desired outcome.

4. Literature Review on Marine Shipping Risk Sources & Frameworks

Publications on RFWs for certain sectors, shipping operations, and generic RFWs (such as ISO 31000) have been developed, but Canada still lacks an overarching RFW for the shipping industry. Frameworks are becoming common for specific industry sectors, such as the ISO 35101 designed for petroleum industries, emphasizing this research's importance (ISO, 2017). The following section will provide an in-depth literature review of the available research and findings on shipping RFWs that are currently published to date. It will do so by examining both peer-reviewed literature and grey literature (mainly NGO and government publications). Specific gaps, themes, recurring findings, pivotal publications etc., in the literature will be discussed. Furthermore, strengths and weaknesses of the existing literature will be noted. Finally, conclusions on the main takeaways and how this paper addresses gaps and contributes new knowledge for further research will be illustrated.

Recent publications focus on a few different trends and themes. First, the literature concentrates on risk assessments for specific vessel types, regions, or operations, rather than an overarching RFW for the entire industry (e.g., Goerlandt & Montewka, 2015; Montewka et al., 2014; EPPR, 2021). Second, there is an array of grey literature publications (primarily governmental) that provides frameworks for the broad spectrum of risk management, but few specifically geared towards Canada and the marine shipping industry (e.g., ISO, 2018; IMO, 2018). A RFW for a private investment firm may be very different than a preferred RFW for the shipping industry (with environment and safety as the main theme), so it is timely to develop more focused findings.

4.1 Literature Summary & Synthesis

In recent years, risk assessment has evolved from a practice primarily used in financial sectors, to a common practice in almost all industries. Consequently, published literature has been increasingly expanding. The period of 2012-2020 had a 76% increase of literature in risk compared to the 2005-2012 period. Within this field, RFWs and shipping risk studies have emerged. To date however, there is minimal literature published on a transparent RFW for the broad Canadian shipping sector, which is the gap in the literature that this paper seeks to fill.

4.1.1 2013-2014

A large theme in the literature is that maritime risk analysis applications and subsequent frameworks are only made for specific regions, and thus lack overarching RFWs. Ozbas (2013) examines the literature of maritime risk assessment, and one conclusion is that existing frameworks are location specific. As a result, the maritime analysis applications can't be used across a geographically broad spectrum. In 2014 and onwards, the literature development of frameworks to establish risk criteria in shipping became more common. The Canadian Arctic simultaneously experienced an influx of vessel traffic. Due to this, Khan et al. (2014) proposed a cause-consequence risk assessment framework for Arctic shipping to determine the likelihood and consequence, and therefore overall level of risk. Common factors included identifying the risk and measuring them on risk matrices. This paper does an effective job at framework creation; however, it lacks the Canadian context and transparency (or easy to perceive by average end-users). The same year Montewka et al. (2014) proposed a risk assessment process for maritime transportation systems. This publication takes a proactive approach to mitigating risk rather than a reactive approach that many frameworks at the time exhibited. This study is effective for quantifying vessel risk from a proactive point of view but does not offer a transparent step-by-step framework to feasibly follow.

4.1.2. 2015-2016

Neves et al. (2015) examined an oil spill RFW which adapts ISO 31000. The developed framework generated valuable techniques and transparency for those that aren't risk practitioners, similar to the goal of this paper. The study is closely related to the outcome of this paper but is specific to oil spills risks rather than the broad spectrum of risk and refers to an outdated ISO 31000 guideline for its framework. Goerlandt & Montewka (2015) published a journal article that somewhat builds on Montewka et al. (2014)'s research. It utilizes Bayesian Network modeling for risk quantification that is applied to a framework approach. Like Montewka et al.'s (2014) research, it is effective for quantification, but doesn't provide step-by-step approaches in the framework. The following year, Mehdi & Schroder-Hinrichs (2016) reviewed existing methods for a risk framework that can be applied to the shipping industry regarding its affiliation with offshore wind farms. The framework that was proposed provides organized flowcharts that explained risk assessment processes, but it is specific for offshore wind energy risk(s).

4.1.3. 2017

Shipping statistics suggest that between the years of 2014-2017, the amount of vessel movement around the globe was at all time high (IMO, 2021). As a result, ship collisions were occurring more frequently (IMO, 2018). Thus, an array of research was being conducted on how to best assess and mitigate these risks from the point of view of all vessel types. Chai et al. (2017) researches the risks of ships being involved in ship collisions and the level of risk based on likelihood and severity of consequence. The results of this study suggest that container ships, bulk carriers, and oil tankers are the three main ships involved in collisions, but passenger ships have high consequence for which a mathematically quantitative framework was developed. The framework is suitable for the specific circumstances of this study but focuses on just ship collision risks and lacks a Canadian context.

Climate change is always necessary to account for in shipping risk studies, due to its impact on natural ocean systems, natural hazards, weather events, ice density, etc. (Hardy, 2003). Hence, Lam & Lassa (2017) proposed risk assessment framework(s) for climate extremes and natural hazards to cargo and ports. The results demonstrated that there are policy and management gaps for multi-risk impact assessment on seaports and their cargo. To mitigate this, they proposed a RFW that analyzes vulnerabilities. The paper emphasizes how this framework is still lacking and that further research is needed. A Canadian context and transparency however lack in the framework approach for it to apply to this paper's proposed RFW.

4.1.4. 2018-2019

The IMO is the governing body for the international maritime industry and is responsible for setting global shipping mandates. The IMO formal safety assessment (FSA) (2018) is a systematic risk assessment procedure aimed at enhancing maritime safety, health, and the marine environment. IMO (2018) differs in nature from the previous literature because it is grey literature produced by an international government organization. The IMO FSA provides users with clear approaches to conducting risk process steps in an organized manner. What IMO FSA lacks is a Canadian context, and it is rather broad even though it is guided towards shipping. Similar to the IMO FSA in its structure and literature type is the OpenRisk guideline for regional risk management (Laine et al., 2018). OpenRisk identifies a lack of transparency in public risk assessments models and challenges of implementing RFWs at various governmental levels. Laine et al. (2018) provides a set of risk analysis tools to facilitate transparency. OpenRisk is superior for providing mariners with transparent risk analysis tools but is only applicable for oil spill response and focuses on European waters.

Also found in the grey literature, is the HAZARD seaport risk assessment toolbox (Bouraffa et al., 2019). The project revealed there is no standard RFW for seaport risk assessment. The results give end users a hybrid approach to conducting risk assessment. However, this study is specific to seaports and does not account for risk analysis of open sea shipping and climate change risk.

4.1.5. 2019-2021

A framework that addresses OpenRisk's lack of climate change risk to ships is Schmitz's (2019) literature review on shipping risk. It considers Canadian Arctic ice melt and has integration and comprehensiveness as a main focal point for the framework. Furthermore, the Government of Canada has acted upon climate changes impact to Canadian Arctic shipping and its subsequent increase with ice melt (Dawson et al., 2017). Recall from section 3.3 that Arctic shipping in Canada falls under the extreme risk quadrant. Therefore, the National Research Council of Canada (NRCC) created the Canadian Arctic Shipping Risk Assessment System (CASRAS) (NRCC, 2020). CASRAS is a useful tool, but it primarily provides marine users with physical applications to become aware of high-risk periods to transit a vessel, and not a RFW itself. Arctic RFW literature continued to increase as Arctic shipping became more prominent. To provide tools for decision-making, Browne et al. (2020) assembled a framework that builds on The Polar Operational Limit Assessment Risk Indexing System (POLARIS). The resulting framework supports voyage planning based on Arctic ice data in various regions.

Furthermore, specific guidelines for Arctic Marine Risk Assessment have been created for any SH's involved with strategies for minimizing shipping risk in the Arctic (EPPR, 2021).

4.1.6. Literature Evaluation

Throughout the literature, there is consistent evidence that there is a need for a RFW for the Canadian shipping industry. A significant amount of the literature provides readers either with quantifiable risk analysis methods, a platform that recommends best practices, or provides real-time updates on current shipping conditions. Furthermore, there is a lack of transparency in the RFWs, as most of the literature is made for experts in the field of risk. A select few have any form of Canadian context, and if they do, they are generally for specific regions and ship-types rather than the entirety of Canada. Furthermore, due to quickly changing hazards, shipping policies and regulations, an updated ISO 31000, etc., the older literature may not be relevant for current shipping operations.

4.2. Literature Analysis

Section 4.1 provided a summary of relevant literature from 2013-2021. It is important to note that not every applicable publication was included. Rather, the literature of most relevance to this paper's research objectives and RFW was summarized. Table 3 provides an overview of the literature on risk analysis and RFW related to Canadian marine shipping. The table demonstrates which literature relates to the RFW attributes in the context of this paper, the approach/methodology of the paper, followed by what the proposed RFW in this paper entails.

Table 3. An overview of the literature on risk analysis and RFW related to Canadian marine shipping and what this paper's RFW entails.

	RFM Attributes						**Approach/Methodology**			
Paper	Canadian Context	All Vessel Types	Transparent	Maritime Related	ISO 31000 Affiliation	Framework	Qualitative	Descriptive	Predictive	Prescriptive
Ozbas, B. (2013)		✓	✓	✓		✓	✓	✓		
Khan et al. (2014)	✓	✓		✓		✓	✓	✓	✓	
Montewka et al. (2014)				✓	✓			✓		✓
Neves et al. (2015)		✓	✓	✓	✓	✓	✓		✓	✓
Goerlandt & Montewka (2015)				✓		✓		✓	✓	
Mehdi & Schroder-Hinrichs (2016)		✓		✓		✓	✓	✓		
Chai et al. (2017)				✓				✓		✓
Lam & Lassa (2017)		✓		✓		✓		✓		✓
IMO (2018)		✓	✓	✓	✓	✓		✓		✓
Laine et al., 2018		✓	✓	✓	✓	✓		✓		✓
Schmitz (2019)	✓	✓		✓			✓			
Bouraffa et al. (2019)		✓	✓		✓			✓		✓
NRCC (2020)	✓	✓		✓					✓	
Browne et al. (2020)	✓	✓		✓			✓			
EPPR (2021)			✓					✓	✓	✓
Parviainen et al. (2021)		✓		✓	✓				✓	
This Paper	✓	✓	✓	✓	✓	✓	✓	✓		✓

There is an array of gaps and common themes throughout the literature. First, much of the literature is not specific to Canada, and if it is, the frameworks generally entail a specific marine region or operation. Second, there is a lack of transparency for end-users in the shipping industry to utilize some of the frameworks as they are designed for experts in the field of risk. Furthermore, few of the studies have the ISO 31000 guideline as a guiding foundation, which is the most widely recognized and accepted risk management guideline (ISO, 2018). The table above evidently demonstrates that this paper addresses these gaps, by focusing on a RFW that is specific to the Canadian context, includes all vessel types, is transparent for end-users, specific to the maritime sector, has ISO 31000 as a guiding foundation, and provides the risk management methods in a framework. Therefore, new knowledge is contributed. Table 3 also indicates that this paper uses qualitative, descriptive, and prescriptive approaches.

5.0 Proposed Risk Framework (Results)

The following section will examine the proposed RFW that could be considered for the Canadian marine shipping sector. These results are meant to inform policymakers, the shipping industry, government, etc., of a comprehensive RFW, with ISO 31000 being the guiding foundation. The components of the RFW will be analyzed as follows: SH consultation, scope context & criteria, risk assessment, risk identification, risk analysis, risk evaluation, risk treatment, risk communication, risk monitoring and evaluation, and finally a summary and figure of the proposed RFW.

As mentioned previously in the paper, the RFW primarily analyzes the steps to assess and act on shipping risk in Canada. Therefore, the risk process pillar of ISO 31000 will be the key focus (see Figure 7). With that said, the main components and themes of the principles and framework pillar are to be assumed to be relevant factors throughout the application of the process pillar. However, the scope of this paper only entails a transparent description of the steps to be taken for assessing shipping risk.

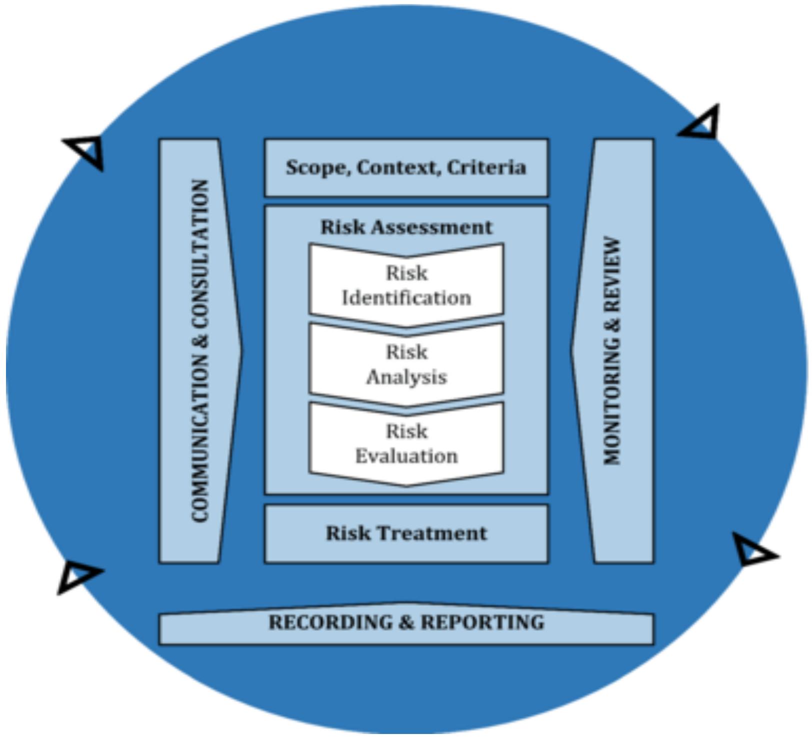

Figure 7. The Process pillar of ISO 31000. From (ISO, 2018).

5.1 Stakeholder Consultation

Engaging with SHs throughout the process is critical for a successful RFW in any sector. SHs are any individuals, groups, or organizations that are affected, involved, or interested by the outcome of a project or operation (Ehler & Douvere, 2009). For the purpose of this paper, the "project or operation" refers to impacts from shipping risks. The importance of SH engagement is accentuated in the shipping sector due to the complexity of spatial and temporal scales, the number of actors involved, a wide array of receptors, etc. (Walker et al., 2018). Although much of this RFW is sequential, SHs are to be consulted as key actors along every step. This may appear to be the first step of the RFW, but it is to be considered and implemented throughout the entire process. ISO (2018) describes risk consultation as the process of obtaining feedback and information to support decision making throughout the process, while understanding the risks. Risk consultation aims to bring expertise into the RFM, ensure different views are considered when evaluating shipping risks, to collect sufficient information to facilitate decision-making, and to build a sense of inclusiveness among those affected by shipping risk (IMO, 2018).

5.1.1 Typical SHs in the Canadian Marine Shipping Sector

Due to the economic, political, temporal, and spatial complexities of shipping in Canada, there can be a wide array of SHs involved. Furthermore, depending on the marine region, vessel type, and timelines there will likely be different SHs. Determining this inclusion criterion will be analyzed in the following section (scope, context & criteria). A comprehensive figure is shown that examines the broad range of SHs that may be involved for assessing risk in Canadian marine shipping operations (see Figure 8).

Figure 8. Various SHs in the Canadian Maritime Sector. Data From: (Ballantyne et al., 2013) & (Strandberg, 2013).

Figure 8 demonstrates some of the possible SHs that should be engaged with throughout the process. However, depending on the context of the shipping operation and evident risks, there may be more or less than what is shown. For the government SH, the main departments and agencies would be Transport Canada (TC), Department of Fisheries & Oceans (DFO), the Canadian Coast Guard (CCG), and Environment & Climate Change Canada (ECCC), as these are the primary overseers of marine related sectors. Furthermore, these departments will be multi-sectoral, which is important to consider when analyzing SHs. These SHs will have necessary connections and consultations among one another throughout the process as well. Some of these SHs will not always be relevant, but it is paramount that all consultations include Indigenous Peoples and nearby communities because they have significant socio-cultural rights that must be considered.

5.1.2 Maritime SH Analysis Process

It can be difficult to assess which SHs are needed for specific shipping risk consultations, due to the wide array of relevant actors that could be included. Therefore, conducting SH analysis can be a useful tool for determining who is best to consult with. SH analysis (in the terms of Canadian shipping) is the process and tools of identifying all SHs, grouping them accordingly to their level of participation, interest, and influence with shipping risks (the receptors, who is most vulnerable to consequences of shipping risk, who is best to consult with to mitigate, etc.) and determine how to best communicate in each step of the RFW (Nguyen et al., 2020).

SH analysis has three fundamental steps that should be executed. First, a brainstorm of who the SHs are for the marine shipping risk (that is, those who affect or are affected by shipping risk). Second, organizing SHs on a rainbow diagram that demonstrates which groups are most affected by the shipping risk, and which groups have the stronger influence on shipping (i.e., affecting sector) is key. This provides valuable information on which SHs are of highest concern regarding the risk, and which SHs have the means of avoiding the risk occurrence to start with (Chevalier & Buckles, 2008). A prototype of what this may broadly look like is demonstrated below, but is important to keep in mind that it will look different depending on the shipping operation (see Figure 9). Third, understanding and communicating with the SHs, and those with high levels of affected and influence (affecting) is critical.

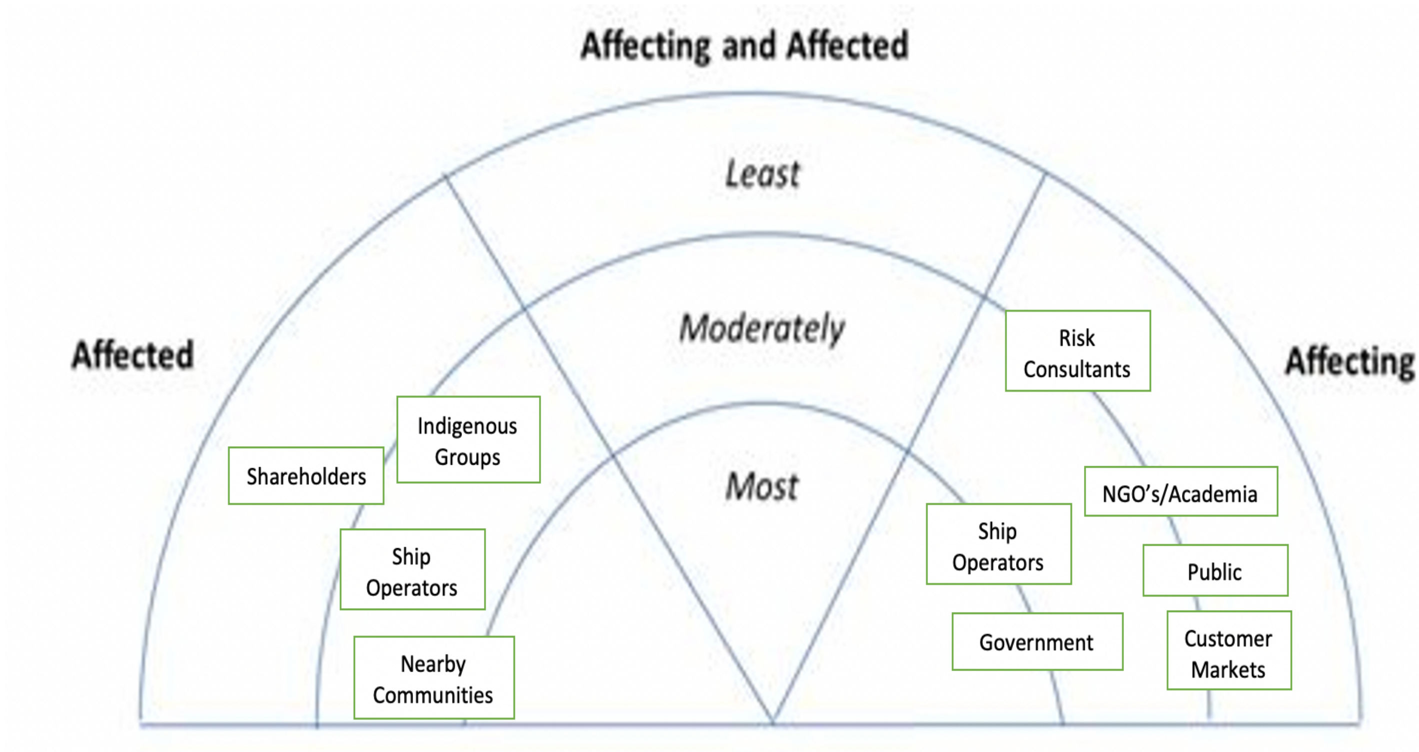

Figure 9. A general idea of where SHs may be place on a rainbow diagram for Canadian shipping risk impacts.

5.1.3 SH Communication Plan

How to communicate with SHs is another important aspect throughout the entire RFW. The SHs that are being consulted with and the specific stage of the RFW may change the steps, but a general best practice is to follow a communication plan. Communication plans typically entail the following: set communication objectives, identify the SH based on SH analysis rainbow diagram development, identify methods of consultation, determining the frequency of communication, and determining who provides consultation updates between SHs (Lucid Content Team, 2021). When building local SH involvement, it is important to consider an engagement process that considers the cultural, scientific, economic, and political contexts that support SH participation (Winther et al., 2020). This method is just a guideline, and individual Canadian shipping risk SH meetings should be conducted on specific SH needs and issues. Thus, communication plans may vary widely. Regardless of the communication plan, SHs nonetheless should be consulted throughout the entire process of the RFW.

5.2 Scope, Context, & Criteria

It is important to establish the scope, context, and criteria of the specific shipping operation, which provides a background for appropriate assessment in further steps. This step includes defining the scope and understanding both internal and external contexts that may be factors for higher or lower risk levels (ISO, 2018). For this context, criteria are the set of guidelines and organizational procedures of a shipping operation. For the context of Canadian shipping risk, this can include anything from vessel type, age of vessel, geographic region, etc. Analyzing shipping risk criteria is a beginning stage in this RFW but should be continually reviewed and reconsidered if necessary, and it can be both tangible and intangible. Shipping risk scope, context & criteria will be examined in the following subsections, with explanatory processes of why it is relevant for the RFW, and some examples.

5.2.1 Scope of the Shipping Operation

It is critical to understand the scope of the specific shipping operation being examined in the RFW. It generally includes goals, the deliverables (the tangibles or intangible goods that will ultimately be produced by the successful completion of the shipping operation), tasks, shipping costs, and shipping timelines, and available risk assessment tools and techniques (Ajmal et al., 2019; ISO, 2018). If the shipping operation is effectively scoped in this stage of the RFW it helps SHs understand the nature of relevant and evolving risks and what might be affected. The scope should be documented into a scope statement to best understand boundaries and procedures.

To provide reference, an example of the shipping operations possible scope of a Marine Atlantic Ferry from North Sydney, Nova Scotia, to Port aux Basque, Newfoundland & Labrador will be analyzed (see Figure 10).

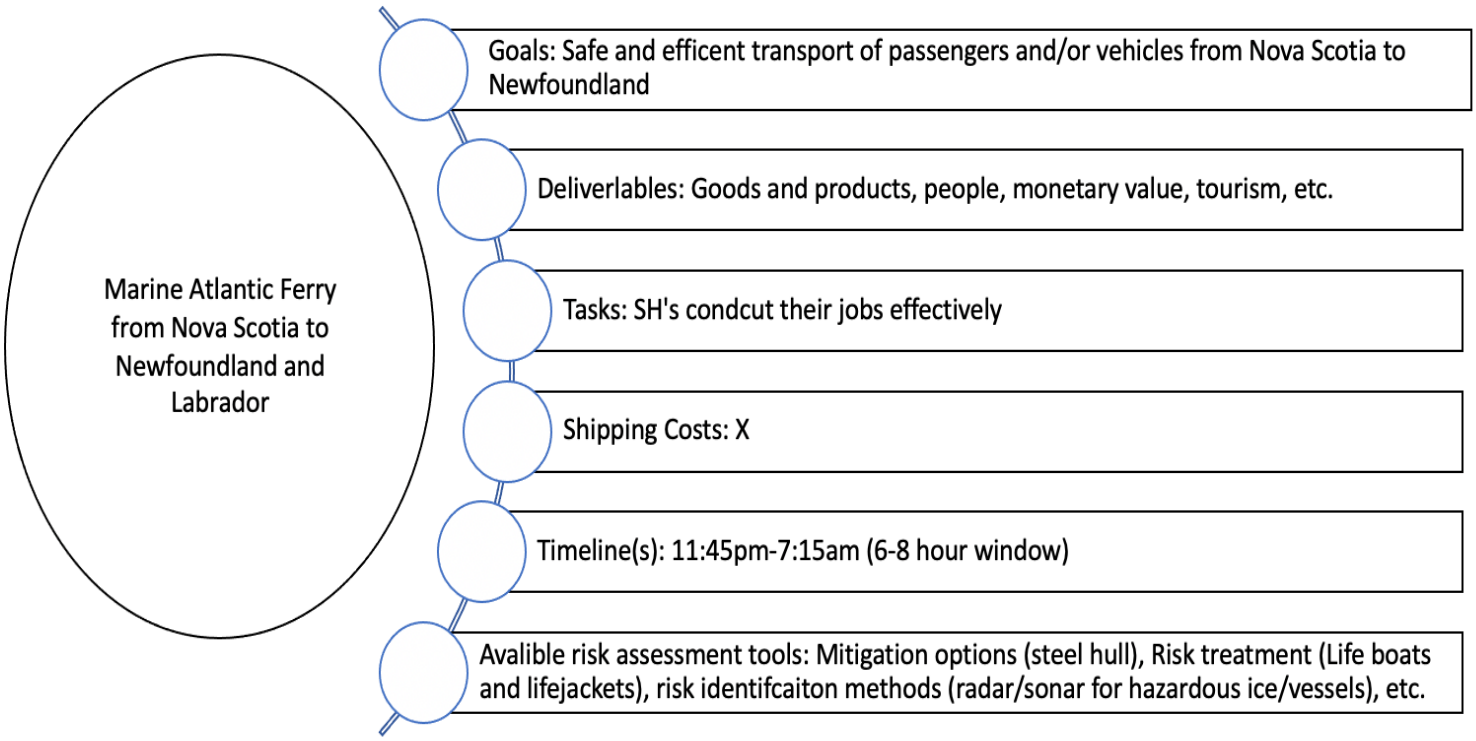

Figure 10. Scope of Marne Atlantic Ferry Shipping Operation(s).

Some of the scope information provided above is speculative but provides an example on how to base the scope. This is an important step because scoping the shipping operation provides a background on the nature of the risks and variables involved with it.

5.2.2 Context of the Shipping Operation

It is important to provide context of both the physical and non-physical assets that are involved in the shipping operation. This provides information on what aspects of the RFW process should be emphasized more while conducting risk assessment. For example, ships with double hulls have two watertight layers on the bottoms of the vessel, providing it with more protection from physical hazards. The majority of ships in Canadian waters have double hulls (especially tankers), but there are still some non-tanker vessels that operate with single hulls (ClearSeas, 2019). As such, the context of a vessel operating with just a single hull should be noted.

There is an array of physical aspects that could be included in the context description, and it ultimately depends on the inherent features of the vessel operation.

Some physical aspects that should be considered are as follows: vessel type, fuel type, number of crew on board, geographic region and their ship lanes in which the vessel will be transiting, hull type, engineering features, what is being shipped (cargo, fuel, people, bulk ore, etc.), propeller type, anchor, type of bulkheads, technological features, engine type, ballast water system, exhaust pipe and its subsequent emissions, the environment, etc. (Jha, 2021). Providing context on these physical attributes helps identify possible risks that may occur in the vessel transit. For example, if you are aware the vessel uses hazardous fuel types, possible risk levels and consequences can be estimated prior to assessment.

Equally important are non-physical attributes such as policies, resources, regulations, temporal components, etc. As with the same as the physical components, it depends on the specifics of the vessel operations, but could include aspects as follows: policies such as the Canada Shipping Act 2001, SOLAS, Oceans Act, CEPA, MARPOL 73/78, marine liability act, Paris convention marine insurance act, etc., shipping timelines, intangible resources, etc.

5.2.3 Criteria of the Shipping Operation

The risk criteria component of this stage essentially provides an overview of the vessel and organization affiliated with the vessel (whether it is government, private firm's bulk carrier, etc.) and the amount of risk that will be deemed acceptable, based on organizational criteria. The risk criteria should reflect values and be consistent with risk management (ISO, 2018). This will vary, but all the criteria should align with Canadian laws and regulations such as environmental, safety, and security laws (Transport Canada, 2020). Specifically, these mandates should mirror part four (safety), six (incidents, accidents, and casualties), eight (pollution prevention and response) of the Canada Shipping Act 2001 (Government of Canada, 2021). Furthermore, risk criteria should match not only federal, but that of provincial and regional regulations. Uncertainties and shipping hazards and the shipping organizations capacity to govern risk should be considered (ISO, 2018). SH engagement is crucial for this step to gather the appropriate criteria that may impact or be impacted by shipping hazards.

5.3 Risk Assessment

Risk assessment is a rather flexible term, but Rousand (2013) describes it as the systematic processes, methods, and tools used to identify the causes of harmful events, to determine the consequence levels of these harmful events, and determine whether the risk is tolerable. These processes can vary depending on what sector risk assessment is being conducted in, and what type of risk (financial, environmental, security, etc.). For this RFW, risk assessment is thus the processes of identifying harmful events to and from vessels in Canadian waters, determining the severity of the risk (primarily to the environment and safety), and deciding if the shipping operation should commence with the known risks (risk tolerability). Risk assessment generally includes the steps of risk identification, risk analysis, and risk evaluation, therefore this RFW will follow these stages (with a focus on the Canadian shipping industry). SH engagement is critical throughout the risk assessment process and should use both best available information and further qualitative and quantitative research (IMO, 2018). The following subsections will break down the RFWs stages of risk identification in Canadian waters, risk analysis, and risk evaluation.

5.3.1 Risk Identification in Canadian Waters

In the maritime sector, risk identification is to find, recognize, and describes risk that might prevent safe and low-impact ship transits from occurring in Canadian waters (the overall goal) (IMO, 2018). While pursuing risk identification, it is critical that the most up-to-date information is used in identifying risks (Lam & Lassa, 2017). For example, using outdated ice charts for identifying areas of potential hazardous ice cover is unsuitable (Government of Canada, 2020). Factors that should be considered are as follows. First, sources of risk are to be identified, which will vary dramatically depending on the context of the vessel operation. This also aligns with identifying risk causes, which entails tangible and intangible events (see Table 4 for examples of tangible and intangible risk sources) such as technological failure or extreme weather. Second, changes in the context, such as a container ship that suddenly starts carrying hazardous substances instead of a normality of non-hazardous substances. Identifying unique vulnerabilities is also important, such as a port system being more susceptible to weather events compared to ports in well-protected inlets (Ducruet et al., 2010). Other factors such as tight deadlines of shipping operations, the general risk acceptability of those operating the vessel, etc., are key elements of the process. Without an effective risk identification stage in the RFW, the next stages are ineffective, making this step critical. Chapman (1998) argues that risk identification has the largest impact on the accuracy of risk assessment, regardless of the sector.

There are no set guidelines for risk identification methods (RIM), as certain RIMs may work better or worse depending on the scope, criteria, and context of the vessel operation. However, there are some best practices for RIMs to use including doing them, in the appropriate order. Figure 11 below proposes the stages that could be included in a best practice, followed by a description of the figure.

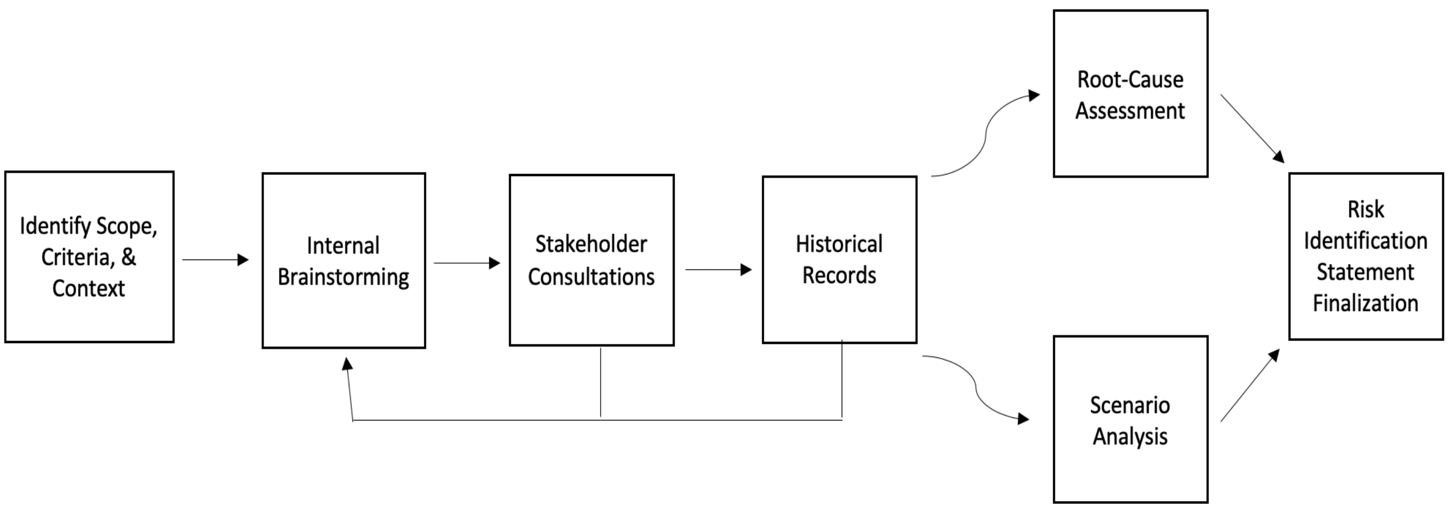

Figure 11. Proposed Risk Identification Methods & Process for Canadian Shipping.

It is first important to incorporate the scope, criteria, and context of the vessel operation to best identify relevant risks. Once this is done, an internal brainstorming exercise could be conducted. Brainstorming is not always the most effective method for identifying risk, but it is the most frequently utilized and is important for laying a base understanding of broad hazards (Chapman, 1998). Brainstorming is an effective method because it allows the internal organization to lay out risks from a broad spectrum (Kobo-Greenhut et al., 2019). For best results, brainstorming could be done in focus groups or breakout groups within the shipping organization.

Once internal brainstorming is conducted, consultations and interviews with SHs is key to fill in risks that may have been missed. SH consultation is arguably the most fundamental step in shipping risk identification because it allows a broad set of groups to identify risks. If it was just the one organization brainstorming, many risks would likely be excluded. For example, identifying all risks of a vessel transiting through Gwaii Haanas National Marine Conservation Area would be close to impossible without input from the local communities and Indigenous Peoples of the region (Parks Canada, 2021). Aside from the importance of SH consultation for its effectiveness, it is also the ethical course of action to include impacted communities, making it a win-win scenario. The risks identified in SH consultations should then be reincorporated back into the internal organization.

Next, it is important to inquire about historical records to determine the risks that were evident in the past, and which risks occurred the most. Canadian shipping incident historical records can be accessed in public databases, or by request of government agencies and/or NGOs (see Transport Canada, 2018; ClearSeas, 2021). There are advantages of utilizing historical records. It provides real data of past incidents and the risk/hazards that were evident that initiated the incident. However, historical records have disadvantages, such as potential lack of detail, or the nature of the incidents changing in the present (Cavendish-Jones, 2021). This is important to keep in mind through the process. Next, partaking in root-cause assessment and scenario analysis could help provide an overview of all risks that may have been missed in previous steps. It is helpful for these to be conducted simultaneously, as they can give input to and from one another (Wang et al., 2021). Ultimately, a finalized statement of all identified risks for the vessel operation should be produced and kept on-hand for next stages of the RFW. This process will look different depending on the scenario but could be used as a base foundation and modified to meet end-user needs.

Risky events and sources of risk will depend on the specificity of the shipping operation, its location, temporal components, etc. However, some risk sources that are likely to be evident in the Canadian shipping sector are listed in Table 4 as both tangible and intangible (for the scope of this specific RFW) (WQIS, 2020).

Table 4. Comprehensive list of possible tangible and intangible risk/risk sources that could be evident in Canadian waters.

Tangible Risk Sources	Intangible Risk Sources
• Ice/Icebergs • Extreme weather • Technological failure/Design Malfunction • Fires/Explosion • Spills • Grounding • Collisions • Ship-Strikes • Engine/Propeller Noise • Hazardous Operating • Etc.	• Tight Shipping Deadlines • Mariner Exhaustion • Lack of Effective Regulations • Mariner Inexperience • Poor Safety Response • Etc.

5.3.2 Risk Analysis

Risk analysis is a crucial component within the broader risk assessment process. The step prior to this analyzed the importance of identifying risks that may appear in a vessel operation. The risk analysis steps build on risk identification by determining the significance, likelihood, consequence(s), and thus, overall level of risk of risk (Dunkelberger, 2021; IMO, 2018). Utilizing risk matrices (discussed in section 3.2) to determine the likelihood that an event occurs and the magnitude of the consequences if it does occur is a substantial portion of risk analysis. Furthermore, the level of detectability of a hazard can also make a shipping operation more or less risky. If a hazard can be detected, the threat can be avoided, eliminating an incident from occurring. Thus, level of shipping risk is based on the *likelihood of occurrence, severity of the consequence*, and *how detectable a risk is before it turns catastrophic* (Nguyen et al., 2019). Risk analysis should also determine how effective existing risk controls are based on the risk level. It is argued by Kulkarni et al. (2020) that risk analysis techniques for shipping accidents should be both qualitative and quantitative. The recommended process for risk analysis is shown below.

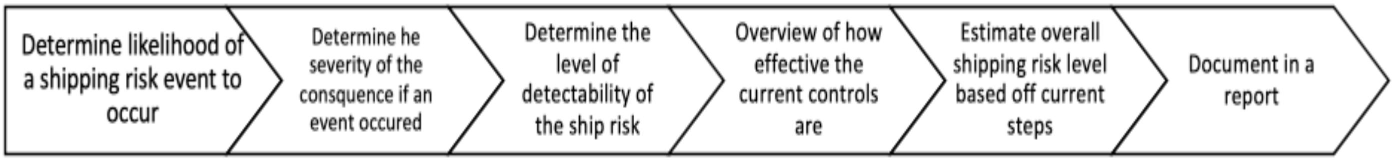

Figure 12. Recommended risk analysis process for determining level of shipping risk.

The first aspect that will be examined is how to determine the *likelihood of a risk event occurring*. To make transparent, we will use an example throughout this subsection of a ferry on the east coast of Canada hitting an iceberg. The first recommendation for determining likelihood of an event is to look at historic data (like that of the risk identification section) (Mentel & Brozyna, 2014). Historic data on shipping incidents provides real data that shows past incidents (recall section 3.3 where it analyzed incidents of ship accidents in the four Canadian marine regions). Analyzing documentation that government agencies have available to get quantifiable data of how many ferries on the east coast have contacted an iceberg gives a reliable statistic of the likelihood for it happening again. For example, if a ferry struck an iceberg 7 times in the past 30 years, and there are 200 transits a year, the quantifiable statistic is:

$$200\ x\ 30 = 6000 \text{ transits}$$

$$\frac{7}{6000} = 0.12\%$$

In our example, if (through historic data) the number of transits and times that a transit encountered an iceberg is known, it can be determined that there is a 0.12% chance the ferry will hit an iceberg. However, due to natural complexities, this number cannot be deemed as exact due to factors such as more icebergs in different seasons, different transit speeds, different ferry operators that have different levels of experience, etc. It nonetheless gives an approximate level of likelihood of the event to reoccur and could be utilized in Canadian shipping risk. It is urged for more data to be made public for mariners and risk practitioners so the RFW can be completed to its full capability.

The second method is through means of shipping science and technology. For example, radar and sonar, iceberg detection technologies, etc., reduce the likelihood of the ferry colliding with an iceberg. It is more difficult to derive an actual numerical statistic from these, but relative “higher risk or lower risk” can be determined depending on how many controls the vessel has in place. For example, a vessel with state-of-the-art technology and equipment for iceberg detection is relatively less likely to hit an iceberg compared to a vessel with none of these instruments in place. Third, the level of likelihood can be determined from common sense combined with SH consultation. This may not give quantifiable data, but likelihood of an event occurring can be determined largely from common sense mixed with SH opinion (Kaptein et al., 2007). For example, consulting with SHs and determining that transiting the ferry near a specific geographic region of ice (gathered from community SHs for example) will increase likelihood of an event. These are three methods for best practice, but there are dozens of ways to determine both qualitative and quantifiable likelihood data that could be considered.

The second aspect that will be examined is how to best calculate *consequence levels* of Canadian shipping risks. First, is relating back again to historic data. Historic data of shipping can show incidents that happened in the past and the severity that the event displayed, which provides an estimate of how severe the consequence could be (Lauden, 1994). Sticking with our example of a ferry striking an iceberg on the east coast of Canada, it is recommended to see what the consequences of the incidents were in the past. It can then be assumed it will be a similar outcome. Furthermore, using tools such as fishbone diagrams and event trees can help determine the possible end outcomes of a shipping incident, from the source (or cause) to the end event and subsequent consequence (Ilie & Ciocoiu, 2010). Consulting with SHs to determine consequence levels is critical. This is because what might be a minor consequence to one SH group, could be severe to another. Thus, adapting methods to average out consequence levels based on SH input is key. Finally, expert advice on consequence levels is recommended. For example, if advice on the consequence level of a spill in the Canadian Arctic is being pursued, consulting with an Arctic and oil spill specialist is more beneficial than consulting with someone who is not familiar with that particular context (ISO, 2018).

The third aspect that will be examined is how to best calculate the *detectability of the risk*. The detectability of the risk means the vessel's and the operator's capability of detecting a risk before it becomes an event, or before it reaches maximum consequence (DuHadway et al., 2019). Sticking with the ferry and the iceberg example, it would be the tools, equipment, technology, training, etc., that is available to detect the risk. For example, a ferry with first-rate iceberg detection methods will lead to less overall risk compared to a ferry vessel that lacks these assets. Determining detectability methods are relatively clear. The more tools and capabilities the vessel has for detecting risk, the better the detectability (Thamhain, 2013).

The fourth and final aspect that should be analyzed is *the effectiveness of existing controls.* Controls are essentially the means available to control the level of risk. In other words, it is the available assets that a shipping vessel must have to lessen the likelihood of an event occurring and lessen the severity of the consequence (IMO, 2018). This is also an aspect that is looked at in the next section (risk evaluation), but a preliminary analysis should be conducted to first understand the level of risk. The best methods for calculating this is to determine both the controls in place that prevent the risk from occurring, and to mitigate the risk if it does occur so its severity is reduced (ISO, 2018). This will include both internal and external controls. Internal aspects include factors such as strength and newness of the vessel, technological enhancements, experienced crew, number of lifeboats on board, etc. External aspects include CCG environmental response capabilities, place of refuge regulations in the region, etc.

Once these four aspects are analyzed, it is important to then estimate the level of risk. This can be done on risk matrices (explained in section 3.3), or through another quantifiable approach shown below (see Figure 13). The four aspects are shown in the shaded rectangles. Depending on how much risk is associated with each category, it could be ranked 3/3 for highest amount of risk or 0/3 for the lowest. By adding up the four fractions at the end, a fraction out of twelve will be presented. The outcome of that number determines the overall level of risk (mild, moderate, or extreme), which is demonstrated in Figure 13. This method is a modified method of semi-quantifiability derived from factor analysis used by Trost & Oberlender (2003) to determine estimates of project success. However, there are other forms of semi-quantifiability that could be utilized.

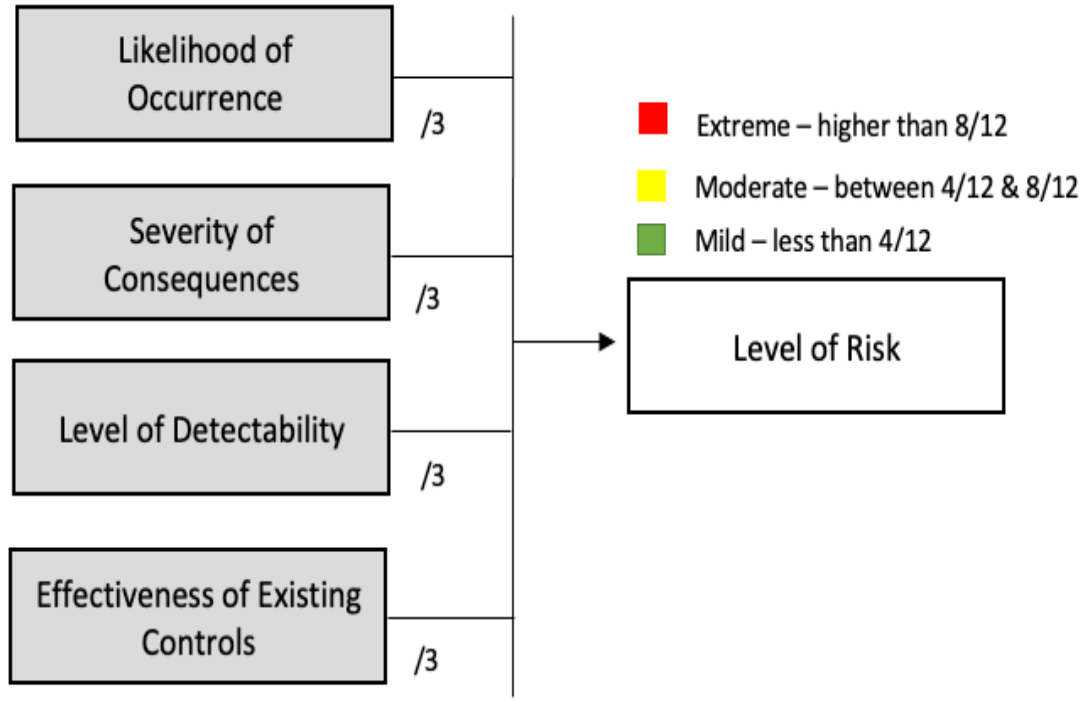

Figure 13. Proposed method for semi-quantifying the level of risk of a shipping operation.

5.3.3 Risk Evaluation

Risk evaluation is the final step of the risk assessment stage of the RFW. The overall purpose is to evaluate the level of shipping risk that was determined in the risk analysis to help guide further decisions (ISO, 2018). This step is not yet meant to address the mitigation of shipping risks, but to see where action is required. If the risk analysis proves that there is extremely low risk or extremely high risk, then there is not as much of a process as there is with questionable/moderate amounts of risk. It is a waste of time and resources to keep evaluating a shipping operation with negligible amounts of risk (as risks are always present). That being said, the appropriate risk mitigations (discussed more in the next section) are still to be enacted and monitored even with negligible risk levels (Mehdi & Schroder-Hinrichs, 2016). Conversely, evaluating a shipping operation that has an extreme level of risk is also a waste of time and resources, unsafe, and against Canadian shipping law in the Canada Shipping Act 2001 (Government of Canada, 2021). For example, it is pointless to keep revaluating a ship containing hazardous substances through a cyclone hundreds of kilometers off the coast of British Columbia with minimal control options, as there is simply too much risk. Thus, the shipping operation should be scrapped or seek alternative means/objectives. Figure 14 demonstrates a process for being presented with extremely high or low risk.

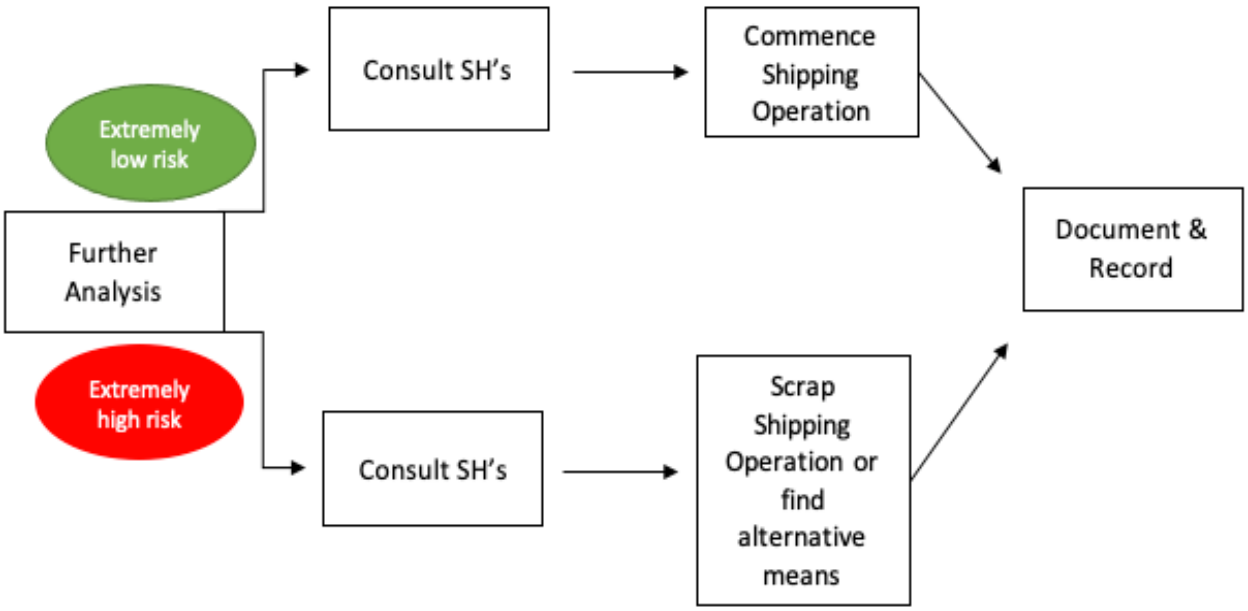

Figure 14. Recommended Risk Evaluation method in case of extremely low or high shipping risk.

For the scenarios where there are moderate amounts of shipping risk, the process will have to undergo further analysis. A fundamental step in risk evaluation is to account for the impacts that the consequences could have to receptors (the entities impacted by risk consequences) and SHs (ISO, 2018). Following steps similar to the risk identification process is recommended for identifying receptors. Key elements to look for are both the number of receptors impacted, and the significance of the receptor. Some receptors have high environmental, economic, or socio-cultural value (Valued Components), and thus should be seen as significant (Heij & Knapp, 2011). Consulting with SHs is critical for determining this. The receptors will widely differ depending on the specificity of the shipping operation.

Risk tolerance is important to evaluate in this step as well. Xi et al. (2021, 3) defines risk tolerance as "the amount of risk an individual is willing to assume in pursuit of a goal or objective". In terms of Canadian shipping, risk tolerance is thus the amount of risk a vessel operation (or the organization involved) is willing to accept. Risk tolerance generally should align with Canadian shipping laws (specifically the Canada Shipping Act 2001), SHs expectations, and the scope, criteria, and context of the shipping operation (refer to section 5.2) (ISO, 2018). These attributes and the amount/significance of the receptors will determine the amount of tolerability. Depending on the severity of the risk, the precautionary principle could also be used (Saltelli & Funtowicz, 2004). The precautionary principle is a principle for decision making under uncertainty when there is a weakly understood potential of harm (Nriagu, 2019). The precautionary principle is relevant in Canadian shipping as there are irreversible consequences that can derive from shipping risks. Thus, under large uncertainties with high levels of consequences, it could be considered. For example, if there are high levels of risk with the uncertainty of a shipping transit, the precautionary principle could be invoked.

Preliminary considerations of risk treatment options should begin to be made throughout the risk evaluation stage (ISO, 2018). Determining effective risk treatment options can be timely and complex, so assuming this during risk evaluation is valuable. If there are any misconceptions or confusion amongst SHs, further analysis should be conducted to better understand the risks and the risk levels (ISO, 2018). It is fundamental to document and record the outcomes of risk evaluation to later be used when assessing risk, as this is valuable information for shipping risk tolerance, SH considerations, etc.

5.4 Risk Treatment

The risk treatment stage of the proposed RFW is integral for successful risk management. The overall goal of the risk treatment stage is to determine and implement the best risk treatment options (RTOs) for minimizing the level of risk of the shipping operation in Canadian waters (ISO, 2018). It is the processes and actions that are needed to select options for shipping risk mitigation and can be both tangible and intangible mitigation methods (Puisa et al., 2021). There is no set definition or guiding structure of what mitigation methods to use for shipping risk in Canada, as this will vary depending on the risks involved, receptors, temporal and spatial factors, etc. The clear end objective however is to make the risk level less severe. It is a common practice to either accept, avoid, transfer, or reduce risk, although transfer is less likely to be used in terms of shipping risk (Long, 2017). There are best practices that should be followed which are specific for the Canadian shipping sector, that can be organized in a process for this RFW. This potential process is proposed in the following subsection.

5.4.1 Proposed Risk Treatment Process for Canadian Marine Shipping Risk(s)

There is a wide spectrum of context(s), risks and risk levels that are present in marine shipping, thus creating diverse options for risk treatment. A proposed transparent process can be used for a base guideline, demonstrated below (see Figure 15).

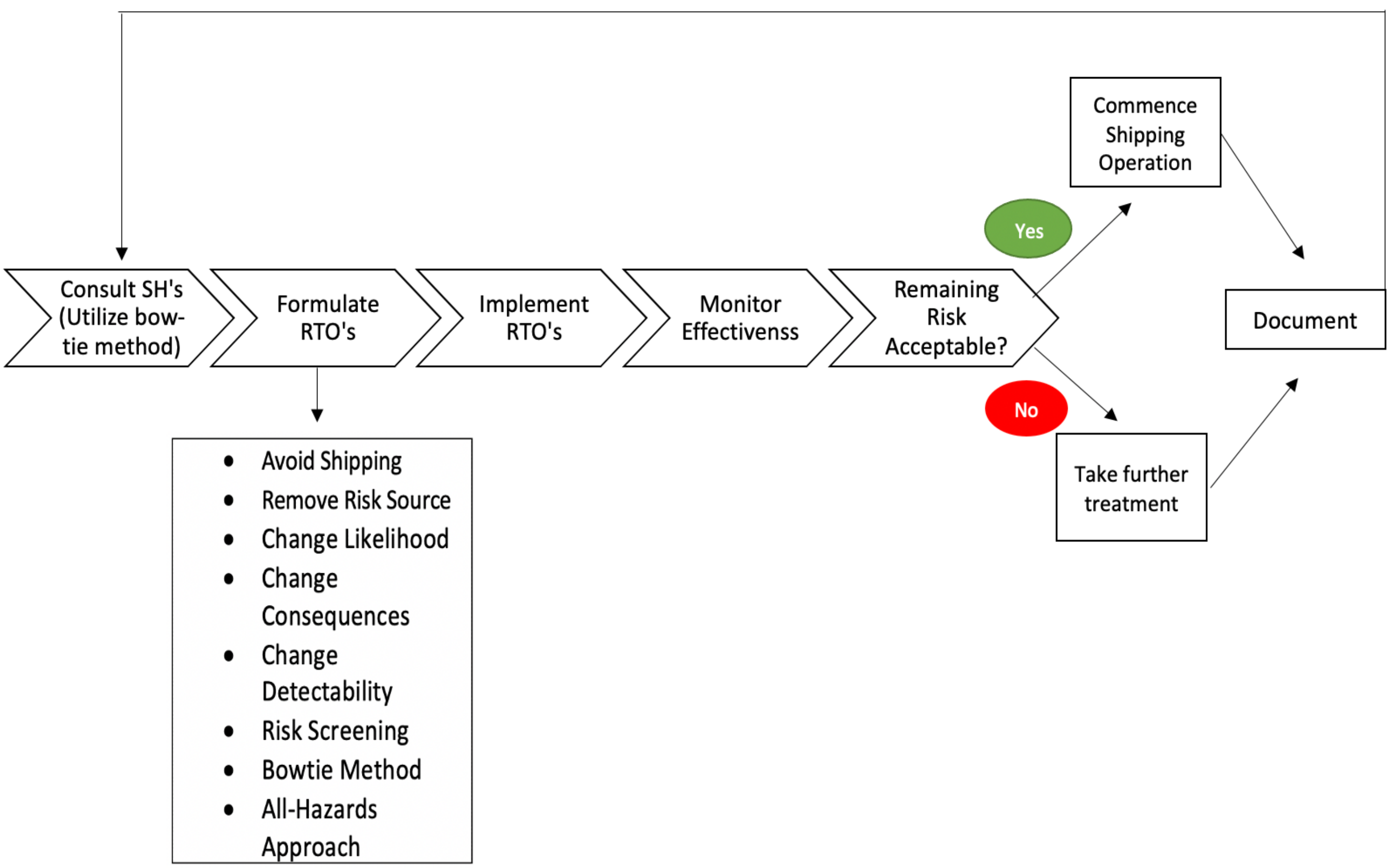

Figure 15. Proposed Risk Treatment Process for Canadian marine shipping risk(s) (based off ISO, 2018).

First and foremost, consulting with SHs on what was determined in the risk evaluation stage and the level of risk is paramount (Laine et al., 2021). Consulting with SHs to determine what possible risk treatment options (RTOs) are readily available and/or feasible to implement is key for formulating RTOs. For example, consulting with Canadian government agencies (TC, DFO, CCG, etc.) to determine what search and rescue or environmental response measures are in place, and their current effectiveness in the specific region would be useful. Utilizing bow-tie diagrams in SH meetings can be a useful tool for demonstrating the risks involved in a shipping operation and the risk control options already in place (which are often done in environmental and safety monitoring assessments) (Ferdous et al., 2013).

After gathering SH insight, formulating ideas of the best RTOs (or risk mitigation) is recommended. The RTOs should be developed in respect to the shipping organizations mandates, objectives, criteria, and the resources that are currently available, and could potentially be made available (ISO, 2018). RTOs can be both proactive mitigation methods, which prevent the hazardous event from happening in the first place, or conversely, reactive methods to lessen the severity of the consequences if a hazardous event were to take place (Elluru et al., 2019). Proactive and reactive can be both intangible and tangible. A combination of both proactive and reactive RTOs could be taken into consideration. However, depending on the consequence and likelihood levels of the shipping risk, one or the other could have more focus. Some examples of these for the Canadian shipping context is demonstrated in Table 5 but can include more than what is shown. Other RTOs can be avoiding the shipping operation altogether, increasing risk detectability methods, risk screening and removing the risk source itself. For example, if the risk level is high because of the utilization of heavy fuel oil, using a more environmentally friendly fuel source would be eliminating that source of risk. RTOs can also be an open-ended risk mitigation strategy rather than individual treatment options.

Table 5. Examples of proactive and reactive RTOs for Canadian shipping.

Proactive RTO’s	Reactive RTO’s
• Strengthened hull • Better ship design • Increased technology on board	• Effective environmental response • Effective search and rescue response

• Better shipping policies • Experienced crew members • Decreased ship-speed • Minimized crew exhaustion • Use of safer fuels • Avoiding storms and ice • Avoiding environmental sensitive areas (ESBA's) • Consistent ship inspection • Having quieter engines/machinery • Etc.	• Oil spill clean-up methods on board • Effective and well-practiced safety procedures • Amount and quality of lifeboats • Fire mitigation tools • Etc.

The next step is to implement the RTOs that have been identified and approved by SHs. Implementation of specific RTOs will likely depend on the financial resources and how much the organization is willing to spend on its implementation (Progoulaki & Theotokas, 2010). For example, a government research vessel may not get a brand-new hull designed and constructed just to undertake one transit, and this criterion will be case-by-case. The implementation stage should also contain documentation of how the RTOs will be implemented, and the resources needed for its implementation (ISO, 2018). Documentation for the organization and government/risk practitioner archives is important to determine the implementation processes.

It is then critical to monitor the effectiveness of how the implementation process went, if the SHs were impacted (positively or negatively), the financial compensations, etc. In some cases, implementing RTOs can create further risks (Long, 2017). After RTOs are implemented, it can be assumed that the overall level of shipping risk is reduced. From here, consulting with SHs and in the internal organization to determine if the risk level is acceptable or not should be performed. If it acceptable, the shipping operation(s) could proceed. If the organization perceives the risk is still unacceptable, more RTOs should be evaluated and applied. No matter which option is taken from this step, all processes should be documented and made readily available back to SHs.

5.4.2 Risk Screening & Awareness

A crucial aspect that should be accounted for in the risk mitigation process is understanding initial screening and prioritization of risks, and when to implement this.

Risk screening/prioritization is commonly used in the healthcare and medical fields as a means of prioritizing high-risk patients but can also be relevant for shipping risk. Ondrusek et al. (2015) describes it as the process of screening out (or prioritizing) high risk scenarios, in this case for proposing RTOs. It can be a waste of resources to develop RTOs for hazards that have such minimal risk levels. For example, a ship colliding with a log in the ocean is extremely low risk, so RTOs shouldn't be undertaken to address situations this innocuous.

Another aspect is the importance of SHs (primarily the ones directly involved with the RTOs; for example, CCG, shipbuilders/designers, DFO, TC, ship operators, etc.) to be made aware of RTO options that are in place. Shipping risks are best mitigated with SHs understanding roles and duties (IMO, 2018).

5.5 Risk Communication

The scope, context & criteria, risk assessment (risk identification, risk analysis and risk evaluation), and risk treatment are all sequential stages in the proposed RFW. On the contrary, SH consultation is an aspect that should be incorporated throughout its entirety. An attribute that should also be incorporated throughout all stages of the RFW is effective risk communication. Although ISO 31000 is the base foundation for this RFW, it fails to account for any methods of how and when risks should be communicated to and between SHs of Canadian shipping. Therefore, it is a beneficial element that will be included for the RFW. Broadly speaking, risk communication is the approach mechanisms and tools to communicate effectively with the public and SHs in times when risk is evident (Sandman, 1993). When threats from shipping hazards arise (for example, an oil spill), SHs may be faced with complex information about the risk that can be difficult to understand for those who are not an expert in the field of risk management. If risk is not communicated effectively with the public, it can spike large controversy and backlash. For example, Sandman (1993) examines how the risk of the Exxon Valdez oil spill was not communicated properly with the public, which created both physical and non-physical implications to the environment, economy, and societal impacts to the public. Furthermore, risk communication can be the means of reporting and communicating risks from one ship operator to another.

5.5.1 Goals and Principles for Communicating Shipping Risk(s)

The best way to communicate shipping risks to the public and SHs can be difficult to determine, as it relates directly to the level of risk. Three primary goals for communication are to increase SH understanding of the risks involved, inform appropriate action, and build credibility (Balog-Way & Besley, 2020). These goals stem from when a risk has already presented itself, and people must be made aware (for example, an oil spill in the Great Lakes). Guiding principles that should be utilized for communicating shipping risk are as follows: truthfulness, helpfulness, clarity, proactiveness, and increased availability (Sandman, 1993). These five principles are demonstrated in Table 6.

Table 6. Goals and Guiding principles for communicating shipping risks to SHs. Based on (Sandman, 1993).

	Truthfulness	**Helpfulness**	**Clarity**	**Proactiveness**	**Increased availability**
Description:	Tell the truth about the risk event at all costs.	Respond directly to SH's and be aware of concerns.	It is key to be transparent to who you are communicating with. Most people are not experts and should be communicated accordingly.	Be proactive with communicating the risk.	The organization(s) responsible should be available to those impacted both directly and indirectly.
Example: ***Oil Spill in Hudson Bay***	SHs should have exact quantities of oil, its consequences, up to date knowledge, etc.	Be helpful to those impacted by answering questions and providing oil spill resources and be sensitive to those impacted.	Use plain oil spill language to the people near the affected region and avoid using terms that will underexaggerate or exaggerate the risk.	Get other SHs to help explain the criteria of the spill.	Develop agencies that will have 24/7 support to those impacted from the spills for both tangible and intangible help.

It is critical to understand the audience that is being communicated to. For example, the way you communicate the risk event with shareholders of a shipping firm should differ from how you'd communicate with fishermen of a nearby town that is impacted. Furthermore, analyzing the most relevant and up-to-date knowledge and communicating this with the public is key.

5.5.2 Internal Risk Communication

Communicating risks as they appear to others involved in the shipping industry is critical to reduce the likelihood of a hazardous event occurring. For example, if a vessel passing through a shipping lane experiences hazardous ice levels that are not picked up on radar, this should be communicated to the government so they can spread communication about this hazard.

5.6. Monitoring and Evaluation

Monitoring and evaluation is a stage in risk management that is often overlooked (Filgueria, 2021). The purpose of monitoring and evaluation is to determine what has occurred as the shipping organization uses this RFW, and to evaluate what should have occurred. Ongoing review of the RFW and how it produces risk management outcomes should be a critical part of the RFW throughout its entirety (ISO, 2018). This should take into consideration what aspects of the RFW worked and monitoring the nature of the risks themselves and determine improvement methods and feedback. Shipping risks are erratic and can vary depending on environmental, economic, socio-cultural, and political factors. Thus, monitoring the RFW and adapting it in accordance with these changes is vital for contemporary RFW procedures.

Monitoring greatly depends on the objectives of the RFW, which is for vessels in Canada to operate with the least amount of environmental and safety risk involved as possible. Thus, the shipping operations themselves must be monitored to determine how successful the RFW is and if it should be modified for specific shipping objectives. One important way of monitoring risks is by measuring indicators within the RFW (M&E, 2017). An indicator is a tool, observable change or event that lets practitioners know whether the RFW is working or not (M&E, 2017). Indicators for RFW monitoring could be both quantitative and qualitative. For quantitative results, a shipping firm or overseeing government organization (likely TC) can quantify the amount of shipping risk incidents in a specific area before this RFW is used, and then again after it is utilized. If the RFW is effective, shipping incident occurrences and/or their consequences will decrease after the RFW is utilized. Qualitative indicators relate to the outcome of the RFW on ship-operator satisfaction and confidence while performing a vessel transit, shipping risk assessments being conducted with greater ease (due to the comprehensiveness and transparent nature of this RFW), etc.

Utilizing Global Affairs Canada's (2018) results-based management rubric can provide further insight into assessing the RFWs success for specific shipping operations. It is a model that focuses on achieving outcomes and incorporating options back into a project (in this case, the RWF) (Global Affairs Canada, 2018). The model for this is shown in Figure 16.

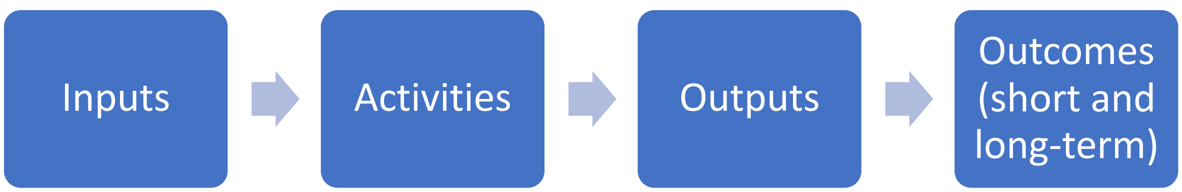

Figure 16. Results-based management rubric for determining the success of an initiative that could be utilized for RFW success on vessel operations. From (Global Affairs Canada, 2018).

Inputs are the resources used to produce an initiatives outcome, *activities* are the work performed to produce outputs, *outputs* are the direct products that stem from an organization, and the *outcomes* are the results of the initiative itself (Global Affairs Canada, 2018). For the context of Canadian shipping, the input would be the RFW itself, the activities would be the actions conducted by SHs to mitigate risks (such as vessel operators using sonar to avoid ice), outputs would be the products being shipped, and outcomes is how successful the vessel operation was. Adaptive management is defined as "a systematic process for continually improving management policies and practices by learning from the outcomes of operational programs" (Government of British Columbia, 2021). Adaptive management techniques should be put in place for how to best use the RFW or adapt the RFW for the specific vessel transit. Adaptive management is crucial for the RFWs success because iterating other risk management steps could work better in practice, which could thus be modified in the RFW. The end goal of this RFW is for safe vessel transiting, so it is encouraged to be modified to match the characteristics of a specific shipping operation if need be. Other monitoring techniques are encouraged for other stages of the RFW. Documenting and recording the processes, SH consultation, results, decisions, etc., are paramount for effective adaptive management into the RFW and for historical data to be used for future assessments (ISO, 2018).

5.7 The Collective RWF

This section aims to provide a summary of the RFW presented as one collective unit. The previous sections provided figures that analyzed the processes of how to best conduct the RFW stages in a comprehensive and transparent manner. This is helpful for demonstrating how the RFW guides the conduct of shipping risk assessment for its specific stages. However, a figure of the collective proposed RFW for the Canadian shipping sector is visualized in Figure 17. The RFW does not differ dramatically from the ISO 31000 process figure, as this is built from its foundation for transparency to the shipping sector, but it is nonetheless unique. The complete RFW is applied to a case study of a vessel operating in Canadian waters in Appendix 1 (see Appendix 1).

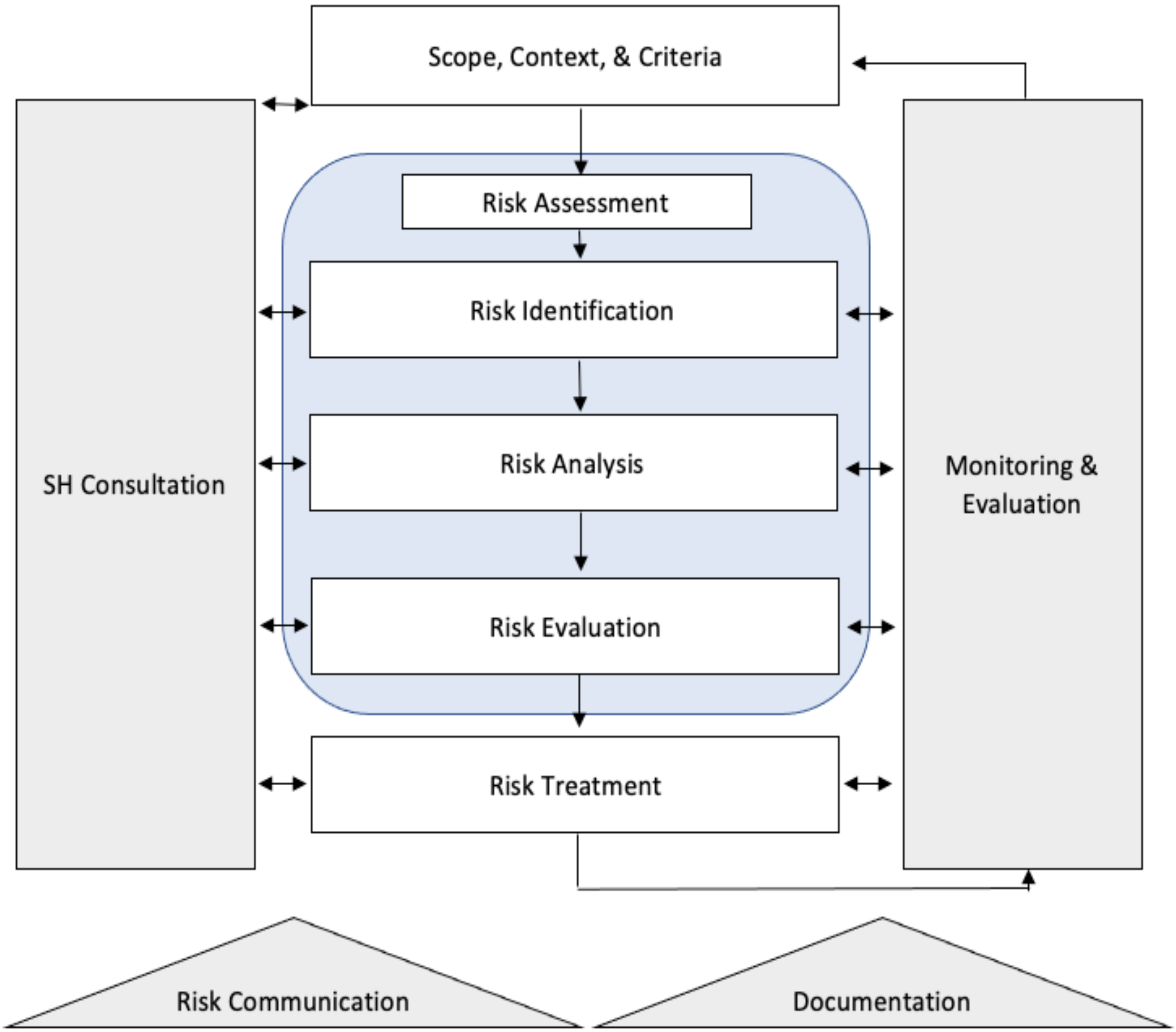

Figure 17. The proposed collective RFW for the Canadian marine shipping industry.

As an overview and recap of the RFW, the SH consultation stage should be conducted throughout the entire RFW. The most prominent SHs relevant to Canadian shipping risk are made evident, with SH analysis and communication plans made available. Following this are numerous sequential steps. Scope, context, and criteria examines background information on the shipping operation and the underlying tangible and intangible factors that should be considered prior to risk assessment. Following this is the risk assessment which involves the stages of shipping risk identification, analysis, and evaluation and determines the hazards evident to Canadian shipping, the level of risk based on various sub-factors, and how to evaluate this risk. Specific process recommendations are provided for how the RFW helps conduct these risk assessment processes in the context of Canadian marine shipping. Risk treatment is then examined which provides a process for how to best mitigate evident shipping risks, common RTOs in Canadian waters, and risk screening attributes. The sequential stages then end, and the RFW examines risk communication methods to SHs, which should be considered throughout the framework's entirety (which is lacking in ISO 31000 but is an important factor). Finally, monitoring and evaluation tools on how to incorporate adaptive management into the RFW are provided.

6.0 Discussion & Recommendations

The marine management problem that this paper is attempting to solve is the lack of a cohesive, comprehensive, and transparent RFW aimed specifically at the Canadian marine shipping industry. There is a range of risk assessment techniques for specific geographic regions and operations, but little evidence of an overarching RFW that explains the stages and best practices. Thus, the previous results section proposed a systematic RFW that could be followed for ship-operators, shipping firms, maritime managers, government policymakers, etc., who are not necessarily experts in the field of risk management. Many of the underlying attributes of the ISO 31000 risk management guideline are included in the RFW for a few reasons. ISO 31000 is the most widely recognized and accepted framework for completing risk assessments, so dramatically deviating from that could cause confusion and unfamiliarity to end-users (Leitch, 2010). The RFW investigates each process stage while elaborating on best practices and recommended sub-processes that could be used for the Canadian shipping sector in a comprehensive and transparent manner. Various process figures are analyzed throughout the proposed RFW to best demonstrate clear actions of the framework. Furthermore, an overarching figure that displays the entire RFW is provided to show a broad summary of the stages and how they interact with one another (which ones are sequential, which are to be applied throughout its entirety, etc.). The RFW figure looks like ISO 31000 as it is used for a foundation, but with certain modifications and adaptions. The end goal is to minimize environmental and safety risks in Canadian shipping operations, so adaptive management and modifications are recommended to be incorporated into the RFW where deemed necessary if it is beneficial to the specific transit.

The outcome of the results shows that a RFW specific to Canadian shipping is likely feasible with the current resources available and could be considered for implementation. The proposed framework borrows risk approaches, methods, data, etc., from other literature and government sources (both internationally and domestically) and applies original recommendations to Canadian shipping for a best practice approach to managing shipping risks. The significance of the RFW is that it creates a balance of an internationally recognized risk management guideline (ISO 31000), and applies it to shipping risk in Canada, with small-scale case studies throughout. The RFW is related to many of the themes and criteria found in the literature review sources, but with specific gaps that it seeks to fill.

The RFW could be beneficial to the Canadian shipping industry because it creates an easy-to-access and easy-to-use framework for measuring and assessing risks. Shipping risk is estimated to increase as human-induced factors (increased resource demand, growing population, human fatigue, etc.) and natural factors (increased storms and unpredictable ice concentrations from climate change, natural disasters, etc.) become more prominent in coming years (Eckhardt, 2020). Furthermore, the Canadian Arctic is experiencing an influx of vessel traffic in the past decade due to climate change induced accessibility, enhanced ship-design/technology, and emerging economic opportunities (Dawson et al., 2017). Current projections are that the Canadian Arctic will become readily available for marine shipping up to six months of the year in coming decades and year-round travel could be feasible by 2100 (Lu et al., 2014). Therefore, it can be assumed that vessel traffic in the Canadian Arctic will continue to increase. The Arctic is a high-risk shipping region due to harsh weather conditions, remoteness, and lack of readily available search and rescue/environmental response to the region. The Port of Vancouver experienced a total tonnage net increase of 5% just between the years of 2015-2017, with that number projected to increase in coming years (Port of Vancouver, 2017). Similarly, the Port of Montreal underwent a net increase of total tonnage of 15.9% between 2016-2019, and the Port of Halifax experienced a 13.2-15.6 % increase (Port of Montreal, 2021; Port of

Halifax, 2021). These statistics are to demonstrate that increased vessel traffic is occurring in all four marine regions of Canada, creating the vital need for a RFW. The proposed RFW is therefore a timely, relevant, and necessary contribution that can be utilized to minimize shipping risks.

The RFW agrees with previous research in this field as there are other proposed frameworks for other regions and vessel types (discussed in the literature review). However, the RFW does not quantify risk but provides insights and recommended guidelines based on literature review. The RFW generally supports existing theories on how to best conduct risk assessment. There are however significant additions and modifications to make it more focused on the research problem.

Despite the evident strengths of the RFW, there are limitations. First, the RFW is an effective means of demonstrating best practices and showing generic examples relevant to Canadian waters. However, the RFW does not provide an exact method on how to quantify the precise amount of risk for vessel operations. The RFW may provide guidance on how to best access data and other methods to determine quantifiability but it doesn't provide direct formulas and tools. This is not a crucial limitation however, because quantifying risk depends on specific criteria, whereas the RFW is meant to be from a broad spectrum. Second, due to the broad and comprehensive nature of the RFW, it may work more effectively for some vessel operations compared to others. It is yet to be determined if this is the case but could be a possibility. However, that is why the importance of utilizing adaptive management techniques for the specific vessel operation is emphasized in the monitoring and evaluation stage. Third, maritime policy and regulations are changed frequently in Canada. In fact, ClearSeas (2021) analyzes over one hundred shipping acts and conventions that Canada is currently committed to. Therefore, if a policy is changed that interferes with the feasibility of something in the RFW, this will have to be continuously updated. It is also possible that some of these processes look better on paper and aren't as feasible in practice. Most of the findings are derived from reliable sources, making this unlikely, but is a possibility.

There are also limitations that could be derived from the methodology. Gathering data from primary sources could have provided valid real-time data as opposed to relying on secondary source data. However, the strengths of utilizing secondary sources by looking at broader data, already derived primary data, etc., outweigh the limitations. The Canadian marine shipping sector is a large sector, creating vast numbers of SHs. Thus, gathering primary source data from all relevant SHs was outside the scope and feasibility of this paper.

This paper creates opportunities for further research into how RFWs should be best developed for Canadian shipping risks. Furthermore, this RFW allows researchers, risk consultants, and other relevant participants to build further in-depth research from each stage of the proposed RFW. With something as complex and broad as shipping risk, specific papers and studies could be allocated to each stage of the RFW with context to Canadian shipping. Additional research is required to determine how the RFW can be modified if shipping policies are implemented. Furthermore, research on how to best incorporate quantifiable risk tools into the RFW is recommended.

7.0 Conclusion

Risk management is a continuously growing field as it becomes incorporated into further sectors, regions, and policies. Risks are inevitably present in day-to-day life but are becoming increasingly prevalent in marine shipping. Fully eliminating risk in the Canadian shipping sector is an unrealistic goal due to the changing nature of risk and its unavoidability. That said, there can be frameworks developed to best detect, manage, and mitigate the risks, which is sometimes overlooked in policy and regulation. As Smith & Fischbaker (2009, 2) put it, "many emergent forms of risk often do not yield to conventional forms of risk assessment and management or indeed to conventional polices at a government level". This can be said for the Canadian shipping industry, as there is still a lack of a cohesive and transparent RFW that can be relied upon for managing the sectors growing risk. Transiting a vessel across any waterway comes with its abundance of risk to begin with, but this is ever-growing as population increases, vessels become larger, climate change impacts become more prominent, etc. From a capitalistic and societal perspective, the transport of goods across Canada's waters has only benefits for people and the economy. However, from an environmental and safety risk perspective, these factors contribute more risk which must be mitigated.

This paper aimed to identify a transparent, cohesive, and comprehensive RFW that could be used in the Canadian shipping sector. Furthermore, its goal was to have a foundation based off the ISO 31000 risk management guideline, as it is an internationally accepted guideline for managing risk. There are many toolboxes and methods for analyzing shipping risk in specific Canadian regions and projects, but little research on a broad framework for Canada. Based on a qualitative analysis of secondary source information regarding risk analysis methods, Canadian shipping risks, and other management techniques, the results provide the readers with a proposed RFW. The RFW itself could use further research to help guide best practices in certain stages but is a feasible base framework.

Rather than focusing on human participants for the results, analyzing secondary source data on risk assessment methods and policies that are already in place in Canada that could be applicable to the RFW was conducted. Much of the final RFW is similar in structure to the ISO 31000 process for the steps of analyzing risk. However, there are critical additions that are built on within each stage, and more stages added where deemed necessary such as risk communication. The final RFW begins with identifying the scope and context of the shipping operation, which then leads into the three stages of assessing the risk: identification, analysis, and evaluation in a comprehensive sequential format. Next, risk treatment options were proposed on how to best mitigate present shipping risks. SH consultation, monitoring and evaluating, risk communication, and documentation are all attributes that are to be incorporated throughout the RFW. The RFW clearly illustrates its potential contributions to Canadian shipping risk, but also raises the question of how to quantify the risks and how to adaptively manage the RFW.

Based on the conclusions, policymakers, managers, risk practitioners, etc., should consider incorporating an RFW into broad shipping mandates. To better understand the implications of a proposed RFW, future studies could address specifics of how to expand the framework into a completely feasible guideline. Furthermore, future studies could address how RFWs can be applied for specific hazards and risks in Canadian shipping. This paper helps solve the management problem of how the cohesive Canadian shipping sector can evaluate risk and assess risk into a simplified RFW. The literature review pointed out that there are a variety of gaps in the research, such as a lack of Canadian context, transparency, and ISO 31000 foundation support. The RFW addresses these evident gaps and makes room for further research and implementation.

It is unreasonable to set end goals and objectives around fully eliminating shipping risk in Canada, as risk is inevitable. However, having effective frameworks in place and up-to-date risk management practices/policies to identify, analyze the level, and treat the risk could help guide Canada to be a leader in marine shipping sustainability and risk control. With practical RFWs in place, Canada has a better chance at mitigating risks in an indispensable sector such as marine shipping.

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Appendix 1: RFW Case Study

Throughout this paper, numerous case examples were utilized to illustrate specific shipping operations at the various subsections of the RFW. The purpose of this Appendix is to provide a case study for a Canadian vessel operation, and work through the entire RFW specific to this one case. Doing so will help provide a clear example of how a vessel operation and organization would use the RFW in its entirety. The example that will be used is a resupply vessel on Canada's Atlantic coast that brings routine resupplies to and from Hibernia oil platform 315km off the coast of St. John's, Newfoundland & Labrador (Offshore Technology, 2021). It is important to note that all the information listed in the case may not be fully accurate but is discussed in terms of best available information at the time of writing.

Determining the relevant SHs that are involved with a resupply vessel to Hibernia oil platform (typically referred to as a platform supply vessel, or a PSV) is the first step of the RFW (refer to section 5.0). First, a brainstorming session of all SHs is to be conducted. The SHs would include (but may not be limited to), nearby Newfoundland communities from which the PSV departs from, NGOs affiliated with safe oil and gas shipping, Indigenous communities, Natural Resources Canada, CCG, TC, DFO, vessels owners and operators (generally run by Suncor Energy) (Tomic, 2020), Newfoundland port terminals and the operators, the crew members on board the PSV and Hibernia oil platform, shareholders, and emergency responders. Second, utilizing methods such as a rainbow diagram to demonstrate the affected SHs and the affecting is crucial (see section 5.1.2). The SHs that would be impacted from shipping risks would include the nearby Newfoundland communities, Indigenous Peoples, the port and vessel operators, crew members and shareholders. Conversely, the impacting SHs (the SHs who have stake in preventing risk consequence) would be the Suncor PSV operators, government, NGOs, etc. Determining how to best communicate with these SHs, creating communication plans based on objectives, and communicating with the SHs throughout the entirety of the RFW is a best practice.

The next stage is to determine the scope, context, and criteria of the PSV resupply to Hibernia platform, which is the first of the sequential steps of the RFW. First, the scope will be analyzed, as follows:

- The goals of the PSV resupply: for the physical supply needed for Hibernia's operations to be transported safely and efficiently to Hibernia and back.
- The deliverables: The physical goods being shipped, such as food, machinery, cleaning supplies, and all other assets needed for Hibernia's operations.
- The tasks: For the PSV operators, port workers, Hibernia platform crew members, etc., to conduct their jobs effectively for successful vessel transit.
- Shipping costs: Depends on weather conditions and current gas prices at the time for which the RFW is applied.
- Available risk assessment tools: Double hulls, lifeboats, risk detectability methods such as technologies for identifying risk, etc.

Next is to identify the context of the PSV resupply operation, in terms of both physical and nonphysical attributes. Both physical and nonphysical attributes of the PSV operation are presented in Table 7. It is important to note that much of this could vary on a case-by-case scenario, but these would be the general attributes.

Table 7. Physical and Non-Physical context attributes for a PSV operation to the Hibernia oil platform.

Physical Attributes	**Non-Physical Attributes (Natural Resources Canada, 2016)**
• PSV vessel (generally 50-100 meters in length) • Liquefied Natural Gas (LNG) • Double steel hull • 4 blade propellers • Diesel engine(s) • Extensive technological feature • The physical supply being shipped • The waterway being transited (The Grand Banks Basin off Newfoundland's East coast) • etc.	• The Canadian Shipping Act • Marine Liability Act • The Canadian Petroleum Resources Act • The Canada Oil and Gas Operations Act • The Canada-Newfoundland Atlantic Accord Implementation Act • The Accord Acts • Crew health • etc.

The relevant criteria of the PSV operation would match those of the organizations/companies' values and will align with Canadian regulations that were identified in Table 7. The main organizations are ExxonMobil, Suncor Energy, Canada Hibernia Holding Corporation, Murphy Oil, Equinor Canada Ltd, etc. (Hibernia, 2021). Determining these organizations values, risk tolerance, and other mandates and assuring that they align with Canadian laws and regulations is key.

Following this step, is the risk assessment stage which includes *risk identification, risk analysis, and risk evaluation*. For these sections, this case study will work through the flow diagrams found in section 5.3 that demonstrate the processes in these stages. First, risk identification will be analyzed in bullet points for each step of the flow diagram (refer to Figure 11).

- Step one: Identify scope, criteria, and context which was done previously.
- Step two: Internal brainstorming methods to identify risks from the oil and gas firms (ExxonMobil, Suncor Energy, etc.), PSV shipping firms (primarily Suncor), and relevant government agencies (TC, DFO, CCG, Natural Resources Canada, etc). Best results could derive from focus groups.
- Step three: SH consultations with public, other users of the marine area (fishermen, research vessels, etc)., Indigenous Peoples, the public, etc. This is both beneficial and ethical to identify risks and concerns that initial internal brainstorming missed.
- Step four: Accessing historical records from the government of Newfoundland and Labrador and/or the federal government of the incidents that have occurred in the Grand Banks/Hibernia oil field would help identify risks that internal brainstorming and SH consulting may have missed.
- Step five: Partaking in a root-cause assessment and scenario analysis will help determine hazards. It could be beneficial to use computerized and technological techniques to gather conclusive results. According to Hibernia (2021), scenario analysis is a method that is already utilized.
- Step six: After the previous steps, the PSV shipping firms will know the evident risks of PSV operations to Hibernia platform. Due to the Grand Banks unique geographic position, large numbers of icebergs flow down from the Canadian Arctic along the Labrador current, creating the nickname of "iceberg alley" (Clarke

& Drinkwater, 2015). Thus, icebergs are a prominent risk for the PSV operation to Hibernia platform. Furthermore, the Grand Banks is known for its harsh weather due its rough seas, and mixing of the warmer Gulf Stream and colder Labrador current, creating unprecedented fog (Clarke & Drinkwater, 2015). Other evident risks would be ship-strikes to whales, oil spills from the PSV vessel itself, technological failure, collision with the Hibernia platform, etc.

After the risks are identified, the next step of the RFW is a risk analysis to determine the overall level of risk of a PSV operation to Hibernia. Similar to the risk identification in this case study, the flow diagram from the risk analysis section (see Figure 12) will be used.

- Step one: Determining the likelihood of one of the risks occurring is the fundamental first step in risk analysis. For this specific case study, we will look at the likelihood of a PSV colliding with an iceberg while en route to Hibernia platform. The Associated Press (2017) indicated that there were record breaking icebergs near the Grand Banks in recent years (around 450). Ship operators and PSV organizations should look to historic records and the technology that the PSV has equipped on the vessel to detect the icebergs. With this information, the likelihood of hazardous events reoccurring can be estimated.
- Step two: PSV organizations should also utilize historic records to determine the severity of the consequence if a PSV did collide with an iceberg. This will depend on the size of the iceberg, ship speed, ship design, etc., but an overall estimate can be produced. Consulting with experts such as the Canadian Ice Service or maritime experts would further give input on the severity of the consequence.
- Step three: Determining the PSVs detectability of the event (in this case, hitting an iceberg) is a fundamental next step. Some vessels may be more outdated than others, which could result in lacking design or technological instruments to detect and avoid iceberg collision. However, most (if not all) PSVs operating in the Grand Banks likely have up-to-date detectability equipment.

- Step four: The effectiveness of existing risk controls is a next critical step to determining overall risk levels. For example, if the PSVs have lifeboats, double hulls, experienced ship operators, etc., makes a significant difference.
- Step five: From the previous four steps, an estimated semi-quantifiable level of risk can be determined. An estimated risk matrix is presented in Figure 18, where the likelihood of hitting an iceberg is relatively low, but the consequences are likely severe, resulting in a moderate amount of risk (Point A). This is a rough estimate, but it likely applicable to real-world applications.

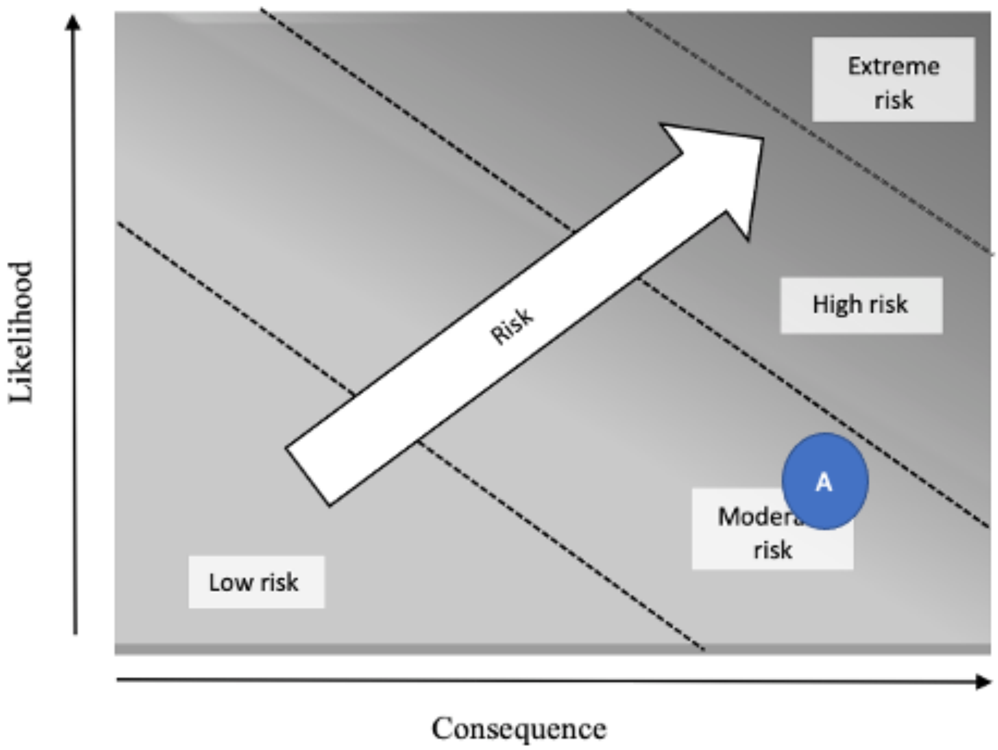

Figure 18. Estimated level of risk of a PSV striking an iceberg in the Grand Banks.

- Step six: Organizations documenting these findings is important for historic data.

The next stage of the RFW involves for risk evaluation, which is to evaluate the level of risk that was previously identified in the risk analysis. Recall from section 5.3.3 that vessel operations with extremely high risk or extremely low risk are less complicated than those of moderate risk because extreme circumstances have easier predictability. Working with SHs to evaluate the risk and assess the risk tolerance of the applicable organizations is key. Currently, the PSVs continually run to the offshore platforms without any incidents occurring to date.

Risk evaluation is the last sub-stage within the risk assessment. Hence, risk treatment is the next sequential stage in the RFW. For the context of a PSV operation to the Hibernia platform, risk treatment is the process and goal of determining and implementing RTOs for minimizing the risk level of colliding with an iceberg in the Grand Banks. Similar to the previous sections in this case study, this stage will work through the steps of risk treatment identified in Figure 15.

- Step one: the first step would be consulting with the previously identified SHs on the outcomes of the risk evaluation, the best possible RTOs moving forward, and determining whether the remaining risk is tolerable. Determining the effectiveness of current RTOs with SHs is a vital step. For example, Suncor shipping should consult with the CCG stationed in Newfoundland and Labrador on the current effectiveness of search and rescue and environmental response if the PSV were to strike an iceberg. Furthermore, consultations with the Canadian Ice Service to ensure that ice charts are up-to-date and accurate would be deemed effective.
- Step two: Formulating RTOs for the PSV operation is the next crucial step. For the context of this case study, RTOs would likely include improved ship hull design to protect the vessel from icebergs, increased funding towards iceberg detection technologies, hiring more experienced ship operators and crew, allocating more funding and resources to the CCG for efficient response, more oceanographers and employees hired for the Canadian Ice Service hired to determine ocean current data to determine where icebergs will likely transit, increased life-saving equipment on board the PSVs, etc.
- Step three: The next step in risk treatment is to implement the previously determined RTOs. The feasibility of RTO implementation heavily depends on the financial resources of the relevant organizations. The oil and gas industry and federal government will likely have the available funding to implement the identified RTOs (as ExxonMobil has an approximate market capitalization of $260

billion). Implementation of these RTOs will likely be time consuming but necessary for safe PSV transits.

- Step four: The following step in risk treatment for this case is to monitor how effective the implemented RTOs are and determine if the remaining risk is tolerable. The monitoring can be conducted by risk-practitioners in the shipping sector and also by the SHs previously identified. If the remaining risk is deemed acceptable, PSV operations with the selected RTOs should proceed. However, if the RTOs are not deemed effective enough, further treatment options should be considered.
- Step five: The final step is to document the steps and conclusions of the RTOs and inform SHs of the final actions, financial burden, effectiveness, etc., of the RTOs.

The sequential stages of the RFW are completed upon the conclusion of risk treatment for the PSV operation to Hibernia platform. However, effective risk communication throughout the process is vital. Risk communications importance for this case study is amplified due to a few factors. First, the energy sector is a significant portion of Newfoundland & Labrador's economy, accounting for approximately 25% of the provinces GDP and making up 41% of their exports (Government of Newfoundland & Labrador, 2021). Thus, the sector and its subsequent risks impact a significant portion of the province's citizens. Due to this, a risk incident of a PSV would likely impact large numbers of people, creating the need for timely and ethical communication of risks. Furthermore, the Grand Banks is a shared marine area between numerous industries, as it is utilized for an array of commercial fisheries. Therefore, in an event of an incident, all SHs that share the marine area need to be informed. The guiding principles discussed in section 5.5 of truthfulness, helpfulness, clarity, proactiveness, and increased availability are all relevant for this case study (see Table 6).

Finally, monitoring and evaluating the effectiveness of the RFW for this specific case study throughout its stages is key. As mentioned in the results, this is meant to be a base RFW for the Canadian shipping industry. Therefore, it is encouraged to modify certain stages in the RFW are encouraged to be modified for the specific shipping operation (in this case a PSV to Hibernia oil platform). The PSV organizations, the oil and gas firms, and the government agencies should be involved in the monitoring and evaluation of the

RFW for the PSV operation, as they are the SHs with the greatest ability to make changes in the RFW. Documentation throughout the entirety of the RFW is also critical so that future PSVs (and other shipping operations alike) are aware of the best practices.